REQUEST FOR COUNCIL ACTION CITY OF SAN DIEGO		CERTIFICATE NUMBER (FOR COMPTROLLER'S USE ONLY)
TO: CITY COUNCIL	FROM (ORIGINATING DEPARTMENT): Public Utilities - Water	DATE: 12/26/2012
SUBJECT: Water Purification Demonstration Project, Project Report		
PRIMARY CONTACT (NAME, PHONE): Marsi Steirer,619-533-4112, M.S. 906	SECONDARY CONTACT (NAME, PHONE): Amy Dorman, 619-533-5248, M.S. 910	

COMPLETE FOR ACCOUNTING PURPOSES

FUND	700011				
DEPT / FUNCTIONAL AREA					
ORG / COST CENTER	2000140001				
OBJECT / GENERAL LEDGER ACCT					
JOB / WBS OR INTERNAL ORDER					
C.I.P./CAPITAL PROJECT No.					
AMOUNT	0.00	0.00	0.00	0.00	0.00
FUND					
DEPT / FUNCTIONAL AREA					
ORG / COST CENTER					
OBJECT / GENERAL LEDGER ACCT					
JOB / WBS OR INTERNAL ORDER					
C.I.P./CAPITAL PROJECT No.					
AMOUNT	0.00	0.00	0.00	0.00	0.00

COST SUMMARY (IF APPLICABLE): Not applicable at this time. This will be pending City Council review and adoption of the Water Purification Demonstration Project Report. When a decision is made to implement a Full-Scale IPR/RA project at San Vicente Reservoir, authorization for funding will be required.

ROUTING AND APPROVALS

CONTRIBUTORS/REVIEWERS:		APPROVING AUTHORITY	APPROVAL SIGNATURE	DATE SIGNED
Liaison Office		ORIG DEPT.	Sasaki, Ann	3/6/2013
		CFO		
		DEPUTY CHIEF		
		COO		
		CITY ATTORNEY	Palmucci, Ray	3/12/2013
		COUNCIL PRESIDENTS OFFICE		

PREPARATION OF: ☒ RESOLUTIONS ☐ ORDINANCE(S) ☐ AGREEMENT(S) ☐ DEED(S)

Adopt the Water Purification Demonstration Project Draft Project Report as a fulfillment of the Demonstration Project elements outlined in Resolutions R-303095 and R-304434.

STAFF RECOMMENDATIONS: Approve the requested action.	
SPECIAL CONDITIONS (REFER TO A.R. 3.20 FOR INFORMATION ON COMPLETING THIS SECTION)	
COUNCIL DISTRICT(S):	All
COMMUNITY AREA(S):	All
ENVIRONMENTAL IMPACT:	This action is exempt from the California Environmental Quality Act (CEQA) pursuant to the State CEQA Guidelines, Section 15262. This determination is based on Section 15004 of the Guidelines which provides direction to lead agencies on the appropriate timing for enviromental review. The project will require further review under the provisions of CEQA.
CITY CLERK INSTRUCTIONS:	Please forward two (2) copies of the resolution to PUD, LRP/WR, MS 906, Attention: Diane Heard

COUNCIL ACTION
EXECUTIVE SUMMARY SHEET
CITY OF SAN DIEGO

DATE: 12/26/2012
ORIGINATING DEPARTMENT: Public Utilities - Water
SUBJECT: Water Purification Demonstration Project, Project Report
COUNCIL DISTRICT(S): All
CONTACT/PHONE NUMBER: Marsi Steirer/619-533-4112, M.S. 906

DESCRIPTIVE SUMMARY OF ITEM:
This action is to adopt the Water Purification Demonstration Project, Project Report in fulfillment of the elements outlined in Council actions approved in 2007 and 2008. These previous actions directed staff to conduct the Indirect Potable Reuse/Reservoir Augmentation Demonstration Project, which evaluated the feasibility of augmenting San Vicente Reservoir with advanced treated purified water.
STAFF RECOMMENDATION:
Approve the requested action.
EXECUTIVE SUMMARY OF ITEM BACKGROUND:
In January 2004, the City Council (Council) approved a study to evaluate options to increase the use of recycled water produced at the City's two water reclamation plants (R-298781). The Water Reuse Study (March 2006, www.sandiego.gov/water/waterreuse/waterreusestudy) identified Reservoir Augmentation of the City's San Vicente Reservoir as the preferred reuse strategy.

In October and December of 2007, the Council voted (R-303095) to accept the Water Reuse Study and proceed with the Indirect Potable Reuse/Reservoir Augmentation (IPR/RA) Demonstration Project (Demonstration Project) to evaluate the concept's feasibility. The project budget was set at $11,811,000. A temporary water rate increase to fund the Demonstration Project was approved by the City Council on November 25, 2008 (R-304434), and was in effect from January 1, 2009 to September 1, 2010.

Beginning in 2009, the City procured consultant services and equipment, and conducted studies to implement the project components requested by Council. The following are the primary Demonstration Project tasks undertaken over the last three years:

1. Convene an Independent Advisory Panel (IAP) to provide an independent expert review of the technical, scientific, and regulatory aspects of the project;
2. Design, install, operate, and test a one million gallons per day (mgd) demonstration-scale Advanced Water Purification (AWP) Facility at the North City Water Reclamation Plant (North City);
3. Conduct a Limnology and Reservoir Detention Study of San Vicente Reservoir to assess residence time and dilution of the purified water, and to assess water quality in the reservoir;
4. Define the State's regulatory requirements for a Full-Scale IPR/RA project;
5. Perform an energy and economic analysis;
6. Perform a pipeline alignment study; and

7. Conduct a public outreach and education program.

Work on all of the above tasks was completed in 2012. The attached staff report provides additional details about key Demonstration Project tasks and their outcomes, and implementation considerations should the Mayor and Council decide to implement a Full-Scale IPR/RA project at San Vicente Reservoir.

FISCAL CONSIDERATIONS:
Not applicable at this time. This will be pending City Council review and adoption of the Water Purification Demonstration Project Report. When a decision is made to implement a Full-Scale IPR/RA project at San Vicente Reservoir, authorization for funding will be required.

EQUAL OPPORTUNITY CONTRACTING INFORMATION (IF APPLICABLE):
Not applicable at this time.

PREVIOUS COUNCIL and/or COMMITTEE ACTION:
On October 29 and December 3, 2007, Council voted (R-303095) to undertake the Demonstration Project. On December 4, 2007, Council directed (R-303237) the Public Utilities Department to add the Demonstration Project to the Integrated Regional Water Management Plan and grant application. On November 18, 2008, Council approved (R-304434) a temporary water rate increase to fund the Demonstration Project. On March 24, 2009, Council approved (R-304764) the Limnology Study of San Vicente Reservoir. On January 26, 2010, Council approved (R-305584) the Project Management and Public Outreach contract. On August 5, 2010, Council approved (R-306069) the Advanced Water Purification Facility contract. Staff provides monthly updates on the status of the Demonstration Project to the Natural Resources & Culture Committee(NR&C). This item will also be heard at NR&C prior to City Council.

COMMUNITY PARTICIPATION AND PUBLIC OUTREACH EFFORTS:
The City sought to ensure information was presented in a clear, understandable, and accessible way to residents in all areas of the City through various channels of communication including direct contact with individuals, written electronic materials, traditional and social media, group presentations, community events, project website, and tours of the demonstration AWP Facility.

KEY STAKEHOLDERS AND PROJECTED IMPACTS:
The California Department of Public Health and the San Diego Water Board are the state agencies that would permit a Full-Scale Project. Staff provided regular updates to the Independent Rates Oversight Committee regarding the AWP Facility and the public outreach and education program.

Sasaki, Ann
Originating Department

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Deputy Chief/Chief Operating Officer

THE CITY OF SAN DIEGO

REPORT TO THE CITY COUNCIL

DATE ISSUED: March 11, 2013 REPORT NO: 13-27

ATTENTION: Natural Resources and Culture Committee, Agenda of

SUBJECT: Water Purification Demonstration Project, *Project Report*

REFERENCE:

1) Resolution Number R-303095 of the City Council accepting the 2006 Water Reuse Study, adopted December 3, 2007.
2) Resolution Number R-303237 of the City Council requesting that the Mayor adopt the San Diego Integrated Regional Water Management Plan, approved December 18, 2007.
3) Report to City Council Number 08-167, November 7, 2008, Proposed Water Rate Increase… to fund An Indirect Potable Reuse Demonstration Project. Resolution Number R-304434 of the City Council approving Water Rate Increases pursuant to increases in the wholesale cost of water and for funding Indirect Potable Water Reuse Demonstration Project, adopted November 25, 2008.
4) Resolution Number R-304764 of the City Council authorizing execution of an agreement to conduct a study for the Indirect Potable Water Reuse/Reservoir Augmentation Demonstration Project with Flow Science Incorporated, adopted April 1, 2009.
5) Resolution Number R-305584 of the City Council authorizing execution of a consultant contract with RMC Water and Environment for Indirect Potable Water Reuse/Reservoir Augmentation Demonstration Project - Project Management and Public Outreach, adopted February 8, 2010.
6) Resolution Number R-306069 of the City Council authorizing execution of an agreement with CDM Smith (formerly Camp Dresser & McKee) for the Indirect Potable Water Reuse/Reservoir Augmentation Demonstration Project - Advanced Water Purification [AWP] Facility, adopted August 5, 2010.

REQUESTED ACTION:

This action is to adopt the Water Purification Demonstration Project, *Project Report* in fulfillment of the elements outlined in Council actions approved in 2007 and 2008. These previous actions directed staff to conduct the Indirect Potable Reuse/Reservoir Augmentation Demonstration Project, which evaluated the feasibility of augmenting San Vicente Reservoir with advanced treated purified water.

STAFF RECOMMENDATION:

Approve the requested action.

SUMMARY:

In January 2004, the City Council approved a study to evaluate options to increase the use of recycled water produced at the City's two water reclamation plants (R-298781). The Water Reuse Study (March 2006) outlines the process undertaken to develop six options to maximize reuse, provides details on stakeholder involvement and outreach efforts, and the water quality research undertaken to assess public health impacts. The Water Reuse Study can be viewed at www.sandiego.gov/water/waterreuse/waterreusestudy. Water Reuse Study stakeholders identified Reservoir Augmentation of the City's San Vicente Reservoir, also known as the NC-3 option, as the preferred reuse strategy.

In October and December of 2007, the City Council voted (R-303095) to proceed with the Indirect Potable Reuse/Reservoir Augmentation (IPR/RA) Demonstration Project (Demonstration Project) to evaluate the feasibility of implementing this concept on a full-scale basis. A temporary water rate increase to fund the Demonstration Project was approved by the City Council (R-304434) in November 2008, went into effect on January 1, 2009, and concluded on September 1, 2010. Beginning in 2009 the Demonstration Project staff procured consultant services and equipment, and conducted studies to implement the project elements identified by the City Council. The Advanced Water Purification Facility, formerly referred to as the Advanced Water Treatment Demonstration Plant, began operating in June 2011. It continues to operate, and is open for public tours.

San Vicente Reservoir Augmentation Concept

The Demonstration Project evaluated the feasibility of conveying 15,000 acre-feet per year (AFY) of purified water to San Vicente Reservoir to augment existing water supplies in the reservoir. San Vicente Reservoir is located near Lakeside and is owned and operated by the City. San Vicente Reservoir is predominately used for municipal water supply purposes and also supports limited recreational activities. As part of the Emergency Storage Project, the San Diego County Water Authority has constructed new conveyance facilities that allow San Vicente Reservoir to serve water treatment plants operated by water agencies throughout the region. The Emergency Storage Project has raised San Vicente Dam by 117 feet, increasing the reservoir's capacity from 90,000 acre-feet to 247,000 acre-feet. Refilling the reservoir will begin in mid-2013 and is expected to take three to five years, depending on the availability of imported water.

Figure 1[1] shows how the reservoir augmentation concept would be implemented on a full-scale basis. Wastewater from homes and businesses would undergo multiple rounds of treatment, including advanced water treatment which renders the water "purified" and similar in quality to distilled water. The purified water would then be sent to the San Vicente Reservoir where it would blend with local runoff and imported supplies. The water would receive one last round of treatment at a drinking water treatment plant before being distributed as drinking water.

A full-scale reservoir augmentation project at San Vicente Reservoir would consist of the following:

- *Enhanced industrial waste control program.* Through this program unwanted constituents are prevented from entering the wastewater stream.

[1] Figures are at the end of this staff report.

- *Primary, secondary, and tertiary treatment at the North City Water Reclamation P*lant (North City). This treatment renders the water safe for irrigation and industrial (non-drinking) purposes.
- *Advanced water purification process consisting of membrane filtration, reverse osmosis, and ultraviolet light/advanced oxidation.* This treatment produces water of a quality similar to distilled water.
- *Residence time and blending with other supplies in the reservoir.* Note that during the Demonstration Project, no purified water was sent to the San Vicente Reservoir. Instead, the purified water was combined with recycled water produced at North City to serve irrigation and industrial demands.
- *Conventional water treatment.* Blended reservoir water would be treated at a drinking water treatment plant prior to distribution to residents and businesses.

Figure 2 shows the locations of proposed treatment and conveyance facilities associated with a full-scale reservoir augmentation project at San Vicente. The full-scale advanced water purification facility (AWP Facility) and conveyance pump station would be located on a vacant parcel of City-owned land across Eastgate Mall from North City. The 22-mile pipeline to San Vicente would be located in the City of San Diego, the City of Santee, the community of Lakeside, and unincorporated County of San Diego.

Figure 2 also shows the areas in the City and the region that would receive purified water produced by a full-scale project.

Figure 3 shows the multiple treatment barriers provided by a full-scale reservoir augmentation project at San Vicente Reservoir. This multiple barrier approach will protect the health and safety of the public water supply by using redundant treatment steps to ensure all unwanted constituents are removed from the water.

Components of the Demonstration Project

In accordance with Council Resolutions R-303095 and R-304434, seven primary tasks – or components - were undertaken for the Demonstration Project. The seven components of the Demonstration Project were:

1. Convene an Independent Advisory Panel to provide independent expert review of the technical, scientific, and regulatory aspects of the project;
2. Design, install, operate, and test a one-million-gallon-per-day demonstration-scale Advanced Water Purification Facility at North City;
3. Conduct a Limnology and Reservoir Detention Study of San Vicente Reservoir to assess residence time and dilution of the purified water, and to assess water quality in the reservoir;
4. Define the State's regulatory requirements for a full-scale reservoir augmentation project at San Vicente Reservoir;
5. Perform an energy and economic analysis;
6. Perform a pipeline alignment study; and
7. Conduct a public outreach and education program.

Figure 4 graphically displays the seven components of the Demonstration Project and the key tasks, meetings, reports, and outcomes, from the start of the project in 2007 through project completion in 2013. The major components of the project are shown along the bottom of the figure, and tasks, meetings, reports, and outcomes of each component are in columns. Important linkages between tasks, reports, or outcomes are shown by arrows.

Project Implementation

Implementation of the Demonstration Project was undertaken by the Public Utilities Department's Long-Range Planning and Water Resources Division. The Division assembled a team of City staff and consultants to execute the various Demonstration Project tasks.

Available Documents

The Water Purification Demonstration Project – *Project Report),* which details the entire process undertaken to implement the Demonstration Project, is included herein as Attachment 1.

Two other key project documents are the *Advanced Water Purification Facility Study Report* and the *Limnology and Reservoir Detention Study of San Vicente Reservoir* (Attachments 2 and 3, provided on companion CD). The former provides a full description of the AWP Facility, the testing and monitoring plan with results, and cost estimates for a full-scale facility. The latter details the studies addressing dilution and retention of purified water in the reservoir, and water quality effects. Because of the size of these reports only a limited number were printed and distributed. However, these reports and other supporting documents are available at the project website (www.purewatersd.org) or can be viewed in City offices at 600 B Street, Suite 600, by contacting project staff at (619)533-4112.

Convene an Independent Advisory Panel

The City contracted with the National Water Research Institutes (NWRI) to form an Independent Advisory Panel (IAP) to provide expert oversight of the key activities and results of the Demonstration Project. The City formed this IAP at the direction and recommendation of the California Department of Public Health (CDPH). The IAP created for the Demonstration Project was similar to expert panels of the Orange County Groundwater Replenishment Project and the City's Water Reuse Study. NWRI assembled a ten-member IAP comprised of academics and professionals with extensive expertise in the science of water reuse, water and wastewater technology, public health, epidemiology, toxicology, water quality, environmental science, public utilities, and regulations.

Over the course of the Demonstration Project, the City and IAP met in a workshop-style setting on numerous occasions to discuss the IAP's advice and perspective on key project milestones. The IAP meetings provided a forum in which the IAP could give feedback to the City and project consultants, who in turn incorporated it into subsequent project work. A total of ten meetings were conducted throughout the course of the project. Representatives from CDPH, California Regional Water Quality Control Board, the San Diego Region (San Diego Water Board), and the County of San Diego Department of Environmental Health regularly attended these meetings and interacted with the IAP, City staff, and project consultants.

In their letter to the City dated November 16, 2012, the IAP stated, *"The Panel believes that the Water Purification Demonstration Project Final Report (October 2012) and supporting documents are responsive to the directives set forth by the City Council. The Panel is also pleased with the responsiveness of the City's staff and consultants to the comments and recommendations made by the Panel."*

Design, Install, Operate, and Test a One-million-gallon-a-day Demonstration-Scale Advanced Water Purification Facility

The primary objectives of the AWP Facility were to:

1. Demonstrate the ability of the treatment process to reliably produce purified water that meets all regulatory standards pertaining to public water supplies; and
2. Demonstrate that continuous and daily monitoring of each water purification process can assure the integrity of the process and that only safe water is produced.

The AWP Facility has the capacity to produce one million gallons per day (mgd) utilizing the same three-step treatment process used at Orange County Water District's 70 mgd Groundwater Replenishment Project. The supply to the AWP Facility is recycled water from North City which is used to serve non-potable recycled water demands in the northern part of the City. The AWP Facility treatment process begins with membrane filtration, followed by reverse osmosis (RO), and ends with ultraviolet light/advanced oxidation (UV/AOP). The *Advanced Water Purification Facility Study Report* (Attachment 2) provides a full description and details of the AWP Facility.

AWP Facility Testing Approach

Testing at the AWP Facility spanned a 12-month period (July 2011 – August 2012). The City prepared a Testing and Monitoring Plan that prescribed the frequency and type of water quality tests to perform on the water processed through the AWP Facility. The Testing and Monitoring Plan included measurements for 342 constituents and parameters (231 regulated constituents and 111 non-regulated constituents)[2]. These constituents and parameters were measured before and after each treatment step and in the imported water aqueduct delivered through the regional aqueduct system. In total, the Testing and Monitoring Plan prescribed more than 9,000 individual water quality tests. The IAP and regulators reviewed and commented on the Draft Testing and Monitoring Plan, and the City finalized it based on their feedback.

The regulated constituents and parameters that apply to this project are represented in Table 1. Two agencies set the water quality standards and goals for the project. CDPH is responsible for protecting the drinking water quality in California. The San Diego Water Board is responsible for protecting the water quality in surface waters from an environmental perspective. As Table 1 indicates, the purified water met all applicable standards and goals for the 231 regulated constituents and parameters.

[2] A constituent is a dissolved chemical element or compound, or a suspended material that is carried in the water (e.g., sodium). A parameter is a physical property whose value can predict the behavior of the water (e.g., temperature).

Table 1 – Water Quality Testing - Regulated Constituents			
Regulations or Guidelines	**Number of Constituents and Parameters**	**Purified Water Results**	**Comments**
California Department of Public Health Goals			
Primary Drinking Water Maximum Contaminant Levels	90	Meets All Regulations	Primary Maximum Contaminant Levels are established to address public health
Secondary Drinking Water Maximum Contaminant Levels	18	Meets All Regulations	Secondary Maximum Contaminant Levels are established to address aesthetics such as color, taste, and odor
Microbial	4	Not Detected	
Notification Levels	30	Meets All Regulations	Drinking Water Notification Levels and Response Levels December 2010. Notification levels are health-based advisory levels established by CDPH for chemicals in drinking water that lack maximum contaminant levels
Groundwater Replenishment Criteria	142	Meets All Regulations	CDPH Groundwater Replenishment Reuse draft Regulation 2011 criteria used in absence of regulations for surface water augmentation.
San Diego Water Board goals for reservoir augmentation (projected)			
Reservoir Limits	143	Meets All Regulations	EPA Numeric Criteria for Priority Pollutants and San Diego Basin Plan Numeric Objectives.
Total	**231**	Unique constituents and parameters because some are in multiple regulations/guidelines.	

Additional testing for 111 non-regulated constituents at various locations in the purification process was performed. These constituents are primarily grouped into two main categories: those included in the USEPA 2012 Unregulated Contaminant Monitoring Rule, which consists of 30 contaminants monitored in drinking water for occurrence information; and constituents of emerging concern (also known as CECs), which are manufactured chemicals, such as pharmaceuticals, personal care products, and pesticides, that have been found in treated wastewater. Results showed the reverse osmosis and advanced oxidation processes were effective at removing the majority of these constituents present in North City recycled water. Of these 111 non-regulated constituents, six were quantifiably detected (above the laboratory reporting limit) in the purified water during at least one sampling event. These six constituents are bromochloromethane, used in fire-extinguishing fluid; hexavalent chromium, formed by

oxidation of chromium in the advanced oxidation process; strontium, a naturally occurring metal and dietary supplement; acesulfame-K, a widely used artificial sweetener; iohexal, a contrasting agent used in X-ray procedures; and triclosan, an antibacterial agent used in handsoap and toothpaste.

Since these non-regulated constituents do not have regulatory limits, the best way to determine the significance of measured concentrations is to compare them to the constituent's Drinking Water Equivalent Level (DWEL) or the USEPA identified Health Reference Level. DWELs and Health Reference Levels both represent an acceptable concentration in drinking water assuming an average person consumes two liters of water per day for 70 years. The measured concentration of these six constituents in the purified water was 100 million times to 18 times lower than associated DWELs and Health Reference Levels.

In general, water quality testing shows the purified water is exceptionally pure, similar to distilled water. For example, TDS (a measure of salt and mineral content) in purified water is about 15 mg/L, compared to TDS in San Diego's source water and drinking water at about 500 mg/L. As a second example, TOC (a measure of carbon that is bound to organic molecules) in purified water is about 0.1 mg/L compared to a TOC of 3.0 mg/L in San Diego's source water and 2.5 mg/L in San Diego's drinking water.

AWP Facility Equipment Integrity Monitoring

Verifying the integrity and reliability of the treatment equipment is critical to assuring the health and safety of the water produced. A critical control point monitoring plan was implemented to identify any changes in performance of the treatment processes that could adversely affect water quality. The plan identified the parameters to be monitored and critical limits which, if exceeded, would either initiate an alarm to alert operators or automatically shut down the process. Parameters and critical limits were established for each treatment step. The critical control point monitoring showed that the equipment maintained its integrity, met the intended treatment performance on a continuous basis, and was reliable throughout the operational period.

AWP Facility Key Findings

Tests for 342 different constituents and parameters showed the purified water met all regulatory limits and had concentrations similar to distilled water. The testing results showed that only safe water is produced.

The operational data gathered during the 12-month testing period validated the concept that continuous and daily monitoring of each water purification process can assure the integrity of the treatment process.

Enhanced Industrial Waste Control Program

An enhanced industrial waste control program serves as the first barrier to protecting public health by preventing undesirable constituents from entering the wastewater stream. The City currently maintains a comprehensive Industrial Waste Control Program, which complies with unique and stringent requirements imposed in the discharge permit for the Point Loma Wastewater Treatment Plant. Further, the City recognizes the prevalence of pharmaceutical research in the North City sewer shed. The City currently prohibits discharges of any pharmaceutical manufacturing products or wastes, including incidental wash water or other pharmaceutical residues, to the sewer.

During the Demonstration Project the City's Industrial Waste Control Program was compared to Orange County Sanitation District's program, which was enhanced to support implementation of Orange County Water District's 70 mgd Groundwater Replenishment System. The Groundwater Replenishment System is indirect potable reuse wherein the purified water is conveyed to a groundwater basin rather than a surface water reservoir as in the City's IPR/RA concept. The two industrial waste control programs are similar. Three potential enhancements were identified for the City to consider implementing should a full-scale reservoir augmentation project at San Vicente Reservoir be implemented:

- *Chemical Inventory Program and Geographic Information System (GIS) Tracking.* Expand the industrial and commercial discharger chemical inventory database linking it to discharger locations that are tracked using GIS software.
- *Pollutant Prioritization Program.* Prioritize pollutants through sampling and characterization of constituents of emerging concerns (CEC's) at the full-scale AWP Facility, and determine if pollutants can be controlled through targeted source control for individual dischargers or commercial sectors.
- *Local Limits Evaluation.* Local limits are wastewater limitations that apply to commercial and industrial facilities that discharge effluent to a wastewater treatment plant like North City. They are developed to meet the industrial waste control program objectives and site-specific needs of the treatment plant and it's receiving waters. The evaluation would consider including additional pollutants of concern on North City's list of local limits, and potentially lowering the limit of pollutants already on the list. It is anticipated that this evaluation could be done in conjunction with the annual local limit evaluations for the Point Loma.

Conduct a Limnology and Reservoir Detention Study of San Vicente Reservoir

Although water purification technology is widely recognized as capable of purifying recycled water into drinkable water, CDPH requires that purified water be retained in an environmental buffer, such as a groundwater basin or a surface water reservoir, before it is used in a drinking water system. Cycling purified water through an environmental buffer is part of the multiple barrier strategy to protect public health through dilution with other water sources and holding time for natural treatment.

The *Limnology and Reservoir Detention Study of San Vicente Reservoir* (San Vicente Reservoir Study) is a component of the Demonstration Project conducted to establish that the reservoir would provide the dilution and retention required by CDPH. Retention is the length of time the purified water is held in the reservoir before it is withdrawn and delivered to the drinking water treatment plant. Dilution is the degree to which purified water is blended with other sources of water. The core of the San Vicente Reservoir Study is a computer-based three-dimensional hydrodynamic model of the reservoir. The model was developed at the University of Western Australia and customized for this project by a team of expert staff and consultants. The model was calibrated and validated using data measured at San Vicente Reservoir[3]. The model was

[3] *Calibration* is the process of aligning the terms and coefficients of the model to the unique conditions at San Vicente Reservoir, using a set of real-world measurements. *Validation* compares the output of a model run to a different set of real-world measurements to confirm the model can accurately predict conditions in the reservoir.

used to assess retention and dilution of the purified water in San Vicente Reservoir and for selecting the best location of the purified water inlet. The model's performance was reviewed and endorsed by the Demonstration Project's IAP. The *Limnology and Reservoir Detention Study of San Vicente Reservoir* (Attachment 3) provides a full description of the model, details of the modeling scenarios, and the results.

The model results demonstrated that the addition of purified water to San Vicente Reservoir would not affect the natural hydrologic characteristics of the reservoir; that is to say, it would not affect the natural stratification, blending, and retention in the reservoir. Dilution and retention of purified water in San Vicente Reservoir would constitute a substantial environmental barrier, sufficient to meet regulatory requirements.

For all anticipated reservoir operating scenarios and purified water inlet locations, the reservoir would dilute the purified water by at least a factor of 200 to one at all times. The modeling work showed that, while it is not possible to calculate a simple metric of the time the purified water resides in the reservoir, the reservoir provides more than adequate retention of purified water to meet all regulatory requirements.

The San Vicente Reservoir Study also assessed water quality in the reservoir. The addition of purified water would not negatively affect any aspect of water quality in San Vicente Reservoir. The dam raise and reservoir enlargement, which are independent of this project, will improve overall water quality in the reservoir by reducing nutrients that cause water quality issues. The addition of purified water will not substantially change these improvements.

Define the State's Regulatory Requirements for a Full-scale Reservoir Augmentation Project at San Vicente Reservoir

The CDPH and the San Diego Water Board would be responsible for establishing the permit requirements for a full-scale reservoir augmentation project at San Vicente Reservoir.

The CDPH would have the authority over the public water supply aspect of a full-scale reservoir augmentation project at San Vicente Reservoir, and would establish the corresponding regulatory criteria. Because the purified water would be considered a "discharge" into the San Vicente Reservoir, the San Diego Water Board would have authority over this aspect of the project and would evaluate any potential effects on water quality in the reservoir. Ultimately, the San Diego Water Board would issue a permit that contains the regulatory requirements of both agencies. Because of each agency's unique interest in, and authority over, a potential full-scale reservoir augmentation project at San Vicente Reservoir, the City engaged separately with CDPH and the San Diego Water Board. Both agencies actively participated in the aforementioned IAP meetings.

Coordination with CDPH

At this time there are no CDPH regulations for IPR/RA. By State law, CDPH is required to adopt reservoir augmentation regulations by the end of 2016. However, in advance of adopting regulations, CDPH can approve reservoir augmentation projects on a case-by-case basis. Therefore, defining the regulatory criteria for San Diego's full-scale reservoir augmentation project at San Vicente Reservoir was one of the Demonstration Project's key objectives. The

City solicited input from CDPH during preliminary work leading up to the Demonstration Project (2005 through 2008) and continued to engage CDPH throughout project execution. The City submitted a proposal for a full-scale reservoir augmentation project at San Vicente Reservoir to CDPH in March 2012. The proposal articulated specific public health protections provided by the City's reservoir augmentation concept, summarized the Demonstration Project's technical results as vetted by the IAP, and suggested a regulatory framework for San Diego's project. On September 7, 2012, the City received a concept approval letter from CDPH stating that the City's project "will not compromise the quality of the water derived from San Vicente Reservoir." Further, the letter reads "Therefore, CDPH approves the San Vicente Reservoir Augmentation Concept."

Coordination with the San Diego Water Board

Throughout the Demonstration Project the City held a series of meetings with the San Diego Water Board that focused on clarifying their regulatory framework for permitting a reservoir augmentation project. On October 12, 2011, the San Diego Water Board adopted Resolution No. R9-2011-0069 whereby they expressed support for a reservoir augmentation project at San Vicente Reservoir. In August 2012, the City submitted to the San Diego Water Board a document titled *Proposed Regional Water Quality Control Board Compliance Approach for San Vicente Reservoir Augmentation*. This document summarizes the key permitting issues and proposes a regulatory pathway the San Diego Water Board could follow to approve a full-scale reservoir augmentation project at San Vicente Reservoir. This process was similar to that undertaken with CDPH. On February 7, 2013, the City received a letter of regulatory concurrence from the San Diego Water Board that stated that "…it strongly supports the efforts of the City to develop the San Vicente Reservoir Augmentation Project and concurs with the City's preferred NPDES permit pathway…"

Perform a Pipeline Alignment Study

Facilities that include a pump station and pipeline will be needed to convey the purified water to San Vicente Reservoir. There is sufficient space on the future AWP Facility site to accommodate the pump station. A study was conducted to identify probable alignments for a 36-inch pipeline to convey purified water from the AWP Facility to San Vicente Reservoir located about 22 miles to the east.

Figure 2 shows the two alignments that were evaluated. The two alignments head in a southerly direction from the potential full-scale AWP Facility located at North City, before going east to San Vicente Reservoir. Both alignments tie into the existing recycled water pipeline that serves the Metropolitan Biosolids Center and other customers southeast of North City. Both pipeline alignments traverse through the City of Santee and the community of Lakeside before reaching San Vicente Reservoir.

- *State Route 52 (SR-52) Alignment*. This alternative runs alongside of SR-52, within the CalTrans right-of-way. An encroachment permit would be required.
- *Mission Gorge Alignment*. This alternative avoids the SR-52 right-of-way and runs through Kearny Mesa and Tierrasanta before traveling to Lakeside via Mission Gorge Road.

Due to the length of this pipeline, the complexity of its construction, and the biological, cultural, and other natural resource values likely to be encountered, additional analysis will be required to refine the alignment. Further study is also required to detail the requirements associated with obtaining a CalTrans encroachment permit, followed by further refinement of the project schedule and cost estimate.

Conduct a Public Outreach and Education

A major component of the Demonstration Project was to educate and inform the public about the need for and the benefits of purified water. The first step to achieving this goal was to develop a plan to guide public outreach activities and ensure those activities were implemented throughout the City in an all-inclusive and comprehensive manner.

Realizing this goal required a communication plan that outlines an outreach strategy with objectives, goals, tools, and a dedicated outreach team. In addition to City staff, consultants were enlisted to aid in outreach, media, and multi-cultural communications.

The communication plan encouraged involvement and dialogue among elected officials, community leaders, stakeholders, residents, and the media. Outreach activities included a speaker's bureau, informational materials (including those for multicultural audiences), stakeholder interviews, AWP Facility tours, community events participation, research surveys, social media, videos, and a dedicated website. Outreach efforts began in 2009, and, since that time, the City conducted 132 presentations throughout the City, hosted informational booths at 42 community events, and hosted 3,244 visitors to the AWP Facility tour as of December 31, 2012.

The concept of the AWP Facility tour is based on the "urban water cycle," a sped-up version of nature's water cycle. The tour divides the water purification process into three areas of interest (membrane filtration, reverse osmosis and UV disinfection) for ease of comprehension and discussion. By providing a tangible facility to demonstrate the science behind water purification, the process is demystified, the multiple layers of oversight are explained, and inaccurate perceptions are corrected.

To gauge the progress of the outreach program, research studies were conducted by Rea & Parker Research and SDSU research students. With a history of public opposition to water purification as a possible water supply option for San Diego, using research to bolster outreach efforts was essential to ensure the messaging and outreach methods were as effective as possible. Polls conducted in 2004, 2011, and 2012 found a steady increase in residents favoring the use of recycled water to diversify the City's water supply. Figure 5 displays the results of these polls.

Outreach efforts have garnered positive coverage both locally and nationally. On January 23, 2011, the San Diego Union-Tribune published an editorial in which the editorial board wrote that it had come to accept the science behind water purification technology and encouraged the rest of San Diego to do the same. Soon after this editorial came a front page cover story in USA Today (March 3, 2011) and, most notably, an article on the cover page of the New York Times (February 10, 2012).

Perform an Energy and Economic Analysis

The *2012 Long-Range Water Resources Plan* (City of San Diego, 2012), which is a separate effort, provides much of the information used for the energy and economic analysis for the Demonstration Project. Other sources of energy and economic information are described in the discussions that follow.

The Long-Range Water Resources Plan is a high-level strategy document that evaluates water supply options for the City through a 2035 planning horizon. The City convened an 11-member stakeholder committee that has provided guidance and input on alternative strategies for meeting San Diego's future water needs. The Long-Range Water Resources Plan addresses population growth, water resource diversification, climate change and other issues that affect water reliability. Various supply options such as conservation, desalination, groundwater, potable and non-potable reuse, local surface water, rainwater harvesting or capture, gray water, and imported water were considered and compiled into supply portfolios. The portfolios were rated against 20 performance measures ranging from affordability and energy footprint, to increased supply reliability and local control, and protecting the environment. The three highest-ranking portfolios all included the full-scale San Vicente IPR/RA concept, and the economic analysis found the full-scale reservoir augmentation project at San Vicente Reservoir to be an advantageous water supply option for the City. The 2012 Long-Range Water Resources Plan is being finalized and will be brought forward for City Council consideration in Spring 2013.

The 2012 Long-Range Water Resources Plan also included an estimate of greenhouse gas emissions, which are a function of energy requirements, for each of the supply options. Indirect potable reuse was found to produce less greenhouse gas emissions than ocean desalination and some groundwater supply options. The energy consumption associated with a full-scale reservoir augmentation project at San Vicente Reservoir is approximately equivalent to that of imported water.

Full-scale San Vicente Reservoir Augmentation Costs

The key components of a full-scale reservoir augmentation project at San Vicente Reservoir would include enhancements to the existing industrial waste control program, a full-scale 15 mgd AWP Facility, and conveyance facilities to deliver the purified water to San Vicente Reservoir.

The estimated gross cost of augmenting San Vicente Reservoir with 15 mgd of purified water is $2,000 per acre-foot. The capital cost and operating and maintenance costs included in the estimate are:

Table 2 – Estimated Capital Costs and Operating and Maintenance Costs[1]		
Cost Item	***Capital Cost***	***Annual Operating and Maintenance Cost***
Advanced Water Purification Facility	$144,700,000	$8,145,000
Increased tertiary production at North City to supply AWPF	$0	$3,965,000
Conveyance Facilities	$224,500,000	$3,385,000
Total	*$369,200,000*	*$15,495,000*
Auxiliary Program Costs		
Initial Enhanced Source Control		$500,000
Annual Enhanced Source Control		$50,000
Annual Public Outreach		$700,000
Total		*$1,250,000*
[1] costs are estimated in 2012 dollars		

The estimate was prepared utilizing a net present value analysis for 50 years. Other key assumptions include:

- Financing through both revenue bonds and State Revolving Loan Funds.
- Continuation of local resource program credits (LRP) from the San Diego County Water Authority and the Metropolitan Water District (MWD) of Southern California. The uncertain future of these credits was addressed by applying a credit that reflects average conditions (i.e. between favorable and unfavorable conditions). Under favorable conditions, the credit is expected to be $450 per acre-foot of water produced, while under unfavorable conditions it is expected to be $100 per acre-foot. The average of $275 per acre-foot was used in estimating the overall cost of reservoir augmentation.
- Grant funding in the amount of 20% of capital costs. Such grants are typical for reuse projects.

Avoided Costs and Other Cost Benefits

The implementation of a full-scale reservoir augmentation project at San Vicente Reservoir will result in avoided wastewater system costs. In order to determine what wastewater system costs could be avoided as a result of implementing full-scale reservoir augmentation, the September *2011 Metro Wastewater Plan* (City of San Diego, 2011) was referenced. The facility requirements described in the Metro Wastewater Plan correspond to Point Loma remaining a chemically-enhanced primary treatment plant. There are several projects included in the Metro Wastewater Plan's long-term capital program. Among these projects is the construction of a

seven-million-gallon wet weather storage facility that would be needed to attenuate flows to Point Loma. In the absence of full-scale reservoir augmentation, this facility would need to be operational by the year 2022. It is estimated that capital and operating costs are, respectively, $123 million and $6.15 million annually. By implementing a full-scale reservoir augmentation, the need for wet weather storage could be eliminated.

A full-scale reservoir augmentation project at San Vicente Reservoir will reduce the flows conveyed to Point Loma. This will reduce annual operations and maintenance costs at Point Loma as well as at Pump Station No. 2 which conveys flows to Point Loma. The 15 mgd flow reduction will reduce these costs, by $2,210,000 and $450,000, respectively.

Table 3 - Avoided Costs and Savings

	Avoided Cost, $	***Avoided Cost, $ per acre-foot***
Point Loma Wet Weather Storage Facility	$123,000,000 (Capital) $6,150,000 (Annual O&M)	$1,000
Reduced Influent Flows at Point Loma	$2,210,000 (Annual O&M)	
Reduced Pumping at Pump Stations No. 2	$450,000 (Annual O&M)	
Total Avoided Costs/Savings	$123,000,000 (Capital) $8,810,000 (Annual O&M)	$1,000

The *net cost* of a full-scale reservoir augmentation project at San Vicente Reservoir after accounting for avoided costs and savings is estimated to be $1,000 per acre-foot of purified water produced and delivered to the reservoir. Figure 6 shows how the projected cost of the water compares to the projected cost of imported water.

In addition to avoided wastewater costs, there may also be savings resulting from reduced salinity in the City's water supply. The salinity of purified water produced at a full-scale AWP Facility after final conditioning will be approximately 50 milligrams per liter. By comparison, imported water has a salinity level of 300 to 600 milligrams per liter. The addition of purified water to San Vicente Reservoir is expected to reduce the salinity level in the reservoir. The estimated savings due to reduced salinity was evaluated by the MWD and United States Bureau of Reclamation in the late 1990s. They found that reduced salinity correlates with longer useful lives of downstream treatment facilities. Further analysis is needed to quantify the salinity benefits resulting from this 15 mgd project at San Vicente Reservoir; and they are not included here. Note also, that savings related to the extended lives of retail customers' plumbing fixtures are also expected; however, these are difficult to quantify and were thus also excluded from the estimated savings.

Demonstration Project Budget and Expenditures

The Demonstration Project budget was established at $11,811,000. Table 4 shows how this was distributed among the project tasks. Actual expenditures through Fiscal Year 2013 are expected to total $11,393,230; this is $417,770 less than the initial budget.

Table 4
Project Budget and Expenditures

Project Task	*Contractor*	*Original Budget*	*Actual Contract*	*Projected Expenditures thru FY 2013*
Program Management	RMC Water Environment	$1,688,000	$1,781,742	$1,635,537
Independent Advisory Panel	National Water Resources Institute	$250,000	$250,000	$217,074
Demonstration-scale Advanced Water Purification (AWP) Facility		$7,400,000	$7,400,000	$7,146,897
Facility	*CDM Smith*		*$6,600,000*	*$6,600,000*
Pad/Canopy	*Ahrens Corporation*		*$600,000*	*$430,439*
Electricity	*NA*		*$200,000*	*$116,458*
Energy and Economic Analysis	Performed in independent project: *City of San Diego Long Range Water Resources Plan, 2012*			
Limnology and Reservoir Detention Study for the San Vicente Reservoir	Flow Sciences, Inc.	$385,000	$420,000	$419,457
Pipeline Alignment Study	RMC Water Environment	$50,000	Included in Program Management Contract	
Public Outreach and Education Program	RMC Water Environment/ Katz & Associates	$1,700,000	$1,499,611	$1,645,866[3]
Contingency		$338,000	$459,647	$328,399
Regulatory Staff Charges[1]				*$122,075*
Non-personnel Expenses[2]				*$206,324*
Contracts Total		**$11,811,000**	**$11,811,000**	**$11,393,230**

[1]Regulatory staff participated in project IAP meetings and reviewed and commented on the AWP Facility Testing and Monitoring Plan. Charges shown are for staff time on these activities.
[2]Non-personnel expenses were incurred in support of above project tasks; majority of expenses were due to production of outreach materials.
[3]Supports extended outreach activities through December 31, 2013

Project funding was obtained through a temporary rate increase approved by City Council in 2008 and was in effect from January 1, 2009 to September 1, 2010; the rate increase raised $10,738,165. The remaining $1,072,835 of the $11,811,000 was obtained through Proposition 50 grant funding. The State has reimbursed the full grant amount less a 10% retention that is typically released after the project is completed.

Subsequent to the rate increase and Proposition 50 grant, the Bureau of Reclamation awarded the City $2,952,750 for project-related expenses. The City has received $2,852,704 in reimbursements from this grant and expects to receive the remaining $100,046 by the end of

June 2013. City project staff expenditures at project completion are estimated to be $1,813,112. Staff positions had already been included in the Department budget and thus were not included in the temporary rate case that funded the contracts. The Bureau of Reclamation grant has gone towards reimbursing these expenditures. Also, the AWP Facility will continue to operate through the end of June 2013; this is eleven and three months, respectively, beyond the 12-month testing period and expiration of the contract the City has with CDM Smith. The estimated cost of extended operations is $200,000 and will also be fully reimbursed via the Bureau of Reclamation grant. The unspent Bureau of Reclamation grant funds plus the under-budget contract expenditures are expected to total $1,357,408 (Table 5). These funds could be applied to initial tasks associated with full-scale implementation if approved by the Mayor and the City Council.

Table 5
Bureau of Reclamation Grant and Unspent Project Funding thru FY 2013

Bureau of Reclamation Grant	***Amount***
City project staff costs	$1,813,112
Extended AWP Facility Operations	$200,000
Total Bureau of Reclamation Grant Expenditures	**$2,013,112**
Unspent Funds	
Unspent Bureau of Reclamation Grant Funds	$939,638
Unspent Contract Funds (see previous page)	$417,770
Total Unspent Project Funds	**$1,357,408**

Implementation Considerations

Should the Mayor and Council decide to implement a full-scale reservoir augmentation project at San Vicente Reservoir, the next steps would include:

1. Determine Local Resource Funding Policy. Because a full-scale reservoir augmentation project at San Vicente Reservoir will benefit both water and wastewater systems, it is expected that these funding sources will be utilized to support implementation. The proportional sharing of costs must be determined in order to prepare separate water and wastewater rate cases to fund the project. The recently-completed Recycled Water Study also identified this as a critical next step to begin in FY13. The estimated consultant cost for this work is $180,000, with work anticipated to continue through FY 14.

2. Determine the Contracting Mode. There are a number of options for contracting out the design and construction of full-scale IPR/RA facilities. Typical options include design-bid-build, design-build, and design-build-operate. The timing of project expenditures will differ among the options, and this must be accounted for in preparing the financing plan and rate cases to support a full-scale reservoir augmentation project at San Vicente Reservoir. The estimated consultant cost to determine the contraction mode is $60,000, with work anticipated to begin in FY14.

3. Refine the Pipeline Alignment. The conveyance system represents 60% of the estimated capital cost of a full-scale reservoir augmentation project at San Vicente Reservoir. Further, the last 7,000 feet of pipeline to reach the reservoir represents 40% of the estimated pipeline cost; the high cost is driven by difficult construction access and tunneling through granitic rock. Alternative alignments for this difficult portion of the pipeline should be investigated for potential cost reductions. If a lower-cost option requires moving the reservoir inlet,

reservoir modeling will also be needed to confirm that the reservoir would still provide the buffering described earlier in this report. The estimated consultant cost is $50,000 to refine the pipeline alignment, and $100,000 to $125,000 for the reservoir modeling to confirm the inlet location. This work is anticipated to begin in FY14 or FY15.

4. Coordinate with Regional Wastewater and Reuse Objectives. The City's recent Recycled Water Study developed reuse program alternatives to divert flows away from Point Loma, thereby addressing regional wastewater issues. The full-scale San Vicente Reservoir augmentation concept that is the subject of this Demonstration Project would be the initial project in all five of the Recycled Water Study's program alternatives. Some of the alternatives call for expanding the AWP Facility at North City beyond the initial 15 mgd capacity, while others do not. Although the Recycled Water Study did not identify a preferred alternative, one needs to be determined so that the scope of conveyance and treatment facilities can be established prior to initiating their designs in FY16.

   Point Loma's discharge permit will be up for renewal in 2015, and it is expected that long-term regional wastewater and reuse plans will be a key aspect of negotiations with the USEPA over Point Loma's discharge permit renewal. City staff will be involved in the coordination effort, and consultant costs are not anticipated for this work.

5. Monitor Development of Direct Potable Reuse Regulations. As communities throughout California explore indirect potable reuse (IPR) options for both groundwater replenishment and reservoir augmentation, it is recognized that a more direct pathway to replenishing a drinking water system with purified water (known as direct potable reuse or DPR) could reduce capital costs and accelerate implementation timelines in some settings. DPR would rely on engineered water purification processes for public health protection, eliminating the need for an intermediary environmental buffer such as a groundwater basin or a surface water reservoir. Senate Bill 918 was signed into law in 2010 and established December 31, 2016 as the time by which CDPH must report on the feasibility of developing regulatory criteria for DPR. Shortly after Senate Bill 918 was signed, California WateReuse Association formed a DPR committee to support CDPH in its investigation. A number of the California WateReuse Association's initiatives are complete or are underway; all are geared to providing guidance in establishing DPR regulatory criteria. In November 2012, the San Diego Integrated Regional Water Management Program selected a joint WateReuse-City project proposal to receive $2.1 million in grant funding. The project will utilize the City's Demonstration AWP Facility to study the effectiveness of DPR treatment and monitoring strategies, with grant-funded work to begin in 2014. There will be no City consultant cost anticipated for this work. The City will continue to monitor development of DPR regulations and will adapt the City's implementation plan based on these developing regulations.

EQUAL OPPORTUNITY CONTRACTING:
Not applicable at this time.

FISCAL CONSIDERATIONS:
Not applicable at this time. This will be pending City Council review and adoption of Water Purification Demonstration Project Report. When a decision is made to implement a Full-Scale IPR/RA project at San Vicente Reservoir, authorization for funding will be required.

PREVIOUS COUNCIL and/or COMMITTEE ACTION:
On October 29 and December 3, 2007, Council voted (R-303095, R-2008-382) to undertake the Demonstration Project. On December 4, 2007, Council directed (R-303237) the Public Utilities Department to add the Demonstration Project to the Integrated Regional Water Management Plan and grant application. On November 18, 2008, Council approved (R-304434) a temporary water rate increase to fund the Demonstration Project. On March 24, 2009 Council approved (R-304764) the Limnology Study of San Vicente Reservoir. On January 26, 2010 Council approved (R-305584) the Project Management and Public Outreach contract. On August 5, 2010 Council approved (R-306069) the Advanced Water Purification Facility contract. Staff provides monthly updates on the status of the Demonstration Project to the Natural Resources & Culture Committee (NR&C). This item will also be heard at NR&C prior to City Council.

COMMUNITY PARTICIPATION AND PUBLIC OUTREACH EFFORTS:
Throughout the duration of the Demonstration Project, the City sought to ensure information was presented in a clear, understandable, and accessible manner to residents in all areas of the City. Information about the Demonstration Project was provided through a variety of formats including direct contact with individuals, written and electronic materials, traditional and social media, group presentations, community events, and tours of the AWP Facility. Strategic planning, materials, activity tracking, and other items related to outreach were regularly presented to the Independent Rates Oversight Committee's Public Outreach and Communications Subcommittee. A CD containing supporting outreach materials accompanies the Project Report.

KEY STAKEHOLDERS AND PROJECTED IMPACTS:
The California Department of Public Health and the San Diego Water Board are the state agencies that would permit a full-scale reservoir augmentation project at San Vicente Reservoir. Staff provided regular updates to Independent Rates Oversight Committee regarding the AWP Facility and the Demonstration Project's public education and outreach efforts.

Roger S. Bailey
Director of Public Utilities

Attachments:

1. *Water Purification Demonstration Project – Project Report*
2. *Advanced Water Purification Facility Study Report* (on companion CD)
3. *Limnology and Reservoir Detention Study of San Vicente Reservoir* (on companion CD)

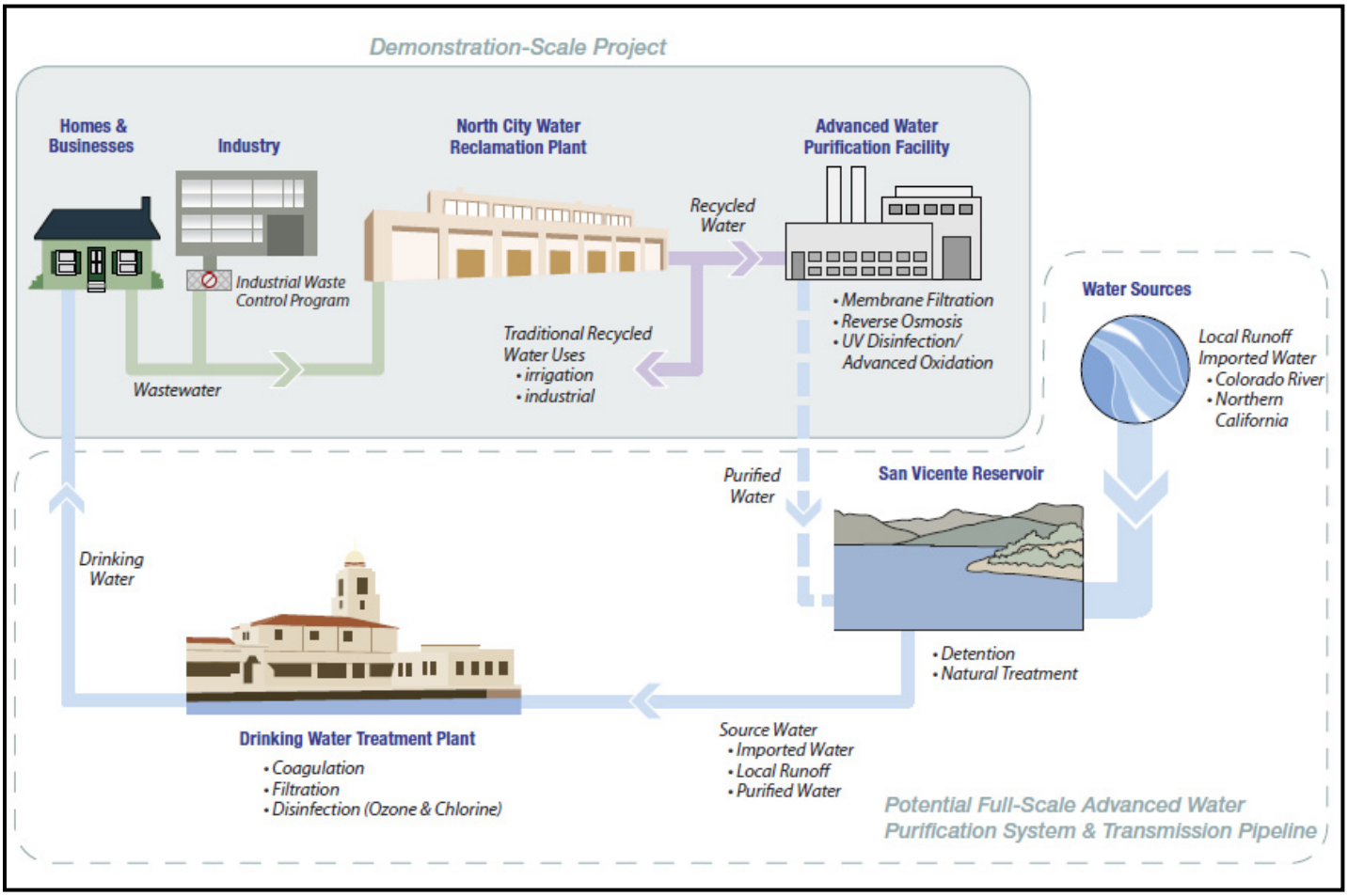


Figure 1 - Concept of a full-scale reservoir augmentation project at San Vicente Reservoir.

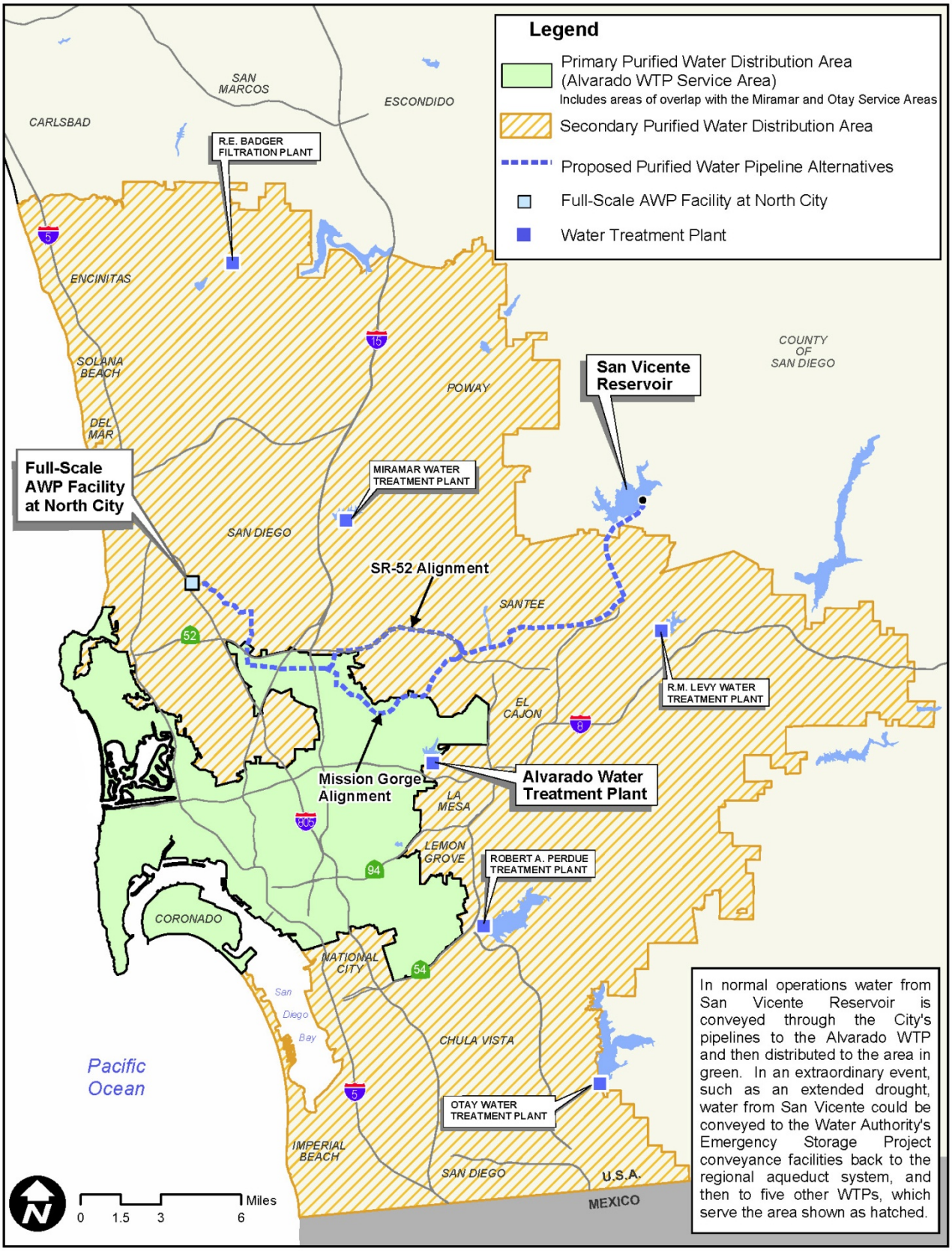


Figure 2 – Location map of a full-scale reservoir augmentation project at San Vicente Reservoir.

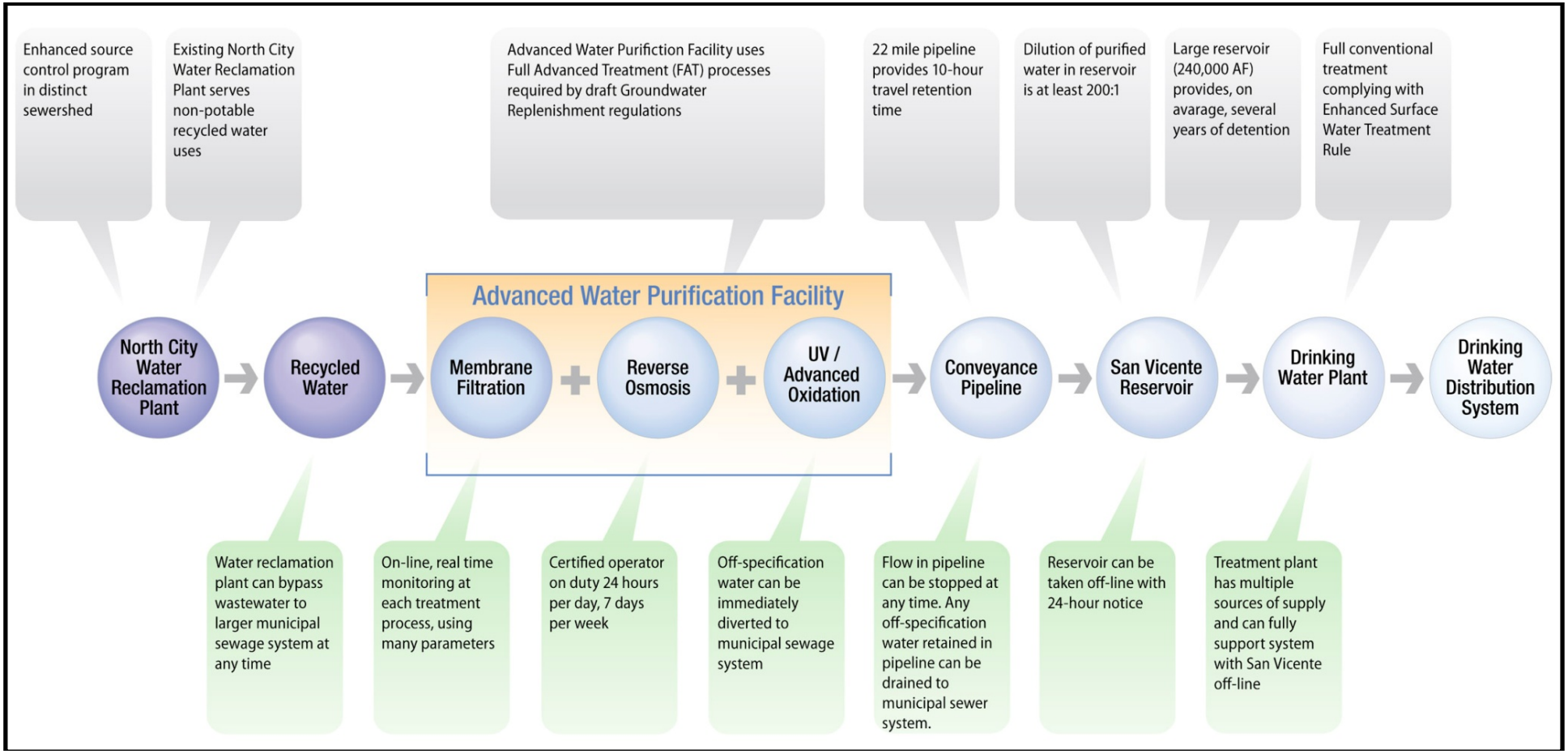
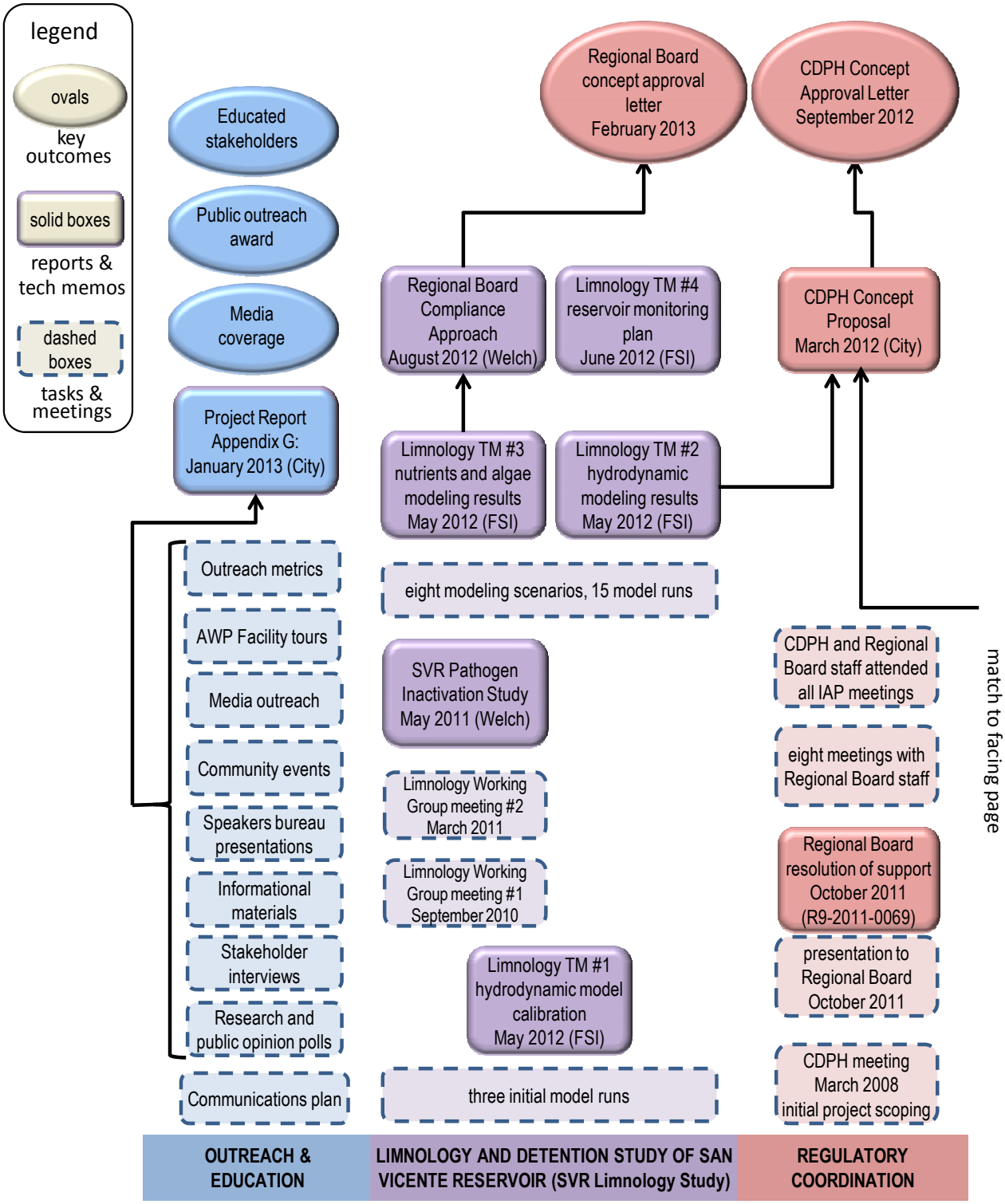
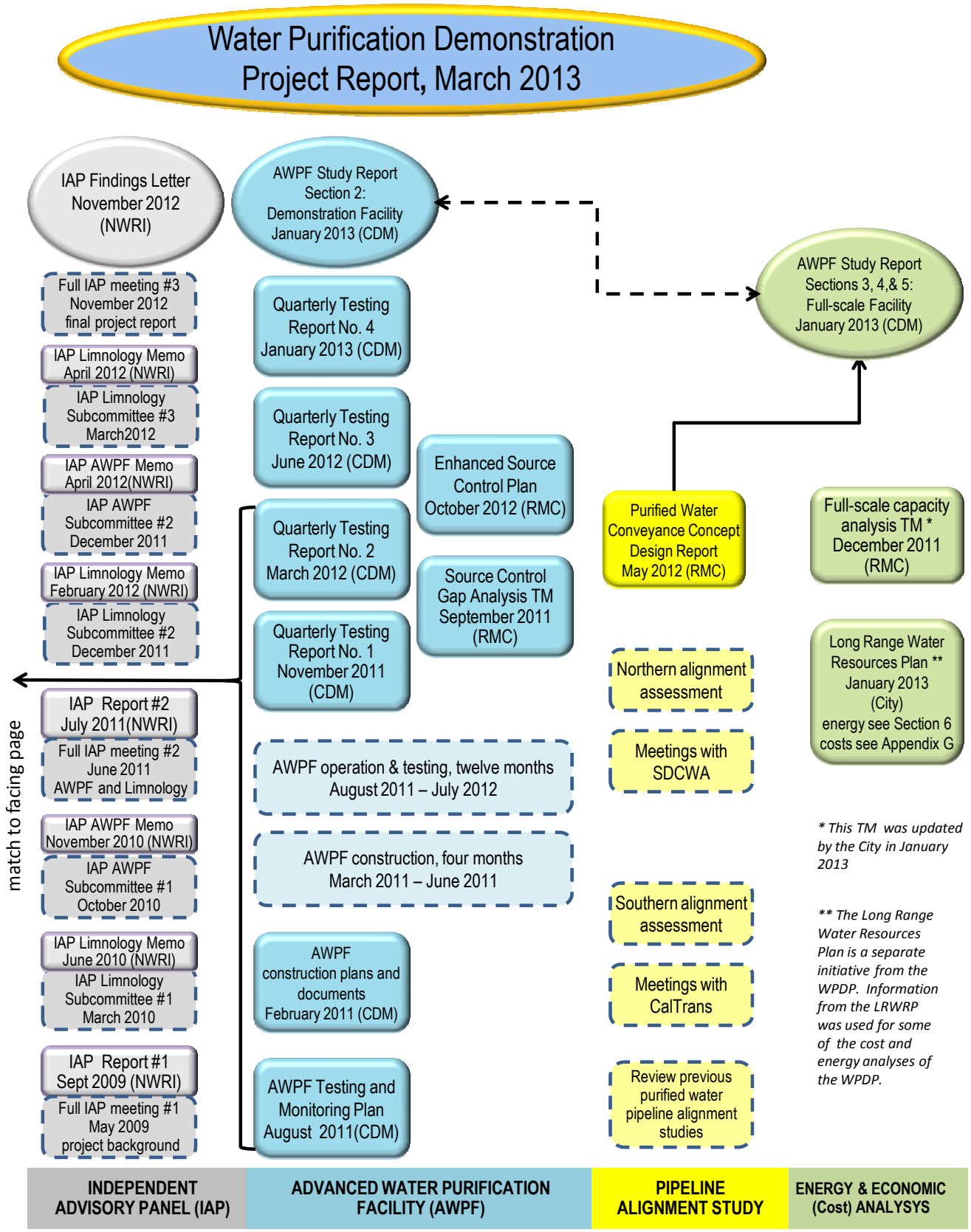


Figure 3 –The multiple treatment barriers provided by a full-scale reservoir augmentation project at San Vicente Reservoir. The treatment steps, or barriers, are shown along the center of the diagram, beginning with wastewater on the left and culminating with potable water on the right. The text boxes along the top describe features of the multiple treatment barriers, while the lower text boxes show operational actions associated with the multiple barriers.

Figure 4: Key tasks, meetings, reports, and outcomes of the Water Purification Demonstration Project, from project start in 2009 through project completion in 2013




Water Purification Demonstration Project Report, March 2013
IAP Findings Letter November 2012 (NWRI)
AWPF Study Report Section 2: Demonstration Facility January 2013 (CDM)
AWPF Study Report Sections 3, 4,& 5: Full-scale Facility January 2013 (CDM)
Full IAP meeting #3 November 2012 final project report
IAP Limnology Memo April 2012 (NWRI)
IAP Limnology Subcommittee #3 March2012
IAP AWPF Memo April 2012(NWRI)
IAP AWPF Subcommittee #2 December 2011
IAP Limnology Memo February 2012 (NWRI)
IAP Limnology Subcommittee #2 December 2011
IAP Report #2 July 2011(NWRI)
Full IAP meeting #2 June 2011 AWPF and Limnology
IAP AWPF Memo November 2010 (NWRI)
IAP AWPF Subcommittee #1 October 2010
IAP Limnology Memo June 2010 (NWRI)
IAP Limnology Subcommittee #1 March 2010
IAP Report #1 Sept 2009 (NWRI)
Full IAP meeting #1 May 2009 project background
match to facing page
Quarterly Testing Report No. 4 January 2013 (CDM)
Quarterly Testing Report No. 3 June 2012 (CDM)
Quarterly Testing Report No. 2 March 2012 (CDM)
Quarterly Testing Report No. 1 November 2011 (CDM)
Enhanced Source Control Plan October 2012 (RMC)
Source Control Gap Analysis TM September 2011 (RMC)
AWPF operation & testing, twelve months August 2011 – July 2012
AWPF construction, four months March 2011 – June 2011
AWPF construction plans and documents February 2011 (CDM)
AWPF Testing and Monitoring Plan August 2011(CDM)
Purified Water Conveyance Concept Design Report May 2012 (RMC)
Northern alignment assessment
Meetings with SDCWA
Southern alignment assessment
Meetings with CalTrans
Review previous purified water pipeline alignment studies
Full-scale capacity analysis TM * December 2011 (RMC)
Long Range Water Resources Plan ** January 2013 (City) energy see Section 6 costs see Appendix G
* This TM was updated by the City in January 2013
** The Long Range Water Resources Plan is a separate initiative from the WPDP. Information from the LRWRP was used for some of the cost and energy analyses of the WPDP.
INDEPENDENT ADVISORY PANEL (IAP)
ADVANCED WATER PURIFICATION FACILITY (AWPF)
PIPELINE ALIGNMENT STUDY
ENERGY & ECONOMIC (Cost) ANALYSYS

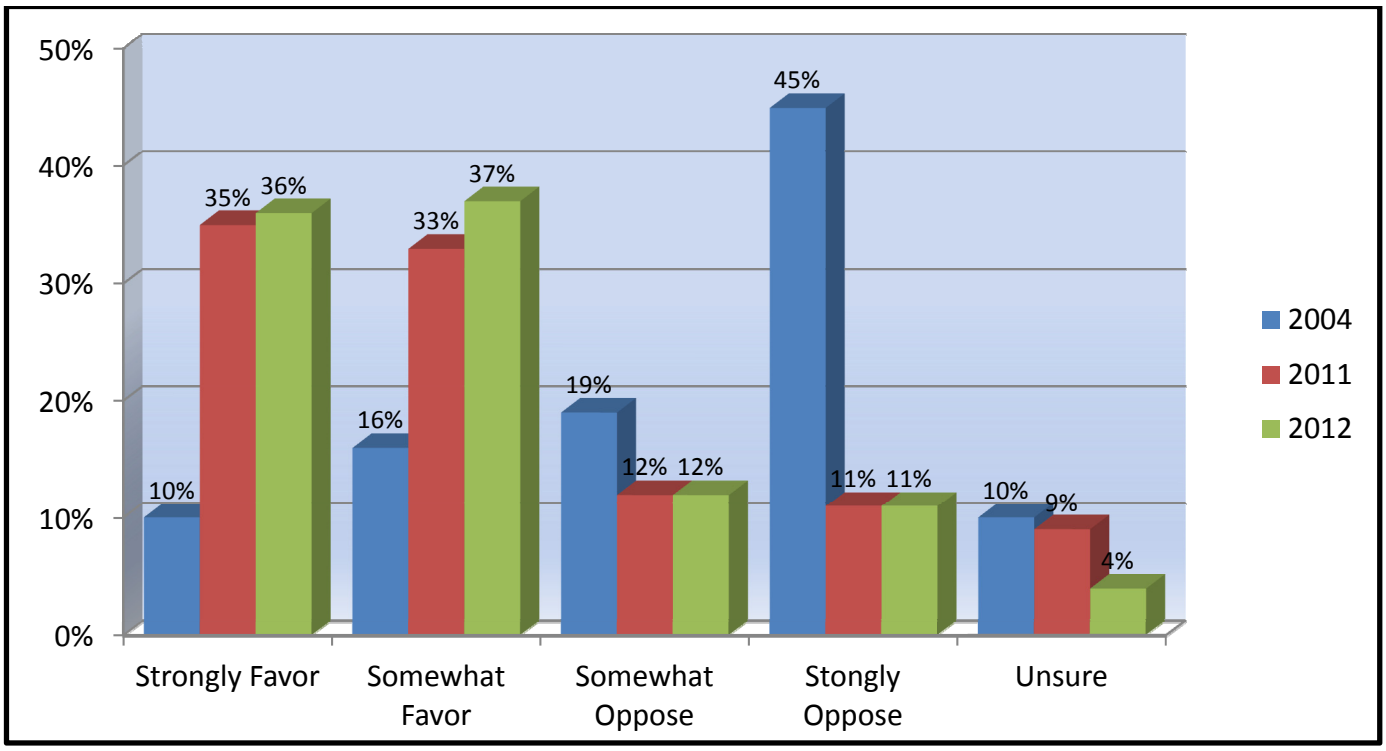


Figure 5 – Results of public opinion polls on the use of advanced treated recycled water as an addition to San Diego's drinking water supply (Rea & Parker Research, 2012 Public Opinion Poll Report).

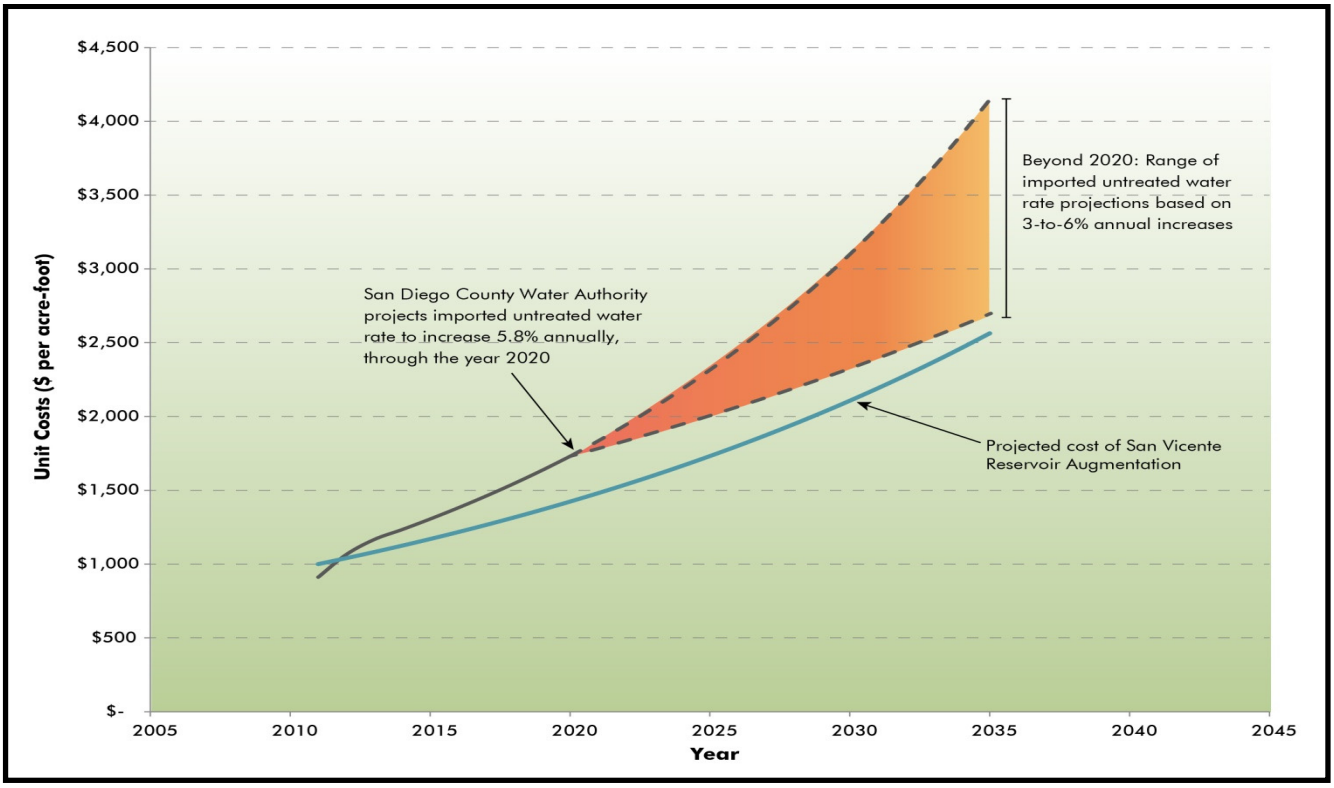


Figure 6 –Projected cost of purified water (solid line) of a full-scale reservoir augmentation project at San Vicente Reservoir compared to actual and projected costs of untreated imported water (dashed lines).

RESOLUTION NUMBER R-_____

DATE OF FINAL PASSAGE _____

A RESOLUTION OF THE COUNCIL OF THE CITY OF SAN DIEGO ADOPTING THE WATER PURIFICATION DEMONSTRATION PROJECT DRAFT PROJECT REPORT AS A FULFILLMENT OF THE DEMONSTRATION PROJECT ELEMENTS OUTLINED IN RESOLUTIONS R-303095 AND R-304434.

WHEREAS, in January 2004, the City Council of the City of San Diego approved a study to evaluate options to increase the use of recycled water produced at the City's two water reclamation plants; and

WHEREAS, the Water Reuse Study identified Reservoir Augmentation of the City's San Vicente Reservoir as the preferred reuse strategy; and

WHEREAS, in October and December 2007, the Council voted through Resolution R-303095 to accept the Water Reuse Study and proceed with the Indirect Potable Reuse/Reservoir Augmentation Demonstration Project [Demonstration Project] to evaluate the concept's feasibility; and

WHEREAS, a temporary water rate increase to fund the Demonstration Project was approved by the Council on November 25, 2008 through Resolution R-304434, and was in effect from January 1, 2009 to September 1, 2010; and

WHEREAS, this action is to adopt the Water Purification Demonstration Project, Project Report in fulfillment of the elements outlined in City Council actions approved in 2007 and 2008; NOW, THEREFORE,

BE IT RESOLVED, by the City Council of the City of San Diego, that the Water Purification Demonstration Project Draft Project Report is adopted as a fulfillment of the Demonstration Project elements outlined in Resolutions R-303095 and R-304434.

APPROVED: JAN I. GOLDSMITH, City Attorney

By _____
Raymond C. Palmucci
Deputy City Attorney

RCP:amt
03/12/2013
Or.Dept:PUD
Doc. No. 529049

I hereby certify that the foregoing Resolution was passed by the Council of the City of San Diego, at this meeting of _____.

ELIZABETH S. MALAND
City Clerk

By_____
Deputy City Clerk

Approved: _____ (date)

_____
BOB FILNER, Mayor

Vetoed: _____ (date)

_____
BOB FILNER, Mayor

THE CITY OF SAN DIEGO

Date of Notice: March 11, 2013

NOTICE OF RIGHT TO APPEAL ENVIRONMENTAL DETERMINATION

DEVELOPMENT SERVICES DEPARTMENT

PROJECT NAME/NUMBER: Water Purification Demonstration Project, *Project Report*

COMMUNITY PLAN AREA: All

COUNCIL DISTRICT: All

LOCATION: N/A

PROJECT DESCRIPTION: Adopt the Water Purification Demonstration Project, *Project Report* (formerly referred to as the Indirect Potable Reuse/Reservoir Augmentation Demonstration Project) in fulfillment of the elements outlined in Resolutions R-303095 (adopted December 3, 2007) and R-304434 (adopted November 25, 2008).

ENTITY CONSIDERING PROJECT APPROVAL: City of San Diego, City Council

ENVIRONMENTAL DETERMINATION: This action is exempt from the California Environmental Quality Act (CEQA) pursuant to the State CEQA Guidelines, Section 15262. This determination is based on Section 15004 of the Guidelines which provides direction to lead agencies on the appropriate timing for environmental review. The project will require further review under the provisions of CEQA.

ENTITY MAKING ENVIRONMENTAL DETERMINATION: City of San Diego Public Utilities Department Staff.

STATEMENT SUPPORTING REASON FOR ENVIRONMENTAL DETERMINATION: The proposed project would not have the potential for causing a significant effect on the environment.

CITY CONTACT: **Nicole McGinnis, Senior Planner**
MAILING ADDRESS: **600 B Street, MS 906, San Diego, CA 92101-4153**
PHONE NUMBER: **(619) 533-4101**

On March 11, 2013, the City of San Diego made the above-referenced environmental determination pursuant to the California Environmental Quality Act (CEQA). This determination is appealable to the City Council. If you have any questions about this determination, contact the City Contact above.

Applications to appeal CEQA determination made by staff (including the City Manager) to the City Council must be filed in the office of the City Clerk within 10 business days from the date of the posting of this Notice OR 15 business days from the date of the environmental determination, whichever occurs earlier. Applications to appeal CEQA determinations made by the Planning Commission from a Process Two or Three Appeal under SDMC section 112.0506 must be filed in the Office of the City Clerk within 10 business days from the date of the Planning Commission's decision. The appeal application can be obtained from the City Clerk, 202 'C' Street, Second Floor, San Diego, CA 92101.

This information will be made available in alternative formats upon request.

DETERMINATION OF

ENVIRONMENTAL EXEMPTION

Pursuant to the California Environmental Quality Act (CEQA) and State CEQA Guidelines

Agency: CITY OF SAN DIEGO **WBS No.**: None **Date:** March 11, 2013

Action/Permit(s): Adopt a report

Description of Activity: **Adopt the Water Purification Demonstration Project, Project Report** (formerly referred to as the Indirect Potable Reuse/Reservoir Augmentation Demonstration Project) in fulfillment of the elements outlined in Resolutions R-303095 (adopted December 3, 2007) and R-304434 (adopted November 25, 2008). The current activity is to adopt a report summarizing a demonstration project. Any subsequent activities will require further review under the provisions of CEQA.

Location of Activity: Not applicable.

1. [ ] This activity is **EXEMPT FROM CEQA** pursuant to:

   [ ] Section 15060(c) (3) of the State CEQA Guidelines (the activity is not a project as defined in Section 15378).

2. [X] This project is EXEMPT FROM CEQA pursuant to State CEQA Guidelines Section checked below:

ARTICLE 19 of GUIDELINES
CATEGORICAL EXEMPTIONS
(Incomplete list)

Section	Short Name
[ ] 15301	Existing Facilities
[ ] 15302	Replacement or Reconstruction
[ ] 15303	New Construction or Conversion of Small Structures
[ ] 15304	Minor Alterations to Land
[ ] 15305	Minor Alteration in Land Use
[ ] 15306	Information Collection
[ ] 15311	Accessory Structures
[ ] 15312	Surplus Government Property Sales
[ ] 15315	Minor Land Divisions
[ ] 15317	Open Space Contracts or Easements
[ ] 15319	Annexation of Existing Facilities and Lots for Exempt Facilities
[ ] 15325	Transfer of Ownership of Interest in Land to Preserve Open Space
[ ] Other	

ARTICLE 18 of GUIDELINES
STATUTORY EXEMPTIONS
(Incomplete list)

Section	Short Name
[ ] 15261	Ongoing Project
[x] 15262	Feasibility and Planning Studies
[ ] 15265	Adoption of Coastal Plans and Programs
[ ] 15268	Ministerial Projects
[ ] 15269	Emergency Projects
[ ] Other	

It is hereby certified that the City of San Diego has determined the above activity to be exempt:

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THE CITY OF SAN DIEGO

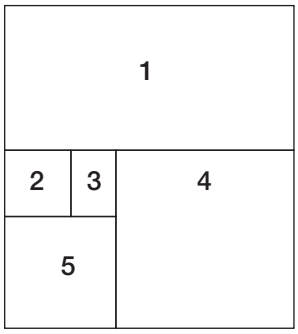
CITY OF SAN DIEGO

Water Purification Demonstration Project

Project Report (Final Draft)

MARCH 2013

On the cover:



1. The Advanced Water Purification Facility
2. Ultraviolet Light/Advanced Oxidation equipment
3. Reverse Osmosis canisters
4. Microfiltration and Ultrafiltration systems
5. San Vicente Reservoir

Printed on recycled paper. This information is available in alternative formats upon request.

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This Water Purification Demonstration Project Report is the culmination of a multi-year program to assess the feasibility of supplementing one of San Diego's local water supply reservoirs, San Vicente Reservoir, with purified water produced at an advanced water purification facility. The combined contributions of the project team, regulatory agency representatives, Independent Advisory Panel members, and local stakeholders were invaluable in implementing a comprehensive project. This section recognizes participants who contributed substantially to this effort.

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Terms and Abbreviations

AF	Acre-feet
AFY	Acre-feet per year
AWP Facility	Advanced Water Purification Facility – the existing demonstration-scale facility constructed and operated for the Water Purification Demonstration Project
Basin Plan	Water Quality Control Plan for the San Diego Basin
Bureau of Reclamation	United States Bureau of Reclamation
CDPH	California Department of Public Health
CEC	Constituent of emerging concern
CEQA	California Environmental Quality Act
City	City of San Diego
City Council	San Diego City Council
CTR	California Toxics Rule
Demonstration Project	Water Purification Demonstration Project
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
EPA	United States Environmental Protection Agency
Full-scale AWP facility	Full-scale AWP facility that would be implemented for future full-scale reservoir augmentation
GIS	Geographic Information Systems
IAP	Independent Advisory Panel
IROC	Independent Rates Oversight Committee
kWh	Kilowatt hours
LRWRP	Long-Range Water Resources Plan
MCL	Maximum Contaminant Level
mgd	Million gallons per day
NDMA	N-Nitrosodimethylamine
North City	North City Water Reclamation Plant
NR&C	Natural Resources & Culture Committee
NPDES	National Pollutant Discharge Elimination System
NWRI	National Water Research Institute
O&M	Operations and maintenance
Orange County GWRS	Orange County Groundwater Replenishment System
Point Loma	Point Loma Wastewater Treatment Plant

Regional Board	San Diego Regional Water Quality Control Board
RWS	City of San Diego Recycled Water Study, 2012
SR-52	State Route 52
State Board	State Water Resources Control Board
Water Authority	San Diego County Water Authority
WDR	Waste Discharge Requirements

Glossary of Terms

1,4-dioxane	A solvent used in industrial and commercial applications. The California Department of Public Health uses 1,4-dioxane as an indicator compound to assess the performance of advanced oxidation since it is difficult to remove from water. The ability of a purification process to remove 1,4-dioxane indicates to the California Department of Public Health that the purification process provides a robust barrier to a wide array of chemicals.
Acre-feet (AF)	A term commonly used in the water industry to measure large quantities of water. An acre-foot is defined as the amount of water required to cover one acre to a depth of one foot. An acre-foot is equivalent to 325,851 gallons and is considered enough water to meet the needs of two families of four with a house and a yard for one year.
Advanced oxidation	A set of chemical treatment processes designed to destroy organic material by breaking down its molecular structure. The advanced oxidation process used at the Advanced Water Purification Facility employs ultraviolet light and hydrogen peroxide, which break down organic molecules into natural elements, such as carbon, hydrogen, and nitrogen.
Advanced Water Purification Facility	The one-mgd demonstration-scale facility located at the North City Water Reclamation Plant. Generally abbreviated as the AWP Facility. The facility is considered "advanced" because of the high level of treatment using reverse osmosis and advanced oxidation. The AWP Facility was one element of the multi-faceted Demonstration Project.
Augmentation of water supply	The process of adding purified water to an existing raw or untreated water supply such as a reservoir, lake, river, wetland, and/or groundwater basin where it will blend with raw water supplies.
Beneficial reuse	The use of recycled water for purposes that contribute to the economy or environment of a community, such as landscape irrigation and industrial purposes.
Beneficial use	Specific designated water uses such as municipal, recreation, and agricultural, which are provided water quality protections to allow those uses to continue to occur in the future.
Blending	Mixing or combining one water source with another, such as combining purified water with imported water sources.

Brackish water	Water that has a higher salt content than fresh water, but not as high as seawater. Usually, the salts must be removed or reduced before the water is usable.
California Department of Public Health (CDPH)	The state agency responsible for public health in California. It is a subdivision of the California Health and Human Services Agency. One of its functions is to develop and enforce drinking water quality standards and regulations for public water systems.
Clean Water Act	The federal law passed in 1977 that establishes how the United States will restore and maintain the chemical, physical, and biological integrity of the country's waters, including oceans, lakes, streams and rivers, groundwater, and wetlands.
Conductivity	The ability to conduct or transmit electricity. Conductivity of water increases with the concentration of dissolved ions, so measuring conductivity provides a measure of the concentration of dissolved ions in water.
Constituent	A dissolved chemical element or compound, or a suspended material that is carried in the water.
Constituents of emerging concern	Unregulated contaminants, including commonly used pharmaceuticals, personal care products, flame retardants, and unregulated pesticides.
Contaminant	An organic or inorganic substance found in water. Some contaminants cause adverse health effects in humans and, therefore, are regulated in drinking water (see Maximum Contaminant Level). Not all contaminants are unsafe.
Conventional wastewater treatment	A combination of treatment steps that stabilizes and removes solids and organic material from wastewater.
Demonstration Project	See Water Purification Demonstration Project
Disinfection	The removal, inactivation, or destruction of microorganisms present in a water supply that may be harmful to humans. Commonly used disinfectants include chlorine and its derivatives, ultraviolet light, and ozone. Chlorine and its derivatives can also be used to provide residual disinfection that protects the water as it goes through the pipes to homes and businesses.
Disinfection byproduct	Chemicals formed during water treatment as a byproduct of reactions between natural organic matter in the water and an added disinfectant. In drinking water, some disinfection byproducts may have potential health concerns.

Drinking water	Water that meets federal drinking water standards as well as state and local water quality standards so that it is safe for human consumption. Water treatment facilities that produce drinking water require a state permit. Also referred to as potable or treated water.
Drinking water treatment plant	In the San Diego region, drinking water treatment plants draw unfiltered water from reservoirs and use a four-step process of coagulation, settling, filtration, and disinfection to produce water that is safe to drink (see drinking water).
Drought	A defined period of time when rainfall and runoff in a geographic area are much less than average.
Environmental buffer	A water body such as a groundwater basin or a surface water reservoir that provides additional dilution and retention of purified water prior to its use as drinking water.
Environmental Impact Statement/Environmental Impact Report	Detailed analysis of impacts of a project on all aspects of the natural and human environment. An Environmental Impact Statement is required by the federal National Environmental Policy Act for federal permitting or use of federal funds. An Environmental Impact Report is required by the California Environmental Quality Act for local projects.
Epilimnion	The top-most layer of warm water present within a stratified water reservoir (see stratification).
Filtration	A process that separates small particles from water by using a porous barrier to trap the particles while allowing the water to pass through.
Groundwater	Water beneath the earth's surface that supplies wells and natural springs. A groundwater basin is any underground area that contains and can store water.
Groundwater Replenishment Reuse Draft Regulation (California Department of Public Health Groundwater Recharge Criteria)	Draft regulation released by the California Department of Public Health in 2011, which reflects the California Department of Public Health Drinking Water Program's proposed regulation for replenishing groundwater with purified water.
Full-scale reservoir augmentation project	A potential third phase of the City's Water Reuse Program, which would include implementation of a full-scale reservoir augmentation project at San Vicente Reservoir (see reservoir augmentation).
Hydrogen peroxide	Chemical added in the ultraviolet disinfection/advanced oxidation step of the advanced water purification process.
Hypolimnion	The bottom-most layer of cool water present within a stratified water reservoir (see stratification).

Imported water	A water source that originates in one hydrologic region and is transferred to another hydrologic region. In San Diego's case, water is imported from Northern California or the Colorado River and travels to San Diego in large above-ground aqueducts or underground pipelines.
Independent Advisory Panel (IAP)	An independent panel of experts convened to provide expert peer review of the technical, scientific, and regulatory aspects of the Demonstration Project.
Indicator compounds or indicator organisms	A common method to evaluate water or wastewater quality using representative chemicals or organisms that are characteristic of a larger group of related chemicals or organisms. Coliform bacteria are common indicator organisms, and trihalomethanes, benzene, 1,4-dioxane, and NDMA are examples of indicator compounds.
Indirect potable reuse	An industry term referring to projects that augment groundwater and surface waters with purified water. This term was originally used to distinguish between direct potable reuse, which is the introduction of purified water into the drinking water system without an intermediate environmental buffer, and systems that did incorporate an environmental buffer. Potable reuse is a general term used to refer to both direct and indirect purified water projects.
Local limits	Local limits are wastewater limitations that apply to commercial and industrial facilities discharging wastewater to a municipal public system. Local limits control the pollutants in wastewater discharges.
Maximum Contaminant Level (MCL)	The highest allowable amount of a contaminant in drinking water, established by the United States Environmental Protection Agency.
Membrane filtration	A type of filtration used to separate particles from water. Membrane filters are characterized by the size of the openings (pores), which are ranked from the largest to the smallest pore size: microfiltration, ultrafiltration, nanofiltration and reverse osmosis.
Microfiltration	A low-pressure membrane filtration process where tiny, hollow, straw-like membranes separate small suspended particles, bacteria and other materials from water. Microfiltration provides efficient preparation of water for reverse osmosis and is used to process food, fruit juices and sodas; and to sterilize medicines that cannot be heated.
Million gallons per day	This term is used to describe the flow of water treated and distributed from a treatment plant each day.

N-nitrosodimethylamine (NDMA)	N-nitrosodimethylamine is a chemical that is found in a variety of natural and man-made sources and can be formed during wastewater treatment. It is used by the California Department of Public Health as an indicator compound to assess the performance of advanced oxidation since it is difficult to remove from water. The ability of a purification process to achieve removal indicates to the California Department of Public Health that the process provides a robust barrier to a wide array of chemicals.
National Pollutant Discharge Elimination System (NPDES)	A federal permit authorized by the Clean Water Act, Title IV, which is required for discharge of pollutants to waters of the United States, and includes any discharge to lakes, streams, rivers, bays, the ocean, wetlands, storm sewer, or tributary to any surface water body.
Non-potable water	Water that is not suitable for drinking because it has not been treated to drinking water standards (see drinking water). Includes recycled water as well as raw or untreated water.
North City Water Reclamation Plant (North City)	Wastewater treatment plant that produces recycled water through a combination of conventional wastewater treatment and tertiary treatment (see conventional wastewater treatment and tertiary treatment).
Orange County Groundwater Replenishment System (GWRS)	A project that employs water purification processes similar to those tested at the AWP Facility, which has been operational since 2008. This project provides a model for the City's potential reservoir augmentation project in that it uses similar water purification technology and is permitted under a similar regulatory framework.
Oxidation	A treatment step used in disinfection, in which oxygen or ozone is added to water to produce a chemical reaction that removes potentially harmful substances.
Pathogens	Disease-causing organisms. The general groupings of pathogens are viruses, bacteria, protozoa, and fungi.
Pipeline system	Pipeline system, including pump station and reservoir inlet structure, which would convey purified water from North City to San Vicente Reservoir. Also referred to as purified water pipeline system.
Point Loma Wastewater Treatment Plant (Point Loma)	Advanced primary wastewater treatment plant that discharges treated wastewater to the Pacific Ocean.
Pretreatment	The treatment of wastewater near its source to remove harmful pollutants before being discharged to a sewer system.
Primary drinking water standards	Legally enforceable federal and state standards that must be met by public water systems. Primary drinking water standards protect public health by limiting the levels of contaminants in drinking water.

Purified water	Water that starts out as wastewater from homes or businesses and is collected and put through a series of treatment and purification steps such that it meets all drinking water standards and can be added to water supplies ultimately used for drinking water. The treatment includes membrane filtration with microfiltration or ultrafiltration, reverse osmosis, and advanced oxidation that consists of disinfection with ultraviolet light and hydrogen peroxide. Purified water may be released into a groundwater basin or surface water reservoir that supplies water to a drinking water treatment facility.
Raw water	Water that has not been treated for use. Examples of raw water are water in the Colorado River aqueduct, the State Water Project aqueduct, open reservoirs (whether filled with imported water or runoff), rivers, naturally-occurring lakes and some well water.
Recycled water	Water that originated from homes and businesses as municipal wastewater and has undergone a high degree of treatment at a water reclamation facility so that it can be beneficially reused for a variety of purposes. This is the type of water that is produced at North City and is the source water for the AWP Facility.
Reservoir augmentation	The process of adding purified water to a surface water reservoir. The purified water undergoes advanced treatment prior to being blended with untreated water in a reservoir. The blended water is then treated and disinfected at a conventional drinking water treatment plant and is distributed into the drinking water delivery system.
Reverse osmosis	A high-pressure membrane filtration process that forces water through the molecular structure of several sheets of thin plastic membranes to filter out minerals and contaminants, including salts, viruses, pesticides, and other materials. The reverse osmosis membranes are like microscopic strainers; bacteria and viruses as well as inorganic and most organic molecules cannot pass through the membranes. Reverse osmosis membranes have a smaller pore size than all other types of membranes.
Retention time	The amount of time that purified water is retained in a water body such as a groundwater basin or surface water reservoir prior to being extracted.
Secondary drinking water standards	Drinking water quality standards that are not enforced, but serve as guidelines to assist public water systems in managing drinking water aesthetic conditions such as taste, color and odor.

Source control	Programs and/or processes in place to provide regulatory oversight of sewer discharges in order to protect the pipeline system and the wastewater treatment plant from harmful discharges. Source control programs typically focus on industrial and commercial (non-residential) customers and may include a variety of activities such as permitting, sampling, enforcement and oversight related to industrial discharges. For projects where purified water would enter the drinking water system via groundwater or surface water augmentation, the California Department of Public Health requires that source control programs be augmented to address residential and commercial facilities, and focus on an expanded set of contaminants that may have public health relevance, such as industrial chemicals, pharmaceuticals, and personal care product residuals sometimes found in wastewater.
Stratification	The formation of layers of water within a reservoir. This is a natural phenomenon that occurs in all reservoirs in North America. During the period of stratification, warm water that is naturally heated by the sun is contained within the top-most layer, or epilimnion, and denser cooler water is contained within the lower layer, or hypolimnion.
Tertiary treatment	Treatment of wastewater to a level beyond secondary treatment but less than water purification. Water treated to this level is considered to be recycled water, which is suitable for many beneficial uses including irrigation and industrial processes. Tertiary water meets treatment and reliability criteria established by Title 22, Chapter 4, of the California Code of Regulations.
Total organic carbon (TOC)	Total organic carbon is a measure of the amount of carbon that is bound in organic molecules, including all natural and man-made organic chemicals.
Ultrafiltration	A membrane filtration process with pore size openings smaller than microfiltration and larger than nanofiltration or reverse osmosis. Also used to characterize the size of particles removed.
Ultraviolet disinfection/advanced oxidation	Process by which water is exposed to ultraviolet light to provide disinfection, similar to the process for disinfecting instruments in medical and dental offices. Additionally, ultraviolet light combined with hydrogen peroxide creates an advanced oxidation reaction that eliminates any remaining compounds in water by breaking them down into harmless compounds.
United States Environmental Protection Agency (EPA)	The federal agency responsible for protecting public and environmental health in the United States. Its functions include developing and enforcing water quality standards for drinking water as well as man-made and naturally-occurring waters of the United States.

Wastewater	Untreated water collected in the sewer system from residences and businesses (e.g., from bathtubs, showers, bathroom sinks, clothes washers, toilets, kitchen sinks, dishwashers, and industrial processes). Wastewater is more than 99 percent water with impurities.
Wastewater collection system (collection system)	System that conveys wastewater from residences and businesses to a wastewater treatment plant such as North City.
Water Purification Demonstration Project (Demonstration Project)	The second phase of the City of San Diego's Water Reuse Program. During this test phase, the Advanced Water Purification Facility was operated for approximately one year to collect operating data, producing one million gallons of purified water per day. The Advanced Water Purification Facility remains online. A study of San Vicente Reservoir was conducted to test the key functions of reservoir augmentation and to determine the viability of a full-scale project. No purified water was sent to San Vicente Reservoir during the demonstration phase.
Water purification process	The process of using water purification technology on recycled water to produce a water supply that can be used for reservoir augmentation and ultimately for drinking water purposes. The process of water purification begins with recycled water, which has already been treated to produce a supply of water safe enough for use in irrigation and industrial purposes. This recycled water is then further treated using water purification technology. The resulting purified water can be used to augment local surface water supplies, which would be treated once more at a drinking water treatment plant to produce drinking water.
Water Quality Control Plan for the San Diego Basin (Basin Plan)	This plan establishes water quality objectives and implementation plans to protect different beneficial uses that are established for specific water bodies in the San Diego Regional Water Quality Control Board region (see beneficial use).
Water Reuse Program	The City's three-phased program, which is a potential local option to increase water supply reliability through the beneficial reuse of water.

Using This Report

This Project Report provides an overview of the technical studies, advanced water purification facility testing, and public education and outreach efforts conducted as part of the City of San Diego's Water Purification Demonstration Project. It also presents findings that support the conclusion that implementation of a reservoir augmentation project at San Vicente Reservoir is feasible.

This Project Report presents background information, key findings for each of the core components of the Demonstration Project, and considerations for full-scale project implementation. It is organized as shown in the following table.

Section A | Introduction and Summary of Findings
Section B | Advanced Water Purification Facility
Section C | San Vicente Reservoir Study
Section D | Regulatory Coordination
Section E | Public Outreach and Education
Section F | Full-Scale Project Considerations
Section G | Summary and Conclusions

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Section A: Introduction and Summary of Findings

The Water Purification Demonstration Project was a multi-year project designed to assess the feasibility of supplementing one of San Diego's local water supply reservoirs, San Vicente Reservoir, with purified water produced at an advanced water purification facility. The project is an integral component of the City's plan to improve water supply reliability by developing local, drought-tolerant water supplies. The Water Purification Demonstration Project involved installing and operating a demonstration-scale advanced water purification facility, studying San Vicente Reservoir, implementing a public outreach and education program, developing conceptual design criteria and costs for a full-scale advanced water purification facility and pipeline facilities, and developing a conceptual pipeline alignment.

The advanced water purification facility is a component of the Water Purification Demonstration Project.

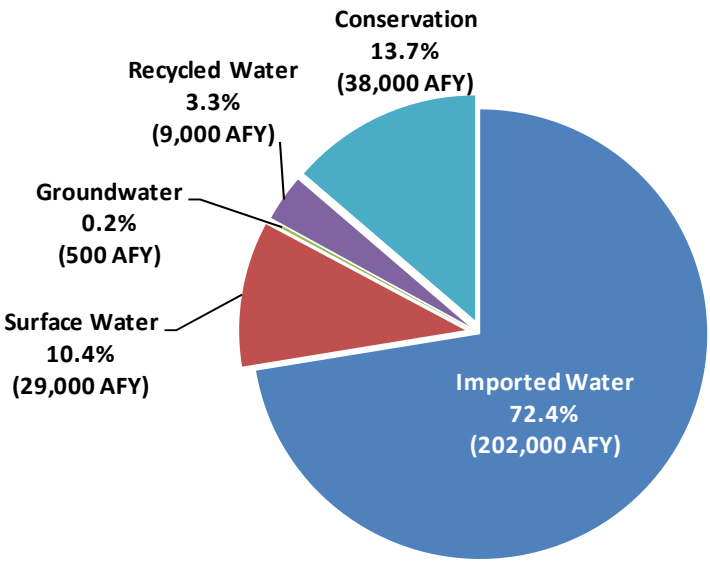
This Project Report provides an overview of the technical studies, advanced water purification facility testing, and public education and outreach efforts conducted as part of the Water Purification Demonstration Project. It also presents findings that support the conclusion that implementation of a reservoir augmentation project at San Vicente Reservoir would be feasible.

In 1813 Spanish settlers and missionaries completed a dam and flume on the San Diego River to supply water to Mission San Diego de Alcala. This effort to secure a dependable water source for the mission was the first water supply project on the West Coast. Two hundred years later San Diego continues its quest to secure reliable and locally controlled sources of water. Using modern technologies and advanced science, the Water Purification Demonstration Project moves the City toward a future of dependable water supplies.

San Diego's Water Supply Reliability Challenges

The City of San Diego (City) provides drinking water to more than 1.3 million people. In addition to supplying approximately 274,000 metered service connections within its own incorporated boundaries, the City supplies water to the City of Del Mar; Santa Fe and San Dieguito Irrigation Districts; and California American Water Company, which, in turn, serves the Cities of Coronado and Imperial Beach and portions of south San Diego (City of San Diego, 2011a). The City's projected total water use in 2015, including wholesale deliveries to other agencies, is

240,000 acre-feet (AF), which is equivalent to 78,000 million gallons, or 210 million gallons per day (mgd) (City of San Diego, 2011a). The City's actual water use in fiscal year 2012, which also included wholesale deliveries to other agencies, was 190,000 AF,(based on data from the City of San Diego, Public Utilities Department, Water Operations Division. This is equivalent to 63 million gallons or 170 mgd. Actual water use varies from year to year because of climatic and economic conditions. Further, the mandatory use restrictions enforced during the 2009/2010 drought appear to have had a lasting effect on water use, as demands have not yet rebounded to their pre-drought levels. The City meets water demands with the following supplies:



Existing water resource mix projected for 2015 normal/average hydrologic conditions (AFY = acre-feet per year) (City of San Diego, 2012c)

- Imported water, which includes water imported from the San Francisco Bay / Sacramento – San Joaquin Delta (Bay-Delta) in Northern California or the Colorado River
- Local surface water
- Groundwater
- Recycled water

San Diego is situated at the end of a complex network of state, federal, and local water projects.

In an average year, approximately 85 to 90 percent of the City's water supplies are imported water, which is water that is supplied from the Bay-Delta in Northern California or the Colorado River through a network of state, federal, and local pipeline facilities (City of San Diego, 2012b). The cost of imported water has increased significantly and is expected to continue to increase into the future. From 2007 to 2012, Metropolitan Water District's (MWD's) imported water costs increased by more than 12 percent annually, and MWD projects its 2014 full service water rate to be seven percent greater than its 2012 rate. Going forward, the San Diego County Water Authority (Water Authority) projects that its untreated water rates will double in less than 10 years (City of San Diego, 2012c).

Environmental stressors, such as ongoing drought in the Colorado River Basin, reduced snowpack and runoff in Northern California, and court-ordered pumping restrictions necessary to protect endangered species, have decreased the reliability of imported water supplies (City of San Diego, 2012b).

Imported water reliability issues, coupled with recurring droughts in the San Diego region, have placed considerable strain on the City's ability to meet water demands. The City has taken a variety of actions to maximize water resources and improve water supply reliability, including the following.

- The City supports a wide array of **water conservation measures** designed to reduce water demands and maximize water use efficiency. A signatory to the Memorandum of Understanding with the California Urban Water Conservation Council since 1991, the City employs a variety of urban Best Management Practices for conserving water (City of San Diego, 2011a). City-wide conservation efforts resulted in an approximate water savings of 34,000 AF in 2010 (City of San Diego, 2011a).
- In 2002, the City developed a **Long-Range Water Resources Plan** (LRWRP) that defines a plan to reduce reliance on imported water supplies and develop and maximize local water resources. The LRWRP is currently being updated (draft 2012 LRWRP) to reflect recent changes in the availability, costs, and reliability of various water supply sources (City of San Diego, 2012c).

A Word About Imported Water Reliability

Water is essential to our quality of life. The City imports 85-90 percent of its water supply from the Bay-Delta in Northern California and the Colorado River. In recent years, both Southern California and the Colorado River system have experienced drought conditions. In addition, legal and regulatory decisions to protect endangered species have restricted the amount of water that can be pumped from Northern California. Since San Diego is at the end of the imported water pipeline, and receives an average of 10-12 inches of rain each year, local, drought-tolerant water supplies are critical to securing a reliable supply of water now and in the future.

Local reservoir levels have been lower than typical due to dry conditions.

Pumping from the Bay-Delta is limited to protect endangered species such as the Delta Smelt.

- The City is a member of the Regional Water Management Group administering the **San Diego Integrated Regional Water Management Program**, which uses an integrated regional approach to address water management issues.
- The City is conducting independent studies as well as participating with the United States Geological Survey and the United States Bureau of Reclamation (Bureau of Reclamation) on **groundwater basin studies and hydrogeologic investigations** to better understand the complex hydrogeology of the San Diego coastal area, the water supply potential of the local groundwater basins, and the potential for desalination of saline groundwater located near the coast (brackish groundwater) (City of San Diego, 2011a).
- The City is implementing a **Water Reuse Program** designed to maximize water reuse.

The following sections discuss the elements of the Water Reuse Program, including the Water Purification Demonstration Project, in more detail.

Maximizing Local Supplies with the Water Reuse Program

In response to San Diego's ongoing water supply challenges, the City initiated a comprehensive Water Reuse Program in the early 2000's. The Water Purification Demonstration Project is the second phase of this initiative designed to maximize the use of recycled water throughout the City.

Phase 1: Water Reuse Study

In 2006, the City completed the Water Reuse Study, which included a comprehensive evaluation of all viable options to maximize the use of recycled water produced by the City's two water reclamation plants (City of San Diego, 2006). The study included analysis and research on the health effects of reuse options and implemented a comprehensive public participation process. Based on the information presented in the Water Reuse Study, a stakeholder group determined that the preferred option for maximizing use of the City's recycled water supply would be to augment existing supplies in the City's San Vicente Reservoir with recycled water—this option is referred to as "reservoir augmentation at San Vicente Reservoir." In response to both the Water Reuse Study and the stakeholder recommendation, the San Diego City Council (City Council) approved the second phase of the Water Reuse Program: the Water Purification Demonstration Project.

What is Reservoir Augmentation?

Reservoir augmentation is the practice of augmenting an existing drinking water supply reservoir by adding purified water. Purified water starts out as wastewater from homes or businesses. It is then collected and put through a series of treatment and purification steps designed to produce purified water that meets all drinking water standards.

Reservoir augmentation as identified in the Water Reuse Study would adhere to the multiple barrier concept that is fundamental to the provision of public health safeguards. These barriers include conventional water recycling treatment as practiced in the San Diego region for more than 30 years, advanced water purification technologies, blending with imported water in San Vicente Reservoir, drinking water treatment at a municipal water treatment plant, and distribution to the City's drinking water system.

Phase 2: Water Purification Demonstration Project

Phase 2 of the Water Reuse Program is the Water Purification Demonstration Project (Demonstration Project). The Demonstration Project, which is the focus of this Project Report, evaluated the feasibility of using water purification technology to produce water that could be sent to San Vicente Reservoir where it would be mixed with a combination of local and imported water supplies prior to being treated at a water treatment plant and distributed as drinking water (see Figure A-1).

(Potential) Phase 3: Reservoir Augmentation at San Vicente Reservoir

Because the concept of using purified water to augment San Vicente Reservoir has been determined to be feasible (as discussed in greater detail in subsequent sections of this Project Report), the Mayor and City Council may consider implementing a reservoir augmentation project at San Vicente Reservoir. The key facilities associated with a reservoir augmentation project at San Vicente Reservoir are presented in Figure A-2.

The City of San Diego's Water Reuse Program

- Phase 1 – The Water Reuse Study, published in 2006
- Phase 2 – The Demonstration Project, which evaluated the feasibility of using purified water to augment San Vicente Reservoir (No purified water was actually sent to the reservoir in Phase 2.)
- (Potential) Phase 3 – The future Full-Scale Reservoir Augmentation Project at San Vicente Reservoir

Figure A - 1: Phase 2 and Potential Phase 3 of the City's Water Reuse Program

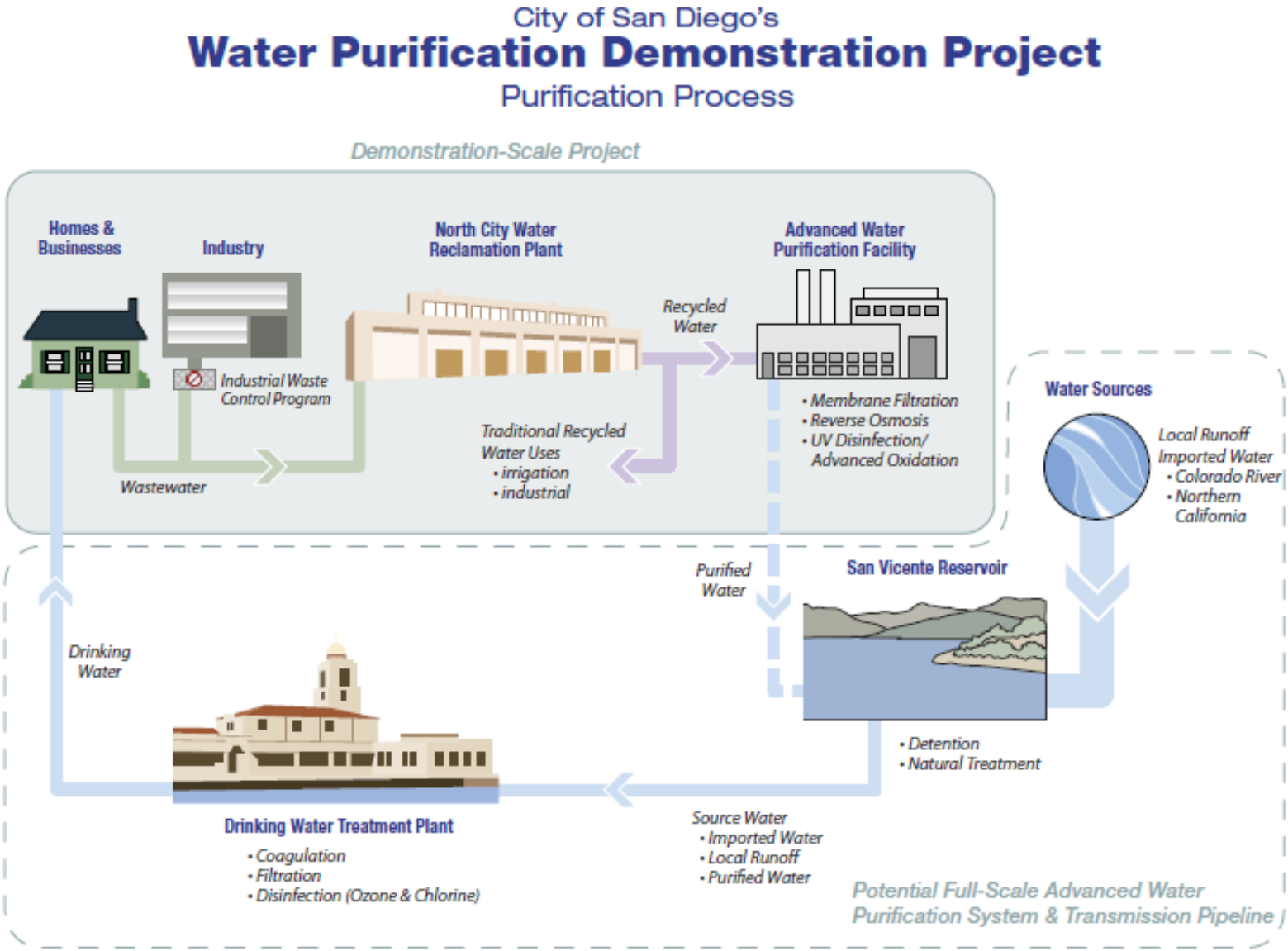
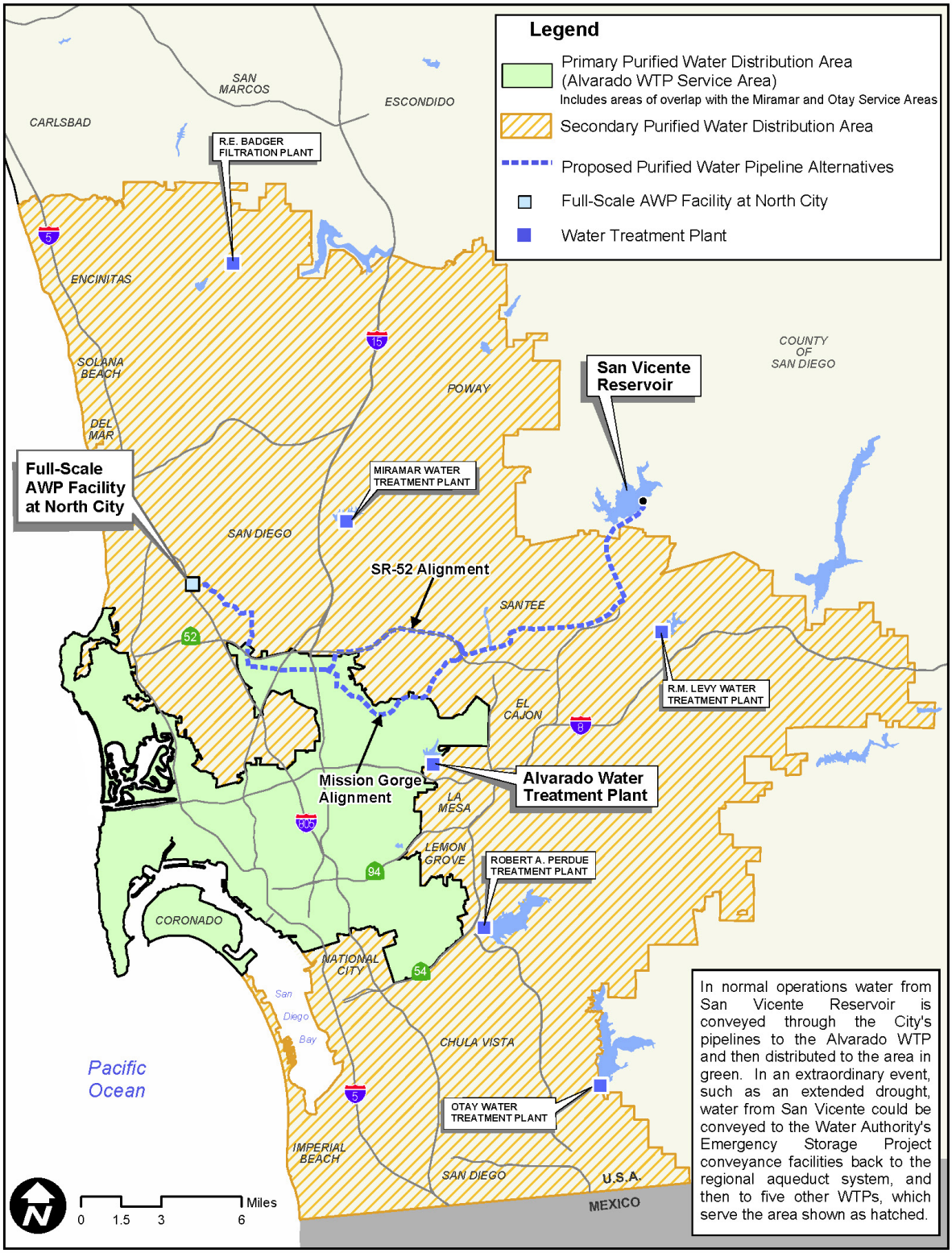


Figure A - 2: Service Area and Facilities of Full-Scale Reservoir Augmentation Project at San Vicente Reservoir



Navigating a Complex Regulatory Setting

Projects in California that involve supplementing ground and surface waters with purified water are regulated by both the California Department of Public Health (CDPH) and the State Water Resources Control Board (State Board) through nine Regional Water Quality Control Boards. To date, seven projects that augment local supplies with purified water have been permitted in California, shown in Table A-1.

Table A - 1: Purified Water Projects Permitted in California

Project Name	Agency	Start Year	Treatment Capacity (mgd)	Actual Deliveries (AFY)[3]
Montebello Forebay Groundwater Recharge Project	Los Angeles County Sanitation District	1962	47.5	50,000
Water Factory 21[1]	Orange County Water District	1977	15.0	10,000
West Coast Basin Seawater Barrier Project	West Basin Municipal Water District	1995	30	5,000
Alamitos Seawater Barrier Project	Water Replenishment District of Southern California	2005	3	3,000
Chino Basin Groundwater Recharge Project[2]	Inland Empire Utilities Agency	2005	18.0	10,000
Dominguez Gap Seawater Barrier Project	Water Replenishment District of Southern California	2006	4.5	1,000
Groundwater Replenishment System Seawater Barrier and Groundwater Replenishment Projects	Orange County Water District	2008	70	66,000 – 72,000

Footnotes:

1. Water Factory 21 began operation in 1976 implementing granular activated carbon. Reverse osmosis was added to treat half the flow in 1977.
2. Full capacity of the Chino Basin Groundwater Recharge Project is 84.4 mgd; however, only 18.0 mgd receives soil aquifer treatment (SAT).
3. AFY = acre-feet per year.

Although these seven permitted projects differ from the City's potential reservoir augmentation project at San Vicente Reservoir—they all focus on augmentation of groundwater supplies as opposed to augmentation of surface water supplies—most use the same water purification technology and have been permitted within the same regulatory framework as the City's potential project. Reservoir augmentation is practiced in other parts of the United States with less rigorous water purification processes. For example, since 1978 the Upper Occoquan Service Authority has added recycled water into a stream above Occoquan Reservoir, which supplies a drinking water treatment plant in Fairfax County, Virginia.

A key component of the Demonstration Project was coordination with both CDPH and the San Diego Regional Water Quality Control Board (Regional Board) to clarify permit conditions and develop sufficient information to determine the regulatory feasibility of a reservoir augmentation project at San Vicente Reservoir. A detailed discussion of regulatory coordination activities conducted as part of the Demonstration Project is presented in Section D of this Project Report.

California Department of Public Health

CDPH is responsible for overseeing public health issues in California and permitting public water supply projects, including projects using purified water to supplement a local water supply. CDPH is in the process of finalizing draft regulations for groundwater augmentation projects using purified water. State legislation passed in 2010 requires CDPH to establish regulations for water purification via surface water augmentation by 2016. In the meantime, surface water augmentation projects like the City's potential reservoir augmentation project at San Vicente Reservoir can be permitted on a case-by-case basis, using the pending groundwater augmentation regulations as guidance. The City's reservoir augmentation project at San Vicente Reservoir would need to meet all state and federal drinking water standards applicable to public water systems, as well as the water purification standards in California's draft groundwater augmentation regulations. The draft groundwater augmentation regulations are very stringent—in many cases exceeding drinking water standards.

Regional Water Quality Control Board

The Regional Board is responsible for developing and enforcing water quality objectives for surface and groundwater bodies within the San Diego region. Because the City's potential reservoir augmentation project at San Vicente Reservoir would involve releasing purified water into San Vicente Reservoir, the project would fall under the jurisdiction of the Regional Board. Unlike groundwater augmentation projects, which often require only a Waste Discharge Requirements (WDR) permit, projects involving release of purified water into surface water bodies require National Pollutant Discharge Elimination System (NPDES) permits. Approval of NPDES permits involves the United States Environmental Protection Agency (EPA) as well as the Regional Board.

An NPDES permit for the City's reservoir augmentation project at San Vicente Reservoir would place limitations on the purified water released into San Vicente Reservoir and incorporate water quality requirements and limits. Surface water quality objectives for San Vicente Reservoir are established by the Regional Board in the *Water Quality Control Plan for the San Diego Basin* (Basin Plan). The Basin Plan establishes water quality objectives for specific water bodies depending on established beneficial uses, which serve as the basis for some NPDES permit limits and conditions.

Regulatory acceptance of the City's Demonstration Project was validated through a Concept Approval letter from the CDPH, a Resolution of Support from the Regional Board, and a Letter of Concurrence from the Regional Board strongly supporting the efforts of the City and concurring on the preferred regulatory pathway.

Independent Advisory Panel

Demonstration Project IAP Members

One example of the high standards established by CDPH for projects involving water purification is the requirement to convene an Independent Advisory Panel (IAP) to provide expert peer review of the technical, scientific, and regulatory aspects of the City's water purification concept. An IAP, organized and managed by the National Water Research Institute (NWRI), was convened in 2009 to oversee the Demonstration Project.

The IAP consisted of 10 academics and professionals with extensive expertise in the science of water reuse, including chemistry, microbiology, treatment engineering, operations engineering, water reuse regulatory criteria, limnology, research science, toxicology, and public and environmental health. The IAP reviewed work products associated with the Demonstration Project and provided feedback on various aspects of the project.

The IAP is a fundamental component of the regulatory framework for the City's reservoir augmentation project at San Vicente Reservoir. This requirement is further discussed in Section D: Regulatory Coordination. Table A-2 summarizes the IAP meetings held in support of the Demonstration Project. Information on the IAP and its review and advisory activities can be found in Appendix F.

Table A - 2: Summary of IAP Meetings

Meeting No.	Date	Topic
1	May 11-12, 2009	Introductory meeting for the full IAP to discuss the Demonstration Project Scope
2	March 29-30, 2010	Limnology (reservoir-related) Subcommittee Meeting No. 1 to discuss set-up and calibration of the San Vicente Reservoir Model[1]
3	September 2, 2010	Limnology Working Group Meeting No. 1 to specify and discuss details pertaining to the San Vicente Reservoir Model[2]
4	October 21, 2010	Advanced Water Purification (AWP) Facility Subcommittee Meeting No. 1 to discuss the draft Testing and Monitoring Plan[3]
5	March 17, 2011	Limnology Working Group Meeting No. 2 to review San Vicente Reservoir modeling scenarios, determine potential "worst case scenarios," and discuss pathogen removal[2]
6	June 6-7, 2011	Second meeting of the full IAP to update the group on the Limnology Subcommittee, Limnology Working Group, and AWP Facility Subcommittee activities, and tour the AWP Facility
7	December 6, 2011	Limnology Subcommittee Meeting No. 2 to review and receive comments on the draft San Vicente Reservoir modeling study, and receive input on proposed reservoir public health-related regulatory conditions[1]
8	December 19, 2011	AWP Facility Subcommittee Meeting No. 2 to review AWP Facility operational and water quality data[3]
9	March 9-21, 2012	Conference calls to review and discuss Draft CDPH Proposal[4]
10	March 13, 2012	Limnology Subcommittee Meeting No. 3 to review the San Vicente Reservoir Water Quality Report[1]
11	November 15-16, 2012	Third meeting of the full IAP to review and comment on the Demonstration Project Report and Quarterly Testing Report No. 4 (CDM Smith and MWH, 2013b)

Footnotes:

1. The Limnology Subcommittee was comprised of four IAP members focused on the Limnology Study.
2. The Limnology Working Group was comprised of two IAP members and project staff specifically assigned to vetting the details of the reservoir study.
3. The AWP Facility Subcommittee was comprised of four IAP members focused on the operation and results of the AWP Facility.
4. An ad-hoc subcommittee provided review and comment via a series of conference calls in lieu of face-to-face meetings.

The Demonstration Project – a Path Forward

On October 29, 2007, the City Council voted to accept the Water Reuse Study and directed the Mayor and City staff to implement actions to demonstrate the feasibility of reservoir augmentation at San Vicente Reservoir. These actions, known as the Demonstration Project, were intended to evaluate the feasibility of implementing a reservoir augmentation project at San Vicente Reservoir by determining whether advanced water purification technology can safely and reliably produce purified water that could be sent to a reservoir and later treated at a drinking water treatment plant and distributed as drinking water.

The budget for the Demonstration Project was $11.8 million. Funding for the project was secured through a $1.07 million California Department of Water Resources Integrated Regional Water Management Program (IRWM) grant, a $2.95 million grant from the Bureau of Reclamation, and a temporary water rate increase approved by City Council in November 2008. This temporary rate increase was in effect from January 2009 to September 2010.

Evolving Terminology

Over time, terminology associated with the City's reservoir augmentation project at San Vicente Reservoir has evolved in response to changes within the industry. When the project was first conceptualized, it was described as an Indirect Potable Reuse / Reservoir Augmentation Demonstration Project. This report refers to the same concept as the Water Purification Demonstration Project (Demonstration Project). Similarly, the Advanced Water Treatment Plant (AWT) conceptualized in early stages of the project is referred to in this report as the advanced water purification (AWP) facility. These changes in terminology reflect an industry-wide recognition that the processes implemented in the AWP facility extend beyond advanced water treatment, and may be more accurately described as water purification processes.

Demonstration Project Components

1. Convene an Independent Advisory Panel
2. Design, construct, and operate a demonstration-scale advanced water purification facility at the North City Water Reclamation Plant
3. Conduct a study of San Vicente Reservoir to establish residence time and water quality parameters and conditions of purified water in the reservoir
4. Perform an energy and economic analysis
5. Define the state's regulatory requirements for a full-scale reservoir augmentation project at San Vicente Reservoir
6. Perform a pipeline alignment study
7. Conduct a public outreach and education program

Note: the 2007 City Council directive referred to the advanced water purification facility as the advanced water treatment (AWT) plant and purified water as AWT water. This has been modified to reflect industry-wide changes in terminology.

Figure A-3 presents an overview of the tasks completed as part of the Demonstration Project, consistent with the City Council's aforementioned actions in 2007 and 2008. Key tasks and meetings, reports, and important outcomes are highlighted.

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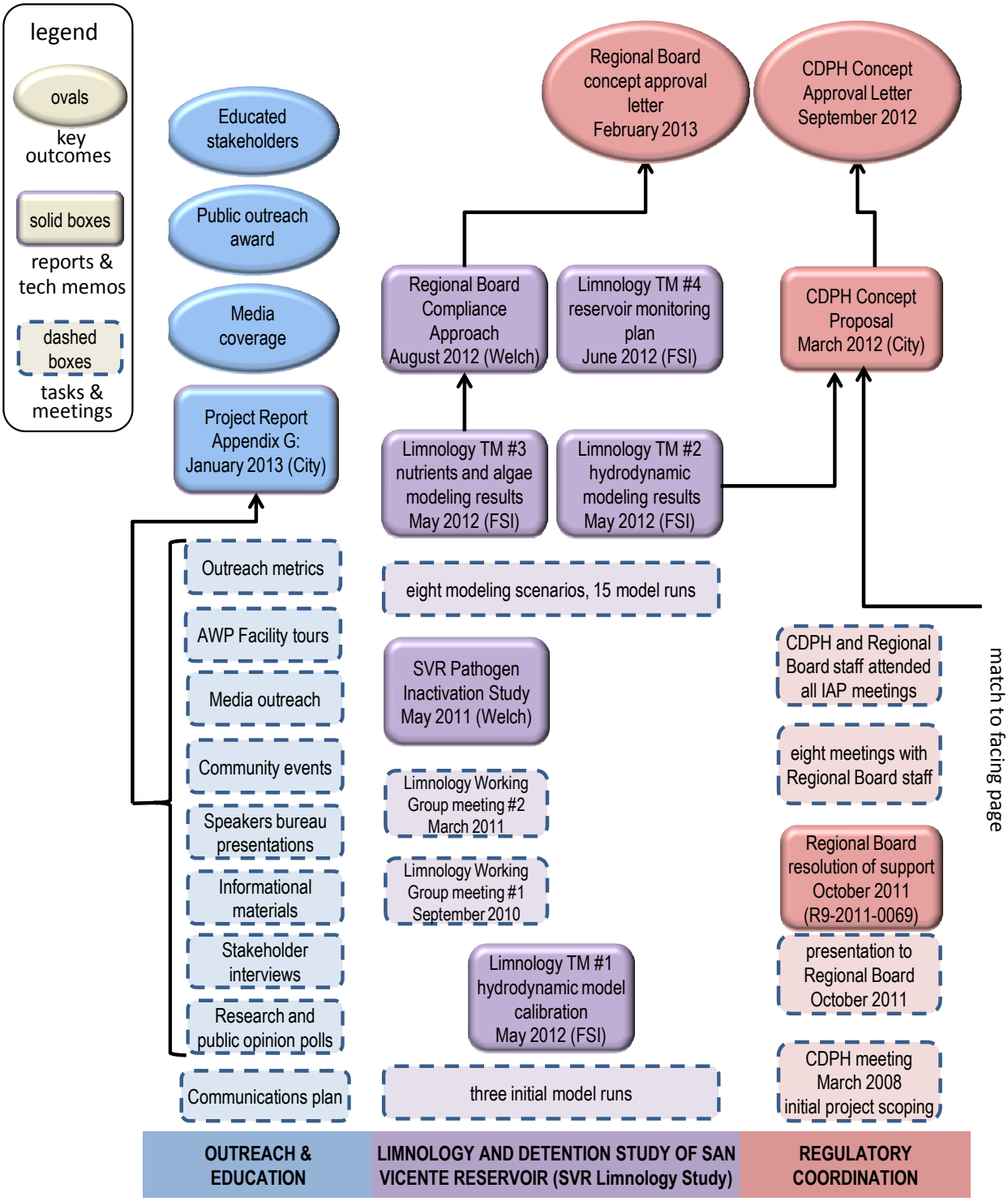
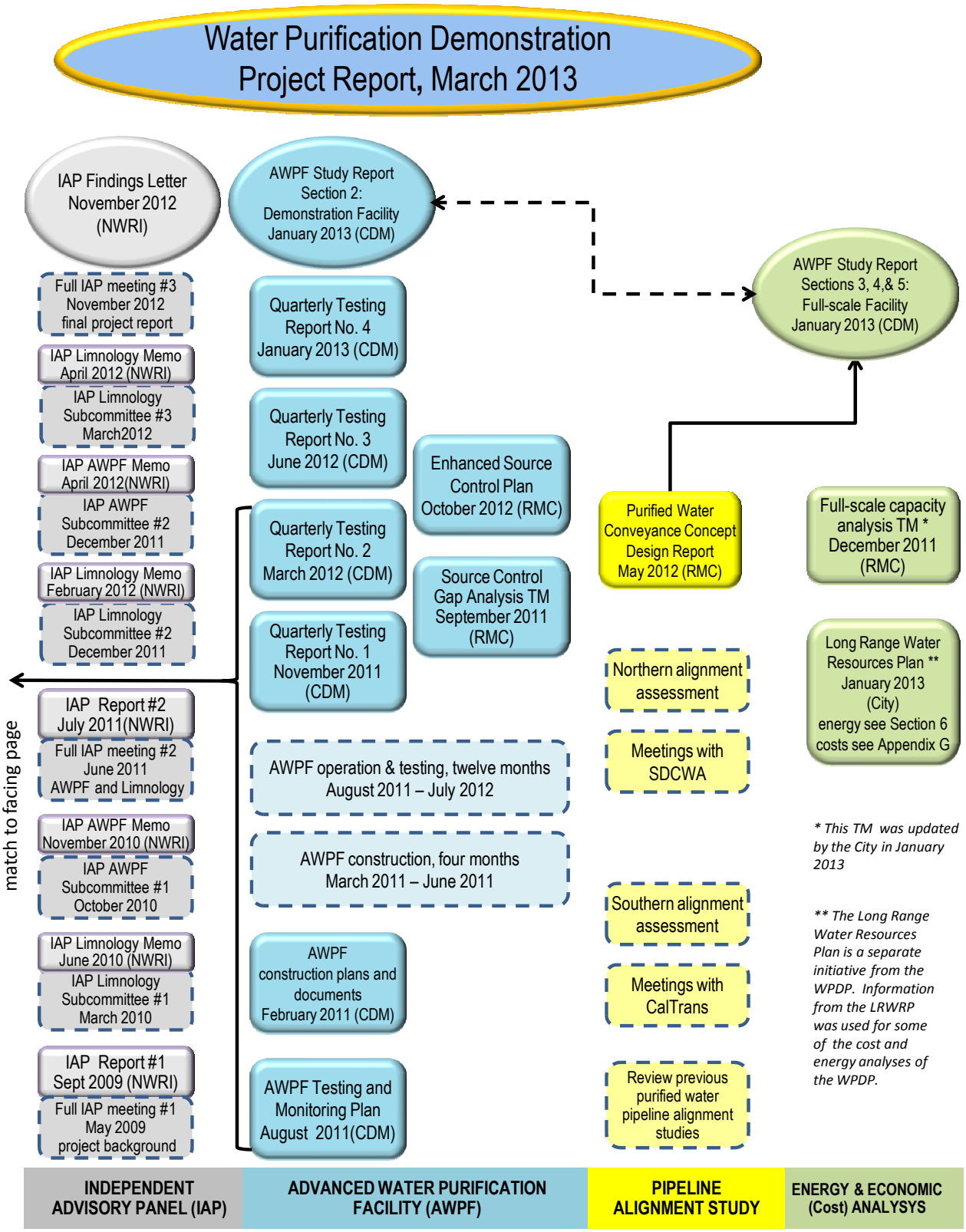
Figure A-3: Key tasks, meetings, reports, and outcomes of the Water Purification Demonstration Project, from project start in 2009 through project completion in 2013




Water Purification Demonstration Project Report, March 2013
IAP Findings Letter November 2012 (NWRI)
AWPF Study Report Section 2: Demonstration Facility January 2013 (CDM)
AWPF Study Report Sections 3, 4,& 5: Full-scale Facility January 2013 (CDM)
Full IAP meeting #3 November 2012 final project report
IAP Limnology Memo April 2012 (NWRI)
IAP Limnology Subcommittee #3 March2012
IAP AWPF Memo April 2012(NWRI)
IAP AWPF Subcommittee #2 December 2011
IAP Limnology Memo February 2012 (NWRI)
IAP Limnology Subcommittee #2 December 2011
IAP Report #2 July 2011(NWRI)
Full IAP meeting #2 June 2011 AWPF and Limnology
IAP AWPF Memo November 2010 (NWRI)
IAP AWPF Subcommittee #1 October 2010
IAP Limnology Memo June 2010 (NWRI)
IAP Limnology Subcommittee #1 March 2010
IAP Report #1 Sept 2009 (NWRI)
Full IAP meeting #1 May 2009 project background
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Quarterly Testing Report No. 4 January 2013 (CDM)
Quarterly Testing Report No. 3 June 2012 (CDM)
Quarterly Testing Report No. 2 March 2012 (CDM)
Quarterly Testing Report No. 1 November 2011 (CDM)
Enhanced Source Control Plan October 2012 (RMC)
Source Control Gap Analysis TM September 2011 (RMC)
AWPF operation & testing, twelve months August 2011 – July 2012
AWPF construction, four months March 2011 – June 2011
AWPF construction plans and documents February 2011 (CDM)
AWPF Testing and Monitoring Plan August 2011(CDM)
Purified Water Conveyance Concept Design Report May 2012 (RMC)
Northern alignment assessment
Meetings with SDCWA
Southern alignment assessment
Meetings with CalTrans
Review previous purified water pipeline alignment studies
Full-scale capacity analysis TM * December 2011 (RMC)
Long Range Water Resources Plan ** January 2013 (City) energy see Section 6 costs see Appendix G
* This TM was updated by the City in January 2013
** The Long Range Water Resources Plan is a separate initiative from the WPDP. Information from the LRWRP was used for some of the cost and energy analyses of the WPDP.
INDEPENDENT ADVISORY PANEL (IAP)
ADVANCED WATER PURIFICATION FACILITY (AWPF)
PIPELINE ALIGNMENT STUDY
ENERGY & ECONOMIC (Cost) ANALYSYS

Summary of Findings

The Demonstration Project generated a substantial amount of data related to expected performance of a reservoir augmentation project at San Vicente Reservoir. Major findings of the Demonstration Project are summarized in the following discussion by project component. Each Demonstration Project component is described in further detail later in this Project Report.

Demonstration Advanced Water Purification Facility

The City operated a demonstration-scale Advanced Water Purification Facility (AWP Facility) to gather information on water quality, equipment reliability, regulatory requirements, capital and operating cost, and energy consumption that could be expected if a full-scale advanced water purification facility (full-scale AWP facility) were constructed. Additional benefits included verifying accuracy of online monitoring equipment, optimizing process cost, conducting public tours, and securing regulatory approval.

The AWP Facility was designed, installed, operated, and tested between September 2010 and July 2012. Start-up of the AWP Facility occurred over a one-and-a-half month period (mid-June 2011 through the end of July 2011), and facility testing spanned the following year (August 2011 through July 2012). Although the testing period is complete, the AWP Facility continues to operate for public tours (refer to Section E of this report) and to gather additional equipment performance data.

The Demonstration Facility was installed and operated to produce and test purified water.

The AWP Facility was designed in accordance with the industry-standard multiple barrier approach for water purification processes established by CDPH in the Groundwater Replenishment Reuse Draft Regulation (CDPH, 2011). The major process components were membrane filtration, reverse osmosis, and ultraviolet (UV) disinfection/advanced oxidation.

Key findings from the AWP Facility include:

<u>Monitoring</u>

- Daily testing to identify potential breaches in the membrane filtration units
- Continuous measurement of total organic carbon (TOC) and conductivity to demonstrate that the reverse osmosis system was performing as expected
- Continuous UV reactor power level monitoring to confirm UV lamp operations
- Daily monitoring of hydrogen peroxide dose and continuous flow confirmation to demonstrate that the target hydrogen peroxide dose was achieved

This daily and continuous testing was conducted throughout the 12-month testing period. This extensive monitoring showed that the AWP Facility equipment met the intended treatment performance on a continuous basis and was reliable throughout the operational period.

Comprehensive Water Quality Testing

- Comprehensive water quality testing at the AWP Facility included more than 9,000 tests of the purified water at various points in the treatment process and for 342 different constituents.
- Water quality of the purified water was compared to regulatory limits, verifying that purified water met all applicable water quality standards.

This comprehensive water quality testing shows that the purified water produced at the AWP Facility is pure, approaching distilled water quality. For example, the total dissolved solids (TDS, a measure of salt content) in the purified water is about 15 milligrams per liter (mg/L), compared to TDS in San Diego's source and drinking water of about 500 mg/L. As a second example, the TOC (a measure of carbon that is bound in organic molecules) in the purified water is about 0.1 mg/L compared to TOC of 3.0 mg/L in San Diego's source water and 2.5 mg/L in San Diego's drinking water (City of San Diego, 2012a, City of San Diego, 2012g).

San Vicente Reservoir Study

Supplementing local water sources with purified water is a practice that is gaining wide-ranging support, due in part to projects such as the Orange County Groundwater Replenishment System (GWRS). Although water purification technology is widely recognized as capable of making recycled water into purified water that is drinkable, the regulatory community requires that purified water be retained in an environmental buffer, such as a groundwater basin or a surface water reservoir, prior to being blended into a drinking water system. Retaining purified water in an environmental buffer is considered an additional public health protection feature since it provides dilution by blending the purified water with other water sources and adequate retention time by holding the purified water prior to its release to a drinking water treatment plant. It should be noted that purified water is the best quality water supply available to San Diego. Introducing purified water into San Vicente Reservoir and blending it with lesser quality raw water sources could improve the overall water quality in San Diego's drinking water system.

San Vicente Reservoir is capable of providing environmental buffer features required by regulatory agencies.

San Vicente Reservoir could serve as a highly effective environmental buffer because, in addition to having sufficient storage available to accommodate fluctuating purified water flows throughout the year, it has unique characteristics that would assist in meeting regulatory requirements. Specifically, its large capacity and other natural characteristics, described in detail in Section C of this report, would allow the reservoir to retain the purified water for a substantial period of time before delivery to a municipal drinking water treatment plant such as the Alvarado Water Treatment Plant for final treatment.

To clearly demonstrate the potential reliability characteristics provided by San Vicente Reservoir, a three-dimensional hydrodynamic computer model of the reservoir was set up, including retention time and dilution components as well as a water quality component. The model was used in conjunction with both the Regional Board and CDPH, whose feedback was important to this process due to regulatory requirements for dilution, retention, and water quality conditions. Model set up and validation were also reviewed by the Demonstration Project's IAP, which formed a subcommittee specifically to work closely with the City and its consultants to review and comment on the various scenarios and data.

For the San Vicente Reservoir Study, 18 separate runs of the three-dimensional hydrodynamic model were performed. From these model runs, the project team - with input from the IAP - selected eight modeling scenarios for further assessment and analysis. These modeling scenarios were selected because they represent the full range of operational conditions that a reservoir augmentation project at San Vicente Reservoir could encounter, ranging from average water supply and demand conditions to extreme drought conditions when water demand would be higher than average and natural water levels (water surface level) within the reservoir would be lower than average. The reservoir model also tested four potential locations where purified water could enter San Vicente Reservoir to determine if the location of the purified water's entrance into the reservoir had an impact on water quality, retention, or dilution. Lastly, the reservoir model took into consideration the San Vicente Dam Raise Project, which will more than double the size of the reservoir. The model was used to simulate water movement through the enlarged reservoir. Table A-3 summarizes the eight model scenarios evaluated. The modeling results were provided in five "sets" of modeling runs and captured the expected result of adding purified water to San Vicente Reservoir under the anticipated operating conditions.

More detailed information on the completed modeling runs is provided in Section C, Table C-1 and the Flow Science reports cited in the References section of this report.

Table A - 3: Summary of Model Scenarios Evaluated

No.	Operating Scenario Evaluated
1	**Base Case – Design Inlet Location:** simulated reservoir conditions under median expected storage and normal expected operations with purified water inlet simulated at the Design Inlet Location, shown on Figure C-2.
2	**Base Case – Existing Aqueduct Inlet Location:** simulated reservoir conditions under median expected storage and normal expected operations, with purified water inlet simulated at the Existing Aqueduct Inlet Location, shown on Figure C-2.
3	**Base Case – New Aqueduct Inlet Location:** simulated reservoir conditions under median expected storage and normal expected operations, with purified water inlet at the New Aqueduct Inlet Location, shown on Figure C-2.
4	**Base Case – Barona Arm Inlet Location:** simulated reservoir conditions under median expected storage and normal expected operations with purified water inlet simulated at the Existing Barona Arm Inlet Location, shown on Figure C-2.
5	**No Purified Water Additions:** simulated reservoir conditions similar to Base Case, except there are no purified water additions and an equal reduction in reservoir outflow.
6	**Extended Drought – Design Inlet Location:** simulated reservoir conditions in a hypothetical two-year drought where a large and constant volume of water is withdrawn monthly from the reservoir without importing additional water to refill the reservoir. Purified water inlet was simulated at the Design Inlet Location, shown on Figure C-2.
7	**Extended Drought – New Aqueduct Inlet Location:** simulated reservoir conditions in a hypothetical two-year drought where a large and constant volume of water is withdrawn monthly from the reservoir without importing additional water to refill the reservoir. Purified water inlet was simulated at the New Aqueduct Inlet Location, shown on Figure C-2.
8	**Emergency Drawdown:** simulates reservoir conditions in a hypothetical emergency drawdown situation.

Key findings from the San Vicente Reservoir Study include:

- The addition of purified water into San Vicente Reservoir would not affect natural hydrologic characteristics of the reservoir, seasonal stratification, or mixing. This finding demonstrates that the addition of purified water would not impede the natural blending and retention in the reservoir.
- Dilution and retention of purified water in San Vicente Reservoir would constitute a substantial environmental barrier, sufficient to meet regulatory requirements.
- For all anticipated reservoir operating scenarios and purified water inlet locations, the reservoir would dilute the purified water at all times by at least a factor of 200 to one prior to conveying to the drinking water treatment plant.

- The addition of purified water would not affect water quality in San Vicente Reservoir. The dam raise and reservoir expansion, which is independent of the Demonstration Project, will improve overall water quality in the reservoir by reducing nutrients that cause water quality issues, and the addition of purified water will not change these improvements. In addition, purified water would reduce the salt concentration in the reservoir and improve drinking water quality.

Regulatory Coordination

Prior to moving forward with implementation, the City's reservoir augmentation project at San Vicente Reservoir would require approval by CDPH and the Regional Board. Neither CDPH nor the Regional Board has specific regulations in place for reservoir augmentation projects. A key objective of the Demonstration Project was to work with these regulatory agencies to establish the project features and operating requirements that would ensure public health protection, enabling approval of the City's reservoir augmentation project at San Vicente Reservoir.

Coordination with applicable regulatory agencies was a critical component of the Demonstration Project.

CDPH has authority to approve reservoir augmentation projects on a case-by-case basis. An additional goal of the Demonstration Project was to facilitate concept approval from CDPH for a reservoir augmentation project at San Vicente Reservoir. The City submitted a proposal to CDPH in March 2012 that presented specific public health protections provided by a reservoir augmentation project at San Vicente Reservoir and summarized technical study results obtained throughout the Demonstration Project and validated by the IAP (City of San Diego, 2012d). The City's proposal, provided in Appendix A, articulated how a reservoir augmentation project at San Vicente Reservoir would provide a robust, multiple barrier approach fundamental to public health protection by incorporating the following elements:

- **Enhanced source control** to prevent potential contaminants from entering the wastewater stream
- **Control of pathogens** (potential disease-causing organisms such as viruses, bacteria, protozoa, and fungi) through the use of existing recycled water treatment and implementation of advanced water purification processes
- **Control of nitrogen compounds** through implementation of advanced water purification processes

- **Reliable removal of regulated contaminants and constituents of emerging concern**, achieved through implementation of an advanced water purification process and monitoring plan focused on removal and frequent measurement of these constituents
- **Reliability and redundancy** to meet regulatory requirements and to prevent purified water from entering San Vicente Reservoir if necessary
- **Monitoring and response plan** designed to detect any unexpected operational issues at the full-scale AWP facility or source water contamination before the purified water reaches San Vicente Reservoir

Based on the multiple barrier approach outlined in the City's proposal, CDPH sent the City a Concept Approval Letter for a reservoir augmentation project at San Vicente Reservoir on September 7, 2012 (Appendix B).

The City also convened a series of meetings with the Regional Board throughout the Demonstration Project that focused on clarifying the Regional Board's regulatory framework for permitting a reservoir augmentation project at San Vicente Reservoir. On October 12, 2011, the Regional Board adopted Resolution No. R9-2011-0069 (provided as Appendix C), which documented the Regional Board's support for a reservoir augmentation project at San Vicente Reservoir. The resolution also established that the Regional Board would regulate the City's project at San Vicente Reservoir through an NPDES permit. In August 2012 the City submitted to the Regional Board a document entitled *Proposed Regional Water Quality Control Board Compliance Approach,* provided as Appendix D (City of San Diego, 2012e). This document summarizes the City's potential reservoir augmentation project at San Vicente Reservoir, identifies key permitting issues, and proposes a regulatory pathway that the Regional Board could follow to approve a full-scale project at San Vicente Reservoir. The Regional Board, working together with the EPA, reviewed the City's submittal and acknowledged in a February 2013 letter that an NPDES permit could be issued for a reservoir augmentation project at San Vicente Reservoir based on the City's preferred regulatory pathway. That letter, provided in Appendix E, also acknowledged both the Regional Board's and EPA's strong support for the City's efforts in considering a full-scale reservoir augmentation project at San Vicente Reservoir.

Key findings from the regulatory coordination effort include:

- The combination of advanced water purification technology and San Vicente Reservoir conditions would provide the necessary safeguards to make reservoir augmentation feasible from a regulatory perspective.
- Regulatory acceptance of the City's Demonstration Project was validated through a Concept Approval letter from CDPH and a Resolution of Support and Letter of Concurrence from the Regional Board.

Public Outreach and Education

The public outreach and education program for the Demonstration Project was a continuation of outreach efforts that started with the Water Reuse Study, building on the foundation laid during that

study. A strategic outreach plan was developed at the outset of the Demonstration Project to guide the continuation of this program. Throughout the duration of the Demonstration Project, the City sought to ensure that information was presented in a clear, understandable, and accessible way to residents in all areas of the City. Information about the Demonstration Project was also provided through a variety of formats including direct contact with individuals, written and electronic materials, traditional and social media, group presentations, community events, and tours of the AWP Facility. Additional information on the public outreach and education program for the Demonstration Project can be found in the companion CD, which is Appendix H of this report. The following outreach activities were completed as part of the Demonstration Project:

- Developed the outreach plan
- Conducted research, including one-on-one stakeholder interviews
- Produced informational materials
- Assembled a speakers bureau composed of project team members and Public Utilities Department staff
- Created a presentation about the project for community groups
- Requested community group recommendations from City Council members to contact for presentation opportunities
- Conducted project presentations to community organizations, internal staff, the City's Independent Rates Oversight Committee (IROC) and Natural Resources & Culture Committee (NR&C)
- Participated in industry conferences
- Developed an email list database of individuals interested in the project
- Distributed eUpdates and electronic newsletters to interested parties
- Participated in community events
- Provided project information to a broad group of media representatives and outlets
- Compiled quarterly metrics reports and analyzed them to guide future outreach activities
- Launched the Urban Water Cycle Tour program, which culminated in AWP Facility tours
- Invited elected officials and project stakeholders to visit the AWP Facility when it began operation in mid-2011
- Developed informational materials, such as a virtual tour video, project white papers and a tour brochure
- Established a social media presence online using Facebook, Twitter, and YouTube
- Implemented continuous improvements in the AWP Facility tours based on feedback from tour guests
- Continuously enhanced the community presentations based on attendee feedback

Key findings from the public outreach effort include:

- Feedback from more than 3,200 individuals who have toured the AWP Facility shows that providing an opportunity to tour the facility increases understanding about water purification processes.
- Survey research shows a steady increase from 2004 (26 percent) to 2011 (68 percent) to 2012 (73 percent) in City residents who favor using advanced treated recycled water as an addition to the City's drinking water supply.

Full-Scale Project Considerations

Potential implications of a full-scale project need to be well understood before a decision to implement such a project can be made. Full-scale project components evaluated during the Demonstration Project included source control enhancement, North City Water Reclamation Plant (North City) operations, full-scale AWP facility construction, pipeline system construction, environmental and regulatory permitting, economic and energy implications, and public outreach. Figure A-4 presents the components of a full-scale reservoir augmentation project at San Vicente Reservoir.

Figure A - 4: Components of a Multiple Barrier Reservoir Augmentation Project at San Vicente Reservoir

Full-scale project considerations include the following.

- **Source Control Enhancement:** The first barrier in the City's multiple barrier approach to water purification is source control, which is the prevention of contaminants from entering the wastewater stream processed at North City. The City already implements a robust Industrial Waste Control Program (IWCP) to protect wastewater treatment processes, recycled water quality, and coastal ocean resources as required by the Point Loma Wastewater Treatment Plant (Point Loma) discharge permit (refer to Section F for more information). The IWCP includes a pretreatment program for the City of San Diego and each of the 15 Participating Agencies, as well as other source control programs. Despite the extensive program currently in place, CDPH requires heightened vigilance and inclusion of residential and commercial programs in systems in which the purified water end product would enter the drinking water system. Orange County Sanitation District (OCSD) has implemented an enhanced source control program to support the GWRS. The City has reviewed that program and concluded that the following components would be appropriate

enhancements to the City's existing IWCP, should the City pursue reservoir augmentation at San Vicente Reservoir.

  - Develop a Chemical Inventory Program and Geographic Information System (GIS) Tracking system, which is an expanded industrial and commercial discharger chemical inventory database linked to discharger locations that are tracked using GIS software
  - Implement a Pollutant Prioritization Program, which would involve prioritizing pollutants through sampling, characterizing constituents of emerging concern (CECs) at the full-scale AWP facility, and determining if pollutants can be controlled through targeted source control for individual dischargers or commercial sectors
  - Perform an annual Local Limits Evaluation, which would consider including additional pollutants of concern on North City's list of local limits, and potentially lowering the limit of pollutants already on the list

- **North City Water Reclamation Plant Operations:** The IAP noted that North City already has key reliability features, including conservative operating criteria and flow equalization, to support a reservoir augmentation project at San Vicente Reservoir.
- **Full-Scale AWP Facility and Pipeline System Components:** The City evaluated construction considerations for a potential full-scale AWP facility with a capacity of 18 mgd and an estimated average production of 15 mgd, including facility components; production capacity; site location and layout; system controls, reliability, and redundancy; and full-scale AWP facility costs. Average production (15 mgd) is expected to be slightly lower than maximum treatment capacity (18 mgd) because production will vary throughout the year due to routine maintenance requirements and seasonal fluctuations in recycled water demand. During periods of low recycled water demand, full production capacity maybe attained, while in months of peak recycled water demand, it will be less than capacity, averaging approximately 15 mgd on a year-round basis. The City completed a conceptual design study for the purified water pipeline system that would be needed to transport water from a full-scale AWP facility (located at North City) to San Vicente Reservoir. This conceptual design study reviewed potential pipeline alignments and pump station specifications. Capital costs for full-scale AWP facility and pipeline system construction, which reflect data and information developed as part of the Demonstration Project, are estimated to be approximately $370 million, with annual operations and maintenance costs estimated to be approximately $16 million per year. This corresponds to a unit cost of approximately $2,000/ AF. This estimate is consistent with the 2012 LRWRP, which estimated that a full-scale reservoir augmentation project at San Vicente Reservoir would cost approximately $2,100/AF, including initial capital and annual operating costs (and energy). This would result in an increase of approximately $6.87 to an average monthly residential water bill. However, the project would also result in approximately $1,000/AF in avoided wastewater costs, resulting in a net cost of approximately $1,000/AF. Projected costs are described in further detail in the AWP Facility and Pipeline System Costs portion of Section F.

- **Environmental and Regulatory Permitting:** The Demonstration Project documented the regulatory requirements associated with a reservoir augmentation project at San Vicente Reservoir. Required regulatory documentation would likely include an Environmental Impact Report (EIR) and an Environmental Impact Statement (EIS); CDPH permitting, which would include developing an Engineering Report, convening three CDPH-led public hearings to comply with Section 116551 of the Health and Safety Code - Augmentation of Source with Recycled Water, issuing CDPH Findings of Fact, and amending the City's Water Supply Permit by CDPH to acknowledge a change of source water; and Regional Board permitting, which would include issuing a tentative permit, holding a public hearing, and issuing the formal permit.
- **LRWRP Energy Analysis:** Energy usage was estimated for a reservoir augmentation project at San Vicente Reservoir through development of the City's draft 2012 LRWRP, which provides the City with a water resources strategy to meet future water needs through 2035. The full-scale reservoir augmentation project at San Vicente Reservoir evaluated in development of the draft 2012 LRWRP would require approximately 2,500 kilowatt hours per acre-foot (kWh/AF) of energy, and would produce approximately 1.0 metric tons of greenhouse gases/AF. By comparison, imported water requires a range of 2,000 kWh/AF to 3,300 kWh/AF of energy, depending on the blend of water from the Colorado River or the Bay-Delta in Northern California, respectively. This corresponds to a range of 0.8 to 1.3 metric tons of greenhouse gases/AF (City of San Diego, 2012c). Since 2003, the blend delivered to the Water Authority has averaged approximately two-thirds Colorado River and one-third water from the Bay-Delta. Future imported water energy consumption will vary depending on actual blend. However, for practical purposes, the reservoir augmentation project at San Vicente Reservoir energy consumption is equivalent to that of imported water.
- **Public Outreach and Education Program:** The City has conducted extensive public outreach and education to make City residents aware of the potential implications and benefits of reservoir augmentation at San Vicente Reservoir. Should the City decide to move forward with a full-scale project, the interest level of the general population would be expected to increase and comprehensive outreach and education would need to continue. It is recommended that, should the City decide to move forward with a reservoir augmentation project at San Vicente Reservoir, the outreach activities conducted during the Demonstration Project be continued.

Summary of Findings

Table A-4 summarizes the Demonstration Project components and findings.

Table A - 4: Summary of Demonstration Project Findings

Project Component	Key Findings
Convene an Independent Advisory Panel	The IAP unanimously concluded that a reservoir augmentation project at San Vicente Reservoir would be a landmark project in the acceptance and furtherance of indirect potable reuse and would contribute to the City of San Diego's water portfolio.
Design, construct, and operate a demonstration-scale advanced water purification facility at the North City Water Reclamation Plant	The AWP Facility was designed, installed, operated, and tested between 2010 and 2012. Purified water produced at the AWP Facility reliably met applicable water quality standards.
Conduct a study of San Vicente Reservoir to establish residence time and water quality parameters and conditions of purified water in the reservoir	Addition of purified water into San Vicente Reservoir would not affect natural reservoir conditions and would meet regulatory requirements.
	San Vicente Reservoir would provide significant dilution of purified water.
	The addition of purified water would not impair existing conditions of San Vicente Reservoir, and could improve nutrient-related water quality issues.
Perform an energy and economic analysis	The estimated capital and annual operational and maintenance costs for a reservoir augmentation project at San Vicente Reservoir are $369 million and $15.5 million/year, respectively. This equates to approximately $2,000/AF, or an increase of approximately $6.87 to an average monthly household water bill. These costs are consistent with the City's draft 2012 LRWRP, which projected a reservoir augmentation project at San Vicente Reservoir to cost approximately $2,100/AF. In addition, the project would generate approximately $1,000/AF in avoided wastewater management costs.
	The reservoir augmentation project at San Vicente Reservoir would require approximately the same amount of energy and produce approximately the same amount of greenhouse gas emissions compared to imported water supplies.
	All three of the highest ranked portfolios in the 2012 LRWRP included a reservoir augmentation project at San Vicente Reservoir as a common resource option.

Project Component	Key Findings
Define the state's regulatory requirements for a full-scale reservoir augmentation project at San Vicente Reservoir	Results from the AWP Facility and reservoir studies provided evidence that the combination of advanced water purification technology and San Vicente Reservoir conditions would provide public health and environmental safeguards that would make reservoir augmentation feasible from a regulatory perspective. Regulatory participation in all IAP meetings and working groups addressing all technical aspects of reservoir augmentation conducted throughout the Demonstration Project enabled the regulators to establish specific guidelines and regulatory pathways to permitting a reservoir augmentation project. CDPH issued a Concept Approval Letter in September 2012 acknowledging that a reservoir augmentation project at San Vicente Reservoir would meet CDPH requirements. The Regional Board issued a letter in February 2013 concurring with the recommended permitting pathway for a reservoir augmentation project at San Vicente Reservoir.
Perform a pipeline alignment study	Conceptual design identified preferred pipeline alignments and estimated capital and annual operations and maintenance costs for the conveyance system to be $225 million and $3.4 million per year, respectively
Conduct a public outreach and education program	Survey research shows a steady increase from 2004 (26 percent) to 2011 (68 percent) to 2012 (73 percent) of City residents who favor using advanced treated recycled water as an addition to the City's drinking water supply.
	Feedback from individuals who have toured the AWP Facility shows that providing an opportunity to tour the facility increases understanding about water purification.

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Section B: Advanced Water Purification Facility

Advanced Water Purification Facility Findings

- Comprehensive water quality program at the AWP Facility included more than 9,000 tests at various points in the treatment process for 342 different chemical constituents, microbial constituents, and water quality parameters. Water quality of the purified water was compared to regulatory limits, verifying that purified water met all applicable water quality standards. This comprehensive water quality testing shows that the purified water produced at the AWP Facility is very pure – approaching distilled water quality.
- Operational data gathered during the 12 month testing period verified continuous and daily monitoring of each water purification process can assure the integrity of the process and that only the highest quality water is produced.

The City recognizes the importance of developing a thorough understanding of the technology, operations, and quality of purified water prior to moving forward with construction of a full-scale AWP facility. In addition, CDPH required the City to demonstrate the ability of the water purification process to produce purified water suitable for addition to San Vicente Reservoir prior to issuing concept approval for a reservoir augmentation project at San Vicente Reservoir.

To this end, the City installed and operated a demonstration-scale facility, referred to as the AWP Facility. An integral component of the Demonstration Project, the AWP Facility generated valuable information that will aid the City in selecting specific process equipment, understanding the quality of water that would be produced by a full-scale AWP facility, securing regulatory approval, and estimating full-scale AWP facility costs, should the City decide to move forward with construction of a full-scale AWP facility.

This section describes the characteristics and performance of the AWP Facility. Additional information on the AWP Facility can be found in AWP Facility Study Report (CDM Smith and MWH 2013a).

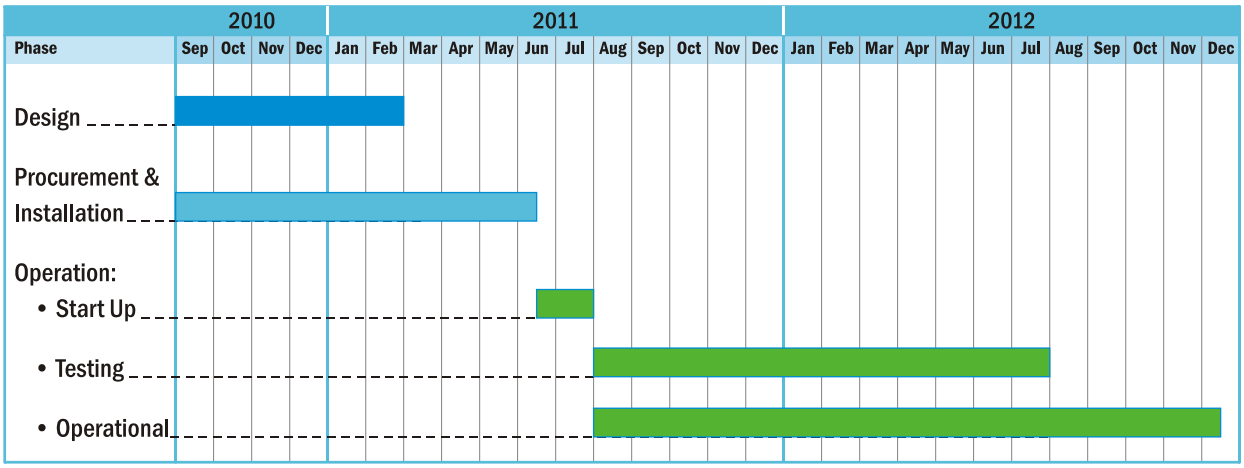
The AWP Facility produced purified water using the same processes as a potential full-scale facility.

What is the AWP Facility?

The main purpose of the AWP Facility was to demonstrate the expected performance of a potential full-scale AWP facility prior to investing in and constructing the larger facility. Demonstration facilities such as the AWP Facility generate valuable information to guide full-scale facility planning and design, support permitting, and confirm the ability of potential full-scale facilities to meet project objectives.

The AWP Facility was designed, installed, operated, and tested between September 2010 and July 2012, as shown graphically in Figure B-1. AWP Facility start-up occurred over a one-and-a-half month period (mid-June 2011 through the end of July 2011), and facility testing spanned the following one year (August 2011 through July 2012). This section summarizes results and conclusions from that test period. Although the testing period is complete, the AWP Facility continues to operate for public tours and to gather additional equipment performance data. More information on public tours conducted at the AWP Facility is included in Section E.

Figure B - 1: AWP Facility Schedule



The AWP Facility produces one mgd of purified water using the same process components and multiple barrier strategy as those currently implemented at the 70 mgd GWRS, which has been operated by the Orange County Water District since 2008.

The AWP Facility provided a venue for conducting tours and educating the public on water purification processes. The facility layout accommodated public viewing and included signage and other visual aids to explain the water purification processes.

The water treated by the AWP Facility was recycled water from North City. No purified water was sent from the AWP Facility to San Vicente Reservoir during the Demonstration Project. All purified water produced at the AWP Facility was returned to the existing North City recycled water system and used for irrigation and industrial purposes.

The Water Purification Process

The AWP Facility was designed in accordance with industry standards for water purification processes established by CDPH in the Groundwater Replenishment Reuse Draft Regulation (CDPH, 2008). CDPH-specified process components included membrane filtration, reverse osmosis, and UV disinfection/advanced oxidation. Each process element is described below.

- **Membrane Filtration:** Membrane filtration is the first step in the water purification process. Water is passed through a material called a membrane, which has openings or "pores" that are large enough for water to pass through, but small enough to prevent particles such as suspended solids, bacteria, and protozoa from passing through.

  The AWP Facility included two types of membrane filtration: microfiltration and ultrafiltration. The microfiltration system had a nominal pore size of 0.1 microns. This means that any contaminants greater than 0.1 micron in size (approximately 300 times smaller than the diameter of a human hair) were removed from the purified water in the microfiltration process. The ultrafiltration process had a nominal pore size of 0.01 microns, meaning that any contaminants greater than 0.01 micron in size (approximately 3,000 times smaller than the diameter of a human hair) were removed.

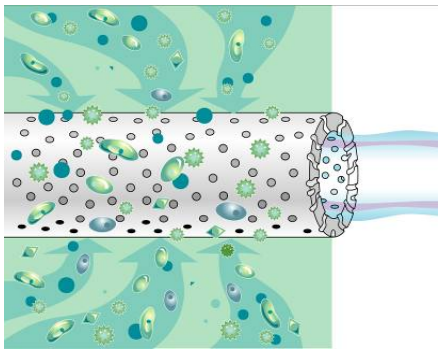


Illustration of membranes used for the membrane filtration process

- **Reverse Osmosis:** The second step in the water purification process, reverse osmosis, is a common water treatment process that is used in many industries to produce purified water. In reverse osmosis, water is forced under pressure through membranes capable of separating extremely small molecules, including salts, viruses, pesticides, and most organic compounds from water. Reverse osmosis produces water that is similar in quality to distilled water. The AWP Facility included two side-by-side reverse osmosis systems, enabling the City to compare the performance of equipment from two manufacturers and two system configurations.

- **UV Disinfection/Advanced Oxidation:** UV disinfection/advanced oxidation is the third step in the water purification process, providing both the primary disinfection step and a second barrier to chemical compounds. In this step, hydrogen peroxide, which is a common household disinfectant, is added to the purified water. The purified water is then exposed to UV light, which is similar to concentrated sunlight. UV light is a powerful disinfectant that is commonly used

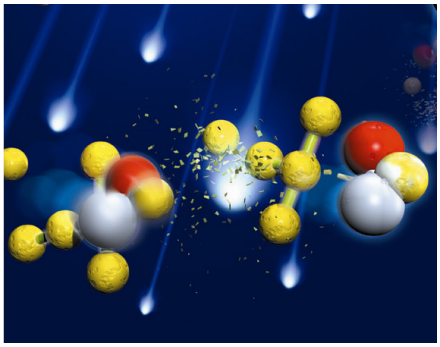


Illustration of UV light photons and hydroxyl radicals breaking up, and effectively destroying, trace contaminants in water.

to disinfect medical and dental equipment.

Advanced oxidation is achieved when UV light breaks chemical bonds and converts hydrogen peroxide into reactive particles known as hydroxyl radicals. These hydroxyl radicals destroy low molecular weight contaminants such as 1,4-dioxane that are known to penetrate the reverse osmosis membrane. In this way, advanced oxidation destroys trace contaminants that may have passed through the reverse osmosis process. The hydroxyl radicals are combined into other molecules in this process and do not persist in the purified water.

AWP Facility Testing Approach

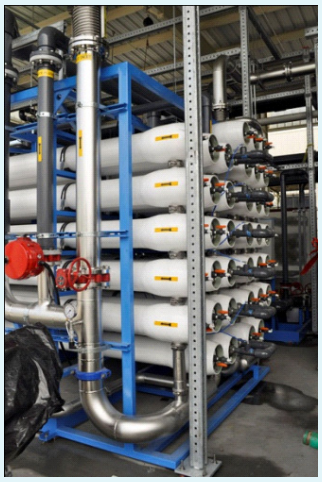
A formal Testing and Monitoring Plan was prepared at the outset of the Demonstration Project with oversight and input from both the IAP and regulatory agencies (CDM and MWH, 2011a). This comprehensive Testing and Monitoring Plan was designed to achieve the following objectives:

1. Validate the overall performance of the water purification process in meeting regulatory requirements.
2. Demonstrate that continuous and daily monitoring of each water purification process can assure the integrity of the process and that only the highest quality water is produced.

AWPFacility Purification Process

The AWP Facility purification process included membrane filtration, reverse osmosis, and ultraviolet disinfection/advancedoxidation This purification process is being successfully used by multiple other projects currently operating in California,including Orange County's GWRS.

Step 1: Membrane Filtration



Step 2: Reverse Osmosis

Step 3: Ultraviolet Disinfection/Advanced Oxidation

Water quality constituents, which are dissolved chemical compounds or suspended materials that may be present in water, were identified for testing and monitoring based on regulatory standards and guidance provided in the following documents:

- Standard water quality criteria established for drinking water (primary and secondary maximum contaminant levels) (EPA, 2009)
- CDPH Drinking Water Notification Levels (CDPH, 2010)
- EPA Total Coliform Rule (EPA, 1989)
- CDPH Groundwater Replenishment Reuse Draft Regulation (CDPH, 2011)
- Environmental Protection Agency California Toxics Rule National Recommended Water Quality Criteria pertaining to aquatic life and human health (EPA, 2000)
- Regional Board Basin Plan Water Quality Objectives (Regional Board, 1994)
- State Board Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California (State Board, 2005)
- State Board Monitoring Strategies for Chemicals of Emerging Concern in Recycled Water (State Board, 2010)

In total, more than 9,000 laboratory tests were conducted on 342 chemical constituents, microbial constituents, and water quality parameters. The samples collected at the AWP Facility were analyzed by certified outside laboratories. A quality assurance/quality control program using multiple laboratories further verified sampling results.

Water Quality Results

Water quality samples of recycled water, imported water, and purified water were collected and analyzed on a quarterly basis during the 12-month testing period. More frequent samples were collected upstream and downstream of each of the process steps for constituents that indicated process performance (CDM and MWH, 2011a, CDM Smith and MWH, 2012a, CDM Smith and MWH, 2012b and CDM Smith and MWH, 2013b). As shown in Table B-1, purified water was tested for all regulated constituents and met all applicable regulations.

Table B - 1: Water Quality –Regulated Constituent Results

Regulations / Guidelines	Number of Constituents	Purified Water Results
California Department of Public Health Goals		
Primary Drinking Water Maximum Contaminant Levels (MCLs) [1]	90	Meets All Regulations
Secondary Drinking Water MCLs[2]	18	Meets All Regulations
Microbial[3]	4	Not Detected
Notification Levels[4]	30	Meets All Regulations
Groundwater Replenishment Criteria[5]	142	Meets All Regulations
State Board Goals for Reservoir Augmentation at San Vicente Reservoir (projected)		
San Vicente Reservoir Limits[6]	143	Meets All Regulations
Total[7]	**231**	

Footnotes:

1. Primary drinking water MCLs are enforceable, human health-based water quality limits.
2. Secondary drinking water MCLs are unenforceable water quality goals related to aesthetic water characteristics such as taste and odor. Purified water met all Federal and State Secondary MCLs with the exception of pH and corrosivity. The potential full-scale AWP facility would include post treatment to meet these requirements.
3. Total Coliform, Fecal Coliform, and Viruses (Somatic and Male Specific Bacteriophage)
4. Notification levels are drinking water quality advisory limits.
5. Groundwater Replenishment Criteria are water quality limits specifically developed for indirect potable reuse via groundwater replenishment.
6. Reservoir limits are EPA Numeric Criteria for Priority Pollutants and San Diego Basin Numeric Objectives.
7. Because some contaminants and parameters are in multiple regulations / guidelines the total of unique parameters is less than the sum.

Relevant unregulated constituents were also measured, including 30 constituents listed in the EPA Unregulated Contaminant Monitoring Rule 3, 90 CECs (pharmaceuticals, and other products typically found in treated wastewater), six nitrosamines, three radionuclides, and lithium.[3] Accounting for overlap, this totals 111 unique additional unregulated constituents. Of these, six constituents were detected in the purified water during at least one sampling event; that is to say, the constituent was detected at a level that the laboratory was able to determine a numerical concentration. In comparison, 21 constituents were detected in the imported aqueduct water during at least one sampling event.

The six constituents detected in the purified water are: Bromochloromethane, used in fire-extinguishing fluid; Chromium (VI), formed by oxidation of chromium (III) in the advanced oxidation process; Strontium, a naturally occurring metal and dietary supplement; Acesulfame-K, a widely used artificial sweetener; Iohexal, a contrasting agent used in X-ray procedures; and

[3] The Unregulated Contaminant Monitoring Rule 3 (UCMR 3) was signed by EPA Administrator, Lisa P. Jackson on April 16, 2012. UCMR 3 will require public water systems to monitor for up to 30 potential drinking water contaminants. Additional information can be found at: http://water.epa.gov/lawsregs/rulesregs/sdwa/ucmr/ucmr3/index.cfm

Triclosan, an antibacterial agent used in hand soap and toothpaste. Since these non-regulated constituents do not have regulatory limits, the best way to determine the significance of measured concentrations is to compare them to the constituent's Drinking Water Equivalent Level (DWEL) or the EPA indentified Health Reference Level. The DWEL and Health Reference Levels both represent an acceptable concentration in drinking water assuming an average person consumes two liters of water per day for 70 years. The measured concentration of these six constituents in the purified water were 10 million times to 18 times lower than associated DWELs and Health Reference Levels.

In general, water quality testing shows that the purified water is approaching distilled water purity. For example, TDS (a measure of salt content) in the purified water is about 15 mg/L, compared to TDS in San Diego's source water and drinking water of about 500 mg/L. As a second example, TOC (a measure of carbon that is bound in organic molecules) in the purified water is about 0.1 mg/L compared to a TOC of 3.0 mg/L in San Diego's source water and 2.5 mg/L in San Diego's drinking water (City of San Diego, 2012a, City of San Diego, 2012g).

For detailed information regarding water quality and other data collected and analyzed for the Demonstration Project, please refer to Quarterly Testing Report No. 4 for the AWP Facility, which is included in the References section of this Project Report.

Integrity Testing and Monitoring

Verifying the integrity and reliability of each water purification process was critical to assure that only the highest quality water is produced by the AWP Facility. Integrity testing uses both mechanical tests and routine water quality sampling to verify that equipment is functioning properly. Integrity monitoring consists of continuous and daily measurements at critical points in the treatment process. During the 12-month testing period, a critical control-point monitoring plan was implemented to identify any changes in performance of the treatment processes that could adversely impact final water quality. Examples of the techniques used to assure reliable performance are illustrated in Table B-2.

Integrity monitoring and critical control point monitoring showed that the AWP Facility equipment remained intact, met the intended treatment performance on a continuous basis, and was reliable throughout the operational period (CDM and MWH, 2013a). During the design phase of a full-scale AWP facility, the City would develop a similar online monitoring and response plan to provide sufficient features and assurances that any foreseeable malfunction could be promptly identified and appropriate responses promptly applied. Overall, the results of both integrity testing and monitoring verified that the purification processes met their intended treatment performance levels on a continuous basis.

Integrity testing and water quality monitoring confirmed that the advanced water purification processes are functioning properly.

Table B - 2: Summary of Advanced Water Purification Process Integrity Monitoring

Critical Control Point	Critical Limit Parameter	Monitoring Frequency	Results
Membrane Filtration	Pressure Decay[1]	Once per day	Results showed that both membrane filtration systems remained intact over the testing periods.
Reverse Osmosis (RO)	TOC[2], Conductivity[3]	Continuous[4]	Both RO systems achieved consistent conductivity rejection, and nearly six months of online TOC monitoring showed the combined RO permeate TOC was consistently below the maximum acceptable level of 0.1 mg/L.
UV Disinfection	Reactor Power Level	Continuous	When any of the 72 lamps or 36 ballasts failed, system alarms and power levels adjusted as programmed, and water quality was not affected.
UV Disinfection/ Advanced Oxidation	Hydrogen Peroxide Dose Rate/ Continuous Flow Confirmation	Once per day by draw down Continuous flow confirmation	

1. Pressure Decay: The operational integrity of membrane filtration systems can be tested by a pressure decay test, which measures the rate of pressure decay (drop) across a membrane over a specified period of time. A sharp drop in pressure can alert operators to a potential defect or leak in the membrane filtration system.
2. TOC is the amount of carbon present in the water, and includes all natural and man-made organic chemicals.
3. Conductivity is the ability to conduct or transmit electricity. Conductivity of water increases with the concentration of dissolved ions, so measuring conductivity provides a measure of the concentration of dissolved ions in water.
4. The term "continuous" may also apply to measurements that are taken frequently (example: every four minutes) and automatically whenever the process is in production.

Performance Indicator Monitoring

The AWP Facility testing also included performance indicator monitoring to determine if any constituents could be used to indicate the treatment efficiency of the reverse osmosis and UV/advanced oxidation processes. Many of the constituents monitored at the AWP Facility were removed by the reverse osmosis to levels at or below quantifiable limits, demonstrating strong performance of the reverse osmosis process. Therefore, identifying usable performance indicators to accurately measure advanced oxidation removal was a challenge.

Sixteen constituents were monitored as performance indicators, and removal generally exceeded 95 percent within the reverse osmosis process when sufficient quantities were present to calculate removals. In some cases, greater than 99.9 percent removal was observed.

Indicator compounds, such as TOC (a measure of carbon bound in organic molecules), conductivity (ability to conduct electricity which corresponds to salt content), monochloramines (a mild disinfectant used to prevent microbial growth in drinking water), and UV 254 (a measure of absorbance of light of a particular wave length as it passes through water), may prove to be more

reliable as CEC removal performance indicators due to their ease of measurement and their reliable presence in the water downstream of both the reverse osmosis and advanced oxidation processes. For the reverse osmosis process, the average removal results were: TOC - 99.6 percent, conductivity - 99.0 percent, and UV254 - 88.8 percent. For the advanced oxidation process, the average removal results were: UV254 - 68.7 percent and monochloramines - 72.8 percent.

Operational Performance

The AWP Facility became fully operational on June 16, 2011. The operation and testing results were presented in quarterly reports over the operating period as summarized in Table B-3 (CDM and MWH, 2011b, CDM and MWH, 2012a, CDM and MWH, 2012b, CDM and MWH, 2013b).

Table B - 3: Operation and Testing Schedule

Testing Period	Testing Quarter	Operating Period		Report Date
		Test Period Start	Test Period End	
1	Quarter 1	6/16/2011	10/31/2011	December 2011
2	Quarter 2	11/1/2011	2/10/2012	March 2012
3	Quarter 3	5/11/2012	5/14/2012	June 2012
4	Quarter 4	5/15/2012	7/31/2012	September 2012

The following subsections summarize the operational specifics of the membrane filtration, reverse osmosis, and UV disinfection and advanced oxidation systems (CDM and MWH, 2013a).

Membrane Filtration

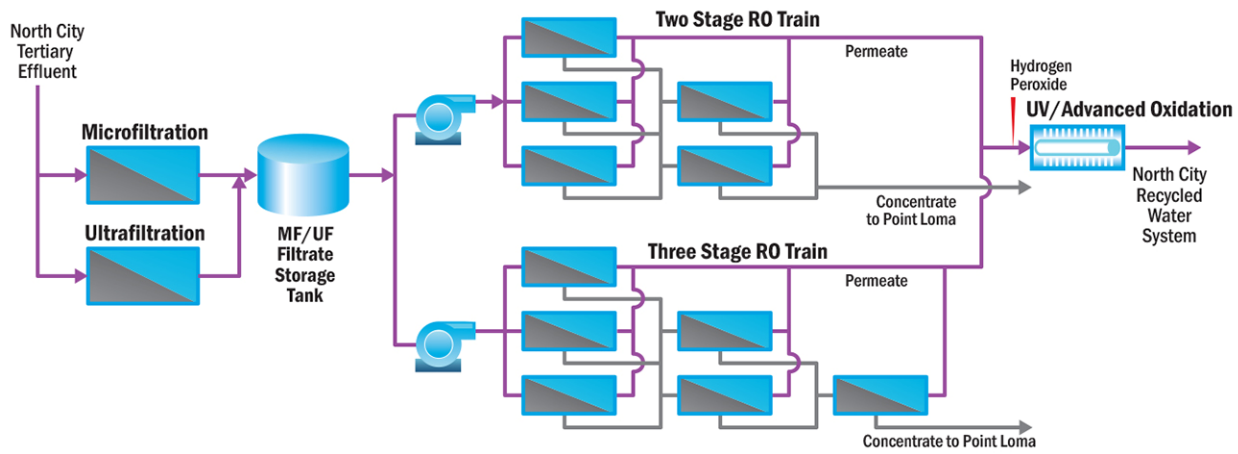
The membrane filtration equipment used at the AWP Facility included two parallel systems, each treating half of the recycled water entering the AWP Facility. One system used microfiltration membranes, while the second system used ultrafiltration membranes. Although both systems were expected to efficiently remove suspended solids, bacteria, and protozoa as the first step in the multiple barrier process, the smaller pore size of ultrafiltration membranes was expected to provide better removal, but with higher energy usage. Side-by-side testing was performed to determine the feasibility of using either microfiltration or ultrafiltration systems for the full-scale AWP facility. More membrane selection options will allow for more competitive bids on full-scale equipment.

Water quality data demonstrated that both systems consistently produced purified water that met water quality objectives for target constituents. Microbial monitoring confirmed that both membrane systems provide a substantial barrier to pathogenic organisms. Both membranes removed more than 99.9 percent of bacteria and more than 99 percent of viruses. The ultrafiltration membranes provided an increased level of protection against the smallest pathogenic organisms (viruses) due to its smaller pore size. The side-by-side testing showed that the smaller pore size on the ultrafiltration membrane did not result in higher pressure/energy requirements.

Reverse Osmosis

Two reverse osmosis configurations, a two-stage configuration and a three-stage configuration, were tested (shown in Figure B-2). The different configurations were tested to identify any operating advantages that one configuration may have over the other. The two-stage and three-stage configurations were tested at both an 80 percent and an 85 percent recovery rate, where recovery rate refers to the percentage of upstream flow that remains in the downstream flow after the reverse osmosis step. Existing AWP facilities in California typically operate at an 85 percent recovery rate, with approximately half of the plants using two-stage configurations and half using three-stage configurations. The testing showed that both the two-stage and three-stage reverse osmosis configurations could reliably operate at 85 percent recovery. The three-stage configuration did not offer the improved system hydraulics that were anticipated.

Figure B - 2: Reverse Osmosis Configurations Tested at the AWP Facility



Water quality testing of the reverse osmosis membranes focused primarily on expected differences in nitrogen, a nutrient of concern for San Vicente Reservoir. Both reverse osmosis configurations exhibited similar water quality performance. Specifically, both systems showed similar ability to remove salts and nitrates and produced purified water that would meet or exceed regulatory requirements.

The three-stage configuration required eight percent more energy than the two-stage configuration. Based on operational performance, the two-stage configuration provided the basis for a full-scale AWP facility layout and cost estimation conducted as part of the Demonstration Project.

Because reverse osmosis uses semi-permeable membranes that only let the smallest molecules pass through, it requires more pressure and energy than the other treatment processes. Both reverse osmosis configurations were equipped with energy recovery devices designed to optimize the overall energy use of the reverse osmosis system. Energy recovery devices are designed to recover energy between reverse osmosis stages, minimizing energy requirements. Specifically, these devices transfer pressure (and associated energy to create pressure) from one reverse osmosis stage to another, thereby reducing the amount of pressure and energy required for each stage. The energy recovery devices tested for the reverse osmosis process demonstrated that these devices performed

successfully and resulted in an eight percent overall energy reduction for the two-stage configuration. The full-scale energy savings with energy recovery devices was assumed to be four to seven percent.

Concentrate produced by the reverse osmosis system would be discharged to Point Loma. Ocean discharges from Point Loma have decreased in recent years, and currently average approximately 150 mgd to 160 mgd. At a recovery rate of 85 percent, a reservoir augmentation project at San Vicente Reservoir producing 15 mgd (average production) of purified water would generate approximately 2.6 mgd of concentrate. This would constitute approximately 1.9 percent of the total Point Loma flow, increasing the TDS of the Point Loma ocean discharge by approximately 100 mg/L – which would not have any insignificant effect.

UV Disinfection and Advanced Oxidation

During the testing period, the UV disinfection and advanced oxidation system, which includes UV light and hydrogen peroxide, was operated to achieve specific removals of n-nitrosodimethylamine (NDMA) and 1,4-dioxane. These chemicals are used by CDPH as indicator compounds to assess the performance of advanced oxidation since both are difficult to remove and the ability of a process to achieve removal indicates that the process provides a robust barrier to a wide array of chemicals. Although NDMA concentrations are extremely low in North City recycled water as compared to other recycled water sources throughout California and nationwide, percent removal can still provide an indication of advanced oxidation system performance.

Performance results demonstrated that, with an adequate amount of hydrogen peroxide and power applied to the UV system, sufficient contaminant removal was achieved to meet regulatory requirements. Because the excellent disinfection capability of UV/advanced oxidation systems has been well established by other full-scale operations (such as the Orange County GWRS), there was no need to test this system's disinfection performance as part of the Demonstration Project. Specifically, deactivation of 99.9999 percent of viruses has been demonstrated for this process operating under similar conditions. Throughout the testing period, the UV/advanced oxidation process achieved the target NDMA and 1,4-dioxane removal rates defined by CDPH (CDPH, 2008; CDPH, 2011).

AWP Facility Findings

Key findings of the AWP Facility include the following.

- The water quality testing and monitoring program at the AWP Facility included more than 9,000 tests at various points in the treatment process and imported water aqueduct for 342 different water quality constituents and microbial parameters. Water quality of the purified water was compared to regulatory limits, verifying that purified water met all applicable water quality standards. Further, this comprehensive water quality testing shows that the purified water is pure, approaching distilled water purity.
- It was demonstrated that continuous and daily monitoring of each water purification process can assure the integrity of the process and that only the highest quality water is produced.

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Section C: San Vicente Reservoir Study

San Vicente Reservoir Study Findings

- The addition of purified water into San Vicente Reservoir would not affect natural hydrologic characteristics of the reservoir, seasonal stratification, or mixing. This finding demonstrates that the addition of purified water would not affect the natural blending and retention in the reservoir.
- Blending and retention of purified water in San Vicente Reservoir would constitute a substantial environmental barrier, sufficient to meet regulatory requirements.
- For all anticipated reservoir operating scenarios and purified water release locations, the reservoir would dilute the purified water by at least a factor of 200 to one at all times.
- The addition of purified water would not substantially affect water quality in San Vicente Reservoir. The dam raise and reservoir expansion, which is independent of the Demonstration Project, will improve overall water quality in the reservoir by reducing nutrients including nitrogen compounds that cause water quality issues, and the addition of purified water will not change these improvements. Addition of purified water would improve some aspects of reservoir water quality, such as reducing salt concentration.

Regulatory agencies require that a substantial environmental buffer, either a groundwater basin or a surface water reservoir, serve as a receptacle for purified water prior to blending into the drinking water system. As recommended as part of the Water Reuse Study, San Vicente Reservoir would provide that environmental buffer if the City were to implement a reservoir augmentation project at San Vicente Reservoir.

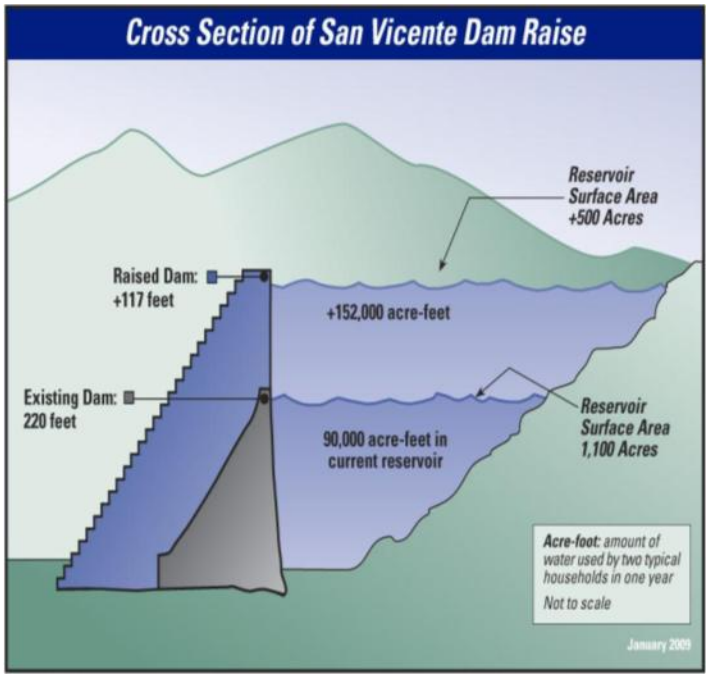
This section describes the San Vicente Reservoir setting, the regulatory considerations for reservoir operation, the reservoir analysis conducted as part of the Demonstration Project, and the results of the reservoir modeling.

The Demonstration Project included an in-depth study of San Vicente Reservoir.

San Vicente Reservoir: A Key Component of San Diego's Water Supply System

San Vicente Reservoir, located near Lakeside, was created by a dam built in

1945 that impounds San Vicente Creek. San Vicente Reservoir is owned and operated by the City's Public Utilities Department and is predominately used for municipal water supply purposes. The reservoir stores imported water, collects local runoff from a 75-square-mile watershed, and stores water transferred from Sutherland Reservoir. San Vicente Reservoir also supports limited recreational activities including boating, fishing, and water skiing.



Historically, San Vicente Reservoir has supplied water to the Alvarado Water Treatment Plant. As part of the Water Authority's Emergency Storage Project, San Vicente Dam is being raised, resulting in an increase in reservoir capacity from 90,000 AF to approximately 247,000 AF. The San Vicente Dam Raise Project will be complete by spring 2013, with refill of the reservoir expected to take three to five years, depending on the availability of imported water. As part of the Emergency Storage Project, new pipelines have been constructed to allow San Vicente Reservoir to receive imported water from the western leg of the regional aqueduct system. San Vicente Reservoir will continue to primarily supply the Alvarado Water Treatment Plant through the City's existing pipelines. The new conveyances of the Emergency Storage Project will also allow water to be sent to other water treatment plants serving all of the City and the entire southern two-thirds of the San Diego region.

San Vicente Reservoir has historically served as an integral component of the City's water supply system. These improvements further solidify the role of San Vicente Reservoir in the region's overall water supply operation, including the ability for the reservoir to play a role in a potential future reservoir augmentation project.

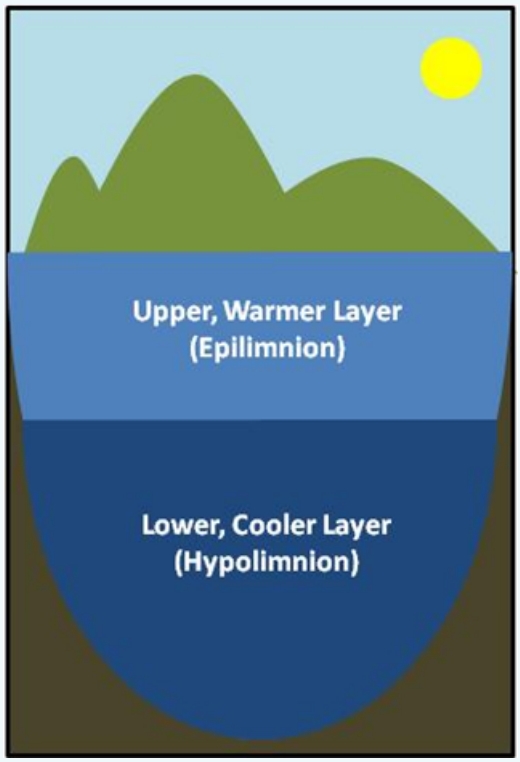
Why Consider San Vicente Reservoir for Reservoir Augmentation?

Purified water produced at the City's AWP Facility has been validated through robust testing as meeting applicable water quality requirements; however, regulatory agencies would require a reservoir augmentation project at San Vicente Reservoir to include an environmental buffer capable of providing adequate retention time and blending of purified water. As described in detail in Section D, Regulatory Coordination, retention time and blending criteria are part of what is known as a multiple barrier approach, which is required by regulatory agencies to ensure that adequate safeguards are in place to protect public health in the event of an unexpected issue with the purified water.

San Vicente Reservoir is an ideal feature for reservoir augmentation because, in addition to having sufficient storage available to accommodate purified water flows throughout the year, it has unique characteristics that assist in meeting regulatory requirements. Specifically, in addition to providing significant blending of purified water with other raw water sources, the reservoir's large capacity and stratification allow it to retain the purified water for a significant period of time before it is delivered for final treatment (refer to the stratification inset below for more information).

A Word About Reservoir Stratification

Reservoir stratification—the formation of "layers" of water within a reservoir—is a natural phenomenon that occurs in essentially all reservoirs in North America, including San Vicente Reservoir. Consistent and predictable stratification has been observed in more than 20 years of monitoring data collected from San Vicente Reservoir. During the period of stratification (approximately 10 months per year), warm water that is naturally heated by the sun is contained within the top-most layer of the reservoir (epilimnion), because warmer water is less dense than cooler water. The more dense, cooler water is contained within the lower layer of the reservoir (hypolimnion). When stratification occurs, the water and any dissolved or suspended constituents contained within the epilimnion do not readily mix with the water and constituents contained within the hypolimnion.



During winter months, the epilimnion cools in response to cooler air temperatures. This causes water temperature in the reservoir to equalize and the epilimnion and hypolimnion mix, causing the reservoir to lose its stratification (destratify).

The fully destratified (mixed) condition lasts for a few weeks to a month and typically occurs in January, February, or March. The natural stratification and mixing of the reservoir is an important phenomenon, because it determines the extent and timing of mixing and retention provided by the reservoir.

Characteristics of San Vicente Reservoir that provide adequate retention time and blending features as required by regulatory agencies are described below.

- **Retention time.** The amount of time that purified water is retained in the reservoir, retention time, would provide time needed to monitor the purified water for water quality purposes—a step necessary to demonstrate that the purified water meets applicable water quality standards. San Vicente Reservoir's natural stratification, combined with a purified water release and withdrawal strategy that takes advantage of reservoir stratification (see stratification inset for more information), would provide purified water entering the

reservoir with a substantial amount of retention time prior to withdrawal and final processing at a drinking water treatment plant and distribution to the City's drinking water system. Therefore, San Vicente Reservoir would be capable of providing adequate retention time as required by regulatory agencies as part of a multiple barrier approach that ensures the protection of public health.

- **Blending.** In addition to retention, the reservoir would provide significant blending, as a relatively small flow of purified water would be released into a large reservoir and blended with other reservoir water supplies prior to withdrawal. Once the San Vicente Reservoir expansion is complete, the reservoir volume will be 16 times greater than the projected annual purified water inflow of 15,000 AFY simulated.[4] This means that purified water would receive significant blending as it travels through the reservoir prior to being withdrawn and treated at a municipal drinking water treatment plant before flowing to the City's distribution system. Therefore, San Vicente Reservoir would be capable of providing adequate blending as required by regulatory agencies.

Under a reservoir augmentation project at San Vicente Reservoir, the City would augment San Vicente Reservoir with an annual average of 15 mgd of purified water. There would be seasonal variation in the amount of purified water produced at the full-scale AWP facility due to variations in the amount of recycled water available from North City, with winter monthly average inflows nearly twice as great as those seen in summer months. If the City were to implement a reservoir augmentation project at San Vicente Reservoir, the reservoir would continue to receive and store local runoff, water transferred from Sutherland Reservoir, and imported water. These water supplies would be blended with purified water, which is among the highest quality water available, prior to being treated at a drinking water treatment plant for delivery to the City's customers.

A reservoir augmentation project at San Vicente Reservoir would involve releasing purified water into the upper layer of San Vicente Reservoir. Because the purified water would be warm compared to the reservoir water and would flow into the reservoir at the surface, it would tend to remain in the upper layer of the reservoir. San Vicente Reservoir's outlet structure, located near the San Vicente Dam, has multiple ports to provide operators with flexibility when withdrawing water from the reservoir and sending it to a municipal drinking water treatment plant for treatment. Operators typically withdraw water for drinking water treatment and distribution from the deeper ports, where water quality is more consistent. Under stratified conditions, in which the upper and lower layers of the reservoir do not mix, purified water would be prevented from flowing directly to the outlet structure, providing a substantial retention time. During the relatively short period in which reservoir stratification would be lost, the reservoir would experience full and complete blending, so that any

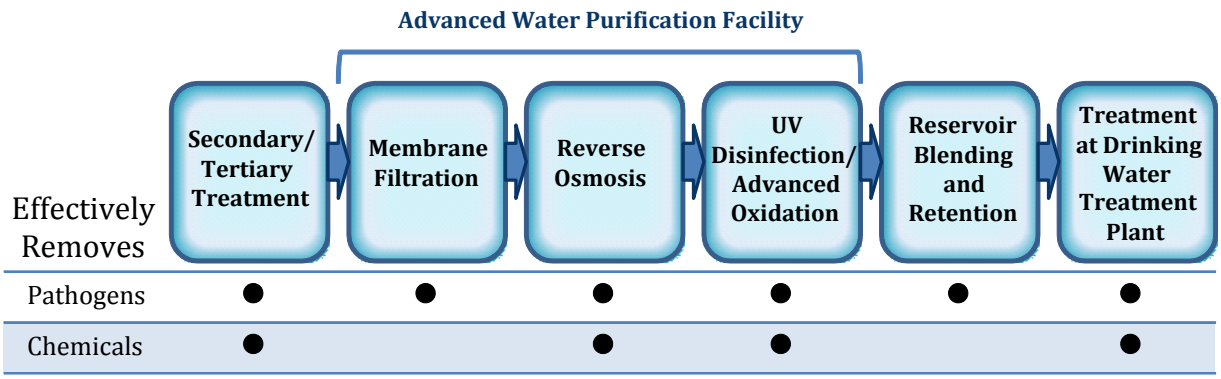
[4] 15,000 AFY was selected as a representative yield for the purposes of reservoir modeling based on previous estimates of project yield, including the Water Reuse Study. This production capacity is approximate to the 15 mgd production capacity now assigned to a full-scale project, and reservoir modeling results obtained during the Demonstration Project are representative of the results expected from a full-scale project.

purified water that were to flow to the outlet would first undergo extensive blending with reservoir water.

San Vicente Reservoir's Role in Assuring Public Health Protection

A reservoir augmentation project at San Vicente Reservoir would protect public health by encompassing multiple barriers to prevent pathogens and chemicals from being introduced into the drinking water supply. While a full-scale AWP facility would provide substantial barriers, and no pathogens or chemicals are expected to be present in the purified water entering San Vicente Reservoir, the reservoir would provide absolute assurance that no target pathogens or chemicals would enter the drinking water supply. This multiple barrier concept is illustrated in Figure C-1.

Figure C - 1: Pathogen and Chemical Removal by Multiple Barriers



Modeling San Vicente Reservoir

To evaluate the potential retention and dilution provided by San Vicente Reservoir, a three-dimensional hydrodynamic computer model of San Vicente Reservoir was set up in order to:

- Determine the effectiveness of San Vicente Reservoir as an environmental buffer capable of providing blending and retention as required by regulatory agencies
- Evaluate any hydrodynamic changes, or changes to movement of water within the reservoir, resulting from introduction of purified water
- Determine whether addition of purified water to San Vicente Reservoir would affect water quality within the reservoir

What is a Three-Dimensional Hydrodynamic Computer Model?

"Hydrodynamics" is the movement of water. The three-dimensional model of San Vicente Reservoir is a computer-based model that simulates and predicts the movement of water in all three directions within the reservoir: up and down, left to right, and forward and back.

The three-dimensional modeling of San Vicente Reservoir used a pair of coupled computer models: the Estuary Lake and Coastal Ocean Model [ELCOM] and the Computational Aquatic Ecosystem

Dynamics Model [CAEDYM]. These models were originally developed at the University of Western Australia. An expert team applied the models for use on the Limnology and Reservoir Detention Study of San Vicente Reservoir. The expert team has experience with similar modeling efforts for Lake Mead in Nevada and for Los Vaqueros Reservoir, Lake Perris, Lake Hodges, and Olivenhain Reservoir in California, plus three previous modeling projects for San Vicente Reservoir.

The computer model was set up, calibrated, and validated using real-world data collected through the Demonstration Project and previous efforts. San Vicente Reservoir modeling initially began in the 1990s when two tracer studies were conducted to establish the reservoir's retention and blending characteristics. During these tracer studies, an inert material (referred to as a tracer) was released into the reservoir, and its movement was monitored to simulate how water particles move and travel throughout San Vicente Reservoir. The three-dimensional hydrodynamic modeling was validated with data from the tracer studies to determine how well the model analyzed known conditions of San Vicente Reservoir. Three-dimensional hydrodynamic modeling was conducted for a variety of reservoir operation conditions and climatic cycles, including wet years, droughts, varying inflows and outflows, and other factors. By comparing data collected during the tracer studies to model predictions, the model was refined to accurately predict the movement of water through the reservoir.

The model was used to focus on hydrodynamic characteristics such as retention time and blending, but included a water quality component, or subroutine. The hydrodynamic modeling analysis consisted of the following steps:

- Prepare a three-dimensional hydrodynamic model to simulate conditions in the old (90,000 AF-capacity) San Vicente Reservoir
- Use extensive historical reservoir water quality data and results from two tracer studies conducted in the late 1990s to calibrate and verify the accuracy of the three-dimensional hydrodynamic model
- Adjust the model to represent the expanded (247,000 AF-capacity) San Vicente Reservoir
- Conduct additional modeling to:
    - Assess the impact of adding purified water on the movement of water in the reservoir, including any potential implications on the formation and duration of the stratified layers
    - Assess the retention time and blending of purified water at various times of the year
    - Assess the impact of alternative purified water release locations on each of the above

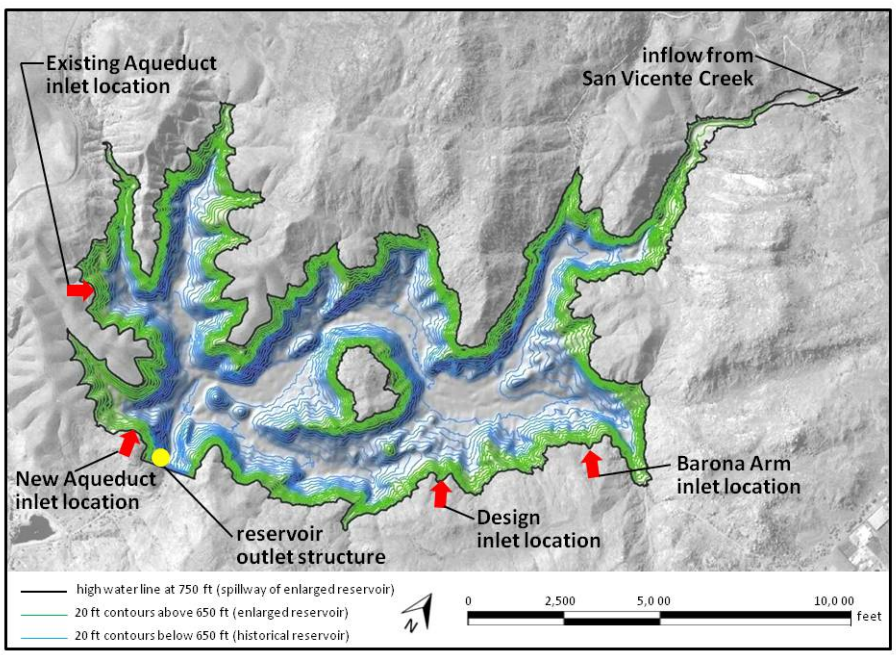
The water quality component of the model was designed to simulate the potential effects of purified water on water quality in San Vicente Reservoir, specifically focusing on algae growth in the reservoir (Flow Science, 2010, Flow Science, 2012a, Flow Science, 2012b). Algal growth is the most important water quality factor affecting the use of the reservoir as a potable water supply, and also

the most important water quality consideration for recreational uses. The water quality modeling analysis consisted of the following steps:

- Apply a water quality component to the three-dimensional hydrodynamic model
- Calibrate and verify the accuracy of the water quality component of the model using extensive historic reservoir water quality data
- Conduct model scenarios to compare water quality for three cases: 1) historic reservoir (90,000 AF), 2) expanded reservoir (247,000 AF), and 3) expanded reservoir with purified water added, compare physical parameters such as temperature and clarity, and nutrients for each case

Another key consideration in the reservoir modeling was the location where purified water would enter San Vicente Reservoir. The modeling effort involved testing four different potential locations to determine if the location of purified water entering the reservoir had an impact on water quality, retention, or blending. Figure C-2 illustrates these locations.

Figure C - 2: Potential Purified Water Inlet Locations



For the San Vicente Reservoir Study, Flow Science performed 18 separate runs of the three-dimensional hydrodynamic model. From these model runs, the project team–with input from the IAP–selected eight modeling scenarios for further assessment and analysis. Table C-1 summarizes the eight modeling scenarios. These modeling scenarios were selected because they represent the full range of purified water inlet locations and operational conditions that a reservoir augmentation project at San Vicente Reservoir could encounter. As such, the modeling effort captured the expected result of adding purified water to San Vicente Reservoir under all anticipated operating

conditions. This modeling approach was a necessary step in the Demonstration Project to validate that San Vicente Reservoir will be able to meet regulatory requirements for retention time and blending under all conditions.

Table C- 1: Summary of Model Scenarios Completed

Model Scenario	Operating Scenario Simulated
1	**Base Case – Design Inlet Location:** reservoir under median expected storage and normal expected operations. Initial reservoir volume was 155,000 AF. Annual flow rates for Aqueduct inflow, runoff, purified water inflow, and dam withdrawal were 3,000, 4,500, 15,000, and 19,000 AFY, respectively. There were no water transfers from Sutherland Reservoir into San Vicente Reservoir. Purified water inlet was simulated at the Design Inlet Location, shown on Figure C-2.
2	**Base Case – Existing Aqueduct Inlet Location:** reservoir under median expected storage and normal expected operations. Initial reservoir volume was 155,000 AF. Annual flow rates for Aqueduct inflow, runoff, purified water inflow, and dam withdrawal were 3,000, 4,500, 15,000, and 19,000 AFY, respectively. There were no water transfers from Sutherland Reservoir into San Vicente Reservoir. Purified water inlet was simulated at the Existing Aqueduct Inlet Location, shown on Figure C-2.
3	**Base Case – New Aqueduct Inlet Location:** reservoir under median expected storage and normal expected operations. Initial reservoir volume was 155,000 AF. Annual flow rates for Aqueduct inflow, runoff, purified water inflow, and dam withdrawal were 3,000, 4,500, 15,000, and 19,000 AFY, respectively. There were no water transfers from Sutherland Reservoir into San Vicente Reservoir. Purified water inlet was simulated at the New Aqueduct Inlet Location, shown on Figure C-2.
4	**Base Case – Barona Arm Inlet Location:** reservoir under median expected storage and normal expected operations. Initial reservoir volume was 155,000 AF. Annual flow rates for Aqueduct inflow, runoff, purified water inflow, and dam withdrawal were 3,000, 4,500, 15,000, and 19,000 AFY, respectively. There were no water transfers from Sutherland Reservoir into San Vicente Reservoir. Purified water inlet was simulated at the Existing Barona Arm Inlet Location, shown on Figure C-2.
5	**No Purified Water Additions:** similar to Base Case, except there are no purified water additions and an equal reduction in reservoir outflow. Initial reservoir volume was 155,000 AF. Annual flow rates for Aqueduct inflow, runoff, and dam withdrawal were 3,000, 4,500, and 4,000 AFY, respectively. There were no water transfers from Sutherland Reservoir into San Vicente Reservoir.
6	**Extended Drought – Design Location:** hypothetical two-year drought where a large and constant volume of water is withdrawn monthly from the reservoir without importing additional water to refill the reservoir. Initial reservoir volume was 155,000 AF. Annual flow rates for Aqueduct inflow, runoff, purified water inflow, and dam withdrawal were 3,000, 4,500, 15,000, and 48,000 AFY, respectively. There were no water transfers from Sutherland Reservoir into San Vicente Reservoir. The volume of water stored in San Vicente Reservoir at the end of the simulation period was about 100,000 AF. Purified water inlet was simulated at the Design Inlet Location, shown on Figure C-2.
7	**Extended Drought – New Aqueduct Inlet Location:** hypothetical two-year drought

Model Scenario	Operating Scenario Simulated
	where a large and constant volume of water is withdrawn monthly from the reservoir without importing additional water to refill the reservoir. Initial reservoir volume was 155,000 AF. Annual flow rates for Aqueduct inflow, runoff, purified water inflow, and dam withdrawal were 3,000, 4,500, 15,000, and 48,000 AFY, respectively. There were no water transfers from Sutherland Reservoir into San Vicente Reservoir. The volume of water stored in San Vicente Reservoir at the end of the simulation period was about 100,000 AF. Purified water inlet was simulated at the New Aqueduct Inlet Location, shown on Figure C-2.
8	**Emergency Drawdown:** simulates a situation in which 66,000 AF of water is withdrawn from the reservoir in January and February of Year 2 and the reservoir is then refilled by adding 66,000 AF of water from the Aqueduct between March and July of Year 2. The rest of the flow rates are the same as the Base Case. Initial reservoir volume was 200,000 AF.

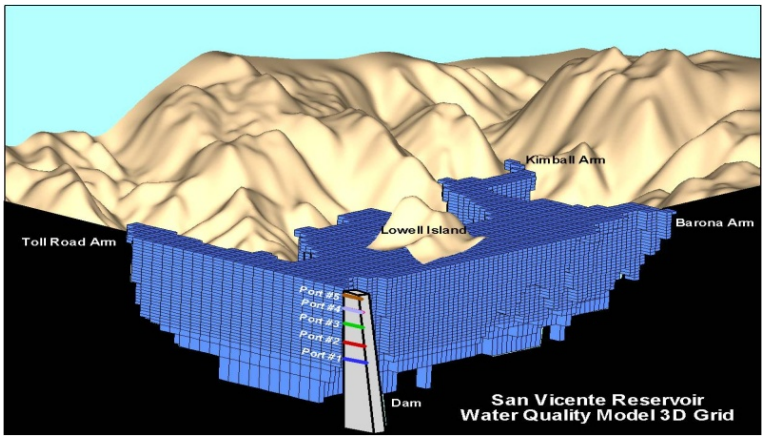
The reservoir model was set up in conjunction with regulatory entities including the Regional Board and CDPH, whose feedback was important to this process due to regulatory requirements for blending, retention, and water quality conditions. Model development and validation were also reviewed by the IAP. A dedicated subcommittee of the IAP was convened to review the model and associated data, and to provide comments to the City's reservoir modeling team throughout the reservoir modeling process. The IAP concluded that the model provides "an effective and robust tool" for assessing the effects of purified water on San Vicente Reservoir (NWRI 2010).

> ***"The Subcommittee (IAP Subcommittee for the San Vicente Reservoir Study) believes that the modeling is sufficiently predictive for purposes of evaluating the input of advanced treated recycled water (purified water)."***
>
> Findings and Recommendations of the Limnology and Reservoir Subcommittee (NWRI 2010)

San Vicente Reservoir Study Findings

Key findings of the San Vicente Reservoir modeling effort are:

- The addition of purified water into San Vicente Reservoir would not affect natural hydrologic characteristics of the reservoir, seasonal stratification, or mixing. This finding demonstrates that the addition of purified water would not affect the natural blending and retention in the reservoir.



The three-dimensional hydrodynamic model allowed the City to simulate potential effects of purified water on San Vicente Reservoir.

- Blending and retention of purified water in San Vicente Reservoir would constitute a substantial environmental barrier, sufficient to meet regulatory requirements.
- For all anticipated reservoir operating scenarios and purified water release locations, the reservoir would dilute the purified water by at least a factor of 200 to one at all times.
- As discussed in Section B: Advanced Water Purification Facility, the purified water produced at the AWP Facility was found to be very pure, approaching distilled water purity. The addition of purified water would not affect any aspect of water quality in San Vicente Reservoir. The dam raise and reservoir expansion, which is independent of the Demonstration Project, will improve overall water quality in the reservoir by reducing nutrients including nitrogen compounds that can stimulate algae growth and cause water quality issues, and the addition of purified water will not change these improvements. Addition of purified water would improve some aspects of reservoir water quality, such as reducing salt concentration.

Section D: Regulatory Coordination

Regulatory Coordination - Key Findings

- The combination of advanced water purification technology and San Vicente Reservoir conditions provide public health and environmental safeguards that make reservoir augmentation feasible from a regulatory perspective.
- Regulatory acceptance of the City's Demonstration Project was validated through a Concept Approval letter from the California Department of Public Health and a Resolution of Support and a letter confirming acceptability of the proposed regulatory pathway from the San Diego Regional Water Quality Control Board.

Prior to implementation, a reservoir augmentation project at San Vicente Reservoir would require approval by CDPH and the Regional Board. Neither CDPH nor the Regional Board has specific regulations in place for projects using purified water for reservoir augmentation, making the process for securing regulatory approval a challenge. A key objective of the Demonstration Project was to work closely with the regulatory agencies to identify appropriate requirements for a reservoir augmentation project at San Vicente Reservoir, and to determine whether a full-scale project incorporating water purification technologies and San Vicente Reservoir could meet these requirements.

This section describes regulatory conditions, including key considerations for each regulatory agency, the process used to identify regulatory requirements for a reservoir augmentation project at San Vicente Reservoir, and an assessment of the feasibility of a reservoir augmentation project at San Vicente Reservoir.

Although reservoir augmentation at San Vicente Reservoir would use the same water purification processes as the Orange County GWRS, its regulatory pathway is less established. CDPH has established guidelines for groundwater augmentation projects such as the Orange County GWRS, but permits reservoir augmentation projects on a case-by-case basis.

Regulatory Conditions

Projects in California that employ water purification processes are regulated by both CDPH and the State Board (administered by the local Regional Boards). To date, seven projects involving groundwater replenishment with purified water have been permitted in California, but no reservoir augmentation projects with purified water have been permitted or are operational statewide. Reservoir augmentation is practiced in other parts of the United States. For example, since 1978 the Upper Occoquan Service Authority has added recycled water into a stream above Occoquan Reservoir that supplies a drinking water treatment plant in Fairfax County, Virginia. The following sections discuss specific regulatory requirements for a reservoir augmentation project at San Vicente Reservoir.

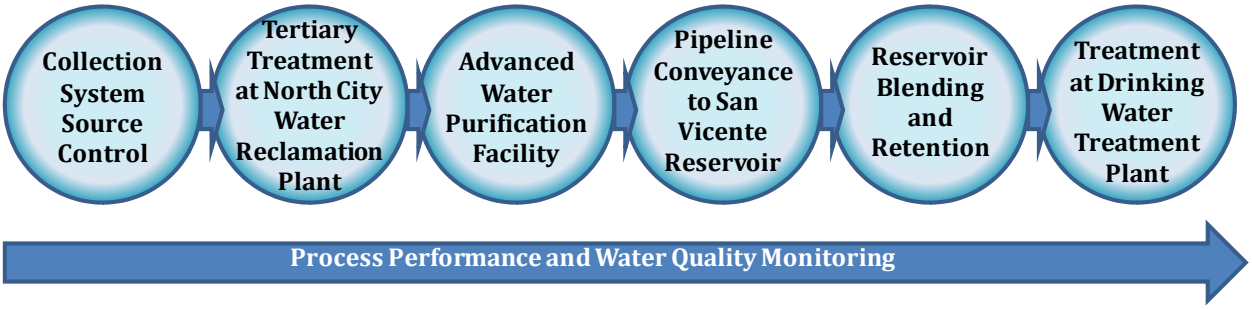
Protecting Public Health: California Department of Public Health

CDPH is responsible for developing and administering regulations to protect public health in California, including permitting public water supply projects. Because the City's reservoir augmentation project at San Vicente Reservoir would include augmentation of drinking water supplies, this project would require approval from CDPH (in the form of a permit) in order to operate.

State legislation passed in 2010 requires CDPH to finalize regulations by December 31, 2013 for projects using water purification for groundwater replenishment such as the Orange County GWRS. That same legislation requires CDPH to adopt regulations for reservoir augmentation projects by December 31, 2016. In advance of adopting regulations, CDPH can approve reservoir augmentation projects such as the City's potential reservoir augmentation project at San Vicente Reservoir on a case-by-case basis.

In order to ensure that public health is protected, CDPH requires that projects involving purified water incorporate a multiple barrier strategy. A multiple barrier strategy protects public health by incorporating safeguards into the process, which ensure that a failure or error at any given treatment step would not compromise public health. The public health safeguards that would be implemented in a reservoir augmentation project at San Vicente Reservoir are presented in Figure D-1, and described further in the following paragraphs.

Figure D - 1: Public Health Safeguards of the Potential Reservoir Augmentation Project at San Vicente Reservoir



Enhanced Source Control. The first step in the multiple barrier strategy for water purification is enhanced source control in the wastewater collection system, which refers to the prevention of contaminants from entering the wastewater stream. The City already operates a robust source control program focusing on controlling contaminants in industrial discharges upstream of North City (refer to Section F for more information). A reservoir augmentation project at San Vicente Reservoir would likely require the City to enhance that program by addressing commercial and residential discharges and focusing on preventing chemicals with potential public health implications from entering the collection system. Strategies to achieve this could include developing a Chemical Inventory Program and GIS Tracking System, implementing a Pollutant Prioritization Program, and performing an annual Local Limits Evaluation, as described in Section F.

Tertiary Treatment. This step would involve some or all of the processes that are already in place at North City to treat wastewater in accordance with Title 22 of the California Code of Regulations. Tertiary treatment produces what is commonly referred to as recycled water, suitable for irrigation and industrial purposes.

Advanced Water Purification Technology. CDPH requires that advanced water purification technology be incorporated into projects that augment the existing wastewater and recycled water treatment steps. Advanced water purification provides additional barriers to potential pathogens and chemical contaminants such as CECs. Advanced water purification technology produces purified water, which refers to recycled water that has been further purified so that it may be released into a groundwater basin or surface water reservoir that supplies water to a drinking water treatment plant (refer to Section B, Advanced Water Purification Facility for more information). A full-scale AWP facility associated with a reservoir augmentation project at San Vicente Reservoir would be located at North City.

Pipeline System Conveyance. Moving purified water from the advanced water purification facility, which would be located at North City, to the San Vicente Reservoir would require construction of a 22-mile extension to the City's existing recycled water system. At peak production capacity, it would take purified water at least 10 hours to travel to San Vicente Reservoir. In the unlikely event of a purification technology malfunction, this travel time would provide an opportunity to capture and divert purified water before it reached San Vicente Reservoir.

San Vicente Reservoir (Environmental Buffer). San Vicente Reservoir would serve as an "environmental buffer," or a natural water barrier that provides blending of purified water with other sources. San Vicente Reservoir would also provide substantial retention, meaning that it would retain purified water for an extended period of time prior to it entering the drinking water treatment plant. This would enable agencies to respond, should an unexpected problem occur in the upstream treatment processes (refer to Section C, San Vicente Reservoir Study for more information). CDPH requires that projects using water purification processes include an environmental buffer.

Drinking Water Treatment Plant. Purified water that is blended with other water sources in San Vicente Reservoir would be considered raw water, not yet suitable for drinking. Following retention

in the reservoir, purified water would receive additional treatment at a drinking water treatment plant prior to public consumption. This would further protect public health by providing an additional barrier to potential pathogens or chemical contaminants. If the City were to implement a reservoir augmentation project at San Vicente Reservoir, this raw water would be treated at the Alvarado Water Treatment Plant or another municipal drinking water treatment plant.

Process Performance and Water Quality Monitoring. CDPH requires that a comprehensive and robust combination of water purification process performance monitoring, and monitoring of the purified water quality, be conducted to assure that all of the safeguards built into projects using water purification continuously function as planned.

CDPH would establish requirements for the City's potential reservoir augmentation project at San Vicente Reservoir through two permitting mechanisms.

- **Water Supply Permit:** The CDPH Water Supply Permit governing the existing drinking water system would need to be amended to include the additional source water (purified water) along with operating and water quality conditions specific to this new source.
- **National Pollutant Discharge Elimination System Permit:** CDPH would provide specific operating and water quality conditions to the Regional Board for inclusion in the NPDES permit discussed in the Regional Board section below.

Together, these operating permits would govern the advanced water purification technologies, operating features, resultant purified water quality requirements, and reservoir operating features providing redundant and reliable public health protections. Ultimately, a reservoir augmentation project at San Vicente Reservoir would need to meet not only drinking water quality standards applicable to all drinking water systems, but additional water quality standards intended to protect the health of aquatic organisms that may be present in the reservoir. Because some aquatic organisms may be more sensitive to certain water quality constituents than humans, some water purification standards are more stringent than conventional drinking water requirements.

Protecting Environmental Health: Regional Water Quality Control Board

The Regional Board is responsible for developing and enforcing water quality objectives for surface water and groundwater bodies within the San Diego region. Since the City's potential reservoir augmentation project at San Vicente Reservoir would involve releasing purified water into San Vicente Reservoir (the required environmental buffer), the project would fall under the jurisdiction of the Regional Board.

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY
SAN DIEGO REGIONAL WATER QUALITY CONTROL BOARD

The Regional Board is responsible for enforcing water quality objectives in the San Diego Region.

The Regional Board's existing regulatory framework is designed to manage the discharge of waste to the environment. Water purification technology has been demonstrated to remove "wastes" from recycled water, and statewide legislation (Assembly Bill 2398) was introduced in 2012 to remove

purified water from the purview of the Regional Board to reflect the position that purified water should not be considered waste due to its exceptional quality. This omnibus legislation has since been tabled, but a stakeholder group is continuing this discussion with the ultimate goal of removing purified water from Regional Board purview. In the meantime, a reservoir augmentation project at San Vicente Reservoir would need to abide by the Regional Board's regulatory framework.

Because groundwater replenishment projects release purified water to groundwater as opposed to surface water, these projects typically require only a WDR permit issued by the Regional Board. The City's reservoir augmentation project at San Vicente Reservoir would involve releasing purified water to a surface water body and would, therefore, require a full NPDES permit, which is more involved than a WDR and includes EPA approval. An NPDES permit for the City's potential reservoir augmentation project at San Vicente Reservoir would place limitations on the purified water released to San Vicente Reservoir in accordance with the Basin Plan, which is the primary source of water quality standards for San Vicente Reservoir. These water quality standards are based on specific uses designated for San Vicente Reservoir. The Regional Board also regulates surface water bodies via the California Toxics Rule, which establishes water quality criteria for 126 priority pollutants. Together, Basin Plan standards and California Toxics Rule criteria provide a comprehensive set of water quality standards designed to protect the integrity and purpose of San Vicente Reservoir.

Regulatory Coordination Activities

The City began working closely with both CDPH and the Regional Board regarding potential reservoir augmentation at San Vicente Reservoir long before the start of the Demonstration Project. The City's Water Repurification Project, initiated in 1994 and formally stopped in 1999, included a regulatory coordination effort that culminated in the conceptual approval of reservoir augmentation at San Vicente Reservoir. New state policies and water quality concerns that emerged following that Water Repurification effort prompted the City to initiate new discussions with CDPH and the Regional Board during the Water Reuse Study. The City first met with both the Regional Board and CDPH in 2004-2005 during development of the Water Reuse Study. The City then met with CDPH in December 2007 to receive an update on the potential regulatory framework for reservoir augmentation at San Vicente Reservoir. Two things were concluded from that meeting:

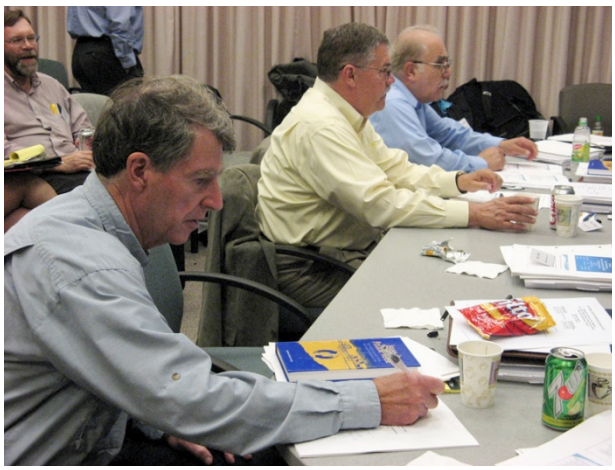
- The City would need to demonstrate the performance of water purification technologies that would be used in reservoir augmentation at San Vicente Reservoir
- An IAP would need to be formed to oversee technical studies and review the findings as required by CDPH to form the basis for concept approval of a reservoir augmentation project at San Vicente Reservoir

Based on initial CDPH input, the City formulated a preliminary plan for the Demonstration Project, and met again with CDPH in March 2008 to present a proposed work plan for the Demonstration Project. The objective of this meeting was to clarify Demonstration Project objectives and obtain input on the City's proposed Demonstration Project work plan that formed the basis for the project

scope and costs that develop the rate case. The City also coordinated with the County of San Diego Department of Environmental Health (DEH) at the request of CDPH; County DEH was invited to all meetings held with the IAP.

Preliminary conversations were also held with the Regional Board. After an initial meeting with Regional Board staff in 2008 to introduce the Demonstration Project concept, subsequent meetings of the IAP and its subcommittees included both regulatory agencies. Table D-1 summarizes the IAP meetings held in support of the Demonstration Project.

Based on initial meetings with CDPH and the Regional Board, a plan to achieve regulatory conceptual approval was developed. This plan provided the framework for regulatory activities that would ultimately lead to preliminary regulatory approval for a reservoir augmentation project at San Vicente Reservoir. This plan identified key technical topics that would need to be addressed and a schedule of regulatory and IAP meetings to address these topics. Topical IAP subcommittees and working groups were convened to support the amount and complexity of technical considerations to be addressed and provide input on specific work products for the Demonstration Project.



The Independent Advisory Panel validated results and conclusions of the Demonstration Project.

The regulatory plan was structured around the following regulatory objectives:

1. Validate the ability of the AWP Facility to produce purified water meeting all regulatory requirements
2. Demonstrate the ability of San Vicente Reservoir to provide a substantial environmental buffer year-round
3. Validate that the addition of purified water would protect San Vicente Reservoir water quality

Technical activities and regulatory and IAP subcommittee meetings were held throughout the Demonstration Project consistent with the regulatory implementation plan. The timing of specific Demonstration Project activities necessary to achieve the regulatory objectives is presented in Table D-1 through D-5.

Table D - 1: Summary of IAP Meetings

Meeting No.	Date	Topic
1	May 11-12, 2009	Introductory meeting for the full IAP to discuss the Demonstration Project Scope
2	March 29-30, 2010	Limnology (reservoir-related) Subcommittee Meeting No. 1 to discuss set-up and calibration of the San Vicente Reservoir Model[1]
3	September 2, 2010	Limnology Working Group Meeting No. 1 to specify and discuss details pertaining to the San Vicente Reservoir Model[2]
4	October 21, 2010	AWP Facility Subcommittee Meeting No. 1 to discuss the draft Testing and Monitoring Plan[3]
5	March 17, 2011	Limnology Working Group Meeting No. 2 to review San Vicente Reservoir modeling scenarios, determine potential "worst case scenarios," and discuss pathogen removal[2]
6	June 6-7, 2011	Second meeting of the full IAP to update the group on the Limnology Subcommittee, Limnology Working Group, and AWP Facility Subcommittee activities, and tour the AWP Facility
7	December 6, 2011	Limnology Subcommittee Meeting No. 2 to review and receive comments on the draft San Vicente Reservoir modeling study, and receive input on proposed reservoir public health-related regulatory conditions[1]
8	December 19, 2011	AWP Facility Subcommittee Meeting No. 2 to review AWP Facility operational and water quality data[3]
9	March 9-21, 2012	Conference calls to review and discuss Draft CDPH Proposal[4]
10	March 13, 2012	Limnology Subcommittee Meeting No. 3 to review the San Vicente Reservoir Water Quality Report[1]
11	November 15-16, 2012	Third meeting of the full IAP to review and comment on the draft Demonstration Project Report, Quarterly Testing Report No. 4, and AWP Facility Study Report (CDM Smith and MWH 2013b)

Footnotes:

1. The Limnology Subcommittee was comprised of four IAP members focused on the Limnology Study.
2. The Limnology Working Group was comprised of two IAP members and project staff specifically assigned to vetting the details of the reservoir study.
3. The AWP Facility Subcommittee was comprised of four IAP members focused on the operation and results of the AWP Facility.
4. An ad-hoc subcommittee provided review and comment via a series of conference calls in lieu of face-to-face meetings.

Objective 1: *Validate the ability of the AWP Facility to produce purified water meeting all regulatory requirements*[5].

A series of actions were taken between October 2010 and December 2012 to assist in validating the ability of the AWP Facility to produce purified water meeting regulatory requirements. Construction of the AWP Facility began in September 2010 and ran through June 2011. During construction, a detailed Testing and Monitoring Plan was developed and revised in coordination with the IAP prior to being submitted to CDPH for approval. Following CDPH approval and completion of AWP Facility construction, the Testing and Monitoring Plan was implemented. The monitoring results were summarized in a Draft AWP Facility Report, which was reviewed with the IAP prior to being submitted to CDPH. Together, these actions have demonstrated that the AWP Facility produces purified water meeting all regulatory requirements. CDPH issued concept approval for the project in September 2012. CDPH's Concept Approval Letter is included as Appendix B to this report. Table D-2 provides an overview of the timeline of each action implemented in support of Objective 1.

Table D - 2: Timeline of Activities Completed in Support of Objective 1

Activity	Date
Procure and Fabricate AWP Facility equipment	October 2010
Prepare Testing and Monitoring Plan	September 2010
Conduct IAP AWP Facility Subcommittee meeting No. 1	October 2010
Submit Testing and Monitoring Plan for CDPH approval	December 2010
Perform AWP Facility Testing	August 2011 – July 2012
Conduct IAP AWP Facility Subcommittee meeting No. 2	December 2011
Submit Concept Proposal for Full-Scale Reservoir Augmentation Project at San Vicente Reservoir to CDPH	March 2012
CDPH issues Concept Approval for Full-Scale Reservoir Augmentation Project at San Vicente Reservoir to CDPH	September 2012
Submit Draft AWP Facility Report for IAP review	October 2012
Submit AWP Facility Draft Quarterly Testing Report No. 4 to CDPH	October 2012

[5] For specific information regarding the AWP Facility, please refer to Section B of this report.

Objective 2: *Demonstrate ability of San Vicente Reservoir to maintain a substantial environmental buffer year-round.*[6]

Demonstrating that San Vicente Reservoir maintains a substantial environmental barrier involves providing evidence that purified water is either held in the reservoir for an acceptable period of time or substantially blended year-round.

Between late 2009 and December 2011, activities were undertaken to demonstrate that San Vicente Reservoir provides a substantial environmental buffer year-round. As described in Section C: San Vicente Reservoir Study, a three-dimensional hydrodynamic computer model was used to demonstrate that purified water would either be held in the reservoir for a period of time acceptable to regulatory agencies or substantially diluted year-round. The model was then reviewed with the IAP to ensure that it would provide an accurate representation of how purified water would move through the expanded reservoir.

Once the computer model was set up and validated by the IAP, modeling was performed to simulate the range of potential conditions for introducing purified water into San Vicente Reservoir under a reservoir augmentation project. A Limnology Working Group was convened to review these initial modeling results and recommend additional model scenarios. The Limnology Working Group was comprised of IAP members specifically assigned to vetting the details of all the reservoir work.

Additional modeling was performed to assess the worst-case conditions in San Vicente Reservoir to demonstrate that, even under these worst-case conditions, the reservoir would provide a substantial environmental buffer. Based on the modeling results, preliminary regulatory metrics for the reservoir were proposed. The results of the modeling efforts were summarized in a Reservoir Study ("Retention and Mixing Report"), which was reviewed with the IAP prior to being submitted to CDPH for consideration. Table D-3 provides an overview of the timeline of each action implemented in support of Objective 2.

The regulatory activities noted above focused primarily on CDPH requirements, because the environmental buffer regulatory standard is required by CDPH. In addition to these activities, the City has worked with Regional Board staff throughout the Demonstration Project, including holding project-specific meetings at the Regional Board office and inviting Regional Board staff to attend IAP meetings.

[6] For specific information regarding the San Vicente Reservoir Study and the San Vicente Reservoir Model, please refer to Section C of this report.

Table D - 3: Timeline of Activities Completed in Support of Objective 2

Activity	Date
Create a three-dimensional hydrodynamic computer model (San Vicente Reservoir Model)	Late 2009
Validate the San Vicente Reservoir Model using 1997 tracer study results	Late 2009
Adjust the San Vicente Reservoir Model to consider components of the expanded San Vicente Reservoir	Early 2010
Conduct IAP Limnology Subcommittee Meeting No. 1 to validate model calibration and applicability	March 2010
Finalize Reservoir Study - Model Development Report (San Vicente Reservoir Model development, validation, scalability)	June 2010
Perform initial modeling	June-October 2010
Conduct Limnology Working Group Meeting No. 1 to review initial model scenario results and recommend additional model scenarios	September 2010
Prepare and Submit draft San Vicente Reservoir Pathogen Removal Issues Paper	November 2010-February 2011
Conduct IAP Subcommittee Meeting No. 2 to assess initial modeling results and pathogen removal capacity of San Vicente Reservoir	March 2011
Assess worse-case San Vicente Reservoir retention scenario using results of second set of San Vicente Reservoir three-dimensional modeling results	April-June 2011
Prepare preliminary reservoir regulatory metrics	August–September 2011
Prepare Reservoir Study –Retention and Mixing Report	August-October 2011
Submit Reservoir Study – Retention and Mixing Report	November 2011
Conduct IAP Subcommittee Meeting No. 3 to review Retention and Mixing Report and preliminary reservoir regulatory metrics	December 2011
Submit Proposal to Augment San Vicente Reservoir with Purified Recycled Water	March 2012
Receive Concept Approval for San Vicente Reservoir Augmentation Project from CDPH	September 2012

***Objective 3**: Demonstrate protection of San Vicente Reservoir water quality (specifically focusing on nutrients).*

Demonstrating that San Vicente Reservoir water quality would not be adversely impacted by a reservoir augmentation project at San Vicente Reservoir involved updating the computer model as described under Objective 2 to include a water quality component, or subroutine, so that the effects

of purified water on reservoir water quality could be simulated. After meeting with the Regional Board, modeling was performed to demonstrate the negligible effect that adding purified water would have on San Vicente Reservoir water quality. Once the results of the modeling scenarios were presented to the Regional Board, the Regional Board adopted a resolution supporting the City's potential reservoir augmentation project at San Vicente Reservoir.

The modeling effort assessed potential effects of purified water on nitrogen loading into San Vicente Reservoir.

The Testing and Monitoring Plan for the AWP Facility was implemented during the period from August 2011 through July 2012. This involved collecting water quality data including parameters of interest to both CDPH and the Regional Board. These data were assessed to determine whether the quality of purified water produced at the AWP Facility would be suitable to meet Regional Board water quality standards, which – in some cases – are more stringent than CDPH standards. Because nutrient levels in purified water would be slightly higher than potentially required by the Basin Plan, additional model scenarios were performed to simulate the effects of adding purified water on nutrient loading to the reservoir.

Results of these simulations were summarized in a Reservoir Study - Water Quality Report, which was submitted to the IAP and the Regional Board. Nutrient loading was determined to be one area in which additional work would need to be completed to clarify regulatory requirements for a potential full-scale AWP facility. The City met with the Regional Board to discuss the results of the water quality evaluation and outline an approach for achieving regulatory compliance. This approach was summarized in a Proposed Regional Board Compliance Approach, which was submitted to the Regional Board for consideration. Table D-4 provides an overview of the timeline of each action implemented in support of Objective 3.

As described above, the City prepared submittals to both CDPH and the Regional Board to conclude the Demonstration Project regulatory coordination activities and elicit regulatory response. These submittals presented the regulatory framework for a potential reservoir augmentation project at San Vicente Reservoir as understood by the City. More detail on these submittals and the regulatory response is presented in the following sections.

Table D - 4: Timeline of Activities Completed in Support of Objective 3

Activity	Date
Meet with Regional Board to introduce the potential San Vicente Reservoir Augmentation Project	October 2008
Rerun initial San Vicente Reservoir model with water quality component	September 2011
Make presentation to Regional Board on Reservoir Augmentation Project at San Vicente Reservoir and Regional Board adopts resolution supporting the City's potential reservoir augmentation project at San Vicente Reservoir	October 2011
Assess AWP Facility monitoring data regarding Regional Board requirements	December 2011 – February 2012
Perform additional model scenarios to assess addition of purified water and reservoir expansion on nutrient loading	November – December 2011
Prepare Reservoir Study – Water Quality Report	January – February 2012
Submit Reservoir Study – Water Quality Report to Regional Board	March 2012
Conduct IAP Limnology Subcommittee meeting No. 3	March 2012
Meet with Regional Board to discuss San Vicente Reservoir 303(d) Listing and associated nutrient regulatory approach	June 2012
Prepare Proposed Regional Board Compliance Approach	June-August 2012
Submit Proposed Regional Board Compliance Approach to Regional Board	August 2012

CDPH Regulatory Acceptability

CDPH has the authority to approve reservoir augmentation projects on a case-by-case basis. One goal of the Demonstration Project was to receive concept approval from CDPH for a potential reservoir augmentation project at San Vicente Reservoir. The City submitted a proposal to CDPH in March 2012 that presented specific public health protections provided by a reservoir augmentation project at San Vicente Reservoir and summarized technical study results obtained throughout the Demonstration Project and validated by an IAP. The City's proposal, provided in Appendix A, articulated how a reservoir augmentation project at San Vicente Reservoir would provide a multiple barrier approach fundamental to public health protection by incorporating the following elements:

- Enhanced source control to prevent potential contaminants from entering the wastewater stream
- Pathogenic microorganism control through implementation of recycled water treatment and advanced water purification processes
- Control of nutrients including nitrogen compounds through implementation of advanced water purification processes
- Monitoring for regulated contaminants, additional chemicals, and other contaminants
- TOC control, achieved through implementation of an advanced water purification process and a monitoring plan focused on removal of these constituents

- Reliability and redundancy to meet regulatory requirements and prevent purified water from entering San Vicente Reservoir if necessary
- Monitoring and response plan designed to detect any unexpected operational issues at the AWP facility or source water contamination before the purified water reaches the reservoir

Based on the multiple barrier approach outlined in the City's proposal, CDPH issued a Concept Approval Letter to the City in September 2012, in which CDPH approved of the reservoir augmentation at San Vicente Reservoir concept proposed by the City (Appendix B).

Based on the body of technical work completed as part of the Demonstration Project and the successful operation of similar projects elsewhere in California, the program elements listed below were suggested to be implemented as part of the CDPH regulatory framework for the City's potential reservoir augmentation project at San Vicente Reservoir.

Table D - 5: Potential Reservoir Augmentation Project at San Vicente Reservoir Regulatory Program Elements - CDPH

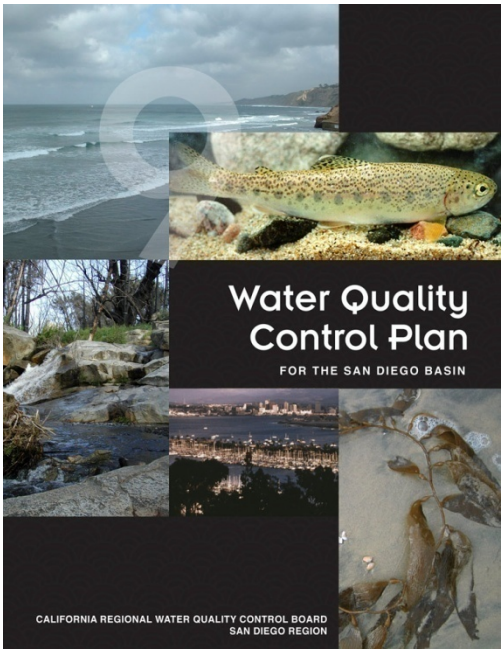
Control Point: Prior to Entering the Wastewater Collection System
• Establish enhanced source control program for the North City service area to prevent target contaminants from entering the wastewater stream.
Control Point: North City Water Reclamation Plant (source of recycled water for advanced water purification)
• Implement flow equalization to deliver a constant flow of recycled water from North City to the AWP Facility, simplifying process operation.
• Achieve full nitrification in the secondary aeration process to assist in reducing the amount of nitrogen in recycled water produced at North City.
• Operate with no return flows from biosolids processes (biosolids from North City are processed off-site) to produce the highest quality recycled water.
• Use tertiary-filtered water from North City as the source water for the AWP Facility.
Control Point: Advanced Water Purification Facility (AWP Facility)
• Treat the entire amount of water sent to the AWP Facility with membrane filtration and reverse osmosis meeting applicable CDPH specifications and performance measures to ensure the best quality of purified water possible.
• Treat the entire amount of water sent to the AWP Facility with advanced oxidation meeting applicable CDPH specifications and performance measures to ensure the best quality of purified water possible.
• Implement a Critical Control Point Monitoring Plan that includes surrogate indicators recommended by the industry at time of implementation. Surrogate indicators allow the City to quickly and easily detect any unexpected treatment process interruptions so that they may be addressed right away.
• Maintain a certified operator on-site at all times (24 hours/day) to ensure proper facility operation and oversight.

Control Point: San Vicente Reservoir
• Maintain an adequate combination of retention time and blending in the reservoir at all times to meet regulatory requirements and provide a barrier to potential pathogens.
• Locate the purified water inlet (where purified water enters the reservoir) and the reservoir outlet (where water leaves San Vicente Reservoir) such that purified water moves along a lengthy path from the inlet to the outlet, increasing the time that the water is held in the reservoir.
• Achieve a minimum blend of purified water with ambient reservoir water, at the outlet, of 100:1 at all times to achieve regulatory requirements to provide a substantial environmental buffer.
• Demonstrate criteria to ensure that purified water moves along a lengthy path from the inlet to the outlet and the criteria for blending of purified water at the outlet using a calibrated and validated hydrodynamic model. This allows the City to demonstrate that the requirements for a substantial environmental buffer would be achieved.
• Release purified water above the lower layer of water within San Vicente Reservoir, and withdraw water from the lower layer when layers are present (refer to Section C of this report for more information). This will allow the City to ensure that purified water remains in the reservoir for a longer period of time prior to being withdrawn.
• Treat water withdrawn from the reservoir at a drinking water treatment plant before distribution to the City's customers to provide an additional level of public health protection.
• Maintain the ability to take the reservoir offline as a source of supply to the drinking water system within 24 hours at all times to allow quick response time in the unlikely event that an unexpected process interruption requires the reservoir to be taken offline.

Regional Board Acceptability

Potential challenges associated with permitting a water purification project within the Regional Board regulatory framework were thoroughly discussed in meetings and correspondence conducted between the City and Regional Board throughout the Demonstration Project. Despite the exceptional quality of the purified water that would be released into San Vicente Reservoir, addressing the full array of applicable state and federal water quality standards, plans, and policies could require substantial time and effort. For example, although the nitrogen level in purified water would be comparable to that in imported water inflows to San Vicente Reservoir, purified water inflows would require a Regional Board permit and compliance with Basin Plan water quality objectives, whereas imported water inflows do not. Nitrogen loading associated with releasing purified water into the reservoir is an example of an issue that would require further Regional Board consideration before a reservoir augmentation project at San Vicente Reservoir could be implemented.

Based on coordination with the Regional Board, the City prepared a submittal to the Regional Board entitled "Proposed Regional Water Quality Control Board Compliance Approach" (Appendix D). This document, submitted to the Regional Board in August 2012, summarized the reservoir augmentation at San Vicente Reservoir concept and identified key permitting issues and Regional Board regulatory decisions and actions that would be required in order for the Regional Board to approve a project at San Vicente Reservoir. This document indicates that based upon the Regional Board's interpretation of nitrogen limits within the Basin Plan, purified water flows to San Vicente Reservoir may be required to achieve a total nitrogen concentration limit of 0.25 mg/L to 1.0 mg/L. Water quality testing undertaken at the AWP facility indicates that the average concentration of total nitrogen in purified water is 0.8 mg/L, meaning that purified water could potentially exceed nitrogen concentration requirements established within the Basin Plan. Although purified water nitrogen concentrations could potentially exceed regulatory limits, total nitrogen concentrations in purified water are comparable to or lower than current water inflows to San Vicente Reservoir. Nitrogen concentrations in imported water inflows to San Vicente Reservoir range from 0.17 mg/L to 0.68 mg/L, and nitrogen concentrations in surface water runoff to San Vicente Reservoir range from 0.18 mg/L to 4.2 mg/L.



Although nitrogen levels in the purified water could potentially exceed Basin Plan requirements, total nitrogen levels in purified water are comparable to or lower than current nitrogen concentrations in San Vicente Reservoir.

The submittal noted the following:

- AWP Facility monitoring data indicate that the purified water supply would be equal or superior in quality to existing San Vicente Reservoir inflows for virtually all constituents. Nitrogen could be the only exception to this, as purified water nitrogen concentrations would be slightly higher than existing imported water inflows to San Vicente Reservoir, but superior in quality to the local runoff captured within the reservoir.
- Comprehensive reservoir modeling conducted as part of the Demonstration Project indicate that nitrogen concentrations under a reservoir augmentation project at the expanded San Vicente Reservoir are projected to be less than historic nitrogen concentrations in the reservoir.

On October 12, 2011, the Regional Board adopted Resolution No. R9-2011-0069, which documented the Regional Board's support for a reservoir augmentation project at San Vicente Reservoir. That resolution, included as Appendix C, also sets forth the Regional Board's proposed means of regulating the full-scale project.

The Regional Board noted that two key procedural questions will determine the pathway the City would need to take to proceed with applying for and receiving an NPDES permit for a full-scale project. These questions include:

- Prior to the Regional Board's consideration of an NPDES permit for reservoir augmentation at San Vicente Reservoir, would the Regional Board, State Board, and EPA need to take actions to modify the Clean Water Act Section 303(d) impaired water list for San Vicente Reservoir?
- Prior to the Regional Board's consideration of an NPDES permit for reservoir augmentation at San Vicente Reservoir, would the Regional Board, State Board, and EPA need to modify any requirements within the Regional Board's Basin Plan?

Excerpt from Regional Board Resolution No. R9-2011-0069

NOW THEREFORE, BE IT RESOLVED THAT, the San Diego Regional Water Quality Control Board:

- Supports the efforts to develop the Reservoir Augmentation Project at the San Vicente Reservoir as a means to reduce reliance on imported water, increase the use of recycled water, and to implement goals in California Water Code section 13510 and the 2008-2012 Strategic Plan Update for the Water Boards.
- In accordance with implementation provisions of the Basin Plan, the San Diego Water Board will regulate San Diego Region recycled water reservoir augmentation projects through the issuance of project-specific NPDES Permits.
- Reservoir augmentation NPDES permits issued by the San Diego Water Board will incorporate requirements established and the provisions recommended by California Department of Public Health.

The City's submittal provided a recommended pathway to address these procedural questions expeditiously, and noted that if the answer to both questions is "no", the pathway for approval would be straightforward. The City believes that this direct approval pathway (no Basin Plan modification or 303(d) list revisions) would be both feasible and appropriate. If the answer to either question is "yes", the project would remain feasible, but up to two years could be added to the project's implementation timeline.

.In response to the City's submittal, the Regional Board issued a letter concurring with the recommended regulatory pathway, acknowledging that neither the 303(d) impaired water listing nor the Basin Plan would need to be modified in order to permit a full-scale reservoir augmentation project at San Vicente Reservoir. This February 2013 Regional Board Letter of Concurrence (Appendix E) also reaffirmed that agency's strong support for the City's efforts in moving forward with a full-scale project, and noted that EPA concurs with this support and regulatory pathway.

Section E: Public Outreach and Education

Public Outreach and Education Findings

- According to tour participant feedback, comprehension of the water purification process increased following the completion of an AWP Facility tour.
- A series of public opinion polls shows a steady increase from 2004 (26 percent) to 2011 (68 percent) to 2012 (73 percent) of City residents who favor using advanced treated recycled water as an addition to the City's drinking water supply.

The public outreach and education program for the Demonstration Project continued from outreach efforts that started with the Water Reuse Study, the first phase of the City's Water Reuse Program. The outreach program for the Demonstration Project built on the foundation that had been laid during the Water Reuse Study.

The San Diego Assembly on Water Reuse

In 2005, the Water Reuse Study included a public outreach program that provided valuable input on how to best increase recycled water use as part of the City's plan for a reliable, long-term water supply. A key element of that public outreach program was the City of San Diego Assembly on Water Reuse, which brought together 59 individuals who resided in San Diego and were recommended by the Mayor and City Council to serve on this group. A non-technical group, these individuals represented a broad range of perspectives about San Diego. They reached agreement on a number of specific recommendations related to water reuse options for the City, including that "…technology and scientific studies support the safe implementation of non-potable and indirect potable use projects" (City of San Diego 2006). In addition to the American Assembly-style workshops, the City conducted several types of public opinion research including individual interviews, focus groups, and an online and telephone survey. To inform the public about the advanced water purification process, they also made presentations to groups, worked with the media, produced electronic newsletters, and established a website.

Because of a history of misinformation about water purification, City Council instructed that public outreach be included as a component of the Demonstration Project. Based on the City Council's directive, an outreach goal was adopted "…to inform and educate San Diego's local leaders, stakeholders and residents about the Demonstration Project."

In addition to the outreach goal, the following objectives were identified at the onset of the public outreach and education program:

- Foster a clear understanding of the Demonstration Project and its goals among all stakeholder groups
- Provide a description of the Demonstration Project and its results to the public
- Provide information on the opportunities and challenges of using reservoir augmentation as a component of diversifying the City's water supply

To accomplish the goal and objectives, a strategic outreach plan was developed to guide the comprehensive public outreach program envisioned for the Demonstration Project. A dedicated public outreach team was established to implement the program and to work closely at every step in the process with the technical team, which included the AWP Facility design and operating teams. The outreach team included the following staff:

- Project director
- Senior public information officer
- Two outreach practitioners dedicated full-time to the project
- Four multicultural consultants
- Media consultant

Throughout the duration of the Demonstration Project, the Public Utilities Department has sought to ensure that information about the Demonstration Project is presented in a clear, understandable, and accessible way to residents in all areas of the City. Information about the Demonstration Project has also been provided through a variety of formats including direct contact with individuals, written and electronic informational materials, traditional and social media, group presentations, community events, and tours of the AWP Facility. Starting in mid-2010, the following activities were completed during the first year of the project:

- Developed the outreach plan
- Conducted research, including one-on-one stakeholder interviews
- Produced informational materials
- Assembled a speakers bureau composed of project team members and Public Utilities Department staff
- Created a presentation about the project for community groups that was used for Speakers Bureau engagements

- Requested recommendations from City Council members to contact for presentation opportunities
- Conducted project presentations to community, planning groups, service clubs and business organizations, internal staff, and the City's IROC and NR&C
- Participated in industry conferences
- Developed an email list database of individuals interested in the project
- Distributed eUpdates and electronic newsletters to interested parties
- Participated in community events
- Provided project information to a broad group of media representatives and outlets
- Compiled quarterly metrics reports and analyzed them to guide future outreach activities

Beginning in mid-2011, the second year saw a continuation of the outreach activities initiated during the first year such as presenting to community, planning groups, service clubs and business organizations, and participating in community events, but added the following activities:

- Launched the Urban Water Cycle Tour program, which culminated in the AWP Facility tours
- Invited elected officials and project stakeholders to visit the AWP Facility when it began operation in mid-2011
- Developed additional informational materials, such as a virtual tour video, project white papers and a tour brochure
- Established a social media presence online using Facebook, Twitter, and YouTube
- Implemented continuous improvements in the AWP Facility tours based on feedback from tour guests
- Continuously enhanced Speaker Bureau presentations based on attendee feedback

All of the numerical data in this report reflects the activity from the commencement of the outreach program in spring 2010 through December 31, 2012. The outreach program is a continuing effort to educate San Diego residents about the potential for reservoir augmentation in the City. Although there is a "cutoff date" for reporting the statistics, the outreach efforts are ongoing. The Demonstration Project outreach program is described in more detail in the following sections. Supporting materials for Section E, Public Outreach and Education, are available on the Public Outreach and Education CD (Appendix H).

Planning, Research and Monitoring

The City's Public Utilities Department was committed to a comprehensive, transparent, and inclusive public outreach program that would inform residents of San Diego about the Demonstration Project. The first step to achieving this goal was to develop a plan to guide public outreach activities and ensure all activities were implemented throughout the City. As with the Water

Reuse Study, the City incorporated research findings to identify outreach activities to ensure all potential audiences had the opportunity to learn more about the Demonstration Project. Additionally, the City tracked its progress in reaching residents in all City Council Districts (using the eight-district map that reflected district boundaries from the beginning of the Demonstration Project until late 2012) through quarterly metrics reports.

Outreach Plan

The outreach plan, completed in May 2010, identified the variety of outreach activities and informational materials necessary to ensure prospective audiences knew about and were engaged in the Demonstration Project and its core element, the AWP Facility. The key points to be presented to City residents included:

- San Diego needs to develop local, reliable, and sustainable sources of water to lessen our dependence on imported water due to multiple factors affecting California's water supply.
- The Water Purification Demonstration Project is examining the use of water purification technology on recycled water to determine the feasibility of full-scale reservoir augmentation in the future.
- The water produced by the purification process goes through multiple steps of advanced treatment and will be tested to meet all water quality, safety, and regulatory requirements.
- No purified water will be added to the San Vicente Reservoir or San Diego's drinking water system during the Demonstration Project.

It was concluded that the most effective and efficient way to achieve the goal of informing San Diego residents about the water purification process was through focusing communication efforts on community leaders, stakeholder groups, and other local organizations. Audiences for the outreach program included local business; environmental, civic, and community leaders from all areas in the City of San Diego, including its vibrant multicultural communities; members of community planning groups and neighborhood councils; elected officials at all levels of government; media representatives; special interest groups such as seniors, the health community, science students, and religious leaders; Public Utilities Department staff; and water agencies throughout the county.

The core elements of the outreach activities were the speakers bureau, community events, and AWP Facility tours. The speakers bureau provided an opportunity for community groups and organizations of all types to learn more about the Demonstration Project through a presentation and opportunity to ask questions. Hosting informational booths at community events allowed for one-on-one discussions with a breadth of San Diegans. The AWP Facility tours provided an opportunity for individuals and groups to visit the facility to see firsthand the purification process and the quality of the water produced.

Research

The outreach plan recommended following previous research protocols to learn more about what residents and stakeholders knew about water reuse in general and water purification specifically. Information was obtained from three main sources: one-on-one stakeholder interviews, a telephone survey of City residents conducted in conjunction with the Water Authority's public opinion polls, and a San Diego State University student research study. Results from the research efforts guided the Demonstration Project's public outreach and information activities.

Stakeholder Interviews

The City recognized the importance of ensuring stakeholders from all communities in the City who had a vested interest in the Demonstration Project knew about it: what it was, what it was not ("Toilet to Tap"), and how they could learn about the Demonstration Project and provide input. This led to 105 one-on-one interviews with stakeholders throughout the City from mid-2010 to mid-2011. Stakeholders were identified through City Councilmember and Water Reliability Coalition member recommendations (see the *Stakeholder and Partner Communication* section) as well as by reviewing lists of stakeholders interviewed during the Water Reuse Study.

In addition to gauging their level of awareness about the Demonstration Project and the advanced water purification process, interviewers sought to learn the best way to provide information about the Demonstration Project to the community or group represented by each stakeholder and to determine what kind of information the stakeholder would need to more clearly understand the purification process. Water quality and public health and safety were the top concerns stakeholders mentioned about the concept of reservoir augmentation. This underscored the importance of providing information about the water purification process and the multiple barriers provided by the membrane filtration, reverse osmosis, and UV disinfection/advanced oxidation steps. It also emphasized the importance of the planned AWP Facility tour program and the need to provide information about how water quality will be monitored.

Public Opinion Polls

The Water Authority regularly conducts public opinion polls to garner information about attitudes toward water issues throughout the county. For the 2012 survey, as with the 2011 and 2004 surveys, the City requested that a statistically-significant sample of approximately 400 City residents be polled to provide a good base of knowledge about water attitudes in the City. According to the findings, nearly three-fourths of City residents favored using recycled water to help diversify the City's water supply (see Figure E-1) and 71 percent believed that recycled water used for irrigation could be further treated to make the water pure and of the highest quality for drinking (see Figure E-2). When the concept of the Demonstration Project was explained to them as part of the poll, over three-fourths of the respondents expressed strong support for it.

Figure E - 1: 2012 Public Opinion Poll – Opinion about Using Advanced Treated Recycled Water as an Addition to Drinking Water Supply

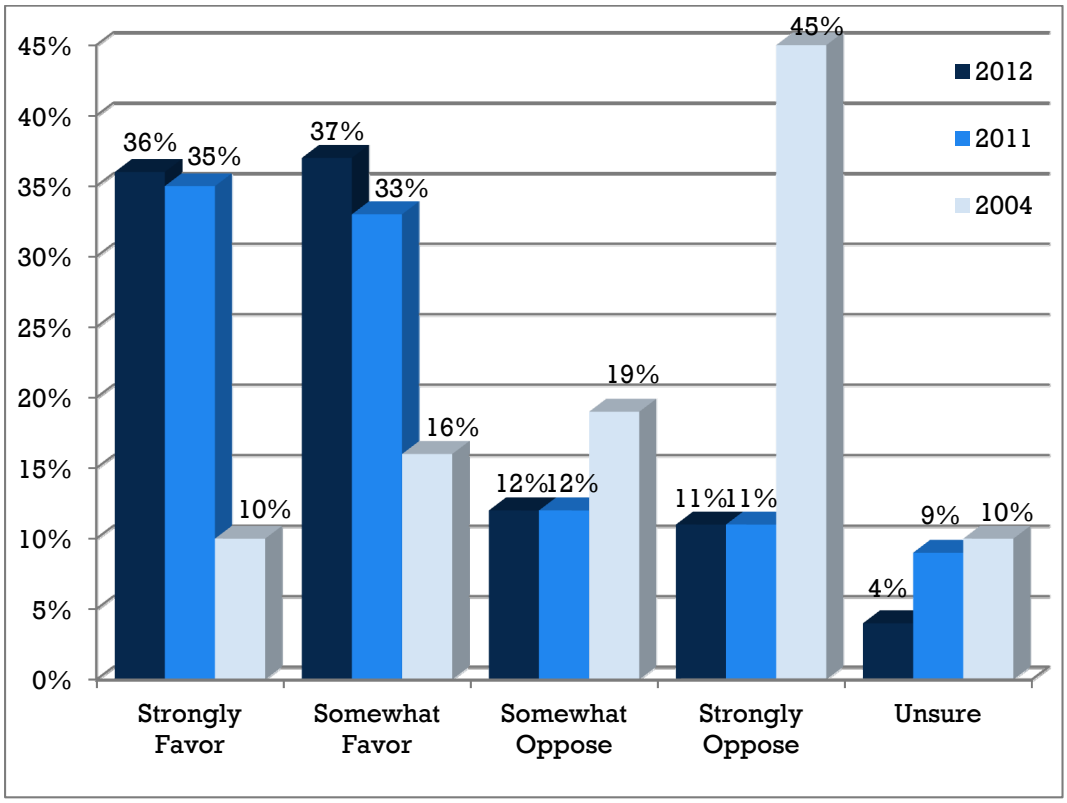
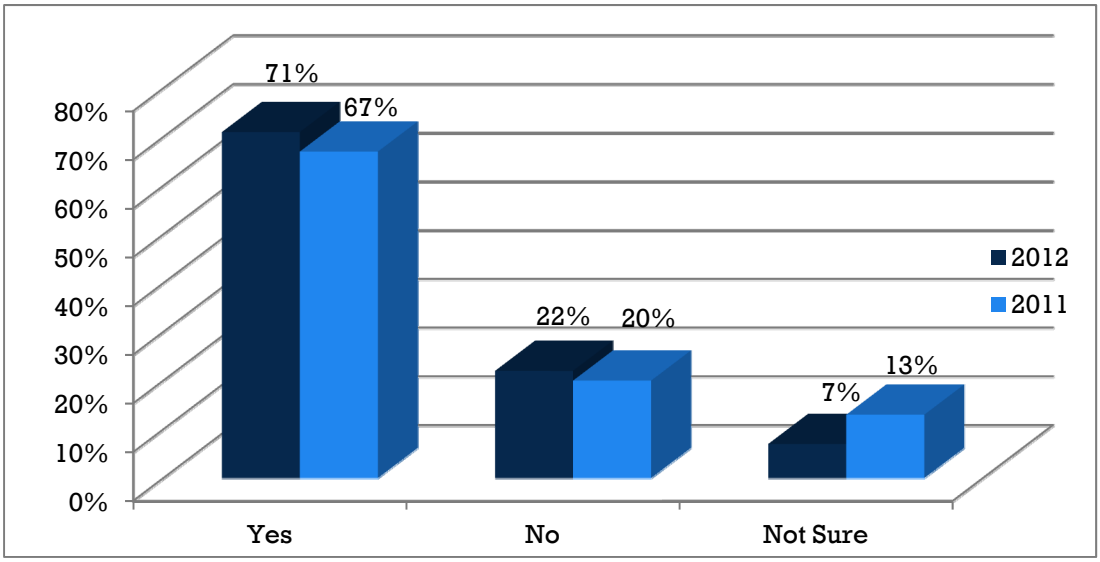


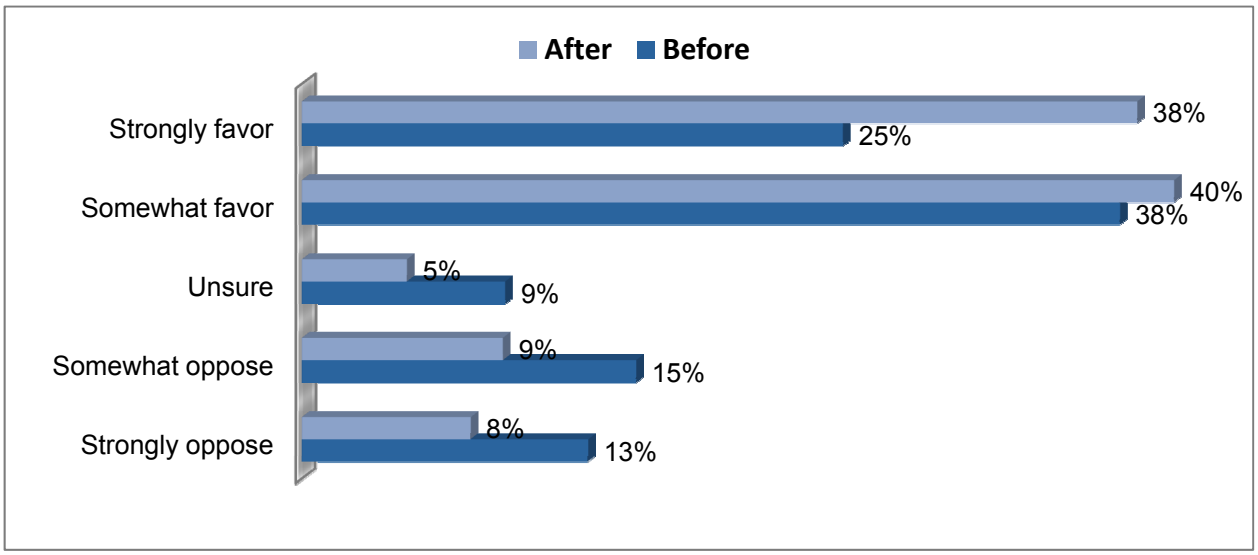
Figure E - 2: 2012 Public Opinion Poll – Is It Possible to Further Treat Recycled Water Used for Irrigation to Make It Pure and Safe for Drinking?



San Diego State University Research Study

A research study regarding the Demonstration Project was conducted in the fall of 2010 by a research methods class at San Diego State University (SDSU). The students conducted 63 in-depth interviews with City of San Diego residents. The information culled from these interviews was used to create a random digit dial telephone survey questionnaire. Students used the questionnaire to interview a statistically-significant sample of 626 San Diego residents by telephone in November 2010. After being read a description of the Demonstration Project, 63 percent of respondents said they supported it. The next step in the process was to provide more information about advanced water treatment to the respondents. This step validated the importance of informing people about the Demonstration Project, since 78 percent were supportive of the Demonstration Project once they learned more about it (see Figure E-3).

Figure E - 3: Impact of Additional Information on Support



Application of Findings

The research findings from the stakeholder interviews, public opinion polls, and the SDSU study helped determine which public outreach activities should be emphasized. For example, since the SDSU research found that people tended to trust scientists most for their water information, engineers and plant operators led AWP Facility tours and emphasized that the entire project is overseen by a team of experts from the IAP. Stakeholders also expressed concerns about water quality in the one-on-one interviews, so an extensive discussion of water quality is included in all project presentations. The purified water quality is also displayed visually at a sink that dispenses water produced at the AWP Facility at the end of the tour.

Outreach Metrics Report

The City's IROC serves as an official advisory body to the Mayor and City Council on policy issues relating to the oversight of the Public Utilities Department's operations. IROC's Outreach and Communication Subcommittee (formerly known as the Public Outreach, Education and Customer Service Subcommittee) noted the importance of measuring and evaluating the Demonstration

Project's outreach activities. The metrics reports that were developed in response to this request summarized completed outreach activities and provided direction for scheduling future activities. Outreach data were compiled into a comprehensive quarterly report that identified outreach activities completed to specific audiences during that reporting period. Included in the reports were the number of tour attendees, community presentations, eUpdates, new contacts, and more. The report also included additional details about each of these activities. A review of the metrics report guided the focus for future outreach activities. This ensured that every community in San Diego had the opportunity to learn about the project, whether through an article in a community newspaper, a water bill insert, attending a presentation, or touring the facility.

Education and Outreach Materials and Tools

Informational materials were developed as tools to explain and disseminate information about the Demonstration Project and the science behind water purification. These materials were tailored to the interests of multiple audiences and were made available in a variety of formats including both print and electronic versions. The materials were created to appeal to multicultural and age-specific audiences, and were translated into Spanish and Vietnamese. To ensure all aspects of the project were clearly understood, project informational materials were posted on the project's website, www.PureWaterSD.org, and distributed or available at presentations, tours, community events, and all other outreach activities.

Fact Sheet

An easy-to-understand fact sheet was developed early in the Demonstration Project to provide a description of the project, highlighting the need for a local, reliable source of water in San Diego and the components of the Demonstration Project. The fact sheet includes a schematic of the advanced water purification process, as well as the water treatment and distribution processes, to clarify any misconceptions about the Demonstration Project. It was written for lay audiences and translated into Spanish and Vietnamese for multicultural outreach opportunities. The fact sheet was distributed at stakeholder interviews, presentations, and community events, and available at AWP Facility tours, all City library branches, City Council offices, and the Mayor's office. It is also on the project website. The fact sheet was also condensed into a "quick facts" version with bullet points for use as reference.

Fact Sheet

Water Reuse Program

Water Purification Demonstration Project

The City of San Diego • Public Utilities Department

Water Purification | Demonstration Project

The City of San Diego has limited local water sources and relies on importing approximately 85 to 90 percent of its water supply. In the past, importing water from the Colorado River and Northern California has been a low-cost, reliable option, but environmental stresses and court-ordered pumping restrictions have continued to reduce the amount of water that can be delivered to San Diego. These circumstances and the threat of further limitations on our water supplies have intensified the need for new sources of water. As part of the City's effort to provide a local and sustainable water supply, the Water Purification Demonstration Project is examining the use of water purification technology to provide safe and reliable water for San Diego's future.

Recycled Water

The Demonstration Project is the second phase of a process evaluating ways for the City to increase its use of recycled water. The first phase was the City's 2005 Water Reuse Study that identified reservoir augmentation as the preferred option for developing recycled water sources. The Demonstration Project will determine if reservoir augmentation is a feasible option for San Diego.

Reservoir augmentation is a multi-step process that includes:

- Using water purification technology on recycled water
- Sending the purified water to a reservoir to blend with existing water supplies
- Treating the blended water again to be distributed as drinking water

The Demonstration Project is underway and will conclude in early 2013. During this time, the Advanced Water Purification Facility will operate for approximately one year and will produce 1 million gallons of purified water per day. A study of the San Vicente Reservoir is being conducted to test the key functions of reservoir augmentation and to determine the viability of a full-scale project. No purified water will be sent to the reservoir during the demonstration phase.

The City of San Diego's water resource strategy includes planning, conservation, recycled water, groundwater, water reuse, and watershed and resource protection to help meet future water needs.

An independent advisory panel of experts is providing oversight on project research to determine (1) if the purification process satisfies all water quality, safety and regulatory requirements of the California Department of Public Health, and (2) the behavior of the reservoir and what will happen if the purified water is added. A summary report detailing the results of the Demonstration Project will be provided to the Mayor and City Council. If deemed technically feasible, and following Mayoral and City Council authorization, a full-scale reservoir augmentation project would be implemented.

Potential benefits of implementing Reservoir Augmentation in San Diego:

- Provide a local and sustainable supply of purified drinking water for San Diego
- Improve the quality of water in the San Vicente Reservoir
- Decrease dependence on imported water
- Increase utilization of recycled water
- Provide a supply of water that uses less energy than imported water
- Have a positive impact on the environment by producing less discharge into the ocean and working toward lower carbon emissions

In an effort to keep San Diego citizens informed , the public outreach program is offering free tours of the Advanced Water Purification Facility and project presentations are being made to groups upon request. For more information, please call (619)533-7572 or email purewatersd@sandiego.gov. To register for a tour, please visit www.purewatersd.org.

The City of San Diego

PUBLIC UTILITIES

City of San Diego Public Utilities Department • Long-Range Planning & Water Resources Division
600 B Street, Suite 600, San Diego, CA 92101 • (619)533-7572 www.purewatersd.org

Printed on recycled paper. This information is available in alternative formats upon request.

Public Information Office 5/25/11

An easy-to-understand fact sheet was developed for distribution and for inclusion on the project website.

Frequently Asked Questions (FAQ)

The most frequently asked questions related to the Demonstration Project were answered in an FAQ to clarify misconceptions and further explain the components of the project. The FAQ was distributed at stakeholder interviews, presentations, and community events, and available at AWP Facility tours, all City library branches, City Council offices, Mayor's office, and on the project website. The questions were updated as needed according to public feedback.

Information Card

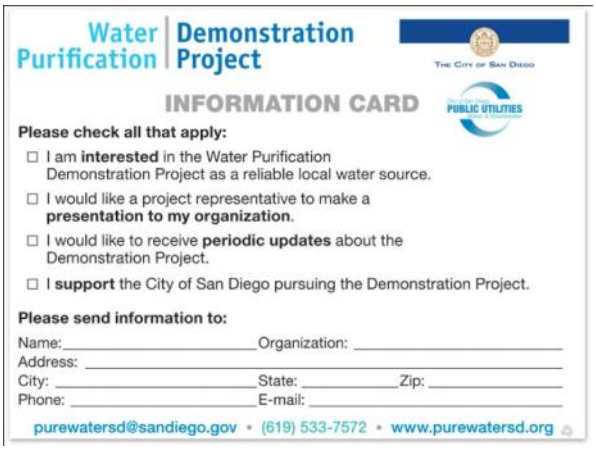
To ensure project information was presented clearly and understandably to all audiences, it was important that information be conveyed about project components in a consistent manner. This reduced confusion and fostered clarity about the Demonstration Project. A business card-sized informational piece was created as a portable, quick-reference item to carry as a reminder of key information points, or project messages, to provide to any audience. The card also included project contact information and the website address for easy reference.

Fact Card

The project fact card was a version of the information card produced for distribution at community events and AWP Facility tours to ensure consistency of project information and to provide contact information and the project website address.

Interest and Information Card

The interest and information card was used at all outreach activities and was designed to allow interested parties, community leaders, tour guests, and presentation participants to provide their contact information, level of interest, and any requests for additional information. A simplified version was created for use at events to gather names and email addresses. The extensive list was compiled and added to an email list to receive project updates, electronic copies of the project newsletter, eUpdates, and information about project involvement opportunities. The card also allowed members of the community to request group presentations or suggest additional groups to contact for a presentation. A total of 1,056 interest cards were collected from stakeholder interviews, community events, presentations, and facility tours. The interest cards included postage and a mailing address if interested parties preferred to complete and mail in the card at a later date.


Water Purification | Demonstration Project

The City of San Diego

INFORMATION CARD

PUBLIC UTILITIES

Please check all that apply:

- ☐ I am **interested** in the Water Purification Demonstration Project as a reliable local water source.
- ☐ I would like a project representative to make a **presentation to my organization**.
- ☐ I would like to receive **periodic updates** about the Demonstration Project.
- ☐ I **support** the City of San Diego pursuing the Demonstration Project.

Please send information to:

Name: _____ Organization: _____
Address: _____
City: _____ State: _____ Zip: _____
Phone: _____ E-mail: _____

purewatersd@sandiego.gov • (619) 533-7572 • www.purewatersd.org

An interest and information card allowed people to provide contact information, indicate level of interest, and request additional information.

Website

The official project website (with the domain name PureWaterSD.org) was designed and hosted on the City website. The site included all project materials, updates, related media, and up-to-date

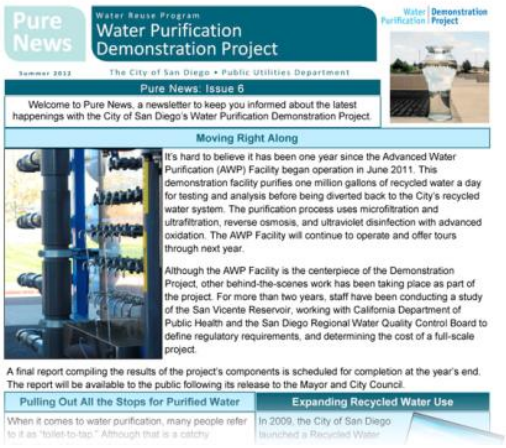
information about the project. For ease of use, a tour sign-up link was located on the home page. The project website was publicized on all informational materials and mementos to encourage an online following.

Content on PureWaterSD.org includes the following:

- AWP Facility tour registration
- Project history
- Email subscription registration system
- eUpdates
- IAP member list and activities
- Informational materials
- White papers
- Videos
- Project PowerPoint presentations
- WateReuse Association PowerPoint "Downstream"
- News coverage and related news clips
- Newsletters
- Completed speakers bureau presentation list
- Contact information
    - Links to project social media pages
    - Presentation request information
- Links to relevant resources or information about water reuse and water purification

Photography

Outreach efforts were documented with photographs, which were used in informational materials such as presentations, advertisements, newsletters and media outreach, and were placed on the project website and social media pages. Photographs were taken at most outreach activities, including community events, presentations, facility tours, and conferences.


Pure News

Water Reuse Program

Water Purification Demonstration Project

Summer 2012

The City of San Diego • Public Utilities Department

Pure News: Issue 6

Welcome to Pure News, a newsletter to keep you informed about the latest happenings with the City of San Diego's Water Purification Demonstration Project.

Moving Right Along

It's hard to believe it has been one year since the Advanced Water Purification (AWP) Facility began operation in June 2011. This demonstration facility purifies one million gallons of recycled water a day for testing and analysis before being diverted back to the City's recycled water system. The purification process uses microfiltration and ultrafiltration, reverse osmosis, and ultraviolet disinfection with advanced oxidation. The AWP Facility will continue to operate and offer tours through next year.

Although the AWP Facility is the centerpiece of the Demonstration Project, other behind-the-scenes work has been taking place as part of the project. For more than two years, staff have been conducting a study of the San Vicente Reservoir, working with California Department of Public Health and the San Diego Regional Water Quality Control Board to define regulatory requirements, and determining the cost of a full-scale project.

A final report compiling the results of the project's components is scheduled for completion at the year's end. The report will be available to the public following its release to the Mayor and City Council.

Pulling Out All the Stops for Purified Water

Expanding Recycled Water Use

Pure News, a newsletter about the project, was published three times a year

Electronic Updates ("eUpdates")

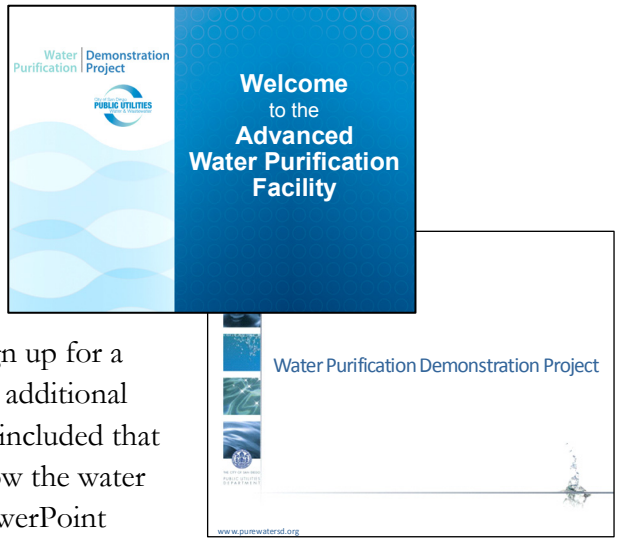
A series of electronic project updates (eUpdates) was designed and distributed by email as a way to provide project information updates as necessary to interested parties. Content included new information, recent media coverage, community involvement events, tour information, and photographs. These emails included brief updates about timely issues that may not be covered in the project newsletters.

Newsletter

A newsletter titled *Pure News* was published three times per year to provide updates on the project, highlight community outreach activities, call attention to project-related media stories, encourage readers to visit the AWP Facility, and share photographs. It was distributed electronically to a list of up to 3,890 interested parties compiled through project outreach activities (refer to the *Promoting the Demonstration Project* section for more information). Copies of the newsletter were printed for distribution at presentations and community events, and each issue has been made available on the project website.

PowerPoint Presentations

PowerPoint presentations were created for the speakers bureau and facility tour program. The presentations provided an overview of San Diego's water supply challenges and how the City is working to meet those challenges. The presentations provided the history of the project; explained its components; and encouraged public participation in the outreach program by letting audience members know how to sign up for a tour, request additional presentations, and easily access additional information about the project. A short video was also included that describes the multiple barrier treatment process and how the water purification equipment works. The objective of the PowerPoint presentations was to explain the science behind water purification. Presentation content was reviewed regularly to consider public feedback and new information. A long and short version of the project presentation was available to accommodate varying presentation timeframes. More information about the presentations and how they were used can be found in the *Business and Community Outreach and Speakers Bureau* sections.



The speakers bureau and facility tour program incorporated PowerPoint presentations to explain the science behind water purification.

Posters, Banners, and Mementos

Posters were created for display at the AWP Facility, presentations, and community events. The posters included images such as a schematic of the water distribution process, the multiple barrier treatment steps, and San Diego's imported water supply system. They provided a visual explanation of project components and referred interested parties to the project website and social media sites to continually build an online following. Banners featuring the project logo and website were also designed and produced to be used at community event exhibits.

Mementos were designed and distributed at community events and facility tours to serve an educational purpose.

Various mementos were distributed at community events and facility tours to serve an educational purpose. Useful and practical mementos featuring the project logo and website address were chosen based on the corresponding outreach activity. They appeal to a wide variety of audiences and remind them of how to get additional project information. Some mementos displayed the multiple barrier process in order to reinforce the science behind the technology.

White Papers

For those seeking in-depth information about the project, two white papers were created and posted online:

- The *City of San Diego Water Purification Demonstration Project, Advanced Water Purification*, which describes the multiple barrier processes and water quality testing in greater detail and addresses strategies that have been developed to manage potential risks from CECs
- *Potable Reuse Projects in the United States*, which includes details about other projects that use water purification processes and a timeline of their construction

Water Bill Inserts

A bilingual insert that announced the opening of the AWP Facility and tour opportunities was included in water bills and circulated for three months in 2011 and 2012. Water bills are delivered to approximately 275,000 ratepayers bimonthly. Based on findings gleaned from tour registration data, many AWP Facility tour participants found out about the tour program from the inserts.

A bilingual insert announcing the opening of the AWP Facility and tour opportunities was included in water bills.

Tour Guide Binder

As part of the tour program, a tour guide binder was developed to contain information relevant for those guiding tours of the AWP Facility. The binder included an in-depth tour script, key project information, and answers to frequently asked questions heard on previous tours. More information about the AWP Facility tours is included in the portion of this section titled *Business and Community Outreach*.

AWP Facility Brochure

To promote the project's tour program, a brochure was designed that highlights the AWP Facility. The brochure includes a brief project overview, a schematic and photos of the facility, an explanation of each of the three treatment barriers involved in the purification process, and information on how to register for a tour and follow the project online. The brochure, geared toward a general audience by using layperson's language, was intended for distribution as a take away at AWP Facility tours, community events, and presentations. It is also available on the project website.

Media Kit

A media kit was developed for distribution to local and national media representatives. The kit included the project fact sheet and FAQ, key information points, local and national news articles, the AWP Facility brochure, information about the Orange County GWRS, the white paper about related projects, a photo CD, and other relevant materials. The kit can be easily updated as needed. Project materials were provided for inclusion in media kits prepared for news conferences on related Public Utilities Department topics.

Tabletop Display Units

Two identical tabletop display units were created, one for display at the AWP Facility and the other to be used at community events. The collapsible and transportable units had Velcro panels, which allowed the display unit to be easily updated and changed as needed. The display units featured images and information about San Diego's water supply challenges, the components of the Demonstration Project, the purification process, and highlights of project media coverage locally and nationally.

The project tabletop display unit

Children's Activity Page

To incorporate children in the educational process, a worksheet was developed that introduced the concepts of water purification while engaging them in fun activities such as a maze, word search, and crossword puzzle. A solutions page was also developed for teachers and parents to check the children's work and to provide them with the correct answers. The activity page was distributed to children at tours and events.

AWP Facility Virtual Tour Video

A video was created that provides a virtual tour of the AWP Facility and the water purification process to ensure the AWP Facility tours were accessible to all San Diegans, including those who may not be able to physically tour the facility. The video includes footage of the equipment and explanations of the multiple barrier treatment process. The virtual tour is featured on the project website, YouTube page, and on DVD. DVDs were distributed to City public libraries for use in educational programs as well as to City Council offices, other elected officials, and other interested parties. The video has been viewed more than 880 times on YouTube.

Community Outreach and Tours

In order to reach a large and diverse segment of San Diego community members, various methods were used to connect with San Diegans. Through community outreach activities, these connections were used to share project information with a wide variety of audiences, such as grade school students, individuals from every community in San Diego, water industry professionals, and elected

officials. The Demonstration Project established a presence throughout San Diego by hosting informational booths at community events, , welcoming guests to tour its AWP Facility, regular updates to decision makers and additional community outreach efforts.

Demonstration Project booth at the Sally Ride Science Festival

City Boards and Commissions

San Diego City Council requested that decision makers be kept informed about the status of the Demonstration Project. Therefore, the project director regularly presented to NR&C and IROC. Updates about the Demonstration Project components were provided at 19 NR&C meetings and five IROC meetings, including presentations to the IROC Environmental and Technical Subcommittee and the IROC Outreach and Communications Subcommittee.

Community Events

Hosting informational booths at community events was an important way to communicate directly with audiences from all over the City, including those who might not have been inclined to seek out water information. The Demonstration Project was featured at 42 community events in all San Diego council districts. These events varied from science expositions to festivals. At the informational booth, educational materials were distributed, project details were discussed, and contact information from booth visitors was collected to continually build a database of interested parties for future outreach. Members of the multicultural team staffed ethnic events to provide project information in a culturally appropriate manner to all San Diego residents.

Urban Water Cycle Tour Program

One of the Demonstration Project's most valuable outreach tools for explaining the science behind water purification technology was the Urban Water Cycle tour program. In the natural water cycle, water evaporates, forming clouds and then returning to earth as precipitation. The "urban water cycle" recognizes that used water from homes and businesses is treated at wastewater treatment plants and discharged to a water body from which it will evaporate. However, the natural process of evaporation and precipitation can be accelerated, as is done by the AWP Facility. Tours were given of water treatment, wastewater treatment, and water purification facilities to provide stakeholders with an up-close experience of the treatment process along with a better understanding of the "urban water cycle."

Tour pathway sign

Prior to the opening of the AWP Facility, stakeholders visited the Alvarado Water Treatment Plant and Point Loma Wastewater Treatment Plant to learn more about what treatment processes are used

at each facility and the need each facility fills. Since its opening in June 2011, the AWP Facility remained the focus of the Urban Water Cycle tour program and was one of the primary outreach activities that provided project information. The tour provided San Diegans with a tangible experience of the Demonstration Project, increased the visibility of advanced water purification technology, corrected inaccurate perceptions about water purification processes, and solidified relationships with stakeholders.

AWP Facility Tour Publicity

The AWP Facility tours were publicized through email invitations, community event informational booths, newsletter articles, media coverage, email updates, social media posts, speakers bureau presentations, newspaper and online advertisements, and water bill insert announcements.

AWP Facility Tour Graphics

A variety of graphic materials were prepared to create an attractive and educational tour experience. The graphic approach reinforced the idea of the water cycle and used words and images that "connect" the viewer to the subject of water. A palette of colors was selected for the graphics to be representative of water. The backgrounds included graphics of waves and bubbles that implied technology and water purification in a simplified way. Icons were used to enhance and illustrate the AWP Facility process, such as H2O molecule decals.

Schoolchildren try to identify the purified water sample.

One of the main graphic elements used in the tour experience was a PowerPoint presentation featuring an animated video of the water purification process. Posters highlighting existing water purification projects, a San Diego County map for guests to identify where they live, banners displaying the urban water cycle, water-related maps, signposts featuring water-related quotations, signs explaining each step of the multiple barrier process, and a "photo-op" backdrop featuring San Vicente Reservoir were located throughout the facility to provide information and keep guests engaged during the entire tour. A blue pathway guided guests through the AWP Facility. Decals were placed along the pathway to illustrate the purification process. The decals early in the pathway showed water contaminated with a number of microorganisms. As the decals neared the end of the pathway following the three purification steps, they were clear and free of contaminants. All of these materials supplemented the messages expressed verbally by the guides throughout the tour.

AWP Facility Tour Logistics

The tour experience consisted of three main parts: an introduction, a facility tour and a closing. Each tour began with a presentation about the City's water supply situation and explanation of the various project components and treatment processes involved, followed by a tour of the facility with explanations of how the many pieces of equipment work together to create the multiple barrier process. At the conclusion, guests compared samples of recycled water, drinking water, and purified water produced at the facility.

AWP Facility Tour Attendees

Guests registered for the tours through an online registration system. Registrants provided contact information, including email addresses, and how they learned about the tour. Not only was the information collected useful for contacting guests prior to the tour, but it served a secondary purpose in expanding the project contact list. The email addresses collected were added to an interested parties email database for future communications.

Tours were offered weekly with a Saturday and/or an evening tour offered at least once a month. Organizations also had opportunities to host meetings on site and take a tour of the facility. Since the facility opened, more than 3,200 guests have attended 243 tours. Tour attendees included many local elected officials and decision makers, such as San Diego Mayor Jerry Sanders, San Diego City Councilmembers, mayors of Del Mar and Solana Beach, councilmembers from Oceanside and Solana Beach, Assemblymembers Atkins and Fletcher, Congressman Filner, and staff from the offices of Senator Boxer, Representative Issa, State Senator Anderson, Assemblymembers Block and Jones, the EPA, the Bureau of Reclamation, Department of the Interior, Office of Management and Budget, and the Senate Appropriations Subcommittee for Energy & Water Development[7]. The Demonstration Project attracted City residents as well as international guests from Armenia, Australia, Azerbaijan, Brazil, China, Georgia, India, Iraq, Kyrgyz Republic, Mexico, Moldova, Spain, Tajikistan, Ukraine, the United Kingdom, and Vietnam.

San Diego Mayor Jerry Sanders toured the AWP Facility with his staff.

Members of the 416th Civil Affairs Battalion (Airborne) following their AWP Facility tour

In order to further engage visitors following the tour, attendees received an email thank you note with a link to the project's Facebook page where guests could view the tour photographs. Tour participants were added to the database of interested parties to ensure they received periodic updates about the project.

Tour Feedback

Following tours of the AWP Facility, guests completed surveys to evaluate their tour experience and understanding of water purification. This tool is used to gauge the success of the information provided and identify areas of needed improvement for the tour. Based on the findings, nearly all of

[7] Titles listed represent the office held at the time of tour. Some of these elected officials may no longer hold the office listed.

the respondents found the tour to be "very informative" (81.4 percent) or "informative" (18.2 percent), and more than 98 percent of respondents said the overall tour was "excellent" (74.6 percent) or "good" (23.7 percent).

The feedback has resulted in the tour program being adapted to meet visitors' needs and to incorporate suggested improvements. For example, respondents who toured early in the program often reported poor audio quality on the tour. After acquiring a better sound system, the audio quality comments dropped significantly. In addition, guests commented on the lack of accessibility for participants with limited mobility. Based on this feedback, a virtual tour video was created that could be viewed in the tour conference room or from a personal computer. Other feedback led to the development of more child-friendly materials, inclusion of additional props, and fine-tuning of other aspects of the tour.

Youth Outreach

Another facet of the outreach program is the cooperative work done with students throughout San Diego, most notably those at the Elementary Institute of Science. The Elementary Institute of Science Commission on Science that Matters is an innovative program that involves students from San Diego high schools in the study of a topic that will result in greater community sustainability. For the 2011/2012 school year, Elementary Institute of Science students created a video about the water purification process to make the project's technical aspects more understandable and appealing for children. Elementary Institute of Science posted the video on their YouTube page (youtube.com/eiscostm06), and the Demonstration Project social media pages linked to the video. The students presented the video and what they learned about the purification process to NR&C in May 2012.

Following their presentation to NR&C, EIS students pose with Project Director Marsi Steirer.

Outreach to young audiences was incorporated in many aspects of the outreach program. Elementary and high school classes, Boy Scout dens, Girl Scout troops, and home-schooled children toured the AWP Facility. Many higher education groups also toured the facility, including water treatment, engineering, law school, and medical school classes. In addition to the tours, the speakers bureau made presentations about the Demonstration Project to elementary and high school classes. Technical information was geared to a younger audience at youth-oriented events such as the Sally Ride Science Festival, the Girl Scouts World of Water Workshop, the San Diego Science & Engineering Expo, and the Greater San Diego Science & Engineering Fair.

Multicultural Organizations

With the help of multicultural experts, all aspects of project outreach were considered through a multicultural lens. Considerations included conducting one-on-one interviews with community

leaders from ethnic or faith-based organizations, producing multilingual materials, distributing news releases and template articles to ethnic media, guiding tours of the AWP Facility for ethnic media representatives, participating in multicultural community events, providing Spanish and Portuguese translators for AWP Facility tours when necessary, and welcoming people of all backgrounds to tour the AWP Facility. This cross-dimensional approach to multicultural outreach ensured diverse audiences were taken into account for all outreach efforts.

Social Media, Conferences and Awards

To promote transparency and project visibility, the outreach program aimed to inform as many City residents as possible about the Demonstration Project. With this goal in mind, social media platforms, email distribution systems, and industry conferences were used to reach a wide variety of people.

Interested Parties

Interested parties who expressed a desire to learn more about the project, either when they visited the website or signed up at events or other outreach activities, were added to a database of email contacts. Other groups, such as stakeholders, media contacts, tour participants, and potential groups for speakers bureau presentations were also included in the database. Contacts were able to easily unsubscribe from email updates if they no longer were interested in the project. After continuously collecting contact information, the database eventually consisted of 3,890 email contacts. The contacts typically received project updates once a month, keeping them informed about the project without bombarding them with emails.

Social Media

Social media sites provided effective opportunities to reach new audiences and maintain contact with existing interested parties. An active social media presence was developed on Facebook, Twitter, and YouTube. The pages were updated and monitored on a daily basis, which included responding to public comments to keep followers engaged. A social media calendar was also developed and updated monthly such that interesting and relevant information could be posted frequently. Community members were encouraged to follow the social media pages at tours and events, on the website, and in newsletters, eUpdates, and other informational materials.

An active social media presence was developed on Facebook, Twitter, and YouTube.

Facebook (www.facebook.com/SanDiegoWPDP)

The latest project information, AWP Facility tour photos, and links to related articles and factoids were posted on the project's Facebook page, adding up to 379 wall posts. The page has received 123 page likes, 12 comments, and 93 likes on page items (e.g., photographs and wall posts).

Twitter (www.twitter.com/PureWaterSD)
Similar yet pithier posts and links were posted on Twitter compared to those posted to Facebook. On Twitter, dialogue about water issues and the Demonstration Project were more readily available, thanks to the social media site's structure. For example, a project mention by Council President Young on Twitter led to dialogue with a community member[8]. Eventually the community member attended the tour and later posted on Twitter about her positive tour experience and her support for the project. The Demonstration Project has 133 followers (i.e., subscribers) of its Twitter page. In addition to the project's own 537 tweets, posts were retweeted 54 times and the project's page was mentioned 75 times by others.

YouTube (www.youtube.com/PureWaterSD)
Project-related videos were posted on the YouTube page, including a virtual tour of the AWP Facility, an animated video explaining the water purification process, project testimonials, and a clip from *California's Gold* with the late Huell Howser that featured the Demonstration Project. The seven videos posted have received a total of 3,121 views. The YouTube page also linked to "favorite" videos posted by other YouTube channels including the video produced by Elementary Institute of Science students and a WateReuse Foundation video about the world's water supply titled *Downstream*.

Seven videos posted about the project on YouTube have received a total of 3,121 views.

Water Agency Collaboration

Although San Diego residents were the primary target audience for project outreach, all of the cities and agencies that receive or could potentially receive (such as in an emergency) drinking water from the San Vicente Reservoir have the potential to be affected by a reservoir augmentation project at San Vicente Reservoir. Water Authority member agencies were kept informed through presentations, meetings, and facility tours. They also received information suitable for sharing on their websites and in outreach materials. All Water Authority member agencies have received information through a presentation or tour.

In addition to providing project information, there was a collaborative effort between the Demonstration Project and the Water Authority. In early 2012, the Water Authority developed a brief video that explained the region's water needs and how full-scale reservoir augmentation could produce a reliable, local drinking water supply. An additional element of this collaboration was a cross-promotion where information was shared about the AWP Facility tours and the Water Authority's San Vicente Reservoir tours at the other's tour program.

[8] Title listed represents the office held at that time.

Trade Shows and Conferences

Since full-scale reservoir augmentation at San Vicente Reservoir would be the first project of its kind in California, the Demonstration Project drew interest from water industry professionals from across the state and the nation. There were 33 presentations made about the technical and outreach aspects of the project at local, national, and international water industry conferences. These presentations increased project visibility and encouraged connections with and learning from experiences of other water industry professionals.

Awards

The Demonstration Project has received recognition for its outreach efforts. In September 2011, the WateReuse Association honored the Demonstration Project as the Public Education Program of the Year for its outreach efforts since inception. The following year in September 2012, the WateReuse Association recognized the Demonstration Project once again, this time as the 2012 Small Project of the Year.

The Demonstration Project has received two awards from the WateReuse Association.

Media Outreach

Effective media outreach required that media representatives receive accurate and timely project information. Information was provided to reporters and editors of local, regional, and national publications, as well as multicultural print publications, online publications, and television and radio outlets at all project milestones. The project has been covered by many media outlets including the *San Diego Union-Tribune, North County Times, Los Angeles Times, USA Today, New York Times, National Public Radio*, and *National Geographic*.

Contact Lists

A comprehensive list of local and national media contacts was developed and information was provided at project milestones and to generate interest in the AWP Facility tour program. News releases and template articles were distributed to various publications: daily newspapers, online media, community newsletters, and trade publications. Members of the multicultural team provided contact information for local, ethnic media representatives and encouraged them to tour the AWP Facility. Stakeholders that have their own publications and newsletters were included in the list.

Media Outreach Activities

There were many components of the media outreach activities. Prior to the opening of the AWP Facility, science reporters were informed about the technical details of the project. This effort resulted in several publications writing about the multiple barrier process before the AWP Facility was operational.

Media representatives were invited to tour the AWP Facility once it became operational. On June 30, 2011, San Diego Mayor Jerry Sanders, Councilmember David Alvarez, Public Utilities Director Roger Bailey, and Demonstration Project Director Marsi Steirer announced the opening of the

one-mgd AWP Facility at a news conference covered by reporters and camera crews from local television news stations and several daily print or online publications.[9]

Template articles were prepared to provide project information through community newspapers, stakeholder publications, and local websites and extend the reach throughout the City. The articles were customized as needed for a variety of outlets and updated articles were prepared as the project progressed. A well-publicized template article from early 2012 promoted the AWP Facility tour program, increasing participation in the tours while raising awareness about the project.

A news release highlighting a group's visit to the facility was submitted for consideration in the group's newsletter or appropriate publication. Tours were covered in several organizational newsletters and campus publications, such as Francis Parker School's online news and SOS Toastmasters' monthly newsletter, which may have otherwise not included a story on the Demonstration Project.

Advertisements

Advertisements announcing the AWP Facility opening and the availability of tours were placed in seven local, ethnic publications (*El Latino, Filipino Press, La Prensa, San Diego Monitor, Voice & Viewpoint, We Chinese in America* [weekend edition], and *Giving Back Magazine*) immediately following the facility opening in summer 2011.

Advertisements in local ethnic publications were used to reach out to multicultural

Depending on the publication, the advertisements ranged from one-eighth to one-quarter of a page in size. Spanish text was used for the advertisements placed in Spanish language publications. These advertisements were an important part of reaching out to multicultural audiences.

Additionally, the tour program was advertised in Voice *of San Diego* (VOSD) in June/July 2012 as part of an advertising package. Since the advertisement placement coincided with the release of the newest Spiderman movie and Comic-Con 2012, a three-frame animated advertisement that featured a Demonstration Project informational booth visitor dressed as Spiderman was placed on the *Voice of San Diego* website. The advertisement included phrases about the tour program that played on Spiderman terminology. Additionally, a static advertisement about the tour program appeared eight times

An animated advertisement featuring a Demonstration Project informational booth visitor dressed as Spiderman was placed on the Voice of San Diego website.

[9] Titles listed represent the office held at the time of the news conference.

in the VOSD Best of the Week and Member Report weekly email blasts. Lastly, a quarter-page tour program advertisement ran in the VOSD monthly magazine.

Media Coverage

As one of the first cities in California to pursue full-scale reservoir augmentation, San Diego has been front and center in media coverage for recycled water projects in the U.S. and around the world. The project was featured in local and national newspapers, online and trade publications, and local radio and television stations. The project and the tour program were also featured in community publications. Many affiliated websites provided links to the project website, informational materials or videos. Using established multicultural media contacts, project coverage was generated in African-American, Latino and Asian publications.

In October 2010, the *Union-Tribune* published an article describing water purification and included graphic diagram of the multiple barrier process. This emphasis on the science of water purification reflected what the Demonstration Project was all about. In January 2011, the *Union-Tribune* recalled its previous criticism of water purification as "toilet to tap" with an editorial piece titled "The Yuck Factor: Get Over It". On a national level, the *New York Times* followed suit with an article in February 2012 titled "As 'Yuck Factor' Subsides, Treated Wastewater Flows From Taps." From 2010 to 2012, information has been provided for many articles such as these that have recognized and contributed to the growing understanding of the scientific efficacy of water purification technology and San Diego's need for a local, reliable source of water. Overall, the project received media coverage from more than 100 publications and news outlets locally and nationally.

The New York Times

© 2012 The New York Times FRIDAY, FEBRUARY 10, 2012

As 'Yuck Factor' Subsides, Treated Wastewater Flows From Taps

By FELICITY BARRINGER

SAN DIEGO — Almost hidden in the northern hills, the pilot water treatment plant here does not seem a harbinger of revolution. It cost $13 million, uses long-established technologies and produces a million gallons a day.

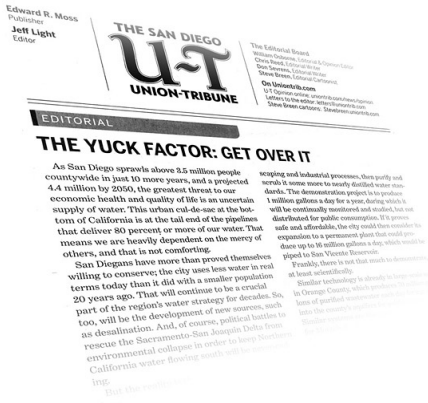
But the plant's very existence is a triumph over one of the most stubborn problems facing the nation's water managers: if they make clean drinking water from wastewater, will the yuck factor keep people from accepting it?

With climate change threatening to diminish water supplies in the fast-growing Southwest, more cities are considering the potential of reclaimed water. A new report from the National Academy of Sciences said that if coastal communities used advanced treatment procedures on the effluent that is now sent out to sea, it could increase the amount of municipal water available by as much as 27 percent.

San Diego's success, 12 years after its City Council recoiled from the toilet-to-tap concept, offers a blueprint for other districts considering wastewater reuse.

For most of the four decades beginning in 1970, the arid West was the fastest-growing region in the country; the population of Nevada quintupled in that period while Arizona's nearly quadrupled. Continued population growth, unmatched by growth in water storage capacity, makes this a "new era in water management in the United States," the science group's report said.

"The pressures on water supplies are changing virtually every aspect of municipal, industrial, and agricultural water practice,


Edward R. Moss
Publisher
Jeff Light
Editor

THE SAN DIEGO UT UNION-TRIBUNE

The Editorial Board

EDITORIAL

THE YUCK FACTOR: GET OVER IT

As San Diego sprawls above 3.5 million people countywide in just 10 more years, and a projected 4.4 million by 2050, the greatest threat to our economic health and quality of life is an uncertain supply of water. This urban cul-de-sac at the bottom of California is at the tail end of the pipelines that deliver 80 percent or more of our water. That means we are heavily dependent on the mercy of others, and that is not comforting.

San Diegans have more than proved themselves willing to conserve; the city uses less water in real terms today than it did with a smaller population 20 years ago. That will continue to be a crucial part of the region's water strategy for decades. So, too, will be the development of new sources, such as desalination. And, of course, political battles to rescue the Sacramento-San Joaquin Delta from environmental collapse in order to keep Southern California water flowing south will continue.

The project received media coverage from more than 100 publications and news outlets locally and nationally.

News coverage was continually monitored and compiled. Links to relevant news articles were posted on the project website and in eUpdates. A media tracking database noted project coverage by newspapers, radio, television, and blogs. Coverage of the Demonstration Project was generally accurate and discussed the technology to be employed to purify the recycled water.

The commitment to providing accurate, science-based information also resulted in more descriptive language being used by publications. Instead of sensational headlines relying on the inaccurate "toilet-to-tap" moniker, publications used more fact-based headlines. Some examples include *Union-Tribune* articles, such as "Water Recycling Key to U.S. Future" (Jan. 10, 2012), "Boosting Reservoirs

with Purified Wastewater?" (May 22, 2012), and "Recycled Water Getting Another Look" (May 23, 2012).

Speakers Bureau

An active speakers bureau gave 132 presentations about the Demonstration Project throughout San Diego and proved to be a vital component of the outreach program. These presentations shared project information with community members and provided an opportunity to receive public feedback about the project and the presentation itself so public questions and perception about water purification in San Diego could be more clearly understood.

In order to ensure an inclusive, broad reach throughout San Diego, an extensive database of community groups with potential interest in the project was created. The list began with groups that received presentations about the Water Reuse Study in 2005 and 2006. Each City Council district office was contacted for recommendations of groups to contact. Presentation scheduling began with the groups recommended by council members, those groups that had been previously involved, and community planning groups throughout the City. Contacts were researched for environmental groups, business associations, religious groups, civic organizations, and other special interest groups. They were then contacted to schedule a presentation. The speakers bureau program provided an opportunity to explain the project components and for community members to ask questions, voice concerns, and obtain accurate information about it.

An active speakers bureau gave 132 presentations about the Demonstration Project throughout San Diego.

The speakers bureau members were tasked with presenting information about the project in community group presentation settings. A PowerPoint presentation was developed to explain San Diego's water supply situation, the components of the Demonstration Project, and how water purification technology works in layperson's terms. The speakers bureau team participated in two workshops to become familiar with the presentation and practiced delivering it and responding to questions. Regular meetings with speakers bureau members were held to discuss feedback from presentations, develop updated presentation slides, and identify questions that should be added to the project FAQ.

The speakers bureau was regularly publicized through all aspects of the outreach program including at community events, at facility tours, on all distributed informational materials, and on the project's website. Contacts in the speakers bureau database were contacted and offered a presentation,

responses were provided to presentation inquiries, equipment and materials were prepared, and presenter feedback forms and group evaluations were collected. Any questions and concerns from the group were recorded in the database and follow-up was performed when necessary.

The speakers bureau successfully presented to groups citywide. The groups had various interests, and many group members followed up with a tour of the AWP Facility. Presentations were made to churches, classrooms, multicultural group meetings, water industry luncheons, community planning meetings, environmental symposia, and more. A broad range of groups proved to be interested in the discussion of San Diego's water supply and receptive to the options being explored by the City, particularly the Demonstration Project.

Stakeholder/Partner Communication

Sharing educational information about the project allowed relationships to be formed with stakeholders and a network of contacts to be developed. Once identified, stakeholders were contacted to participate in one-on-one stakeholder interviews, schedule group presentations, place project information in their relevant publications, and tour the AWP Facility. All of the stakeholders were added to the interested parties' database so they would receive regular email updates about the project.

American Assembly

As mentioned previously, in 2004 and 2005 a broad-based group of City residents participated in an American Assembly-style process to review the City's Water Reuse Study findings. The American Assembly members concluded that reservoir augmentation was the most viable use of highly treated recycled water for San Diego and that it could provide a local, reliable supply of water crucial to the City's future.

Because American Assembly participants played such an essential role in the eventual development of the Demonstration Project and were already invested in it, they were immediately identified as key stakeholders. Early in the project, members of the American Assembly were updated about the project status, informed about outreach opportunities, and encouraged to remain involved. In addition to being added to the email update contact list, the American Assembly participants were directly contacted in early 2012 to encourage them to tour the facility or register for a presentation if they had not done so already.

Water Reliability Coalition

Beginning in 2009, a unique union of diverse San Diego organizations came together to form the Water Reliability Coalition (WRC; formerly the IPR Coalition) in support of the Demonstration Project. This independent, broad-based coalition consisted of 23 environmental, technical, business, and ratepayer advocacy groups that promote the exploration of water purification in San Diego (see sidebar for list of organizations). The group was instrumental in maintaining momentum for the Demonstration Project by attending and providing testimony at City Council and other civic meetings. Additionally, they provided an independent voice about water purification and the need for a sustainable water supply for San Diego. In 2010, the San Diego Chapter of WateReuse California presented special recognition awards to each WRC organization in recognition of their support of water reuse, and in particular of water purification in San Diego.

As early supporters of the Demonstration Project, the WRC was updated about the project and invited to tour the AWP Facility. The Water Reliability Coalition's role was to provide their own opinion about the project as a non-governmental group. Additional information about the WRC can be found at www.sdwatersupply.com.

WRC
WATER RELIABILITY COALITION

Coalition Members:
- BIOCOM
- Building Industry Association of San Diego
- Building Owners and Managers Association, San Diego Chapter
- Citizens Coordinate for Century 3
- Coastal Environmental Rights Foundation
- Empower San Diego
- Endangered Habitats League
- Environmental Health Coalition
- Friends of Infrastructure
- Industrial Environmental Association
- National Association of Industrial and Office Properties, San Diego Chapter
- San Diego and Imperial Counties Labor Council
- San Diego Audubon Society
- San Diego Regional Economic Development Corporation
- San Diego Coastkeeper
- San Diego County Apartment Association
- San Diego County Taxpayers Association
- San Diego Regional Chamber of Commerce
- San Diego River Park Foundation
- Sierra Club, San Diego Chapter
- Surfrider Foundation, San Diego Chapter
- Sustainability Alliance of Southern California
- Utility Consumers' Action Network

Stakeholders

As mentioned previously, a number of community leaders were identified and interviewed in one-on-one meetings to gather their feedback on relevant water issues. A broad range of perspectives was sought from all sectors of the community since every industry, group, and individual is affected by the City's water supply. Stakeholder organizations were engaged, including construction, industrial, medical, education, business, and tourism sectors. To ensure the interests and concerns of all San Diego residents were captured, multicultural organizations and leaders in multicultural communities were sought to participate in the stakeholder interview process.

Following the interviews, the relationships with the community leaders and their organizations were reinforced in several ways: providing them with

information requested during the interview, sharing template articles for inclusion in their organizational outreach materials, encouraging them to host a speakers bureau presentation, and inviting them to tour the AWP Facility.

Information Lines and Emails

To promote two-way communication, project telephone information lines and an email address were set up to allow community leaders to contact project staff easily. Three information lines were set up for overall project questions, speakers bureau registration, and tour information, respectively. Also, an email address (PureWaterSD@sandiego.gov) was promoted as the point of contact for all project-related questions and concerns.

The project received, responded to, and tracked 182 email and telephone inquiries from members of the public who inquired about it and requested presentations and tours, in addition to members of the public who requested tours by email. Each email and telephone inquiry was tracked on a form that recorded contact information and the information requested. The outreach hotlines were useful for providing a central contact point for the public. The goal was to respond to telephone and email inquiries within one business day. If a question required a more technical response, technical staff assisted in developing an accurate response that addressed the contact's concerns.

Internal Department Communications

The City of San Diego Public Utilities Department's 1,414 staff members were an important audience for the Demonstration Project since they could be asked about it while working in the field, responding to customer service inquiries, attending or staffing community events, or talking with their own friends and family. Therefore, internal audiences were kept informed about the project and provided with as much information as possible.

Internal Meetings

Information about the project was presented to Public Utilities staff at internal division meetings. Since all of the division staff were invited to and typically attended these meetings, many internal staff could be reached at once. The presentations explained project details and answered questions for an audience with unique interests that varied from those of the general public.

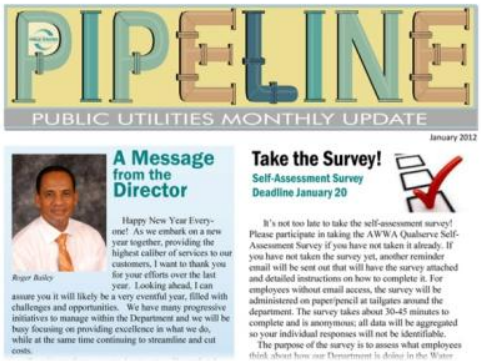
Project information was also shared at a series of three tailgate trainings, which are required classes for field personnel. Prior to the presentation, attendees were tested to determine their water purification knowledge. Following the presentation, the attendees were tested again to show what they learned through the presentations.

Intranet

The Public Utilities Department houses its own intranet site its staff. The site provides employee resources, department information, and related news. Information about AWP Facility tours and the virtual tour video are posted on the Intranet page. Also, the project's Pure News newsletters were posted on the intranet's page of Public Utilities Department newsletters.

Pipeline

Pipeline is the Public Utilities Department's internal monthly newsletter. It is emailed to Public Utilities staff, posted in break rooms, and available on the department's intranet page. Project updates, City staff tour invitations, and general information are submitted for inclusion in Pipeline, as necessary. Overall, information about the Demonstration Project was included in 14 issues of *Pipeline*.


PIPELINE

PUBLIC UTILITIES MONTHLY UPDATE

January 2012

A Message from the Director

Happy New Year Everyone! As we embark on a new year together, providing the highest caliber of services to our customers, I want to thank you for your efforts over the last year. Looking ahead, I can assure you it will likely be a very eventful year, filled with challenges and opportunities. We have many progressive initiatives to manage within the Department and we will be busy focusing on providing excellence in what we do, while at the same time continuing to streamline and cut costs.

Roger Bailey

Take the Survey!

Self-Assessment Survey Deadline January 20

It's not too late to take the self-assessment survey! Please participate in taking the AWWA Qualserve Self-Assessment Survey if you have not taken it already. If you have not taken the survey yet, another reminder email will be sent out that will have the survey attached and detailed instructions on how to complete it. For employees without email access, the survey will be administered on paper/pencil at tailgates around the department. The survey takes about 30-45 minutes to complete and is anonymous; all data will be aggregated so your individual responses will not be identifiable.

The purpose of the survey is to assess what employees think about how our Department is doing in the Water

Information about the Demonstration Project was included in 14 issues of Pipeline, the Public Utilities Department's internal monthly newsletter.

City Staff Tours

To address the unique interests and concerns of Public Utilities Department staff, 16 AWP Facility tours were provided for City staff only. These tours were publicized through internal emails, Pipeline, and on the intranet. Public Utilities supervisors and supervisors in other City departments, such as Storm Water, requested additional tours to accommodate their staff members. These tours proved valuable in educating a large number of City staff about the project and providing in-depth information to them.

Public Utilities Department staff tour the AWP Facility.

Public Outreach and Education Findings

Key findings of the public outreach and education program are as follows:

- Feedback from individuals who have toured the AWP Facility shows that providing an opportunity to tour the facility increases understanding about water purification processes.
- Research shows a steady increase from 2004 (26 percent) to 2011 (68 percent) to 2012 (73 percent) in City residents who favor using advanced treated recycled water as an addition to the City's drinking water supply.

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Section F: Full-Scale Project Considerations

Full-Scale Reservoir Augmentation Considerations

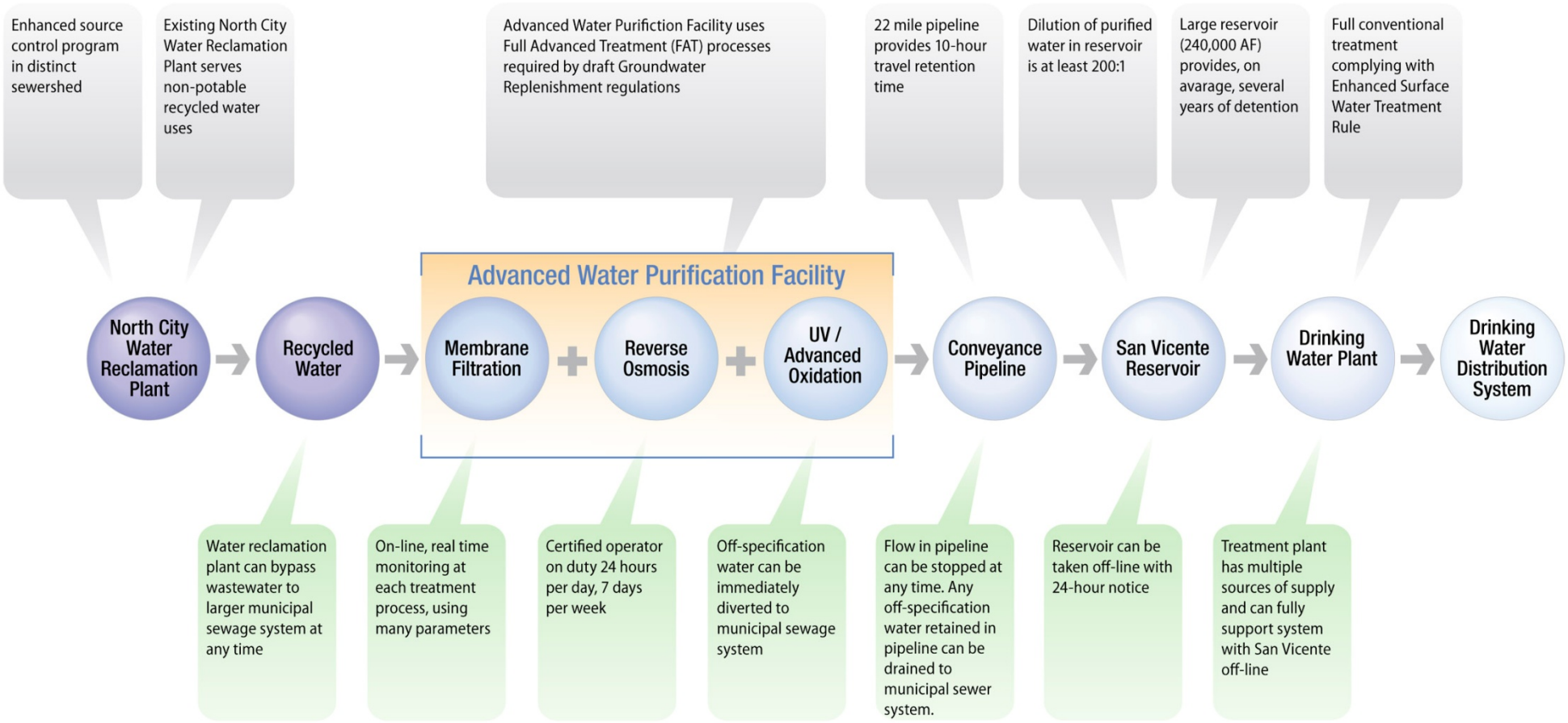
- Full-Scale Components of a Multiple Barrier Strategy
- Source Control Enhancement
- North City Water Reclamation Plant
- Advanced Water Purification Facility
- Pipeline System
- AWP Facility and Pipeline System Cost Estimates

The City must fully understand all potential implications of a reservoir augmentation project at San Vicente Reservoir prior to deciding whether or not to implement such a project. The Demonstration Project included an assessment of the full-scale project components that would be required, and an evaluation of potential operational requirements and other considerations associated with each component. The results of that assessment are summarized in this section.

Full-Scale Components of a Multiple Barrier Strategy

A reservoir augmentation project at San Vicente Reservoir would require a series of water purification components, focused on achieving a multiple barrier strategy, as required for regulatory approval. A multiple barrier strategy protects public health by incorporating safeguards to ensure that a failure or error at any given treatment step would not compromise public health. The components of a multiple barrier strategy that would be implemented for reservoir augmentation at San Vicente Reservoir are illustrated in Figure F-1 and described in further detail below. Please note that, although a full-scale project's multiple barrier strategy includes San Vicente Reservoir and a municipal drinking water treatment plant such as the Alvarado Water Treatment Plant, these facilities would not require modification. As such, those steps of the multiple barrier strategy are not addressed in this section.

Figure F - 1: Components of a Multiple Barrier Reservoir Augmentation Project at San Vicente Reservoir



Source Control Enhancement

The first step in the multiple barrier strategy for reservoir augmentation at San Vicente Reservoir would be source control, which refers to the prevention of contaminants from entering the wastewater stream. All wastewater systems have source control programs. The City's source control program, referred to as IWCP, was implemented in 1982 to regulate industrial discharges into the San Diego Metropolitan Sewage System (Metro System). The program was required as part of the NPDES permitting process for Point Loma, and the South Bay Water Reclamation Plant (SBWRP). The IWCP applies and enforces federal pretreatment regulations set forth by the EPA, and it satisfies the following objectives:

- To protect and improve receiving water quality;
- To prevent the discharge of toxic and potentially harmful pollutants in concentrations which would interfere with treatment plant operations or pass through the plant to the receiving waters;
- To protect system personnel and plant facilities by limiting discharges of potentially hazardous, harmful, or incompatible pollutants;
- To prevent contamination of treatment plant sludge in order to maximize beneficial reuse options for biosolids;
- To protect the quality of recycled water.

The City participates in the "No Drugs Down the Drain" program, which alerts California residents about problems associated with flushing medications down the drain. This program is an example of the City's existing source control efforts.

The City's IWCP is designed to support the existing discharge to the ocean via Point Loma, and goes beyond typical source control programs by implementing an EPA- and Regional Board-approved Urban Area Pretreatment Program (UAPP). The City has taken the following steps in implementing the UAPP that extend beyond typical source control programs:

- Developed local limits that comply with UAPP provisions of the Ocean Pollution Reduction Act; local limits are re-evaluated annually.
- Implemented Industrial Management Practices to minimize the discharge of toxic pollutants, such as Batch Discharge approvals, and solvent management plan requirements at all laboratories, including research and development, medical, and analytical laboratories.
- Include prohibitions on the discharge of pharmaceutically-active ingredients, including unused pharmaceuticals, expired pharmaceuticals, rejected batches or lots, and

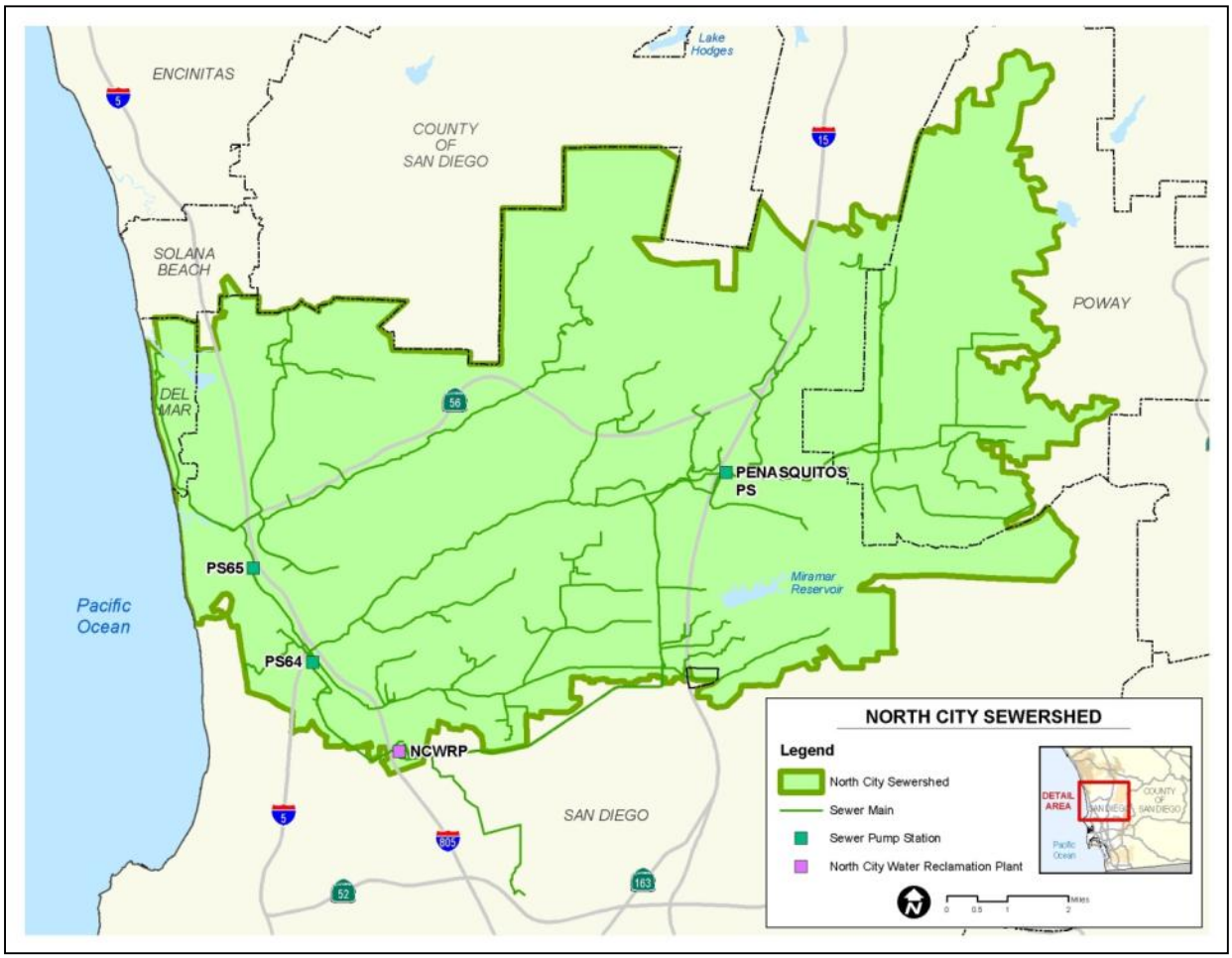
pharmaceuticals received in take-back programs in new and renewal permits for medical and biotech facilities tributary to North City.

- Require facilities that generate biohazardous waste to comply with the July 2005 California Medical Waste Management Act and revisions and amendments thereto, set forth in the California Health and Safety Code, Sections 117600 – 118360. Facilities must certify every six months as to compliance with the pharmaceutical discharge prohibition and biohazardous waste management requirements. The Program has procedures in place to evaluate the need for additional controls, and to develop and enforce new local limits and facility or sector-specific Industrial Management Practices as needed to ensure and maintain required effluent quality.

For projects where purified water would enter the drinking water system via groundwater or surface water augmentation, CDPH requires that source control programs be augmented to address residential and commercial discharges and consider an expanded set of contaminants that may have public health relevance, such as industrial chemicals, pharmaceuticals, and personal care product residuals sometimes found in wastewater.

Because the source of purified water for potential reservoir augmentation at San Vicente Reservoir is North City, that facility's service area would be the focus of an enhanced source control program. Figure F-2 depicts the North City service area.

Figure F - 2: North City Service Area



In order to identify potential supplements to the City's IWCP to address possible regulatory requirements associated with a potential reservoir augmentation project, the City reviewed the existing source control program being implemented by OCSD. OCSD's Source Control Program was enhanced to support the currently operational Orange County GWRS, which employs water purification processes similar to those that would be implemented for reservoir augmentation at San Vicente Reservoir. Comparison with OCSD's program illustrated that the City's existing program is robust and goes beyond applicable regulatory requirements for ocean discharges. However, based on that review and the heightened vigilance required to protect drinking water systems, it was concluded that the following components should be considered, should the City pursue reservoir augmentation at San Vicente Reservoir.

- **Chemical Inventory Program and GIS Tracking.** The City may need to implement an expanded industrial and commercial discharger chemical inventory database, which is linked to discharger locations that are tracked using GIS.
- **Pollutant Prioritization Program.** The City may be expected to develop a program to prioritize pollutants through sampling and characterization of CECs at the full-scale AWP

facility and determine if pollutants can be controlled through targeted source control for individual dischargers or commercial sectors.

- **Local Limits Evaluation.** To support a full-scale reservoir augmentation project at San Vicente Reservoir, a local limits evaluation may need to be performed for the North City service area, taking into consideration compliance criteria established by regulatory agencies. Local limits are wastewater limitations that apply to commercial and industrial facilities that discharge to a common treatment plant. They are developed to meet the source control program objectives and site-specific needs of the local treatment plant and its receiving waters. The evaluation would consider including additional pollutants of concern (POCs) on North City's list of local limits, and potentially lowering the limit of pollutants already on the list. An annual re-evaluation of the limits may be necessary to ensure compliance with new and evolving regulations for purified water. This evaluation could be done in conjunction with the annual local limits evaluation for Point Loma.

North City Water Reclamation Plant

North City would be a key component of a reservoir augmentation project at San Vicente Reservoir, providing conventional wastewater and tertiary water treatment technologies to water feeding the AWP facility. North City has been operating since 1997, and has a current design capacity of 30 mgd based on an annual average daily inflow rate; however, North City was master-planned for expansion to 45 mgd (City of San Diego 2012b). The IAP noted that North City already has complex reliability features, including conservative operating criteria and flow equalization, to support a reservoir augmentation project at San Vicente Reservoir.

North City is an existing facility that would serve as a key component of a full-scale reservoir augmentation project by providing recycled water to a full-scale AWP Facility.

No physical modification would be necessary for North City as part of a reservoir augmentation project at San Vicente Reservoir, although some operational adjustments could be made, including use of different chemicals and adjustment of certain operating procedures to complement the operation and performance of the full-scale AWP facility.

Full-Scale Advanced Water Purification Facility

As explained in Section B, Advanced Water Purification Facility, the City operated the AWP Facility for one year, producing one mgd of purified water using the same process components that would be used in a full-scale AWP facility. Operating the AWP Facility enabled the City to identify recommendations for design of a full-scale AWP facility (CDM Smith and MWH, 2013a). The full-

scale components and design considerations identified as part of the Demonstration Project are summarized below.

Facility Components

The full-scale AWP facility would include the same general process components as the AWP Facility, as well as additional components necessary to address water quality and testing results from the AWP Facility. Table F-1 identifies the necessary full-scale AWP facility components and identifies which components were demonstrated at the one-mgd AWP Facility.

Production Capacity

An analysis was conducted to define an initial capacity for the full-scale AWP facility. That analysis evaluated the overall capacity of North City and recycled water availability considering existing irrigation and industrial users. Due to the seasonal variation in demand from existing recycled water users (more irrigation demand occurs in the summer months), more purified water would be available to augment San Vicente Reservoir during winter months. The initial full-scale AWP facility production capacity was determined to be 18 mgd. Average production (15 mgd) is expected to be slightly lower than maximum treatment capacity (18 mgd) because production will vary throughout the year due to seasonal fluctuations in recycled water demand and routine maintenance requirements. During periods of low recycled water demand, production would reach full production capacity, while in months of peak recycled water demand, it will be less than capacity, averaging approximately 15 mgd on a year-round basis.

Based on the full-scale capacity analysis, preliminary design criteria were developed for an 18-mgd capacity facility. The capital cost estimates presented later in this section are based on an 18-mgd maximum treatment capacity, because the infrastructure needs to be sized to be capable of delivering the maximum production of 18 mgd. The operations and maintenance (O&M) cost estimates are based on an annual average production of 15 mgd, because this is the average expected production for which annual, ongoing expenses will be incurred.

This production capacity analysis is summarized in the Full-Scale Reservoir Augmentation Capacity Analysis Technical Memorandum (RMC, 2011). The City updated this technical memorandum in January 2013.

Site Location and Layout

The full-scale AWP facility would be located on 10.3 acres of vacant City-owned property immediately north of North City. The site layout for the full-scale AWP facility was developed to locate the administrative building on the south side of the facility for visitor access. Process areas not enclosed in a building would be installed under canopies. A pipe gallery/access tunnel would be provided under Eastgate Mall Road, connecting North City to the full-scale AWP facility just west of the guard shack. Figure F-3 presents the preliminary site layout and location for the full-scale AWP facility.

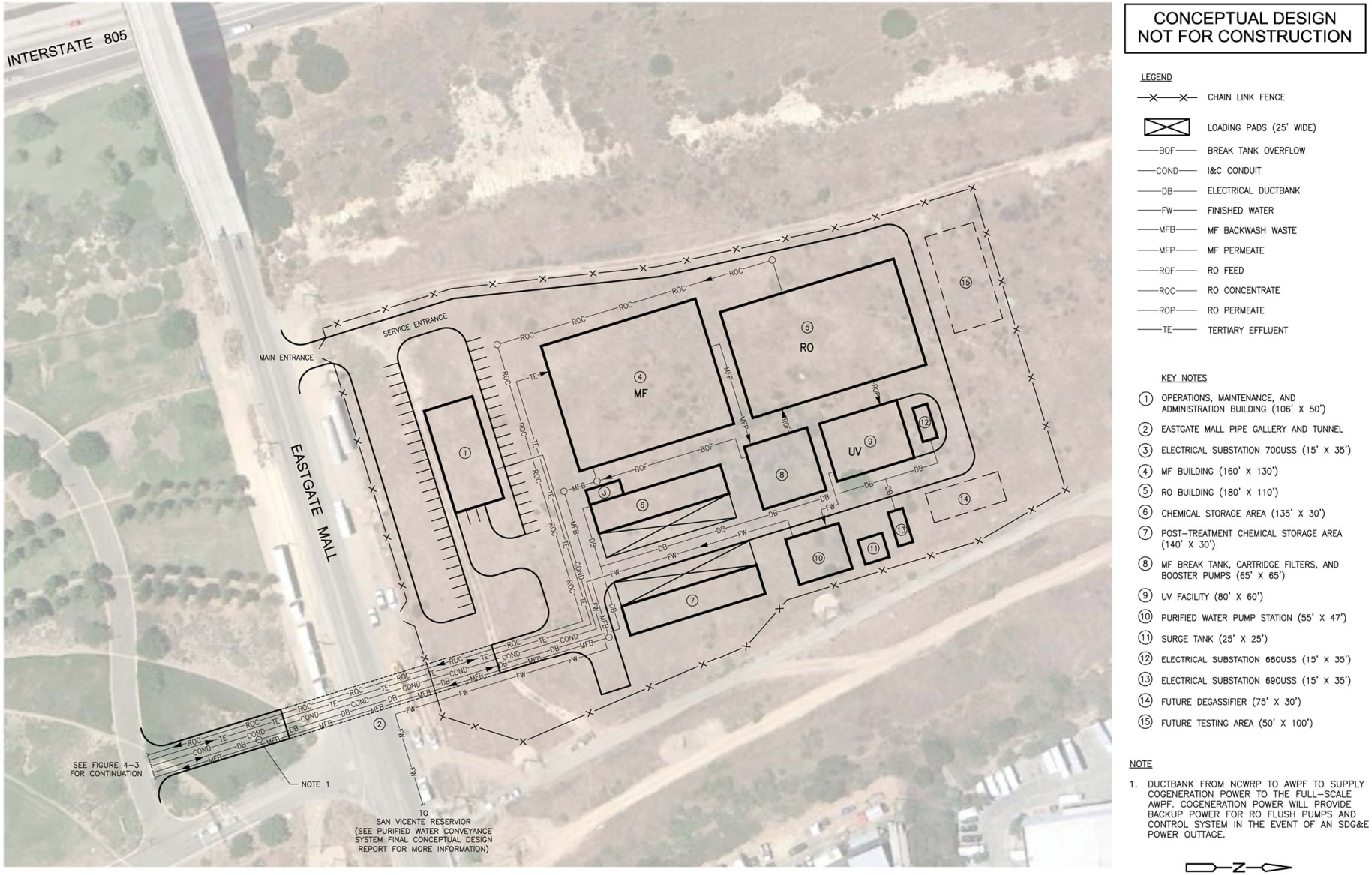
Table F - 1: Full-Scale AWP Facility Components

Full-Scale AWP Facility Component	Demonstrated at 1- mgd AWP Facility?	Purpose
Pump station to send North City water to the full-scale AWP facility	No	A new pump station would need to be constructed to pump water from North City to the full-scale AWP facility site.
Pre-treatment chemical addition	Yes	Pre-treatment would continue to be applied for the full-scale system to reduce contaminants that may harm the AWP Facility equipment.
Membrane filtration (either microfiltration or ultrafiltration)	Yes	Membrane filtration would continue to be the first stage in the water purification process for the full-scale AWP facility.
Membrane filtration break tank	Yes	A membrane filtration "break tank" would continue to be used to hold water before it is sent to the reverse osmosis system. This will help to stabilize flows.
Reverse osmosis booster pumps	Yes	"Booster pumps," pump stations used to move water from the membrane filtration to the reverse osmosis process, would continue to be used.
Reverse osmosis pre-treatment chemical addition	Yes	Pre-treatment before the reverse osmosis stage would continue to be applied to reduce contaminants that may harm the reverse osmosis membranes.
Cartridge filters	No	Cartridge filters would be added to help protect the reverse osmosis membranes.
Reverse osmosis feed pumps	Yes	"Feed pumps," send water into the reverse osmosis system would continue to be used to directly control the pressure of water entering the reverse osmosis system.
Reverse osmosis system	Yes	A reverse osmosis system would continue to be the secondary and main stage in the water purification process for the full-scale AWP facility.
UV disinfection/advanced oxidation using UV light with hydrogen peroxide	Yes	An UV disinfection/advanced oxidation system would continue to be the third and final stage in the water purification process for the full-scale AWP facility.
Post-treatment/ stabilization chemical addition	No	Post-treatment would be added for the full-scale AWP facility system. This step will include adding treatment chemicals to stabilize the purified water and ensure that it does not have corrosive properties that could potentially damage the conveyance pipeline to San Vicente Reservoir.
Purified water pump station	No	A purified water pump station would be added to transport purified water from the full-scale AWP facility to San Vicente Reservoir.
Operations Center	No	An operations center building would be added to conduct necessary operations and testing procedures for the full-scale AWP facility.

Footnotes:

1. Yes indicates the component was demonstrated by the AWP Facility. No indicates that, while not demonstrated by the AWP Facility, the component would be necessary for a full-scale facility.

Figure F - 3: Preliminary Layout and Location for the Full-Scale AWP Facility



System Controls, Reliability, and Redundancy

North City treats wastewater flows that would otherwise be treated at Point Loma. Flows to North City can be diverted to Point Loma, allowing North City to be shut down or taken "offline" any time. Point Loma can therefore serve as a back-up system, where flows can be sent from the North City service area when needed. The full-scale AWP facility would be able to be taken offline by halting delivery of recycled water from North City. Although the full-scale AWP facility would have the ability to be shut down at any time, facility design would need to include standard redundancy features that would allow the full-scale AWP facility to continue to operate at its optimal capacity when a particular process unit was offline for maintenance or cleaning.

Continuous monitoring and the ability to immediately shut down the full-scale AWP facility are critical components of the overall reliability of water purification processes. Instrumentation and automation would be provided to continuously verify that processes are operating as expected. The control system would include electronic monitoring that would automatically shut down the facility if a problem was detected. This would prevent water that does not meet the water quality requirements from being introduced into San Vicente Reservoir. Manual checks would also be performed on each system to identify operational trends and detect anomalies that require attention. These electronic systems controls and manual procedures, together with critical control point monitoring (see Section B, Advanced Water Purification Facility), would assure that only the highest quality water leaves the full-scale AWP facility.

Pipeline System Components

The City's Water Repurification Project efforts in the 1990s generated a conceptual pipeline (conveyance) system for a reservoir augmentation project that would convey purified water from North City to San Vicente Reservoir. However, because conditions have changed substantially since the Water Repurification Project was completed, a new conveyance study was required to analyze how water could be conveyed from the full-scale AWP facility (North City) to San Vicente Reservoir. In 2012, a conceptual design study was completed to update recommendations for the purified water conveyance system, including potential pipeline alignments and pump station specifications (RMC, 2012). The new conveyance study also comprehensively analyzed conditions that have changed since the Water Repurification Project was completed. In addition, the conceptual design provided estimates of the associated capital and operations and maintenance costs for the pipeline system components.

Components of the purified water pipeline system would include:

- Purified water pump station
- Purified water pipeline
- Reservoir inlet structure

An overview of the findings from the conceptual design study, including potential pipeline alignments and operational features of the pipeline and purified water pump station, are provided below.

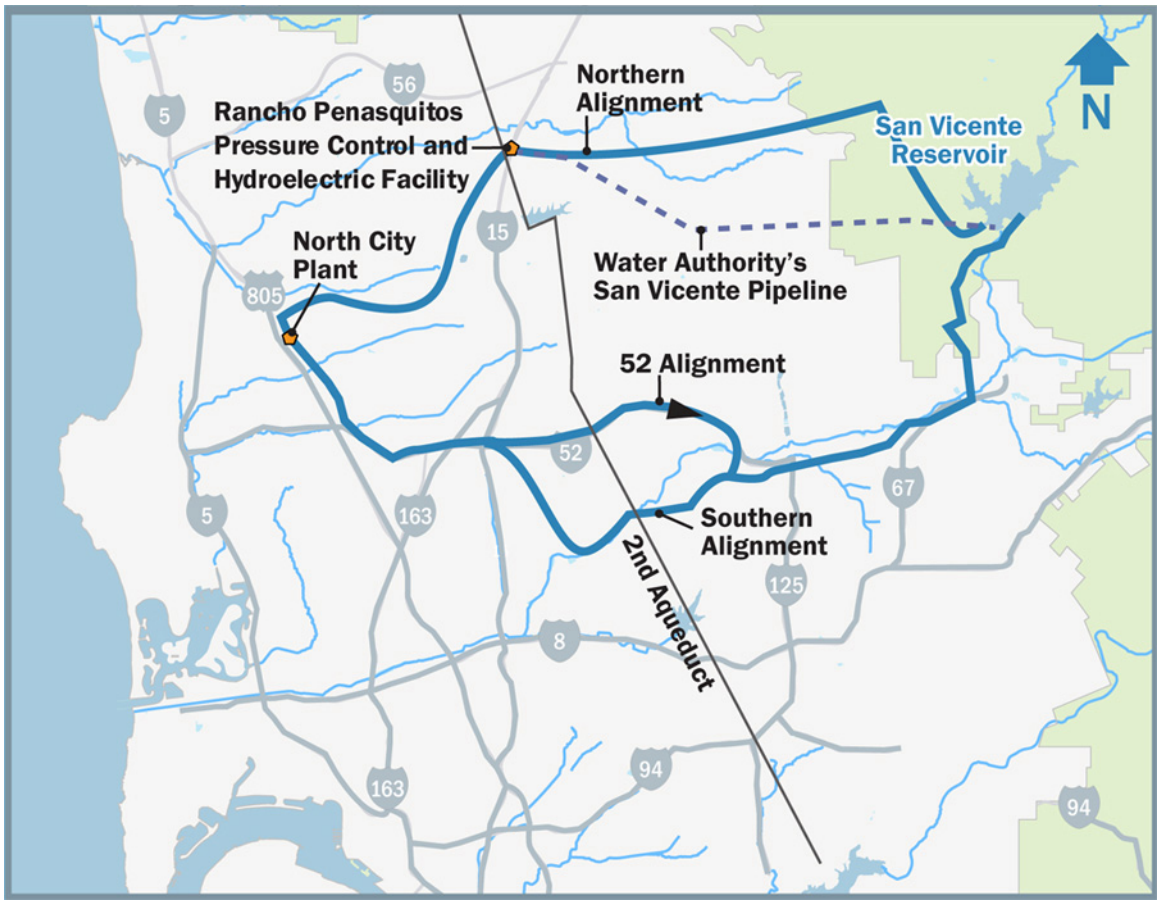
Purified Water Pump Station

A new pump station would be required at the full-scale AWP facility to transport purified water through the pipeline to San Vicente Reservoir. The capacity of this pump station would match the operating range of the AWP facility, with the potential to expand as necessary. Preliminary recommendations for pump types and clear well capacity (needed to counterbalance AWP facility production and pump station operation) were also provided in the conveyance conceptual design study.

Purified Water Pipeline

A series of alternative pipeline alignments to convey purified water from the full-scale AWP facility to San Vicente Reservoir were evaluated. These alignments are described below, and the potential location of these alignments is illustrated in Figure F-4.

Figure F - 4: Potential Purified Water Pipeline Alignments



Northerly Alignments

Two northerly alignments were considered to transport purified water to San Vicente Reservoir, referred to as the northern alignment and the San Vicente Pipeline alignment. The northern alignment, originally evaluated during the Water Repurification Project, is approximately 24 miles long, and follows city streets from North City to the Water Authority's Rancho Peñasquitos

Pressure Control and Hydroelectric facility, which is adjacent to the Second Aqueduct near Mercy Road and Black Mountain. From there, the alignment travels along Pomerado Road to Spring Canyon Road to Scripps Poway Parkway, then south along Highway 67, with a purified water inlet structure near the First Aqueduct inlet structure at San Vicente Reservoir. The close proximity of the purified water inlet to the First Aqueduct inlet structure could pose a challenge, as it would reduce reservoir retention time and blending, which are required to satisfy regulatory requirements. The alignment also traverses challenging terrain, and an encroachment permit would be required from Caltrans to place the pipe in the Highway 67 right-of-way. This alignment should be studied further in the preliminary design phase.

San Vicente Pipeline Alignment

The second northern alignment, the San Vicente Pipeline, is a connection to an existing pipeline that is operated by the Water Authority as part of the region's Emergency Storage Project. The Emergency Storage Project was implemented to connect a network of reservoirs, pipelines, and other facilities that can be used to store and move water throughout the San Diego region in the event of a natural disaster such as an earthquake or drought. The San Vicente Pipeline is 11 miles in length, and connects the Second Aqueduct, which supplies imported water to the west side of San Diego County, to San Vicente Reservoir. Due to the proximity of the San Vicente Pipeline to North City, the fact that it connects to San Vicente Reservoir, and the expected limited use of this pipeline (expected to be used primarily under emergency conditions), this pipeline was considered as a potential pipeline option for a reservoir augmentation project at San Vicente Reservoir. Approximately 10 miles of new pipeline would be needed to connect to the existing 11-mile San Vicente Pipeline.

Through meetings with the Water Authority, it was determined that the San Vicente Pipeline not only conveys water to San Vicente Reservoir, but is also used to convey water directly to the Morena Pipeline and Helix Water District Pipeline, both of which supply imported water directly to the Helix Water District's Levy Water Treatment Plant. Due to this direct connection to the Levy Water Treatment Plant (lacking an environmental buffer), use of the San Vicente Pipeline to convey purified water to San Vicente Reservoir could not be considered during the Demonstration Project.

It is recognized that, should the Water Authority and Helix Water District make other arrangements to transport water from the Second Aqueduct to the Levy Water Treatment Plant, a purified water conveyance strategy including the San Vicente Pipeline could be feasible from a regulatory standpoint. Should the City decide to proceed with a full-scale project, it is recommended that this option be further explored. Further, in the event that regulatory conditions change such that an environmental buffer is no longer required between a purified water source and a drinking water system, use of the San Vicente Pipeline could become feasible from a regulatory perspective.

Southerly Alignments

Purified water conveyance research conducted during the Water Repurification Project in the 1990s focused primarily on a southerly alignment. This alignment included use of the existing recycled water pipeline serving the Metropolitan Biosolids Center and other customers to the southeast of

North City. In addition, it relied on a longitudinal encroachment of a Caltrans right-of-way along State Route 52 (SR-52) and construction of a pipeline along Mast Boulevard in the Santee area. This alignment was re-evaluated as part of the Demonstration Project. Significant changes have occurred along this pipeline alignment since the 1990s. As a result of these changes, the City investigated two alternative southerly alignments for a purified water pipeline: the original approximately 22-mile alignment, including a SR-52 encroachment, and an approximately 23-mile alternative alignment through Mission Gorge that avoids SR-52. Based on the updated analysis conducted as part of the Demonstration Project, a southerly alignment appears to provide the best opportunity to convey purified water from North City to San Vicente Reservoir. Consequently, the cost estimate presented in the following section is representative of a southerly alignment. At the current level of planning and cost estimation, there is no appreciable difference in costs between the two southerly alignments.

Construction Impacts

Construction along any of the potential alignments would require stream crossings and analyses of adjacent native habitat and cultural resources. In addition, construction could potentially generate traffic, noise, and other environmental impacts, depending on its location and magnitude. Moving forward, additional environmental analyses will be required to determine specific features of each alignment such as potential impacts to biological, cultural, and other resources, which would make one alternative superior over the other from an environmental impact point of view.

Pipeline Draining

CDPH would require that purified water from a full-scale AWP facility be captured and prevented from entering San Vicente Reservoir in the unlikely event of a problem at the full-scale AWP facility. The pipeline transporting purified water to the reservoir would be generally on an uphill slope, facilitating the capture and diversion of flows away from San Vicente Reservoir if necessary. In a reservoir augmentation project at San Vicente Reservoir, drain lines would be included in the pipeline system design to enable off-specification flows to be diverted to local sewer systems. Along a southern alignment, this reliability feature would require the diversion of flows to both Santee and San Diego sewer systems.

Purified Water Inlet Structure

The purified water inlet structure would enable purified water to be released from the conveyance pipeline into San Vicente Reservoir. The inlet structure would be positioned at an elevation that would always remain above the surface of the water in the reservoir, and it would include a spillway. Engineering studies conducted in the 1990s provided a preliminary design for this inlet structure, which was reviewed as part of the Demonstration Project. This inlet structure is still feasible.

A series of purified water inlet locations were studied as part of the Reservoir Study conducted by Flow Science (refer to Section C, San Vicente Reservoir Study for more information). While all locations studied were determined to meet regulatory requirements for blending and travel time, a conservative location on the southeast edge of the reservoir (the Design Purified Water Inlet Location) was used as the basis for estimating conveyance pipeline costs.

AWP Facility and Pipeline System Costs

AWP facility and pipeline system costs were evaluated in terms of overall capital and O&M costs; unit costs, which reflect the capital and O&M costs spread over the project life and presented in terms of cost per AF of water produced; and effects on an average monthly household water bill. Avoided wastewater system costs were also quantified. These costs are described below.

Capital and O&M Costs

Capital and O&M costs for the AWP facility and purified water pipeline system are presented in Tables F-2 and F-3, respectively. These cost estimates were based on preliminary facility engineering, and would be updated during final design should the City decide to move forward with a full-scale project. Costs for the purified water pipeline system were developed as part of the Conveyance Conceptual Design Study, and costs for the full-scale AWP facility were developed as part of the Advanced Water Purification Facility Study (CDM Smith and MWH, 2013a). Total capital costs for a reservoir augmentation project at San Vicente Reservoir are estimated to be approximately $369 million, with O&M costs estimated to be $15.5 million per year.

Table F - 2: AWP Facility and Purified Water Pipeline System Preliminary Capital Cost Estimate

Parameter	Capital Cost[1]
AWP Facility Construction Costs	
AWP Facility Influent Pump Station	$2,800,000
Site Civil/Yard Piping	$5,800,000
Operations, Maintenance, and Administration Building	$1,600,000
Membrane Filtration Break Tank and Pump Station	$4,000,000
Chemical Storage Area #1 (Pre-Treatment Chemical Facility)	$2,400,000
Membrane Filtration Facility	$25,300,000
Reverse Osmosis Facility	$21,300,000
UV Disinfection and Advanced Oxidation System	$9,900,000
Chemical Storage Area #2 (Post-Treatment Chemical Facility)	$2,100,000
AWP Facility Construction Subtotal	**$75,200,000**
Contingency (30% of Construction Total)	$22,600,000
Insurance, Bonds, Overhead & Profit	$12,700,000
AWP Facility Construction Total	***$110,500,000***
AWP Facility Implementation Costs	
Engineering & Pre-Construction (20% of Total Construction Cost)[2]	$22,100,000
Environmental Documentation and Mitigation	$1,000,000
Construction Management (10% of Total Construction Cost)	$11,100,000
AWP Facility Implementation Total	***$34,200,000***
Total AWP Facility Capital Cost (Construction Total + Implementation Total)	**$144,700,000**
Purified Water Pipeline System Construction Costs	
Purified Water Pump Station	$8,000,000
Purified Water Pipeline	$114,200,000
Pipeline System Construction Total	***$122,200,000***
Pipeline System Implementation Costs	
Contingency (30% of Construction Total)	$36,700,000
Engineering & Construction Management (30% of Construction Total)[2]	$36,700,000
Environmental Documentation and Mitigation	$24,400,000
Land Acquisition	$4,500,000
Pipeline System Implementation Total	***$102,300,000***
Total Pipeline System Capital Cost (Construction & Implementation)	**$224,500,000**
Total Capital Cost (Construction + Implementation + Source Control)	**$369,200,000**

1. Costs for the purified water pipeline system were developed as part of the conveyance conceptual design study, and costs for the full-scale AWP facility were developed as part of the Advanced Water Purification Facility Study (CDM Smith and MWH, 2013a).
2. Includes costs associated with regulatory compliance and permitting.

Table F - 3: AWP Facility and Purified Water Pipeline System Preliminary O&M Cost Estimate

Parameter	Annual O&M Cost[1]
Power Costs	
AWP Facility Influent Pump Station	$306,000
Membrane Filtration System	$43,000
Reverse Osmosis System	$1,614,000
UV Disinfection and Advanced Oxidation System	$185,000
Miscellaneous Equipment	$7,000
Buildings	$481,000
Purified Water Pump Station	$1,657,000
Power Costs – Subtotal	***$4,293,000***
Chemical Costs	
Membrane Filtration Pretreatment	$223,000
Reverse Osmosis Pretreatment	$431,000
Hydrogen Peroxide for Advanced Oxidation	$216,000
Post Treatment	$358,000
Membrane Cleaning	$103,000
Chemical Costs – Subtotal	***$1,331,000***
Replacement of Consumables	
Membrane Filtration Membranes	$441,000
Reverse Osmosis Cartridge Filters and Reverse Osmosis Membranes	$319,000
UV Lamps and Ballasts	$281,000
Replacement of Consumables – Subtotal	***$1,041,000***
AWP Facility Maintenance Costs	***$1,409,000***
Treatment at North City to Support AWP Facility[2]	***$3,965,000***
Purified Water Pump Station Maintenance Costs	***$228,000***
Purified Water Pipeline Maintenance Costs	***$1,500,000***
Other Annual Costs (Compliance Testing and Security)	$310,000
Annual Labor Costs	$1,418,000
Total Annual O&M Cost	**$15,495,000**

1. Costs for the purified water pipeline system were developed as part of the conveyance conceptual design study, and costs for the full-scale AWP facility were developed as part of the Advanced Water Purification Facility Study (CDM Smith and MWH, 2013a).
2. Cost to increase North City tertiary water production above what is needed to meet non-potable recycled water demands.

Auxiliary Program Costs

Additional auxiliary program costs to support a full-scale project are presented in Table F-4. These cost estimates were based on preliminary cost estimates for a source control program and a public outreach program. Costs for the Source Control Program were developed as part of the Enhanced Source Control Plan for the Full-Scale Advanced Water Purification Facility Technical Memorandum (RMC, 2013).

Table F - 4: Auxiliary Program Cost Estimate

Parameter	Auxiliary Cost
Auxiliary Upfront Cost	
Source Control Program Upfront Cost[1]	$500,000
Auxiliary Annual Cost	
Source Control Program Annual Costs[2]	$50,000
Public Outreach Annual Program Costs[3]	$700,000

1. Source control upfront costs include a chemical inventory program and GIS tracking database (approximately $50,000), a pollutant prioritization program to be completed by existing City staff (approximately $50,000 for initial set-up work), and a local limits evaluation for North City (approximately $400,000). For additional information on source control program costs, refer to the Enhanced Source Control Plan for the Full-Scale Advanced Water Purification Facility Technical Memorandum (RMC, 2013).
2. Source control annual costs include $25,000/yr for annual updates to the chemical inventory program and GIS tracking database, an average of $10,000/yr for periodic updates to the pollutant prioritization program, and $15,000/yr, on average, for updates to the local limits analysis. For additional information on source control program costs, refer to the Enhanced Source Control Plan for the Full-Scale Advanced Water Purification Facility Technical Memorandum (RMC, 2013).
3. Public outreach annual costs include initial start-up of outreach efforts. Annual public outreach costs will be scaled back following full-scale reservoir augmentation project operations.

Unit Costs

A net present value analysis was performed on the capital and O&M costs presented above. Based on this analysis, the unit cost of a reservoir augmentation project as San Vicente Reservoir would be approximately $2,000/AF, as shown in Table F-5. Key assumptions of this analysis included:

- The project life is 50 years.
- Financing would be received through rates, revenue bonds, and State Revolving Funds.
- The Water Authority's Local Resource Program (LRP) credits would continue. The uncertain future of these credits was addressed by applying a credit that reflects a midpoint between favorable and unfavorable conditions. Under favorable conditions, the credit is expected to be $450/AF of water produced, while under unfavorable conditions it is expected to be $100/AF. The average of $275/AF was used in estimating the overall cost of reservoir augmentation.
- Grant funding in the amount of 20 percent of capital costs would be received. Such grants are typical for water recycling projects.

Table F - 5: Projected Unit Costs

Project Component	Projected Unit Cost[1]
AWP Facility	$1200/AF
Purified Water Pipeline System	$700/AF
Source Control	$50/AF
Public Outreach	$50/AF
Total	$2,000/AF

1. Assumes a project life of 50 years, financing through both revenue bonds and State Revolving Funds, LRP credits of $275 / AF, and grant funding in the amount of 20% of capital costs.

The projected unit cost of $2,000/AF is consistent with projections developed for the Indirect Potable Reuse - Phase I project evaluated in development of the 2012 LRWRP, which was estimated to cost approximately $2,100/AF, including initial capital and annual operating costs (including energy). A key difference between the costs developed for the LRWRP and the costs presented in this Project Report is that the LRWRP costs do not reflect any potential grant funding or low-interest loans. Neither the costs developed for this study nor the LRWRP costs reflect any cost savings from reduced wastewater treatment and disposal (see Avoided Wastewater Costs section, below).

Household Water Bill

The anticipated effect of a reservoir augmentation project at San Vicente Reservoir on an average monthly household water bill was also calculated. Assuming an average residential usage volume of 14 hundred cubic feet per month, an average untreated water supply cost to the City of approximately $962/AF, and an average total water use of approximately 194,000 AFY, a reservoir augmentation project at San Vicente Reservoir with an average flow of 15 mgd and a unit cost of $2,000/AF would result in an increase of approximately $6.87 per month on an average residential water bill. For comparison, the average residential water bill (fiscal year 2012-2013) was approximately $72.03 per monthly billing cycle (water charges only).

This projected increase does not take into consideration projected increases in monthly water bills expected as the result of increasing imported water supply costs that would occur with or without a reservoir augmentation project at San Vicente Reservoir. It should also be recognized that such a project would provide value to the customer in increased supply reliability and reduced reliance on imported water.

Avoided Costs

The implementation of a reservoir augmentation project at San Vicente Reservoir would result in avoided wastewater system costs, as well as savings related to reduced salinity in the City's water supplies. Avoided wastewater system costs result from the elimination of costly capital improvement needs and in reduced operations and maintenance costs. In order to determine what capital improvements could be avoided as a result of implementing full-scale reservoir augmentation, the

September 2011 Metro Wastewater Plan (Plan) was referenced. The facility requirements described in the Plan correspond to Point Loma remaining a chemically-enhanced primary treatment plant. There are several projects included in the Plan's long-term capital program. Among these projects is the construction of a seven-million-gallon wet weather storage facility that would be needed to attenuate flows to Point Loma. In the absence of full-scale reservoir augmentation, this facility would need to be operational by the year 2022. Its estimated capital and operating costs are $123 million and $6.2 million per year, respectively.

Implementation of a reservoir augmentation project at San Vicente Reservoir would also reduce the flows conveyed to and treated at Point Loma. Annual operations and maintenance savings related to reduced treatment and conveyance, respectively, are approximately $2.2 million and $450,000 per year.

The TDS (a measure of salt content) of purified water produced at the AWP Facility was approximately 15 mg/L. This is in contrast to imported water TDS, which is approximately 500 mg/L and has occasionally exceeded 600 mg/L (City of San Diego, 2012a, City of San Diego, 2012g). The estimated monetary savings to a drinking water system due to reduced salinity was evaluated by MWD and the Bureau of Reclamation in the late 1990s. They found that reduced salinity correlates with longer useful lives of downstream treatment facilities. Savings related to the extended lives of retail customers' plumbing fixtures would also be expected. The savings associated with reduced salinity were further evaluated in Water Reuse Study (City of San Diego, March 2006) specifically for the City's setting and determined to equal $250/AF. The Recycled Water Study (City of San Diego, July 2012) re-evaluated the savings and conservatively applied $100/AF in its financial analysis. While it is anticipated that salt reduction benefits would be observed as a result of a reservoir augmentation project at San Vicente Reservoir, this benefit has not been analyzed as part of the Demonstration Project, and has not been monetized.

These avoided costs, summarized in Table F-6, yield an associated net unit cost of $1,000/AF.

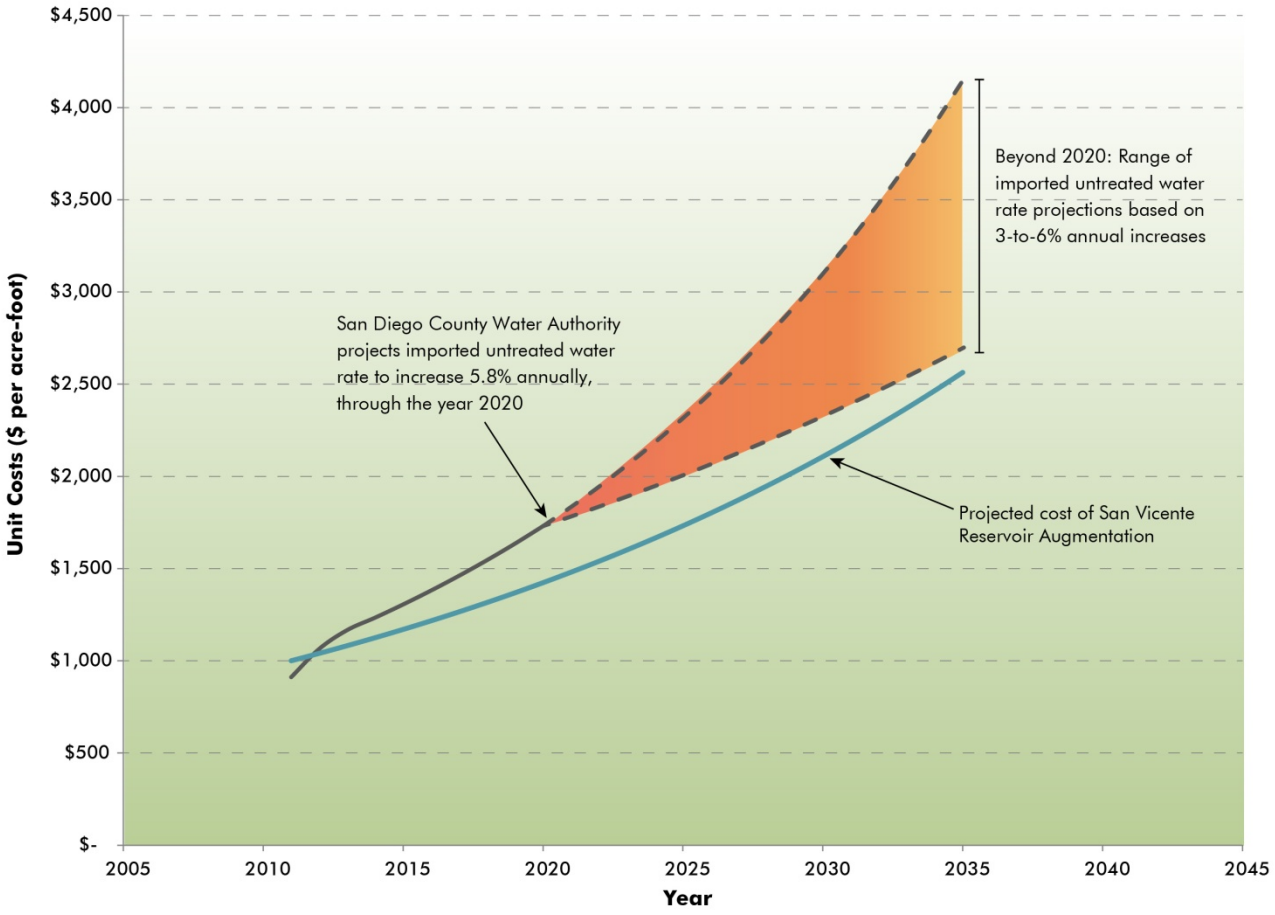
Table F - 6: Avoided System Costs

Benefit	Avoided Cost	Avoided Cost per AF
Point Loma Wet Weather Storage Facility	$123,000,000 (Capital) $6,150,000 (Annual O&M)	$1,000
Reduced Treatment at Point Loma	$2,200,000 (Annual O&M)	
Reduced Pumping at Pump Stations No. 2	$450,000 (Annual O&M)	
Reduced Salinity in Water Supplies		Not monetized
Total Avoided Costs/Savings		$1,000

The current cost of untreated imported water as of January 2013 is $1,039/AF. Imported water costs are expected to increase at a rate of 5.8 percent per year through 2020, and between three and six percent per year after 2020. Figure F-5 presents the current and projected cost of imported water compared to the net cost of water from a reservoir augmentation project at San Vicente Reservoir.

As shown in this figure, the unit cost of imported water supplies exceeds the net unit cost of supplies from a reservoir augmentation project at San Vicente Reservoir.

Figure F - 5: Current and Projected Cost of Water Supplies



For additional cost information, please refer to Section 8.4 of the City of San Diego Recycled Water Study (City of San Diego, 2012b), provided in Appendix G.

Energy

An energy analysis requested by City Council for water supply options will be completed by the consultant preparing the City's 2012 LRWRP. The report is anticipated to be submitted for City Council review and acceptance in early 2013.

Because no single water supply option can meet all goals of the 2012 LRWRP, a range of options (including conservation, groundwater, non-potable reuse, reservoir augmentation, rainwater, gray water, ocean desalination, and imported water) was considered to form eight portfolios and diversify the approach to meet the objective of the plan. Over 20 performance measures were used to

comprehensively evaluate each portfolio, which were ranked in terms of their cumulative performance.

Based on these rankings, and their climate change adaptation benefits, three portfolios consistently ranked highest. All three of these highest ranked portfolios included reservoir augmentation at San Vicente Reservoir as a common resource option. The inclusion of a full-scale (15-mgd average flow) reservoir augmentation project as a resource option in all three of the highest ranked portfolios is significant because, if approved by the public, City Council and CDPH, reservoir augmentation at San Vicente Reservoir would be validated based on cost, energy footprint, and other criteria as a recommended near term resource strategy.

One quantitative performance measure for "energy footprint" of the City's water sources is the cumulative carbon dioxide emissions. Energy use can be illustrated by kWh /AF or tons of carbon dioxide emissions per AF. Reporting of greenhouse gas emissions (of which carbon dioxide is considered the largest, or primary component) by major source is required by the California Global Warming Solutions Act (AB 32, 2006). The City's reliance on imported water that originates hundreds of miles away and requires energy-intensive pumping contributes significantly to greenhouse gas emissions.

Greenhouse gas emissions are calculated based on typical per unit energy requirements for each source of water supply, including energy requirements for distribution and wastewater treatment if applicable. The energy (kWh/AF) of each water supply option in the 2012 LRWRP was converted to carbon dioxide equivalents (San Diego, 2012c). Carbon dioxide emissions are a reflection of the energy required to produce water, not the type of energy used, for each water resource. While imported water sources have different sources of energy than local water resources, it is assumed that all water resources use the same energy resource for simplicity.

The 15-mgd reservoir augmentation project at San Vicente Reservoir (estimated to require 2,500 kWh of energy per AF) would produce approximately 1.0 metric tons of greenhouse gases/AF. By comparison, imported water requires a range of 2,000 kWh/AF to 3,300 kWh/AF of energy, depending on the blend of water from the Colorado River or the Bay-Delta in Northern California, respectively. This corresponds to a range of 0.8 to 1.3 metric tons of greenhouse gases/AF (City of San Diego, 2012c). Since 2003, the blend delivered to the Water Authority has averaged approximately two-thirds Colorado River and one-third water from the Bay-Delta. Future imported water energy consumption will vary depending on actual blend. However, for practical purposes, the reservoir augmentation project at San Vicente Reservoir energy consumption is equivalent to that of imported water.

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Section G: Summary and Conclusions

In an average year, approximately 85 to 90 percent of the City of San Diego's water supplies are imported water (City of San Diego, 2011a). Imported water reliability issues, coupled with recurring droughts in the San Diego region, have placed considerable strain on the City's ability to meet water demands. The City has taken a variety of actions to maximize water resources and improve water supply reliability, including moving forward with a three-phased Water Reuse Program designed to maximize the use of recycled water throughout the City. The Water Reuse Program is an integral component of the City's plan to improve water supply reliability by developing local, drought-tolerant water supplies.

The City's 2006 Water Reuse Study (Phase 1 of the Water Reuse Program) included a comprehensive evaluation of all viable options to maximize the use of recycled water produced by the City's two water reclamation plants. Based on this study, a stakeholder group determined that the preferred option for maximizing use of the City's recycled water supply would be to augment existing supplies in the City's San Vicente Reservoir with purified water (reservoir augmentation at San Vicente Reservoir).

The City recently completed Phase 2 of the Water Reuse Program, the Water Purification Demonstration Project. This three-year project assessed the feasibility of supplementing San Diego's San Vicente Reservoir with purified water produced at an advanced water purification facility located at North City. The Demonstration Project involved constructing and operating a small-scale advanced water purification facility, studying San Vicente Reservoir, implementing a public outreach and education program, coordinating with regulatory agencies, and developing conceptual design criteria and costs for a full-scale AWP facility and purified water conveyance facilities. The concept of using purified water to augment San Vicente Reservoir has been determined to be feasible, and the Mayor and City Council may consider implementing a full-scale reservoir augmentation project at San Vicente Reservoir, which would be Phase 3 of the Water Reuse Program.

The Demonstration Project consisted of the following components:

1. Convene an Independent Advisory Panel
2. Design, install, and operate a demonstration-scale advanced water purification facility at the North City Water Reclamation Plant
3. Conduct a study of San Vicente Reservoir to establish residence time and water quality parameters and conditions of purified water in the reservoir
4. Perform an energy and economic analysis

5. Define the state's regulatory requirements for a full-scale reservoir augmentation project at San Vicente Reservoir
6. Perform a pipeline alignment study
7. Conduct a public outreach and education program

The Demonstration Project generated a significant body of data related to the expected performance of a full-scale reservoir augmentation project at San Vicente Reservoir. Each Demonstration Project component was designed to generate evidence and findings to assess the feasibility of such a project. Each of these components is summarized below.

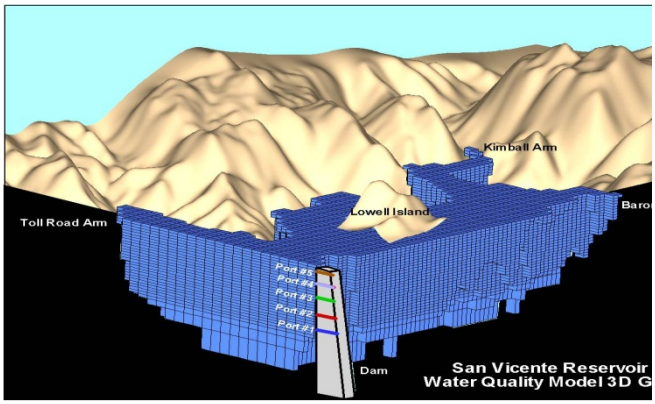
- ***Component: Convene an Independent Advisory Panel.*** An IAP organized and managed by NWRI was convened in 2009 to oversee the Demonstration Project. The IAP consisted of ten academics and professionals with extensive expertise in the science of water reuse, including water and wastewater technology, public health, epidemiology, toxicology, water quality, environmental science, limnology, public utilities, and industry regulations. The IAP unanimously concluded that the project will "…be a landmark development in the acceptance and furtherance of indirect potable reuse and will contribute to the City of San Diego's water portfolio. The proposed project will supplement existing sources and provide a greater degree of independence, thus improving the reliability of the existing water supply." The IAP findings can be found in Appendix F.
- ***Component: Design, construct, and operate a demonstration-scale advanced water purification facility at the North City Water Reclamation Plant.*** The AWP Facility was designed, installed, operated, and tested between 2010 and 2012. The ability to produce purified water meeting all regulatory standards was evaluated by performing water quality testing on 12 months of purified water samples produced by the AWP Facility. The AWP Facility produced purified water that reliably met applicable water quality standards, and on-line monitoring confirmed the continuous acceptable performance of water purification technologies. Although the testing period is complete, the AWP Facility has continued to operate for public tours and to gather additional equipment performance data.

Water quality monitoring showed that purified water met all applicable regulatory standards.

- ***Component: Conduct a study of San Vicente Reservoir to establish residence time and water quality effects of purified water in the reservoir.*** A detailed study of San Vicente Reservoir was conducted to establish residence time and water quality effects of purified water in the reservoir. Blending, retention time, and water quality in the reservoir were evaluated by using a robust computer model. The model was set up and applied by an expert team and validated by the IAP. It was

determined that blending and retention of purified water in San Vicente Reservoir would constitute a substantial environmental barrier, sufficient to meet regulatory requirements, and that the addition of purified water would not adversely affect natural reservoir conditions and mixing. The modeling showed that the enlargement of the reservoir will improve nutrient-related water quality issues compared to the historical reservoir, and that adding purified to the enlarged reservoir will not substantially affect these improvements.

- ***Component: Perform an energy and economic analysis.*** Costs were developed based on concept-level facility plans prepared as part of the Demonstration Project and validated based on existing operating projects. Full-scale project implementation costs were estimated to be $2,000/AF, with net costs reduced to approximately $1,000/AF when considering wastewater system avoided costs. A full-scale reservoir augmentation project at San Vicente Reservoir would require approximately the same amount of energy and generate green house gas emissions comparable to imported water, based on an energy analysis conducted as part of the LRWRP.
- ***Component: Define the state's regulatory requirements for a full-scale reservoir augmentation project at San Vicente Reservoir.*** Regulators participated in all IAP meetings and working groups addressing all technical aspects of reservoir augmentation conducted throughout the Demonstration Project. This technical background enabled the regulators to establish specific guidelines and regulatory pathways to permitting a reservoir augmentation project at San Vicente Reservoir. A Concept Approval Letter was issued for the project by CDPH, and the Regional Board issued a Resolution of Support for the reservoir augmentation at San Vicente Reservoir, and a Letter of Concurrence confirming the preferred pathway to permit a full-scale project.



The three-dimensional Water Quality Model Output demonstrated that the addition of purified water would improve nutrient-related water quality issues in San Vicente Reservoir.

- ***Component: Perform a pipeline alignment study.*** In 2012, a conceptual design study was completed to update recommendations for the purified water conveyance system, including potential pipeline alignments and pump station specifications (RMC, 2012). The new conveyance study also comprehensively analyzed conditions that have changed since the Water Repurification Project was completed.
- ***Component: Conduct a public outreach and education program.*** Comprehensive City-wide outreach enabled key stakeholders and interested members of the public to gain an understanding of how purified water offers a technically feasible and reliable supplemental water supply. Recent survey research showed that when provided with information about

the water purification process, respondents strongly or somewhat favor adding recycled water to the local drinking water supply. Feedback from individuals that toured the AWP Facility showed that providing an opportunity to tour the facility increases understanding about water purification.

Overall, the AWP Project achieved its stated objectives, and demonstrated that water purification technology may be feasibly used to produce water that could be sent to San Vicente Reservoir to be available to drinking water treatment plants for distribution as drinking water.

Table G-1 provides the summaries and findings generated throughout the course of the Demonstration Project.

Targeted presentations proved to be a vital component of the outreach program, increasing the public's understanding about water purification and the Demonstration Project.

Table G - 1: Demonstration Project Findings and Conclusions

Component	Summary	Findings
Convene an Independent Advisory Panel	The IAP provided expert peer review of the technical, scientific, and regulatory aspects of the Demonstration Project. The IAP met ten times over the course of the Demonstration Project.	The IAP found that purified water would meet or exceed all drinking water requirements and provide multiple barriers for public health protection; reservoir modeling verified that the reservoir will provide 100-fold dilution of purified water, CDPH and the Regional Board have indicated support for the project, and City staff has implemented an effective public outreach program. The IAP found the AWP Facility produced water of a higher quality than any source available to the City of San Diego and unanimously concluded that a reservoir augmentation project at San Vicente Reservoir would be a landmark project in the acceptance and furtherance of indirect potable reuse and would improve the reliability of the City of San Diego's water supply portfolio. See IAP reference letter in Appendix F.
Design, install, and operate a demonstration-scale advanced water purification facility at the North City Water Reclamation Plant	The Demonstration AWP Facility has been in operation since June, 2011. The 12-month testing period took place from August 2011 to July 2012. Comprehensive water quality testing included measurements for 342 constituents and parameters before and after each treatment step, and in the imported aqueduct water. A total of more than 9,000 water quality tests were performed.	Water quality of the purified water was compared to regulatory limits, verifying that purified water met all applicable water quality standards. This comprehensive water quality testing showed that the purified water produced at the AWP Facility is pure, approaching distilled water purity. Continuous and daily monitoring of each water purification process can assure the integrity of each treatment step and that only high quality water is produced.

Component	Summary	Findings
Perform a study of San Vicente Reservoir to establish residence time and water quality parameters and conditions of purified water in the reservoir	A detailed Limnology and Reservoir Detention Study of San Vicente Reservoir was conducted to establish residence time and water quality effects of purified water in the reservoir. Blending, retention time, and water quality in the reservoir were evaluated by using a three-dimensional hydrodynamic model.	The addition of purified water into San Vicente Reservoir would not affect natural hydrologic characteristics of the reservoir, seasonal stratification, or mixing. Blending and retention of purified water in the reservoir would constitute a substantial environmental barrier, sufficient to meet regulatory requirements. For all anticipated reservoir operating scenarios and purified water release locations, the reservoir would dilute the purified water by at least a factor of 200 to one. The addition of purified water would not substantially affect water quality in San Vicente Reservoir. The dam raise will improve overall water quality and the addition of purified water will not change these improvements.
Perform an energy and economic analysis	Cost were evaluated for a full-scale reservoir augmentation project at San Vicente Reservoir in terms of overall capital and operational and maintenance costs; unit costs, which reflect the capital and O&M costs spread over the project life and presented in terms of cost per AF of water produced.	The estimated capital and annual operational and maintenance costs for a full-scale reservoir augmentation project at San Vicente Reservoir are $369 million and $15.5 million per year, respectively. This capital and annual costs for a full-scale project yielded an estimated unit cost of $2,000/AF. This unit cost is comparable to the $2,100/AF unit cost estimated in the LRWRP for a full-scale (15 mgd average production) reservoir augmentation project at San Vicente Reservoir.

Component	Summary	Findings
Perform energy and economic analysis, cont'd	As part of the 2012 Long-Range Water Resources Plan, an energy analysis for a reservoir augmentation project at San Vicente Reservoir was performed.	Accounting for wastewater system avoided costs, the estimated net unit cost of a reservoir augmentation project at San Vicente Reservoir is $1,000/AF, which is comparable to the current imported water cost. A full-scale reservoir augmentation project at San Vicente Reservoir was estimated to require 2,500 kWh/AF of energy and would produce approximately 1.0 metric tons of greenhouse gases/AF. A full-scale project would consume energy and produce green house gas emissions that are equivalent to imported water and less than ocean desalination.
Define the state's regulatory requirements for a full-scale reservoir augmentation project at San Vicente Reservoir	Throughout the Demonstration Project the City engaged separately with the California Department of Public Health and the San Diego Regional Water Quality Control Board. In addition, both agencies actively participated in ten IAP meetings.	The California Department of Public Health issued a concept approval of the City's San Vicente Reservoir Augmentation Project. The San Diego Regional Water Quality Control Board, with concurrence from the United States Environmental Protection Agency issued concept approval as well.
Perform a pipeline alignment study	A conceptual design study was completed to update recommendations for the purified water conveyance system, including potential pipeline alignments and pump station specifications.	The estimated capital and annual operational and maintenance costs for the conveyance system are $225 million and $3.4 million, respectively. Updated analysis of the pipeline alignment confirmed that a southerly alignment appears to be the most feasible.

Component	Summary	Findings
Conduct a public outreach and education program	A comprehensive public outreach and education program was conducted throughout the city to educate San Diego's local leaders, stakeholders and residents about the Demonstration Project	Recent research showed that when provided with information about the water purification process, respondents favor use of purified water to supplement local water supply via reservoir augmentation at San Vicente Reservoir. Feedback from individuals that toured the Advanced Water Purification Facility showed that providing an opportunity to tour the facility increases understanding about water purification.

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Supporting Documents Referenced in this Report

In addition to this Project Report, many technical studies, testing reports, and outreach documents were produced as part of the Demonstration Project. Those documents, which were used as the basis for the Project Report, are listed below for reference. The public may schedule an appointment with the Public Utilities Department for viewing of these documents as well as other project related documents that are not posted on the project website. Due to the size of these documents, the distribution was limited.

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APPENDICES

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Appendix A: Proposal to CDPH to Augment San Vicente Reservoir with Purified Recycled Water

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THE CITY OF SAN DIEGO

City of San Diego
Water Purification Demonstration Project

Proposal to Augment San Vicente Reservoir with Purified Recycled Water

March 22, 2012

City of San Diego
PUBLIC UTILITIES
Water & Wastewater

Water Purification | Demonstration Project

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This proposal was prepared by the Water Purification Demonstration Project team, which consists of City staff, plus staff of RMC Water and Environment and its sub-consultants.

This proposal was reviewed by members of the project's Independent Advisory Panel.

The City of San Diego thanks the California Department of Public Health for its participation and input over the past two years regarding the City's Water Purification Demonstration Project. This participation and input has been invaluable as the City's project team structured the proposed project and this proposal.

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List of Acronyms

AFY	Acre-Feet per Year
AOP	Advanced Oxidation Processes
AWPF	Advanced Water Purification Facility
CCP	Critical Control Point
CCR	California Code of Regulations
CDPH	California Department of Public Health
CEC	Chemicals of Emerging Concern
CTR	California Toxics Rule
EPA	Environmental Protection Agency
GWRS	Ground Water Replenishment System
IAP	Independent Advisory Panel
IPR/RA	Indirect Potable Reuse / Reservoir Augmentation
MCL	Maximum Contaminant Level
MF	Microfiltration
µg/L	micrograms per liter (equivalent to parts per billion)
mg/L	milligrams per liter (equivalent to parts per million)
mgd	million gallons per day
NCWRP	North City Water Reclamation Plant
NDMA	N-Nitrosodimethylamine
ng/L	Nanograms per liter (equivalent to parts per trillion)
NPDES	National Pollutant Discharge Elimination System
NWRI	National Water Research Institute
OCSD	Orange County Sanitation District
OCWD	Orange County Water District
PLWTP	Point Loma Wastewater Treatment Plant
RO	Reverse Osmosis
SWRCB	State Water Resources Control Board
TOC	Total Organic Carbon
UF	Ultrafiltration
UV	Ultraviolet
WPDP	Water Purification Demonstration Project

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Section 1 Introduction

The purpose of this proposal is to obtain concept approval from the California Department of Public Health for the City of San Diego's Indirect Potable Reuse / Reservoir Augmentation Project at San Vicente Reservoir. The project would supplement the roughly 240,000 acre-foot San Vicente Reservoir with up to 15,000 acre-feet per year of purified recycled water produced at the City's North City Water Reclamation Plant. The City understands that California Department of Public Health's concept approval would be specific to the proposed project at San Vicente Reservoir.

In 2007, the San Diego City Council called for a demonstration project that would assess the feasibility of full-scale Indirect Potable Reuse / Reservoir Augmentation. Under direction of the Mayor, the City's Public Utilities Department implemented the Water Purification Demonstration Project to achieve this objective.

The key regulatory authority to approve an Indirect Potable Reuse / Reservoir Augmentation (IPR/RA) project lies with the California Department of Public Health. A final decision by the City to implement a full-scale project will depend, in part, on obtaining concept approval from CDPH.

California Department of Public Health (CDPH) does not yet have formal regulations for IPR/RA. Therefore, this proposal consists of two elements. First, in Sections 1 through 6 the proposal presents the project and its regulatory setting, and the results and conclusions reached in the Water Purification Demonstration Project (WPDP). Second, in Section 7 this proposal presents a suggested regulatory framework of the City's IPR/RA project.

This proposal is organized into seven sections.

Section 1: Introduction

Section 2: Current Activities Supporting Implementation of the Project

Section 3: Need for the Project

Section 4: Regulatory Setting

Section 5: Components of the Full-Scale IPR/RA Project

Section 6: Public Health Protections Provided by the Full-Scale IPR/RA Project

Section 7: Elements of the Suggested Regulatory Framework

Section 2 Current Activities Supporting Implementation of the Project

Scientific research and engineering analyses have been conducted over the last two years as part of the City's WPDP, a phase of work designed to substantiate regulatory and economic feasibility and assess public acceptability of the full-scale project. The project includes the construction and operation of a 1 mgd advanced water purification demonstration facility (herein referred to as the demonstration facility) that uses the same feed water as will be used for a full-scale advanced water purification facility (AWPF). Detailed studies of the demonstration facility's performance are being conducted over the course of one-year of operation, including four quarterly reports on water quality.

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To date, three elements of the Water Purification Demonstration Project (WPDP) that are applicable to this concept proposal have been completed.

An assessment of the City's existing wastewater source control program, resulting in a review of City's industrial pretreatment requirements and identification of potential additional source control features to support an IPR/RA project.

Operation of the water purification demonstration facility built as part of the WPDP, which includes full-scale components of micro-filtration or ultra-filtration, reverse osmosis, and ultraviolet disinfection and advanced oxidation; plus testing and monitoring of the demonstration facility yielding first and second quarter reports.

The San Vicente Reservoir Hydrodynamic Study, including development of a 3-dimensional model to assess the reservoir's hydrodynamic responses.

2.1. Independent Advisory Panel

In addition to the above work elements, the National Water Research Institute (NWRI) has convened a ten-member Independent Advisory Panel (IAP) to support the City and regulators in assessing the results of the WPDP and the viability of a full-scale project. Through IAP meetings and project working group meetings, IAP members have been updated on the findings of the WPDP work elements. Feedback received from subsequent review meetings with the IAP has been incorporated into major project documents.

2.2. CDPH Participation

In March 2008, the City met with CDPH to discuss the scope and expectations of the WPDP. Based in part on CDPH input, a 1 mgd demonstration facility was constructed and the studies of San Vicente Reservoir were initiated. A cornerstone of the City's efforts has been keeping CDPH actively engaged throughout the project. California Department of Public Health staff members have been encouraged to attend IAP meetings and have been active participants in project working group meetings. Through these meetings, CDPH has reviewed reservoir technical studies and demonstration facility testing results that support the findings presented in this proposal.

2.3. Public Outreach

A comprehensive public outreach program is essential to moving past negative public perceptions associated with using purified recycled water for potable purposes. To move the public beyond these perceptions, a communication plan was prepared that outlines activities to encourage involvement among community leaders, stakeholders, and residents. Activities include a speakers bureau, developing written materials for English-speaking and non-English speaking audiences, stakeholder interviews, brochures, research surveys, videos, electronic updates, and a website. Tours of the demonstration facility are also available for an up-close experience of the treatment process. To date, more than 1,850 people have attended more than 145 tours.

Outreach efforts have garnered positive coverage both locally and nationally. On January 23, 2011, the San Diego Union-Tribune published an editorial in which the editorial board wrote that it had come to accept the science behind water purification technology and encouraged the rest of San Diego to do the same. Soon after this editorial there was a front page cover story in USA Today (March 3, 2011) and, most notably, an article on the cover page of the New York Times (February 10, 2012).

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As a result of this extensive outreach effort, public opinion polls show that strong opposition to indirect potable reuse dropped from 45 percent in 2004 to 12 percent in 2009 to 11 percent in 2011 [San Diego County Water Authority, 2011). The 2011 survey also found that 65 percent of respondents either strongly favored or somewhat favored advanced treated recycled water (referred to as purified water in the City's project) as an addition to the region's supply of drinking water – a dramatic increase over the results of the 2004 survey where only 26 percent of respondents indicated a favorable rating.

Section 3 Need for the Project

Even with aggressive conservation efforts, the City estimates it will need approximately 35 percent more water in 2030 than was required in 2010 (City of San Diego, 2010). For years, the City has attempted to diversify and enhance its existing water supply. The City's 2002 Long-Range Water Resources Plan (City of San Diego, 2002) identifies the need for the City to develop additional local water supply sources as a means of providing reliability and protection from water supply shortages.

In 2004, the San Diego City Council directed the City Manager to conduct a study to evaluate options for increasing the beneficial use of the City's recycled water. The Water Reuse Study (City of San Diego, 2006) found that the strategy of augmenting a local reservoir with purified water both "maximizes the use of the available recycled water supply" and provides the "lowest overall unit cost" of the reuse strategies that were evaluated. In October 2007, the San Diego City Council accepted the Water Reuse Study and recognized the North City-3 strategy, also known as San Vicente Indirect Potable Reuse, as their preferred alternative.

Reservoir augmentation using San Vicente Reservoir would enable the City to maximize available, but unused, recycled water produced at the NCWRP. Currently an average of 7,500 AFY of the recycled water produced at NCWRP is used for irrigation and industrial purposes; the remaining water produced at NCWRP is discharged to the ocean. Recognizing this loss of a valuable resource, the San Diego City Council, in September 2008, approved moving forward with the WPDP. In November 2008, the City Council approved a water rate increase to fund the WPDP.

Section 4 Regulatory Setting

Indirect potable reuse projects via groundwater recharge by surface spreading are generally covered under the California Code of Regulations (CCR), Title 22, Water Recycling Criteria, which enables CDPH to approve such projects on a case-by-case basis. California Department of Public Health has also drafted regulations specific to groundwater replenishment projects using both surface and subsurface applications. Although not adopted, the Draft Groundwater Recharge Regulations (CDPH, 2011; the latest release is dated November 21, 2011) have received substantial review and revision. These draft regulations provide a basis for CDPH to approve groundwater replenishment projects. Six groundwater replenishment projects have been approved over the years by CDPH based through a case-by-case review of each individual project. Currently, there are no existing or draft CDPH regulations that address indirect potable reuse using surface water augmentation.

In 1994, the City, in partnership with the San Diego County Water Authority, initiated a series of technical studies on indirect potable reuse. These included pilot testing of advanced treatment technologies and studies of reservoir hydrodynamics for the purpose of assessing the potential to augment San Vicente Reservoir with purified water from NCWRP (City of San Diego, 1996 and San Diego County Water Authority, 1994). In August 1994, based on a feasibility study submitted by the City, the California Department of Health Services (as CDPH was then called) issued conditional concept approval for that project (California Department of Health Services, 1994). Although deemed technically feasible, work on this "water repurification" project was discontinued in 1999.

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Prompted by the City's proposed "water repurification" project, the State of California assembled a blue ribbon panel to assess surface water augmentation. In 1996, the State Water Resources Control Board (SWRCB), in partnership with the California Department of Water Resources and the Department of Health Services, adopted a Framework for Indirect Potable Reuse via Surface Water Augmentation based on the recommendations of this blue ribbon panel (State Water Resources Control Board, 1996).

In 2003, a State Recycled Water Advisory Committee was convened to provide guidance in achieving the State's water recycling goals. One of the findings of the Advisory Committee was that, through a combination of previous research and policy direction (including the 1996 framework document), a sufficient basis was in place to enable the regulatory community to approve surface water augmentation projects. That basis included the then-applicable version of the Draft Groundwater Recharge Regulations.

In 2010, Governor Schwarzenegger signed into law SB 918, which requires CDPH to adopt uniform water recycling criteria for groundwater recharge by December 31, 2013, and for surface water augmentation by December 31, 2016 if a specified expert panel, convened pursuant to the bill, finds that the criteria would adequately protect public health.

Due to the unique project setting and features being proposed by the City, and the City's desire to make a decision on proceeding with a full-scale project by the end of calendar year 2012, CDPH is being formally requested to issue conceptual project approval based on this concept proposal and the scientific research being conducted as part of the City's WPDP.

Based on the State's 1996 framework document, CDPH's 2011 Draft Groundwater Recharge Regulations (specifically relating to subsurface application with full advanced treatment), and input provided by CDPH during the course of the WPDP, the following elements are expected to provide the framework for regulating the City's full-scale IPR/RA project:

- enhanced wastewater source control
- pathogenic microorganism control
- control of nitrogen compounds
- control of regulated contaminants, monitoring of additional chemicals and contaminants, and control of total organic carbon
- reliability and redundancy
- monitoring and response plan consisting of
    - AWPF integrity monitoring
    - San Vicente Reservoir retention and blending
    - mitigation of an AWPF system failure by San Vicente Reservoir

The following sections describe full-scale project components and address how the City's proposed project will meet the above provisions.

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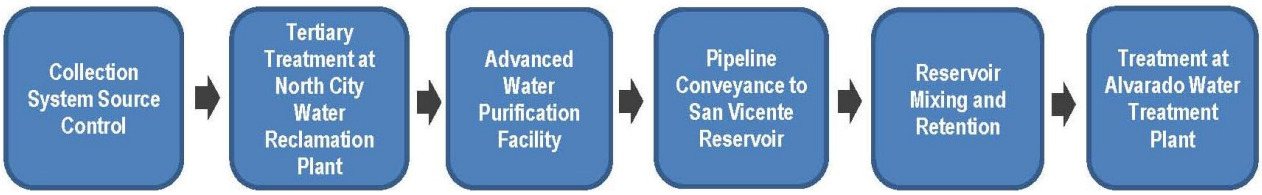
Section 5 Components of the Full-Scale IPR/RA Project

The components of the City's full-scale IPR/RA project are shown in the schematic and described in more detail below.

Components of the Full-Scale IPR/RA Project



5.1. Existing Wastewater Source Control Program

The City maintains a comprehensive industrial pretreatment and source control program approved by the U.S. Environmental Protection Agency for control of waste discharges from industrial sources into the wastewater collection system. The City is responsible for water quality sampling and monitoring the entire wastewater system through treated effluent to fulfill the requirements of its National Pollutant Discharge Elimination System (NPDES) permits issued by the San Diego Regional Water Quality Control Board. The main components of the industrial pretreatment and source control program are

- grant and manage industrial user permits;
- establish sampling, analysis, reporting, record keeping, and notification requirements;
- perform inspections and monitor discharges; and
- enforce limits and authorize penalties for discharge violations.

The program organizes all industrial users into 27 sewersheds throughout the City, four of which cumulatively correspond to the area upstream of NCWRP. Because the full-scale AWPF will be located at NCWRP, these already-established sewersheds will ease the implementation of any enhanced source control practices that may apply specifically to industrial dischargers upstream of the full-scale project. At present there are 198 industries with industrial user permits in the NCWRP drainage area, 102 of which are research and development companies. The remaining 96 industries cover 49 different industry types including car washes, gas stations, electronic equipment manufacturers, and veterinary services.

5.2. North City Water Reclamation Plant

The NCWRP is a 30-mgd water reclamation plant serving roughly 7,500 AFY of recycled water to irrigation and industrial customers throughout the North City area. NCWRP operates as a scalping plant, receiving flows that would otherwise be treated at the Point Loma Wastewater Treatment Plant (PLWTP). As such, flows can be diverted at any time from NCWRP and sent to PLWTP. Biosolids are sent offsite for processing, with no return flow to NCWRP.

NCWRP consists of primary sedimentation, secondary aeration with full nitrification and partial denitrification, secondary clarification, deep bed anthracite filtration, and chlorine disinfection. Although chlorine disinfection is provided to meet the requirements specified in the Water Recycling Criteria for the current nonpotable uses of the recycled water, to control formation of trihalomethanes flows supporting the IPR/RA project would be diverted to the AWPF prior to chlorine disinfection.

The facility operates as a scalping plant, with flow equalization facilities mitigating impacts from diurnal flow variations, supporting a stable biological process. All waste streams are sent offsite to PLWTP for disposal.

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Aerial of NCWRP

5.3. Advanced Water Purification Facility

The City proposes to build an 18-mgd capacity AWPF meeting the requirements stipulated in the pending draft CDPH groundwater recharge regulations for subsurface application. The demonstration facility, being operated as part of the WPDP, has validated the performance of standard AWPF technologies at full-scale on NCWRP tertiary filter effluent.

The full-scale facility will have the following main process components.

Membrane filtration Tertiary effluent will flow to a low pressure membrane filtration process consisting of either microfiltration (MF) or ultra-filtration (UF). In addition to minimizing reverse osmosis fouling by removing colloidal and suspended particles, low pressure membranes provide a barrier to a wide array of microbes and will assist in meeting the project's microbial removal targets.

Reverse osmosis All AWPF flow will receive reverse osmosis (RO) treatment, the primary barrier to organic chemicals. The RO system will meet the applicable salt rejection specification established by CDPH. Permeate from the RO system will flow to AOP, while concentrated brine from the RO system will be discharged back to the sewer (downstream of the diversion to NCWRP).

Disinfection, photolysis, and advanced oxidation The advanced oxidation (AOP) step, as it is referred to in the City's project, actually serves three purposes. High intensity UV irradiation provides the primary disinfection step in the AWPF. High intensity UV irradiation also provides photolysis of certain classes of organic chemicals such as NDMA. With the addition of hydrogen peroxide, high intensity UV provides an additional barrier to oxidizable contaminants. The AOP

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process will be designed to adhere to the criteria for advanced oxidation established in the Draft CDPH GWR regulations.

Although the City has tested UV as the primary source of disinfection and advanced oxidation, it is recognized that ozone is also being considered in certain IPR projects. While the City is not proposing to use ozone at this time, it may be considered as this project moves into the facility planning and design phase.

Reverse Osmosis Membranes at the Demonstration Facility

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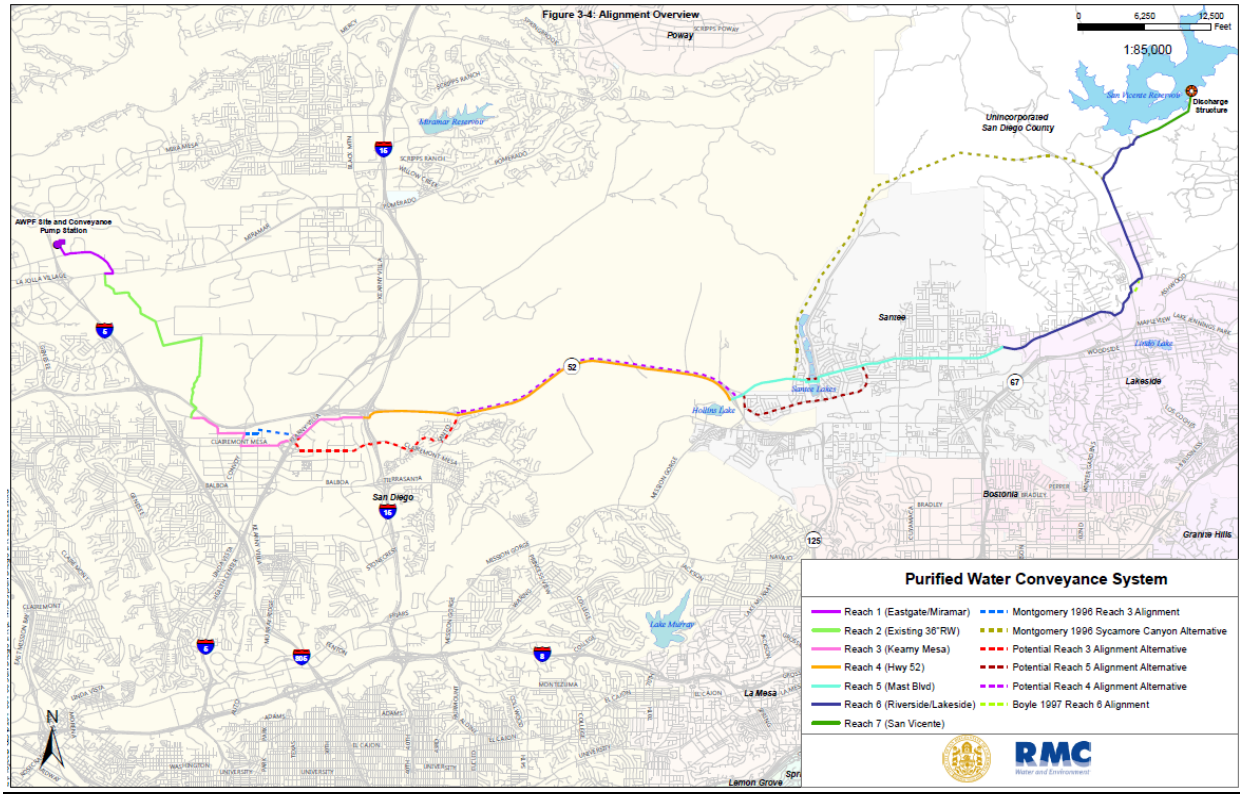
5.4. Purified Water Conveyance to San Vicente Reservoir

Purified recycled water will be pumped through a 23-mile, 36-inch diameter pipeline to San Vicente Reservoir. The static lift from the purified water pump station at the AWPF to San Vicente Reservoir is about 445 feet. A flow control structure at the reservoir outlet and surge control facilities will be required to optimize flow conditions in the pipeline.

The travel time of the purified water from the pumping station to the reservoir discharge structure is approximately 10 hours, based on a maximum pumping rate of 18 mgd. Should there be an operation malfunction at the AWPF, this would allow time to interrupt conveyance before any affected water reaches the reservoir. The pipeline could then be used to hold the affected water while the situation is assessed and resolved based on an approved response plan. The pipeline will be designed so that, if necessary, the entire volume of the pipeline could be drained to a local sanitary sewer via dedicated infrastructure; thus, off-specification water would be sent to the PLWTP.

Potential Alignments of the Conveyance Pipeline



5.5. San Vicente Reservoir

San Vicente Reservoir is located approximately 25 miles northeast of San Diego. The dam was built in 1945. It impounds San Vicente Creek, a tributary of the San Diego River. The dam and reservoir is owned and operated by the City's Public Utilities Department. San Vicente Reservoir impounds local runoff from its 75 square-mile catchment, stores water transferred from Sutherland Reservoir, and stores water imported from the Colorado River and northern California. The reservoir's dominant use is municipal water supply; all other uses of the reservoir are subordinate to water supply. The reservoir also supports limited recreational activities including boating, fishing, and water skiing, although these activities have been suspended during construction of facilities to raise San Vicente Dam. As part of the

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San Diego County Water Authority's (SDCWA) Emergency Storage Project, San Vicente Reservoir is being enlarged (i.e., the dam is being raised) from its historical size of 90,000 AF to 247,000 AF. Construction of the expansion is scheduled to be complete by 2013, with refilling expected to take a few years depending on availability of imported water. The City and SDCWA will share storage capacity in the reservoir. The Emergency Storage Project provides local reservoir storage and pipeline connections to serve the region should the imported water supply be disrupted. The enlarged reservoir will be substantially filled prior to initiation of the full-scale IPR/RA project.

With the full-scale IPR/RA project, the City is proposing to augment water stored in San Vicente Reservoir with purified water from the AWPF. The full-scale IPR/RA project will place an annual average of 15,000 AF of purified water into the reservoir. There will be seasonal variation in the inflow of purified water due to non-potable demands at NCWRP, with winter monthly average inflows as high as 18 mgd and summer monthly average inflows as low as 9.5 mgd. The City will have the flexibility to fill San Vicente Reservoir using other water sources, such as local runoff and imported water. After implementation of the full-scale IPR/RA project, the reservoir will continue to store local runoff, imported water, and water transferred from Sutherland Reservoir. Purified water will blend with these other waters and will, in essence, substitute for a similar amount of imported water.

Generally, San Vicente Reservoir provides a substantial retention time for the purified water prior to conveyance to the potable water treatment plant. Based on an average 19,000 AFY reservoir withdrawal and an average reservoir volume of 155,000 AF (based on SDCWA preliminary SVR operations plan), the theoretical average purified water retention time in the reservoir would be on the order of eight years. It should be noted that during the winter months when destratification of the reservoir occurs portions of the purified water inflow will not be retained for this long. During this destratified period, however, the reservoir - and the purified water inflow - undergoes substantial mixing, essentially diluting purified water with the full volume of water in the reservoir. This hydrodynamic effect is further discussed in Section 6.

All operations of San Vicente Reservoir are fully in control of the City. Outflow from the reservoir and inflows to the reservoir (other than runoff) are controlled by the City. There are no releases from the reservoir to the natural stream system downstream. All outflows from the reservoir are pipeline conveyances to the municipal water system. The City has the ability to shut off outflow from the reservoir at any time without disrupting supplies to the municipal system.

San Vicente Reservoir

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5.6. Alvarado Water Treatment Plant

Under normal operations water withdrawn from San Vicente Reservoir is conveyed to the City's 200-mgd Alvarado Water Treatment Plant, which serves the central portion of the City. The plant has recently been upgraded to meet federal Safe Drinking Water Act requirements. The Alvarado Water Treatment Plant is a conventional water treatment facility using ozone as a disinfectant. The filtration and disinfection achieves a minimum 3-log *Giardia* cyst reduction and 4-log virus reduction.

The Alvarado Water Treatment Plant has multiple sources of supply. There are direct connections to the SDCWA's First and Second Aqueducts, which carry imported water. The City's El Monte Pipeline carries combined flows from El Capitan Reservoir and San Vicente Reservoir – the plant can receive water from either of these reservoirs or a blend from both reservoirs. Water can be pumped to the plant from Lake Murray, which is immediately adjacent. Each of these sources is at the immediate control of the plant operator, an any of these sources can be shut off without disrupting the Alvarado Water Treatment Plant's capacity or its ability to supply the distribution system. Thus, should San Vicente Reservoir need to be taken offline for any reason, the Alvarado Water Treatment Plant's full demand can be served by the other sources.

Through agreements with SDCWA, a portion of San Vicente Reservoir's storage may be used in emergency and extended drought conditions to supply water treatment plants serving the southern half of San Diego County. In an emergency event, other plants that could be supplied from San Vicente Reservoir are the City's Miramar and Otay Water Treatment Plants, the Helix Water District's Levy Treatment Plant, the Sweetwater Authority's Purdue Water Treatment Plant, and the Santa Fe Irrigation's Districts Badger Water Treatment Plant. Each of these is a full conventional treatment plant achieving virus and *Giardia* reductions comparable to those achieved at the Alvarado Water Treatment Plant.

Alvarado Water Treatment Plant

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Section 6 Provision of Public Health Protections by the Full-Scale IPR/RA Project

San Diego's full-scale IPR/RA Project will adhere to the multi-barrier concept that is fundamental to the provision of public health safeguards in IPR projects. The regulatory discussion in Section 5 introduced the elements that are necessary to ensure that public health protections are provided by the full-scale IPR/RA Project, consisting of:

- enhanced wastewater source control
- pathogenic microorganism control
- control of nitrogen compounds
- control of regulated contaminants, monitoring of additional chemicals and contaminants, and control of total organic carbon
- reliability and redundancy
- monitoring and response plan consisting of
    - AWPF integrity monitoring
    - San Vicente Reservoir retention and blending
    - mitigation of an AWPF system failure by San Vicente Reservoir

The following sections describe these provisions in more detail.

6.1. Enhanced Wastewater Source Control

The City's existing wastewater source control program will be expanded to support the IRP/RA project. The City has conducted discussions with Orange County Sanitation District (OCSD) who, as a project co-sponsor with Orange County Water District (OCWD), provides source water for the Ground Water Replenishment System (GWRS). The intent of the discussions was to identify additional applicable source control strategies that would enhance the City's existing program in an IPR setting.

The City's source control program and that of Orange County are similar. Both programs strive to prevent adverse impacts on the treatment facilities and the environment in compliance with state and federal requirements for industrial pretreatment programs. The City recognizes that the OCSD program serves as a model of an expanded source control program that includes contaminants that may be harmful to human health and drinking water supplies in compliance with CDPH goals for IPR projects. As an example, OCSD's enhanced source control program controls NDMA through the following actions.

Incorporate monitoring requirements for NDMA in industrial permits which have the potential to discharge a significant amount of NDMA. This is known as local limit monitoring.

Establish voluntary BMPs for NDMA discharges.

Monitor for NDMA at low concentrations (at least parts per trillion), and do this monitoring at least quarterly. Both OCSD and OCWD independently monitor the GWRS influent (secondary effluent). The GWRS influent and purified recycled water is monitored by OCWD at low detection levels (parts per trillion) on a weekly basis. Close communication between OCSD and OCWD is maintained, particularly if any unusual NDMA spikes are detected.

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In the case that an unusual NDMA spike is detected, OCSD uses its geographic information system database to identify potential dischargers upstream of the sampling site. This ability to identify upstream dischargers improves response time and the overall effectiveness of the program.

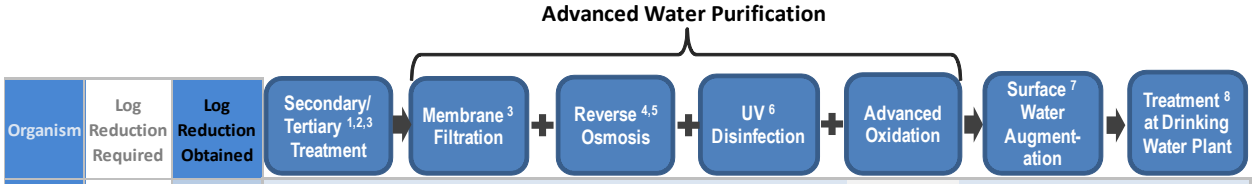
The City recognizes the preponderance of pharmaceutical research in the NCWRP sewershed. As such, the enhanced wastewater source control program will include specific strategies for pharmaceutical manufacturers. The City currently prohibits discharges of any pharmaceutical manufacturing products or wastes, including incidental wash water or other pharmaceutical residues, to the sewer. Among the strategies that may be added to expand the wastewater source control program are measures such as requiring pharmaceutical manufacturers to report the pharmaceutically-active ingredients in their products, the volume of product they produce annually, the volume of wastes generated, and the disposed methods for the wastes. The City intends to submit a robust source control program for CDPH's review as part of the formal permitting process.

6.2. Pathogenic Microorganism Control

Pathogen removal is one of the key criteria for IPR projects. The November 21, 2011 draft groundwater recharge regulations require a total of at least 12-log enteric virus, 10-log *Giardia* cyst and 10-log *Cryptosporidium* oocyst reduction from raw sewage to drinking water (i.e., to the potable water distribution system). San Diego's full-scale IPR/RA Project can easily meet these removal goals.

The figure below illustrates the theoretical pathogen log reduction provided by the San Diego IPR/RA project. In addition to the removal that occurs at the AWPF, there are multiple barriers for pathogen removal, including at least 2-log reduction at NCWRP, 2-log reduction at San Vicente Reservoir, and 2-log reduction of *Cryptosporidium* and 4-log reduction of viruses at the surface water treatment plant.

Pathogen Removal in the City's IPR/RA Treatment Process



Organism	Log Reduction Required	Log Reduction Obtained	Secondary/ Tertiary 1,2,3 Treatment	Membrane 3 Filtration	Reverse 4,5 Osmosis	UV 6 Disinfection	Advanced Oxidation	Surface 7 Water Augment-ation	Treatment 8 at Drinking Water Plant
Cryptosp-oridium	10	**18**	2	4	2	6		2	2
Giardia	10	**19**	2	4	2	6		2	3
Viruses	12	**16**	2	0	2	6		2	4

1 Water Reuse Issues, Technologies, and Applications, Takashi Asano, et al., 2007

2 A Guide to Waterworks Design, Saskatchewan Ministry of Environment, January 2008

3 California Surface Water Treatment Rule Alternative Filtration Technology Summary, CDPH DDWEM Technical Programs Branch, August 2011

4 Study of Wastewater Reclamation Using Backwashable Capillary Ultrafiltration And Encapsulated Reverse Osmosis Membrane Modules, Hydranautics, June 1999

5 Reverse Osmosis and Nanofiltration, American Water Works Association and Robert Bergman, October 2007

6 Demonstration of UV Disinfection and Oxidation - System Performance Validation Report, Orange County Groundwater Replenishment System, July 2004

Australian Guidelines for Water Recycling: Managing Health and Environmental Risks - Augmentation of Drinking Water Supplies, 2008, Table 4.9

7 Water Purification Demonstration Project: Limnology and Reservoir Detention Study of San Vicente Reservoir - Hydrodynamic Modeling Study, Flow Science, Inc., November 22, 2011

8 Long Term 2 Enhanced Surface Water Treatment Rule, USEPA, January 2006

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While not necessary, it may be possible for the project to increase its log reduction credits. For example, integrity testing procedures such as the TRASAR testing used to obtain credit for membrane filtration may become available for RO. Also, advanced oxidation provides yet another microbial barrier that is not accounted for in figure above.

Under normal operation, the project benefits from the advanced disinfection technologies provided by the Alvarado Water Treatment Plant. However, it is noted that all the potable water treatment plants that could potentially receive water from San Vicente Reservoir are required to operate with a minimum removal credit of 4 logs for viruses and 2 logs for *Cryptosporidium*. Therefore, during emergency and extreme drought scenarios when San Vicente Reservoir water may be diverted to other surface water treatment plants, the log removal credits will easily be met.

6.3. Control of Nitrogen Compounds

The secondary treatment process at NCWRP fully nitrifies and partially denitrifies. Coupled with RO at the AWPF, purified water is expected to easily meet the CDPH standard for total nitrogen for direct injection IPR projects of 5 mg/L. Based on First and Second Quarter AWPF Monitoring Reports, AWPF product in a full-scale facility would have total nitrogen of less than 1 mg/L.

6.4. Regulated Contaminants, Additional Chemicals and Contaminant Monitoring, and Total Organic Carbon Control

Based on the results from the water quality monitoring during the first six months (i.e., the first and second quarterly sampling results), the purified water met all drinking water standards that exist for the protection of human health (CDM, 2012). The standards include primary and secondary drinking water standards, disinfection by-products, and notification levels.

Primary drinking water standards Purified water met all primary standard criteria for all 91 pollutants, most measurements were below detection limits.

Secondary drinking water standards All 15 parameters were in compliance with the secondary standard, all below regulated levels.

Disinfection byproducts Disinfection byproduct levels were below regulatory requirements for drinking water.

Notification Levels All compounds were below drinking water notification levels.

Overall, the purified water met all treatment goals for the demonstration project. These goals were based on a combination of CDPH's November 2011 draft groundwater recharge regulations and RWQCB's Water Quality Control Plan for the San Diego Region (aka the Basin Plan).

CECs include currently-used pesticides, industrial chemicals, endocrine disrupting compounds, and pharmaceuticals and personal care products. The "Final Report Monitoring Strategies for CECs in Recycled Water, Recommendations of the Science Advisory Panel" (State Water Resources Control Board, 2010) recommended monitoring indicator compounds based on toxicological relevance (NDMA, 17 beta-estradiol, caffeine, and triclosan) and process performance indicators (DEET [N,N-diethyl-meta-toluamide], gemfibrozil, iopromide, and sucralose) in groundwater recharge projects. While the SWRCB report did not address surface water augmentation projects, this same monitoring program has been applied to the demonstration facility. Of the 91 chemicals of emerging concern monitored at the

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demonstration facility, all were non-detectable with the exception of low level detections of six compounds (theobromine, oxolinic acid, iohexal, diethanolamine, acesulfame-k, and triclosan). The results of the initial monitoring at the demonstration facility will be used to develop a customized monitoring program for chemicals of concern for the full-scale IRP/RA Project.

Total organic carbon (TOC) is an indicator of treatment process performance and can be used as a surrogate for the potential of a water supply to form disinfection byproducts. The purified water TOC and total disinfection byproducts were substantially lower than the imported water supply, and the TOC was consistently less than the target of 0.5 mg/L.

The testing indicated that NDMA concentrations were below the reporting limit of 2 ng/L.

Of the constituents in purified water measured at detectable and reportable levels, nearly all were present at lower concentrations than in the untreated imported water brought into the San Diego region.

6.5. Reliability and Redundancy

As a scalping plant, the NCWRP can go offline at any time either by ceasing diversion from the sewer or diverting off-specification product back to the sewer for treatment at PLWTP. The full-scale AWPF will also have the capability to go offline by ceasing to receive tertiary water from NCWRP or diverting off-specification water back to either the NCWRP head works or to the sewer for treatment at PLWTP. A variety of on-line monitoring techniques will be employed as noted in the next section.

Additionally, the Alvarado Water Treatment Plant is capable of receiving its full water demand from several other water sources that are not connected to San Vicente Reservoir. In the case of an extended discharge of off-specification purified water that would cause San Vicente Reservoir to exceed acceptable source water quality, it will be possible to discontinue San Vicente Reservoir draw to Alvarado Water Treatment Plant and use the other sources until the problem is resolved.

6.6. Monitoring and Response Plan

CDPH has included a response retention time requirement in its Draft Groundwater Recharge Regulations to address potential treatment failures. While this requirement is applicable to plug flow conditions found in groundwater recharge systems that produce water of drinking water quality, it is not amenable in a raw water reservoir setting where inflows mix through the entire reservoir during the critical winter destratified condition, and is subjected to subsequent surface water treatment with additional microbial and organic chemical removal capabilities. Although during most of the year substantial retention is provided by the reservoir, the predominant value of a large reservoir is the mixing and dilution that is achieved prior to withdrawal and conveyance to downstream water treatment.

For an IPR / reservoir augmentation setting, a monitoring and response plan needs to mitigate two types of hypothetical “treatment failures.”

<u>AWPF Malfunction</u> This hypothetical event is characterized as a malfunction of a process or processes at the AWPF. As a worst case, this event would allow filtered NCWRP effluent to flow into the purified water conveyance pipeline. As noted, the purified water conveyance pipeline would provide up to 10 hours to identify a malfunction, validate the malfunction, and stop flows in the conveyance pipeline before the off-specification water would be released into San Vicente Reservoir. If necessary, water in the conveyance pipeline could be diverted into the sanitary sewer system. The City’s strategy to address this type of an event is keyed to AWPF integrity monitoring, and is discussed in Section 7.6.1 below.

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AWPF Source Water Excursion This hypothetical event is characterized as an elevated level of a constituent of concern in the source water to the AWPF, while the AWPF is operating as designed. This elevated level of constituent of concern would be identified during the routine periodic comprehensive water quality monitoring performed on the AWPF product. The size, mixing, and dilution capacity of San Vicente Reservoir enables the City to address this type of treatment failure, as described in Section 7.6.2 below.

6.6.1. AWPF Integrity Monitoring

The ability of the combination of MF, RO and AOP technologies to remove microbial and chemical contaminants from recycled water is well-established. The demonstration facility currently being tested using NCWRP filter effluent will provide further evidence of the capabilities of these technologies to purify the water that will be used for the full-scale IPR/RA Project. The AWPF will be fully capable of producing water that meets all applicable standards. The questions that must be addressed are: What happens if the plant is not operating properly? How long would it take to respond and correct an operational problem at the plant? What is the relative risk to the public attributable to an operational problem at the plant?

As part of the demonstration project, a Critical Control Point (CCP) monitoring plan for the AWPF is being prepared with input from both the IAP and regulators. It is anticipated that the CCP monitoring plan will be similar to the CCPs specified in the GWRS Operation, Maintenance, and Monitoring Plan, which has been approved by CDPH. The plan will be validated through water quality testing of the demonstration facility at various points along the treatment process. The main purpose of CCP monitoring plan is to provide a systematic approach for applying tools, techniques, and practices to monitor and maintain the integrity of the various AWPF unit processes. The following are key components of the CCP monitoring plan.

- Baseline performance of each unit process under “intact” conditions will be confirmed and established prior to start–up.
- Continuous verification of integrity will be maintained throughout the operational period.
- On-going maintenance and operational practices to mitigate integrity breaches will be implemented on all unit processes.
- The integrity data will be recorded and analyzed.
- Measurable performance criteria will be developed along with action plans to respond to changes in performance due to breaches in integrity.

The main feature of the CCP monitoring will be online (i.e., continuous and real-time) monitoring, online feedback, daily water quality verifications, and automatic control of the system to ensure each system unit is functioning properly. The current monitoring strategy at the demonstration facility has the following components.

- Monitoring of membrane filtration with daily pressure decay tests, bacterial analysis, and online turbidity.
- Monitoring of reverse osmosis with online TOC and online electrical conductivity. Ultra Violet transmittance is also an indication of RO performance.
- Monitoring of advanced oxidation with online UV transmittance, online power draw, and verification of hydrogen peroxide flow.

With appropriate alarms and shutoff mechanisms keyed to these on-line monitoring techniques, it is anticipated that one would know within minutes if there was a problem with system performance at the

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AWPF. Response to events could range from heightened scrutiny of operating performance to diverting the purified water to the NCWRP headworks or sewer until the problem was isolated and corrected.

As noted, the travel time of the water from the AWPF pumping station to San Vicente Reservoir outlet structure through the conveyance pipeline is approximately 10 hours. If a treatment failure occurred and purified water was for some reason not immediately diverted, there would still be time to stop conveyance of the affected water to the reservoir. The pipeline could then be used to hold the affected water while the situation is monitored and resolved in consultation with CDPH. If necessary, the entire volume of the pipeline could be drained to sanitary sewer via dedicated infrastructure. These drains would be in the overall sewershed of the PLWTP; thus, all off-specification water retained in the pipeline would be sent to the PLWTP.

During the design phase of this project, the City would develop an AWPF on-line monitoring and response plan that provides sufficient features and assurances to demonstrate that any foreseeable AWPF malfunction could be identified and responded to, via product water diversion or other appropriate remedy, within the conveyance time afforded by the purified water conveyance pipeline. Design features would be incorporated into the purified water conveyance pipeline design to drain off-specification water away from the reservoir and to the sewer.

6.6.2. San Vicente Reservoir Retention and Blending

The primary purpose of including San Vicente Reservoir in the full-scale IPR/RA project is to provide substantial retention and blending of purified water in a natural setting prior to delivering it to a water treatment plant for final treatment and distribution. In other words, the reservoir acts as an environmental buffer to significantly dilute any constituents that may be conveyed to the reservoir with the purified water. In the event of a treatment failure not detected by on-line monitoring, such as a source water excursion, San Vicente Reservoir would protect the downstream water treatment plant from receiving compromised source water.

One of the key characteristics of San Vicente Reservoir is the presence of distinct density stratification - a thermocline - separating the epilimnion (the top-most layer in a stratified reservoir) from the hypolimnion (the dense, bottom layer in a stratified reservoir) throughout much of the year. Density stratification persists for about ten months of every year. The consistent and predictable density stratification of San Vicente Reservoir is demonstrated by monitoring data spanning twenty-two years. During the period of stratification, warm light water - and associated constituents - in the epilimnion does readily not mix with the colder heavier water in the hypolimnion. The purified water inflow will be at the surface, and the purified water itself is warm and light; thus, the inflowing purified water will remain in the epilimnion. Outflows from the reservoir are typically deep. This provides is a substantial barrier to short-circuiting of purified water throughout the period of stratification. For a short period each year San Vicente Reservoir loses stratification (i.e., mixes top to bottom). This loss of stratification occurs during winter when the epilimnion cools and water temperature throughout the reservoir equalizes. The fully destratified condition lasts for a few weeks to a month and typically happens in January, February, or March. During the destratified period the reservoir becomes fully mixed, with incoming purified water flows mixing with the entire reservoir volume prior to reaching the reservoir outlet. This mixing and associated dilution would attenuate any AWPF source water excursion or unforeseen extended AWPF malfunction.

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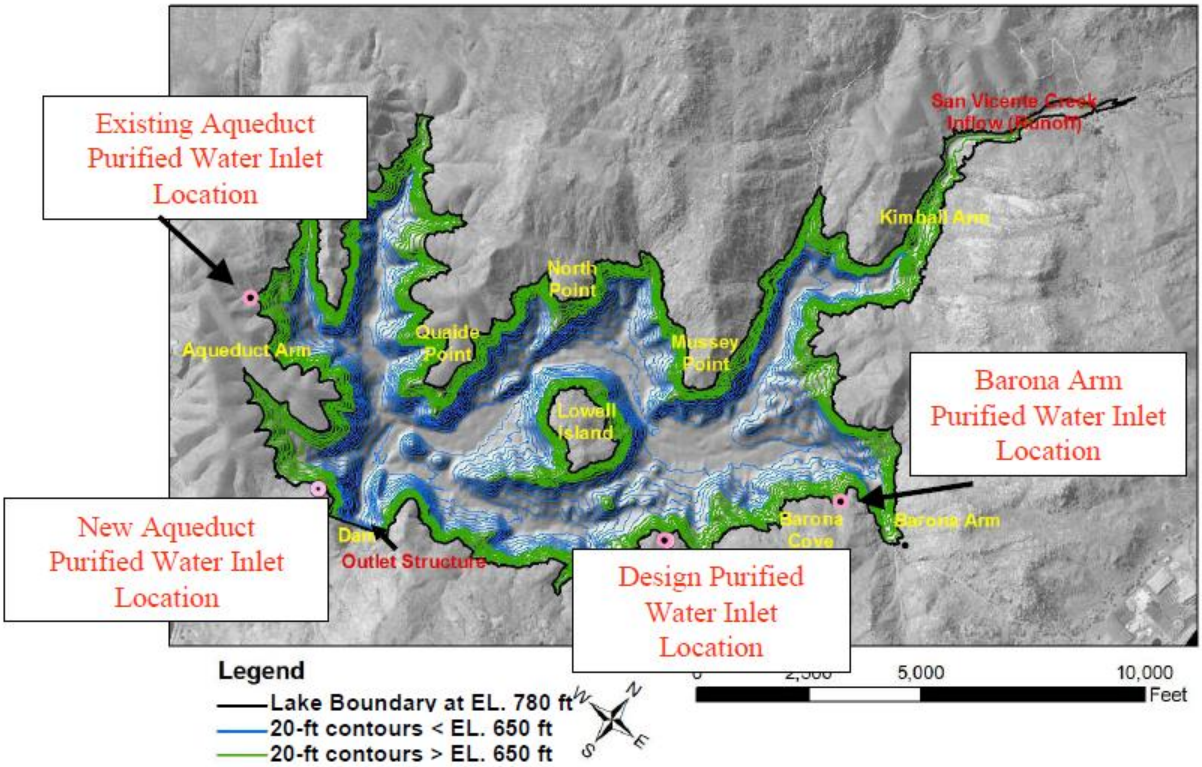
As part of the demonstration project, a three-dimensional model of San Vicente Reservoir was developed to evaluate the hydrodynamic and water quality effects of augmenting the reservoir wit purified water (Flow Science, 2010). The model was used to predict residence time, blending, and dilution that will occur over a range of reservoir operating conditions (Flow Science, 2011). The modeling scenarios vaired the following reservoir characteristics.

- Reservoir operations with and without the addition of purified water.
- Operating the reservoir in normal years, over an extended drought, and during an emergency drawdown.
- Introducing purified water into the reservoir in one of four different inlet locations.

Modeled Inlet Locations



The model was calibrated using real-world monitoring data, and validated using field tracer work conducted in the 1990's. The model was then used to simulate eight reservoir operating scenarios. In each of these simulations, various hypothetical tracers were added to the purified water inflow to illustrate the transport, mixing, and dilution of constituents carried with the purified water. In particular, decaying tracers (decay rate of 1 log per month, i.e., a reduction in concentration by a factor of 10 per month) were used to study the dilution and inactivation of potential pathogens entering the reservoir and to evaluate the ability of the reservoir to reduce pathogen concentration before they reach the reservoir outlet. Non-decaying tracers were used to simulate chemical constituents. In all simulations, tracers were added to the reservoir's inflow over a 24-hour period, which is analogous to simulating the reservoir's response to a system failure at the AWPF which leads to the release of off-specification product to the reservoir for a full day. This 24-hour tracer release period was an assumption to support reservoir modeling, and is not related to an hypothetical treatment failure duration.

The IAP reviewed the development and validation of this model and concluded that the model "is a robust tool for simulating reservoir performance" (NWRI, 2010) and "the modeling effort has resulted in an

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effective and robust model that the City can use to assess the hydrodynamic response of the reservoir" (NWRI, 2012).

There are four key findings of the 3-dimensional hydrodynamic modeling study.

- The addition of purified water into the reservoir does not impact the duration or strength of stratification.
- San Vicente Reservoir provides a substantial barrier to pathogenic organisms due to natural features including photolysis, temperature, and natural predation. Using CDPH's virus reduction metric of 1 log/month in a groundwater setting (this assumption was approved by IAP as reasonable, albeit conservative), San Vicente Reservoir provides greater than 6-log virus reduction for the ten months of each year the reservoir is stratified, and at least a 2-log virus reduction during the destratified portion of the year.
- For all anticipated reservoir operational scenarios and purified water inlet locations, including emergency drawdown and extended drought scenarios, at all times the reservoir provides at least a 200:1 dilution of a 24-hour purified water release event prior to withdrawal from the reservoir.
- During typical operations and using the inlet location currently under consideration (referred to in reservoir hydrodynamic modeling as "design inlet location"), the reservoir provides greater than 2000:1 dilution of a 24-hour purified water release event prior to withdrawal from the reservoir.

6.6.3. Mitigation of a Treatment Failure by San Vicente Reservoir

San Vicente Reservoir provides safety features for both types of hypothetical "treatment failures" in an IPR/RA setting. This mitigation is provided by substantial retention and mixing during the stratified (predominant) portion of the year, and by mixing and dilution during the destratified (lesser) portion of the year.

<u>AWPF Malfunction</u> As noted, the City will develop a plan to identify and respond to an AWPF malfunction using a combination of treatment process integrity and on-line monitoring, plus the travel time in the purified water conveyance pipeline. The reservoir provides a backup protection should that AWPF malfunction last longer than 10 hours. As described above, the minimum dilution a 24-hour release of AWPF flow would undergo in the reservoir prior to withdrawal and conveyance to a downstream water treatment plant is 200:1. This means that in order for a chemical constituent of concern with acute health implications to impair San Vicente Reservoir as a raw water source, the concentration of that constituent over the 24 hour period would need to be in excess of 200 times the applicable MCL or notification level. In reviewing the results of tertiary effluent monitoring at NCWRP over the last several years, there is no monitored chemical constituent that approaches this level.

<u>AWPF Source Water Excursion</u> The primary benefit of the reservoir would be to retain and dilute an extended discharge of a constituent due to its elevated level in the wastewater source to the AWPF, while the AWPF is operating as designed. This benefit can be quantified in terms of mixing and dilution that would be provided by the reservoir during an extended "event." Assuming a monthly comprehensive water quality monitoring frequency, and a second month to identify and respond to a water quality excursion, a hypothetical elevated constituent discharge might occur for up to 60 days before corrected. Assuming the reservoir is a nominal 175,000 AF, for an 18 mgd discharge (highest flow being proposed), it would require that an acutely toxic contaminant level being discharged over that 60 day period (having undergone full AWPF) would need to be roughly 50 times greater than the applicable MCL or notification level to impair the reservoir as a raw water source. This is obviously a highly unlikely scenario.

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These scenarios illustrate that implementation of AWPF integrity monitoring combined with the volume and mixing capability in San Vicente Reservoir provides a robust combination of reliability features, assuring that IPR/RA can be implemented at San Vicente Reservoir in a safe and reliable manner.

Section 7 Elements of the Suggested Regulatory Framework

Sections 1 through 6 describe the many studies the City has conducted to assess the potential of blending purified water from the NCWRP into San Vicente Reservoir while maintaining adequate and redundant public health safeguards. The results of these studies have been affirmed by an Independent Advisory Panel and reviewed by the California Department of Health Services. Based on this body of work, and the successful operation of potable reuse projects elsewhere in California, the following elements are offered for CDPH's consideration in establishing the regulatory framework for this project.

- Wastewater source control
  - Establishment of an enhanced source control program for the NCWRP service area similar to that established for Orange County's Groundwater Replenishment System (GWRS) project
- At the North City Water Reclamation Plant (NCWRP)
  - Flow equalization to deliver a constant flow to the AWPF
  - Achievement of full nitrification in the secondary aeration process
  - Operation with no return flows from biosolids processes (biosolids from NCWRP are processed off-site)
  - Tertiary filtered effluent will be the source water for the AWPF
- At the Advance Water Purification Facility (AWPF)
  - Treatment of entire flow stream with reverse osmosis (RO) meeting applicable CDPH specifications and performance measures
  - Treatment of entire flow stream with advanced oxidation (AOP) meeting applicable CDPH specifications and performance measures
  - Implementation of a Critical Control Point Monitoring Plan that includes surrogate indicators recommended by the industry at time of implementation
  - Ability to identify a potential treatment malfunction (based on CDPH-approved on-line process performance monitoring systems), validate that malfunction, and divert AWPF product from the conveyance pipeline in less time than the retention time provided by the conveyance pipeline prior to release to the reservoir (minimum travel time for San Diego project is 10 hours)
  - Certified operator on-site at all times (24 hours/day)
- At San Vicente Reservoir
  - A 12-month theoretical hydraulic retention will be maintained in the reservoir at all times
  - Location of the purified water inflow and the reservoir outflow such that short-circuiting of purified water from the inlet to the outlet is minimized
  - Minimum dilution of purified water with ambient reservoir water, at the outflow, of 100:1 to be maintained at all times
  - Criteria to minimize short circuiting and the criteria for dilution of purified water at the outflow [i.e., the second and third criteria above] to be demonstrated using a calibrated and validated hydrodynamic model

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- Purified water will be discharged above the thermocline, and withdrawals will be below the thermocline, when a thermocline is present
- Water from reservoir to be treated at a full conventional water treatment plant before distribution as potable water
- Ability to take the reservoir offline as a source of supply to the municipal water system within 24 hours to be maintained at all times

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Appendix B: California Department of Public Health Concept Approval Letter

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State of California—Health and Human Services Agency
California Department of Public Health

RON CHAPMAN, MD, MPH
Director & State Health Officer

EDMUND G. BROWN JR.
Governor

September 7, 2012

Roger S. Bailey
Director, Public Utilities Department
City of San Diego
9192 Topaz Way, MS 901
San Diego, CA 92123

Marsi Steirer
Deputy Water Department Director
City of San Diego
600 B Street, 13th Floor
San Diego, CA 92101

Dear Mr. Bailey and Ms. Steirer:

CITY OF SAN DIEGO SAN VICENTE RESERVOIR AUGMENTATION CONCEPT

The California Department of Public Health (CDPH) has reviewed the March 22, 2012, City of San Diego Water Purification Demonstration Project, Proposal to Augment San Vicente Reservoir with Purified Recycled Water (Report) and the City of San Diego San Vicente Reservoir Augmentation Concept Summary. The purpose of this letter is to respond to the City's request for CDPH review and approval of the project concept.

The City of San Diego's (City) proposed project for surface water augmentation (SWA) using advance treated recycled water would be the first planned project of its type in California. To obtain CDPH approval for an actual SWA project, the City must provide an adequate basis for CDPH to make a finding that the SWA project "poses no significant threat to public health", as required in the Health & Safety Code (H&S Code), Section 116551. CDPH has authority to condition a permit (H&S Code Section 116540) "as it deems necessary to assure a reliable and adequate supply of water at all times that is pure, wholesome, potable, and does not endanger the health of consumers." Nothing in this letter is intended to waive CDPH's authority.

The final design, engineering report, operations plan, contingency plan, response plan, and water quality monitoring plan for this project have not yet been developed; all of these are required prior to being issued a permit.

Based on CDPH's review of the City's March 22, 2012, submittal, CDPH has concluded that the project, as conceived, when properly designed, constructed, and operated, will not compromise the quality of the water derived from the San Vicente Reservoir. Therefore, CDPH approves the San Vicente Reservoir Augmentation Concept.

In order for CDPH to permit the project and make the finding that the project poses no significant threat to public health, the City will need to provide the additional information outlined above, including, but not limited to, the final design, engineering report, operations plan, contingency plan, response plan, and water quality monitoring plan.

CDPH staff will continue to be available to your staff for technical discussions and to answer questions on CDPH's requirements for SWA projects. If you have any questions on these comments or would like to discuss them, please contact me at (916) 449-5577.

Sincerely,

Leah Godsey Walker, P.E., Chief
Division of Drinking Water and Environmental Management

cc:

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Appendix C: San Diego Regional Water Quality Control Board Resolution of Support

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California Regional Water Quality Control Board

San Diego Region

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http:// www.waterboards.ca.gov/sandiego

October 24, 2011

In reply refer to:
244506:JCOFRANCESCO

Ms. Marsi A. Steirer
Deputy Director, Public Utilities Department
City of San Diego
600 B Street, Suite 600, MS 906
San Diego, CA, 92101

Dear: Ms. Steirer

SUBJECT: ADOPTION OF RESOLUTION NO. R9-2011-0069, A RESOLUTION IN SUPPORT OF THE CITY OF SAN DIEGO'S SAN VICENTE RESERVOIR AUGMENTATION PROJECT

Thank you again for coming to the San Diego Water Board meeting on October 12, 2011. The information that you provided to the Board Members demonstrate the City's efforts to bring more sustainable local water to our region. The San Diego Water Board's adoption of Resolution No. R9-2001-0069 and their comments during the meeting show that they are in support of the City's efforts and look forward to the possibility of indirect potable reuse in the San Diego Region. My staff and I will continue to work closely with the City to resolve any remaining water quality requirements related to the San Vicente Reservoir Augmentation Project.

Enclosed is a copy of the adopted resolution for your records. Please do not hesitate to contact myself or my staff (Joann Cofrancesco at 858-637-5589 or jcofrancesco@waterboards.ca.gov) regarding this project.

Respectfully,

DAVID W. GIBSON
Executive Officer

DWG:dtb:rwm:jlc

cc: (by email): Anthony Van, City of San Diego, Associate Engineer-Civil, AVan@sandiego.gov
Enclosures: Resolution No. R9-2011-0069

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD

SAN DIEGO REGION

RESOLUTION NO. R9-2011-0069

A RESOLUTION IN SUPPORT OF THE CITY OF SAN DIEGO'S SAN VICENTE RESERVOIR AUGMENTATION PROJECT

WHEREAS, the California Regional Water Quality Control Board, San Diego Region (hereinafter, San Diego Water Board), finds that:

1. California Water Code section 13510 states, *the people of the state have a primary interest in the development of facilities to recycle water containing waste to supplement existing surface and underground water supplies and to assist in meeting the future water requirements of the state.*

2. The Strategic Plan Update 2008-2012 for the Water Boards includes a priority to increase sustainable local water supplies available for meeting existing and future beneficial uses.

3. The City of San Diego (City) has prepared a water recycling plan entitled, City of San Diego, Recycled Water Master Plan Update 2005 (Master Plan), which identifies non-potable reuse opportunities for recycled water. Subsequently the City prepared the Water Reuse Study Final Draft Report, March 2006, which includes the Master Plan and identifies opportunities for indirect potable reuse (IPR). In October 2007, the San Diego City Council recognized San Vicente Reservoir Augmentation as their preferred IPR strategy.

4. To determine the feasibility of a full-scale reservoir augmentation project, the City of San Diego is currently evaluating the use of advanced water purification technology to provide safe and reliable water. Should this evaluation prove successful, the City plans to construct a full-scale advanced water treatment plant to supplement the current treatment processes at its North City Water Reclamation Plant and a 23-mile pipeline to transport the advanced treated recycled water to San Vicente Reservoir, where it would blend with imported untreated water and reside for several months (per state health regulation) prior to being sent to water treatment plants for additional treatment and distribution as potable water.

5. The San Diego Water Board has a long history of taking actions in support of beneficial water recycling projects in the Region. These actions included amending the *Water Quality Control Plan for the San Diego Basin* (Basin Plan) in 1996 to provide an exception to the prohibition for recycled water discharges to a lake or reservoir used for municipal water supply.

6. On September 22, 2011, this item was publicly noticed in the Meeting Notice and Agenda, which was posted on the San Diego Water Board's website and distributed to interested persons via the ListServ Management System.

7. On October 12, 2011, the San Diego Water Board conducted a public hearing on tentative Resolution No. R9-2011-0069.

NOW THEREFORE, BE IT RESOLVED THAT, the San Diego Regional Water Quality Control Board:

1. Supports the efforts to develop the Reservoir Augmentation Project at the San Vicente Reservoir as a means to reduce reliance on imported water, increase the use of recycled water, and to implement goals in California Water Code section 13510 and the 2008-2012 Strategic Plan Update for the Water Boards.

2. In accordance with implementation provisions of the Basin Plan, the San Diego Water Board will regulate San Diego Region recycled water reservoir augmentation projects through the issuance of project-specific NPDES Permits.

3. Reservoir augmentation NPDES permits issued by the San Diego Water Board will incorporate requirements established and the provisions recommended by California Department of Public Health.

I, David W. Gibson , Executive Officer, do hereby certify the foregoing is a full, true, and correct copy of a resolution adopted by the California Regional Water Quality Control Board, San Diego Region, on October 12, 2011.

David W. Gibson
Executive Officer

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Appendix D: Proposed Regional Water Quality Control Board Compliance Approach

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PROPOSED REGIONAL WATER QUALITY CONTROL BOARD COMPLIANCE APPROACH

Final Draft

City of San Diego
Water Purification Demonstration Project
San Vicente Reservoir Augmentation

August 2012

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List of Abbreviations

AF	acre-feet
AFY	acre-feet per year
AWP Facility	Advanced Water Purification Facility
Basin Plan	*Water Quality Control Report for the San Diego Region*
CEQA	California Environmental Quality Act
CDPH	State of California Department of Public Health
CFR	*Code of Federal Regulations*
CTR	California Toxics Rule
CWA	Clean Water Act
Demonstration Project	City of San Diego Water Purification Demonstration Project
DO	dissolved oxygen
EIR	Environmental Impact Report
EPA	United States Environmental Protection Agency
FSI	Flow Science Incorporated
full-scale project	Full-scale indirect potable reuse (reservoir augmentation) project
IAP	Independent Advisory Panel
MCL	Maximum Contaminant Level (drinking water standard)
mgd	million gallons per day
mg/l	milligrams per liter
NCWRP	City of San Diego North City Water Reclamation Plant
N:P	ratio of total nitrogen to total phosphorus
NPDES	National Pollutant Discharge Elimination System
NWRI	National Water Research Institute
Point Loma	City of San Diego E.W. Blom Point Loma Wastewater Treatment Plant
Regional Board	California Regional Water Quality Control Board, San Diego Region
RO	reverse osmosis
TM	Technical Memorandum
Title 22	Division 4, Chapter 3, Title 22 of the *California Code of Regulations*
UV	ultraviolet

Summary

The City of San Diego has implemented the Water Purification Demonstration Project (Demonstration Project) to assess the feasibility of a full-scale indirect Potable Reuse/Reservoir Augmentation project (hereinafter full-scale project) at San Vicente Reservoir. The Demonstration Project includes a 1 million gallon per day (mgd) advanced water purification facility (AWP Facility) at the North City Water Reclamation Plant and associated treatment, reservoir modeling and limnology studies to assess full-scale project feasibility.

One of the key objectives of the Demonstration Project is to coordinate with the California Department of Public Health (CDPH) and California Regional Water Quality Control Board, San Diego Region (Regional Board) to identify applicable regulatory requirements for reservoir augmentation. Using guidance received from CDPH staff and input from an Independent Advisory Panel of recognized public health and water quality experts, the City has submitted a project proposal to CDPH that (1) outlines the City's proposed concept for a full-scale project at San Vicente Reservoir, and (2) requests CDPH conceptual approval of a full-scale project at San Vicente Reservoir.

This report summarizes the proposed San Vicente Reservoir water purification concept, and identifies key permitting issues and Regional Board regulatory decisions and actions that would be required in order for the Regional Board to approve a full-scale project at San Vicente Reservoir.

In October 2011, the Regional Board adopted Resolution No. R9-2011-0069, which expressed support for the City's water purification project concept. The resolution also outlined the Regional Board's approach toward permitting a full-scale project at San Vicente Reservoir through the issuance of a NPDES (National Pollutant Discharge Elimination System) permit that implements requirements established within the Regional Board's *Water Quality Control Plan for the San Diego Basin* (Basin Plan).

AWP Facility monitoring data indicate that the purified water supply will be equal to or superior in quality to existing San Vicente Reservoir inflows for virtually all constituents. Nitrogen may be the only exception to this, as purified water nitrogen concentrations will be slightly higher than existing imported water inflows to San Vicente Reservoir, but superior in quality to the local runoff captured within the reservoir. Comprehensive reservoir modeling conducted as part of the Demonstration Project, however, indicate that nitrogen concentrations under a full-scale project at the expanded San Vicente Reservoir are projected to be lower than historic nitrogen concentrations in the reservoir.

While the Regional Board supports the proposed water purification and reservoir augmentation concept, Regional Board staff indicate that the Regional Board has yet to address two key procedural questions which will determine the exact pathway the City will need to take to proceed with applying for and receiving a NPDES permit for a full-scale project. These questions include:

1. Prior to the Regional Board's consideration of a NPDES permit for a full-scale project at San Vicente Reservoir, will the Regional Board, State Water Resources Control Board (State Board), and U.S. Environmental Protection Agency (EPA) need to take actions to modify the Clean Water Act (CWA) Section 303(d) impaired water list for San Vicente Reservoir?
2. Prior to the Regional Board's consideration of a NPDES permit for a full-scale project at San Vicente Reservoir, will the Regional Board, State Board, and EPA need to modify any requirements within the Regional Board's Basin Plan?

The City understands that the Regional Board is currently coordinating with EPA and the State Board to address these questions. If the answer to both pending questions is "no", the pathway for project approval is straight-forward, and the City could be in a position to submit an application to the Regional Board for a NPDES permit for a full-scale project at San Vicente Reservoir in less than 18 months after the date the City Council approves and funds the project. The City believes that this direct approval pathway (no Basin Plan modification or 303(d) list revisions) is both feasible and appropriate.

If the Regional Board, State Board, or EPA determine that the answer to either or both pending questions is "yes", the full-scale project remains feasible, but the project implementation schedule would be lengthened. In this event, four to five years may be required to achieve modifications in the 303(d) list and/or Basin Plan to procedurally support the Regional Board's issuance of a NPDES permit for a full-scale project at San Vicente Reservoir.

The City requests that Regional Board staff coordinate with State Board and EPA staff to determine whether the Regional Board can move forward with implementing attainable NPDES requirements for a full-scale reservoir augmentation project without the need for (1) revision of the San Vicente Reservoir 303(d) listings, or (2) modification of the Basin Plan. The City also requests any guidance or recommendations the Regional Board can offer relative to implementing a full-scale reservoir augmentation project at San Vicente Reservoir.

Section 1 Purpose of Report

The City of San Diego proposes an indirect potable reuse project (also known as reservoir augmentation) that would supplement the approximate 240,000-acre-foot San Vicente Reservoir with up to 15,000 acre-feet per year (AFY) of purified recycled water produced at an advanced water treatment facility that would be sited at the City's North City Water Reclamation Plant (NCWRP). This report:

(1) summarizes results from the City's Water Purification Demonstration Project (Demonstration Project) that is assessing the feasibility of full-scale project at San Vicente Reservoir,

(2) describes the proposed concept for introducing purified water from a full-scale project to San Vicente Reservoir,

(3) summarizes permitting guidance received from the staff of the California Regional Water Quality Control Board, San Diego Region (Regional Board),

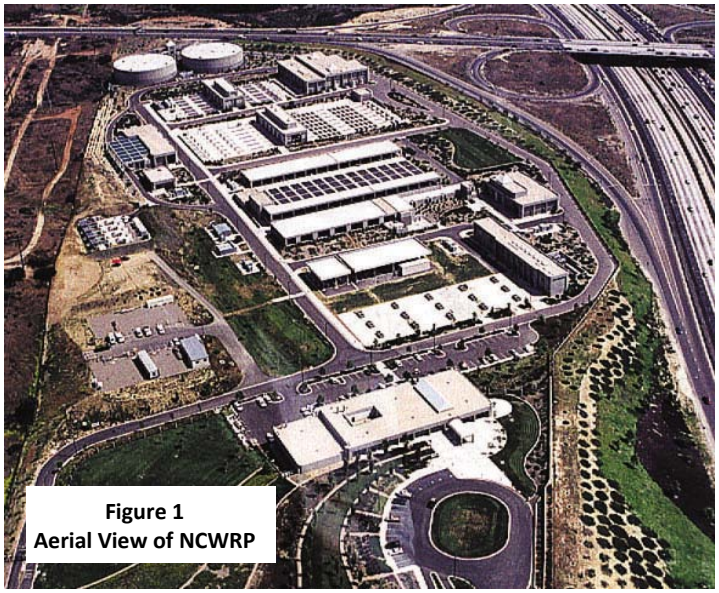

Figure 1
Aerial View of NCWRP

(4) identifies two key pending Regional Board decisions that will determine how the City proceeds with Regional Board NPDES permitting requirements, and

(5) identifies the approach preferred by the City for achieving project approval from the Regional Board.

Section 2 Water Purification Demonstration Project

Planning Background. In 1994, the City, in partnership with the San Diego County Water Authority, initiated a series of technical studies to assess the potential for indirect potable reuse at San Vicente Reservoir. Based on the results of these studies, which included pilot testing of advanced treatment technologies and studies of reservoir hydrodynamics, the Department of Health Services (now called California Department of Public Health, or CDPH) issued conditional concept approval for that project in 1994.

Demonstration Project Elements. The City chose not to pursue indirect potable reuse in the 1990s, but in 2007 the City of San Diego City Council issued a directive to initiate a renewed feasibility assessment of the concept at San Vicente Reservoir. In accordance with this Council action, the Public Utilities Department launched the Demonstration Project. Key elements of the Demonstration Project include:

- Constructing a 1 mgd advanced water purification facility (AWP Facility) at the NCWRP and operating the facility for one year to assess treatment technologies and the effectiveness of purified water treatment.
- Initiating a comprehensive hydrodynamic study that included three-dimensional modeling of San Vicente Reservoir to assess hydrodynamic, water quality, and biostimulation issues at the reservoir.
- Coordinating with CDPH and the Regional Board to define probable regulatory requirements for a full-scale project.
- Implementing a public education and outreach program.
- Conducting energy and economic analyses.

The National Water Research Institute (NWRI) assembled a ten-member Independent Advisory Panel (IAP) to provide independent expert oversight of the Demonstration Project effort. Table 1 presents the IAP members.

Table 1
NWRI Independent Advisory Panel (IAP)

IAP Panel Members and Organizations	
George Tchobanoglous, Ph.D., P.E. (IAP Chair) University of California, Davis	Richard Gersberg, Ph.D., (IAP Vice-Chair) San Diego State University
Michael Anderson, Ph.D. University of California, Riverside	Richard Bull, Ph.D. Consulting Toxicologist
Joseph Cotruvo, Ph.D. Joseph Cotruvo Associates	James Crook, Ph.D., P.E. Water Reuse and Public Health Consultant
Sunny Jiang, Ph.D. University of California, Irvine	Audry D. Levine, Ph.D., P.E., DEE U.S. Environmental Protection Agency
David R. Schubert, Ph.D. Salk Institute for Biological Studies	Michael P. Wehner Orange County Water District

Treatment Studies. The 1 mgd AWP Facility utilizes tertiary treated water from the NCWRP as a source of influent. AWP Facility treatment processes consist of:

- membrane filtration,
- reverse osmosis (RO),
- ultraviolet (UV) disinfection, and
- advanced oxidation.

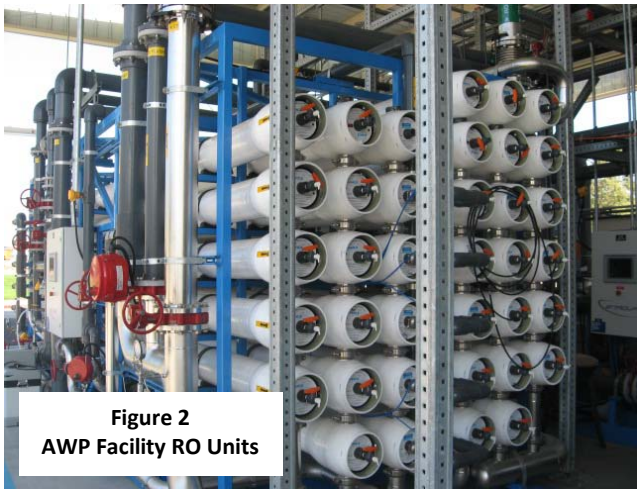

Figure 2
AWP Facility RO Units

On the basis of data collected since operation of the AWP Facility was initiated in July 2011, the City has concluded that:

- NCWRP recycled water (the influent to the AWP Facility) typically complies with most CDPH drinking water Maximum Contaminant Levels (MCLs).
- Concentrations of minerals in the purified water are significantly lower than existing imported supplies.
- Concentrations of phosphorus in the purified supply are near zero.
- Concentrations of nitrogen in the purified water are comparable (but depending on the blend of Colorado River and State Water Project supplies, can be slightly higher than) the existing imported water supply.
- The purified water consistently and reliably complies with all CDPH MCLs.
- The advanced purification processes provide a level of reliability and pathogen inactivation that is consistent with (or is superior to) anticipated CDPH requirements.
- The advanced purification treatment process train utilized as part of the Demonstration Project is appropriate for a full-scale project.

Reservoir Limnology Studies: Hydrodynamics. As a key element of the Demonstration Project, the City has completed a comprehensive Reservoir Detention and Limnology Study of San Vicente Reservoir (Limnology Study) to assess how a potential full-scale project might influence hydrodynamic, water quality, and biostimulation conditions within San Vicente Reservoir. The primary advantage of retaining purified water in San Vicente Reservoir is to provide substantial retention and blending of purified water in a natural setting prior to delivering it to a water treatment plant for final potable water treatment and distribution. Such reservoir retention provides an environmental buffer between purified water treatment and potable water treatment. This environmental buffer effect is provided through the following:

- *Thermal Stratification.* Above a temperature of 4° C (39° F), warmer waters are less dense than cooler waters. As reservoir surface waters warm in the spring months, the warmer buoyant waters remain near the reservoir surface, resulting in further warming by convective and solar radiation. By mid-spring, a strong thermocline is formed which acts as a barrier to separate the warmer surface waters (epilimnion) from the deeper cool waters (hypolimnion). In San Vicente Reservoir, this thermal stratification persists for approximately 10 months each year, until winter when epilimnion temperatures are reduced to the point where wind-driven energy is sufficient to completely mix the reservoir. A full-scale project would take advantage of this thermal stratification by discharging less dense (warmer and less saline) purified water to the epilimnion and withdrawing raw potable supplies from the hypolimnion. Using this technique, the thermal stratification provides for significant retention times and a significant barrier to reservoir short-circuiting (e.g. preventing the withdrawal of purified water soon after it is introduced to the reservoir).

- *Reservoir Size*. San Vicente Reservoir is currently undergoing an expansion that will raise the height of San Vicente Dam by 117 feet and increase the reservoir storage capacity from 90,000 AF to over 240,000 AF. The introduction of 15,000 AFY of purified water to San Vicente Reservoir would represent a relatively modest annual quantity compared to the reservoir capacity, and would result in significant dilution. During times the reservoir is not thermally stratified, this high degree of dilution would ensure that only a small fraction of reservoir waters withdrawn during complete mix conditions would be comprised of recently introduced purified water.

Figure 3
San Vicente Reservoir Prior to Expansion

As an initial element of the Limnology Study, Flow Science Incorporated (FSI) calibrated a numerical three-dimensional model (ELCOM) of San Vicente Reservoir hydrodynamics. Model results were verified by utilizing observed reservoir and tracer study data. The results of this analysis were documented in two Limnology Study Technical Memoranda (FSI, 2010; FSI 2011).

The Technical Memoranda and model were peer-reviewed by the IAP, which concluded that the ELCOM model was "an effective and robust tool" for simulating thermoclines and hydrodynamics of the San Vicente Reservoir and assessing options for the purified water inlet location. (NWRI, 2010)

FSI used the calibrated model to simulate augmenting San Vicente Reservoir inflow with purified water under a range of future operating conditions, including:

- alternatives with and without the addition of purified water,
- normal, extended drought, and emergency drawdown reservoir operating scenarios, and
- four alternative purified water inlet locations (see Figure 4 on page 7).

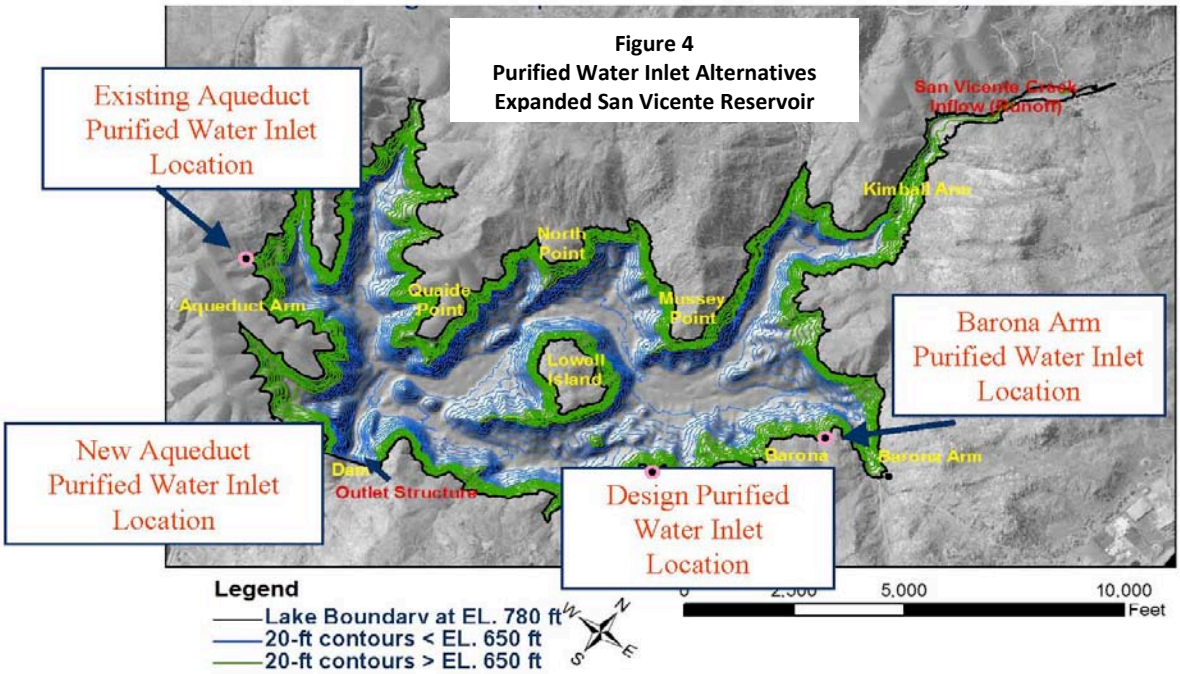

Figure 4
Purified Water Inlet Alternatives
Expanded San Vicente Reservoir

Key conclusions of the hydrodynamic modeling effort presented by FSI (2011) include:

- Expansion of San Vicente Reservoir will increase the volume of the hypolimnion, but will not discernibly affect the depth, duration or strength of thermal stratification.
- The reservoir would provide a substantial barrier to pathogen organisms due to solar radiation (photolysis effects), temperature effects and natural predation.
- For all anticipated reservoir operational scenarios and purified water inlet locations, at all times the reservoir provides at least a 200:1 dilution of a 24-hour purified water release event prior to withdrawal.
- During typical operations and using the inlet location currently under consideration (referred to in reservoir hydrodynamic modeling as "design inlet location"), the reservoir provides greater than 2000:1 dilution of a 24-hour purified water release event prior to withdrawal.

Reservoir Limnology Studies: Water Quality and Biostimulation. As an additional element of the Limnology Study, FSI superimposed and calibrated an aquatic ecosystem dynamics model (CAEDYM) on the ELCOM hydrodynamic model. The CAEDYM model (see Figure 5 on page 8) assesses nutrient loads, nutrient concentrations, water clarity, and algae. Model results were verified by utilizing observed nutrient concentrations, algae concentrations and Secchi disk data from San Vicente Reservoir. Results of the nutrient and biostimulation modeling effort were documented in Limnology Study Technical Memorandum #3 (FSI, 2012a). The nutrient and biostimulation Technical Memorandum and the model were peer-reviewed by the IAP, which concluded that the combined hydrodynamic/nutrient model (ELCOM plus CAEDYM) was an effective and robust tool for assessing biological water quality for nutrients. (NWRI, 2010)

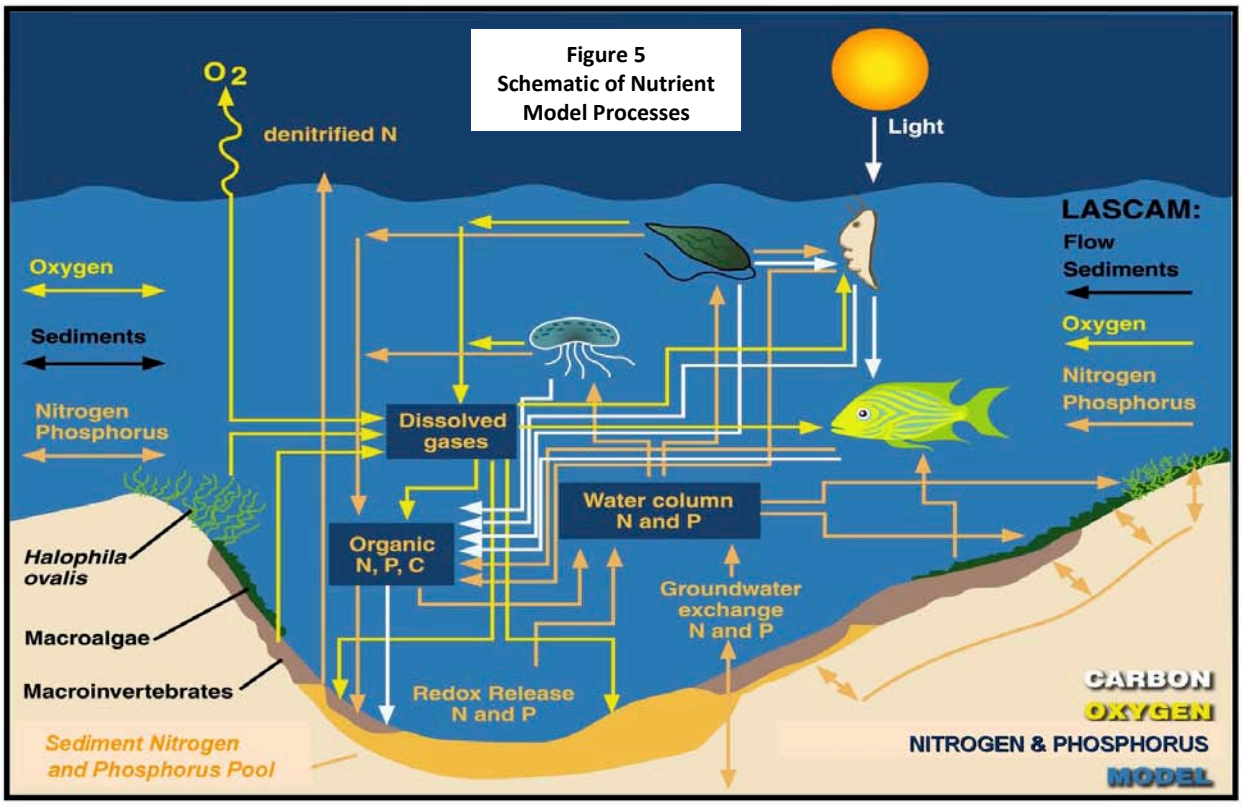

Figure 5
Schematic of Nutrient Model Processes

FSI used the calibrated ELCOM plus CAEDYM model to simulate nutrient and biostimulation conditions at San Vicente Reservoir under:

1) existing conditions prior to reservoir expansion (Existing Case),
2) the expanded reservoir with no purified water inflow (No Purified Water Case), and
3) the expanded reservoir with purified water inflow (Base Case).

As part of the modeling effort, FSI used data from the AWP Facility to estimate purified water nitrogen and phosphorus concentrations. Observed nitrogen and phosphorus data from 2006-2007 were used to characterize nitrogen and phosphorus concentrations in the San Vicente Reservoir runoff inflow and imported water inflow. Table 2 (page 9) compares nitrogen and phosphorus concentrations in the reservoir inflow sources.

Key conclusions of the nutrient and biostimulation modeling effort presented by FSI (2012a) include:

- Nutrient sediment release from the reservoir bottom constitutes a significant portion of all nutrient loadings into the reservoir water column for all modeled scenarios.
- Expansion of the reservoir will result in increased sediment nutrient loadings as a result of increased depth and wetted sediment surface area.

- Despite the higher sediment nutrient releases for the expanded reservoir, nutrient concentrations in the water column are projected to be reduced due to the larger volume of water in the expanded reservoir.
- Concentrations of chlorophyll-α in the epilimnion are simulated as being reduced for all expanded reservoir scenarios, likely as a result of projected reductions in water column nutrient concentrations.
- Under all simulated scenarios, anoxic conditions are projected to occur in the hypolimnion once oxygen demands use up the available dissolved oxygen. This effect naturally occurs in all thermally stratified reservoirs, independent of whether or not purified water is introduced.
- San Vicente Reservoir hypolimnion volumes are significantly increased as a result of reservoir expansion for all simulated scenarios. This increased hypolimnion volume will lead to a slight increase in the number of days that anoxic conditions occur in the hypolimnion for the simulated reservoir expansion scenarios, regardless of whether or not purified water is introduced to the reservoir.
- Chlorophyll-α concentrations will be lower and average Secchi depths will be greater (i.e., improved water clarity) in the expanded reservoir than in the existing reservoir, regardless of whether or not purified water is introduced into San Vicente Reservoir.
- Since the nitrogen:phosphorus (N:P) ratio in the purified water is projected to be approximately 160:1, the Base Case scenario (expanded reservoir with purified water inflow) is projected to be more phosphorus-limited than historic (90,000 AF reservoir capacity) conditions.

Table 2
San Vicente Reservoir Inflow Nutrient Concentrations[1]

Parameter	Concentration in mg/l		
	Purified Water[2]	Imported Water Inflow[3]	Runoff Inflow[4]
Nitrate and nitrite	0.64	0.12 - 0.47	0.02 - 3.0
Ammonia[5]	0.14	0.02 - 0.09	0.02 - 0.5
Total nitrogen	0.78	0.17 - 0.68	0.18 - 4.2
Total phosphorus	0.004	0.024 - 0.081	0.22 - 0.32

1 From FSI (2012a).
2 Based on results of DEMONSTRATION PROJECT demonstration plant effluent data for 2011-2012.
3 Range of observed data for the aqueduct inflow during 2006-2007.
4 Range of observed data in surface runoff into San Vicente Reservoir during 2006-2007 from Kimball Creek, San Vicente Creek, Barona Creek, Tool Road Creek, and Aqueduct Creek.
5 Ammonia is in the form of ionized ammonia (NH_4^+-N).

Table 3 summarizes the nutrient and biostimulation results for the modeled scenarios. As shown in Table 3, chlorophyll-α concentrations are projected to be less with the expanded reservoir and the proposed purified water inflow than under current conditions. The simulations predict that reservoir water clarity under the Base Case (expanded reservoir and purified water inflow) is projected to be improved compared to existing conditions.

Table 3
Summary of Nutrient and Biostimulation Model Results[1,2]

Model Scenario	Average Annual Number of Days Hypolimnion is Anoxic[2,3,4]	Average Chlorophyll-α Concentration in Surface Waters[,2,4]	Average Secchi Depth[2,4]
Existing Case[5] (existing reservoir capacity and no purified water)	189 days (52%)	5.8 µg/l	3.2 meters
Expanded Reservoir with no purified water[6]	207 days (57%)	3.1 µg/l	4.8 meters
Base Case[6] (expanded reservoir with purified water inflow)	215 days (59%)	3.7 µg/l	4.3 meters

1 ELCOM/CAEDYM model results presented by FSI (2012a).
2 Based on two-year simulation using hydrologic data for 2006 and 2007.
3 Number of days in which the average hypolimnion dissolved oxygen concentration is less than 0.5 mg/l.
4 Average annual value for the two-year simulation.
5 Initial reservoir volume of 64,000 AF in year 1 and 64,000 AF in year 2.
6 Initial reservoir volume of 155,000 AF in years 1 and 2.

Coordination with CDPH. Regulatory coordination was another key element of the Demonstration Project evaluation. The City engaged CDPH staff in establishing the Demonstration Project work plan. CDPH staff have attended IAP workshops and have been active participants in working group meetings. Through these venues, CDPH has reviewed reservoir technical studies and purified water treatment results.

CDPH has indicated that requirements for a full-scale project would be, in part, based on providing a level of public health protection equivalent to that provided within CDPH's 2011 "Draft Regulations for Groundwater Replenishment with Recycled Water" (Groundwater Recharge Regulations). (CDPH, 2011) Based on guidance provided by CDPH to date, the following elements are expected to provide the framework for CDPH regulation of a full-scale project at San Vicente Reservoir:

- Enhanced Wastewater Source Control
- Pathogenic Microorganism Control
- Control of Nitrogen Compounds
- Regulated Contaminants, Additional Chemicals, and Contaminant Monitoring, and Total Organic Carbon Control

- Reliability and Redundancy
- Monitoring and Response Plan
    - AWP Facility Integrity Monitoring
    - San Vicente Reservoir Retention and Blending
    - Mitigation of an AWP Facility system failure by San Vicente Reservoir

In accordance with provisions within Senate Bill 918, CDPH is required to adopt uniform water recycling criteria for indirect potable reuse (reservoir augmentation) by December 31, 2016, provided that an expert panel (convened pursuant to the bill) finds that the criteria would adequately protect public health. In advance of adopting uniform criteria, CDPH can review reservoir augmentation projects on a case-by-case basis. In March 2012, the City submitted a draft proposed reservoir augmentation project proposal and request for conceptual approval to CDPH. CDPH is currently reviewing the draft submittal. (City of San Diego, 2012)

Coordination with Regional Board. The City has engaged Regional Board staff throughout the Demonstration Project feasibility evaluation. This coordination has included a number of project-specific meetings held at the Regional Board office and Regional Board staff attendance at IAP sessions.

The most recent City meeting with Regional Board staff focused on (1) Regional Board interpretation of Basin Plan nutrient water quality objectives and (2) potential implications of the CWA Section 303(d) impaired water listings for San Vicente Reservoir. This report is submitted as a follow-up to the most recent meeting of June 18, 2012, and addresses pathways for demonstrating compliance with Regional Board requirements.

Public Education and Outreach. The Demonstration Project effort also included a public education and outreach plan that included developing:

- a communication plan,
- speakers bureau,
- multi-language information materials and brochures,
- stakeholder interviews and research surveys,
- videos, electronic updates and a website, and
- AWP Facility tours.

Outreach efforts have garnered positive coverage both locally and nationally. On January 23, 2011, the *San Diego Union-Tribune* published an editorial declaring that the newspaper editorial board accepts the science behind water purification technology and encourages the rest of San Diego to do the same. National media coverage has included a front page cover story in *USA Today* (March 3, 2011) and an article on the cover page of the *New York Times* (February 10, 2012).

Demonstration Project Report. The City Public Utilities Department is currently developing a project report that summarizes the results of the Demonstration Project feasibility effort. Submittal of the report to the City of San Diego City Council is scheduled for late 2012.

Section 3 Full-Scale Project Concept

The concept for a full-scale project at San Vicente Reservoir is based on guidance from CDPH and the IAP. The project concept components are illustrated in Figure 6 (below). Figure 7 (page 13) summarizes the primary roles and key public health protection features of the project elements.

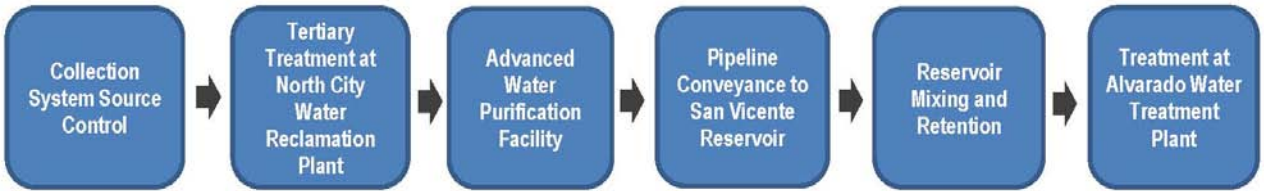

Figure 6
Components of the Full-Scale Project

Collection System Source Control. The City maintains a comprehensive industrial pretreatment and source control program approved by EPA to control waste discharges from industrial sources into the wastewater collection system. The main components of the program are:

- evaluating, issuing and administering industrial user permits,
- establishing sampling, reporting, record keeping, and notification requirements for industrial dischargers,
- performing compliance inspections and compliance monitoring, and
- enforcing permit requirements, requiring corrective actions, and authorizing penalties for discharge violations.

As part of the City of San Diego NPDES permit and 301(h) waiver for the Point Loma Wastewater Treatment Plant (Point Loma), the City is required to implement an Urban Area Pretreatment Program per Title 40, Section 125.65 of the *Code of Federal Regulations* (40 CFR 125.65).

Regulations established in 40 CFR 125.65 require 301(h) dischargers to demonstrate that the combination of enhanced source control and wastewater treatment provides the equivalent to secondary treatment for the removal of toxic constituents. The Urban Area Pretreatment Program requirements of 40 CFR 125.65 have been incorporated into the Point Loma NPDES permit adopted by the Regional Board and EPA (Order No. R9-2009-0001, NPDES CA0107409).

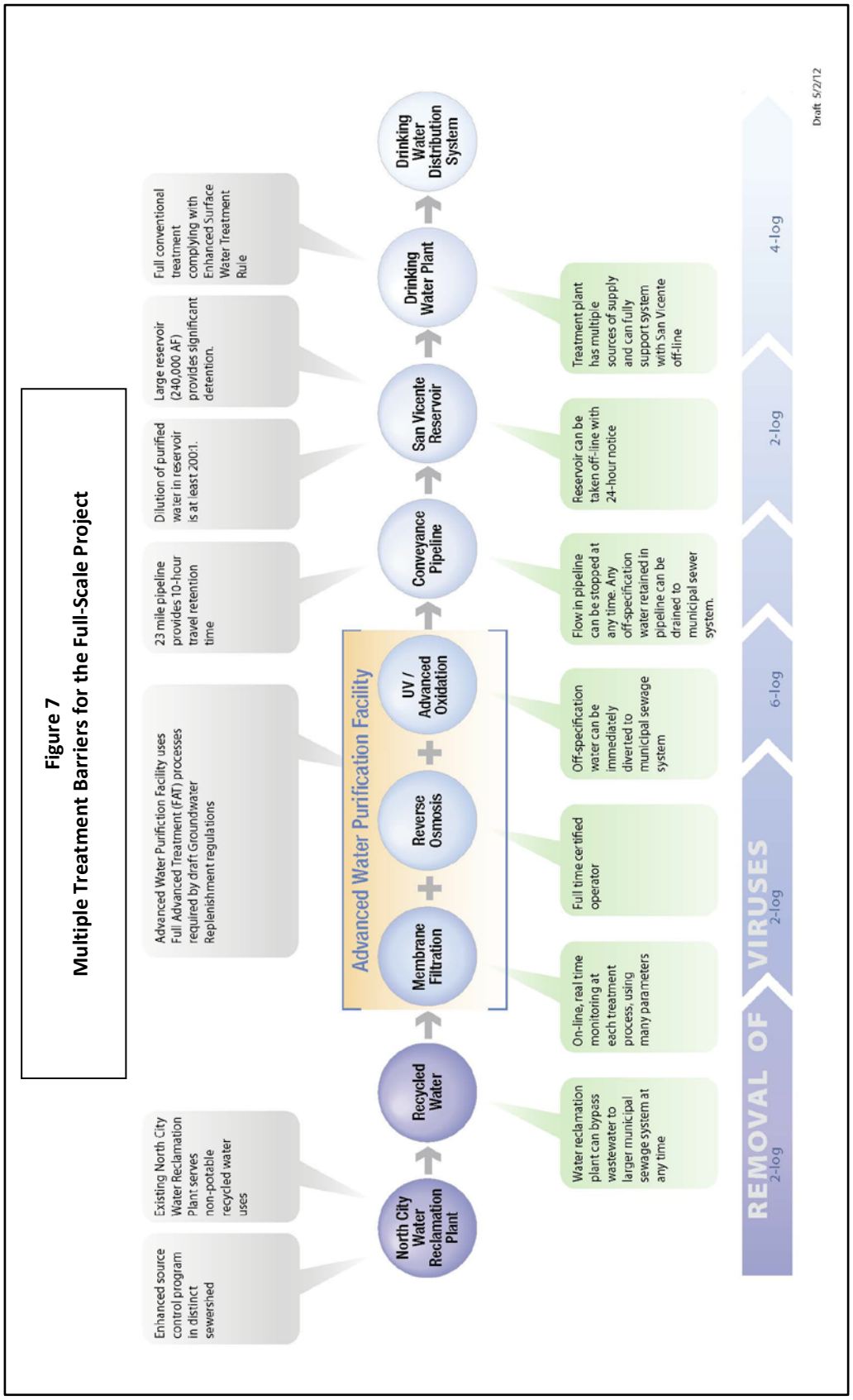

Figure 7
Multiple Treatment Barriers for the Full-Scale Project

The City's source control program organizes industrial users into 27 sewersheds. Four of these sewersheds are tributary to the NCWRP, where the full-scale AWP Facility will be located. The City's pretreatment program currently regulates 198 industries within these four sewersheds. A total of 102 of these industrial users are research and development companies. The remaining 96 industries cover 49 different industry types including car washes, gas stations, electronic equipment manufacturers and veterinary services.

North City Water Reclamation Plant. The NCWRP is a 30-mgd water reclamation plant serving roughly 7,500 AFY of recycled water to irrigation and industrial customers throughout the North City area. NCWRP operates as a scalping plant, receiving flows that would otherwise be treated at Point Loma. Biosolids are sent offsite for processing, with no return flow to the NCWRP. NCWRP treatment processes include:

- headworks and barscreens,
- aerated grit removal,
- primary sedimentation,
- secondary aeration with aerated and anoxic selector zones to achieve full nitrification and partial denitrification,
- secondary clarification, and
- deep bed anthracite tertiary filtration.

NCWRP recycled water used for irrigation use undergoes chlorination, but NCWRP recycled water flows directed to the AWP Facility project would be diverted prior to chlorine disinfection to control formation of chlorination byproducts. NCWRP also includes flow equalization, which allows for near-constant flowrates through the secondary treatment facilities, maximizing the stability of the plant's biological processes.

Advanced Water Purification Facility. As part of a full-scale project, NCRWRP tertiary treated recycled water would serve as an influent flow to the proposed 18 mgd AWP Facility. AWP Facility treatment processes would include:

Membrane Filtration: Tertiary effluent will flow to a low pressure membrane filtration process consisting of either microfiltration or ultra-filtration. In addition to minimizing RO fouling by removing colloidal and suspended particles, low pressure membranes provide a barrier to a wide array of microbes and will assist the project in meeting microbial removal targets.

Reverse Osmosis: All AWP Facility flow will undergo RO treatment, the primary barrier to organic chemicals. The RO system will meet applicable salt rejection specifications established by CDPH. Concentrated brine from the RO treatment will be discharged back into the sewer for treatment at Point Loma.

Disinfection/Photolysis/Advanced Oxidation: Permeate from the RO process would undergo disinfection and advanced oxidation. High intensity UV irradiation provides both the primary disinfection step in the AWP Facility and photolysis of certain classes of organic chemicals such as

NDMA. With the addition of hydrogen peroxide, high intensity UV provides an additional barrier (to RO) for oxidizable contaminants. The advanced oxidation process will be designed to adhere to criteria established in the Draft CDPH Groundwater Recharge Regulations.

A flow analysis study conducted as part of the Demonstration Project evaluated source water availability due to NCWRP's seasonal irrigation demands, and identified 18 mgd as the optimum capacity for a full-scale AWP Facility. The 18 mgd AWP Facility would annually produce approximately 15,000 AFY of purified water.

Conveyance to San Vicente Reservoir. Purified recycled water will be pumped through a 23-mile, 36-inch diameter pipeline to San Vicente Reservoir. The static lift from the purified water pump station to San Vicente Reservoir is approximately 445 feet. A flow control structure at the reservoir outlet and surge control facilities will be required to optimize flow conditions in the pipeline.

The travel time of the purified water from the AWP Facility to the reservoir would be approximately 10 hours, based on a maximum pumping rate of 18 mgd. In case of an operation malfunction at the AWP Facility, this would allow time to interrupt conveyance before any affected water reaches the reservoir. The conveyance system will include features allowing the entire volume of the pipeline to be drained to sanitary sewer.

Reservoir Storage. Under the full-scale project, approximately 15,000 AFY of purified water would be introduced into San Vicente Reservoir. The purified water inflow would augment existing reservoir inflows (aqueduct inflow, local runoff, and transfers from Sutherland Reservoir) and replace a commensurate amount of imported water that would otherwise be introduced into the reservoir.

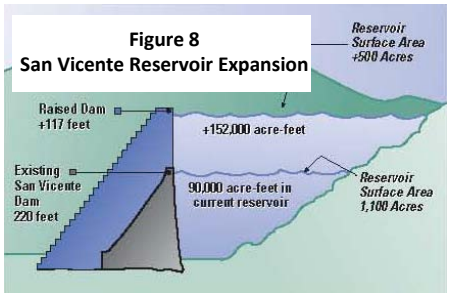

Figure 8
San Vicente Reservoir Expansion

San Vicente dam and reservoir are owned and operated by the City of San Diego Public Utilities Department. San Vicente Reservoir impounds local runoff from its 75 square-mile catchment, stores water transferred from Sutherland Reservoir, and stores water imported from the Colorado River and northern California. The reservoir's principal use is for municipal water supply. The reservoir also supports limited recreational activities including boating, fishing, and water skiing, although these activities have been suspended during construction of facilities to raise San Vicente Dam.

While San Vicente Reservoir is being expanded to a capacity exceeding 240,000 AF, the additional capacity is to be primarily utilized for emergency storage purposes. During non-emergency conditions, annual inflows to and withdrawals from the reservoir are not expected to be significantly different from historic operations. It is anticipated that the expanded San Vicente Reservoir will be substantially filled prior to initiation of a full-scale project.

The amount of imported water introduced to San Vicente Reservoir depends on water availability, water price, and the operational needs of the City of San Diego and San Diego County Water Authority, but has typically averaged approximately 20,000 to 30,000 AFY. Runoff inflow the reservoir varies significantly depending on hydrologic conditions, but typically averages approximately 4,500 AFY, a total roughly equivalent to the annual evaporation from the reservoir. (FSI, 2010) Thus, under typical conditions, a 15,000 AFY purified water flow would represent roughly half of the annual San Vicente Reservoir inflow. As demonstrated by the Demonstration Project Limnology Studies (see pages 4 - 8), a 15,000 AFY purified water inflow into San Vicente Reservoir would result in significant reservoir detention.

San Vicente Dam has overflowed on only a few occasions since its construction in 1943; the most recent spill occurred in 1995. San Vicente Reservoir overflows are not projected to occur once the reservoir is expanded. As a result, is not projected that any waters (imported or purified) introduced into the expanded reservoir will be released to downstream water bodies (San Vicente Creek and the San Diego River).

Potable Water Treatment. Water withdrawn from San Vicente Reservoir would undergo conventional potable water treatment prior to conveyance to potable water customers. Under normal operations, water from San Vicente Reservoir is conveyed to the City of San Diego Alvarado Water Treatment Plant which serves the central portion of San Diego.

Through agreements with the San Diego County Water Authority, a portion of San Vicente Reservoir's storage may be used in emergency and extended drought conditions to supply water treatment plants serving the southern half of San Diego County. In an emergency event, other water treatment plants that could be supplied from San Vicente Reservoir include the City's Miramar and Otay Water Treatment Plants, Helix Water District's Levy Treatment Plant, the Sweetwater Authority's Purdue Water Treatment Plant, and the Santa Fe Irrigation's Districts Badger Water Treatment Plant.

Section 4 Regional Board Support and Guidance

Regional Board Resolution of Support. On October 12, 2011, the Regional Board adopted Resolution No. R9-2011-0069, which documents the Regional Board's support of the City's proposed reservoir augmentation project at San Vicente Reservoir, and sets forth the Regional Board's proposed means of regulating the project. Resolution No. R9-2011-0069 states that:

> ***NOW THEREFORE, BE IT RESOLVED THAT****, the San Diego Regional Water Quality Control Board:*
>
> 1. *Supports the efforts to develop the Reservoir Augmentation Project at the San Vicente Reservoir as a means to reduce reliance on imported water, increase the use of recycled water, and to implement goals in California Water Code section 13510 and the 2008-2012 Strategic Plan Update for the Water Boards.*

2. *In accordance with implementation provisions of the Basin Plan, the San Diego Water Board will regulate San Diego Region recycled water reservoir augmentation projects through the issuance of project-specific NPDES Permits.*
3. *Reservoir augmentation NPDES permits issued by the San Diego Water Board will incorporate requirements established and the provisions recommended by California Department of Public Health.*

City and Regional Board Coordination. As part of the Demonstration Project, City of San Diego and Regional Board staff held a series of coordinating meetings to discuss Demonstration Project progress and issues associated with Regional Board issuance of a NPDES permit for a full-scale project at San Vicente Reservoir.

Should the City Council choose to move forward with a full-scale project at San Vicente Reservoir, Regional Board staff indicate that the City will be required to submit a "Report of Waste Discharge" in application for a NPDES permit. As part of the Demonstration Project coordination effort, City and Regional Board staff have discussed information needs for the Report of Waste Discharge, which will include:

- describing the proposed full-scale project and purified water quality,
- evaluating water quality effects on San Vicente Reservoir,
- demonstrating compliance with Basin Plan water quality standards,
- demonstrating compliance with *California Toxics Rule* standards, and
- demonstrating compliance with CDPH requirements.

Pending Regional Board Procedural Decisions. While Resolution No. R9-2011-0069 confirms Regional Board support for the reservoir augmentation concept, Regional Board staff indicate that they are still working to finalize staff recommendations on two key procedural issues that will influence the pathway and schedule for securing a NPDES permit for a full-scale reservoir augmentation project at San Vicente Reservoir. These two key procedural questions include:

1. Prior to the Regional Board's consideration of a NPDES permit for reservoir augmentation at San Vicente Reservoir, will the Regional Board, State Board, and EPA need to take actions to modify the CWA Section 303(d) impaired water list for San Vicente Reservoir?
2. Prior to the Regional Board's consideration of a NPDES permit for reservoir augmentation at San Vicente Reservoir, will the Regional Board, State Board, and EPA need to modify any requirements within the Regional Board's Basin Plan?

Regional Board staff indicate that they are seeking guidance from EPA and the State Board in determining the answers to these questions.

Section 5 Basin Plan Compliance

As indicated by Regional Board staff, a key element of a NPDES application for a full-scale project at San Vicente Reservoir involves demonstrating compliance with Basin Plan water quality standards. How the Regional Board, State Board, and EPA resolve the two above-noted procedural questions will, in part, depend on how the agencies interpret and apply existing Basin Plan water quality standards to the proposed project. This section summarizes key Basin Plan compliance issues for a full-scale project at San Vicente Reservoir.

Basin Plan Overview. The Basin Plan establishes water quality concentration objectives to protect designated beneficial uses of San Vicente Reservoir. The Basin Plan surface water quality objectives have been approved by EPA as federal water quality standards that are subject to regulation and enforcement under provisions of the CWA. Basin Plan water quality objectives within San Vicente Reservoir, in part, are established for:

- mineral parameters,
- CDPH drinking water parameters, and
- phosphorus and nitrogen.

Mineral Parameters. The Basin Plan establishes numerical mineral concentration objectives for San Vicente Reservoir for total dissolved solids, chloride, sulfate, percent sodium, iron, manganese, boron, and fluoride. Because the purified water supply will undergo full RO treatment, the purified water supply is projected to contain concentrations of these mineral constituents that are significantly below the Basin Plan water quality objectives. Concentrations of minerals in the purified water will also be significantly below existing concentrations in both the imported water and local runoff inflow to San Vicente Reservoir. As a result, the proposed project will improve the mineral quality of water in the reservoir, and compliance with Basin Plan mineral parameters will not be an issue of concern for a full-scale project at San Vicente Reservoir.

CDPH Drinking Water Parameters. The Basin Plan incorporates State of California drinking water MCLs as surface water quality objectives. AWP Facility treatment processes have been selected (and tested during the Demonstration Project) to ensure that a full-scale project will comply with the MCLs. As noted, the City has submitted a draft project proposal to CDPH that documents projected compliance with CDPH requirements and presents the result of testing at the AWP Facility to document compliance with CDPH MCLs.

Phosphorus and Nitrogen. The Basin Plan establishes the following narrative and numerical water quality objectives to prevent adverse biostimulatory effects in surface waters:

> *Concentrations of nitrogen and phosphorus, by themselves or in combination with other nutrients, shall be maintained at levels below those which stimulate algae and emergent plant growth. Threshold total Phosphorous (P) concentrations shall not exceed 0.05 mg/l in any stream at the point where it enters any standing body of water, nor 0.025 mg/l in any standing body of water. A desired goal in order to prevent plant nuisances in streams and other flowing waters appears to be 0.1 mg/l total P. These values are not to be*

exceeded more than 10% of the time unless studies of the specific water body in question clearly show that water quality objective changes are permissible and changes are approved by the Regional Board. Analogous threshold values have not been set for nitrogen compounds; however, natural ratios of nitrogen to phosphorus are to be determined by surveillance and monitoring and upheld. If data are lacking, a ratio of N:P = 10:1 shall be used.

Phosphorus. As shown in Table 2 (see page 9), the AWP Facility treatment processes achieved near total removal of phosphorus. Based on the AWP Facility treatment results, purified water from a full-scale project at San Vicente Reservoir is projected to comply with the Basin Plan numerical water quality objectives for total phosphorus by a significant margin.

Nitrogen. As part of the full-scale project, existing NCWRP operations and facilities would be optimized for nitrogen removal. Additional nitrogen removal would occur through membrane filtration and RO treatment. Despite this advanced degree of nitrogen removal, the purified water supply is projected (see Table 2 on page 9) to contain total nitrogen concentrations on the order of 0.8 mg/l. The purified water is projected to be highly phosphorus limited, with a N:P ratio on the order of 160:1 or more.

The Basin Plan objective for total nitrogen has been subject to varying interpretation over the years as to whether the objective represents a numerical objective or narrative objective. The Basin Plan establishes numerical concentration objectives for phosphorus and states that "analogous thresholds for nitrogen have not been established". At the same time, however, the Basin Plan directs that natural nitrogen to phosphorus (N:P) ratios are to be determined through surveillance and upheld. Current Regional Board interpretation of the Basin Plan nitrogen objective, as presented to the City during a June 18, 2012 meeting, is that the Basin Plan surface water nitrogen objective consists of (1) a narrative objective prohibiting biostimulation effects that adversely impact beneficial uses, and (2) a numerical objective based on upholding "natural" N:P ratios.

The Basin Plan objective that natural N:P ratios be identified and upheld is derived from water quality criteria published by EPA (1976) in *Quality Criteria for Water* (Red Book). The Red Book N:P guidance recognized that biostimulation is limited by the availability of the least available nutrient. The availability of phosphorus limits biostimulation growth when N:P ratios are greater than approximately 10:1, while the availability of nitrogen limits biostimulation growth when N:P ratios are less than approximately 10:1. In the absence of data on whether nitrogen or phosphorus is limiting biostimulation, the Basin Plan presents guidance that a 10:1 N:P ratio should be used for assessing conformance with the narrative biostimulation objective.

Nitrogen concentration effluent limits established by the Regional Board in a reservoir augmentation NPDES permit will, in part, be determined by how the Regional Board chooses to interpret the "upholding natural N:P ratios" Basin Plan objective. If the Regional Board were to apply a 10:1 N:P ratio in establishing standards for introducing purified water to San Vicente Reservoir, the Board might require the purified water to achieve a total nitrogen concentration limit of 0.25 mg/l to 0.5 mg/l. In this event (see Section 5), modification of the Basin Plan nitrogen objective could be required to support implementation of a full-scale project at San Vicente Reservoir.

As a result of the uncertainty on how the Basin Plan nitrogen objective translates to NPDES permit limits, additional Regional Board guidance on Basin Plan nitrogen and N:P compliance will be required to:

- identify probable purified water total nitrogen effluent limits that would be recommended by the Regional Board in the NPDES permit, and
- determine whether or not modification of the Basin Plan total nitrogen objectives for San Vicente Reservoir will be required prior to Regional Board consideration of a NPDES permit for a full-scale project at San Vicente Reservoir.

Dissolved Oxygen. The Basin Plan designated San Vicente Reservoir as supporting both warm water habitat and cold water habitat. The Basin Plan requires that dissolved oxygen (DO) concentrations be maintained at 5.0 mg/l for warm water habitats, and 6.0 mg/l or more for cold water habitats. The Basin Plan also requires that mean annual DO concentrations be maintained at 7.0 mg/l or more.

The purified water would contain high concentrations of DO, and would not contain any discernible quality of oxygen-demanding material. Further, reservoir modeling conducted as part of the Limnology Study indicates no significant differences in DO concentrations within the epilimnion (where the purified water would be introduced) between the purified water and no purified water scenarios. (FSI, 2012a)

Despite these facts, however, a demonstration of compliance with the Basin Plan DO requirement will depend on Regional Board interpretation of the Basin Plan. The existing Basin Plan DO objectives are not based on and do not take into account thermal stratification in reservoirs. Once reservoirs stratify, no source of dissolved oxygen is available to the hypolimnion, and (in the absence of artificial aeration) hypolimnion DO concentrations naturally fall below the Basin Plan objectives in all thermally stratified reservoirs. As a result, compliance with the Basin Plan dissolved oxygen concentration objectives in the hypolimnion are not sustainable under natural conditions in San Vicente Reservoir or any other thermally stratified reservoir.

Demonstrating this natural effect, reservoir modeling conducted as part of the Demonstration Project Limnology Study (see Table 3 on page 10) indicates that hypolimnetic anoxia (DO concentrations of less than 0.5 mg/l) will occur slightly more than half of the year as a result of thermal stratification, regardless of whether or not reservoir augmentation is implemented.

Because the existing Basin Plan dissolved oxygen concentrations are inconsistent with conditions that naturally occur within stratified reservoirs, additional Regional Board guidance on Basin Plan DO compliance will be required to:

assess probable dissolved oxygen requirements that would be recommended by the Regional Board in the NPDES permit to implement the Basin Plan DO objectives, and

determine whether or not modification of the Basin Plan dissolved oxygen objectives for San Vicente Reservoir will be required prior to Regional Board consideration of a NPDES permit for a full-scale project at San Vicente Reservoir.

Section 6 California Toxics Rule Compliance

California Toxic Rule. EPA in 2000 promulgated the *California Toxics Rule*, or CTR (40 CFR 131), which establishes water quality standards for inland surface waters of California. The CTR establishes the following standards for discharges to inland surface waters:

- maximum (acute) concentration standards for toxic inorganic and organic constituents for the protection of freshwater aquatic habitat,
- continuous (chronic) standards for toxic inorganic and organic constituents for the protection of freshwater aquatic habitat, and
- standards for the protection of human health (consumption of organisms and consumption of water plus organisms).

Projected CTR Compliance. Data from the AWP Facility indicate that CTR standards for metals and cyanide are not projected to represent a compliance concern for a full-scale project, as (1) the NCWRP tertiary effluent contains low concentrations of these compounds, and (2) RO treatment to be provided as part of the AWP Facility is effective in removing such inorganic compounds.

Figure 9
AWP Facility at NCWRP

For these same reasons, the Demonstration Project data also has not indicated any toxic organic constituent which appears to represent a compliance concern. (It should be noted that bromodichloromethane was detected in one AWP Facility sample at a level above the CTR limit, but bromodichloromethane was normally below detection limits and this single sample result is considered an anomaly.) While no CTR compliance issues have been identified through Demonstration Project monitoring, CTR standards for the protection of public health include several standards that are significantly more stringent than can be reliably analyzed using available detection technology and detection limits. CTR-regulated compounds that include standards more stringent than available detection limits include:

- chlorinated pesticides such as DDT, Aldrin, Dieldrin, Heptachlor,
- polychlorinated biphenyls (PCBs),
- poly-aromatic hydrocarbons (PAHs), and
- N-nitrosodimethylamine (NDMA).

No reason appears to exist for chlorinated pesticides, PCBs, and PAHs to appear in the NCWRP effluent. Additionally, RO typically achieves significant removal of these compounds. The City's Demonstration Project testing included special focus on NDMA, as:

- NDMA is occasionally present in Southern California recycled water supplies,
- typical RO removal efficiencies for NDMA are on the order of 50 percent, and
- the CTR standard for NDMA is 0.00069 µg/l.

Despite these original concerns, however, existing Demonstration Project purified water data do not indicate that NDMA will represent a compliance issue. If the City chooses to move forward with a full-scale project at San Vicente Reservoir, however, the City's NPDES Report of Waste Discharge will reassess NDMA to determine if implementation of additional NDMA compliance measures are appropriate.

Section 7 Pathways for Demonstrating Regulatory Compliance

Implementation Approach. The City has submitted a preliminary project proposal to CDPH seeking conceptual approval for a full-scale reservoir augmentation project at San Vicente Reservoir. The Public Utilities Department is also scheduled to submit a feasibility report to the City Council in late autumn 2012.

Should the City Council choose to move forward with a full-scale project at San Vicente Reservoir, the City will initiate work to develop additional information required to support the design, environmental review, and regulatory permitting for the project. Such additional work would support:

- ongoing coordination with CDPH in support of modifying the City's CDPH water supply operating permit,
- assessing compliance with provisions of the California Environmental Quality Act (CEQA), and
- coordination with the Regional Board to assess Basin Plan compliance issues and information needs for submitting a Report of Waste Discharge to the Regional Board in application for a NPDES permit for a full-scale project.

Basin Plan Concentration Standards. The Basin Plan provides clear implementation guidance on the development of NPDES effluent standards for mineral constituents, drinking water MCLs, and total phosphorus. As noted in Section 6, available purified water data demonstrate compliance with Basin Plan water quality objectives. For these constituents, the City proposes the following pathway for demonstrating compliance of a full-scale project:

- present the results of Demonstration Project monitoring data and demonstrate that the AWP Facility purified water complies with applicable Basin Plan objectives, and
- submit the results of the comparison in a Report of Waste Discharge submitted in application for NPDES requirements for a full-scale project.

CTR Standards. Figure 10 schematically presents the process the City will utilize to demonstrate compliance with CTR standards. As noted in Section 6, available Demonstration Project data indicate compliance with applicable CTR standards for toxic organic and inorganic constituents without the need for an assigned mixing zone or dilution credit.

In the event additional data indicate a potential need for the consideration of a CTR mixing zone, the City will conduct studies to assess mixing zone hydraulics, dilution, and concentrations of CTR constituents at the edge of the mixing zone. As part of the dilution studies, the fate (e.g. half-life) of discharged constituents would be evaluated in order to assess re-entrainment effects.

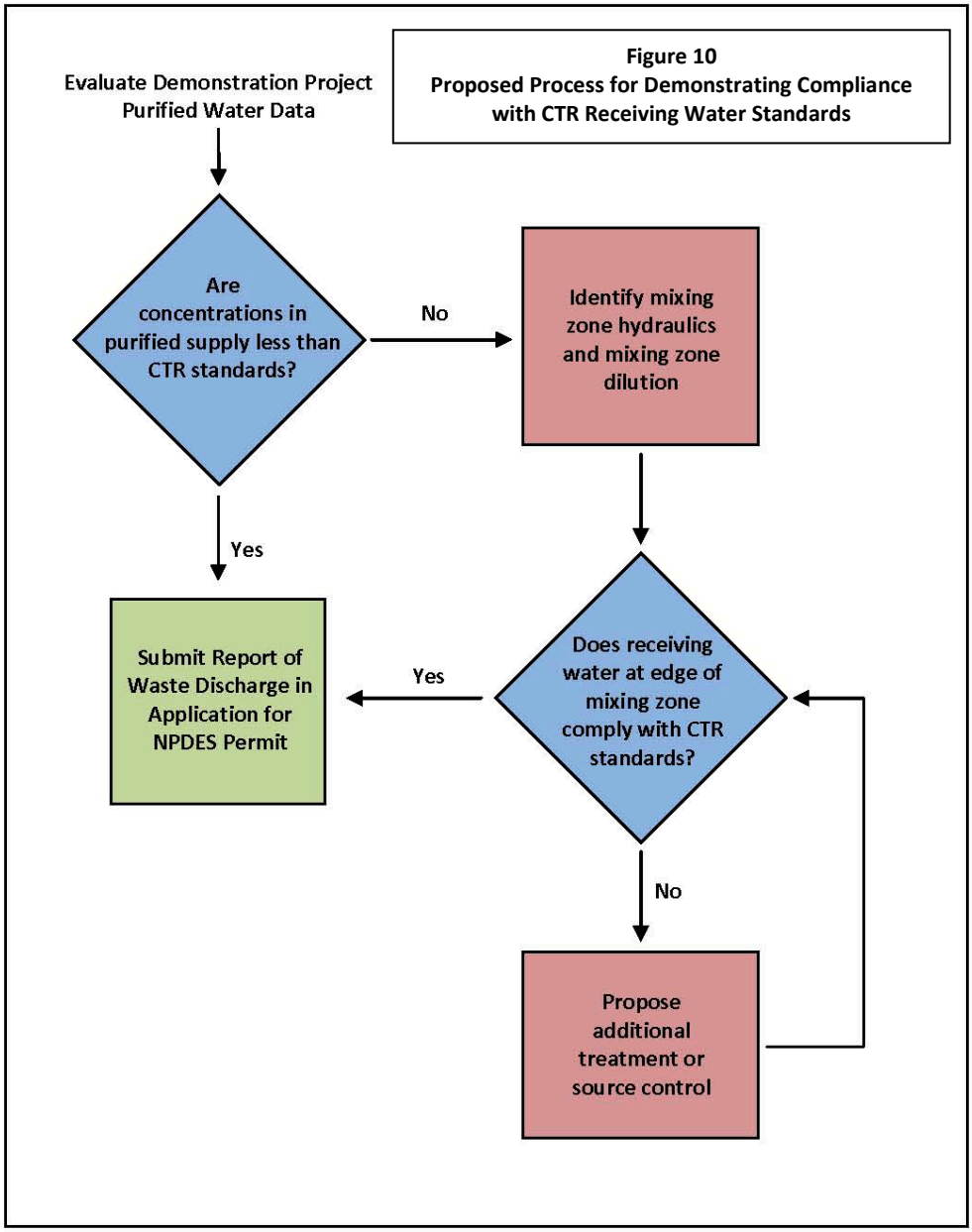

Figure 10
Proposed Process for Demonstrating Compliance with CTR Receiving Water Standards

Total Nitrogen and N:P Ratios. Additional coordination with Regional Board staff will be required to evaluate the appropriate pathway for regulatory approval of with respect to total nitrogen. Regional Board guidance will be required to address whether (1) modification of the Basin Plan or (2) modification of the CWA Section 303(d) impaired water body list will be required prior to Regional Board consideration of a NPDES permit for full-scale project at San Vicente Reservoir.

Figure 11 (page 25) presents the regulatory pathways for addressing issues associated with total nitrogen in San Vicente Reservoir. As shown in Figure 11, if the Regional Board, EPA, and State Board determine that no modifications of the 303(d) list or Basin Plan are required to support a full-scale project at San Vicente Reservoir, the City could directly move forward (if approved by the City Council) with preparing:

- a Report of Waste Discharge in application for a full-scale project at San Vicente Reservoir, and
- an Environmental Impact Report (EIR) that assesses compliance with provisions of CEQA.

While CEQA does not apply to the issuance of NPDES permits, the City recognizes the Regional Board preference for applicants to utilize the normal CEQA compliance process for assessing construction and operation impacts prior to the Regional Board's processing of a NPDES permit. Accordingly, the City anticipates completing an EIR and demonstrating compliance with CEQA in advance of Regional Board consideration of a NPDES permit for the full-scale project at San Vicente Reservoir.

303(d) Implications. One of the key factors that will dictate the pathway for regulatory approval of a full-scale project at San Vicente will be how regulators choose to interpret requirements established within Section 303(d) of the CWA. It is the City's understanding that the Regional Board has yet to determine whether revision of the existing CWA Section 303(d) impaired water list is required prior to issuing a NPDES permit for a full-scale project at San Vicente Reservoir.

In accordance with requirements established within CWA Section 303(d), the Regional Board identifies surface waters not complying with applicable water quality standards (impaired waters), and establishes priorities and schedules for the preparation of Total Daily Maximum Load (TMDL) and waste load allocations required to attain and maintain the standards. In 2008, the Regional Board added San Vicente Reservoir to the 303(d) list as a Category 5 (TMDL-required) impaired water body, and scheduled a TMDL for year 2021 to address the non-compliance.

The Regional Board's 2008 rationale for the 303(d) listing of San Vicente Reservoir for total nitrogen was based on the use of a "default" N:P ratio of 10:1 and data indicating that San Vicente Reservoir total nitrogen concentrations routinely exceeded 0.25 mg/l. In presenting the justification for the San Vicente Reservoir 303(d) listing, the Regional Board did not address or identify San Vicente Reservoir "natural" N:P ratios. Additionally, the 303(d) listing for San Vicente Reservoir only considered historic loads associated with the pre-expansion reservoir.

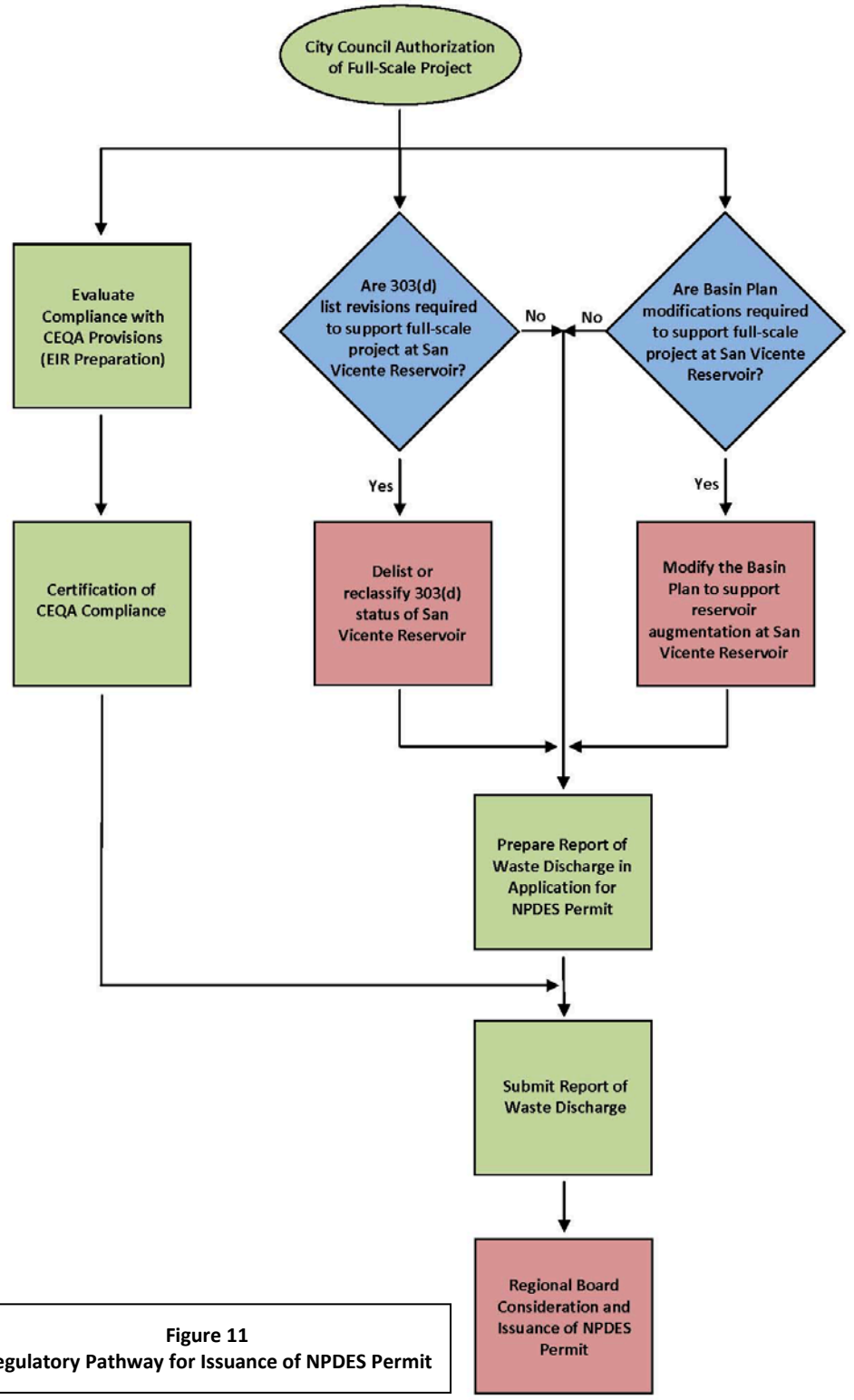

Figure 11
Regulatory Pathway for Issuance of NPDES Permit

Regional Board guidance is required to address if and how the 2008 303(d) impaired water listing of the historic San Vicente Reservoir applies to the expanded San Vicente Reservoir, and whether or not the existing 303(d) listings properly addressed San Vicente Reservoir N:P ratios. Additional Regional Board guidance will be required to address how the 303(d) listing of San Vicente Reservoir influences how the Regional Board can establish NPDES concentration limits for total nitrogen.

The City understands that the EPA and Regional Board are currently assessing implications of a 2007 ruling by the U.S. Court of Appeals for the Ninth Circuit that addressed a case involving issuance of a NPDES permit for a discharge to a 303(d) listed water. This Court of Appeals ruling appeared to place restrictions on when and how NPDES permits can be issued for discharges to 303(d) impaired waters. EPA has not yet issued guidance on how to interpret and apply this ruling. The regulatory pathway to project approval will, in part, depend on the direction of this guidance, and may include the need to:

- delist San Vicente Reservoir as being impaired for total nitrogen,
- revise the 303(d) listing to address identifying and upholding "natural" N:P ratios, or
- modify the San Vicente 303(d) listing to a lesser category (e.g. Category 4, where no TMDL is required).

Interpretation of Basin Plan N:P Objective. Regional Board guidance (see Figure 11) is also required to determine whether or not modification of the Basin Plan is required prior to Regional Board consideration of a NPDES permit for a full-scale project at San Vicente Reservoir.

As noted, the Basin Plan does not establish "analogous thresholds" for nitrogen, but requires that natural N:P ratios be identified and upheld. How the Regional Board chooses to interpret this requirement will influence the City's pathway to regulatory approval. Under the proposed project concept, approximately 15,000 AFY of imported water would be replaced by purified water that contains extremely low concentrations of phosphorus (resulting in N:P ratios on the order of 160:1 or more). Such a consistent purified water flow would allow the reservoir epilimnion (which comprises the euphotic portion of the reservoir where photosynthesis can occur) to be maintained in a phosphorus-limited mode (high N:P ratios). In minimizing the potential for biostimulation by upholding this high N:P ratio, Regional Board could be justified in establishing an attainable purified water NPDES effluent total nitrogen limit (e.g., a limit on the order of 1.0 mg/l). Under this interpretation, modification of the Basin Plan total nitrogen objective may not be necessary in order for the Regional Board to implement attainable effluent nitrogen limits for a full-scale project at San Vicente Reservoir. Additionally, an argument can be made that no basis exists for identifying "natural" N:P ratios in the historic San Vicente Reservoir because:

- the reservoir is being replaced by a larger reservoir which will be subject to a different set of natural conditions, and
- historic N:P ratios in the reservoir have been largely a function of how the reservoir is operated and which source of imported water (e.g. State Project Water or Colorado River) is being delivered to the reservoir, , as opposed to "natural" conditions.

Dissolved Oxygen. As described in Section 6, the Basin Plan implements a "one-size-fits-all" approach in applying a fixed set of dissolved oxygen concentrations to all San Diego Region surface waters. Basin Plan dissolved oxygen objectives do not take into account thermal stratification conditions in San Diego Region reservoirs, and are not physically sustainable in the hypolimnion under natural conditions once a thermocline has been established. The Regional Board has not addressed this Basin Plan inconsistency to date, and the reservoir augmentation project at San Vicente Reservoir would represent the first circumstance since the 1976 adoption of the Basin Plan in which the Regional Board is asked to consider NPDES requirements for a discharge to a thermally stratified reservoir.

Coordination with Regional Board staff will be required to assess implications of Basin Plan dissolved oxygen concentrations on a full-scale project at San Vicente Reservoir. In the event that the Regional Board determines that Basin Plan modifications are required to support the reservoir augmentation concept, such Basin Plan modifications (see Figure 11 on page 25) would be required in advance of (or in parallel with) developing the NPDES Report of Waste Discharge.

Section 8 Implementation and City-Preferred Pathway

Implementation Schedule for Preferred Pathway. As documented herein, the full-scale project will comply with all CDPH requirements and conform to applicable Basin Plan mineral standards, drinking water standards, and CTR standards. Additional Regional Board guidance, however, is required regarding whether or not:

- Revisions in the CWA Section 303(d) impaired water listings for San Vicente Reservoir are required prior to Regional Board issuance of a NPDES permit for the project, and
- Modifications in the Basin Plan are required prior to Regional Board issuance of a NPDES permit for the project.

The City believes that it is both feasible and appropriate for the Regional Board to consider and issue a NPDES permit for a full-scale project at San Vicente Reservoir without revisions to either the 303(d) list or Basin Plan. The pathway for project approval (see Figure 11) is straight-forward if the Regional Board and EPA agree with this interpretation.

Table 4 (page 28) presents a preliminary implementation time line for issuance of a NPDES permit for a full-scale project if no Basin Plan or 303(d) list modifications are required. Virtually all of the technical information required for preparation of a Report of Waste Discharge has been developed as part of the Demonstration Project. As a result, the City could prepare the requisite NPDES application documents concurrent with the City's CEQA compliance work. Under this scenario, the City could submit a NPDES application to the Regional Board immediately upon certification of CEQA compliance for the full-scale project. It is anticipated that the Regional Board should be able to issue a NPDES permit (and EPA approve the NPDES permit) within 12 months of the date the NPDES application is submitted.

Table 4
NPDES Permit Implementation Schedule
If No 303(d) List or Basin Plan Modifications are Required

Task	Elapsed Time After City Council Approves and Funds the Full-Scale Project at San Vicente Reservoir											
	Year 1				Year 2				Year 3			
	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr
City Approvals and CEQA Certification												
City Council approval of funding for full-scale project at San Vicente Reservoir	●											
CEQA consultant selection; draft EIR preparation; public review and comment	■	■	■	■	■	■	■	■				
City Council certification of CEQA compliance for full-scale project									●			
NPDES Permit Application and Approval												
City coordination with Regional Board staff and CDPH	■	■	■	■	■	■	■	■	■	■		
City selection of technical consultant; contract issuance and notice to proceed					■	■						
Preparation of draft and revised draft Reports of Waste Discharge for full-scale project							■	■				
City submits Report of Waste Discharge to Regional Board									●			
Regional Board staff reviews Report of Waste Discharge and coordinates with City for any additional required data									■	■	■	
Regional Board staff prepares Tentative NPDES permit; public comment period											■	
Regional Board consideration and approval of NPDES permit for full-scale project												●
EPA approval of NPDES permit												●

Implementation Pathway if 303(d) List Revisions are Required. The City understands that EPA proposes to soon issue guidance to the states on how to issue NPDES permits for inflows to 303(d)-listed receiving waters. If EPA and the Regional Board determine that 303(d) revisions are required prior to issuance of a NPDES permit for a full-scale project at San Vicente, justification exists for supporting such a 303(d) delisting or modification. This justification, in part, is based on the following:

- The original 2008 303(d) listing did not examine historic N:P data and ratios as required by the Basin Plan, but instead used a default 10:1 N:P ratio that the Basin Plan states is to be used "in the absence of available data."
- The original 2008 303(d) total nitrogen listing of San Vicente Reservoir was based on historic concentrations and nutrient loads associated with the former 90,000 AF reservoir capacity.

- Demonstration Project reservoir modeling results show that reservoir nutrient concentrations will be lower with expansion of the reservoir.
- San Vicente Reservoir is dominated by imported water inflows, and 303(d) listing of potable water storage reservoirs essentially comprised of imported water is not appropriate.
- Conformance with the Basin Plan biostimulation objectives can be provided through operating the reservoir in a phosphorus-limited mode.

While significant justification exists for delisting or revising the 303(d) listing for San Vicente Reservoir, a number of tasks would be required to proceed through the 303(d) listing process, including:

- coordination between City staff and regulators to determine the required 303(d) revisions,
- bringing technical consultants on-board (if required) to support the 303(d) revision process,
- conducting a technical evaluation of the 303(d) criteria and proposed revisions,
- developing technical documents justifying the proposed 303(d) revisions,
- reviewing proposed 303(d) revisions through the Regional Board stakeholder input and triennial review process,
- preparing the Regional Board staff report for the proposed 303(d) revisions,
- presenting the proposed 303(d) revisions to the Regional Board,
- forwarding the proposed 303(d) list to the State Board,
- State Board staff review of the proposed 303(d) revisions and coordination between State Board and Regional Board staffs,
- conducting the State Board public review and hearing process,
- State Board approval of the proposed 303(d) revisions,
- submitting the proposed 303(d) revisions to EPA, and
- EPA review and approval of the proposed 303(d) revisions.

If 303(d) list revisions are required, State Board and EPA review and approval of the 303(d) list revisions would comprise a significant portion of the overall implementation schedule. The process for achieving revision of the San Vicente Reservoir 303(d) listing could add an additional two to five years to the project implementation schedule, depending on:

- the State Board and Regional Board schedule for the next update to the 303(d) list,
- whether delisting of San Vicente Reservoir or modification of the listing category will be required,
- whether Basin Plan modifications are required in conjunction with the 303(d) list revisions,
- Regional Board staff availability, priorities, and funding, and
- EPA and State Board review and approval.

Implementation Pathway if Basin Plan Revisions are Required. In coordination meetings between the City and Regional Board, Regional Board staff have indicated a preliminary position (subject to confirmation by EPA) that the Basin Plan allows the Regional Board the flexibility to assess N:P ratios on a site-by-site basis and establish project-specific N:P ratios for any given receiving water. The City contends that this flexibility should allow the Regional Board to establish achievable NPDES permit limits for total nitrogen without the need for revision of the Basin Plan, in part, based on the following:

- Historic reservoir N:P data will no longer be applicable to the expanded San Vicente Reservoir, and N:P ratios in the expanded reservoir are largely dependent on which water sources (e.g. Colorado River water, State Water Project water, or purified water) the City stores in the reservoir.
- Reservoir modeling indicates that nutrient concentrations will be reduced in the expanded reservoir compared to historic conditions, regardless of whether or not reservoir augmentation is implemented.
- Implementation of a full-scale project at San Vicente Reservoir would allow the City to better manage biostimulation by maintaining phosphorus-limited conditions in the reservoir.
- Reservoir modeling can be used to help predict and manage potential biostimulation conditions.

If Basin Plan modifications are required prior to issuance of a NPDES permit, tasks required to proceed through the Basin Plan modification process would include:

- coordination between City staff and regulators to determine the required Basin Plan revisions,
- bringing technical consultants on-board to support the Basin Plan revision process,
- assembling data and technical documents to support the proposed Basin Plan revisions,
- assessing conformance of the proposed Basin Plan revisions with applicable state and federal water quality policies,
- preparing the Regional Board staff report and administrative record that supports and justifies the proposed Basin Plan revisions,
- preparing the Tentative Resolution for Basin Plan modification,
- conducting the Regional Board review, public input, and hearing process,
- Regional Board consideration and adoption of the proposed Basin Plan modifications,
- State Board staff review of the proposed Basin Plan modifications,
- State Board consideration and approval of the proposed Basin Plan modifications,
- Review and approval of the proposed Basin Plan modifications by the State of California Office of Administrative law, and
- EPA review and approval of the proposed Basin Plan modifications.

Once the Regional Board has approved the proposed Basin Plan modifications, an additional 12 to 24 months may be required for State Board, Office of Administrative Law, and EPA approval. As a result, the process for revising the Basin Plan could add two to three years to the overall project implementation schedule, depending on:

- the nature of the proposed revisions (e.g. revision of numerical standards vs. revision of implementation provisions),
- Regional Board staff availability, priorities, and funding, and
- State Board, Office of Administrative Law, and EPA review and approval.

Requested Regional Board Feedback. The full-scale project remains technically feasible whether or not EPA or the Regional Board determine that revision of the Basin Plan or 303(d) list is required prior to Regional Board issuance of a NPDES permit for the full-scale project at San Vicente. Requiring such Basin Plan modifications or 303(d) list revisions in advance of the NPDES permit issuance, however, would lengthen the City's implementation schedule and potentially affect the City's decision on whether and how to proceed with a full-scale reservoir augmentation project at San Vicente Reservoir.

The City requests that Regional Board staff coordinate with State Board and EPA staff to determine whether the Regional Board can move forward with implementing attainable NPDES requirements for the City's proposed project without the need for (1) revision of the San Vicente Reservoir 303(d) listings, or (2) modification of the Basin Plan. The City also requests any guidance or recommendations the Regional Board can offer relative to implementing a full-scale project at San Vicente Reservoir.

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Appendix E: San Diego Regional Water Quality Control Board Letter of Concurrence

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CALIFORNIA
Water Boards

EDMUND G. BROWN JR.
GOVERNOR

MATTHEW RODRIQUEZ
SECRETARY FOR
ENVIRONMENTAL PROTECTION

California Regional Water Quality Control Board, San Diego Region

February 7, 2013

In reply refer to:
244506jllim

Ms. Marsi A. Steirer
Deputy Director. Public Utilities Department
City of San Diego
600 B Street, Suite 600, MS 906
San Diego, CA. 92101

Subject: Indirect Potable Reuse/Augmentation Project at San Vicente Reservoir

Ms. Steirer:

The City of San Diego (City) submitted, for review and comments, a technical report dated August 2012 entitled, *Proposed Regional Water Quality Control Board Compliance Approach, Final Draft* (Report). The City is proposing an Indirect Potable Reuse/Reservoir Augmentation Project that would supplement the approximate 240,000-acre-foot San Vicente Reservoir with up to 15,000 acre-feet per year (AFY) of purified recycled water produced at a full-scale advanced water treatment facility to be sited at the City's North City Water Reclamation Plant (NCWRP) (hereinafter Project). The Report examines key water quality regulations, permitting issues, and other factors that could affect the timeline for issuance of a National Pollutant Discharge Elimination System (NPDES) permit for discharging purified recycled water into San Vicente Reservoir. The City requested that San Diego Water Board coordinate with the U.S. Environmental Protection Agency, Region 9 (USEPA) in reviewing the Report to determine whether the Board can move forward with implementing attainable NPDES permit requirements for the City's Project without the need for (1) revision of the Clean Water Act (CWA) section 303(d) impairment listings for the San Vicente Reservoir, or (2) modification of the *Water Quality Control Plan for the San Diego Basin* (Basin Plan).

The San Diego Water Board, with concurrence from USEPA, strongly supports the efforts of the City to develop the San Vicente Reservoir Augmentation Project and concurs with the City's preferred NPDES permit pathway described in the Report. The San Diego Water Board has prepared the following comments, in consultation with USEPA, regarding the City's preferred NPDES permit pathway for the Project:

1. Modification of the San Diego Water Board's Basin Plan should not be necessary to prescribe an effluent limitation for nitrogen based on a ratio of nitrogen to phosphorus (N:P ratio) that accounts for the specific water quality factors relevant to the expanded San Vicente Reservoir. The Report indicates the City is projecting the advanced water treatment process discharge will comply with the Biostimulatory Substances total phosphorus water quality objective by a significant margin. With respect to nitrogen, the

Biostimulatory Substances water quality objective allows the San Diego Water Board the flexibility to assess N:P ratios on a site-by-site basis and establish project-specific N:P ratios for any given receiving water in lieu of a 10:1 N: P ratio. The San Diego Water Board does not anticipate that a Basin Plan amendment will be necessary to accomplish this. The San Diego Water Board understands the San Vicente Reservoir is currently undergoing an expansion that will raise the height of San Vicente Dam by 117 feet and increase the reservoir storage capacity from 90,000 acre-feet (AF) to over 240,000 AF. The expanded Reservoir will be subject to a different set of natural conditions that can influence water quality in the Reservoir. Moreover, the historic ratios of nitrogen to phosphorus (N:P ratios) in the Reservoir have largely been a function of how the Reservoir is operated and which source of imported water (e.g. State Project Water or Colorado River) is being delivered to the Reservoir. All of these factors will be considered in developing the supporting rationale and assumptions to derive a site-specific N:P ratio and NPDES Permit numerical nitrogen effluent limitation for the Project discharge to the Reservoir.

2. Modification of the CWA section 303(d) list to remove San Vicente Reservoir will not be required to issue a NPDES permit for the Project. San Vicente Reservoir is identified on the 303(d) list as a water quality limited segment where water quality standards for chloride, color, sulfates, total nitrogen as N and pH are not met and a Total Maximum Daily Load (TMDL) is required, but not yet completed. The TMDL for San Vicente Reservoir is currently scheduled for completion in 2019. Applicable NPDES federal regulations set forth at 40 CFR 122.4(i) do require that once a TMDL is in place, a discharger proposing a new facility discharge of a pollutant of concern must a) demonstrate that there are sufficient remaining pollutant load allocations to allow for the discharge and b) meet the conditions of the TMDL. Modifications to the 303(d) listing for San Vicente Reservoir, if warranted and necessary, may be completed after the issuance of the NPDES permit.

3. The Report indicates the quality of purified recycled water is expected by the City to comply with all California Toxic Rule (CTR) water quality standards for toxic organic and inorganic constituents without the need for an assigned mixing zone or dilution credit. In the event additional data indicate a potential need for the consideration of a CTR mixing zone, it will be necessary for the City to conduct and complete studies to assess mixing zone hydraulics, dilution, and concentrations of CTR constituents at the edge of the mixing zone in advance of the NPDES permit issuance. The San Diego Water Board may grant mixing zones to the City in accordance with the provisions established in the *Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California.* The allowance for a mixing zone is discretionary and would only apply to a discharge regulated under an NPDES permit.

The heading portion of this letter includes a San Diego Water Board code number noted after "In reply refer to:" In order to assist us in the processing of your correspondence please include this code number in the heading or subject line portion of all correspondence and reports submitted to the San Diego Water Board pertaining to this matter.

If you have any questions regarding this matter please contact David Barker by e-mail at DBarker@waterboards.ca.gov or by phone at (858) 467-2989.

Respectfully,

David Gibson
Executive Officer

DTG:JS:DTB

Tech Staff Info & Use	
Order No.	none
Party (GT/CIWQS) ID	39639
File No.	none
WDID	none
NPDES No.	none
Reg. Measure ID	none
Place ID	244506
Person ID	None
Inspection ID	n/a

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Appendix F: Independent Advisory Panel Findings

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NWRI National Water Research Institute

Joint Powers Agreement Members

Inland Empire Utilities Agency

Irvine Ranch Water District

Los Angeles Department of Water and Power

Orange County Sanitation District

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West Basin Municipal Water District

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November 16, 2012

Ms. Marsi A. Steirer
Deputy Director
Public Utilities Department
City of San Diego
600 B Street, Suite 600
San Diego, CA 92101

Dear Ms. Steirer:

The National Water Research Institute (NWRI) is pleased to transmit this letter on the findings of the Independent Advisory Panel (Panel) to assist the City of San Diego, California, with its Indirect Potable Reuse/Reservoir Augmentation (IPR/RA) Project.

A previous NWRI Panel, formed in 2004, was asked to review various water reuse options in a report prepared by the City. The Panel submitted a final letter report to the City on December 1, 2005. The Panel found that appropriate alternative water reuse strategies for the City of San Diego had been identified. Subsequently, the City elected to proceed with a pilot demonstration project on indirect potable reuse, known as the Water Purification Demonstration Project (herein, referred to as the "Demonstration Project").

Purpose of 2009-2012 Panel

In 2009, the City requested that NWRI form a Panel to provide expert peer review of the technical, scientific, regulatory, and policy aspects of the proposed Demonstration Project under development by the City, based on the findings from the 2004 Panel's final letter report. The purpose of the Demonstration Project was to evaluate the feasibility of using advanced treatment technology to produce purified water from the tertiary effluent of the North City Water Reclamation Plant that can be sent to the expanded San Vicente Reservoir, blended with other raw water, treated in the existing Alvarado drinking water treatment plant, and distributed as potable water.

As part of the Panel process, the Panel was charged with:

- Assisting the City and California Department of Public Health (CDPH) to establish a pathway to move from the draft groundwater regulations to surface water augmentation criteria. This effort includes recommending criteria (or suggested regulations) and verifying the various optional advanced water treatment (AWT) and reservoir strategies that will ensure safe drinking water at consumer taps.
- Assisting the City in developing the Demonstration Project work plan. This effort includes a review of the reservoir modeling studies and performance of the AWT demonstration plant.

The Panel included 10 members who represented local and national expertise in environmental engineering, water reuse regulations, toxicology, environmental chemistry, limnology, microbiology, and other fields relevant to the project. Six of the Panel members were part of the 2004-2005 Panel.

Panel Activities

The full Panel met three times during the period of 2009-2012 and held three subcommittee meetings on limnology and reservoir operation and two subcommittee meetings on the Advanced Water Purification Facility. Panel members also participated in two working group meetings held by the City on limnology and reservoir operation. Each Panel meeting or subcommittee meeting resulted in a report that was prepared by members of the Panel and submitted to the City. A total of seven reports were prepared by the Panel.

Findings

The City's staff and consultants are to be commended for the positive and thoughtful approach they used to address the many challenges associated with the planning and implementation of the Demonstration Project. The Panel believes that the *Water Purification Demonstration Project Final Report (October 2012)* and supporting documents are responsive to the directives set forth by the City Council. The Panel is also pleased with the responsiveness of the City's staff and consultants to the comments and recommendations made by the Panel. The Panel recognizes that:

1. The City considered various options for municipal wastewater reuse strategies and selected a proven treatment process scheme for indirect potable reuse that will meet or exceed all health and safety requirements, based on the successful implementation of the Groundwater Replenishment System at the Orange County Water District. The Advanced Water Purification Facility was operated by the City for a period of 13½ months in various modes to assess alternative membrane filtration equipment and reverse osmosis operational configurations. The findings from the Demonstration Project showed that the purified water met or exceeded all of the drinking water requirements and also provided multiple barriers for regulated and unregulated chemical and microbial constituents. The water produced is of a higher quality than any source available to the City of San Diego.

2. With the help of consultants, City staff has undertaken an extensive program of modeling the behavior of both the existing and expanded San Vicente Reservoir, with respect to water quality and hydrodynamics. The model was verified and is an effective tool in simulating future impacts of the addition of purified water to the reservoir. The reservoir provides a minimum of hundred-fold (2 logs) dilution of the purified water added to the reservoir. In fact, for the majority of water quality constituents, the quality of the purified water is better than the water in the reservoir.

3. City staff has met and engaged with the local and state public health and water quality control agencies to ensure that the water produced would meet and exceed all health and safety requirements for all designated uses, including indirect potable reuse. Based on a review of the material provided by the City, CDPH has issued a letter approving the indirect potable reuse project concept. In addition, the Regional Water Quality Control Board San Diego Region (working in conjunction with the State Water Resources Control Board and U.S. Environmental Protection Agency) is also working with the City to develop a plan that will allow for the addition of purified water to the reservoir.

4. City staff has conducted an extensive public outreach program involving a speaker's bureau, community events, facility tours, surveys, and social media. Because of the outreach effort, community support has increased significantly. The City staff has been forthcoming, open, and transparent in describing all aspects of the indirect potable reuse project to the public, including encouraging the public to tour the Advanced Water Purification Facility.

Conclusion

It is the unanimous conclusion of the Panel that the project as described in the *Water Purification Demonstration Project Final Report* will be a landmark development in the acceptance and furtherance of indirect potable reuse and will contribute to the City of San Diego's water portfolio. The proposed project will supplement existing sources and provide a greater degree of independence, thus improving the reliability of the existing water supply. The successful implementation of the full-scale water purification project will facilitate additional potable reuse in San Diego and other communities in California and the United States.

Respectfully submitted by the NWRI Independent Advisory Panel,

George Tchobanoglous, Ph.D., R.E., NAE
University of California, Davis
Panel Chair

James Crook, Ph.D., P.E.
Water Reuse Consultant
Vice-Chair

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University of California, Riverside

Richard J. Bull, Ph.D.
Washington State University
(Retired)

Joseph A. Cotruvo, Ph.D.
U.S. EPA (Retired)

Richard Gersberg, Ph.D.
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University of California, Irvine

Audrey D. Levine, Ph.D., P.E.
Battelle Memorial Institute

David R. Schubert, Ph.D.
Salk Institute

Michael P. Wehner
Orange County Water District

cc: Jeffrey J. Mosher, NWRI

Appendix G: Summary of Cost Assumptions (Section 8.4 of the City of San Diego 2012 Recycled Water Study)

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8.4 Financial Evaluation of Alternatives

A financial evaluation was performed, which included each Integrated Reuse Alternative considered in this Study. The financial evaluation was prepared to ultimately help decision-makers compare the costs of different water reuse approaches and to aid in making decisions about whether to invest in the water reuse system. The guiding principles for the evaluation included:

- Provide transparent costing of alternatives.
- Provide multiple opportunities at workshops and Stakeholder meetings to review, discuss, and debate project costs.
- Prepare a comparative financial evaluation of the Integrated Reuse Alternatives and include financing costs.
- Compare the water reuse alternative costs to other options facing the City and Participating Agencies.

The financial evaluation included a Net Present Value financial spreadsheet model (financial model). The financial model was used to calculate and compare unit costs (in terms of dollars per acre foot) for each Integrated Reuse Alternative against the current cost of imported untreated water. The financial model included fixed and variable inputs, which were used to perform a sensitivity analysis.

8.4.1 Financial Model Cost Components

The costing process consisted of a multi-step approach. The following summarizes the major steps:

- **Development of Unit Costs for Infrastructure.** Unit costs for treatment and conveyance facilities were prepared to estimate infrastructure costs. The unit costs were based on 23 Bid Summaries, two formal agency estimating tools, 14 project cost estimates, and insight and experience from the three national consulting team members performing this Study. The unit costs were first reviewed in the Coarse Screening Session and updated through the course of the project. One revision included modifying the unit costs to provide economy of scale adjustments (i.e. larger facilities are less expensive to build and operate than smaller facilities with similar processes and construction methods). This adjustment was based on City cost data and the EPA's *Guide to the Selection of Cost-Effective Wastewater Treatment Systems* (EPA-430/9-75-002; July 1975).
- **Integrated Reuse Alternative Costs.** Costs for each alternative were developed and reviewed in the Coarse Screening Session and the Fine Screening Session. The costs included:
  - **Capital Costs.** Capital costs were developed using the Study's unit costs described above. Capital costs were multiplied by cost factors related to the difficulty of construction at each site. Factors varied from 1.0 to 1.5 times the unit costs. Tunneling allowances were also included as an allowance for utility conflicts and for avoiding high traffic areas, streams, freeways, rail, or sensitive environmental areas.
  - **Operation and Maintenance Costs.** Operation and maintenance costs were also developed based on the Study's unit costs (for treatment facilities) and values developed in the 2005 Water Reuse Study (for conveyance facilities including pipelines, pump stations and reservoirs). Treatment facility costs included labor, chemicals, energy, and materials. Costs for conveyance facilities were calculated as a percentage of the capital costs. An electricity cost of $0.12 per kilowatt-hour was used for treatment and pump station operations.
  - **Soft Costs.** A 50-percent soft cost allowance was provided for Engineering, Administration, Legal, Construction Management and Environmental Permitting costs

- **Land Acquisition.** Although a majority of the facilities planned are located on City parcels, additional land or alignments may need to be acquired. A cost equal to 4 percent of the estimated construction cost was included for these purposes.

- **Financial Model Assumptions.** Financial model assumptions were coordinated for consistency with other City financial model assumptions. These assumptions were fixed for all scenarios. It is the practice of the City to finance 20-percent of all capital projects with rates and fees. Funds derived from rates are the main source of funds for day-to-day operational and maintenance costs and debt coverage requirements. The assumptions related to financing include the following:
  - Interest rate of 5.5 percent on revenue bonds and 2.5 percent on State Revolving Fund (SRF) loans
  - Repayment period of 30 years on revenue bonds and 20 years on SRF loans
  - Issuance costs of 2.5 percent on revenue bonds and 1.0 percent on SRF loans
  - Debt coverage of 1.25 percent on revenue bonds and 1.2 percent on SRF loans
  - Maximum loan under SRF of $50 million per year
  - Complying with revenue bonds requires a reserve amount equal to one payment to be set aside at issuance
  - O&M escalation for chemical, energy, and labor set at 4.0 percent; Capital cost escalation set at 3.0 percent
  - Net Present Value analysis for 50 years
  - ENR Los Angeles cost basis index of 10051.30

8.4.2 Comparative Costs Basis Using a Sensitivity Analysis

The costs for the reuse program proposed in this Study will be compared to the cost of imported untreated water, and other alternative water supply projects (such as desalination). It is important to note that the cost presented for the reuse alternatives in this Study are fully loaded (including capital, O&M and financing costs). It is common for other new alternative water supply costs to be partial costs, including overly optimistic assumptions or certain exclusions. The costs for the alternatives presented in this Report were prepared to provide thorough and realistic budgetary estimates

8.4.3 Gross Costs

Gross Costs were calculated to determine the investment required for each Integrated Reuse Alternative. To achieve a realistic picture of Gross Costs, the financial evaluation included a sensitivity analysis with bracketed (bookend) conditions, using variables described as follows and summarized in Table 8-12:

- **Favorable Condition.** The favorable condition assumed the best-case scenario using the most favorable cost variables. This included 30-percent grant funding, $450 per acre-foot local resource program credits for 20 years, and a 20-percent project contingency.
- **Unfavorable Condition.** The unfavorable condition assumed the worst-case scenario related to the variable costs. This condition included 10-percent grant funding, $100 per acre-foot local resource program credits for 20 years, and a 40-percent project contingency.

Table 8-12. Gross Costs Variables

Item	Description	Favorable Scenario	Unfavorable Scenario	Average
Grants	To help offset the costs associated with projects, the City can apply for grants to help finance a portion of the capital projects. Grants usually consist of funds that are obtained from state or federal agencies and do not need to be paid back. This is the preferred option among municipal utilities. The grants usually have stipulations regarding the type of projects that can be included and how the money is managed; therefore, additional administrative costs also come with the funds. Typically, grant amounts vary depending on the project type. Projects promoting water reuse have generally been well supported, with multiple programs such as the Bureau of Reclamation's Title XVI Program and California's bond measures. The analysis assumes receiving grant funding offsetting 10 to 30-percent of each Integrated Reuse Alternative's capital costs.	30%	10%	20%
Local Resource Program	To help offset the costs associated with new water projects, the City has participated in the Local Resource Program offered by MWD and the Local Water Supply Development funding provided by the SDCWA (these two programs are collectively referred to herein as the LRP). The LRP was created to promote the development of water recycling and groundwater recovery projects in order to replace an existing demand or prevent a new demand on imported water supplies. Since the City relies indirectly on imported water from MWD/SDCWA, it may be eligible to receive a credit up to $450 per acre-foot produced. The program is dependent on available funding and agency approvals and usually comes with a fixed term. For this Study, a 20-year term and a funding level of $100 to $450 per acre-foot were assumed. One caveat is that the LRP credit is discontinued once the cost to produce the alternative water supply source becomes cheaper than the cost of imported water.	$450/acre-foot, 20 years	$100/acre-foot, 20 years	$275/acre-foot, 20 years
Project Contingency	A project contingency was added to the construction costs of all alternatives. Contingencies are important at this level of planning to account for unknown conditions or additional facilities needed once more detailed evaluations or design is complete. The analysis assumes project contingencies adding 20-percent to 40-percent to the Integrated Reuse Alternative's capital costs.	20%	40%	30%

8.4.4 Net Costs

Net Costs are considered "real" or "true" costs for the purposes of comparing reuse projects to imported untreated water and other alternative water sources. Net Costs account for savings, offsets and credits that occur as a result of the reuse projects. For example, constructing a new reuse plant upstream of the Point Loma Plant reduces flows to the Point Loma Plant, resulting in lower capital and operational costs at the Point Loma Plant. These reduced costs are subtracted from the Gross Costs to get the Net Costs or "true" program cost. This is similar to the Orange County Groundwater Replenishment System, which was responsible for substantial savings by avoiding costly outfall improvements.

The variables associated with the Net Cost calculations are described in Table 8-13. Additional information regarding Net Costs is included in a Cost Methodology Summary included in Appendix H. The Cost Methodology Summary is presented in an informative, frequently asked question (FAQ) format. This document summarizes direct and indirect wastewater savings calculations and includes a graphical comparison of the key wastewater facilities included in this Study with the City's September 2011 Draft Wastewater Master Plan facilities.

Table 8-13. Net Cost Variables

Component	Description	Savings
Tier 1 - Direct Wastewater System Savings • Reduction of flows to downstream facilities • Remaining Point Loma capacity is upgraded to Secondary	The Study's Alternatives achieve the goal of offloading flows away from the Point Loma Plant, resulting in reduced capital and operating costs at downstream wastewater facilities. The direct wastewater system savings were calculated by comparing the size of the Point Loma Plant proposed in the City's September 2011 Draft Wastewater Master Plan (adjusted to a secondary treatment option) to the smaller Point Loma Plant size (which includes secondary treatment) in this Study (assuming the reuse projects in this Recycled Water Study are implemented). The cost difference is the savings directly attributable to these reuse projects. See Appendix H for additional details.	$557 million (capital savings) $27.6 million/year (operation and maintenance savings)
Tier 2 - Salt Reduction Credit • Water quality improvements to water & wastewater systems due to indirect potable reuse • Homeowner and business benefits not included in total	Similar to the 2005 Water Reuse Study, a salt credit was considered to account for the benefits of salinity reduction in the watershed. The salt credit basis is from the 1999 Salinity Management Study (MWD, USBR). The quantitative credit shown is the financial benefits of extending the life of the municipal water and wastewater treatment systems from having lower salinity levels in the water and wastewater flows. The San Vicente and Otay Lakes Reservoirs could see dramatic reductions in salinity levels from the proposed indirect potable reuse projects. Downstream agency facilities including drinking water treatment plants and the Harbor Drive advanced water purification facilities would benefit from this reduced salinity. In addition to the benefit shown, there is a benefit to water customers, since water heaters, clothes washers, dishwashers, and fixtures will also last longer with lower salinity levels. The combined savings included in the City's 2005 Water Reuse Study was $250/AF. The $100/AF value used in this Study only accounts for the estimated municipal treatment equipment savings.	$100/acre foot (not including customer savings)
Tier 3 - Indirect Wastewater System Savings • Remaining Point Loma capacity maintained at CEPT • Quantifies savings if this approach is attributable to the reuse program	The Point Loma Plant will either continue to use chemically enhanced primary treatment or will require upgrades to secondary treatment. This Study does not provide an opinion on whether CEPT or secondary treatment processes should be employed at the Point Loma Plant. However, it is prudent to summarize the reduced Point Loma capital and operational costs if CEPT status could be maintained for the remaining Point Loma Plant capacity after reuse projects and with the South Bay Diversion. The indirect wastewater savings are therefore calculated as the avoided secondary treatment costs at the Point Loma Plant. See Appendix H for additional details.	$463 million (capital savings) $13.0 million/year (operation and maintenance savings).
Qualitative Water System Savings	The local, regional and statewide water systems were considered for potential savings from increasing water reuse. Since quantitative costs could not be developed with current available information, qualitative benefits were considered, particularly at the regional and statewide level. The region's local water treatment plants treat water from local runoff (which is limited) and imported untreated water from the SDCWA and MWD (which is subject to cutbacks and higher price fluctuations). Indirect potable reuse projects provide a reliable, uninterruptable untreated water equivalent that would help supply the local water treatment plants that ratepayers have invested in over the past decade. Indirect potable reuse projects may defer or eliminate the need to expand the imported untreated water conveyance system needed to serve these treatment plants. The SDCWA Master Plan (currently underway) may help quantify what these benefits are in future updates to this Study. In addition, Stakeholders emphasized an additional benefit related to the need to fix water supply conditions in the California Bay-Delta (which has the potential for substantial cost impacts for Southern California). Water reuse projects reduce the burden on importing water from the Bay-Delta, providing an additional benefit for these projects.	Quantitative benefits are speculative, therefore this category is currently considered qualitatively

8.4.5 Cost Summary for Integrated Reuse Alternatives

The Integrated Reuse Alternative costs are summarized in Table 8-14. The table includes a tiered breakout of summary level costs based on the Gross Costs and Net Costs categories described above. As shown, the costs for A1, A2 and B3 are nearly identical to each other, and slightly higher than B1 and B2. For the A1/A2

comparison to B1/B2, the increased costs occur mainly due to the additional wastewater facilities and pumping needed to divert flows from Morena to the North City Plant. For the B3 comparison to B1/B2, B3 adds an additional plant and does not have the same economy of scale that the B1 and B2 Alternatives have. Implementation steps are included later in this Chapter, which include steps to further develop the Alternatives and look for additional cost savings.

Table 8-14. Cost Summary (2011 $/AF)

Alternative	Average Gross Costs	Net Costs		
		Tier 1 - Direct Wastewater System Savings	Tier 2 - Salt Reduction Credit	Tier 3 - Indirect Wastewater System Savings
		Remaining Point Loma capacity upgraded to Secondary	*Water Quality Benefit to Water/Wastewater System*	*Remaining Point Loma capacity maintained at CEPT*
A1: North City 45 mgd; Split Harbor Dr. AWPF	$1,900	$1,300	$1,200	$800
A2: North City 45 mgd; Consolidated Harbor Dr. AWPF	$1,900	$1,300	$1,200	$800
B1: North City 30 mgd; Split Harbor Dr. AWPF	$1,700	$1,100	$1,000	$600
B2: North City 30 mgd; Consolidated Harbor Dr. AWPF	$1,700	$1,100	$1,000	$600
B3: North City 30 mgd; Consolidated Harbor Dr. AWPF; Mission Gorge AWPF	$1,900	$1,300	$1,200	$800

Notes:

- *All Alternatives include South Bay Option C2 expansion with the Spring Valley No. 8 Diversion*
- *Direct and indirect wastewater system savings based on a comparison between the City's September 2011 Draft Wastewater Master Plan and the reduced wastewater facility sizing and pumping required as a resulted of the projects included in this Recycled Water Study (see Appendix H).*
- *Totals are in 2011 dollars (ENR Los Angeles Index value of 10,051.30, June 2011) and are based on a net present value analysis using a detailed financial model.*
- *Financial model sensitivity analysis generally produced cost ranging +/- $200/AF of the values shown. Favorable conditions could result in lower costs than shown.*

Key Study Conclusion

The Alternative Net Costs represent the costs that should be compared to other water sources – particularly imported untreated water. The average costs of the Alternatives above are:

- Cost assuming direct wastewater savings = $1,200/AF
- Cost assuming above plus salt credit = $1,100/AF
- Cost assuming above plus indirect wastewater savings = $700/AF

These costs compare well to the 2011 untreated water cost of $904 per acre foot, and are more economical than most other new water supply concepts being proposed.

The net cost tiers are summarized as follows:

- **Tier 1: Net Costs with Direct Wastewater System Savings.** This tier includes the Direct Wastewater System Savings that occur as a result of the water reuse projects in this Study which help to avoid approximately 100 mgd of secondary treatment improvements at the Point Loma Plant. This tier represents the first threshold in which the Alternative costs should be considered for comparison to the cost of other water sources – such as imported untreated water or other new water sources. The comparison, as outlined in the next section, is very favorable compared to untreated water and more economical than most water supply concepts being proposed at this time.
- **Tier 2: Net Costs with the Salt Credit (Including Tier 1 Savings).** This tier includes the Salt Reduction Credit Savings and adds a $100/acre-foot credit occurring as a result of the water quality benefits created by implementing indirect potable reuse projects. The savings included is attributable to benefits received by agency facilities downstream of the new projects, including wastewater facilities. Additional savings (not accounted for in this total) would be experienced by homeowners and business as described in Chapter 6. Although these benefits are real, the ability to recover these savings and allocate them to the reuse program led to extracting this element as a separate unit cost tier so it may be considered separately from other savings.
- **Tier 3: Net Costs with Indirect Wastewater System Savings (including Tier 1 and Tier 2 Savings).** As described in the table above, this Study does not provide an opinion on whether the Point Loma Plant should continue to use CEPT treatment processes or upgrade to secondary processes. However, it was considered appropriate to list the Net Costs of the new water if the water reuse program proposed in this Study led to maintaining CEPT treatment for the remaining flows that reach the Point Loma Plant (i.e., the remaining flows that are not recycled upstream).

The Study Alternative's Net Costs were extrapolated based on a 3.5-percent inflation rate and compared to projected untreated imported water rate as shown in Figure 8-8. The 2011 SDCWA municipal and industrial untreated imported water rate was $904 per acre foot. The existing rate was inflated through 2020 based on the "low-rate" scenario values provided by the SDCWA in April 2011 (which averages to a 5.8-percent annual increase). Beyond 2020, the untreated water cost projectionswere bracketed based on various infiltration scenarios ranging from 3 to 6 percent (shown as the shaded area). These scenarios compare well to the Net Costs of the Study's Alternatives (shown as solid lines). The Study's Net Costs shown are the average of all the Study Alternatives and an average of the Favorable and Unfavorable scenario (i.e., the lower cost B1/B2 Alternatives and the favorable scenario would lower the reuse costs further). As shown, the average Tier 1 and Tier 2 cost curves have Net Costs lower than most of the untreated imported water rate scenarios. If the Tier 3 savings are attributed to the projects in this Study, the program would have significantly lower Net Costs than all untreated imported water rate scenarios. An additional consideration is the long-term effects that other local water projects and reduced demands are causing to MWD/SDCWA rates. As purchases decline, rates must increase to cover fixed costs. This is likely to cause imported water costs to inflate faster than locally controlled projects. Overall, the conclusion of this analysis supports the water reuse program proposed in this Study.

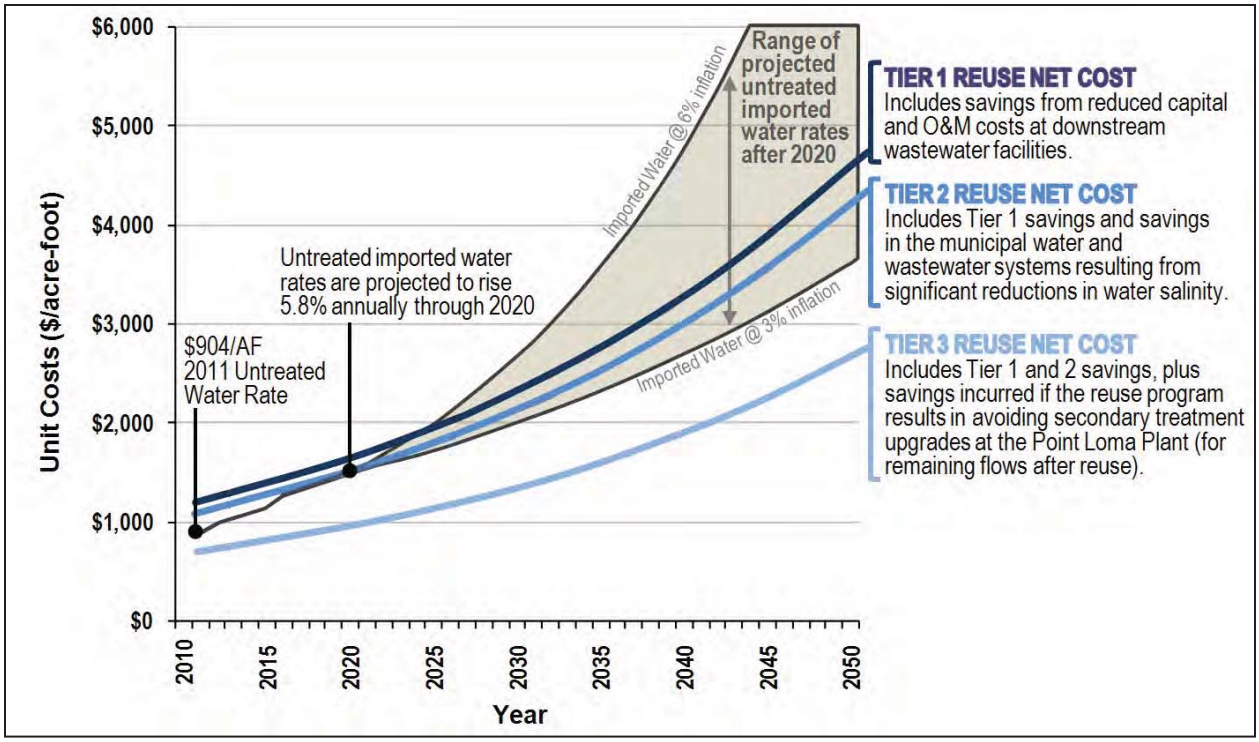

Figure 8-8. Comparison of Reuse Alternative Net Costs to Imported Untreated Water

The Integrated Reuse Alternative Net Costs compare well to projected untreated imported water rates. Untreated water rates are projected to rise 5.8 percent through 2020 and there remain many uncertainties regarding future costs associated with the Bay-Delta fix and imported water.

A detailed cost breakdown for the Favorable and Unfavorable Financial Evaluation scenarios is included in Tables 8-15 and 8-16, respectively. Capital and operation and maintenance cost estimates for each Integrated Reuse Alternative can be found in Appendix F.

Table 8-15. Financial Details for the Favorable Scenario

Item	Theme A1	Theme A2	Theme B1	Theme B2	Theme B3
O&M and Capital Debt					-
Interest from Reserve	25,769,150	25,923,958	23,557,882	23,663,931	25,715,525
Operation & Maintenance	1,757,803,600	1,753,642,189	1,612,278,853	1,599,768,756	1,799,893,592
Debt Service	876,467,167	881,123,259	776,617,870	779,795,118	854,165,858
Total PV Cost	$2,608,501,617	$2,608,841,490	$2,365,338,840	$2,355,899,943	$2,628,343,925
Total Cost, Annual Payments	$154,061,888	$154,081,962	$139,700,342	$139,142,867	$155,233,804
Capital (PAYGO Financed)					
PAYGO Financing	321,118,587	322,724,896	283,626,663	284,730,678	311,771,510
Total PV Cost	$321,118,587	$322,724,896	$283,626,663	$284,730,678	$311,771,510
Total Cost, Annual Payments	$18,965,729	$19,060,600	$16,751,402	$16,816,607	$18,413,677
Credits/Avoided Costs					
LRP Credit	200,257,301	200,257,301	191,430,259	191,430,259	196,474,283
Total PV Cost	$200,257,301	$200,257,301	$191,430,259	$191,430,259	$196,474,283
Total Cost, Annual Payments	$11,827,487	$11,827,487	$11,306,149	$11,306,149	$11,604,056
Tier 1: Wastewater O&M Avoided Costs	515,354,315	515,354,315	515,354,315	515,354,315	515,354,315
Wastewater PAYGO/Debt Avoided Costs	436,611,784	436,611,784	436,611,784	436,611,784	436,611,784
Total PV Cost	$951,966,099	$951,966,099	$951,966,099	$951,966,099	$951,966,099
Total Cost, Annual Payments	$56,224,498	$56,224,498	$56,224,498	$56,224,498	$56,224,498
Tier 2: Salt Credit	184,706,087	184,706,087	178,800,483	178,800,483	182,175,128
Total PV Cost	$184,706,087	$184,706,087	$178,800,483	$178,800,483	$182,175,128
Total Cost, Annual Payments	$10,909,009	$10,909,009	$10,560,216	$10,560,216	$10,759,527
Tier 3: CEPT O&M Avoided Costs	242,457,015	242,457,015	242,457,015	242,457,015	242,457,015
CEPT PAYGO/Debt Avoided Costs	362,889,796	362,889,796	362,889,796	362,889,796	362,889,796
Total PV Cost	$605,346,812	$605,346,812	$605,346,812	$605,346,812	$605,346,812
Total Cost, Annual Payments	$35,752,661	$35,752,661	$35,752,661	$35,752,661	$35,752,661
Water Produced (AF)	96,162	96,162	96,162	96,162	96,162
Gross Costs (Includes O&M, Capital, Grants and LRP)					
Total Costs NPV	$2,729,362,903	$2,731,309,085	$2,457,535,244	$2,449,200,361	$2,743,641,152
Total Cost, Annual Payments	$161,200,131	$161,315,075	$145,145,595	$144,653,325	$162,043,425
Total Cost: $/AF (2011)	$1,700	$1,700	$1,500	$1,500	$1,700
Total Cost: $/Gallon (2011)	$0.0052	$0.0052	$0.0046	$0.0046	$0.0052
Net Cost Tier 1 (Direct Wastewater System Savings)					
Total Costs NPV	$1,777,396,804	$1,779,342,987	$1,505,569,145	$1,497,234,263	$1,791,675,053
Total Cost, Annual Payments	$104,975,633	$105,090,577	$88,921,097	$88,428,827	$105,818,927
Total Cost: $/AF (2011)	$1,100	$1,100	$900	$900	$1,100
Total Cost: $/Gallon (2011)	$0.0034	$0.0034	$0.0028	$0.0028	$0.0034
Net Cost Tier 2 (Salt Credit Plus Tier 1 Savings)					
Total Costs NPV	$1,592,690,717	$1,594,636,899	$1,326,768,662	$1,318,433,779	$1,609,499,925
Total Cost, Annual Payments	$94,066,623	$94,181,568	$78,360,881	$77,868,611	$95,059,400
Total Cost: $/AF (2011)	$1,000	$1,000	$800	$800	$1,000
Total Cost: $/Gallon (2011)	$0.0031	$0.0031	$0.0025	$0.0025	$0.0031
Net Cost Tier 3 (Indirect Wastewater System Savings Plus Tier 1 and Tier 2 Savings)					
Total Costs NPV	$987,343,905	$989,290,088	$721,421,850	$713,086,968	$1,004,153,114
Total Cost, Annual Payments	$58,313,963	$58,428,907	$42,608,221	$42,115,950	$59,306,739
Total Cost: $/AF (2011)	$600	$600	$400	$400	$600
Total Cost: $/Gallon (2011)	$0.0018	$0.0018	$0.0012	$0.0012	$0.0018

** See section 8.4 for assumptions. The total costs were adjusted as noted to 2011 $'s for comparison to the SDCWA untreated water costs.*

Table 8-16. Financial Details for the Unfavorable Scenario

Item	Theme A1	Theme A2	Theme B1	Theme B2	Theme B3
O&M and Capital Debt					-
Interest from Reserve	40,515,384	40,756,326	36,991,977	37,156,991	40,385,393
Operation & Maintenance	1,757,803,600	1,753,642,189	1,612,278,853	1,599,768,756	1,799,893,592
Debt Service	1,385,732,744	1,392,960,001	1,224,977,635	1,229,911,800	1,347,713,119
Total PV Cost	$3,103,020,960	$3,105,845,864	$2,800,264,511	$2,792,523,565	$3,107,221,318
Total Cost, Annual Payments	$183,268,918	$183,435,761	$165,387,683	$164,930,491	$183,516,997
Capital (PAYGO Financed)					
PAYGO Financing	357,032,668	358,816,714	315,338,882	316,565,050	346,633,018
Total PV Cost	$357,032,668	$358,816,714	$315,338,882	$316,565,050	$346,633,018
Total Cost, Annual Payments	$21,086,867	$21,192,235	$18,624,372	$18,696,791	$20,472,649
Credits/Avoided Costs					
LRP Credit	44,501,622	44,501,622	42,540,058	42,540,058	43,660,952
Total PV Cost	$44,501,622	$44,501,622	$42,540,058	$42,540,058	$43,660,952
Total Cost, Annual Payments	$2,628,330	$2,628,330	$2,512,477	$2,512,477	$2,578,679
Tier 1: Wastewater O&M Avoided Costs	515,354,315	515,354,315	515,354,315	515,354,315	515,354,315
Wastewater PAYGO/Debt Avoided Costs	436,611,784	436,611,784	436,611,784	436,611,784	436,611,784
Total PV Cost	$951,966,099	$951,966,099	$951,966,099	$951,966,099	$951,966,099
Total Cost, Annual Payments	$56,224,498	$56,224,498	$56,224,498	$56,224,498	$56,224,498
Tier 2: Salt Credit	184,706,087	184,706,087	178,800,483	178,800,483	182,175,128
Total PV Cost	$184,706,087	$184,706,087	$178,800,483	$178,800,483	$182,175,128
Total Cost, Annual Payments	$10,909,009	$10,909,009	$10,560,216	$10,560,216	$10,759,527
Tier 3: CEPT O&M Avoided Costs	242,457,015	242,457,015	242,457,015	242,457,015	242,457,015
CEPT PAYGO/Debt Avoided Costs	362,889,796	362,889,796	362,889,796	362,889,796	362,889,796
Total PV Cost	$605,346,812	$605,346,812	$605,346,812	$605,346,812	$605,346,812
Total Cost, Annual Payments	$35,752,661	$35,752,661	$35,752,661	$35,752,661	$35,752,661
Water Produced (AF)	96,162	96,162	96,162	96,162	96,162
Gross Costs (Includes O&M, Capital, Grants and LRP)					
Total Costs NPV	$3,415,552,006	$3,420,160,956	$3,073,063,335	$3,066,548,557	$3,410,193,384
Total Cost, Annual Payments	$201,727,454	$201,999,666	$181,499,577	$181,114,805	$201,410,966
Total Cost: $/AF (2011)	$2,100	$2,100	$1,900	$1,900	$2,100
Total Cost: $/Gallon (2011)	$0.0064	$0.0064	$0.0058	$0.0058	$0.0064
Net Cost Tier 1 (Direct Wastewater System Savings)					
Total Costs NPV	$2,463,585,907	$2,468,194,857	$2,121,097,236	$2,114,582,458	$2,458,227,285
Total Cost, Annual Payments	$145,502,956	$145,775,167	$125,275,079	$124,890,306	$145,186,468
Total Cost: $/AF (2011)	$1,500	$1,500	$1,300	$1,300	$1,500
Total Cost: $/Gallon (2011)	$0.0046	$0.0046	$0.0040	$0.0040	$0.0046
Net Cost Tier 2 (Salt Credit Plus Tier 1 Savings)					
Total Costs NPV	$2,278,879,820	$2,283,488,770	$1,942,296,753	$1,935,781,975	$2,276,052,157
Total Cost, Annual Payments	$134,593,947	$134,866,158	$114,714,863	$114,330,091	$134,426,941
Total Cost: $/AF (2011)	$1,400	$1,400	$1,200	$1,200	$1,400
Total Cost: $/Gallon (2011)	$0.0043	$0.0043	$0.0037	$0.0037	$0.0043
Net Cost Tier 3 (Indirect Wastewater System Savings Plus Tier 1 and Tier 2 Savings)					
Total Costs NPV	$1,673,533,008	$1,678,141,958	$1,336,949,941	$1,330,435,163	$1,670,705,346
Total Cost, Annual Payments	$98,841,286	$99,113,498	$78,962,202	$78,577,430	$98,674,280
Total Cost: $/AF (2011)	$1,000	$1,000	$800	$800	$1,000
Total Cost: $/Gallon (2011)	$0.0031	$0.0031	$0.0025	$0.0025	$0.0031

** See section 8.4 for assumptions. The total costs were adjusted as noted to 2011 $'s for comparison to the SDCWA untreated water costs.*

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Appendix H: Public Outreach and Education
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Appendix H:
Public Outreach and Education

Appendix Introduction

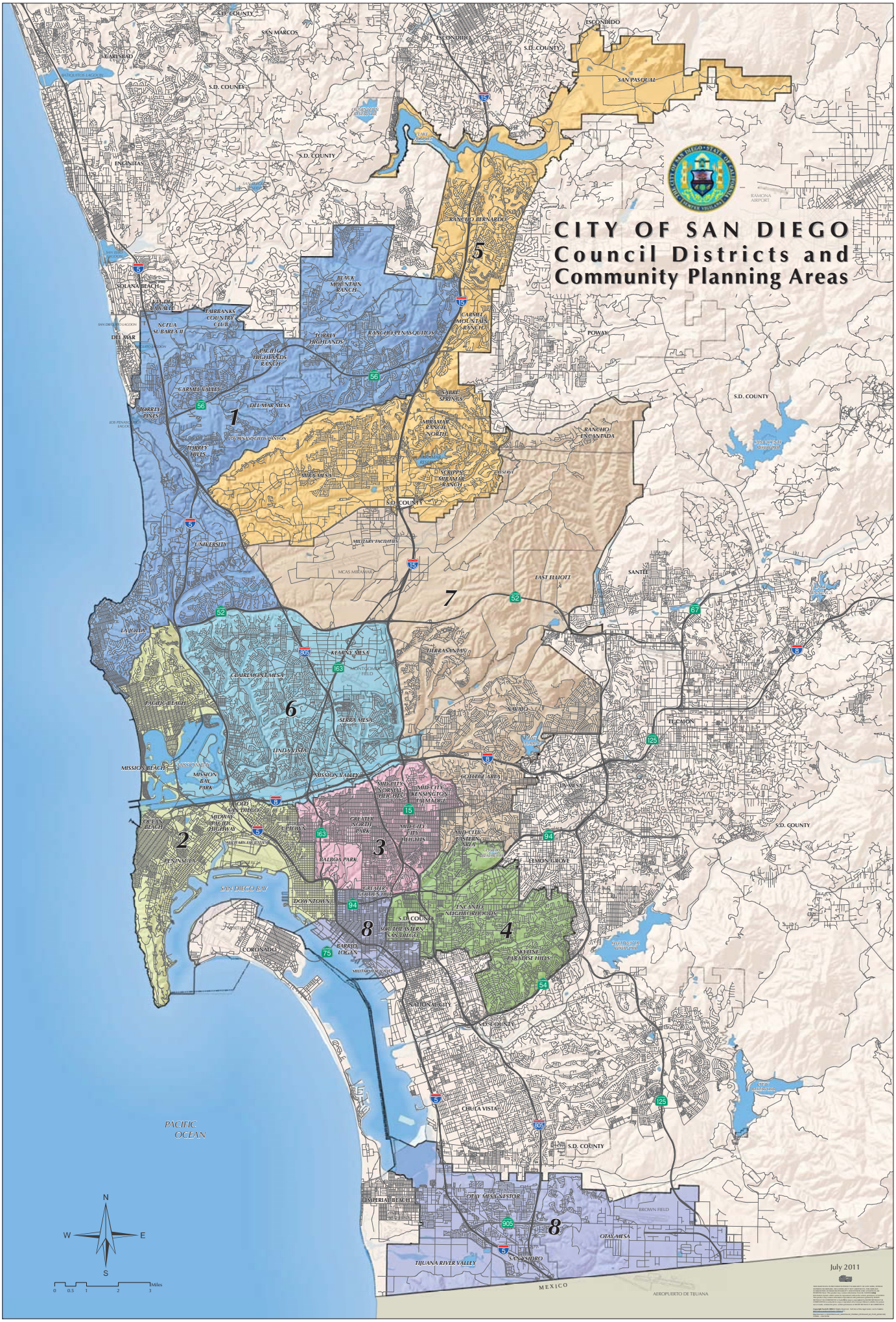
This appendix includes materials from the City of San Diego's Water Purification Demonstration Project's public outreach and education program from spring 2010 through December 31, 2012. These materials correspond to those referenced in Section E: Public Outreach and Education of the Project Report document.

The appendix is divided into seven parts, which correspond with those found in Section E:

- Planning, Research and Monitoring.....Section 1
- Education and Outreach Materials and Tools..... Section 2
- Community Outreach and Tours..... Section 3
- Social Media, Conferences and Awards ..... Section 4
- Media Outreach..... Section 5
- Speakers Bureau..... Section 6
- Internal Department Communications..... Section 7

A table of contents is found at the beginning of each section of the appendix to describe in further detail the materials found on the following pages. In electronic format, the table of contents includes hyperlinks that link directly to the pages within the document.

For council districts mentioned within the materials, the eight-district San Diego City Council map that reflected district boundaries from the beginning of the Demonstration Project until late 2012 was referenced. This map is displayed on the following page.


CITY OF SAN DIEGO
Council Districts and
Community Planning Areas
1
2
3
4
5
6
7
8
S.D. COUNTY
SAN MARCOS
ESCONDIDO
CARLSBAD
ENCINITAS
SOLANA BEACH
DEL MAR
POWAY
SAN PASQUAL
RANCHO BERNARDO
BLACK MOUNTAIN RANCH
CARMEL MOUNTAIN RANCH
TORREY HIGHLANDS
RANCHO PENASQUITOS
NUTUA SUBAREA II
FAIRBANKS COUNTRY CLUB
PACIFIC HIGHLANDS RANCH
CARMEL VALLEY
DEL MAR MESA
TORREY PINES
LOS PENASQUITOS CANYON
TORREY HILLS
SABRE SPRINGS
MIRAMAR RANCH NORTH
RANCHO ENCANTADA
MIRA MESA
SCRIPPS MIRAMAR RANCH
MILITARY FACILITIES
MCAS MIRAMAR
UNIVERSITY
EAST ELLIOTT
SANTEE
LA JOLLA
KEARNY MESA
TIERRASANTA
CLAIREMONT MESA
PACIFIC BEACH
SERRA MESA
NAVAJO
EL CAJON
LINDA VISTA
MISSION BEACH
MISSION BAY PARK
MISSION VALLEY
MID-CITY: CITYWIDE SERVICES
MID-CITY: KENSINGTON-TALMADGE
COLLEGE AREA
LA MESA
OLD SAN DIEGO
MIDWAY-PACIFIC HIGHWAY
OCEAN BEACH
UPTOWN
CENTRE CITY
GREATER NORTH PARK
MID-CITY: MID-CITY HEIGHTS
MID-CITY: EASTERN AREA
LEMON GROVE
PENINSULA
BALBOA PARK
SAN DIEGO BAY
DOWNTOWN
GREATER GOLDEN HILL
ENCANTO NEIGHBORHOODS
SOUTHEASTERN SAN DIEGO
CORONADO
BARRIO LOGAN
SKYline-PARADISE HILLS
NATIONAL CITY
CHULA VISTA
PACIFIC OCEAN
IMPERIAL BEACH
OTAY MESA-NESTOR
OTAY MESA
SAN YSIDRO
TIJUANA RIVER VALLEY
BROWN FIELD
MEXICO
AEROPUERTO DE TIJUANA
RAMONA AIRPORT
N
S
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Miles
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July 2011

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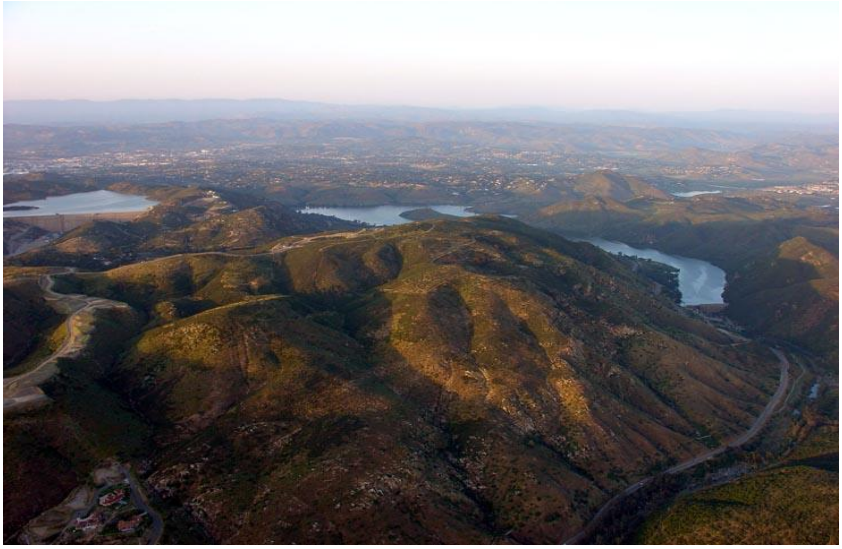
2011 Public Opinion Poll Report

The City sub-sample of the 2011 Public Opinion Poll Report can be found on the following pages. The appendix is not included in this document, but it can be found at http://www.sandiego.gov/water/waterreuse/demo/links.shtml.



SAN DIEGO COUNTY WATER AUTHORITY: 2011 PUBLIC OPINION POLL REPORT

CITY OF SAN DIEGO SUB-SAMPLE (n = 403)

Prepared for

City of San Diego
Public Utilities Department
600 B Street, Suite 600
San Diego, CA 92101

Prepared by

Rea & Parker Research
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San Diego, CA 92142
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May 2011

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Executive Summary

The San Diego County Water Authority has conducted a public opinion survey within its service area in San Diego County in order to measure the region's opinion regarding various water related issues. Rea & Parker Research was selected to be the lead consultant for this 2011 Public Opinion Poll. Rea & Parker Research also conducted surveys for the Water Authority in 2000, 2003, 2004, 2005, 2006, 2008, and 2009. A portion of this public opinion poll, as in 2004, was specifically geared to residents within the City of San Diego. This 2011 study established the following as its primary objectives:

- the level of public concern about cost of water and rising rates
- tolerance for additional rate increases to support reliability projects
- drivers for recent reductions in water use
- likelihood for regional water use to "rebound"
- progress toward Strategic Plan objectives

The purpose of this report is to present the results of the San Diego County Water Authority 2011 Public Opinion Poll specifically for residents located within the City of San Diego.

The San Diego City portion of the survey was conducted by a random telephone sample of 403 respondents, which equates to a margin of error +/-4.9 percent @ 95 percent confidence. The sample included 45 residents who were only cell phone users (do not use land-line telephone). All participants were at least 18 years old and had lived in San Diego County at least one year.

Respondents are predominantly White (53 percent), with 28 percent Hispanic/Latino, 8 percent African-American/Black, 7 percent Asian/Pacific Islander, and 4 percent American Indian/Native American and Mixed Ethnicities. Residents earn a median household income of $52,200 per year (23 percent earning $100,000 or more and another 23 percent earning under $25,000). They have a median age of 48 years and have lived in the County for a median of 22 years.

Among respondents, 45 percent possess a Bachelor's Degree or more, with 27 percent having a High School education or less. The zip codes most represented in the survey are as follows: 92105 (7 percent), 92114, 92129, 92154 (6 percent each), 92115, and 92128 (5 percent each). Home ownership percentage is 62 percent, with a mean of 3.02 persons per household.

Survey Findings

The 2011 Public Opinion Poll focused on five essential topics. It sought to identify and analyze, in particular,

- the level of public concern about cost of water and rising rates
- tolerance for additional rate increases to support reliability projects
- drivers for recent reductions in water use
- likelihood for regional water use to "rebound"
- progress toward Strategic Plan objectives

As such, this report has been divided into six essential information components as follows:

- Opinions about Local Issues
- Value and Cost of Water
- Water Reliability, Diversification, and Rate Tolerance

- Attitudes about Water Conservation,
- Opinions about the Use of Recycled Water
- Attitudes about the Local Agricultural Industry and Water

Opinions about Local Issues

- Residents identified the most important issues in the City of San Diego as the Economy and Jobs (29 percent), Financial Problems in Government including high taxes (17 percent), and the Quality and Cost of Education (9 percent), followed by Gasoline Prices and Water Supply and Quality (each 7 percent). This focus on jobs and government financial problems is not surprising since, during this past year, there has been considerable, sustained attention devoted to the fiscal stress of local and state governments as well as the economy as a whole.
- Water Supply and Quality rose modestly in importance from 3 percent in 2004 to its current level of 7 percent.

Value and Cost of Water

- Water is seen as a relatively good value for the amount of money paid compared to other utilities such as gas and electric.
- Among all respondents, 31 percent viewed gas and electric service as the best value, followed by water at 23 percent. Among all City respondents, except those who do not pay their own water bill, water (26 percent) was rated as even a closer second to gas and electric (27 percent) in terms of value.
- Despite considering water to be a relatively high value utility, over one-half of the residents (52 percent) feel that the cost of water is too expensive.
- Over three-fifths are either very concerned or somewhat concerned about the increasing price of water.
- In order to minimize this high cost, residents are willing to consider replacing their lawn area with low water plants (27 percent) and collecting water from showers and reusing the grey water for other household uses (21 percent).

Water Reliability, Diversification, and Rate Tolerance

Water Reliability

- Among residents of City of San Diego, almost four-fifths (78 percent) find that the current supply of water is either very reliable or somewhat reliable. This positive attitude regarding water supply reliability represents a substantial increase from the results of the 2004 survey where 66 percent of the residents found the water supply to be very reliable or somewhat reliable.
- Residents feel that water supply reliability is largely staying the same (48 percent) and nearly one-fourth (24 percent) feel that it is improving.
- Residents indicate that the most critical thing can be done to ensure a safe and reliable water supply for San Diego County residents and businesses is conservation (25 percent) -- “voluntary conservation” (14 percent) and

mandatory conservation (11 percent) – followed by recycling (22 percent), and seawater desalination (13 percent).

- Regarding conservation, the current survey represents a 10 percent increase over the 2004 results (from 15 percent to 25 percent).
- Recycled water has grown in prominence as a critical issue during the current survey period – doubling from 11 percent in 2004 to 22 percent in 2011.
- While still a critical issue, desalinated water sustained a moderate decline in importance from 17 percent in 2004 to 13 percent in the current survey.

Diversification Plan and Rate Tolerance

- Four-fifths of San Diego City residents are in support of the San Diego County Water Authority's Diversification Plan that is intended to ensure the reliability of the County's water supply.
- Residents indicate that recycled water (28 percent) and seawater desalination (25 percent) are the two most important parts of the Plan.
- There is a near equal split in opinion about the necessity of water rate increases that may be necessary to pay for projects that are designed to improve water supply reliability, with 45 percent doubting that all the water projects are necessary and 44 percent feeling that increases in water rates are necessary to fund these projects that will maintain reliability of the water supply.
- As such, 43 percent of residents are willing to pay more per month for the Plan that is intended to ensure the reliability of the County's water supply. The median increase that respondents are willing to pay is $15 per month.

Water Conservation

Water Use in Past Year

- Water conservation is a significant component in San Diego County's water supply plans. Over one-fourth of respondents reported that their household water usage has decreased during the past year largely as a result of less outdoor watering (31 percent), taking shorter showers and not allowing the water to run unnecessarily (16 percent each).
- Among those who reduced their water usage, more than one-third were motivated to do so because of cost and household budgetary reasons, with another 14 percent sensitive to rising water rates. Almost one-third is conserving because it is "the right thing to do."
- The vast majority of those who have decreased their water usage in the past year (82 percent) indicated that their reduced water usage is permanent.
- Requests made by water agencies to residents in an effort to motivate them to conserve water have been successful – nearly three-fifths of respondents indicate that these requests have positively influenced them.
- Three-fourths of respondents think that using tiered water rates as a means to convince people to use water wisely is appropriate.

Water Use in the Future

- If current water restrictions are lifted, over four fifths of all respondents would continue to comply with these restrictions primarily because they feel it is a reasonable and proper ethic (49 percent of all respondents).
- It is most encouraging that when water agencies no longer take an active role in restricting water use, all respondents indicate that they are not likely to increase their water use to a great extent (20 percent). On the other hand, a less cool and less wet year would lead to more than half (52 percent) of the respondents returning to a higher usage than they incurred during the past year.

Water Conservation as a Civic Responsibility

- Residents compared water conservation with other civic responsibilities. Voting in public elections, not littering or polluting, and recycling used materials are seen as more of one's civic responsibility than conserving water. Water conservation is seen as more of a civic responsibility than serving on a jury.

Opinions about the Use of Recycled Water

Recycled Water

- Support for the use of recycled water to supplement drinking and household water supplies is strong.
- Two-thirds of respondents believe that it is possible to further treat water used for irrigation to make the water pure and safe for drinking.
- Nearly one half of the respondents (47 percent) think that drinking water already contains recycled water. These respondents think that drinking water already contains recycled water because they heard news stories, the smell and taste of the water is bad, or they can see recycling plants and assume that they are being used for drinking water.
- Over two-thirds of respondents either strongly favor or somewhat favor advanced treated recycled water as an addition to the supply of drinking water – a dramatic increase over the results of the 2004 survey where only 26 percent of respondents indicated a favorable rating.
- It is noteworthy that that over one-half of those who were originally not strongly in favor of using recycled water for drinking purposes would find it acceptable as a drinking water supply supplement if it received advanced treatment and if certain other safety measures were assured. This is an increase of about 15 percent over the approximately 35 percent who changed their mind in 2004 as a result of these additional considerations.

City of San Diego Water Purification Demonstration Project

- Four-fifths (80 percent) of San Diego City residents have not heard about the City of San Diego Water Purification Demonstration Project. Among these residents 11 percent have heard about the Project and know that it involves recycled water for drinking and household use.

- When the Project was explained to the respondents, they expressed strong support – over three-fourths indicating a favorable rating.

Attitudes about the Local Agricultural Industry and Water

- San Diego City residents have shown substantial support for their agricultural community – nearly four-fifths feel that local farmers and agriculture are very important to the local economy.
- Residents further feel, to a large extent (84 percent) that reduced water rates for the agricultural industry should be maintained.

Introduction and Methodology

The San Diego County Water Authority has, over the years, conducted a public opinion survey within its service area in San Diego County in order to measure public opinion regarding water issues. Rea & Parker Research was selected to be the lead consultant for this 2011 Public Opinion Poll. Rea & Parker Research, in association with Flagship Research, also conducted public opinion polls for the Water Authority in 2000, 2003, 2004, 2005, 2006, and 2009 and two water conservation surveys in 2008 to test the effectiveness of conservation messages. This continuity of survey administration greatly facilitates the tracking of responses from year-to-year, including the consistency of wording and interviewing that adds to the statistical reliability of such comparisons.

The City of San Diego requested that the sample include about 400 respondents specifically residing within the boundaries of the City. It was also requested by the City of San Diego that specific questions pertaining only to City residents be included in the survey. This same request was made in 2004 by the City of San Diego. Accordingly, Rea & Parker Research has compared 2004 survey data with the results of the current survey where questions were the same or nearly the same.

The purpose of this report is to present the results of the San Diego County Water Authority 2011 Public Opinion Poll for respondents located within the City of San Diego.

The 2011 Public Opinion Poll focused on five essential topics. It sought to identify and analyze, in particular,

- the level of public concern about cost of water and rising rates
- tolerance for additional rate increases to support reliability projects
- drivers for recent reductions in water use
- likelihood for regional water use to "rebound"
- progress toward Strategic Plan objectives

As such, this report has been divided into six essential information components as follows:

- Opinions about Local Issues
- Value and Cost of Water
- Water Reliability, Diversification, and Rate Tolerance
- Attitudes about Water Conservation,
- Opinions about the Use of Recycled Water including the City of San Diego Water Purification Demonstration Project
- Attitudes about the Local Agricultural Industry and Water

Sample

The 2011 Public Opinion Poll was conducted during late March and early April, 2011 by a random telephone sample of 403 respondents located within the City of San Diego. The random sample was

selected by random digit dialing from the zip codes contained within the City of San Diego. This sample yields a margin of error of +/- 4.9 percent @ 95 percent confidence. The sample includes 45 residents who are only cell phone users (do not use land-line telephone). All participants were at least 18 years old and had lived in San Diego County at least one year. It is important to note that the sample of 403 is a subset of the larger sample of 821 representing the entire San Diego Water Authority service area.

The margin of error for this survey represents the widest interval that occurs when the survey question represents an approximate 50%-50% proportion of the sample. When it is not 50 percent-50 percent, the interval is somewhat smaller. For example, in the survey findings that follow, 75 percent of respondent households believe that using tiered water rates as a means to convince people to use water wisely is appropriate. This means that there is a 95 percent chance that the true proportion of the total population within the City of San Diego who believe tiered water rates are appropriate is between 70.1 percent and 79.9 percent (75 percent +/- 4.9 percent).

Survey Instrument

The survey instrument contained 52 questions, including 69 individual survey items (variables). The survey instrument was administered in both English and Spanish. A copy of the survey is attached in the Appendix. A total of 65 respondents (16.0 percent) elected to respond in Spanish. The number of respondents who wished to take the survey in Spanish in the current survey is considerably higher than in 2004 when 7 percent preferred to respond to the survey in Spanish. The Cooperation Rate (Complete/Known Eligibles + Proportionate Share of Refusals) for the survey was 79.6 percent. . Mean survey administration time was 22 minutes per respondent.

Respondent Characteristics

Table 1 presents certain demographic characteristics of the survey respondents and also provides the 2004 characteristics for comparative purposes. In 2011, over one-half of the respondents are White (53 percent), with 28 percent Hispanic/Latino, 8 percent African-American/Black, 7 percent Asian/Pacific Islander, and 4 percent American Indian/Native American and Mixed Ethnicities. Residents earn a median household income of $52,200 per year (23 percent earning $100,000 or more and another 23 percent earning under $25,000). They have a median age of 48 years and have lived in the County for a median of 22 years. Among respondents, 45 percent possess a Bachelor's Degree or more, with 27 percent having a High School education or less. The zip codes most represented in the survey are as follows: 92105 (7 percent), 92114, 92129, 92154 (6 percent each), 92115, and 92128 (5 percent each). Home ownership percentage is 62 percent, with a mean of 3.02 persons per household. Among White

and Asian respondents, 72 percent are homeowners; Black/African-American homeowners are 45 percent; and Hispanics/Latinos have 40 percent homeowners.

Table 1 **City of San Diego Survey Respondent Demographics**		
Demographic Characteristic	**2011**	**2004**
Gender		
Male	45%	51%
Female	55%	49%
Median Age (Years)	48	47
Median Number of Years Lived in Community	22	22
Highest Grade/Level of School Completed		
High School or Less	27%	16%
Some College	28%	32%
Bachelor's Degree	28%	25%
Some Graduate School	17%	27%
Ethnicity		
White	53%	63%
Latino/Hispanic	28%	17%
African-American/Black	8%	7%
Asian/Pacific Islander	7%	9%
Native American/Mixed	4%	4%
Median Household Income	$52,200	$57,700
Home Ownership Percentage	62%	70%
Type of Housing		
Single Family Detached	60%	
Condominium	18%	
Apartment	20%	
Mobile Home	2%	
Mean Number of Persons per Household	3.02	2.75
Major Residential Zip Codes		
92105	7%	5%
92114	6%	
92129	6%	6%
92154	6%	5%
92115	5%	6%
92128	5%	
Pay Own Water Bill	72%	69%
Preferred Language—Spanish	16%	7%

Differences between the current 2011 survey respondents and the respondents from the 2004 survey are as follows:

- 2011 survey respondents have completed less higher education than respondents in 2004.
- 2011 respondents are less represented by Whites and more represented by Hispanics/Latinos than the respondents in 2004, representing the increasing size of the Hispanic/Latino population and a greater willingness to participate.

- The percentage of homeowners (62 percent) is generally lower than in 2004—reflecting the growth in Hispanic/Latino participation and current home ownership/foreclosure problems. Yet, a somewhat larger proportion of households pay their own water bill (72 percent) than in 2004 instead of having it paid by a landlord or homeowners association, for example.
- The number of persons per household has increased to above 3 persons

Survey Findings

Each section of the report will begin with a very brief abstract, or summary of highlights within the ensuing section, in order to orient the reader to what is to follow. Charts have been prepared for each section that depict the survey results for the 2011 survey and for the 2004 where questions have been repeated and can be directly compared. Each section will include a discussion of the findings from the 2011 survey, with key comparisons drawn regarding results from 2004. Detailed statistical frequency distributions are contained in the Appendix.

Lastly, subgroup analyses for different age groups, various levels of education, gender, home ownership/rental status, household size, residential tenure in the community, different income categories, and water bill payers/non-payers and ethnicity of residents of the City of San Diego will be presented in a succinct, bulleted format when statistical significance and relevance warrants such treatment.

Opinions about Local Issues

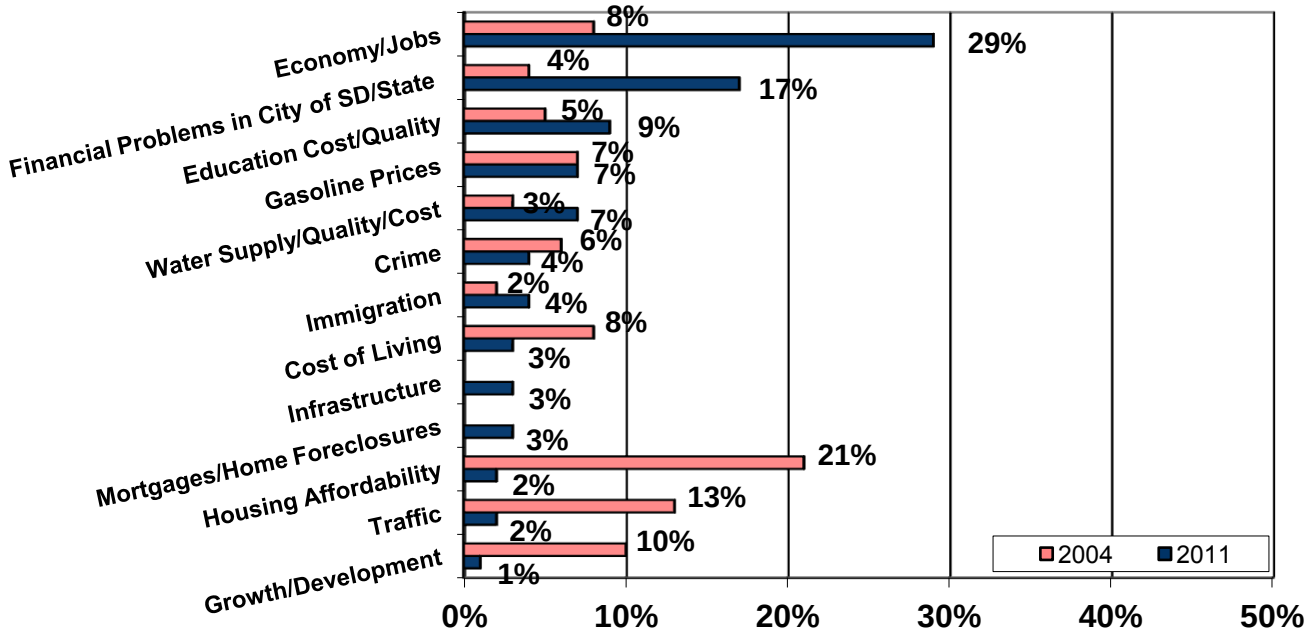
SUMMARY: Residents identified the most important issues in the City of San Diego as the Economy and Jobs (29 percent), Financial Problems in Government including high taxes (17 percent), and the Quality and Cost of Education (9 percent), followed by Gasoline Prices and Water Supply and Quality (each 7 percent).

Chart 1 shows that the most important current issues identified by residents of the City of San Diego are the Economy and Jobs (29 percent), Financial Problems in the City of San Diego and the State including high taxes (17 percent), and the Quality and Cost of Education (9 percent), followed by Gasoline Prices and Water Supply and Quality (each 7 percent). This focus on jobs and government financial problems is not surprising, since, during this past year, there has been considerable attention devoted to the fiscal stress of local and state governments as well as problems in the economy as a whole. Water Supply and Quality rose in importance from 3 percent in 2004 to its current level of 7 percent.

In 2004, respondents indicated that the most important issues were housing affordability (21 percent) traffic (13 percent), and growth and development (10 percent). Other responses that did not receive

enough mention to merit an individual listing in the chart can be viewed in the Appendix, where the full listing of responses is displayed.

Chart 1
Most Important Issues Facing City of San Diego Residents



Value and Cost of Water

<u>Summary:</u> Water is seen as a relatively good value for the amount of money paid compared to other utilities such as gas and electric. Among all respondents, 31 percent viewed gas and electric service as the best value, followed by water at 23 percent. Among all City respondents, except those who do not pay their own water bill, water (26 percent) was rated as even a closer second to gas and electric (27 percent) in terms of value. Despite the high value attributed to water, however, over one-half of the residents feel that the cost of water is too expensive.

<u>Relative Value of Water and Other Utilities</u>: Residents were asked their opinion regarding the utility that provides them with the best value for the money paid. **Chart 2** shows the survey results for all residents in the City of San Diego. Among all respondents, 31 percent viewed gas and electric service as the best value, followed by water at 23 percent. Among all City respondents, except those who do not

pay their own water bill (**Chart 3),** water (26 percent) was rated as even a closer second to gas and electric (27 percent).

It should be noted that **Charts 2 and 3** show two percentages for each utility -- one percentage represents the utility of first choice among the respondents and the second percentage represents a composite weighting that takes the first, second, and third rankings for each utility into account. For example, in **Chart 3**, it is shown that residents rated gas and electric (27 percent first choice; 27 percent weighted choice) as the utility with the best value for the amount of money paid and water (26 percent first choice; 23 percent weighted choice) as the second best value.

The following subgroups are more likely to believe that water is a good value for the money paid:

- Older residents (75 years of age and older – 33 percent versus under 75 years of age – 21 percent).
- Residents of single family homes (27 percent) and mobile homes (25 percent) versus residents of apartments (15 percent).
- Those who prefer to communicate in Spanish (33 percent) versus those who prefer English (21 percent).
- Residents who pay their own water bill (26 percent) versus those whose landlord pays their water bill (14 percent).

The following subgroups are more likely to believe that gas and electric is a good value for the money paid:

- Younger residents (18 – 24 years of age – 60 percent versus 25 years of age and older – 29 percent).
- Residents of condominiums (30 percent) and single family homes (25 percent) versus residents of apartments (49 percent) and mobile homes (50 percent).
- Those who prefer to communicate in Spanish (41 percent) versus those who prefer English (29 percent).
- Homeowners whose water bill is paid by the landlord (47 percent) versus homeowners who pay their own water bill (27 percent).

Cost of Water: **Chart 4** demonstrates that, despite its high degree of valuation, more than one-half (52 percent) of respondents feel that the cost of water is too expensive and another 42 percent feel that the cost is fair and reasonable. **Chart 5** reports the level of resident concern regarding the prospect of continued increases in water rates. This concern was measured on a 5-point scale, where 1 = not at all concerned to 5 = very concerned. Over three fifths (61 percent) recorded ratings of very concerned (48 percent) and somewhat concerned (13 percent). The mean rating is 3.73 is indicative of a higher level of concern and this is consistent with the relatively high percentage of respondents who feel the cost of water is too expensive.

Chart 2
Best Values Among Utilities

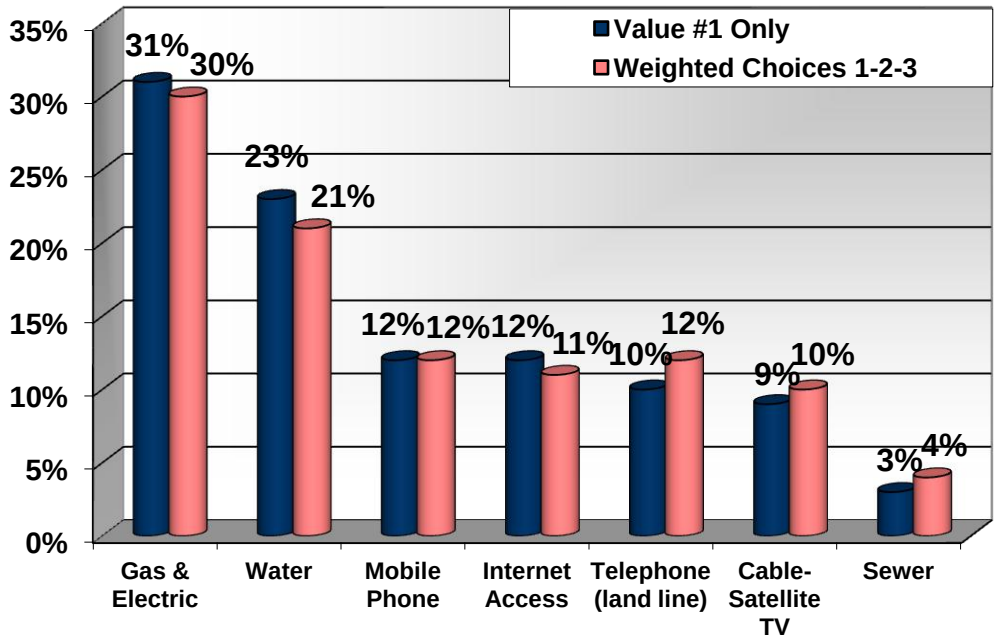


Chart 3
Best Values Among Utilities
(Water bill payers only)

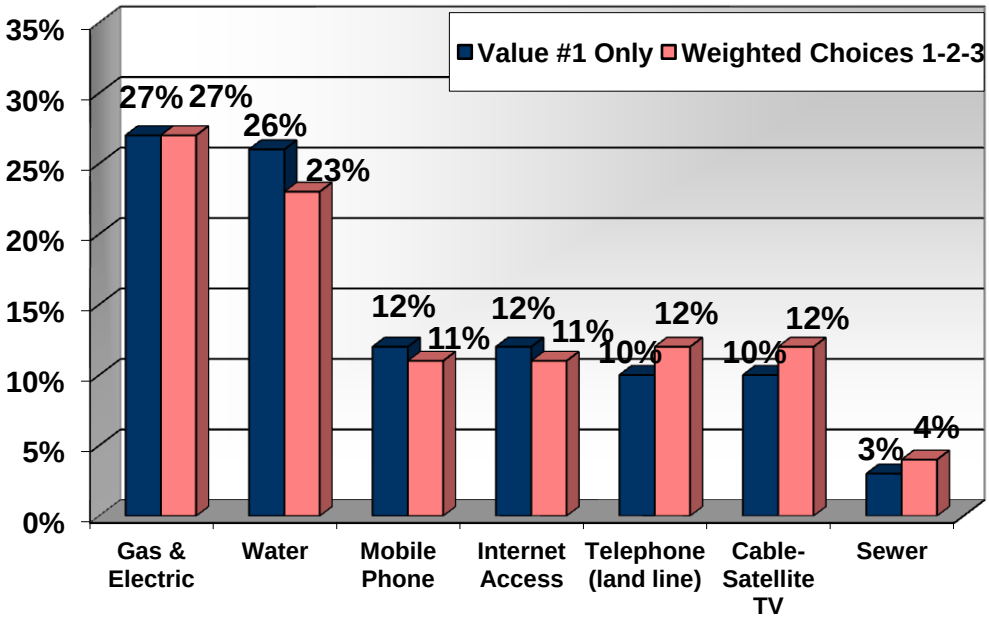


Chart 4
Cost of Water

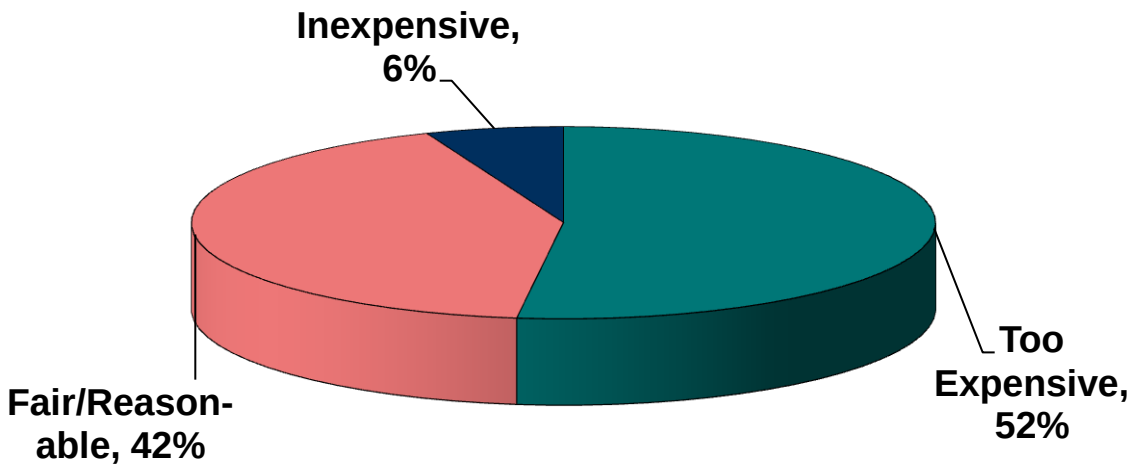
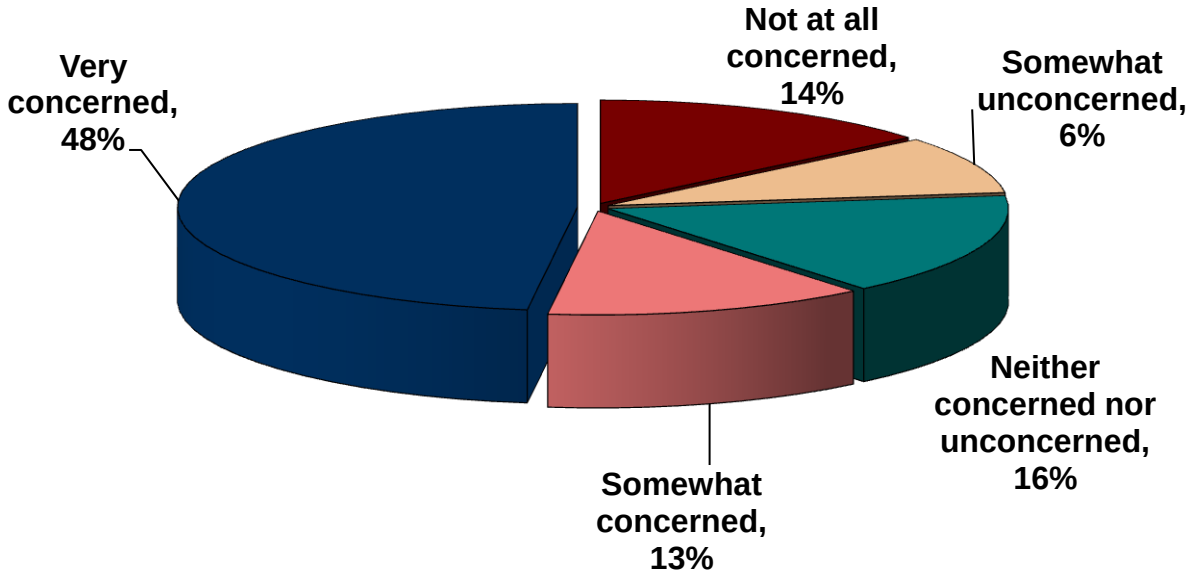


Chart 5
Concern About Continued Increases in Water Rates
(scale: 1=not at all concerned.....5=very concerned--mean = 3.73)



The following subgroups believe that the cost of water is too expensive:

- African-Americans (57 percent) versus Whites (46 percent), Asians (48 percent), and Latinos (51 percent).
- Residents of apartments (51 percent) and single family homes (48 percent) as opposed to residents of mobile homes (22 percent).
- Spanish speaking respondents (57 percent) versus English speaking residents (45 percent).
- Household members who pay their own water bill (51 percent) as opposed to the residents whose landlord pays the water bill (41 percent).

The following groups differ regarding their level of concern about the prospect of continued increases in water rates. The differences are expressed in terms of mean scores that are based on a scale of 1 to 5, where 1 = not at all concerned, 2 = somewhat unconcerned, 3 = neither concerned nor unconcerned, 4 = somewhat concerned, and 5 = very concerned.

- African-Americans (mean of 4.20) and Whites (mean of 3.81) are more concerned about water rate increases than are Latinos (3.42).
- Smaller household sizes are more concerned about water rate increases than are larger households (2 persons per household – mean of 3.99 and 3 person households – mean of 3.89 versus 5 person households – mean of 3.31).

In order to minimize increases in water rates, 27 percent indicated that they were willing to replace their lawn area with low water plants; another 21 percent were willing to collect grey water from showers and reuse the water for other household uses. Beyond these two actions, residents expressed further interest in replacing grass with artificial turf (16 percent) and making use of high-efficiency irrigation systems (15 percent) (**Chart 6**).

The following subgroups are more likely to replace their lawn area with low water plants as the one thing they would do in order to minimize increases in water rates.

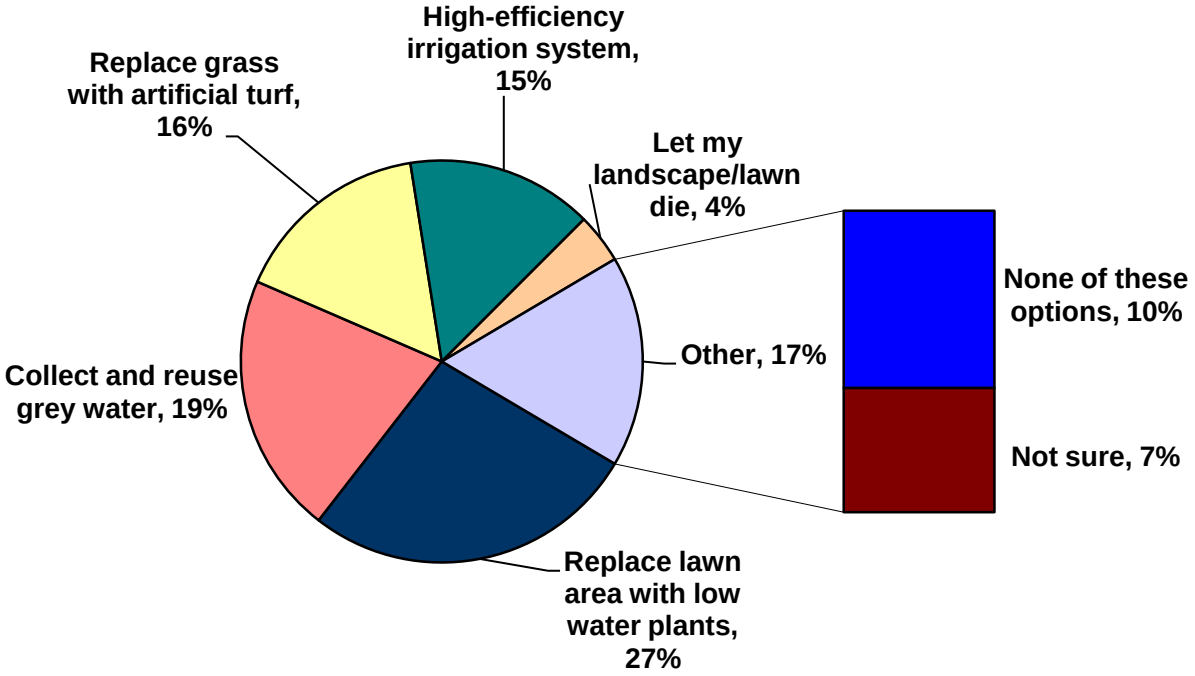
- Latino residents (31 percent) and White residents (28 percent) versus African- Americans (13 percent) and Asians (17 percent).

The following subgroups are more likely to collect water from other household uses and reuse the water as the one thing they would do in order to minimize increases in water rates:

- Asian residents (28 percent) and Latino residents (26 percent) versus African-Americans (17 percent) and Whites (18 percent).

- Spanish speaking residents (29 percent) versus English speaking residents (19 percent).

Chart 6
Willingness to Undertake the Following in Order to Minimize Increases in Water Rates



Water Reliability, Diversification and Rate Tolerance

SUMMARY: Among residents of the City of San Diego, nearly four-fifths find that the current supply of water is either very reliable or somewhat reliable. This positive attitude toward water supply reliability represents a substantial increase from the results of the 2004 survey where 59 percent of the residents found the water supply to be very reliable or somewhat reliable. Residents indicate that the most critical thing that can be done to ensure a safe and reliable water supply for San Diego County residents and businesses is conservation followed by water recycling and water desalination.

Four-fifths of the residents are in support of the San Diego County Water Authority's Diversification Plan that is intended to ensure the reliability of the County's water supply. There is a near equal split in opinion about the necessity of water rate increases to pay for projects designed to improve water supply reliability. More than 40 percent of residents are willing to pay more per month for the Plan. The median increase that respondents are willing to pay is $15 per month.

Water Reliability: Chart 7 shows that among residents of the City of San Diego, nearly four-fifths (78 percent) find that the current supply of water is either very reliable (44 percent) or somewhat reliable (34 percent). This positive attitude toward water supply reliability represents a substantial increase from the

results of the 2004 survey where 59 percent of the residents found the water supply to be very reliable or somewhat reliable.

Chart 7
Reliability of Water Supply

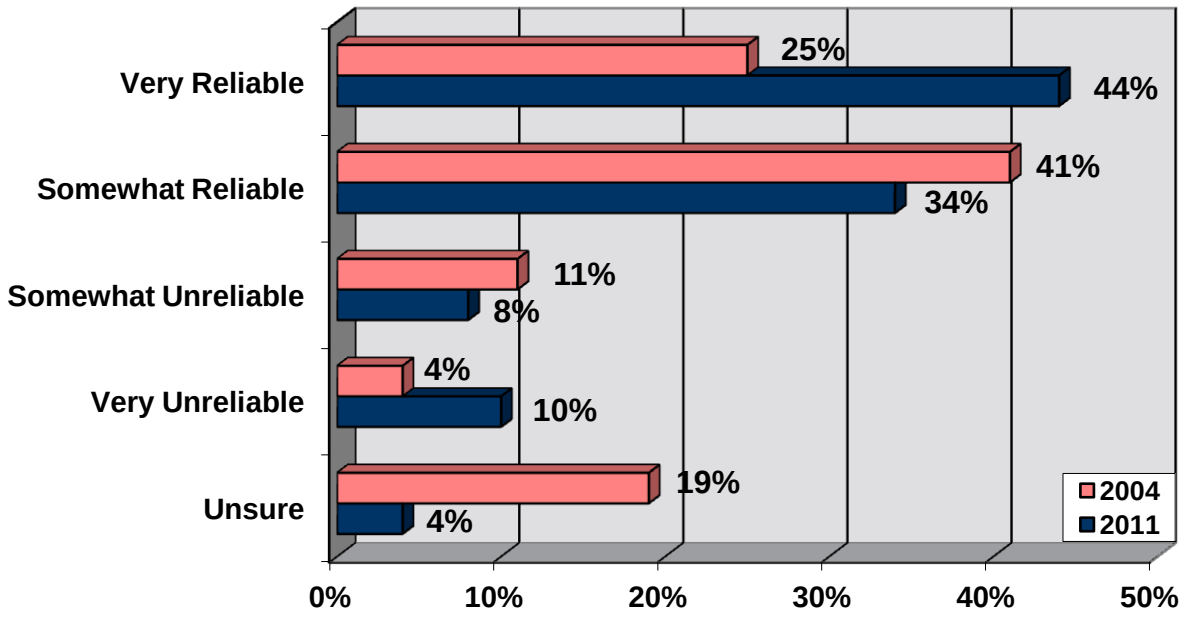


Chart 8 shows that confidence in the water supply is generally stable (48 percent feel that water supply reliability is staying the same) or improving (24 percent). Approximately one-fifth (22 percent) of the residents believe that the water supply reliability is worsening.

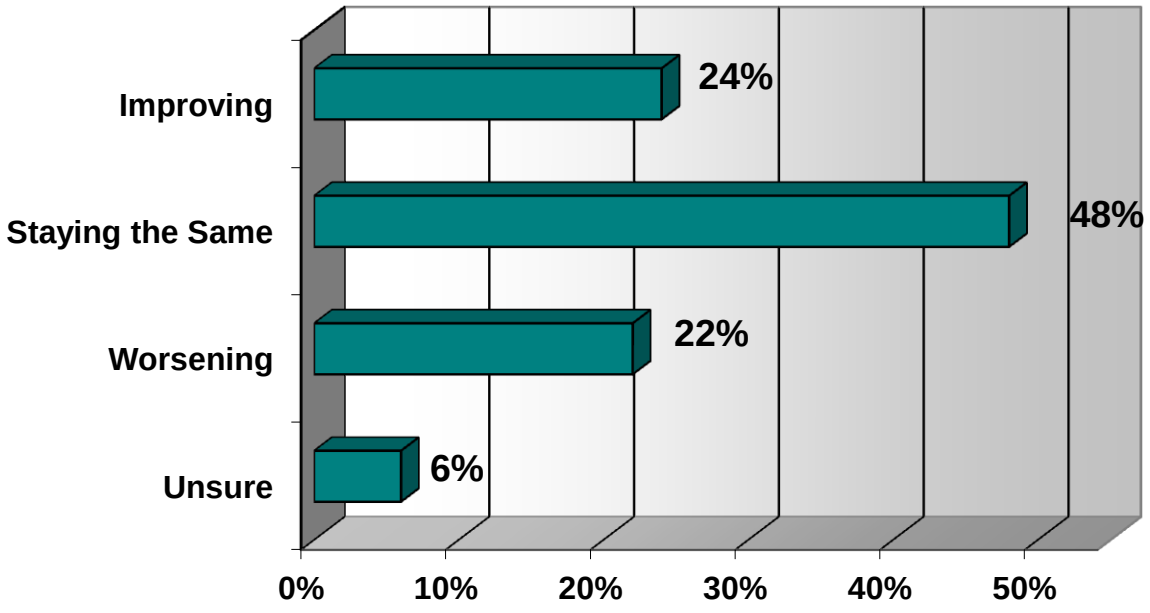
The following groups are less sure that reliability is improving:

- Residents who prefer to communicate in Spanish (37 percent) versus those who prefer to communicate in English (21 percent).
- Residents with one year of graduate school or more education (39 percent) versus those who have a bachelor's degree or less education (19 percent).
- White residents (27 percent0 versus Black residents (3 percent).

When respondents were asked what they think is the most critical thing that can be done to ensure a safe and reliable water supply for San Diego County residents and businesses, 25 percent indicated some form of conservation – either voluntary (14 percent) or mandatory (11 percent). This represents a 10 percent increase from the 2004 survey where 15 percent of respondents, at that time, indicated that conservation

(mandatory and voluntary conservation was not specified) was the most critical thing that would ensure the reliability of the water supply. In the current survey, "recycled water" (22 percent) followed conservation as a critical thing that would ensure water reliability – doubling the response to recycled water in the 2004 survey. Desalination, which was high on the list in 2004 at 17 percent, fell to some extent in the current survey to 13 percent (**Chart 9**).

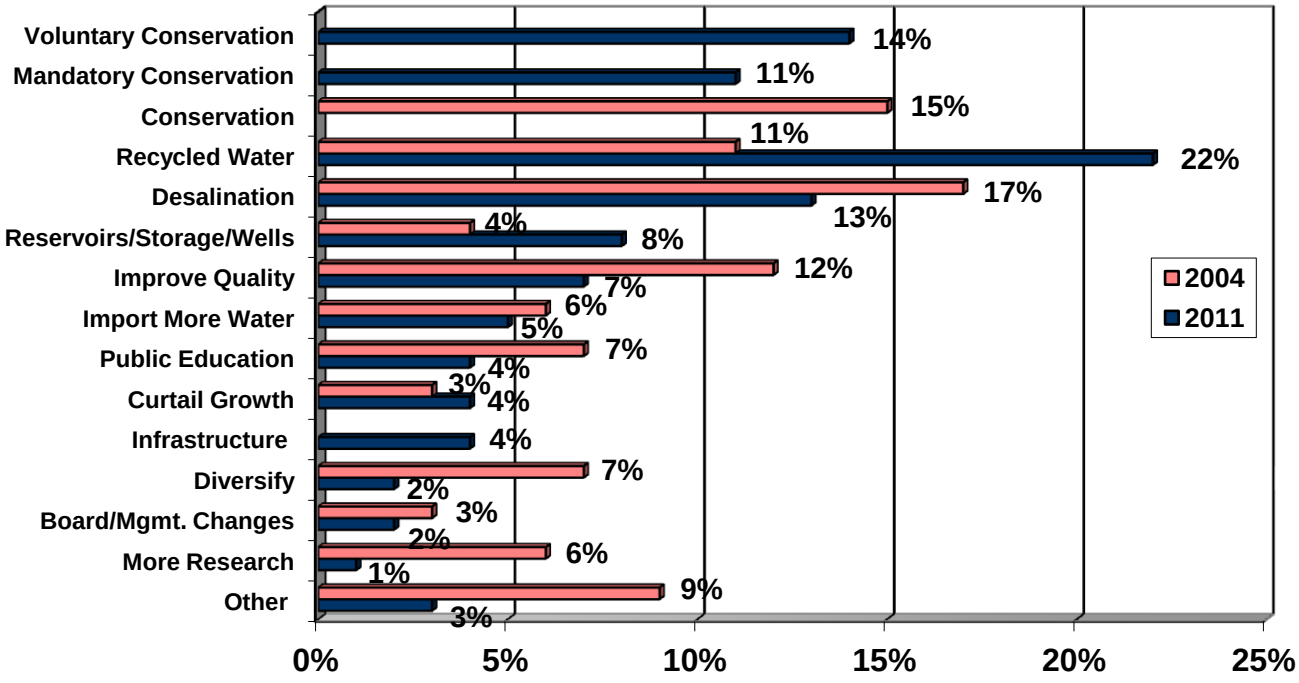
Chart 8
Water Supply Reliability Improving/Worsening



The following subgroups are more likely to think that mandatory conservation is the single most critical thing that can be done to ensure a safe and reliable water supply for San Diego County residents and businesses:

- African-American residents and Hispanic residents (each 17 percent) versus White residents (7 percent).
- Shorter term residents of the County as opposed to longer term residents (1 – 5 years – 22 percent versus 6 years or more – 9 percent).
- Renters (15 percent) versus homeowners (9 percent).

Chart 9
Most Critical Thing that Can be Done to Ensure Safe and Reliable Water Supply for San Diego County



The following subgroups are more likely to think that voluntary conservation is the single most critical thing that can be done to ensure a safe and reliable water supply for San Diego County residents and businesses:

- Residents of condominiums (17 percent) versus residents of apartments and single family homes (12 percent each).
- Spanish speaking residents (18 percent) versus English speaking residents (13 percent).
- Whites (15 percent) and Latinos (14 percent) versus African-Americans (6 percent).

The following subgroups are more likely to think that water recycling is the single most critical thing that can be done to ensure a safe and reliable water supply for San Diego County residents and businesses:

- Spanish speaking residents (41 percent) versus English speaking residents (18 percent).
- Latinos (36 percent) versus Whites (18 percent) and African-Americans (17 percent).
- Residents of apartments (35 percent) versus residents of single family homes (21 percent) and condominiums (17 percent).

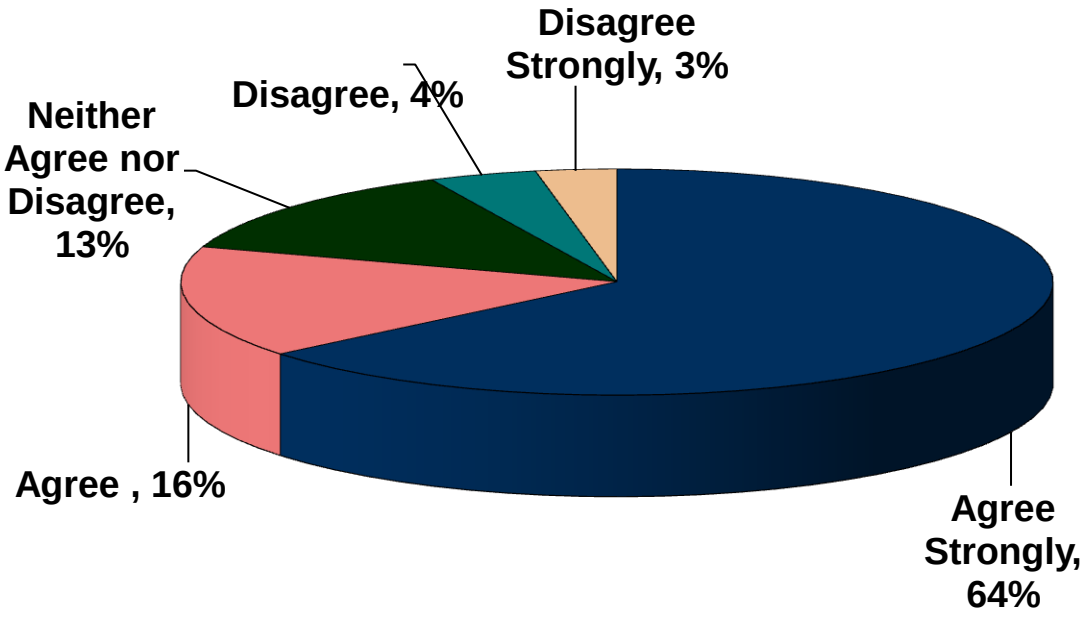
- Renters (27 percent) versus homeowners (9 percent).

The following subgroups are more likely to think that desalination is the single most critical thing that can be done to ensure a safe and reliable supply for San Diego County residents:

- Homeowners (16 percent) versus renters (8 percent).
- Longer term residents of the County as opposed to shorter term residents (26 or more years – 19 percent versus 25 years or less – 9 percent).
- Residents of condominiums (20 percent) versus residents of apartments (5 percent).
- White residents (16 percent) versus African-American and Latino residents (6 percent each).

Diversification Plan and Rate Tolerance: **Chart 10** shows that four-fifths (80 percent) of City of San Diego residents are in support of the San Diego County Water Authority's Diversification Plan with ratings of strongly agree (64 percent) and agree (16 percent). The mean rating of 1.66 (based on a scale of 1 to 5, where 1 = strongly agree and 5 = strongly disagree) underscores this high level of support for the Diversification Plan. Residents indicate that the most important part of the Diversification Plan is recycled water (28 percent) followed by seawater desalination (25 percent) **(Chart 11).**

Chart 10
Opinion about Diversification Plan
(scale: 1= Agree Strongly..5= Disgaree Strongly---mean = 1.66)



The following subgroups are more likely to believe that seawater desalination is the most important part of the diversification plan:

- Residents with more education as opposed to those with less education (bachelor's degree or more – 31 percent versus less than a bachelor's degree – 20 percent).
- Males (34 percent) versus females (18 percent).
- English speaking residents (27 percent) versus Spanish speaking residents (12 percent).

The following subgroups are more likely to believe that recycled water is the most important part of the Diversification Plan:

- Residents with less education as opposed to those with more education (high school or less – 45 percent versus 1 year of college or more – 22 percent).
- Spanish speaking residents (55 percent) versus English speaking residents (23 percent).

Chart 11
Most Important Component of Diversification Plan

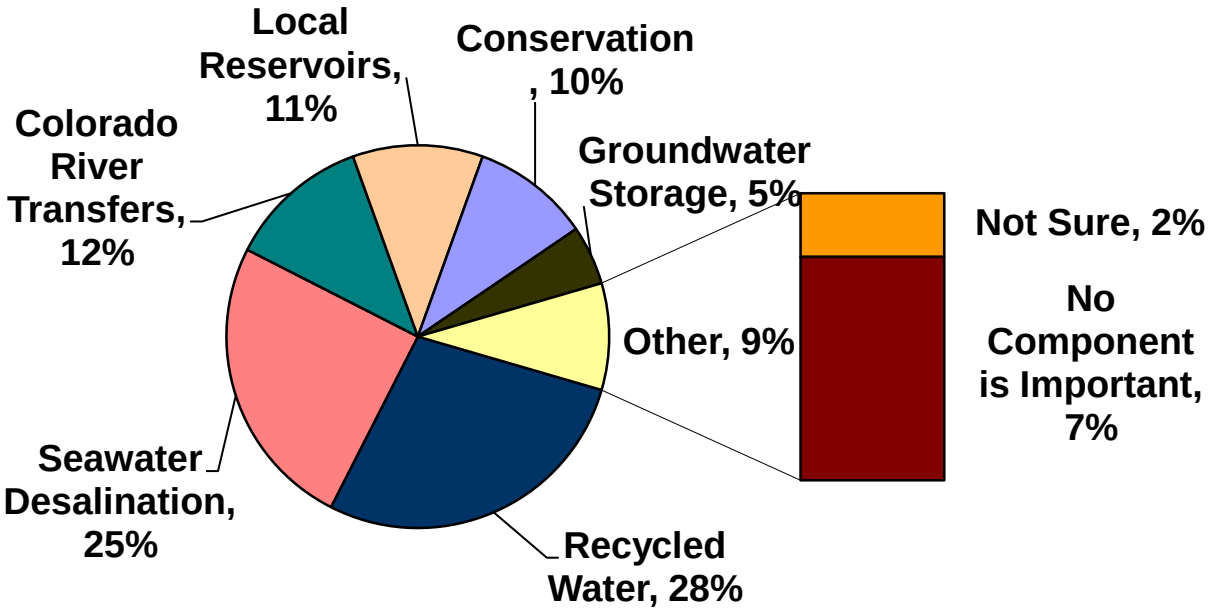


Chart 12 shows that among the 43 percent of residents who are willing to pay more per month for diversification and ultimately water supply reliability, 26 percent of them (11 percent of the total population) are willing to pay an additional $6 to $10 per month and 21 percent (9 percent of the total

population) are willing to pay an additional $11 to $20 per month. The median increase that respondents indicate a willingness to pay is $15 per month.

- Larger household sizes are willing to pay more than smaller household sizes to support diversification.

Chart 13 shows that there is a near equal split in opinion about the necessity of water rate increases to pay for projects designed to improve water supply reliability, with 45 percent feeling that water rates are too high and doubt that these water projects are necessary and 44 percent feeling that increases in water rates are necessary to maintain reliability of the water supply.

- Residents who prefer to communicate in Spanish (64 percent) are more likely to oppose water rate increases than those who prefer English (42 percent).
- Individuals who rent their home tend to oppose water rate increases more so than do those who own their homes (rent – 53 percent versus own – 42 percent).
- Respondents who have lived in the County for less than 40 years (50 percent) are more likely to oppose water rate increases than those who have lived in the County for more than 40 years (32 percent).

Chart 12
Willingness to Pay More per Month for Diversification Plan
(43 percent of the 72 percent who pay their own bill are willing to pay more: median = $15)

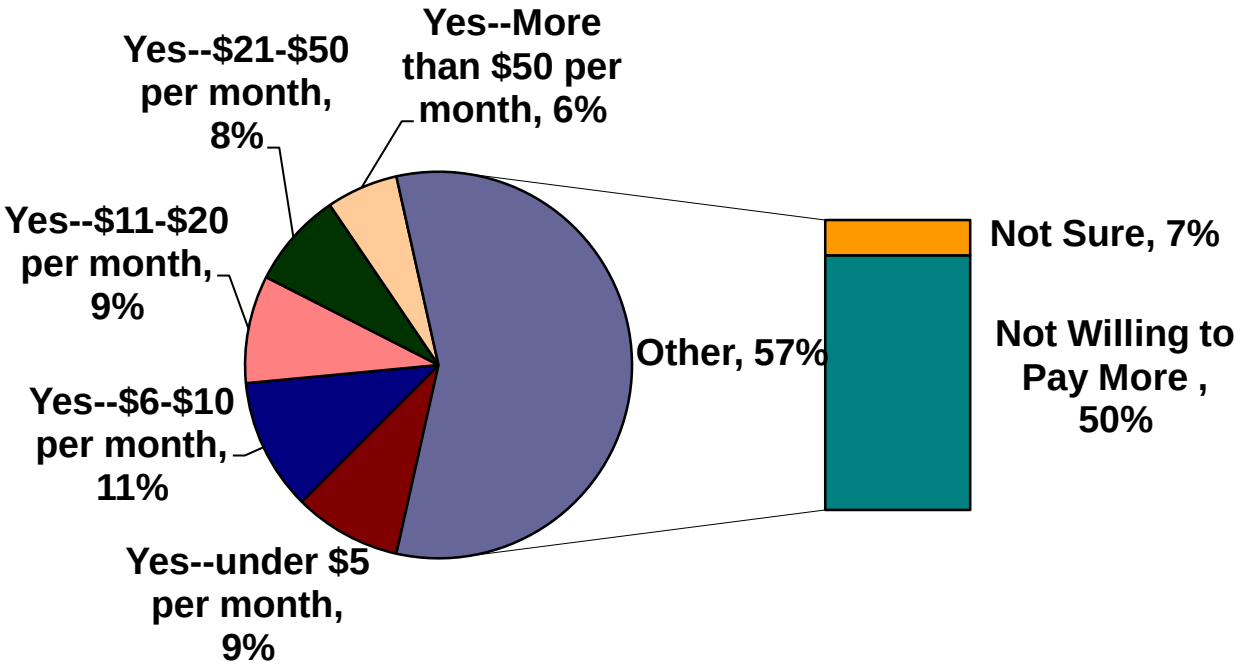
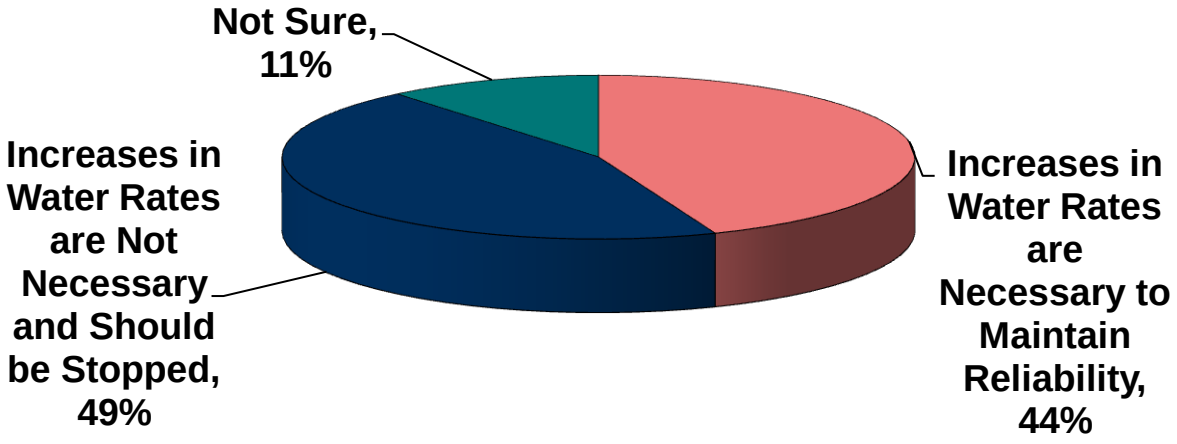


Chart 13
Support for Increased Water Rates to Pay for Projects to Improve Reliability
(among 72 percent who pay their own bills)



Attitudes about Water Conservation

SUMMARY: Water conservation is a significant component in San Diego County's water supply plans. Over one-fourth of respondents reported that their household water usage has decreased during the past year largely as a result of less outdoor watering, taking shorter showers and not letting the water run unnecessarily. Among those who reduced their water usage, almost one-half were motivated to do so for financial reasons ("we are watching our budget" = 35 percent and "rising water rates" = 14 percent). Another one–third (31 percent) felt that conservation is the "right thing to do". The vast majority—over four-fifths—indicated that their reduced water usage is permanent.

It is most encouraging that when water agencies no longer take an active role in restricting water use, respondents who have reduced their water usage during the past year indicate that they are not likely to increase their water use (20 percent). On the other hand, a less cool and less wet year would lead to more than half (52 percent) of those who have reduced their water use during the past year returning to higher usage. Among all respondents, whether they have reduced their use in past year or not, if water restrictions are lifted, over four-fifths would continue to comply with these restrictions primarily because they feel it is a reasonable and proper ethic or residents have learned to live with less water.

Requests made by water agencies to residents in an effort to motivate them to conserve water have been successful – nearly three-fifths of respondents indicate that these requests have strongly influenced them. Three-fourths (75 percent) of respondents think that using tiered water rates as a means to convince people to use water wisely is appropriate.

Residents compared water conservation with other civic responsibilities. Voting in public elections, not littering or polluting, and recycling used materials are seen as more of one's civic responsibility

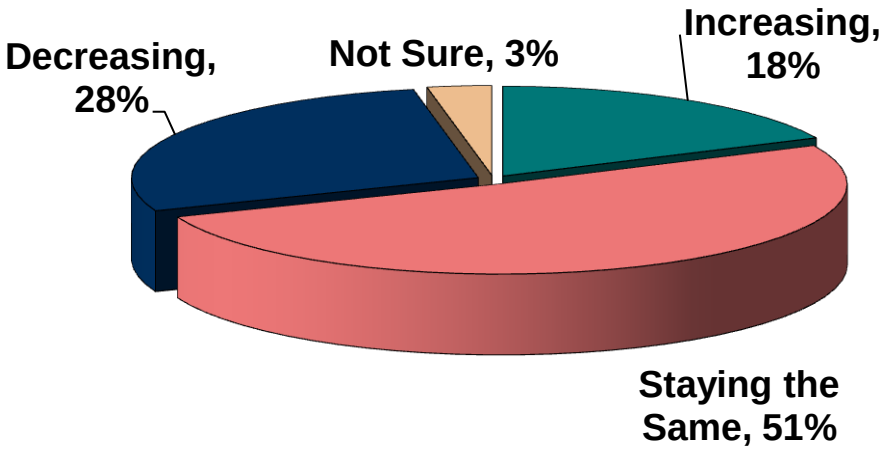
than conserving water. Water conservation is seen as more of a civic responsibility than serving on a jury.

<u>Water Use in the Past Year:</u> **Chart 14** shows that over one-fourth of respondents (28 percent) indicated that their household water usage has decreased over the past year. Among those who indicated that their household water usage has decreased, nearly one-third (31 percent) indicated that they did less watering outdoors. Others indicated that they take shorter showers and they do not allow the water to run unnecessarily (16 percent each) (**Chart 15).**

The following subgroups are more likely to indicate that their household water use has decreased over the past year:

- Whites (32 percent) and Hispanics (29 percent) versus African-Americans (10 percent).
- Residents with higher income levels as opposed to those with lower income levels ($75,000 or more – 38 percent versus under $75,000 – 27 percent).
- Residents who pay their own water bills (33 percent) versus residents whose landlords or homeowners association pays the water bill (18 percent).
- Larger household sizes as opposed to smaller household sizes (6 or more persons per household – 45 percent—versus 1 person per household and 2 persons per household – 7 percent each.

Chart 14
Water Use Increasing or Decreasing Past Year



The following subgroups tend to reduce their water usage by using less water outdoors:

- Homeowners who pay their own water bill (36 percent) versus homeowners whose landlord pays their water bill (6 percent).
- Residents of single family homes (40 percent) versus residents of apartments (8 percent) and condominiums (7 percent).
- Residents who prefer to communicate in English (35 percent) versus those who prefer Spanish (12 percent).
- Homeowners (40 percent) versus those who rent their homes (12 percent).

The following subgroups tend to reduce their water usage by taking shorter showers:

- Residents of apartments and mobile homes (33 percent each) versus residents of single family homes (12 percent) and condominiums (21 percent).
- Residents who prefer to communicate in Spanish (41 percent) versus those who prefer English (12 percent).
- Renters (38 percent) versus those who own their home (8 percent).

The following subgroups tend to reduce their water usage by not allowing the water to run unnecessarily:

- Residents whose landlord pays the water bill (47 percent) versus residents who pay their own water bill (10 percent).
- Renters (19 percent) versus those who own their own home (13 percent).

Chart 15
Major Step by Household to Reduce Water Use in Past 6 Months
(among 28 percent of households that indicated decreasing water usage)

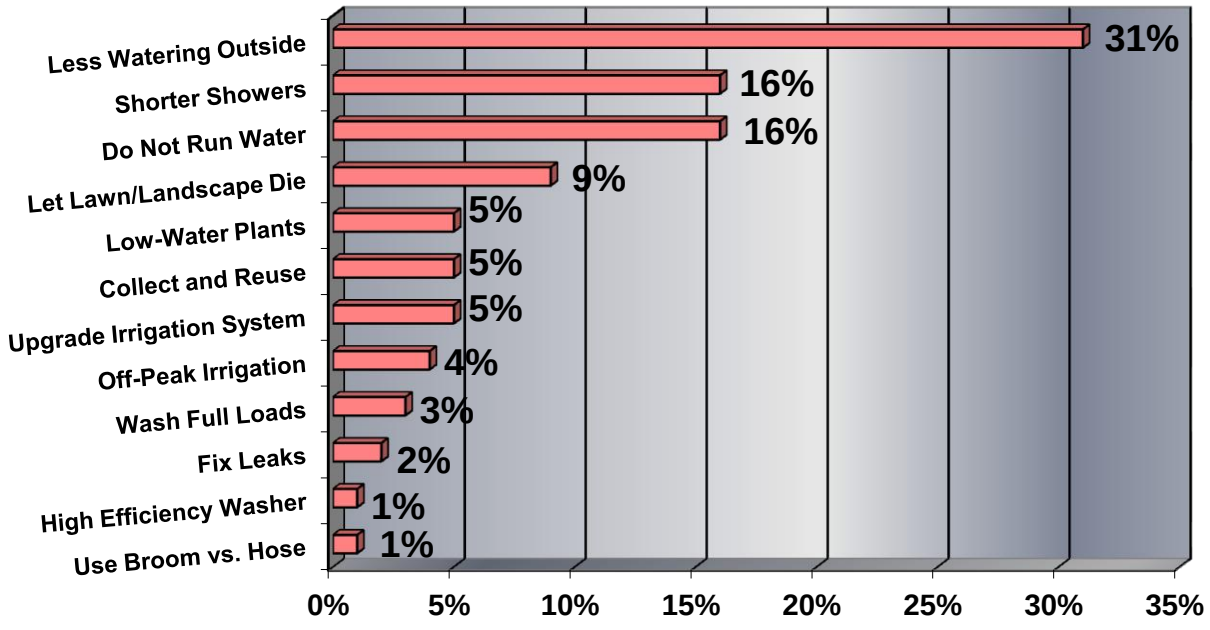


Chart 16 indicates that among those who indicated that their household water usage has declined, nearly one-third (35 percent) were motivated to reduce water usage through their interest in saving money plus 14 percent who indicated an awareness of increasing water rates. Another 31 percent felt that reducing water usage is the "right thing to do." Among those who indicated that their household water usage has declined, a large majority (82 percent) think that their reduced use of water is permanent while 15 percent think their reduction is temporary (**Chart 17**).

The following subgroup is motivated to reduce its household water usage because it is "the right thing".

- Residents whose landlord pays their water bill (67 percent) versus residents who pay their own water bill (26 percent).

The following subgroup is particularly motivated to reduce their household water usage because they are trying to save money:

- Residents who pay their own water bill (40 percent) versus residents whose landlord pays their water bill (7 percent).

Chart 16
Primary Motivation for Water Use Reduction
(among 28 percent of households that have reduced water use in past year)

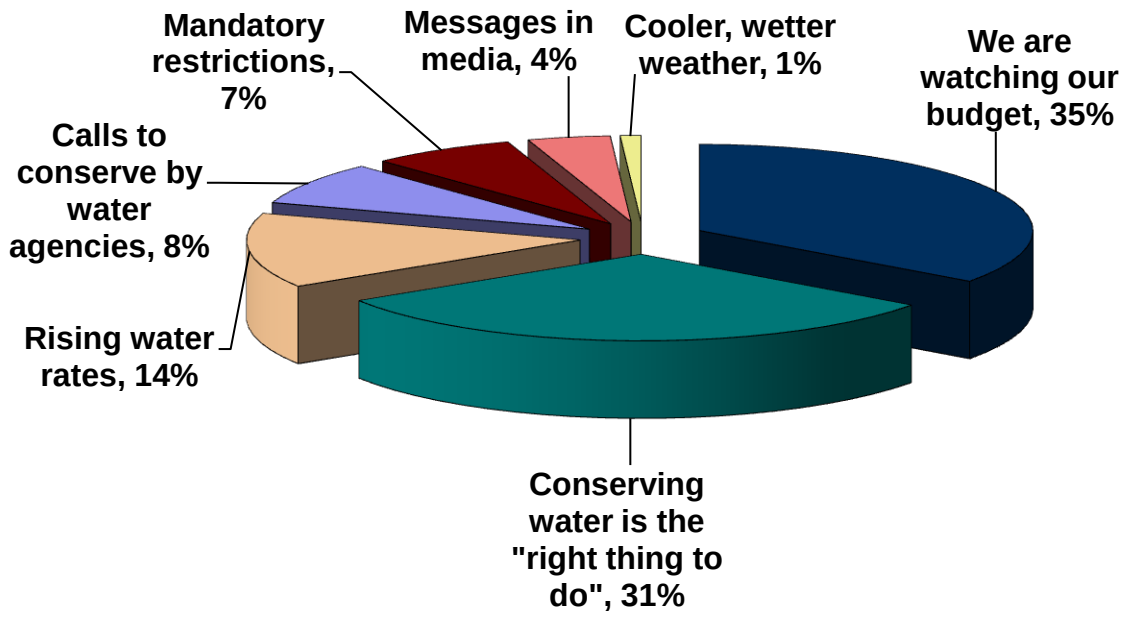


Chart 17
Is Reduced Use Permanent?
(among 28 percent of households that indicate reduced water usage in past year)

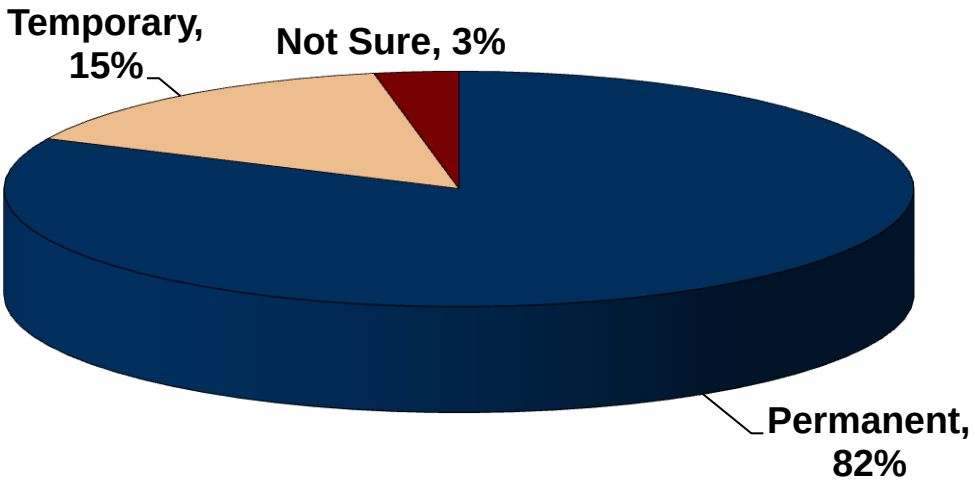
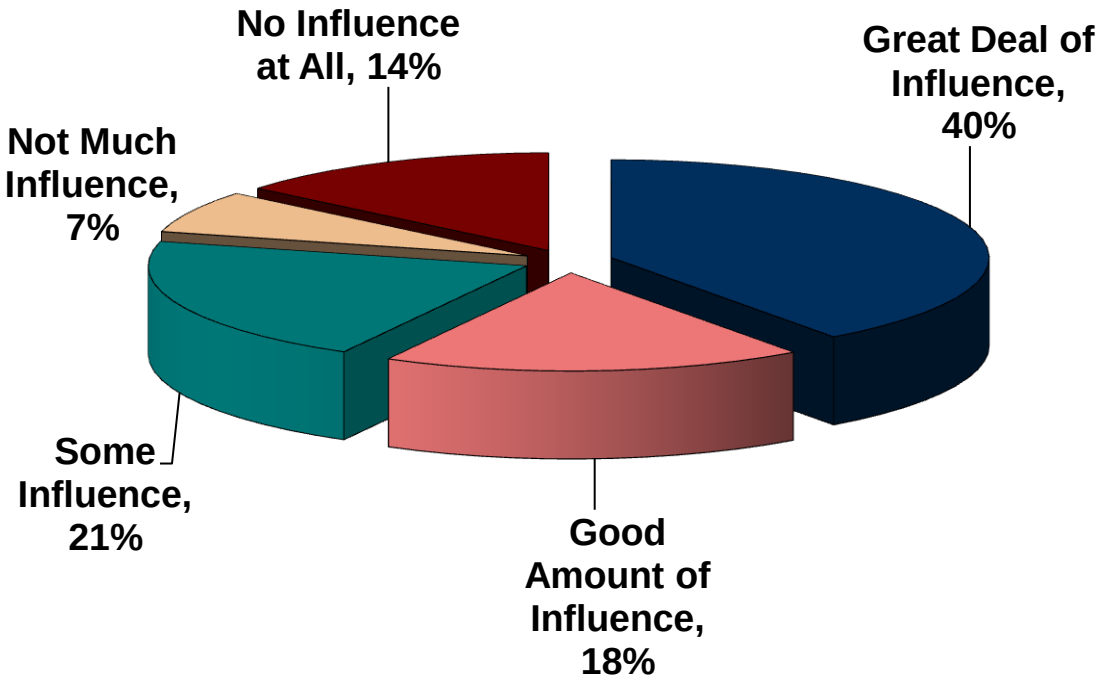


Chart 18 reports the impact that, among all respondents, requests for increased voluntary conservation made by water agencies have had on residents' water use. Nearly three-fifths of respondents (58 percent) indicate that these requests have a great deal of influence (40 percent) or a good amount of influence (18 percent). On a scale of 1 to 5, where 1 = a great deal of influence and 5 = no influence at all, the mean rating measuring the impact of these calls is 2.36, indicating that these call messages are working relatively well. **Chart 19** shows that three-fourths (75 percent) think that water agencies' use of tiered water rates as a means to convince people to use water wisely is appropriate.

The following groups differ with regard to the impact they feel water agencies have in motivating people to pursue voluntary conservation. The differences are expressed in terms of mean scores that are based on a scale of 1 to 5, where 1 = a great deal of influence, 2 = a good amount of influence, 3 = some influence, 4 = not much influence, and 5 = no influence at all.

- Residents with a higher level of education are less influenced by water agency calls than are residents with a lower level of education (1 year of graduate school or more – mean of 2.85 versus less than a bachelor's degree – mean of 2.21).
- Larger household sizes tend to be influenced by agency calls more so than smaller household sizes (4 persons per household – mean of 2.04 and 5 persons per household – mean of 2.19 versus 1-to-3 person households -- mean of 2.75 for both 1 and 2 person households and 3 person households – mean of 2.58).
- Homeowners (mean of 2.30) are more likely to be influenced by agency calls than are renters (mean of 2.45).

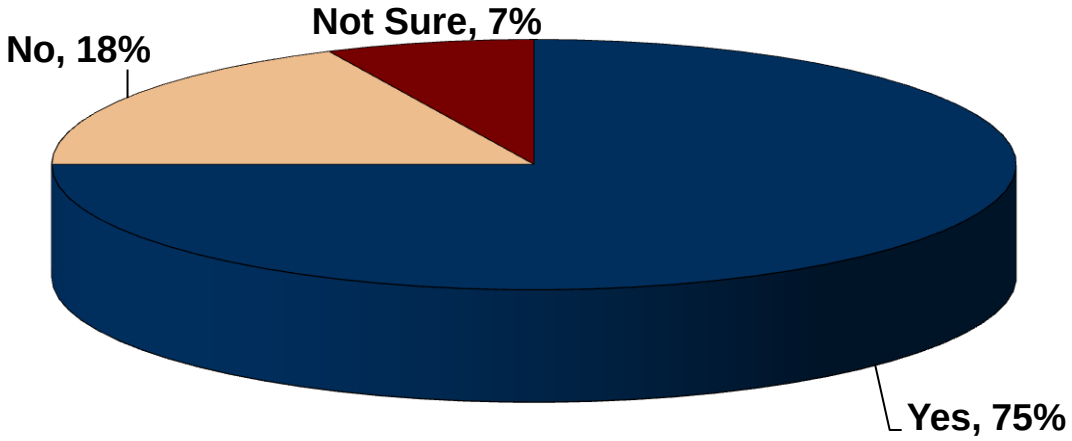
Chart 18
Influence of Requests for Voluntary Conservation from Water Agencies
(Scale: 1=Great Deal of Influence..5=No Influence at All---mean = 2.36)



The following subgroups tend to favor using tiered water rates as a means of convincing people to use water wisely.

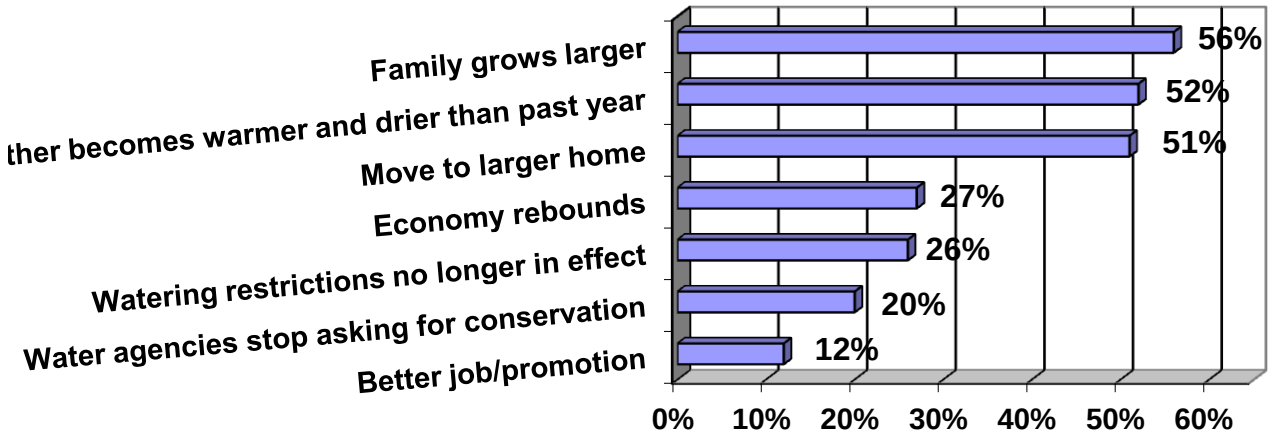
- Lower income residents as opposed to higher income residents (under $50,000 – 83 percent versus $50,000 and over – 68 percent).
- Renters (81 percent) versus homeowners (70 percent).

Chart 19
Appropriateness of Tiered Water Rates to Encourage Using Water Wisely



<u>Water Use in the Future</u>: Respondents were asked to indicate if they will or might increase their water usage if various conditions and situations were to prevail. Among the findings reported in **Chart 20**, it is most encouraging that when water agencies no longer take an active role in restricting water use, respondents indicate, to a great extent, that they are not likely to increase their water usage (20 percent). Similarly, when water agencies stop asking for residents to practice conservation there is no surge in water use expected (26 percent). On the other hand, a less cool and less wet year would lead to more than one half (52 percent) of the respondents returning to higher usage. Understandably, as family size grows larger, respondents indicate that they will increase water usage (56 percent) and, similarly, respondents are likely to increase water use when they move to a larger home (51 percent). When the economy rebounds (27 percent) or the respondent obtains a better job or a job promotion (12 percent), residents indicate that they are not likely to increase their water usage to a great extent.

Chart 20
Conditions Under Which Respondents Would Increase Water Use



The following subgroups are more inclined to increase their water usage when the weather becomes warmer and drier:

- Asians (76 percent) and African-Americans (73 percent) versus whites (44 percent).
- Residents who indicate that their reduced use of water is temporary (65 percent) as opposed to permanent (55 percent).

The following subgroups are more likely to increase their water usage when the economy rebounds:

- Residents with less education as opposed to residents with more education (less than a bachelor's degree – 34 percent versus bachelor's degree or more education – 17 percent).
- Asian residents (48 percent) and Latino residents (41 percent) versus White residents (16 percent).
- Spanish speaking residents (45 percent) versus English speaking residents (23 percent).
- Residents who indicate that their reduced water use is temporary (41 percent) as opposed to permanent (17 percent).

The following subgroups are more likely to increase their water usage when their family grows in size:

- Younger residents as opposed to older residents (18 – 24 years of age – 88 percent versus 25 years of age and over – 55 percent).
- Asian residents (83 percent) versus White residents (50 percent).
- Larger household sizes as opposed to smaller household sizes (3 or more persons per household – 69 percent versus 1 and 2 persons per household – 59 percent).

- Shorter term residents of the County as opposed to longer term residents (15 years and under – 70 percent versus 16 years and over – 47 percent).
- Residents who believe that their reduced water use is temporary (71 percent) as opposed to permanent (50 percent).

The following subgroups are more likely to increase their water usage when they get a better job or promotion:

- Homeowners whose landlord pays their water bill (18 percent) versus homeowners who pay their own water bill (10 percent).
- Younger residents as opposed to older residents (18- 24 years of age – 41 percent versus 25 years of age and over – 11 percent).
- Spanish speaking residents (25 percent) versus English speaking residents (10 percent).
- Residents who believe that their reduced water use is temporary (18 percent) as opposed to permanent (10 percent).

The following subgroups are more likely to increase their water usage when watering restrictions are no longer in effect:

- Younger residents as opposed to older residents (18- 24 years of age – 59 percent versus 25 years of age and over – 24 percent).
- Residents with less education as opposed to those with more education (bachelor's degree or less – 28 percent versus 1 year of graduate school or more – 15 percent).
- Asian residents (48 percent) versus White residents (17 percent).
- Residents who believe that their reduced use of water is temporary (35 percent) as opposed to permanent (23 percent).

The following groups are more likely to increase their water usage when they move to a larger home:

- Younger residents as opposed to older residents (34 years of age and under – 64 percent versus 35 years of age and over – 47 percent).
- Asian residents (72 percent) versus White residents (45 percent).
- Residents of condominiums (67 percent) versus residents of mobile homes (44 percent) and single family homes (43 percent).
- Renters (60 percent) versus homeowners (45 percent).
- Residents who believe that their reduced use of water is temporary (65 percent) as opposed to permanent (47 percent).

The following subgroup is more likely to increase their water usage when agencies stop asking them to conserve water:

- Less educated (bachelor's degree or less – 22 percent) versus 1 year of graduate school or more – 10 percent).

According to **Chart 21**, if mandatory water restrictions are lifted, over four-fifths (81 percent) of all survey respondents (whether or not they have reduced their usage in the past year) would continue to

comply with these restrictions, and 9 percent are unsure. The main reasons cited by respondents for continuing to comply with water restrictions once they have been lifted are presented in **Chart 22**. The dominant response is that saving and conserving water is a reasonable and proper ethic (49 percent of the 81 percent so inclined = 40 percent of all respondents. The second highest response is that residents have learned to live with less water (24 percent of 81 percent = 19 percent of all respondents). **Chart 23** shows that there are three main reasons why residents will not continue to observe restrictions once they are lifted. These residents indicate that they need more water for their landscape, lawn, and garden (26 percent) and they provide the rationale that if restrictions are not mandatory, then conservation must not be necessary and they generally want to use more water (each 22 percent).

Chart 21
Continue to Observe Restrictions Even if Lifted?

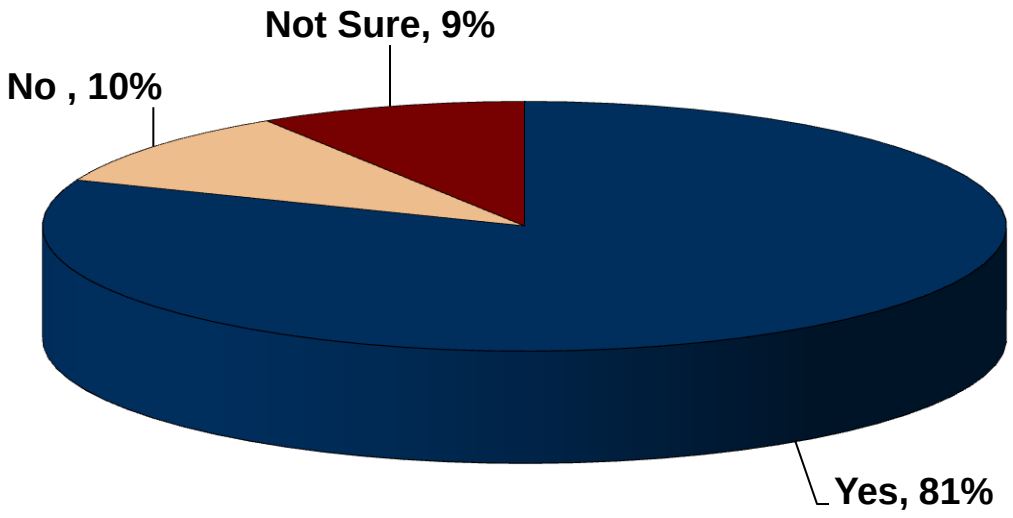


Chart 22
Reasons for Continuing to Conserve after Restrictions Lifted
(among 81 percent who indicated that they would continue to observe restrictions)

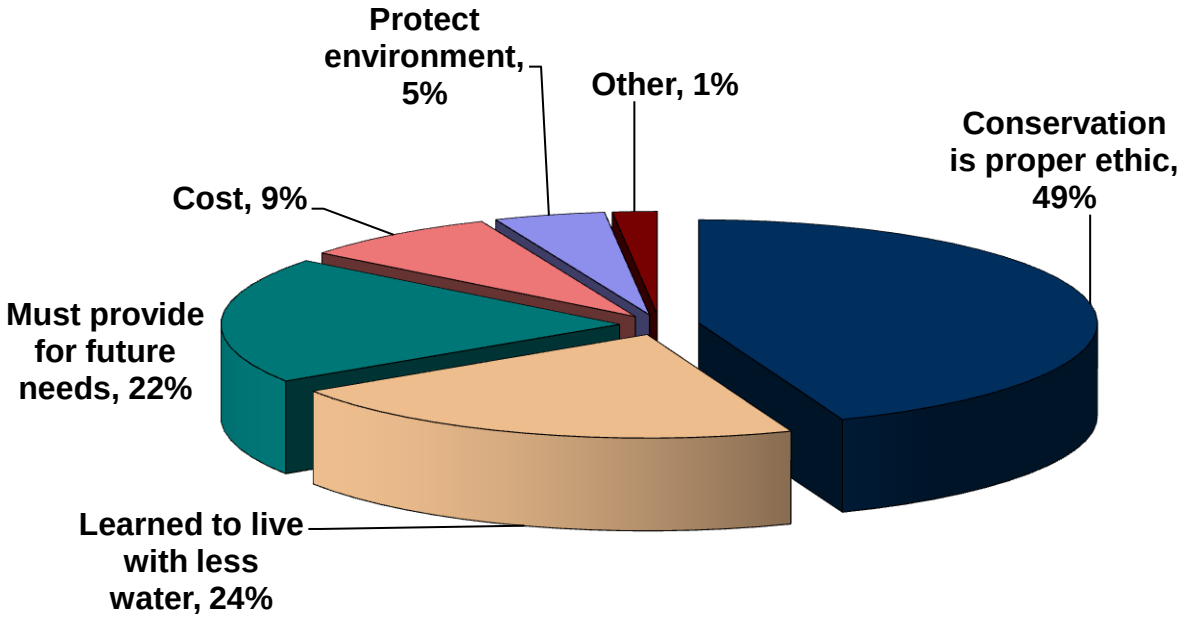


Chart 23
Reasons to Not Continue Observing Restrictions
(among 10 percent who indicated that they will not continue)

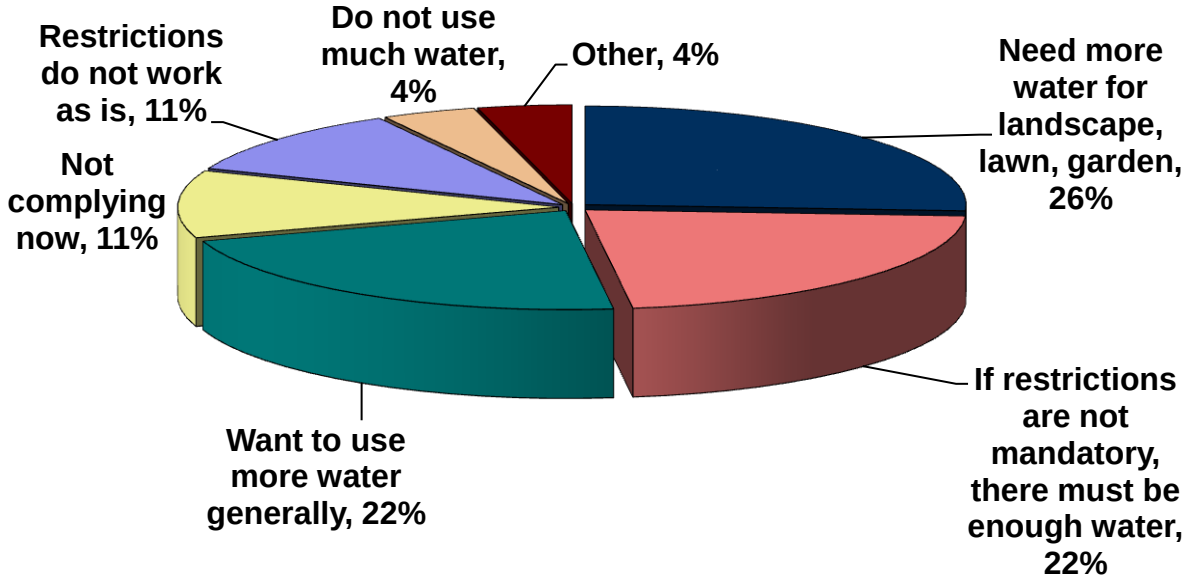
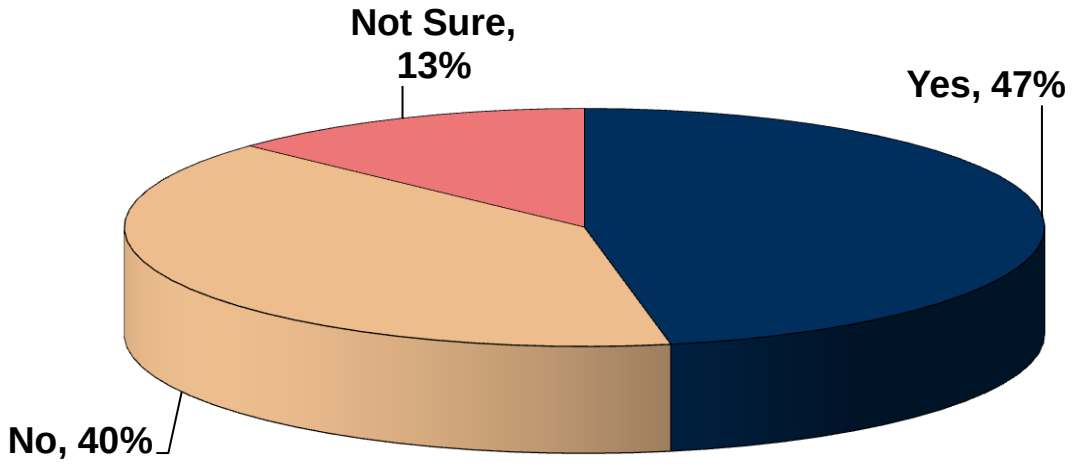


Chart 24 shows that nearly one-half (47 percent) of respondents think that water use restrictions should be made permanent in San Diego County regardless of the current year's water supply conditions; 40 percent do not think restrictions should be made permanent and 13 percent are unsure.

The following subgroups think that water use restrictions should be made permanent in San Diego County regardless of the current years' water supply conditions:

- Residents with less education as opposed to those with a higher level of education (less than a bachelor's degree – 54 percent versus a bachelor's degree or more or more – 41 percent).
- Lower income residents (under $25,000 – 68 percent versus $25,000 and above – 41 percent).
- Residents who prefer to communicate in Spanish (66 percent) versus residents who prefer English (44 percent).

Chart 24
Make Restrictions Permanent



Water Conservation as a Civic Responsibility: Chart 25 shows the extent to which respondents feel that certain activities are regarded as their civic responsibility. The chart further indicates whether these activities are more or less of a civic responsibility than is conserving water. It is noteworthy that, among the civic activities mentioned, the one that has the highest indication of being a civic responsibility is recycling used materials (84 percent). Respondents accorded serving on a jury the lowest level of civic

responsibility (61 percent). Voting in public elections, not littering or polluting, and recycling used materials are seen as more of a civic responsibility than conserving water**.** Water conservation is seen as more of a civic responsibility than serving on a jury**.**

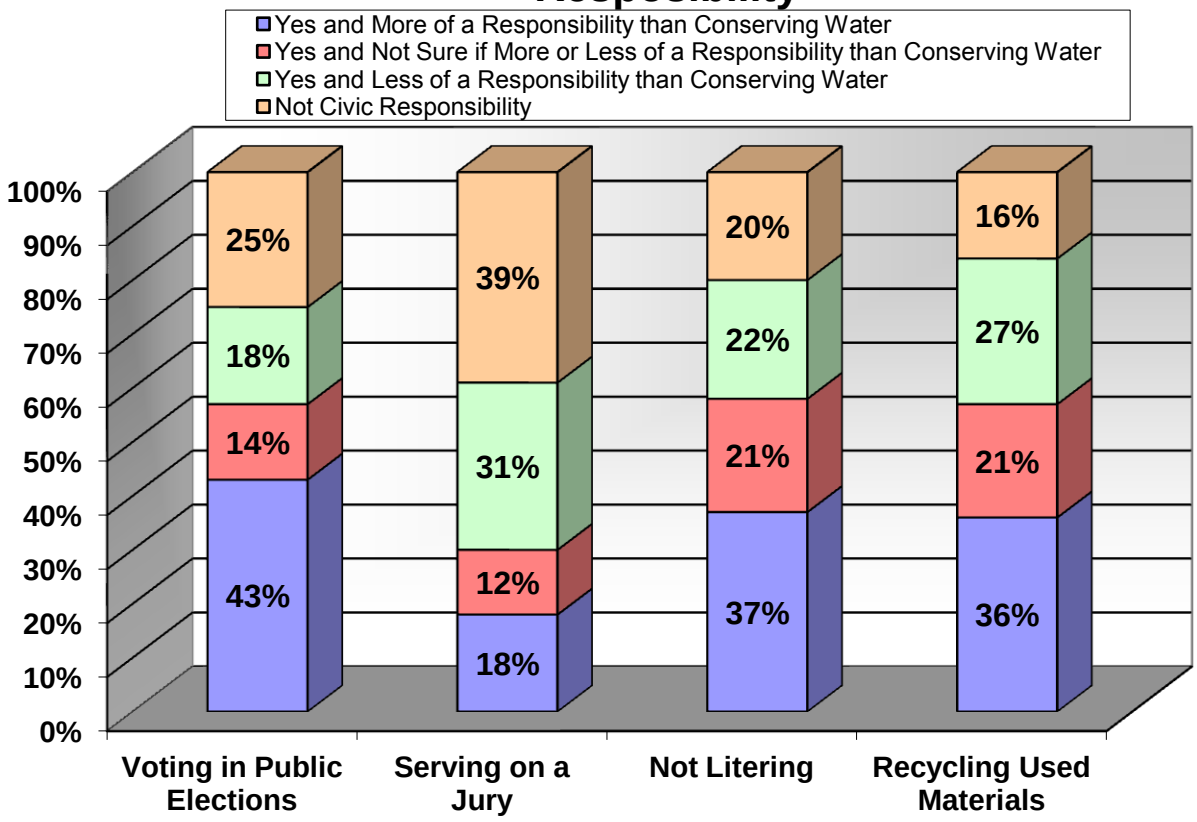
The following subgroup is somewhat more inclined to feel that preventing pollution and not littering is less of a civic responsibility than conserving water:

- English speaking residents (30 percent) versus Spanish speaking residents (15 percent).

The following subgroup is somewhat more inclined to feel that recycling used materials is more of a civic responsibility than conserving water:

- Spanish speaking residents (65 percent) versus English speaking residents (39 percent).

Chart 25
Water Conservation as a Comparative Civic Resposibility



Recycled Water

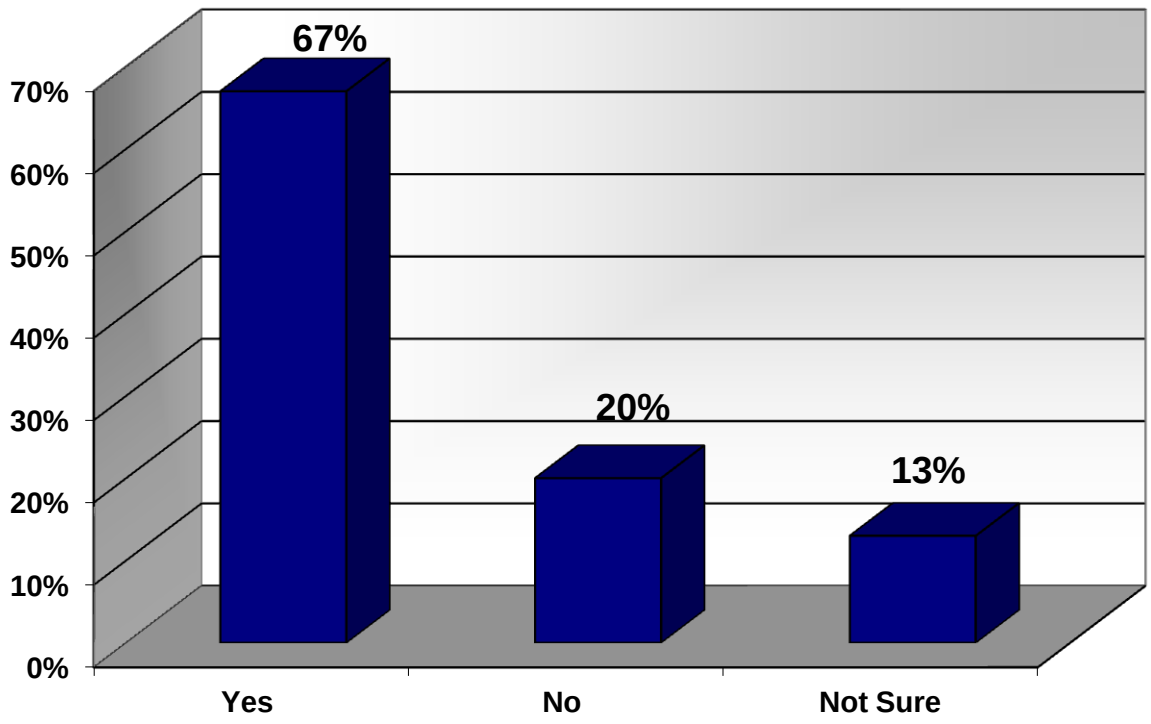
SUMMARY: Support for the use of recycled water to supplement drinking and household water supply is strong. Two-thirds of respondents believe that it is possible to further treat water used for irrigation to make the water pure and safe for drinking. Over two-thirds of respondents either strongly favor or somewhat favor advanced treated recycled water as an addition to the supply of drinking water.

It is noteworthy that that over one-half of those who were originally not strongly in favor of using recycled water for drinking purposes would find it acceptable if the water received advanced treatment and if certain other safety measures assured. This is an increase of about 15 percent over the approximately 35 percent who similarly changed their mind in 2004 as a result of this additional information.

Four-fifths (80 percent) of San Diego City residents have not heard about the City of San Diego Water Purification Demonstration Project. Among these residents, 11 percent have heard about the Project and know that it involves recycled water for drinking and household use. When the Project was explained to them, residents expressed strong support – over three-fourths indicating a favorable rating.

Recycled Water for Drinking and Household Use: Chart 26 shows that two-thirds (67 percent) of respondents believe that it is possible to further treat recycled water used for irrigation to make the water pure and safe for drinking.

Chart 26
Possible to Further Treat Recycled Water Used for Irrigation to Make It Pure and Safe for Drinking

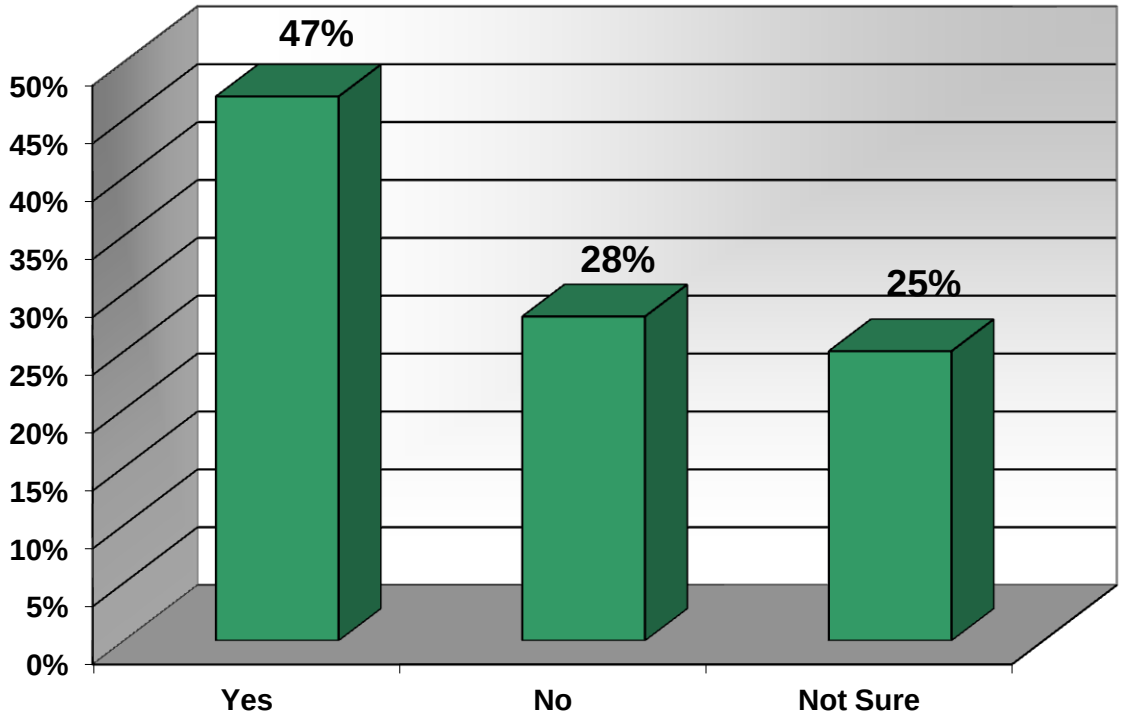


The following groups tend to believe more strongly that it is possible to further treat recycled water used for irrigation to make water pure and safe for drinking:

- Residents whose landlord pays the water bill (74 percent) versus homeowners who pay their own water bill (66 percent).
- Respondents who rent their home (75 percent) versus those who own their home (62 percent).

Chart 27 indicates that just under one-half of the respondents (47 percent) believe that drinking water already contains recycled water. Among the 47 percent of respondents who think that drinking water contains recycled water, three primary reasons are provided to explain why they feel this way. Respondents hear that water is recycled from news stories (21 percent), water tastes and smells bad (19 percent), and respondents see signs, recycling plants and know that such technology is available—the combination of which leads them to believe that it is being implemented already (14 percent) (**Chart 28**).

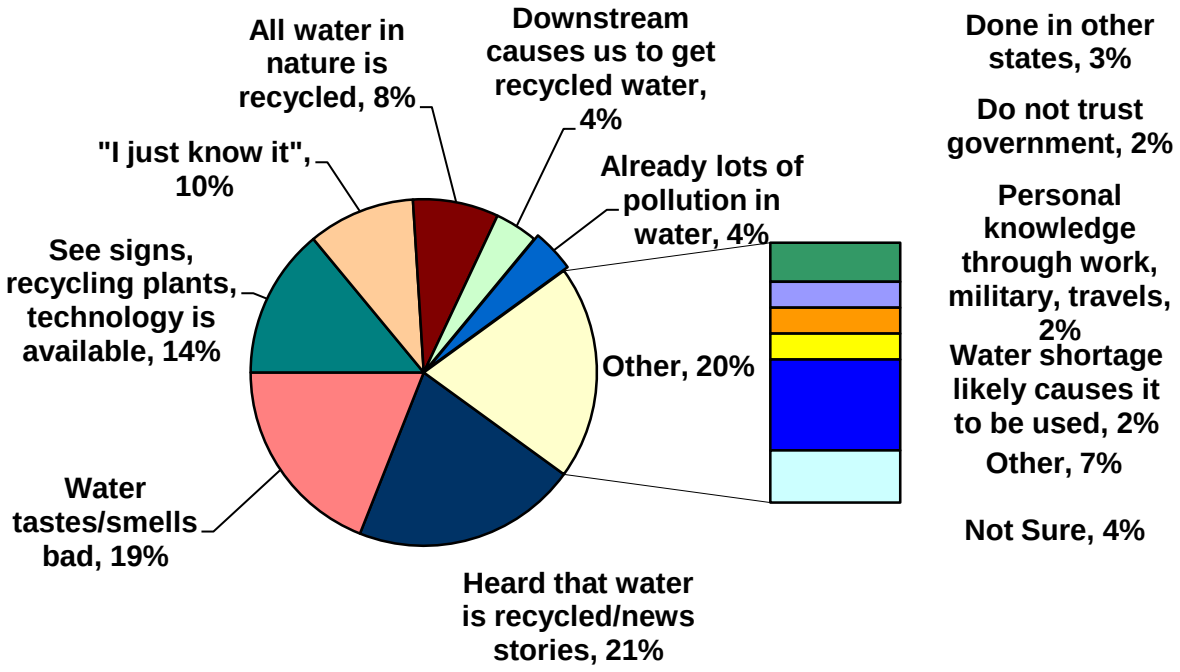
Chart 27
Believe that Drinking Water Already Contains Recycled Water?



The following group tends to think that drinking water already contains recycled water:

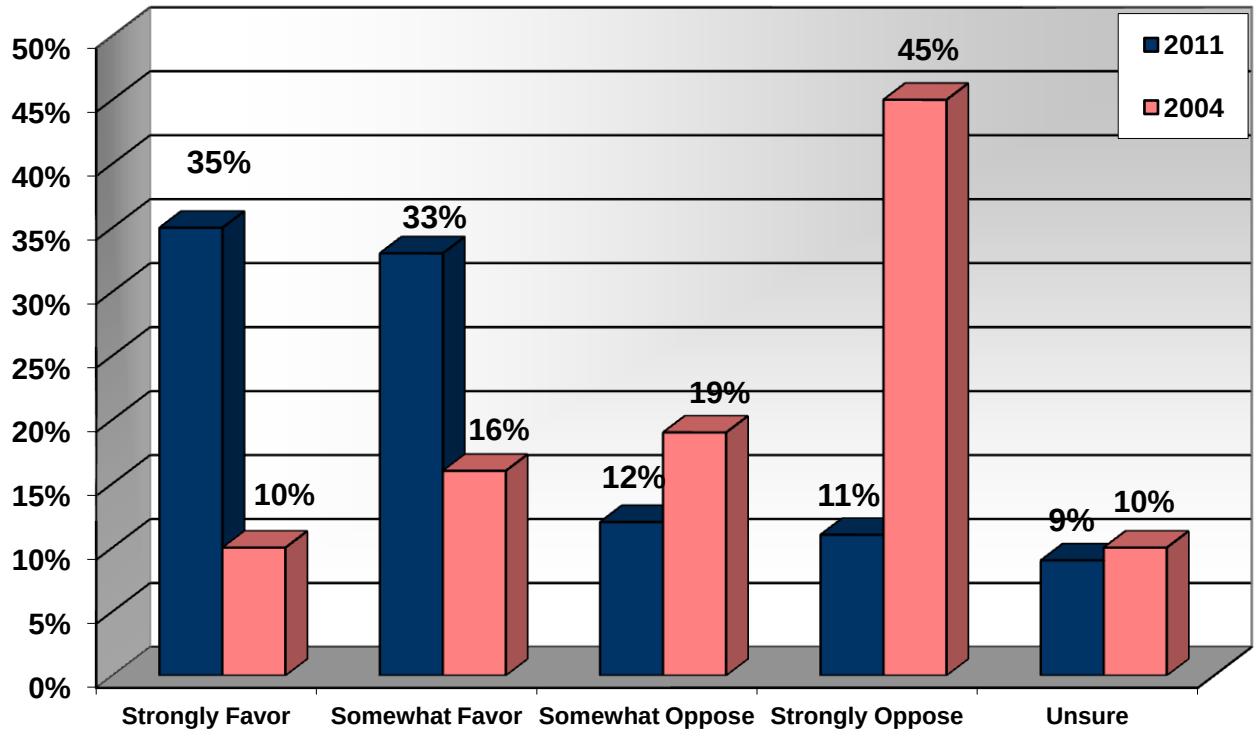
- Residents whose landlord pays the water bill (53 percent) versus residents who pay their own water bill (47 percent).

Chart 28
Reasons for Belief that Drinking Water Already Contains Recycled Water
(among 47 percent who think that drinking water contains recycyled water)



Respondents were asked whether or not they would favor using advanced treated recycled water as an addition to the supply of drinking water and that such advanced techniques include ultra-filtration, reverse osmosis, and advanced oxidation. (Explanations of these processes were provided upon request). **Chart 29** indicates that over two-thirds (68 percent) of the respondents either strongly favor (35 percent) or somewhat favor (33 percent) advanced treated recycled water as an addition to the supply of drinking water. It is important to note that this represents a dramatic increase in support for advanced treatment over the 2004 survey where only 26 percent of the respondents either strongly favored or somewhat favored advanced treated recycled water.

Chart 29
Opinion About Using Advanced Treated Recycled Water as an Addition to Drinking Water Supply
(scale 1 = Strongly Favor..5 = Strongly Oppose--mean = 1.99)



The following groups differ regarding their opinion about using advanced techniques to treat recycled water so that it can serve as an addition to the drinking water supply. The differences are expressed in terms of mean scores that are based on a scale, where 1 = strongly favor, 2 = somewhat favor, 3 = somewhat oppose, and 4 = strongly oppose.

- Younger residents are more in favor of advanced water recycling techniques than are older residents (35-44 years of age – mean of 1.76 versus 65-74 – mean of 2.20).
- Asians (mean of 1.83), Latinos (mean of 1.91), and Whites (mean of 1.98) are more inclined to favor advanced recycling techniques than are African-Americans (mean of 2.63).

Respondents, who did not already **strongly favor** the use of recycled water as an addition to the drinking water supply, were asked if they would accept recycled water for drinking purposes if it were subject to such advanced treatment and if they learned the following facts about recycled water (**Charts 30 - 32).**

The percentages reflect only those customers who formerly did not strongly favor the use of recycled water as an addition to the drinking supply but who changed their minds upon learning that:

- California drinking water standards are very strict and recycled drinking water would exceed those standards (54 percent); This represents a substantial increase from the results of the 2004 survey where an affirmative response of 38 percent was recorded (**Chart 30**).
- Recycled drinking water is used in other U.S. communities (50 percent); again, this represents a large (17 percent) increase over the 2004 survey result (**Chart 31).**
- Recycled drinking water could supply up to 10 percent of local supply (51 percent--only 30 percent were influenced by this statement in 2004--**Chart 32**).

Chart 30
Likelihood of Accepting Recycled Water to Supplement Drinking Water if Respondent Learned of Very Strict California Drinking Water Standards
(asked of 65 percent who were somewhat or less in favor of using recycled water for drinking)

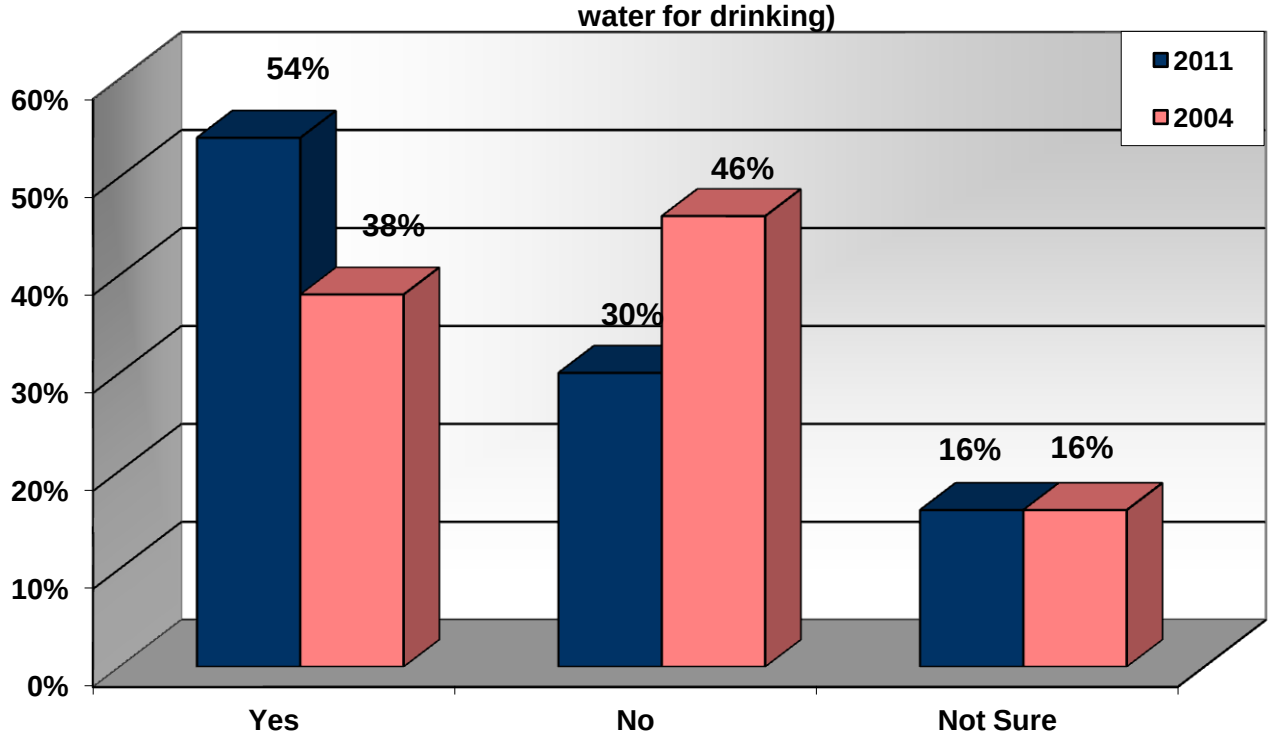
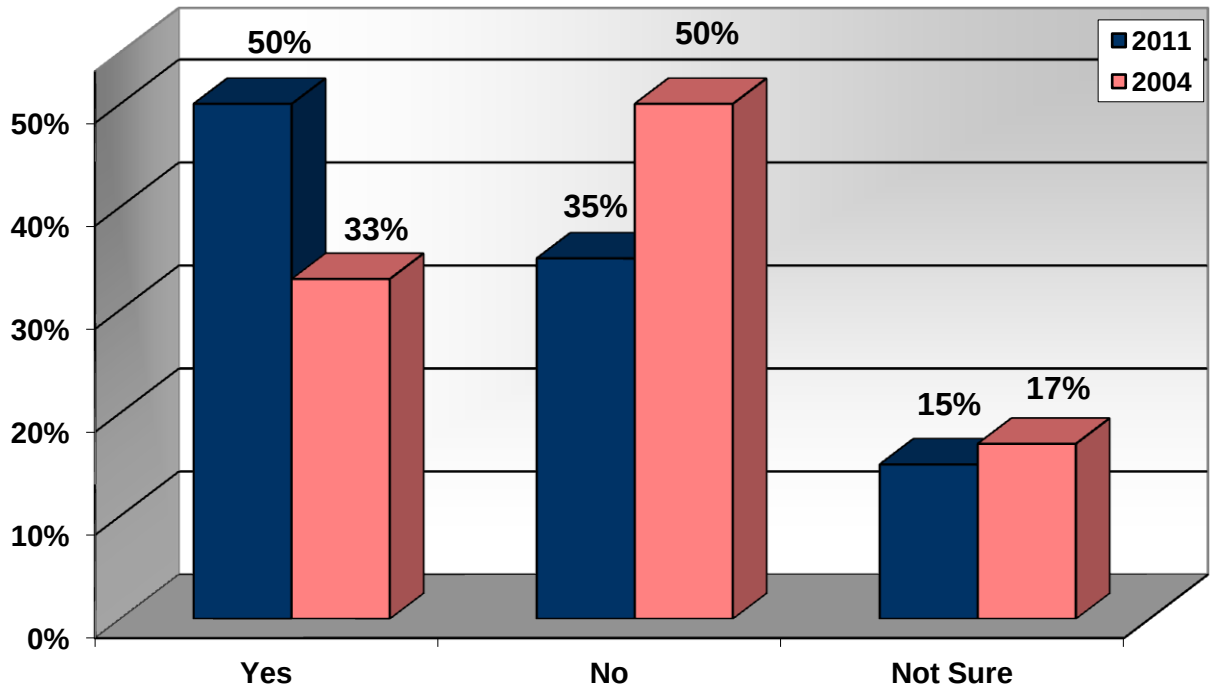


Chart 31
Likelihood of Accepting Recycled Water to Supplement Drinking Water if Respondent Learned that Other Communites Use Recycled Water as a Supplement
(asked of 65 percent who were somewhat or less in favor of using recycled



These findings show that over one-half of those who were originally not strongly in favor of using recycled water for drinking purposes would find it acceptable if it received advanced treatment and if certain other safety measures were assured. This is an increase of about 15 percent over the approximately 35 percent who changed their mind in 2004.

Table 2 shows that movement toward being more in favor of the use of recycled water for drinking water purposes differs, as would be expected, depending upon the degree to which the respondent was initially opposed or in favor of using recycled water for this purpose in the first place. Omitting all of those who were strongly in favor to begin with, it can be seen that the more in favor a respondent was initially, the easier it is for this information to sway his or her opinion. Among those who were previously somewhat in favor of recycled water being added to the drinking water supply, 67-72 percent are influenced by this information to be more in favor of this use of recycled water. It is striking that 34-45 percent of those

who were formerly unsure are so moved by this added information to favor the use of recycled water for drinking purposes.

Chart 32
Likelihood of Accepting Recycled Water to Supplement Drinking Water if Respondent Learned that Recycled Water Could Supply up to 10 Percent of Local Drinking Water
(asked of 65 percent who were somewhat or less in favor of using recycled water for drinking)

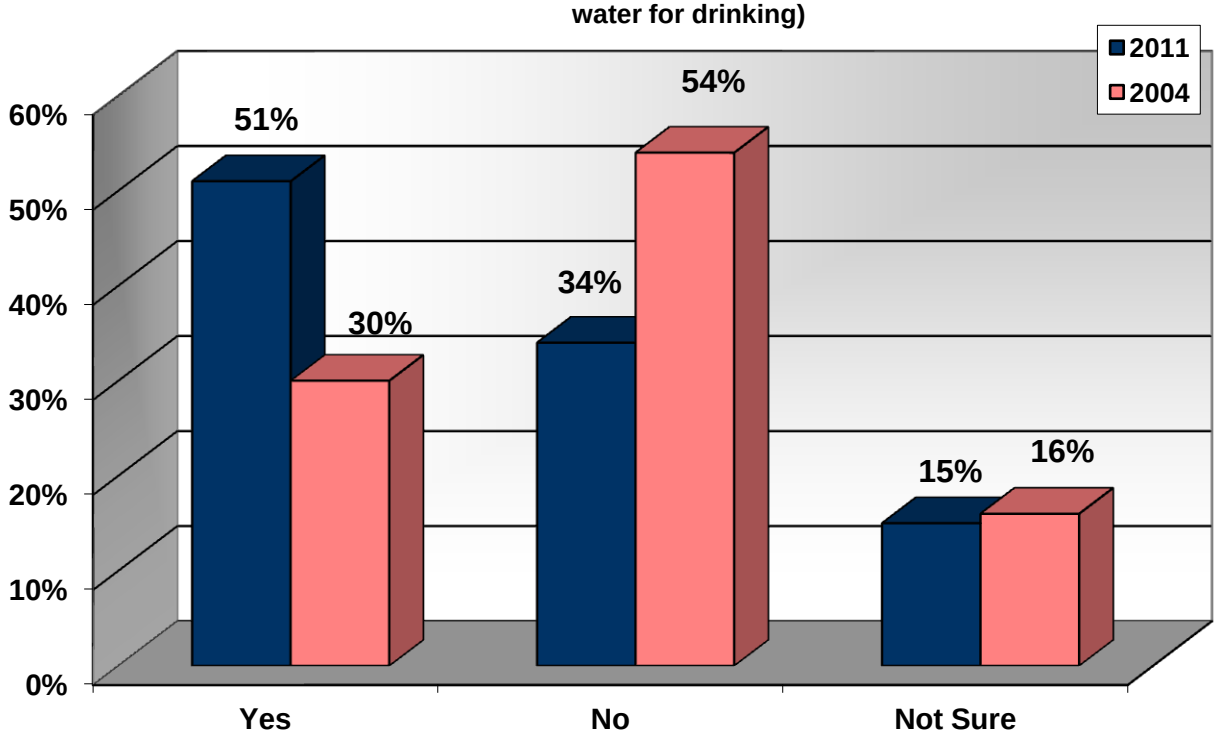


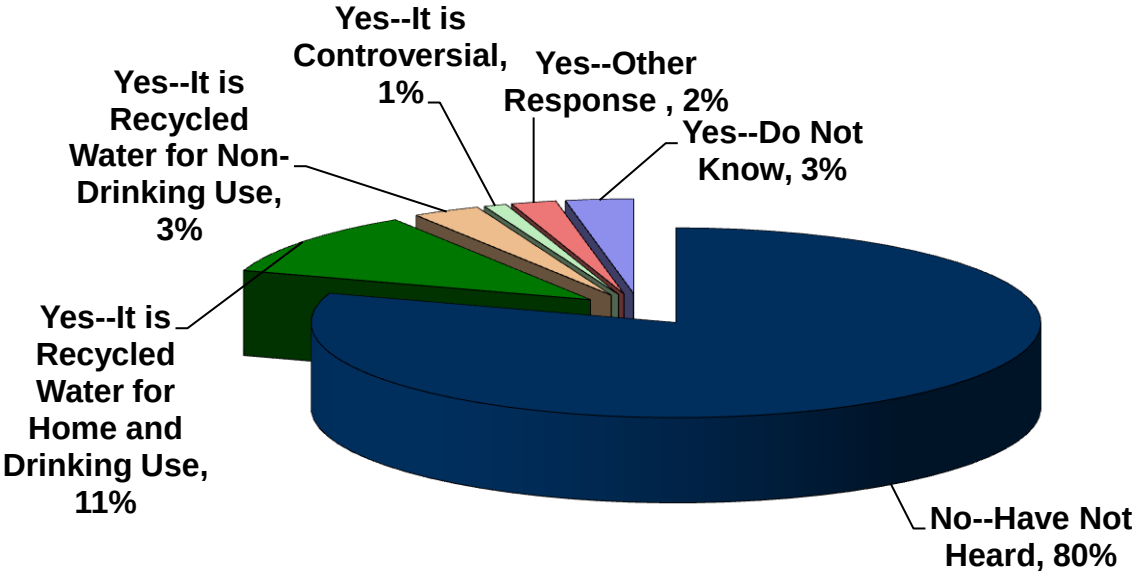
Table 2 Shift in Opinion Using Recycled Water (Percentages Represent Respondents Now Likely to Accept Recycled Water for Drinking Water Purposes)				
	Formerly Somewhat in Favor	Formerly Somewhat Opposed	Formerly Strongly Opposed	Don't Know/ Unsure
California drinking water standards are very strict and recycled drinking water would exceed those standards	72%	48%	16%	40%
Recycled drinking water is used in other U.S. communities	65%	50%	18%	34%
Recycled drinking water could supply up to 10 percent of local supply	67%	38%	21%	45%

The following subgroup is especially influenced by the knowledge that recycled water could supply as much as 10 percent of our local drinking water supplies:

- Residents whose landlord pays the water bill (59 percent) versus residents who pay their own water bill (48 percent).

<u>City of San Diego Water Purification Demonstration Project</u>: Chart 33 shows that 80 percent of San Diego City residents have not heard of the City of San Diego Water Purification Demonstration Project. Among the 20 percent who have heard about this project, 11 percent know that it involves recycled water for drinking and household purposes and 3 percent believe that the project involves recycled water for a purpose other than household and drinking use.

Chart 33
Heard about City of San Diego Water Purification Demonstration Project



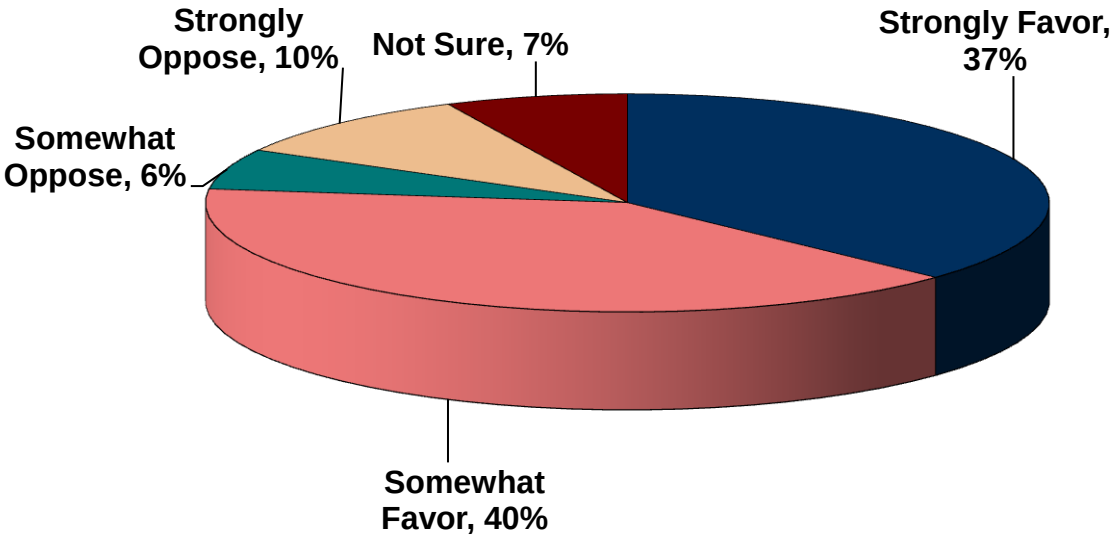
Respondents were subsequently informed about the nature and purpose of the Water Purification Demonstration Project. When so informed, residents expressed substantial support for the Project. **Chart 34** shows that 77 percent of residents either strongly favor (37 percent) or somewhat favor (40

percent) the goals of the Project. This response represents strong approval for the use of recycled water for drinking purposes.

The following subgroups are less likely to have heard about the San Diego City Water Purification Demonstration Project:

- Residents whose landlord pays the water bill (88 percent) versus residents who pay their own water bill (78 percent).
- Renters (87 percent) versus homeowners (76 percent).

Chart 34
Opinion about Water Purification Demonstration Project
(scale: 1 = Strongly Favor..4 = Strongly Oppose--mean = 1.87)



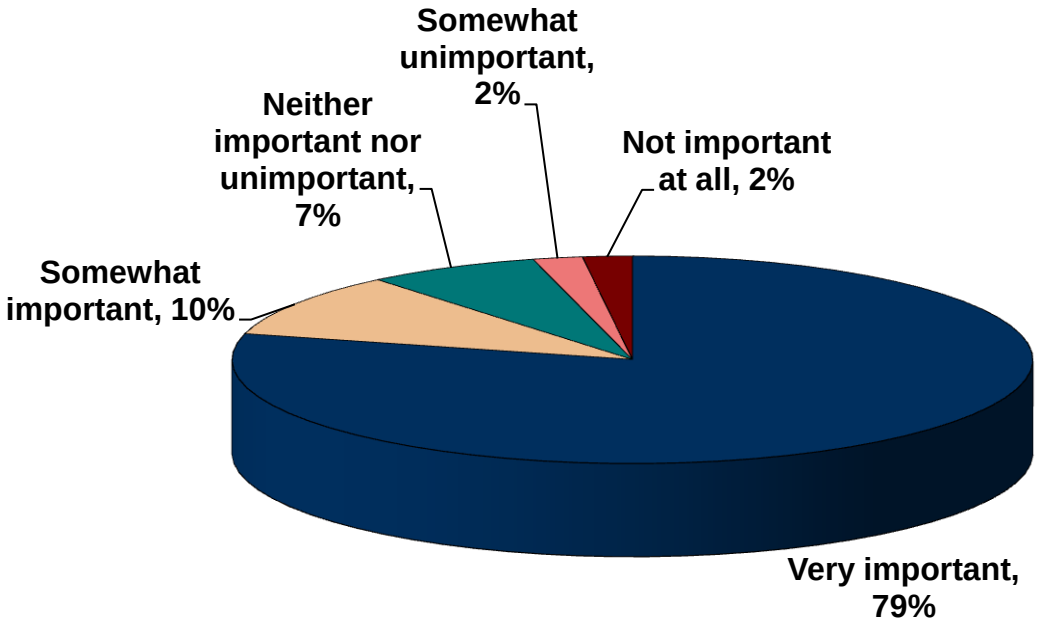
Attitudes about the Local Agricultural Industry and Water

SUMMARY: San Diego City residents have shown substantial support for their local agricultural community – over four-fifths feel that local farmers and agriculture are very important to the local economy. They further feel that reduced water rates for the agricultural industry should be maintained.

Chart 35 shows that nearly four-fifths (79 percent) of respondents feel that local farmers and agriculture are very important to the local economy. On a scale of 1 to 5, where 1 = very important and 5 = not

important at all, the mean importance rating is 1.37. This represents a substantial indication of the region's support for its agricultural community.

Chart 35
Importance of Local Farmers and Agriculture to San Diego Economy
(scale: 1 = Very important..5 = Not at all important--mean = 1.37)



This positive attitude toward farmers and agriculture is further corroborated in **Chart 36** which shows that 84 percent of respondents feel that reduced water prices for farmers and agriculture should be maintained.

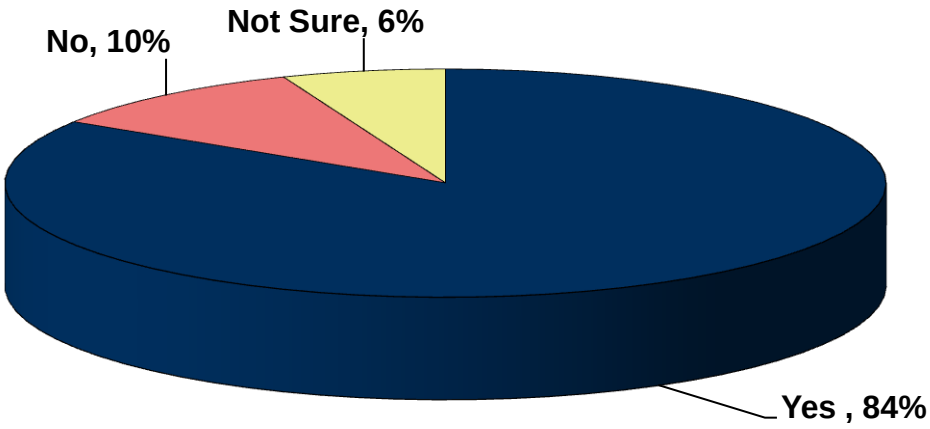
The following groups are more likely to think that reduced water prices for farmers should be maintained:

- Those who prefer to communicate in English are more likely to favor the maintenance of reduced water prices for farmers than are those who prefer Spanish (English speaking – 87 percent; Spanish speaking – 72 percent).
- Residents of single family homes and condominiums (87 percent each) versus residents of apartments (76 percent) and mobile homes (78 percent).
- Residents who own their homes (88 percent) versus those who rent their homes (81 percent).

The following groups differ regarding how important they think farmers and agriculture are to the San Diego economy. The differences are expressed in terms of mean scores that are based on a scale where 1 = very important to 5 = not important at all.

- Latinos (mean of 1.18) regard farmers and agriculture as being more important to the San Diego economy than do Whites (mean of 1.47) and Asians (mean of 1.57).
- Residents with one year of graduate work or more (mean of 1.20) attach more importance to farmers and agriculture than do those with a high school education or less (mean of 1.61).

Chart 36
Maintain Reduced Water Rates for Farmers and Agriculture



2012 Public Opinion Poll Report

The City sub-sample of the 2012 Public Opinion Poll Report can be found on the following pages. The appendix is not included in this document, but it can be found at http://www.sandiego.gov/water/waterreuse/demo/links.shtml.

San Diego County Water Authority
2012 Public Opinion Poll Report
City of San Diego Sample Subset

CITY OF SAN DIEGO PUBLIC UTILITIES

600 B Street—Suite 600 **San Diego, CA 92101**

August 16, 2012

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Executive Summary

The San Diego County Water Authority has conducted a public opinion survey within its service area in San Diego County in order to measure the region's opinion regarding various water related issues. Rea & Parker Research was selected to be the lead consultant for this 2012 Public Opinion Poll. Rea & Parker Research also conducted surveys for the Water Authority in 2000, 2003, 2004, 2005, 2006, 2008, and 2009, and 2011. A portion of this public opinion poll, as in 2004 and 2011, was specifically geared to residents within the City of San Diego, in particular concerning the City of San Diego Water Purification Demonstration Project. This 2012 study has established the following as its primary objectives:

- Identify the level of public concern about cost of water and rising rates
- Assess the tolerance for additional rate increases to support desalination
- Identify major drivers for recent reductions in water use
- Determine factors that might increase the likelihood for regional water use to "rebound"
- Recycled water and the City of San Diego Water Purification Demonstration Project

This continuity of survey administration greatly facilitates the tracking of responses from year-to-year, including the consistency of wording and interviewing that adds to the statistical reliability of such comparisons.

The purpose of this report is to present the results of the San Diego County Water Authority 2012 Public Opinion Poll specifically for residents located within the City of San Diego.

The San Diego City portion of the survey was conducted by a random telephone sample of 400 respondents, which equates to a margin of error +/-4.9 percent @ 95 percent confidence. The sample included 74 residents who were only cell phone users (do not use land-line telephone). All participants were at least 18 years old and had lived in San Diego County at least one year.

Respondents are predominantly White (61 percent), with 21 percent Hispanic/Latino, 11 percent African-American/Black, 5 percent Asian/Pacific Islander, and 2 percent American Indian/Native American and Mixed Ethnicities. Residents earn a median household income of $57,700 per year (24 percent earning $100,000 or more and 12 percent earning under $25,000). They have a median age of 54 years and have lived in the County for a median of 27 years.

Among respondents, 61 percent possess a Bachelor's Degree or more, with 12 percent having a High School education or less. The zip codes most represented in the survey are as follows – each with 5 percent-to -6 percent of the respondents: 92104, 92105, 92110, 92115, 92116, 92117, 92128, and 92154. Home ownership percentage is 66 percent, with a mean of 2.90 persons per household.

Survey Findings

The 2012 Public Opinion Poll focused on six essential topics. It sought to identify and analyze, in particular,

- Identify the level of public concern about cost of water and rising rates
- Assess the confidence and trust in the regional water supply

- Evaluate progress made toward water conservation
- Assess the importance of desalination to the reliability of the water supply
- Evaluate progress made toward Strategic Plan objectives
- Water recycling

As such, this report has been divided into seven sections, as follows:

- Opinions about Local Issues
- Relative Value of Water and Other Utilities
- Water Reliability and Plans to Diversify Water Sources
- Seawater Desalination
- Attitudes about Water Conservation
- Opinions about the Use of Recycled Water (including attitudes about the City of San Diego Water Purification Demonstration Project)
- Water Rates

Opinions about Local Issues

- Residents identified the most important issues in San Diego County as the Economy and Jobs (36 percent), Financial Problems in Government including high taxes (19 percent), the Quality and Cost of Education (10 percent) followed by Water Supply Quality and Cost (9 percent) and Infrastructure (5 percent). The high level of concern regarding the condition of the economy was also found in the 2011 survey. The top two issues are not surprising since, during the past few years, there has been considerable, sustained attention devoted to the fiscal stress of local and state governments as well as the problems in the economy as a whole.
- One third of respondents (33 percent) are aware that the San Diego County Water Authority has filed a lawsuit alleging that the Metropolitan Water District is overcharging San Diego County ratepayers for the cost of transporting imported water to San Diego.

Relative Value of Water and Other Utilities

- Water is seen as a good value for the amount of money paid compared to other utilities; however, water has fallen relative to gas and electric as a good value since 2011.
- When asked to indicate the best value among utilities, 37 percent indicate that gas and electric is the best value and 16 percent rank water as such.
- Among all respondents, when first, second and third choices are weighted, 29 percent view gas and electric as the best value among utilities, with water second at 17 percent.

Water Reliability and Plans to Diversify Water Sources

Water Reliability

- Among residents of the City of San Diego, nearly four-fifths find that the current supply of water is either very reliable (37 percent) or somewhat reliable (42 percent) and can be consistently relied upon to meet the region's needs. This positive attitude toward water supply reliability is highly consistent with the results of the 2011 survey. Both the 2011 and 2012 survey years represent a clear enhancement in the perception of water supply reliability from the results of the 2004 survey.
- However, respondents are expressing a decreasing level of confidence in how they perceive the trend in the water supply (improving, worsening, or staying the same). Just over one-tenth (13 percent) of residents feel that water supply reliability is improving – a decrease of 11 percent from the 24 percent level recorded in 2011, and 27 percent see the supply as worsening—a 5 percent increase over 2011.
- Nearly three-fifths of respondents (59 percent) have trust in the ability of local water agencies to provide clean, safe, water for their customers.
- Almost one-third (32 percent) of respondents have either a great deal of trust (7 percent) or a good amount of trust (25 percent) in the ability of local water agencies to obtain water at reasonable prices.
- Nearly one-half of the respondents (49 percent) are aware of efforts by the San Diego County Water Authority to make the water supply more reliable. Respondents identified the following efforts as particularly noteworthy in this regard: water transfers and water importation from the Colorado River and the Imperial Valley (19 percent), improvement of the infrastructure (17 percent), and seawater/ocean water desalination (11 percent).
- The most critical things that can be done to ensure a safe and reliable water supply for San Diego County residents and businesses are to improve the quality of the water (19 percent), pursue seawater desalination (13 percent) and improve infrastructure (10 percent).

Diversification Plan

- Over one third of respondents indicate that the most important part of the Water Authority's Diversification Plan is seawater desalination (34 percent) followed by recycled water (21 percent), and the development of local reservoirs (18 percent). Seawater desalination continues to be regarded as the most important component of the Diversification Plan in the view of the respondents. Recycling has declined since 2011 in its importance as a component of the Diversification Plan. Local reservoirs have gained substantial ground.
- Three-fifths (60 percent) of residents are in support of the San Diego County Water Authority's Diversification Plan with ratings of strongly agree (40 percent) and agree (20 percent). This represents a decline in support of the Diversification

Plan from the results of the 2011 survey where 80 percent either strongly agreed or agreed that the Diversification Plan would improve water supply reliability.

Seawater Desalination

- Over four-fifths (82 percent) of respondents feel that seawater desalination is important to the reliability of the water supply (53 percent -- very important and 29 percent -- somewhat important).
- Respondents are most favorably influenced toward desalination by the following message: "Desalinated water is a drought-proof local supply of water," which is followed very closely by "Desalinated water reduces the San Diego region's dependence on supplies from the Metropolitan Water District" and by "Desalination will reduce the region's demand for supplies of imported water from Northern California and the Colorado River." The least influential message is as follows: "Desalinated water is competitive with the cost of developing other new sources of water supplies."
- Nearly two-thirds (66 percent) expressed a willingness to pay something more per month to add seawater desalination to the water supply. Among this 66 percent, 57 percent indicated that they would pay $5 or more additionally per month.
- Among those who indicated a precise amount, the average (mean) additional amount they are willing to pay is $13 per month.

Attitudes about Water Conservation

Water Use in Past Year

- Water conservation is a significant component in San Diego County's water supply plans. Over one-fourth of respondents (26 percent) indicated that their household water usage has decreased over the past year. This represents a decline of 2 percent among those who indicated that they decreased their water usage in 2011 (28 percent). This decline is offset, however, by a 4 percent decline in those indicating that their usage had increased.
- Among those who indicated that their household water usage has declined, nearly one-half (48 percent) feel that reducing water usage is the "right thing to do." In 2011, a somewhat smaller (but still substantial) percentage was motivated to reduce water usage because it is the "right thing to do" (31 percent).
- Over one-fourth (27 percent) were motivated to reduce water usage because they are watching their budget and this represents a slight decline since 2011 when 35 percent were so motivated by budgetary concerns to reduce their water usage.
- The vast majority—almost 90 percent—indicated that their reduced water usage is permanent and this is consistent with the 2011 finding.

Water Use in the Future

- It is most encouraging that when water agencies no longer take an active role in restricting water use, respondents who have reduced their water usage during the past year indicate that they are not likely to increase their water use to a great extent (22 percent would increase). When the economy rebounds, only 18 percent anticipate increasing their water usage.
- On the other hand, a less cool and less wet year would lead to nearly three-fifths (57 percent) of those who have reduced their water use during the past year returning to higher usage. These views about higher water in the future parallel the views of the 2011 survey respondents.

Water Conservation as a Civic Responsibility

- Virtually all of the respondents (95 percent) think that it is their civic responsibility to use water as efficiently as possible.
- In the current survey period as well as in 2011, respondents regard water conservation as a greater civic responsibility than serving on a jury. For voting in public elections and not littering/not polluting, water conservation is seen as less of a civic responsibility. Water conservation and recycling used materials are closer to equality as civic responsibilities.

Opinions about Recycled Water

- Over 7 in 10 respondents (71 percent) believe that it is possible to further treat recycled water previously used for irrigation to make the water pure and safe for drinking. This represents a slight increase over the 2011 survey finding where two-thirds (67 percent) felt that it is possible to further treat recycled water for drinking purposes.
- Nearly three fifths of the respondents (56 percent) believe that drinking water already contains recycled water. This reflects a clear upward movement in the percentage of those who hold this belief – 47 percent in 2011.
- Three primary reasons are provided to explain why respondents feel that drinking water already contains recycled water. Respondents feel they hear that water is recycled from news stories (19 percent), they “just know it” (includes hunches and common sense) (17 percent), and water tastes and smells bad (16 percent). In 2011, hearing about recycled water from news stories was also the most dominant reason (21 percent). The reason “just know it” increased in importance by 7 percent from the 10 percent reported in 2011.
- Nearly three-fourths (73 percent) of the respondents either strongly favor (36 percent) or somewhat favor (37 percent) advanced treated recycled water as an addition to the supply of drinking water. This represents an increase in support for advanced treatment over the 2011 survey where 68 percent of the respondents either strongly favored or somewhat favored advanced treated recycled water. Interest in using such advanced techniques has increased substantially since 2004.

- Among the 20 percent who have heard about the Water Purification Demonstration Project, 6 percent know that it involves recycled water for drinking and household purposes – a decline of 5 percent from the 11 percent who correctly identified the purpose of the project in 2011. When respondents were informed about the Project, they expressed substantial support for the Project – over three-fourths either strongly favoring the project or somewhat favoring it. This level of support parallels the support indicated in the 2011 survey.

Water Rates

- Over two-fifths (45 percent) of respondents feel that the cost of water is too expensive and another 54 percent feel that the cost is fair and reasonable. This represents a decline from the 2011 survey period among those who feel the cost of water is too expensive -- in 2011, 52 percent indicated water was too expensive. This result points to a trend toward an enhanced understanding of and tolerance for the cost of water.
- The dominant causes that residents indicate for increases in water rates are more water being consumed by customers (20 percent) and less rain in San Diego (18 percent)—both of which are not correct.
- Three-fifths of respondents (60 percent) feel that increases in water rates are necessary to maintain reliability of the water supply while well over one-third of the respondents (36 percent) feel that increased water rates are not necessary and should be stopped. This reaffirms the shift from the 2011 survey results toward an understanding of and a tolerance for water rate increases. In the 2011 survey, there was a near equal split in opinion about the necessity of water rate increases to pay for projects designed to improve water supply reliability.
- Despite their seeming understanding of increasing water rates, almost two-thirds (65 percent) indicate that they very concerned (41 percent) or somewhat concerned (24 percent) about the prospect of continued increases in water rates. This level of concern is consistent with the results of the 2011 survey where 61 percent were either very concerned or somewhat concerned about continued increases in water rates.

Introduction and Methodology

The San Diego County Water Authority has, over the years, conducted a public opinion survey within its service area in San Diego County in order to measure public opinion regarding water issues. Rea & Parker Research was selected to be the lead consultant for this 2012 Public Opinion Poll. Rea & Parker Research, in association with Flagship Research, also conducted public opinion polls for the Water Authority in 2000, 2003, 2004, 2005, 2006, 2009, and 2011 and two water conservation surveys in 2008 to test the effectiveness of conservation messages. This continuity of survey administration greatly facilitates the tracking of responses from year-to-year, including the consistency of wording and interviewing that adds to the statistical reliability of such comparisons.

The City of San Diego requested that the sample include about 400 respondents specifically residing within the boundaries of the City. It was also requested by the City of San Diego that specific questions pertaining only to City residents be included in the survey. These same questions were specifically directed at issues pertaining to the City of San Diego Water Purification Demonstration Project. This same process of additional questions for the City of San Diego sub-sample was followed in 2004 and in 2011. Accordingly, Rea & Parker Research has compared 2004 and 2011 survey data with the results of the current survey where questions were the same or nearly the same.

The purpose of this report is to present the results of the San Diego County Water Authority 2012 Public Opinion Poll for respondents located within the City of San Diego.

The primary objectives of the 2012 research are as follows:

- Identify the level of public concern about cost of water and rising rates
- Assess the confidence and trust in the regional water supply
- Evaluate progress made toward water conservation
- Assess the importance of desalination to the reliability of the water supply
- Evaluate progress made toward Strategic Plan objectives
- Identify knowledge and opinions about the Water Purification Demonstration Project (City sub-sample only)

As such, this report has been divided into seven essential information components as follows:

- Opinions about Local Issues
- Relative Value of Water and Other Utilities
- Water Reliability and Plans to Diversify Water Sources
- Seawater Desalination

- Attitudes about Water Conservation
- Opinions about the Use of Recycled Water (including attitudes about the City of San Diego Water Purification Demonstration Project)
- Water Rates

Sample

The 2012 Public Opinion Poll was conducted between July 9 and July 25, 2012, including a random telephone sample of 400 respondents located within the City of San Diego. The random sample was selected by random digit dialing from the zip codes contained within the City of San Diego. This sample yields a margin of error of +/- 4.9 percent @ 95 percent confidence. The sample includes 74 residents who are only cell phone users (do not use land-line telephone). All participants were at least 18 years old and had lived in San Diego County at least one year. It is important to note that the sample of 400 is a subset of the larger sample of 816 representing the entire San Diego Water Authority service area.

The margin of error for this survey represents the widest interval that occurs when the survey question represents an approximate 50%-50% proportion of the sample. When it is not 50 percent-50 percent, the interval is somewhat smaller. For example, in the survey findings that follow, 49 percent of respondent households indicate that they are aware of efforts by the San Diego County Water Authority to make the supply of water even more reliable. This means that there is a 95 percent chance that the true proportion of the total population of the Water Authority's service area who have this awareness is between 44.1 percent and 53.9 percent (49 percent +/- 4.9 percent).

Survey Instrument

The survey instrument contained 41 questions, including 69 individual survey items (variables). The survey instrument was administered in both English and Spanish. A copy of the survey is attached in the Appendix. A total of 18 respondents (4.5 percent) elected to respond in Spanish

Respondent Characteristics

Table 1 presents certain demographic characteristics of the survey respondents and also provides the 2011 characteristics for comparative purposes. In 2012, respondents are predominantly White (61 percent), with 21 percent Hispanic/Latino, 11 percent African-American/Black, 5 percent Asian/Pacific Islander, and 2 percent American Indian/Native American and Mixed Ethnicities. Residents earn a

median household income of $57,700 per year (24 percent earning $100,000 or more and 12 percent earning under $25,000). They have a median age of 54 years and have lived in the County for a median of 27 years. Among respondents, 61 percent possess a Bachelor's Degree or more, with 12 percent having a High School education or less. The zip codes most represented in the survey are as follows – each with 5.0-6.0 percent of the respondents: 92104, 92105, 92110, 92115, 92116, 92117, 92128, and 92154.

Table 1
City of San Diego Survey Respondent Demographics

Demographic Characteristic	2012	2011
Gender		
Male	57%	45%
Female	43%	55%
Median Age (Years)	54	48
Median Number of Years Lived in Community	27	22
Highest Grade/Level of School Completed		
High School or Less	12%	27%
Some College	27%	28%
Bachelor's Degree	36%	28%
Some Graduate School	25%	17%
Ethnicity		
White	61%	53%
Latino/Hispanic	21%	28%
African-American/Black	11%	8%
Asian/Pacific Islander	5%	7%
Native American/Mixed	2%	4%
Median Household Income	$57,700	$52,200
Home Ownership Percentage	66%	62%
Type of Housing		
Single Family Detached	69%	60%
Condominium	15%	18%
Apartment	15%	20%
Mobile Home	1%	2%
Mean Number of Persons per Household	2.90	3.02
Pay Own Water Bill	68%	72%

The home ownership percentage is 66 percent, with a mean of 2.90 persons per household. Among White and Asian respondents, 74 percent are homeowners. This is consistent with the 2011 homeownership rate for Whites and Asians of 72 percent. Black/African-American homeowners have

increased from 45 percent in 2011 to 54 percent in the current survey and the homeownership rate for Hispanics/Latinos has also increased to 54 percent from their 2011 homeownership rate of 40 percent.

Other differences between the current 2012 survey respondents and the respondents from previous years are as follows:

- The 2012 survey respondents have completed more higher education than respondents in 2011.
- The 2012 respondents are more represented by Whites and less represented by Hispanics/Latinos than the respondents in the 2011 survey.
- The percentage of homeowners (70 percent) is higher than in 2011, as is the percentage of single-family residence dwellers.
- Respondents in 2012 are somewhat older in 2012 than they were in 2011 (2012 median of 54 years of age versus 2011 median of 48 years of age) and have resided in County for a longer term (27 years in 2012 versus 22 years in 2011).
- A smaller percentage of respondents pay their own water bills in 2012 than in 2011.

Survey Findings

Each section of the report will begin with a very brief abstract, or summary of highlights within the ensuing section, in order to orient the reader to what is to follow. Charts have been prepared for each section that depict the survey results for the 2012 survey and for the 2011 and 2004 surveys where questions are repeated and results can be directly compared. Each section will include a discussion of the survey periods. Detailed statistical frequency distributions and a full listing of verbatim open-ended responses are contained in the Appendix along with the survey instrument for reference.

Lastly, subgroup analyses for different age groups, various levels of education, gender, home ownership/rental status, household size, residential tenure in the community, different income categories, cell phone only/land line users, and water bill payers/non-payers and ethnicity of residents of the City will be presented in a succinct, bulleted format when statistical significance and relevance warrants such treatment.

Opinions about Local Issues

SUMMARY: Residents identified the most important issues is San Diego County as the Economy and Jobs, Financial Problems in Government including high taxes, and the Quality and Cost of Education. The high level of concern regarding the condition of the economy was also found in the 2011 survey. The first two ranked issues are not surprising since, during the past few years, there has been considerable, sustained attention devoted to the fiscal stress of local and state governments

as well as the economy as a whole. The concern for the quality and cost of education as well as the quality and supply of water are similar in 2012 and 2011.

One-third of respondents are aware that the San Diego County Water Authority has filed a lawsuit alleging that the Metropolitan Water District is overcharging San Diego County ratepayers for the cost of transporting water to San Diego.

Chart 1 shows that the most important current issues identified by residents of the City of San Diego are the Economy and Jobs (36 percent), Financial/Political Problems in Government including high taxes (19 percent), and the Quality and Cost of Education (10 percent), followed by the Quality and Cost of Water (9 percent) and Infrastructure (5 percent). The high level of concern regarding the condition of the economy, found in the 2011 survey, is repeated in the current survey. Respondents report that governmental financial problems also remain at the high level of concern found in the 2011 survey results. In fact, this concern for the general economy and fiscal problems in government has increased to some extent in the current survey. This is not surprising since, during the past few years, there has been considerable attention devoted to the fiscal stress of local and state governments as well as problems in the economy as a whole. The concern for the quality and cost of education as well as the cost, quality and supply of water are similar in 2012 and 2011.

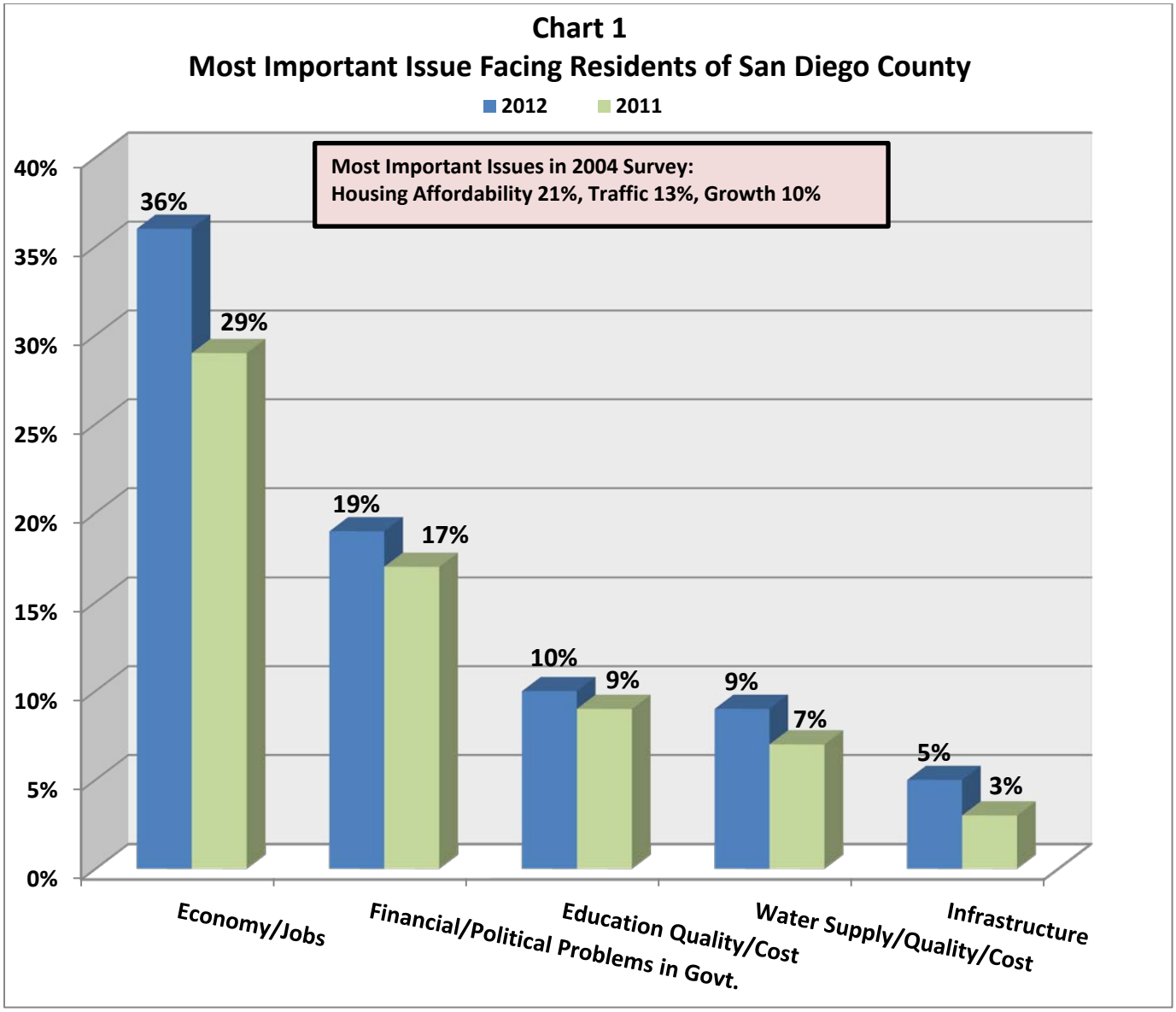
In 2004, respondents indicated that the most important issues were housing affordability (21 percent) traffic (13 percent), and growth and development (10 percent). Other responses that did not receive enough mention to merit an individual listing in the chart can be viewed in the Appendix, where the full listing of responses is displayed.

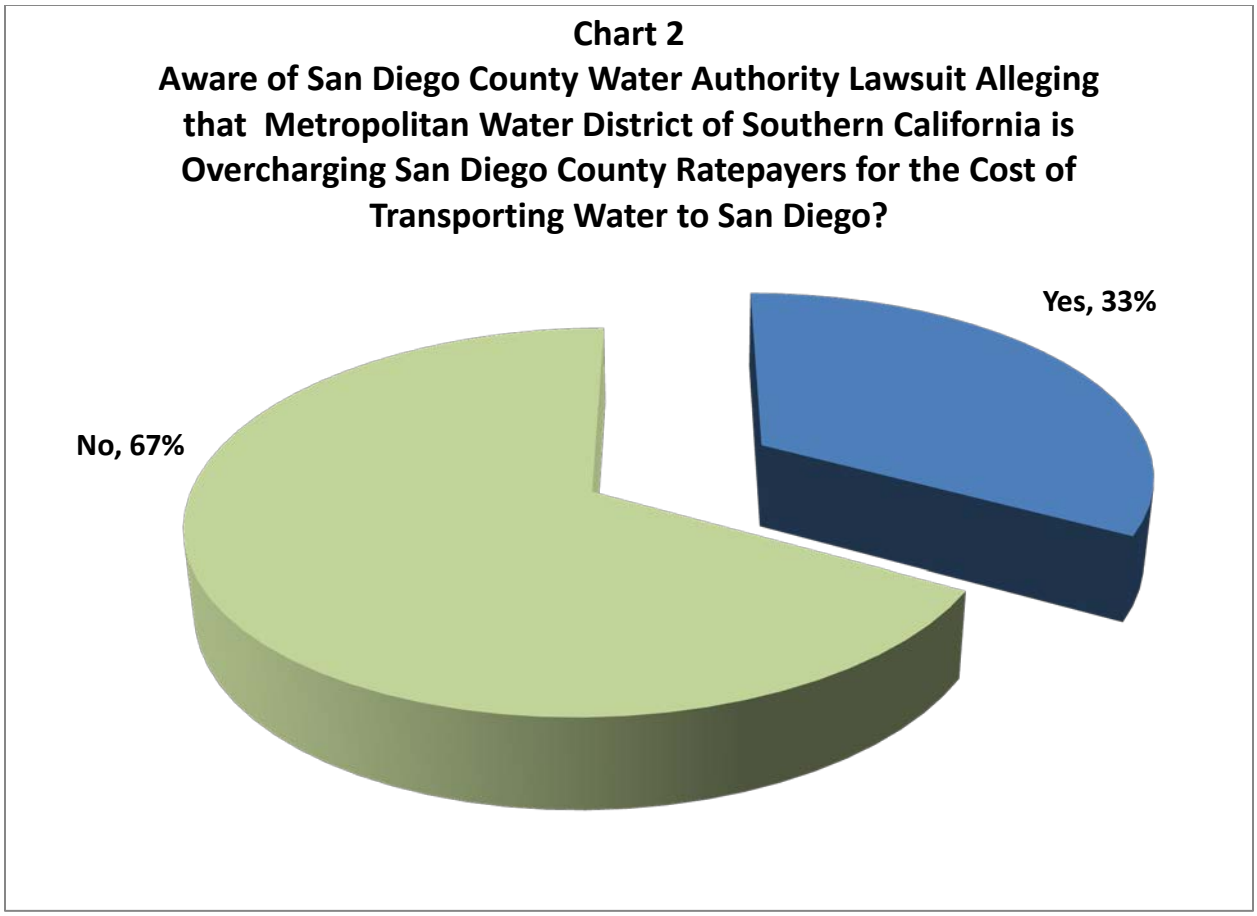
Respondents were asked whether they are aware that the San Diego County Water Authority has filed a lawsuit against the Metropolitan Water District of Southern California for overcharging San Diego County taxpayers for the cost of transporting imported water to San Diego. **Chart 2** shows one-third of City respondents (33 percent) are aware of this lawsuit.

The following groups are more likely to be aware that the San Diego County Water Authority has filed a lawsuit alleging that the Metropolitan Water District is overcharging San Diego County ratepayers for the cost of transporting imported water:

- Males (39 percent) versus females (26 percent).
- Residents who pay their own water bill (37 percent) as opposed to those whose water bill is paid by someone else such as a landlord (26 percent).

- Homeowners (39 percent) versus renters (24 percent).
- Asians (47 percent) and Whites (37 percent) versus Blacks/African-Americans (27 percent) and Hispanics/Latinos (21 percent).
- Residents who are 65 years of age and over (54 percent) versus residents who are 44 years of age and under (18 percent).
- Longer term residents of the County (45 or more years – 49 percent versus 20 years or less – 23 percent).





Relative Value of Water and Other Utilities

Summary: Water is seen as a relatively good value for the amount of money paid in comparison to other utilities, such as gas and electric service and phone service. However, water has fallen relative to gas and electric as a good value since 2011. When asked to indicate the best value among utilities, 37 percent indicate that gas and electric is the best value and 16 percent rank water as such. Among all respondents, when the data are weighted for the utilities of first choice, second choice, and third choice, 29 percent view gas and electric service as the best value, followed by water at 17 percent.

Residents were asked their opinion regarding the utility that provides them with the best value for the money paid. **Chart 3** shows the survey results for all City of San Diego respondents. Water is seen as a relatively good value for the amount of money paid in comparison to other utilities, including gas and electric service, phone service, and Internet access, among others. When asked to indicate the best value among utilities, 37 percent indicate that gas and electric is the best value and 16 percent rank water as such. Among all respondents, when the data are weighted for the utilities of first choice, second choice,

and third choice, 29 percent view gas and electric service as the best value, followed by water at 17 percent. In 2011, respondents also considered gas and electric as the best relative value (30 percent); however, it is noteworthy that the relative value of water fell by 4 percent (from 21 percent in 2011 to 17 percent in 2012).

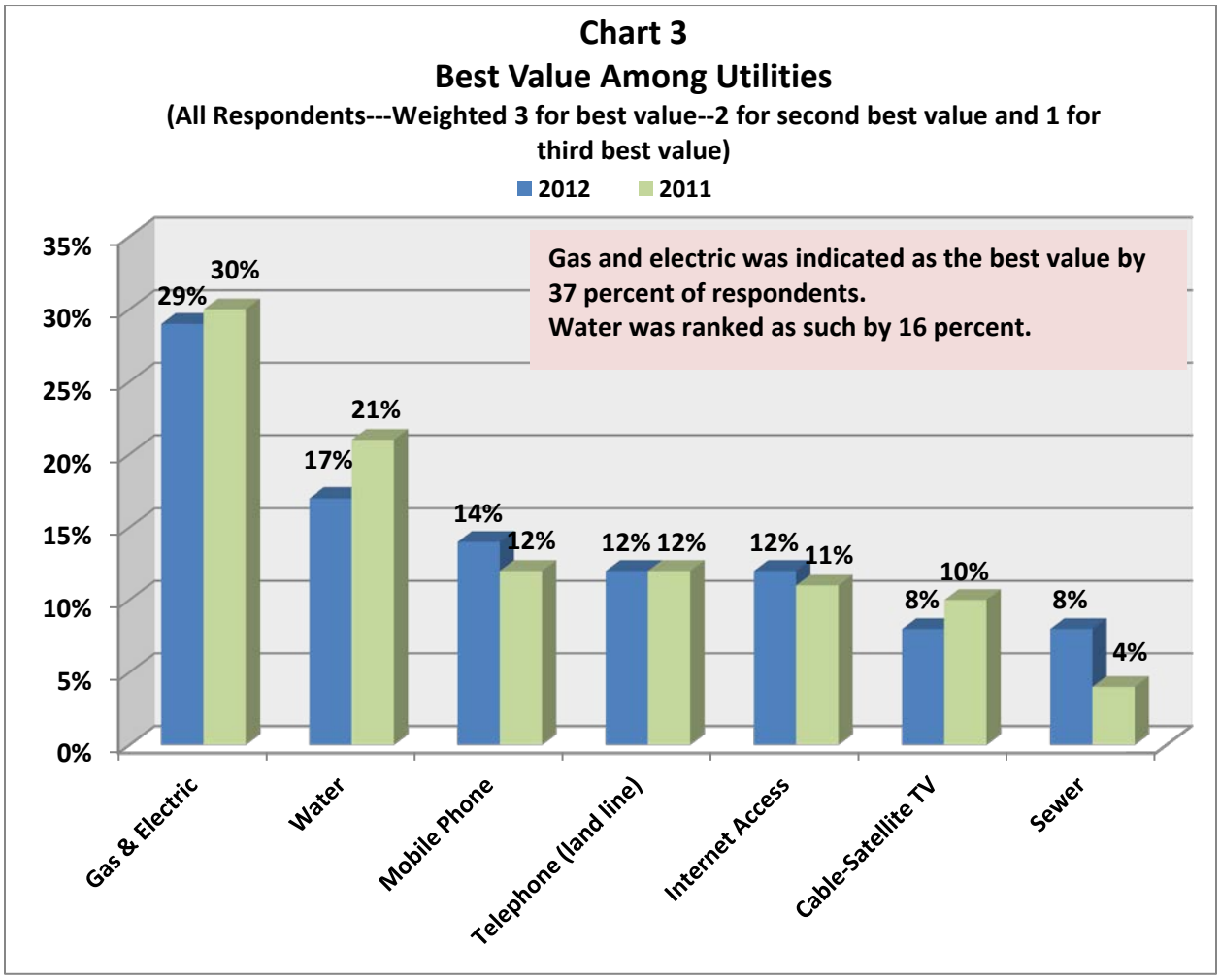
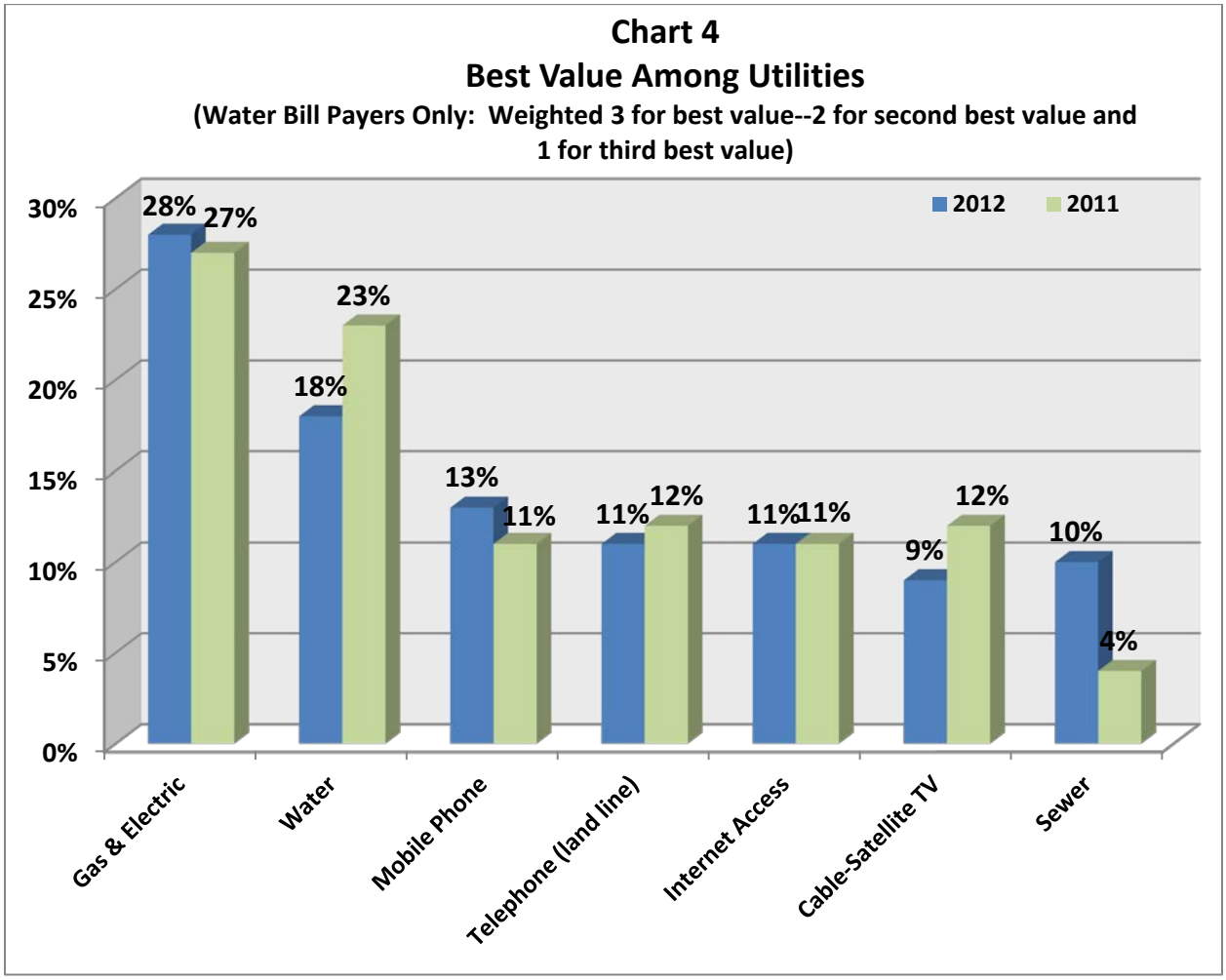


Chart 4 shows how certain respondents view the relative value of utilities by including only those who pay their own water bill. This exclusion attempts to control for those who do not pay their own water bills (thereby causing their assessment of value to be less relevant than those who do pay their own bills). As a result of this screen, the relative value of gas and electric decreases by 1 percent (from 29 percent to 28 percent) and the relative value of water increases by 1 percent (from 17 percent to 18 percent). It should be noted that trash collection is not included in the analysis because residents of the City of San Diego do not pay directly for trash collection.

- Those who pay their own water bill (18 percent) tend to choose water as the best value among various utilities more so than do those whose water bills are paid by their landlord or homeowners' association, for example (12 percent).



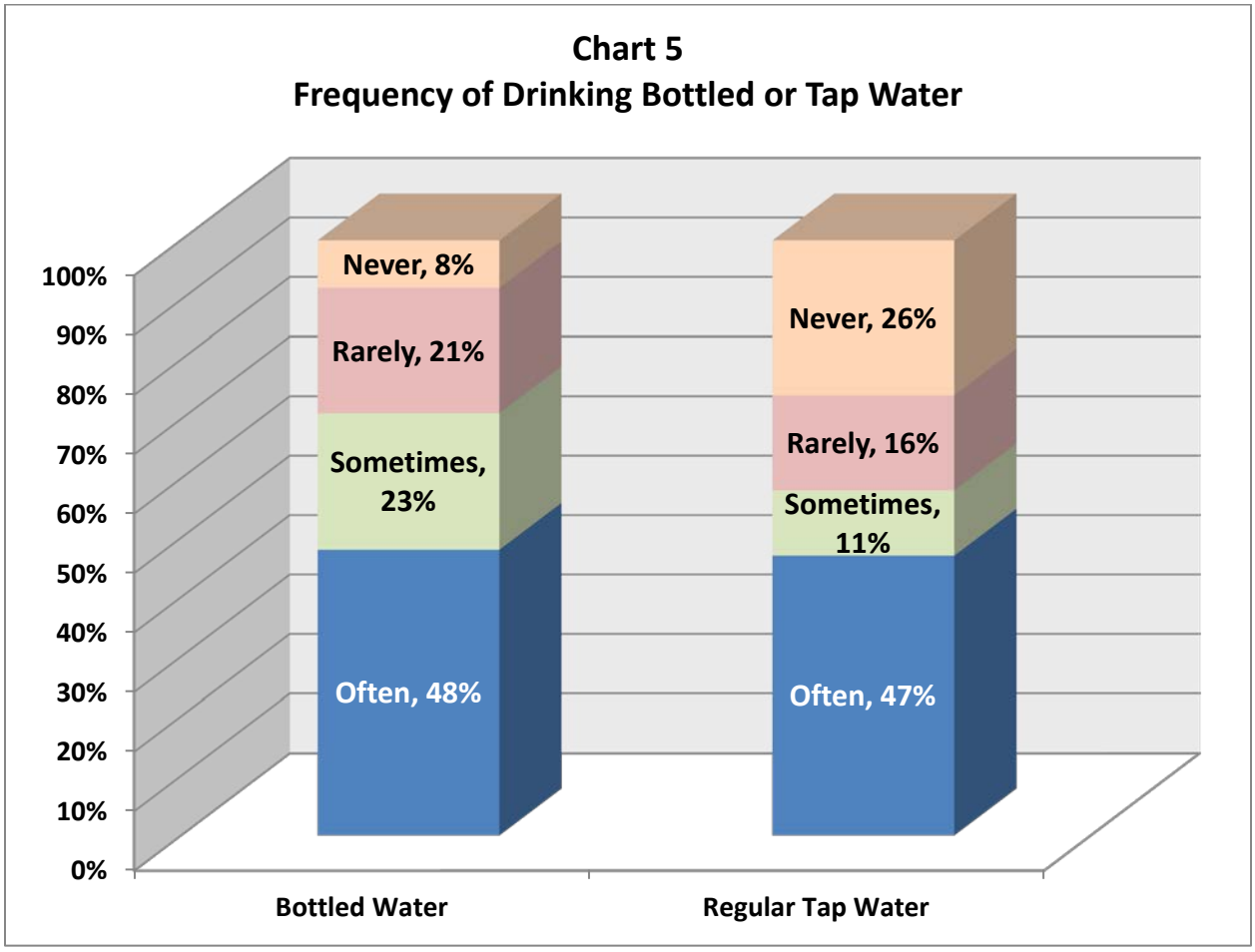
Water Reliability and Plans to Diversify Water Sources

SUMMARY: Among City of San Diego residents, more than three-fourths find that the current supply of water is either very reliable or somewhat reliable and can be consistently relied upon to meet the region's needs. This positive attitude toward water supply reliability is highly consistent with the results of the 2011 survey. Both the 2011 and 2012 survey years represent a clear increase in the perception of water supply reliability from the results of the 2004 survey. However, respondents are expressing a decreasing level of confidence in how they perceive the trend in the water supply.

Nearly three-fifths of respondents have trust in the ability of local water agencies to provide clean, safe, water for their customers. Almost one-third of respondents have either a great deal of trust or a good amount of trust in the ability of local water agencies to obtain water at reasonable prices.

Respondents identified the following efforts as particularly noteworthy on the part of the Water Authority in ensuring a safe and reliable water supply: water transfers and water importation from the Colorado River and the Imperial Valley, improved infrastructure, and seawater/ocean water desalination. One third of respondents indicate that the most important part of the Water Authority's Diversification Plan is seawater desalination followed by recycled water and the development of local reservoirs. Three-fifths of residents are in support of the San Diego County Water Authority's Diversification Plan. This represents a decline in support of the Diversification Plan from the results of the 2011 survey.

Water Reliability: Respondents tend to drink bottled water more frequently than they do tap water. More than seven in ten respondents (71 percent) either drink bottled water often or sometimes. By contrast, less than three-fifths (58 percent) drink tap water often or sometimes (**Chart 5**).



The following groups are more likely to drink bottled water often than are complementary groups:

- Residents with less education (less than a bachelor's degree – 57 percent versus bachelor's degree or more education – 42 percent).
- Blacks/African-Americans (68 percent) and Hispanics/Latinos (60 percent) versus Whites (40 percent).
- Larger households (3 or more persons – 52 percent versus households of 1-2 persons – 43 percent).

The following groups are more likely to drink tap water often than are complementary groups:

- Males (54 percent) versus females (39 percent).
- Homeowners (53 percent) versus renters (37 percent).
- In terms of ethnicity, Whites (56 percent) versus Hispanics/Latinos (38 percent), Blacks/African/Americans (32 percent), and Asians (26 percent).

Chart 6 demonstrates that there is confidence in the water supply to meet the region's needs while **Chart 7** shows that a relatively small percentage of the population feels that this reliability is improving. **Chart 6** shows that among residents of the City of San Diego, nearly four fifths (79 percent) find that the current supply of water is either very reliable (37 percent) or somewhat reliable (42 percent) and can be consistently depended upon to meet the region's needs. Under one-fifth (17 percent) find the water supply to be very or somewhat unreliable. This positive attitude toward water supply reliability is highly consistent with the results of the 2011 survey. In both the current survey and in the 2011 survey, confidence in the reliability of the water supply is higher than reported in the 2004 survey where 66 percent perceived the water supply to be either very or somewhat reliable.

- Younger and middle-aged residents (18-54 years of age) think that the water supply is very reliable (45 percent) more so than do older residents (55 years of age and older—30 percent).

Chart 7 demonstrates that respondents are expressing a decreasing level of confidence in the perceived reliability of the water supply – whether the supply is improving, worsening, or staying the same. Just over one-tenth (13 percent) of City residents feel that the trend in water supply reliability is improving – a decrease of 11 percent from the 24 percent level recorded in 2011. There is also a small increase among those who feel that the trend in the reliability of the water supply is worsening (22 percent in 2011 to 27 percent in 2012).

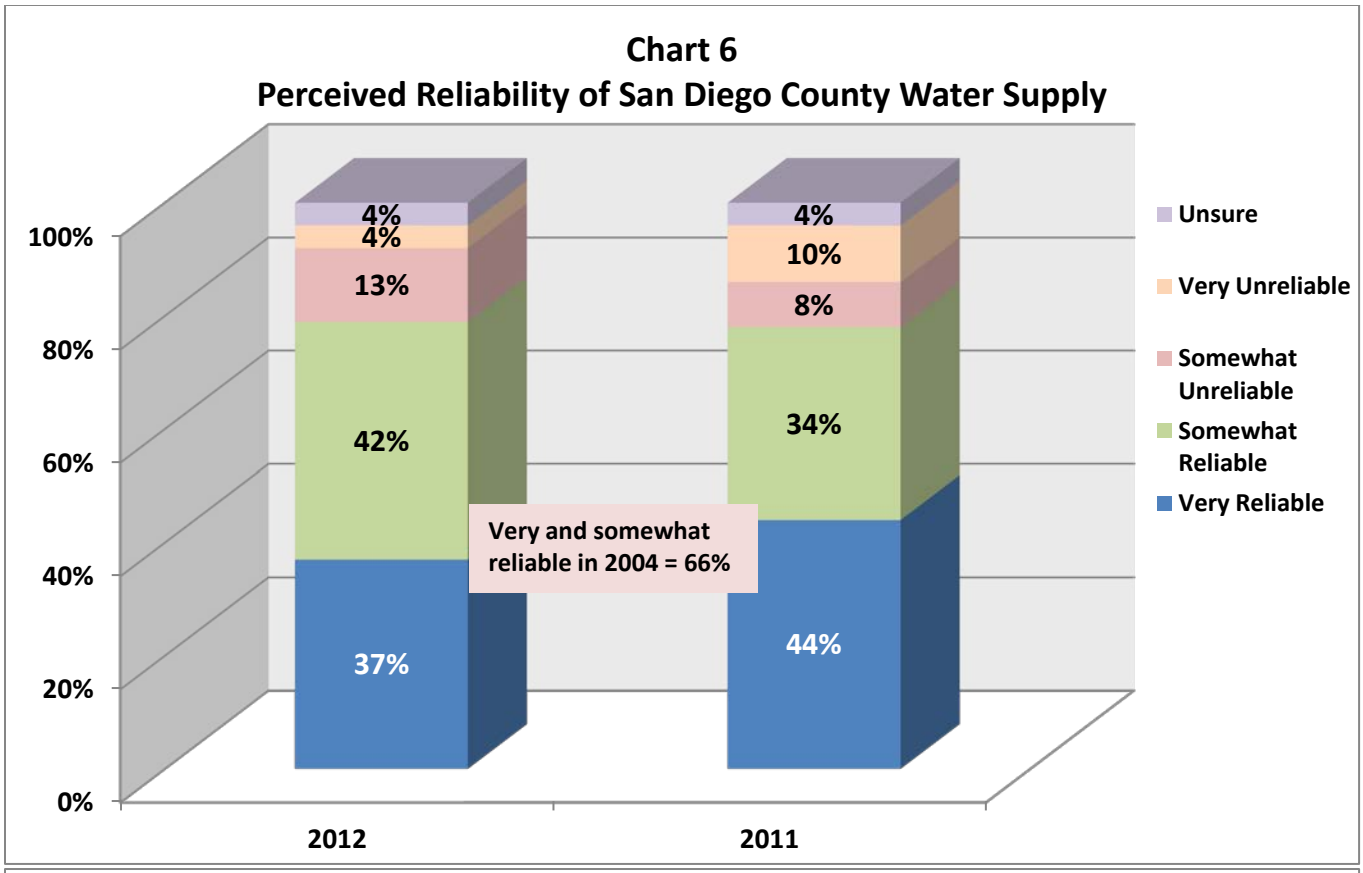


Chart 6
Perceived Reliability of San Diego County Water Supply
100%
80%
60%
40%
20%
0%
4%
4%
13%
42%
37%
4%
10%
8%
34%
44%
Very and somewhat reliable in 2004 = 66%
2012
2011
Unsure
Very Unreliable
Somewhat Unreliable
Somewhat Reliable
Very Reliable

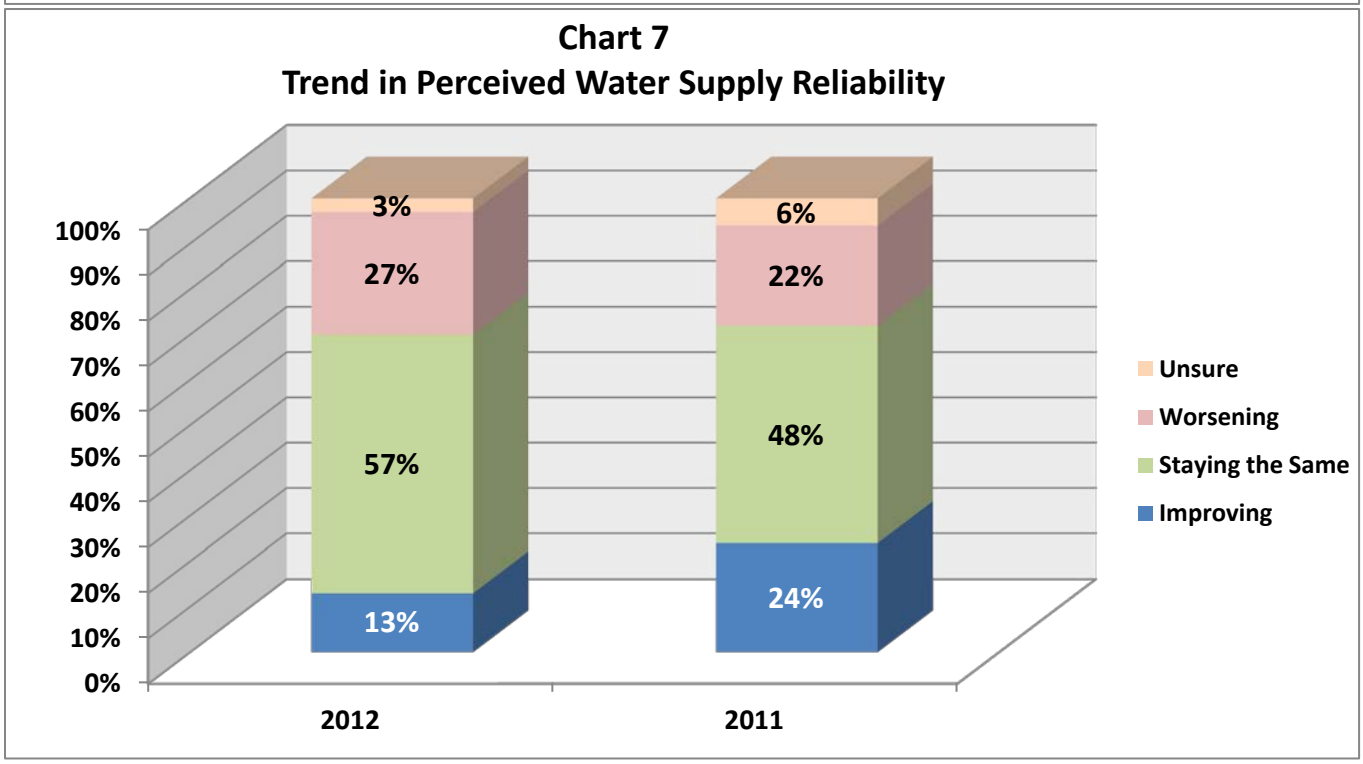


Chart 7
Trend in Perceived Water Supply Reliability
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
3%
27%
57%
13%
6%
22%
48%
24%
2012
2011
Unsure
Worsening
Staying the Same
Improving

The following groups of respondents are more likely to think that the reliability of the County's water supply is worsening than do their complementary groups:

- Those who pay their own water bill (34 percent) versus those who do not (15 percent).
- Homeowners (33 percent) versus renters (20 percent).
- Long-term residents of more than 20 years (34 percent) see a worsening supply more so than do those who have resided in the County for 20 years or less (19 percent).

Chart 8 shows that nearly three-fifths of City respondents (59 percent) have a substantial amount of trust in the ability of local water agencies to provide clean, safe, water for its customers (20 percent a great deal of trust and 39 percent a good amount of trust). Only 12 percent expressed a lack of trust – not much trust (7 percent) and no trust at all (5 percent).

Regarding trusting local water agencies to deliver clean, safe water to their customers, the following groups indicate a good or great deal of trust in contrast to their counterparts:

- High income residents ($150,000 and more) –83 percent versus those earning less than $150,000—58 percent.
- Those who characterize their consumption of regular tap water as "often" (69 percent) indicate a good or great deal of trust in contrast to those who never use it (40 percent).

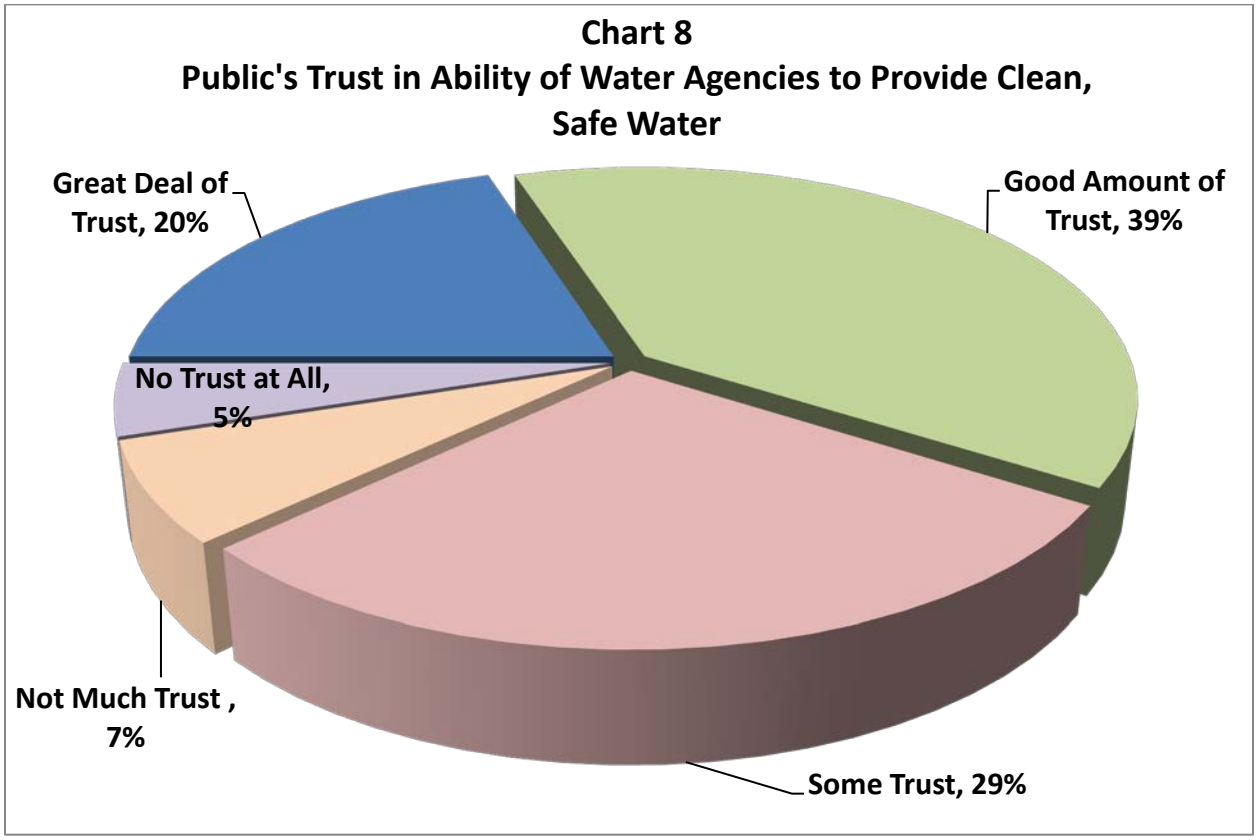
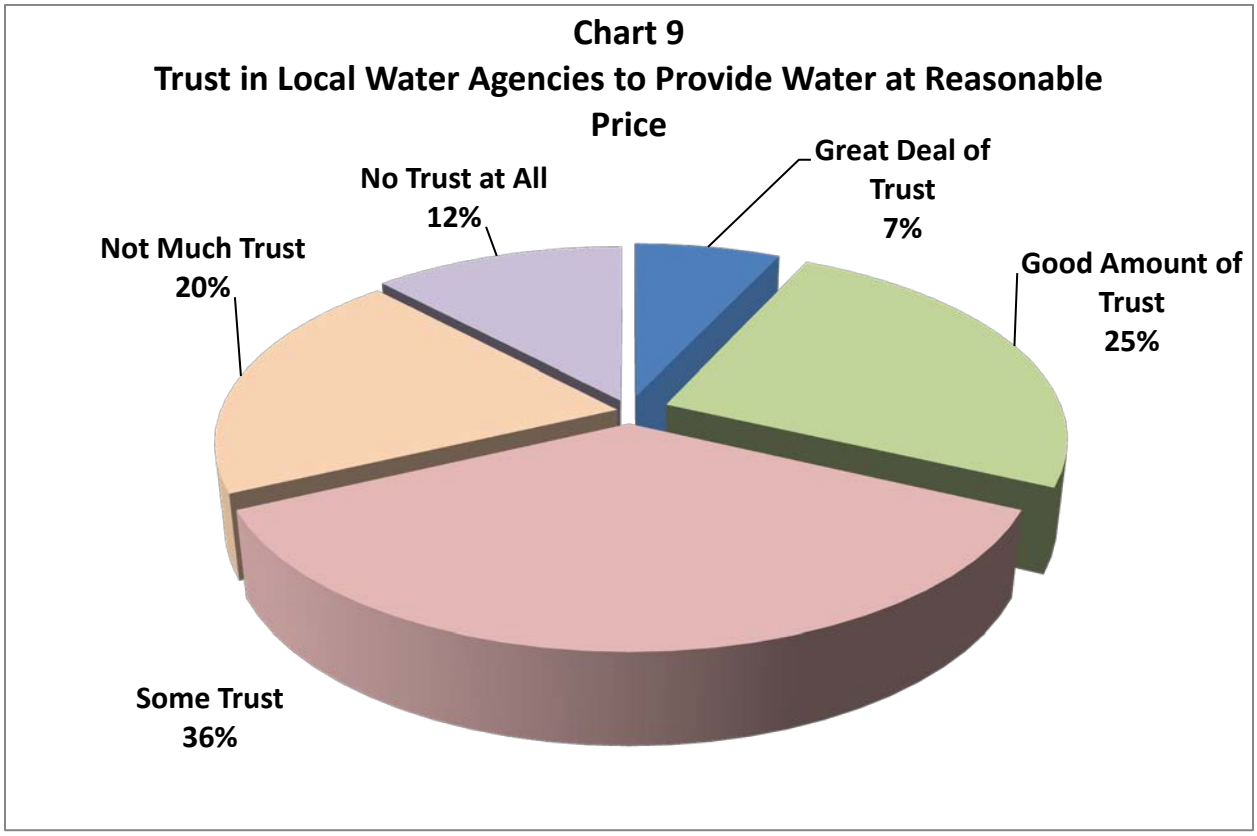


Chart 9 indicates that 32 percent of respondents have either a great deal of trust (7 percent) or a good amount of trust (25 percent) in the ability of local water agencies to obtain water at reasonable prices. About one-third (32 percent) lack trust in the ability of local water agencies to provide water at reasonable prices – not much trust (20 percent) and no trust at all (12 percent).

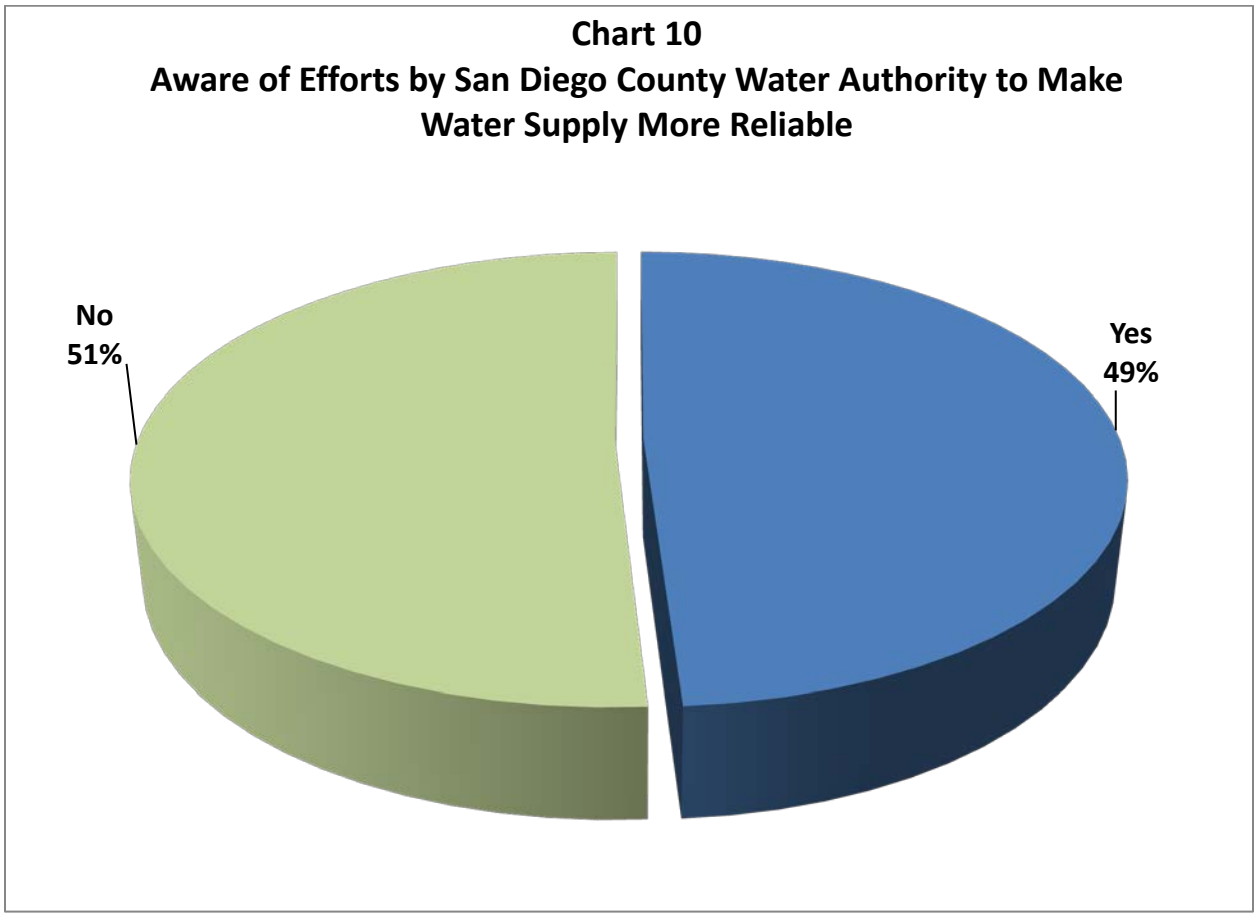
Trust in local water agencies to provide clean, safe water at reasonable prices also shows interesting differences among these groups of respondents:

- Asians (53 percent) show a great or good deal more trust that water prices will be reasonable than do Hispanics/Latinos (22 percent), Whites (31 percent) or Blacks/African-Americans (35 percent).
- Those who do not pay their own bills have a good or great deal of trust that water prices will be reasonable (42 percent) more so than do those who are responsible for making these payments (27 percent).
- Renters indicate a good or great deal of trust (35 percent) more so than do homeowners (29 percent).
- Younger residents indicate a good or great deal of trust (age 18-44 -- 44 percent) more so than do those residents 45 years of age or older (24 percent).
    - Using means, the mean age of residents with a great or good deal of trust in the reasonableness of prices is 46.6 years of age in contrast to those with not much or no trust at all (mean = 56.5 years of age)

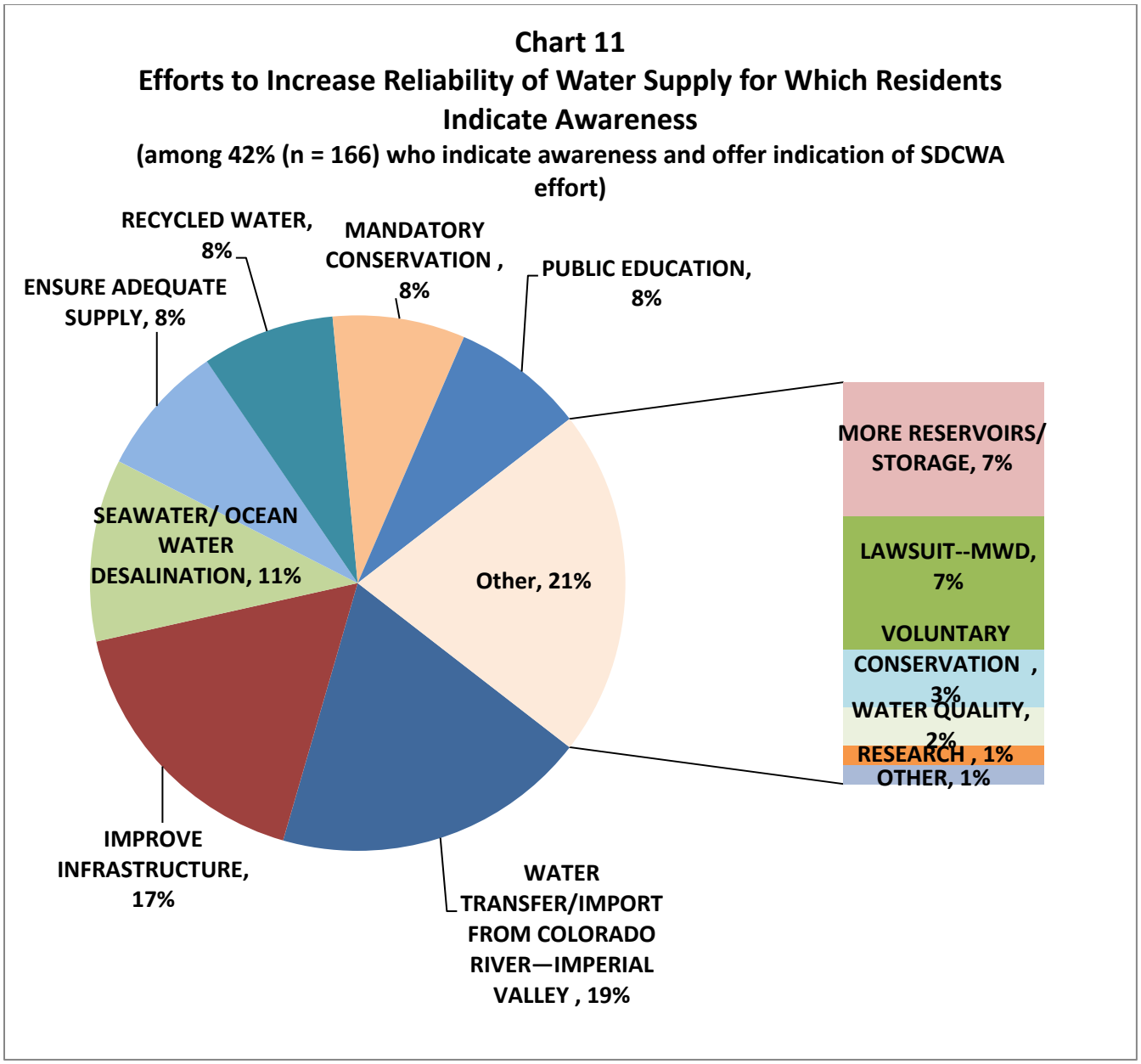


Nearly one-half of the respondents (49 percent) are aware of efforts by the San Diego County Water Authority to make the water supply more reliable (**Chart 10**).

- Frequent tap water consumers (often use = 58 percent) tend to be aware of efforts by the San Diego County Water Authority to make the water supply more reliable more so than those who sometimes, rarely or never drink tap water (40 percent).



Respondents, who indicated their awareness of such efforts, were asked to identify one of these efforts. Nearly one-fifth (19 percent) mentioned water transfer and water importation from the Colorado River and the Imperial Valley, another 17 percent mentioned improvement of infrastructure, and 11 percent indicated seawater/ocean water desalination. Other efforts mentioned by the respondents are public education, ensuring an adequate supply of water, recycled water, and mandatory conservation (each 8 percent) (**Chart 11**).



When asked which one thing the respondents were aware of, differences among groups again were in evidence.

- Men indicated desalination (14 percent) more so than did women (6 percent).
- Men also named water transfers from the Colorado River (21 percent), infrastructure (19 percent) reservoirs (9 percent), and the MWD lawsuit (8 percent) more so than did women (14 percent, 12 percent, 1 percent and 4 percent, respectively)
- Women, on the other hand, listed public education (15 percent), mandatory conservation (14 percent) and voluntary conservation (10 percent) more so than did men (5 percent, 6 percent and 1 percent, respectively).

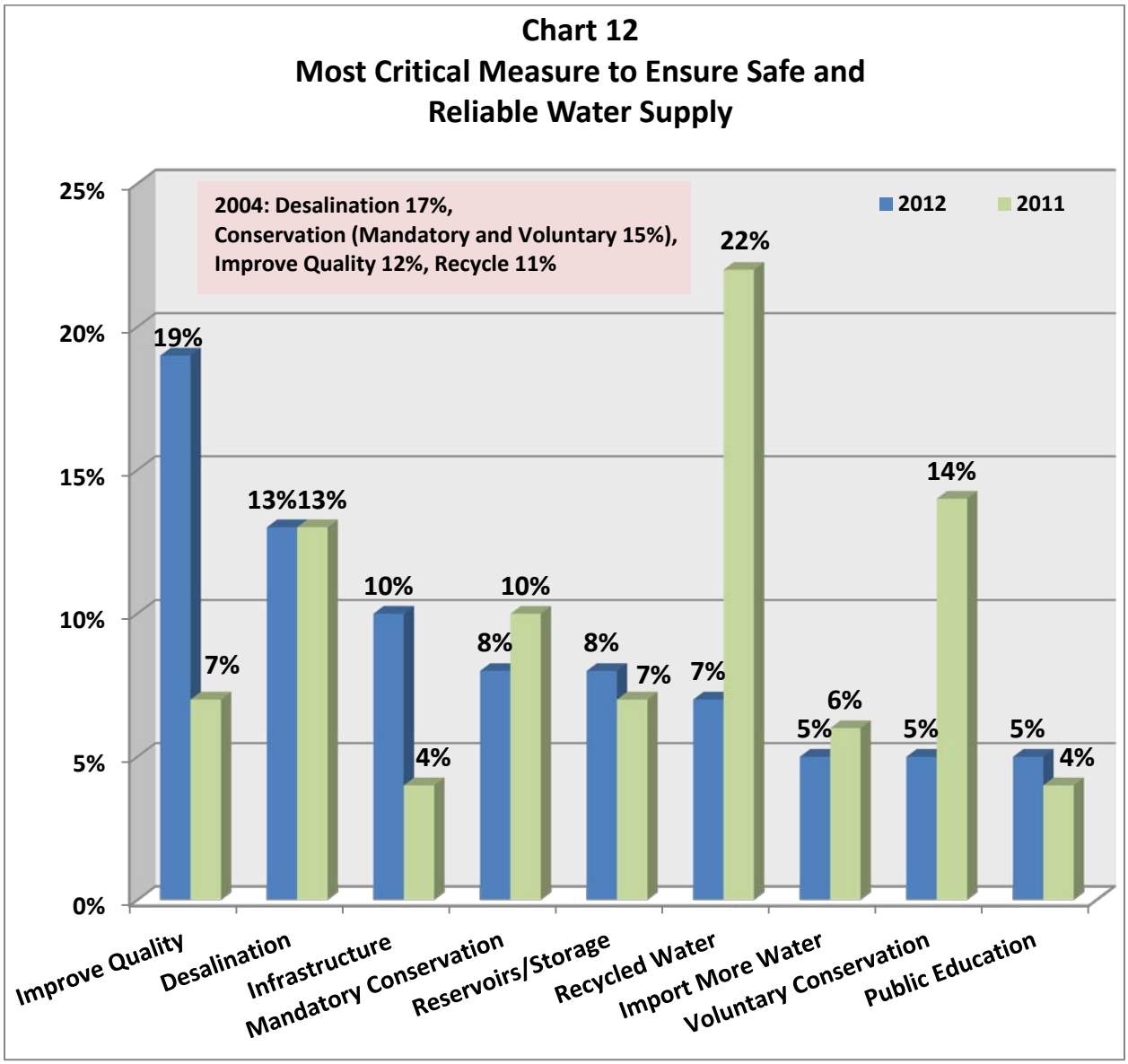
- Homeowners indicated water transfers (22 percent), infrastructure (19 percent), the MWD lawsuit (10 percent) and reservoirs (8 percent) more so than did renters (11 percent, 13 percent, 0 percent and 4 percent, respectively).
- Renters listed mandatory conservation (15 percent), recycling (13 percent), and voluntary conservation (7 percent) more than did homeowners (5 percent, 6 percent, and 3 percent, respectively).
- There were a substantial number of differences by ethnicity as follows:
    - Whites were highest among ethnic groups in mentioning water transfers (22 percent) and the MWD lawsuit (10 percent).
    - Blacks/African-Americans were highest for mandatory conservation (25 percent), public education (25 percent) and recycling (17 percent).
    - Hispanics/Latinos were highest for infrastructure (25 percent).
    - Asians were highest for desalination (29 percent) and reservoirs (14 percent).
- Larger households of 5 or more persons mentioned water transfers (39 percent), voluntary conservation (22 percent), mandatory conservation (17 percent), and public education (17 percent) more so than did households with 4 or fewer residents.
- Smaller households of 3 or less mentioned desalination (16 percent), recycled water (12 percent) and the MWD lawsuit (8 percent).

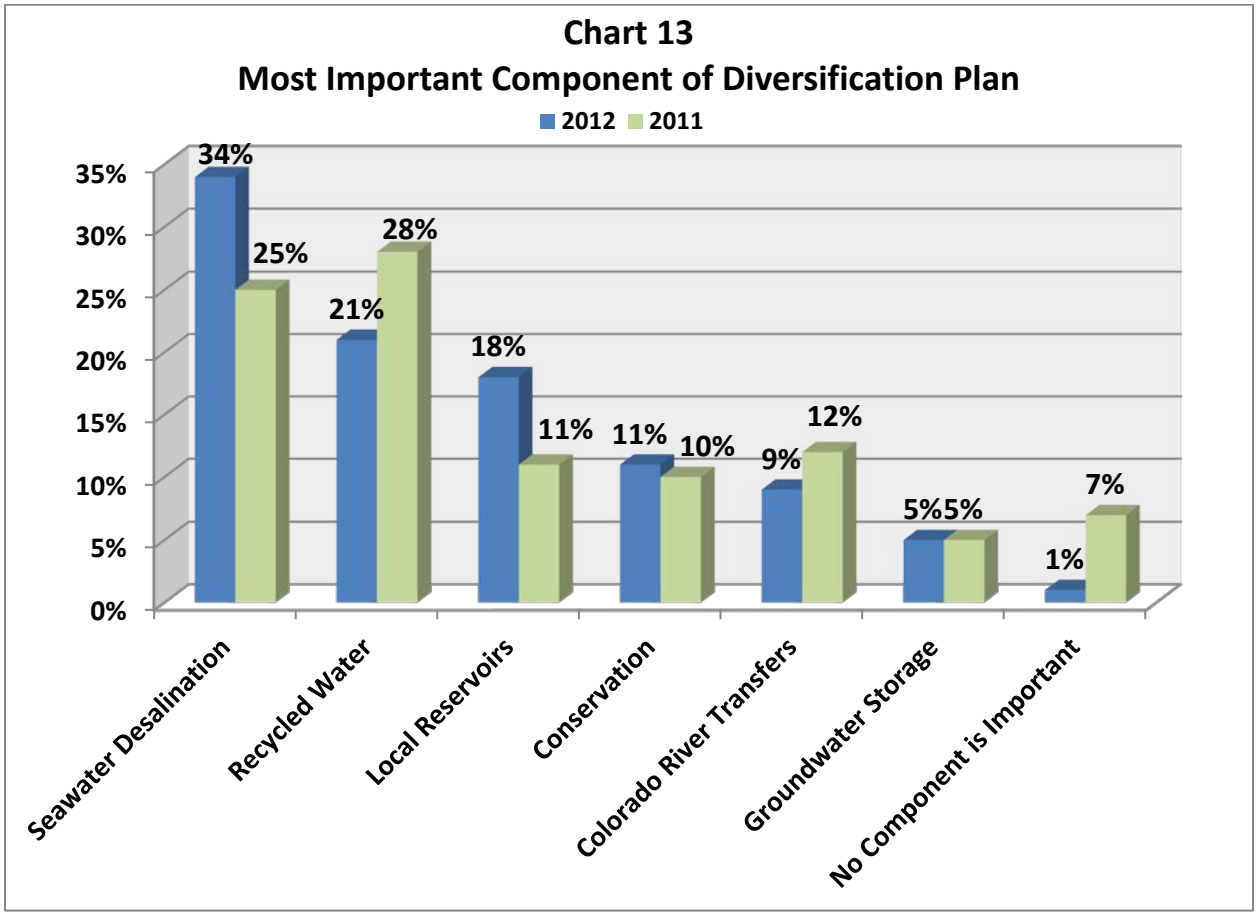
When respondents were asked what they think is the most critical thing that can be done to ensure a safe and reliable water supply for San Diego County residents and businesses, 19 percent indicated that the Water Authority could improve the quality of the water. This response was followed by seawater desalination (13 percent) and infrastructure improvement (10 percent). Since the 2011 survey, water quality and infrastructure issues have increased in importance as critical measures to ensure a safe and reliable water supply. Conservation (both mandatory and voluntary combined) has declined in importance to 13 percent – a decline of 11 percent since the 2011survey. The 2012 results represent a return to the 2004 level when only 15 percent of City respondents regarded conservation as important to safeguard the water supply. Recycled water has lost ground as a critical issue during the current survey period, falling to 7 percent from the 2011 high of 22 percent. Desalinated water remains steady as a critical issue in all three survey periods – 2012, 2011, and 2004 (**Chart 12**).

- Those who never drink regular tap water think that improving water quality is the most critical thing that the Water Authority can do (33 percent for those who never drink tap water versus 14 percent for those who drink tap water rarely, sometimes or often).

Diversification Plan: Over one third of respondents indicate that the most important part of the Water Authority's Diversification Plan is seawater desalination (34 percent) followed by recycled water (21 percent), and the development of local reservoirs (18 percent). Seawater desalination remains the most important component of the Diversification Plan in the view of the respondents. In fact, those who

support desalination increased by 9 percent since 2011 when 25 percent felt that desalination was the most important component of the Diversification Plan. Respondents indicate that recycled water has a declining level of importance as a component of the Diversification plan (28 percent in 2011 versus 21 percent in 2012). Local reservoirs have gained substantial ground increasing from 11 percent in 2011 – a 7 percent gain over the current survey results (**Chart 13).**



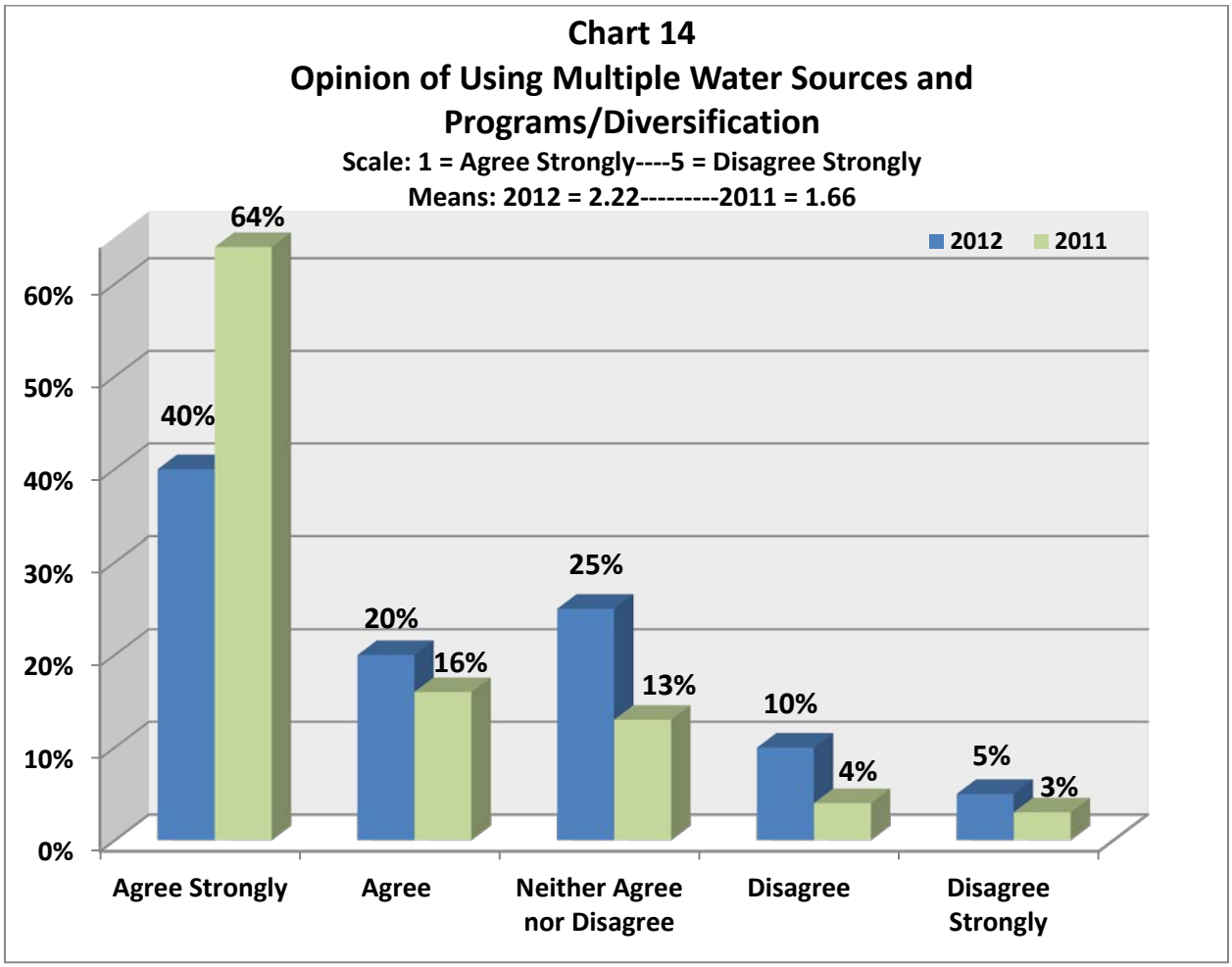


Differences exist among groups pertaining to the most important components of the Water Authority's Diversification Plan.

- Households of 4 or more persons are stronger in their indicated importance of expanding local reservoirs (25 percent) and water transfers (11 percent) versus households of 3 or less (15 percent and 8 percent, respectively).
- Smaller households of 3 or less consider recycled water (21 percent) and conservation (12 percent) to be more important than do larger households (16 percent and 9 percent)

Chart 14 shows that three-fifths (60 percent) of residents are in support of the San Diego County Water Authority's Diversification Plan with ratings of strongly agree (40 percent) and agree (20 percent). This represents substantial decline in support of the Diversification Plan from the results of the 2011 survey where 80 percent either strongly agreed or agreed that the Diversification Plan would improve water

supply reliability. The mean rating of 2.22 (based on a scale of 1 to 5, where 1 = strongly agree and 5 = strongly disagree) confirms this declining level of support from the 2011 finding where the mean rating was 1.66.



Significant differences among groups regarding agreement or disagreement with the Diversification Plan are as follows:

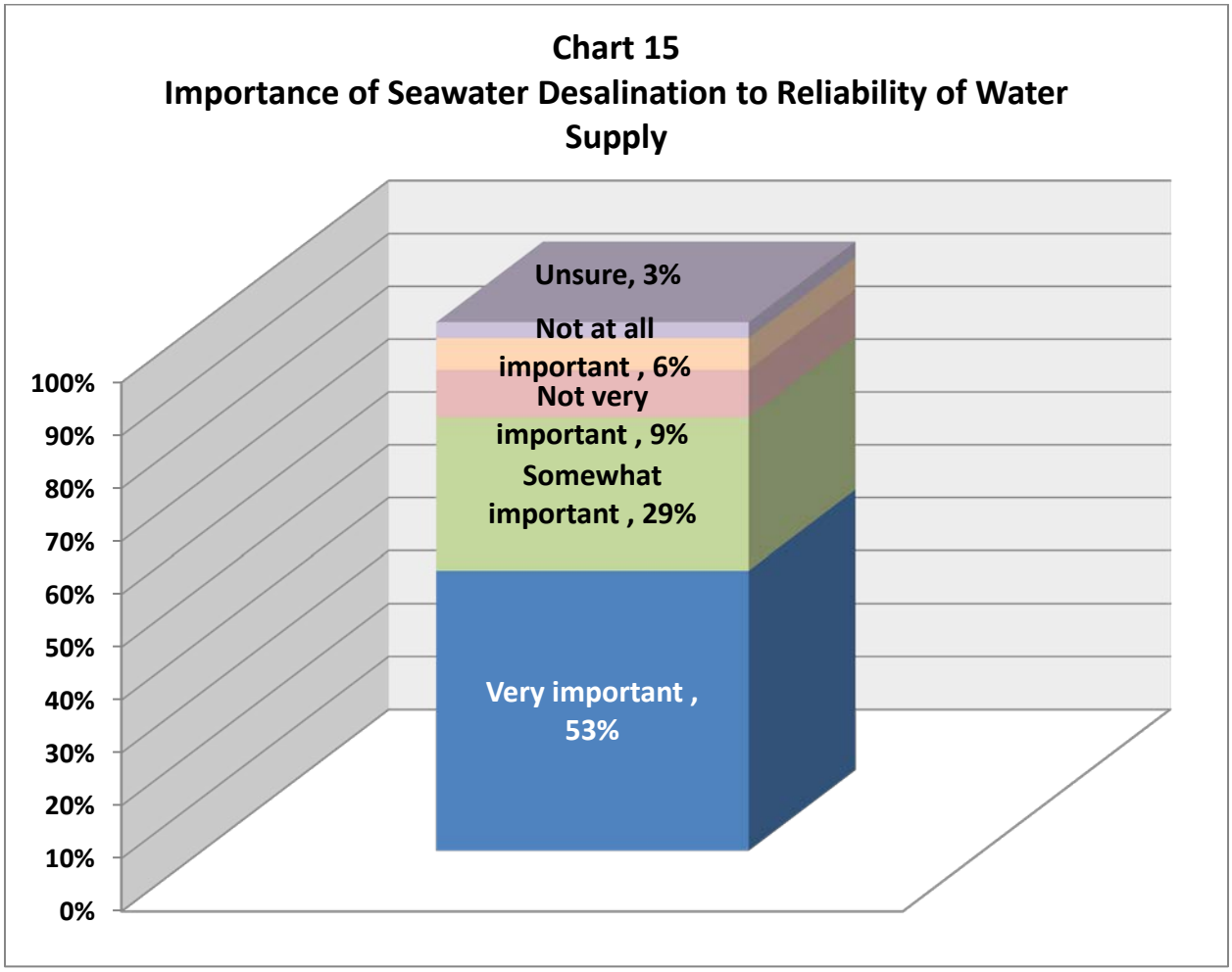
- One the 1-5 scale, there is greater agreement among more educated residents (mean of 2.06 for those with one year or more of graduate school) versus among those with a high school diploma or less (2.72).
- Income is lower by approximately $30,000 among those who disagree strongly with the Diversification Plan compared to all other agreement or disagreement categories.

Seawater Desalination

<u>SUMMARY</u>: Over four-fifths of respondents feel that seawater desalination is important to the reliability of the region's water supply. Respondents are most favorably influenced toward desalination by the following message: "Desalinated water is a drought-proof local supply of water." The least influential message is as follows: "Desalinated water is competitive with the cost of developing other new sources of water supplies."

Nearly two-thirds expressed a willingness to pay something more per month to add seawater desalination to the water supply—almost three-fifths indicating $5 or more. In 2011, less than half indicated a willingness to pay $5 for a more general benefit of increased water supply reliability. Among those who indicated a precise amount, the mean additional amount they are willing to pay is $13 per month and the median amount is $10.

Chart 15 demonstrates that over four-fifths (82 percent) of respondents feel that seawater desalination is important to the reliability of the Water Supply (53 percent -- very important and 29 percent -- somewhat important).



- Males think that desalination is more important than do females--59 percent of men think that desalination is very important in contrast to 44 percent of women.

Five statements were read to the respondents regarding desalination. After each statement, respondents were asked how influenced they were by these statements. The response was based on a scale of 1 to 5, with 1 being very favorably influenced toward desalination and 5 being not favorably influenced at all. The most influential statements were "Desalinated water is a drought-proof local supply of water" (mean of 1.95), "Desalinated water reduces the San Diego region's dependence on supplies from the Metropolitan Water District" (mean of 1.99), and "Desalination will reduce the region's demand for supplies of imported water from Northern California and the Colorado River" (mean of 2.05). The least influential statement is "Desalinated water is competitive with the cost of developing other new sources of water supplies" (mean of 2.55). In all statements except the least influential one, about two-thirds of respondents (range of 67 to 69 percent) indicated that they were either very influenced or somewhat influenced by the statement. In the least influential statement, only 46 percent were either very influenced or somewhat influenced (**Chart 16**).

In testing these messages about desalination, a number of differences among the groups became evident:

- Men are more favorably influenced by the messages about desalination being drought-proof (61 percent very favorably influenced versus 43 percent for women). Men are also more favorably influenced by the message about desalination reducing the region's dependence on imported water (53 percent very favorably influenced for men versus 42 percent for women) and by the message about desalination reducing dependence upon MWD (55 percent for men versus 43 percent for women).
- Spanish language survey respondents are very or somewhat favorably influenced by the message about the cost of desalination (80 percent) more so than are those who took the survey in English (50 percent).
- Interestingly, cost registers more strongly with those who do not pay for their own water usage (63 percent very or somewhat favorably influenced) versus those who do pay their own bill (46 percent).
- The message about desalination reducing the dependence on MWD carries more weight with those residents who use only their cell phones (74 percent very or somewhat favorably influenced) versus those who use land line telephones at least some of the time (64 percent).

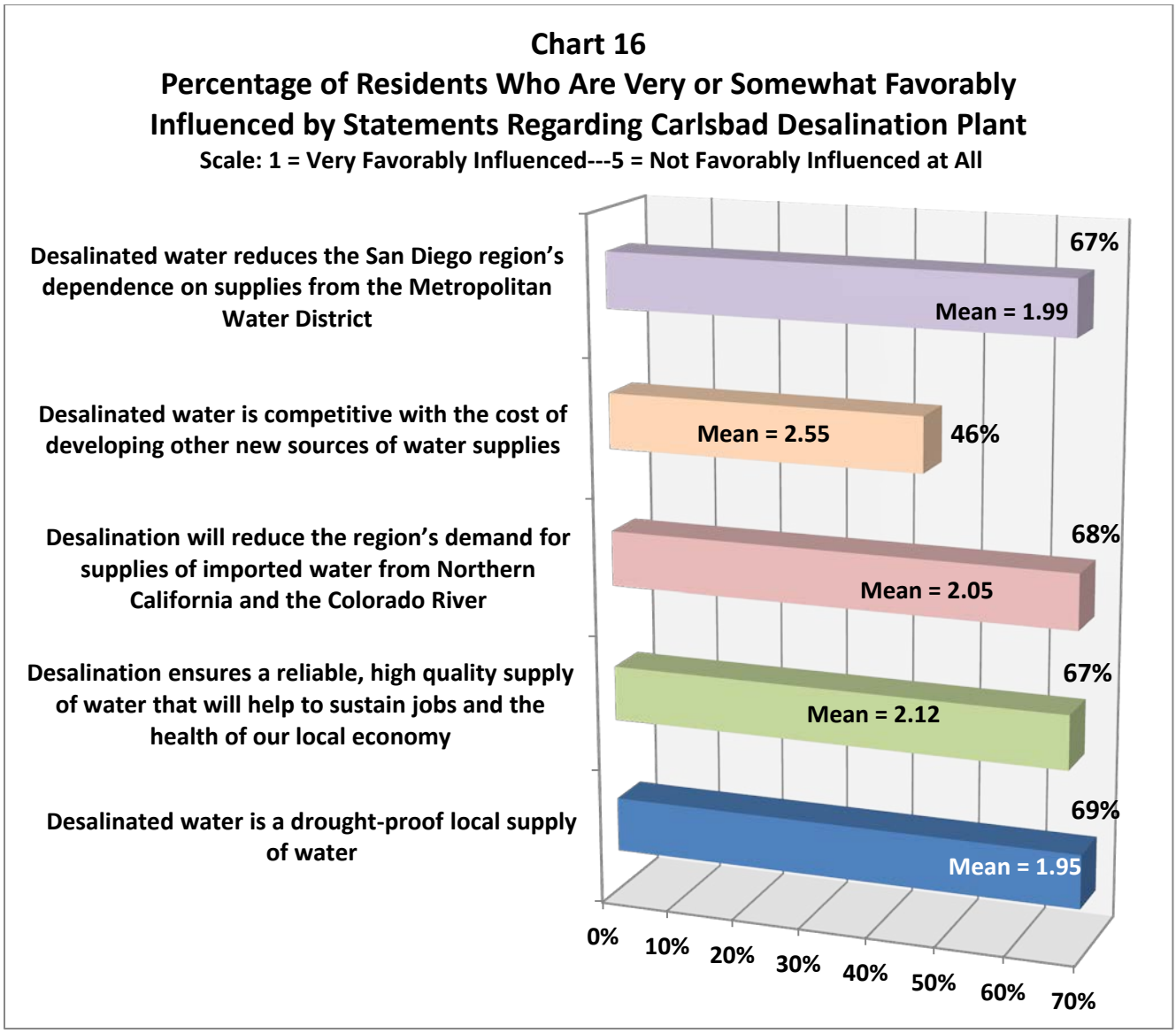
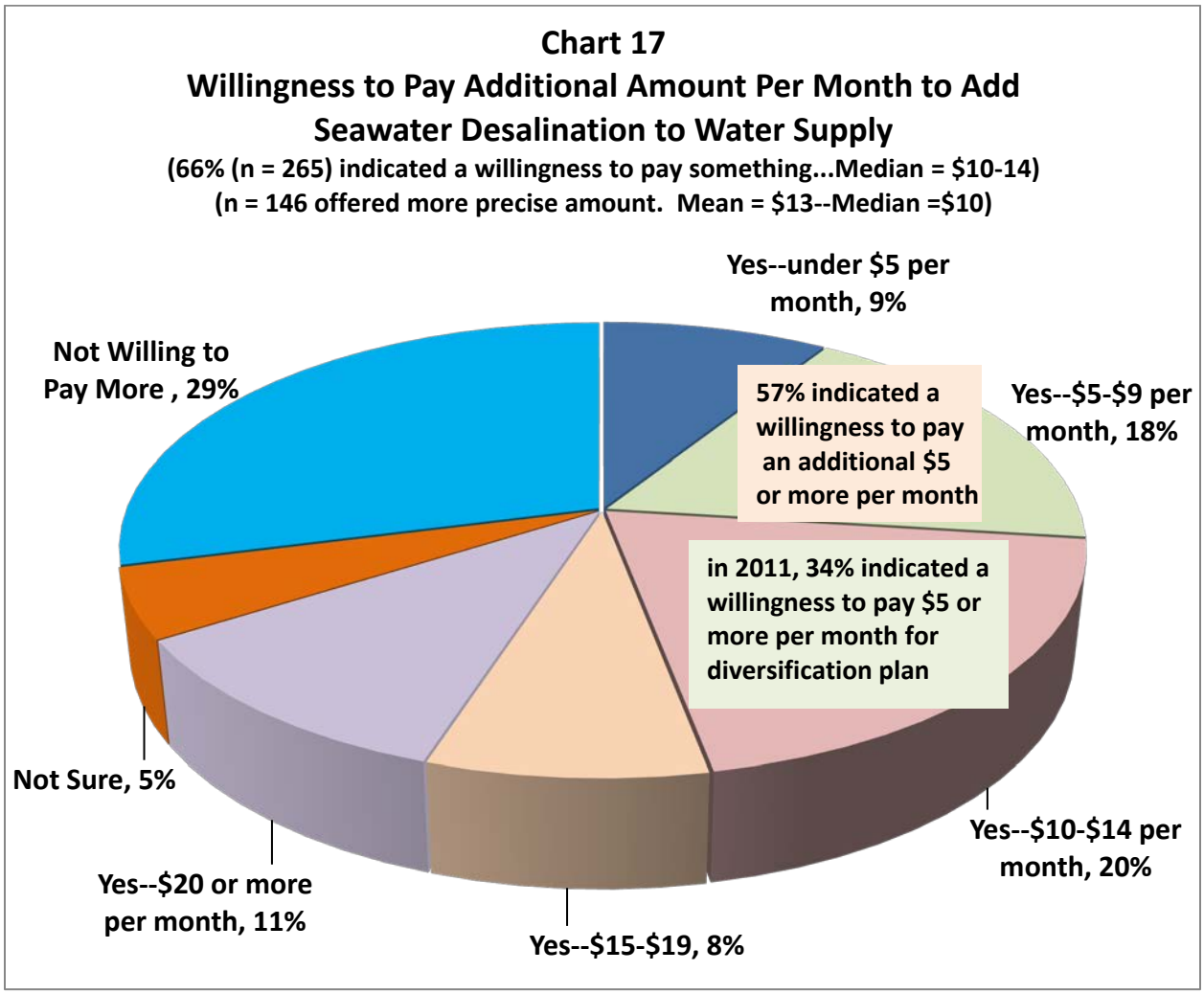


Chart 17 shows that nearly two-thirds (66 percent) expressed a willingness to pay something more per month to add seawater desalination to the water supply. Nearly three-fifths (57 percent) are willing to pay an additional $5 or more per month. Among those who indicated a precise amount, the mean additional amount they are willing to pay is $13 per month and the median amount is $10.

Significant differences among groups regarding willingness to pay an additional amount for desalination are as follows:

- Whites are willing to pay an additional mean amount of $15 per month and Hispanics/Latinos and Asians are both willing to pay $10.
- Single person households are willing to pay $9 per month and 3 or more person households are willing to pay $12, but 2-person households expressed a willingness to pay $17 per month.



Attitudes about Water Conservation

SUMMARY: Water conservation is a significant component in San Diego County's water supply plans. One-fourth of respondents indicated that their household water usage has decreased over the past year. This represents a small decline from those who indicated that they decreased their water usage in 2011 but is offset by a similar decline among those whose use has increased. Among those who indicated that their household water usage has declined, nearly one-half did so because they feel that reducing water usage is the "right thing to do." In 2011, a somewhat smaller (but still substantial) percentage was motivated to reduce water usage because it is the "right thing to do." Over one-fourth (27 percent) were motivated to reduce water usage because they are watching their budget and this represents a decline of 8 percent since 2011 when 35 percent were so motivated by budgetary concerns to reduce their water usage. The vast majority—almost 90 percent—indicated that their reduced water usage is permanent and this is consistent with the 2011 finding.

It is most encouraging that when water agencies no longer take an active role in restricting water use, respondents who have reduced their water usage during the past year indicate that they are not likely to increase their water use (approximately one-fifth will increase usage). On the other hand, a less cool and less wet year would lead to nearly three-fifths of those who have reduced their water use during the past year returning to higher usage. Under most conditions and circumstances, these views about higher water usage in the future parallel the views of the 2011 survey respondents.

Virtually all of the respondents (95 percent) think that it is their civic responsibility to use water as efficiently as possible. In the current survey period as well in 2011, respondents regard water conservation as a greater civic responsibility than serving on a jury. In the current survey as well as in 2011, water conservation is close to the same level as recycling used materials in terms of perceived civic responsibilities. Voting in public elections and not littering/not polluting are strongly regarded as higher civic obligations than water conservation.

Water Use: Past Year **Chart 18** shows that over one-fourth of respondents (26 percent) indicated that their household water usage has decreased over the past year. This represents a small decline of 2 percent among those who indicated that they decreased their water usage in 2011 (28 percent). However, there is also a decline of 4 percent since 2011 among those who indicate that their water usage increased (18 percent in 2011 to 14 percent in 2012). These differences are reconciled by those who indicated that their water usage has remained the same (59 percent in 2012 versus 48 percent in 2011).

Change in water usage during the past year is further informed by the following differences among groups of residents:

- Cell-only users indicate that 10 percent of them have increased their water usage during the past year in contrast to 15 percent of land line users.
- Women have increased water usage (19 percent) more so than have men (10 percent).

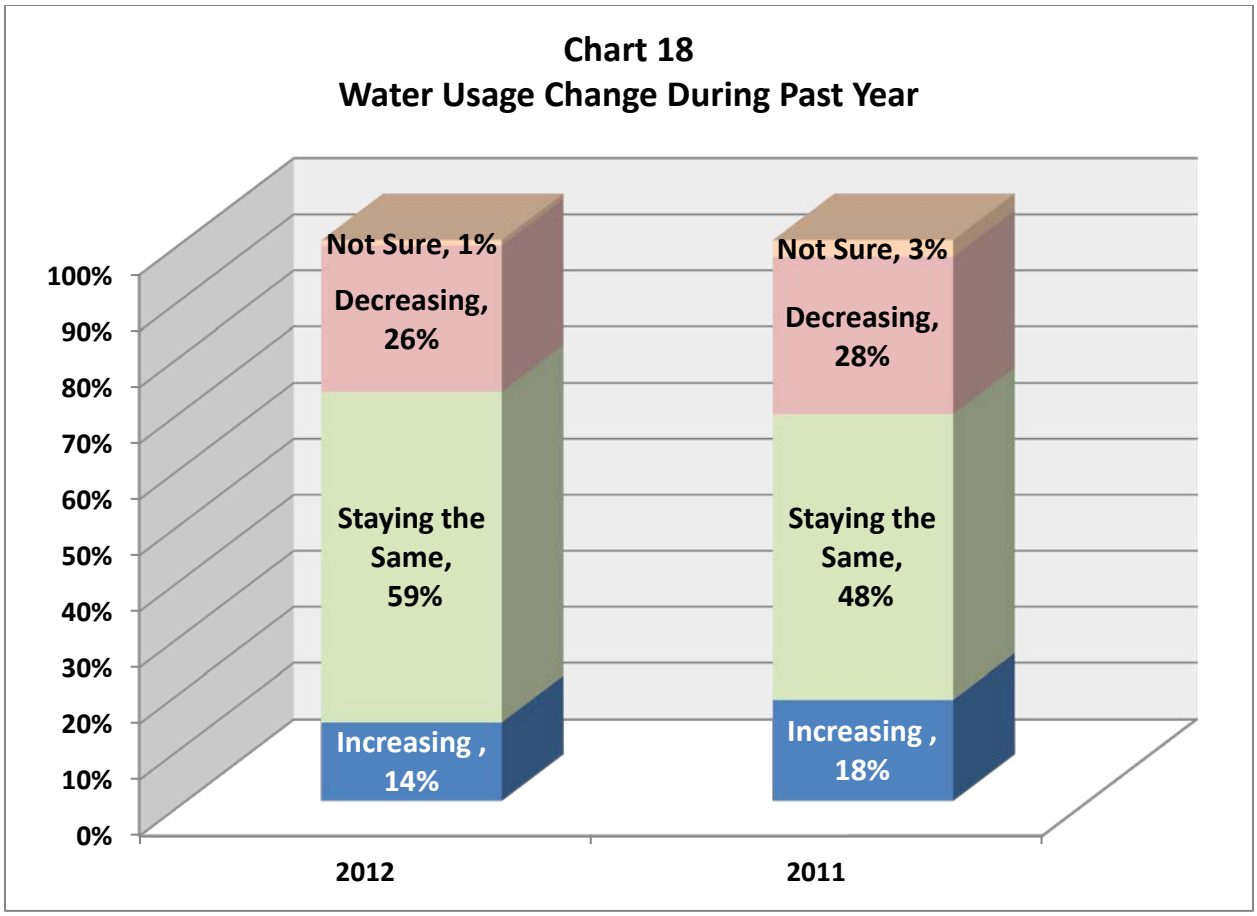


Chart 19 indicates that, among those who indicated that their household water usage has declined, nearly one-half (48 percent) – a dominant plurality-- feel that reducing water usage is the "right thing to do." In 2011, a somewhat smaller (but still substantial) percentage was motivated to reduce water usage because it is the "right thing to do" (31 percent). Over one-fourth (27 percent) were motivated to reduce water usage because they are watching their budget and this represents a decline of 8 percent since 2011 when 35 percent were so motivated by budgetary concerns to reduce their water usage. Among those who indicated that their household water usage has declined, a considerable majority (89 percent) thinks that their reduced use of water is permanent (**Chart 20**). This finding is consistent with the result of the 2011 survey – 82 percent believed their reduction in water use to be permanent.

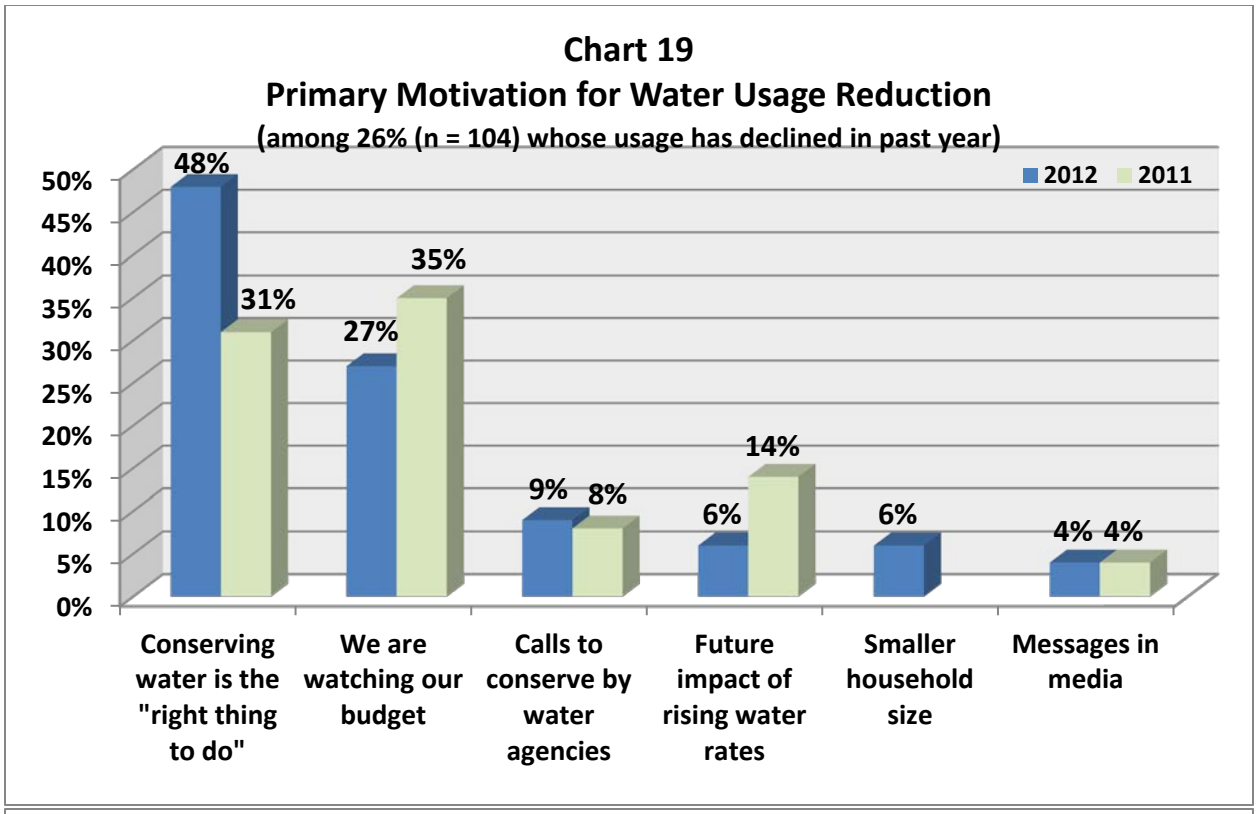


Chart 19
Primary Motivation for Water Usage Reduction
(among 26% (n = 104) whose usage has declined in past year)
2012
2011
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
48%
31%
27%
35%
9%
8%
6%
14%
6%
4%
4%
Conserving water is the "right thing to do"
We are watching our budget
Calls to conserve by water agencies
Future impact of rising water rates
Smaller household size
Messages in media

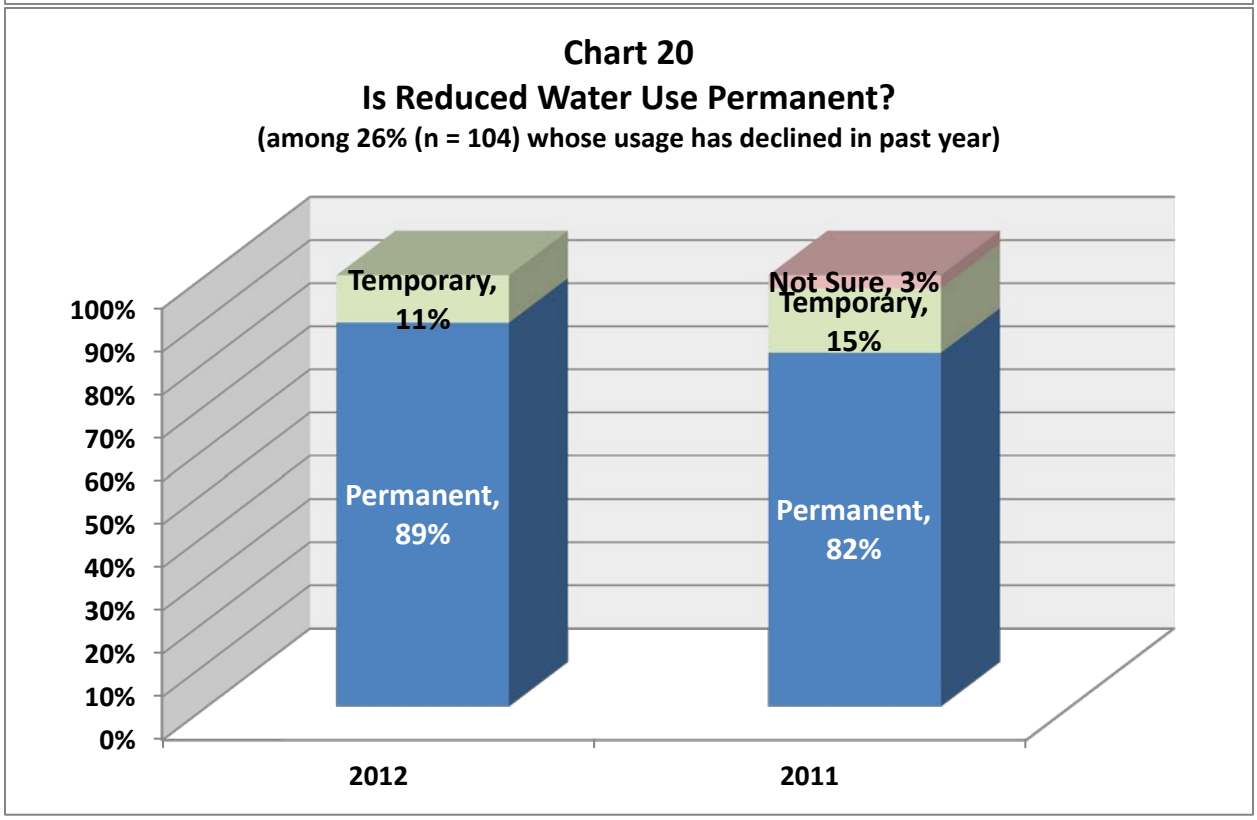
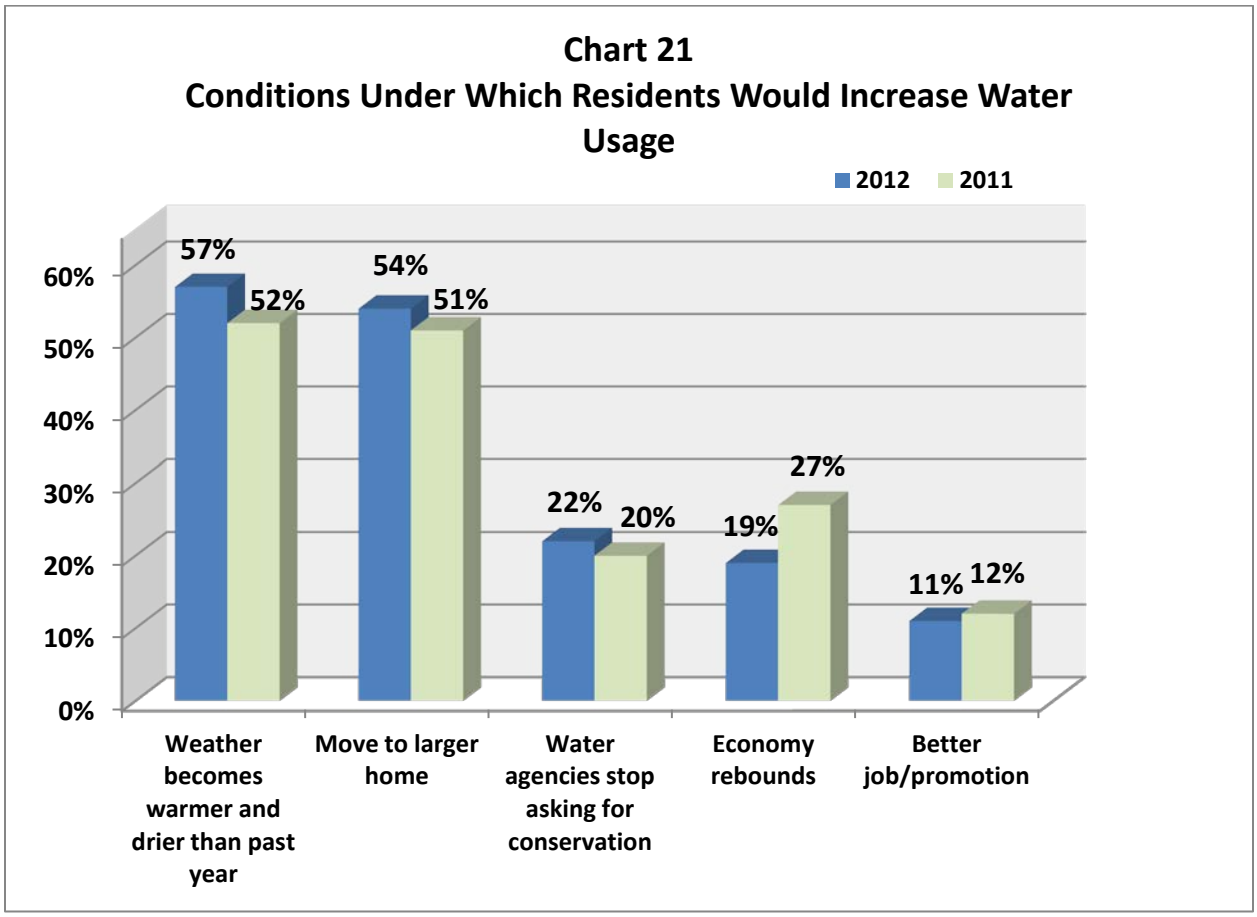


Chart 20
Is Reduced Water Use Permanent?
(among 26% (n = 104) whose usage has declined in past year)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Temporary, 11%
Permanent, 89%
Not Sure, 3%
Temporary, 15%
Permanent, 82%
2012
2011

Permanent reductions in water use are indicated more by the following groups:

- College degree or more (95 percent) versus less than a college degree (78 percent).
- Those who often or sometimes drink tap water (95 percent) versus rarely or never drink tap water (78 percent).

Water Use in the Future: Respondents were asked to indicate if they will or might increase their water usage if various conditions and situations were to prevail. Among the findings reported in **Chart 21**, it is most encouraging that when water agencies stop asking for residents to practice conservation there is no surge in water use expected (22 percent). On the other hand, a less cool and less wet year would lead to nearly three-fifths (57 percent) of the respondents returning to higher usage.



Understandably, when families move to a larger home, respondents indicate that they will increase water usage (54 percent). When the economy rebounds (19 percent) or the respondent obtains a better job or a job promotion (11 percent), residents indicate that they are not likely to increase their water usage. These various projections on the part of the current respondents parallel those that were made in 2011except in the area of an economic rebound. In this case, there is a decline of 8 percent from the 27 percent in 2011 who indicated they would use more water as the economy improves.

The following subgroups are more inclined to increase their water usage when the weather becomes warmer and drier:

- Women are more inclined to increase their usage if the weather turns warmer and drier (65 percent versus 52 percent for men).
- More frequent drinkers of bottled water are also more inclined to increase their water usage if the weather becomes warmer and drier—65 percent of those who drink bottled water often versus 46 percent of those who drink bottled water rarely or never.

The following subgroups are more likely to increase their water usage when the economy rebounds:

- Women (26 percent) more than will men (15 percent)
- Renters more than will homeowners (28 percent versus 15 percent).
- Those residents with one year of college or less (28 percent) plan to increase their water usage more so than do those with a college degree or more (14 percent).
- Blacks/African-Americans (33 percent) and Hispanics/Latinos (28 percent) indicate that they are more likely to increase their usage in a recovering economy than are Whites (15 percent) and Asians (17 percent).
- Incomes of under $25,000 per year (36 percent) versus $25,000 and less than $75,000 (24 percent) and $75,000 or more (12 percent)
    - Mean income among those who plan to increase their usage in a rebounding economy is $67,000 annually in contrast to $85,000 among those who do not think that they will increase usage.
- Ages 44 and under (27 percent) versus those residents who are 45 years of age or more (15 percent).

If water agencies were to stop asking their customers to conserve, the following groups would be more likely to increase their water usage:

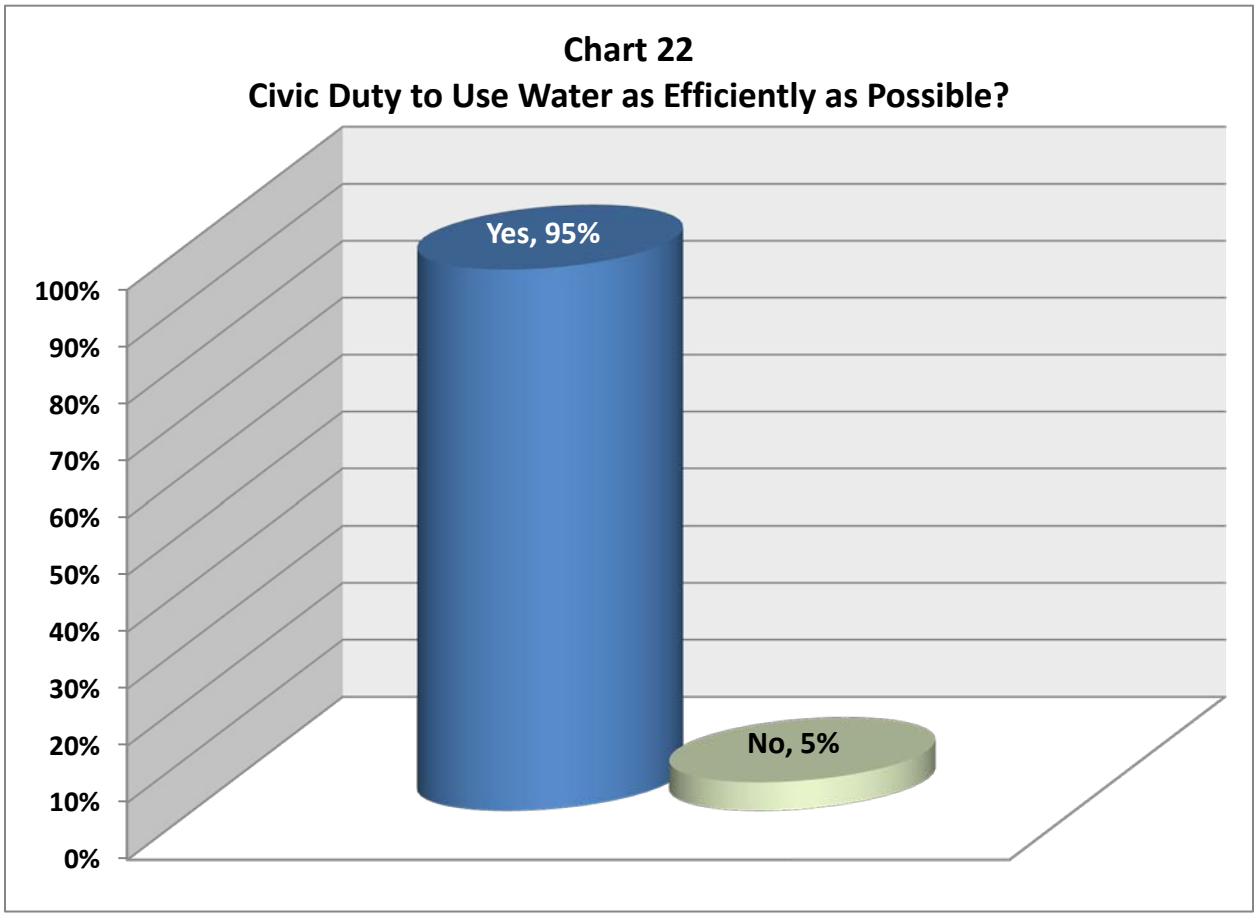
- Women (28 percent) in contrast to men (19 percent)

The other three possible events—a larger home, better job, or larger family are personal events in contrast to those above and share many similarities. In particular, renters, apartment and condominium dwellers, those who do not pay their own water bills, residents 18-44 years of age, and non-Whites all indicate that,

if these events were to happen in their lives, their consumption of water is more likely to increase than if these events were to occur to other residents of the City of San Diego.

<u>Water Conservation as a Civic Responsibility</u>: Chart 22 shows that virtually all of the respondents (95 percent) think that it is their civic responsibility to use water as efficiently as possible.

- Those who never drink bottled water think of water conservation as less of a civic responsibility (85 percent) than those who drink it at least rarely (96 percent).



Voting is seen as a civic responsibility differently by the following groups:

- Residents 45 years of age or older demonstrate a 95 percent rate for voting being a civic responsibility in contrast to those under 45 years of age (86 percent).
- Whites (95 percent) and Asians (100 percent) are more inclined toward voting being a civic responsibility than are Hispanics/Latinos (88 percent) or Blacks/African-Americans (85 percent).

Regarding jury duty as a civic responsibility,

- Whites (91 percent) and Asians (90 percent) more than Hispanics/Latinos (84 percent) and Blacks/African-Americans (76 percent).

Not Polluting and Not Littering are seen as a civic responsibility by:

- Those who drink bottled water often (99 percent) in contrast to those who never drink bottled water (91 percent).
- Residents 25 years of age and older (98 percent) versus those 18-24 years of age (82 percent).
    - Those who see not littering or polluting as a civic responsibility average 10 years of age older than those who do not see these as civic responsibilities.

Water conservation is seen as more of a civic responsibility than voting by:

- Ages 18-44 (49 percent) versus ages 45 or more (29 percent).
- Renters (47 percent) more than owners (31 percent).
- Those who do not pay for their own water (45 percent) versus those who do (33 percent).

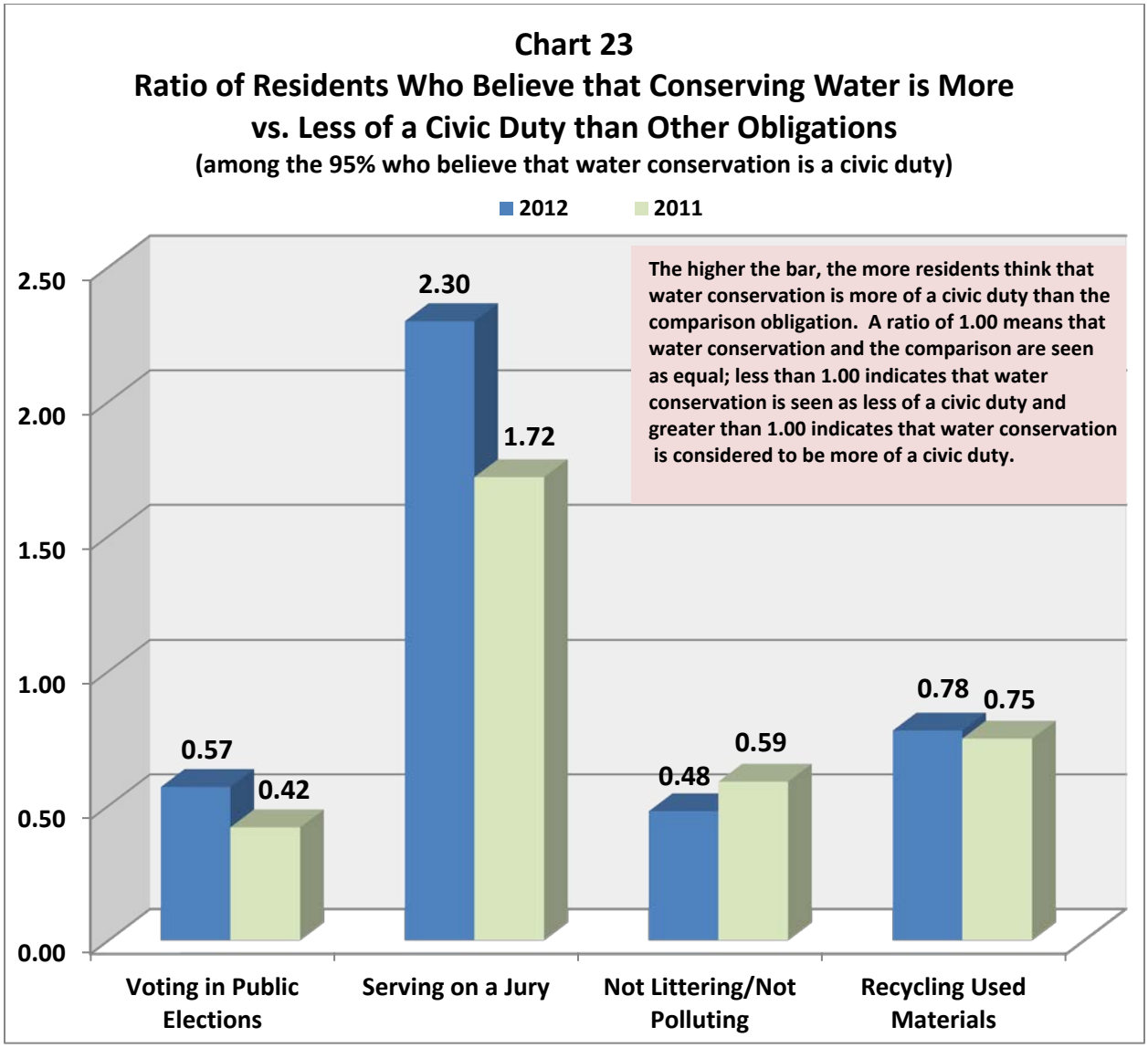
Chart 23 demonstrates how respondents feel about water conservation compared to other civic obligations. The comparison between water conservation and each of the other civic obligations is measured in terms of a ratio that measures those who feel that water conservation is more of a responsibility than these other civic obligations versus those who feel that water conservation is less of a civic responsibility. A ratio of 1.00 means that water conservation and the obligation with which it is being compared are equal in terms of how respondents perceive their civic responsibilities. A ratio of less than 1.00 indicates that water conservation is viewed as less of a civic responsibility than the comparison obligation and a ratio of greater than 1.00 means that water conservation is considered to be more of a civic duty that the obligation with which it is compared. In the current survey period as well in 2011, respondents regard water conservation as a greater civic responsibility than serving on a jury. In the current survey as well as in 2011, water conservation is closer to the same level as recycling used materials in terms of perceived civic responsibilities. Voting in public elections and not littering/not polluting are strongly regarded as higher civic obligations than water conservation.

Water conservation is seen as more of a civic responsibility than jury duty by:

- Ages 18-44 (81 percent) versus ages 45 or more (62 percent).

Water conservation is also seen as more of a civic responsibility than not littering or polluting by:

- Those who earn more than $50,000 annually (39 percent) versus those who earn less than $50,000 (18 percent).
- Those who pay their own water bills (37 percent) versus those who do not (25 percent).



Opinions about the Use of Recycled Water

SUMMARY: Over 7 in 10 respondents believe that it is possible to further treat recycled water that has been used for irrigation to make the water pure and safe for drinking. This represents a slight increase over the 2011 survey finding where two-thirds felt that it is possible to further treat recycled water for drinking purposes.

Nearly three-fifths of the respondents (56 percent) believe that drinking water already contains recycled water. This reflects a clear upward movement in the percentage of those who hold this belief – 47 percent in 2011. Three primary reasons are provided to explain why they feel this way. Respondents think that they hear from news stories that water is recycled, they "just know it" (includes hunches and common sense) and water tastes and smells bad.

Nearly three-fourths (73 percent) of the respondents either strongly favor or somewhat favor advanced treated recycled water as an addition to the supply of drinking water. This represents a slight increase in support for advanced treatment over the 2011 survey where 68 percent of the City respondents either strongly favored or somewhat favored advanced treated recycled water.

These findings show that approximately 70 percent of those who were originally not strongly in favor of using recycled water for drinking purposes would find it acceptable if recycled water received advanced treatment and if certain other safety measures were assured. This is an increase of about 20 percent over the approximately 50 percent who changed their mind in 2011.

Among the 20 percent who have heard about the Water Purification Demonstration Project, 6 percent know that it involves recycled water for drinking and household purposes – a decline of 5 percent from the 11 percent who correctly identified the purpose of the project in 2011. When respondents were informed about the Project, they expressed substantial support for the Project – over three-fourths either strongly favoring the project or somewhat favoring it. This level of support parallels the support indicated in the 2011 survey.

Chart 24 shows that over 7 in 10 respondents (71 percent) believe that it is possible to further treat recycled water used for irrigation to make the water pure and safe for drinking. This represents a slight increase over the 2011 survey finding where two-thirds (67 percent) felt that it is possible to further treat recycled water for drinking purposes.

Groups that view the possibility of making recycled water pure and safe for drinking differently from one another are:

- People who often or sometimes drink tap water are more optimistic than those who drink tap water less frequently. Those who drink tap water often or sometimes are 83 percent in belief that recycled water can be made pure and safe. Those who drink tap water rarely or never drink tap water are at 67 percent.
- Cell-phone only users are more positive (88 percent) than are land line telephone users (74 percent).

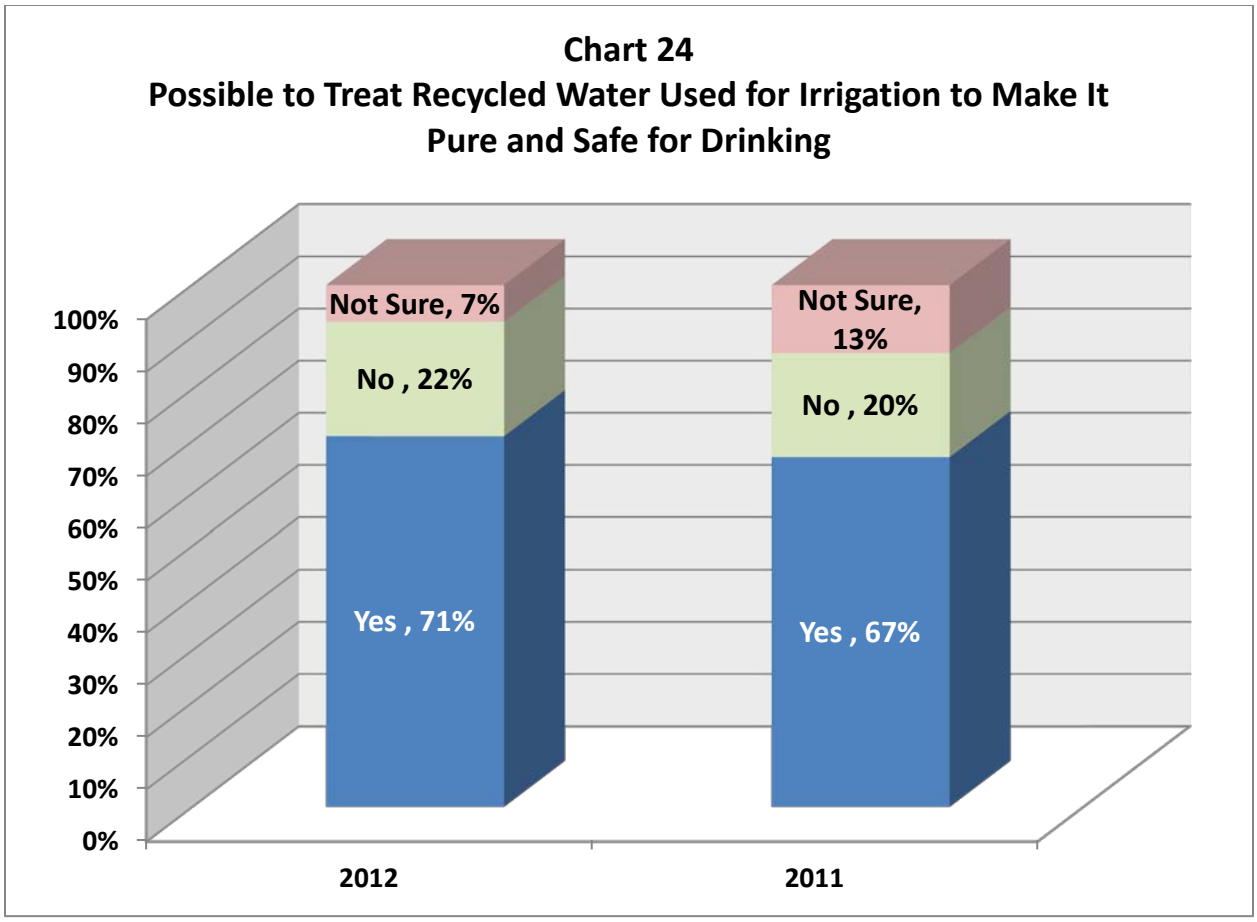
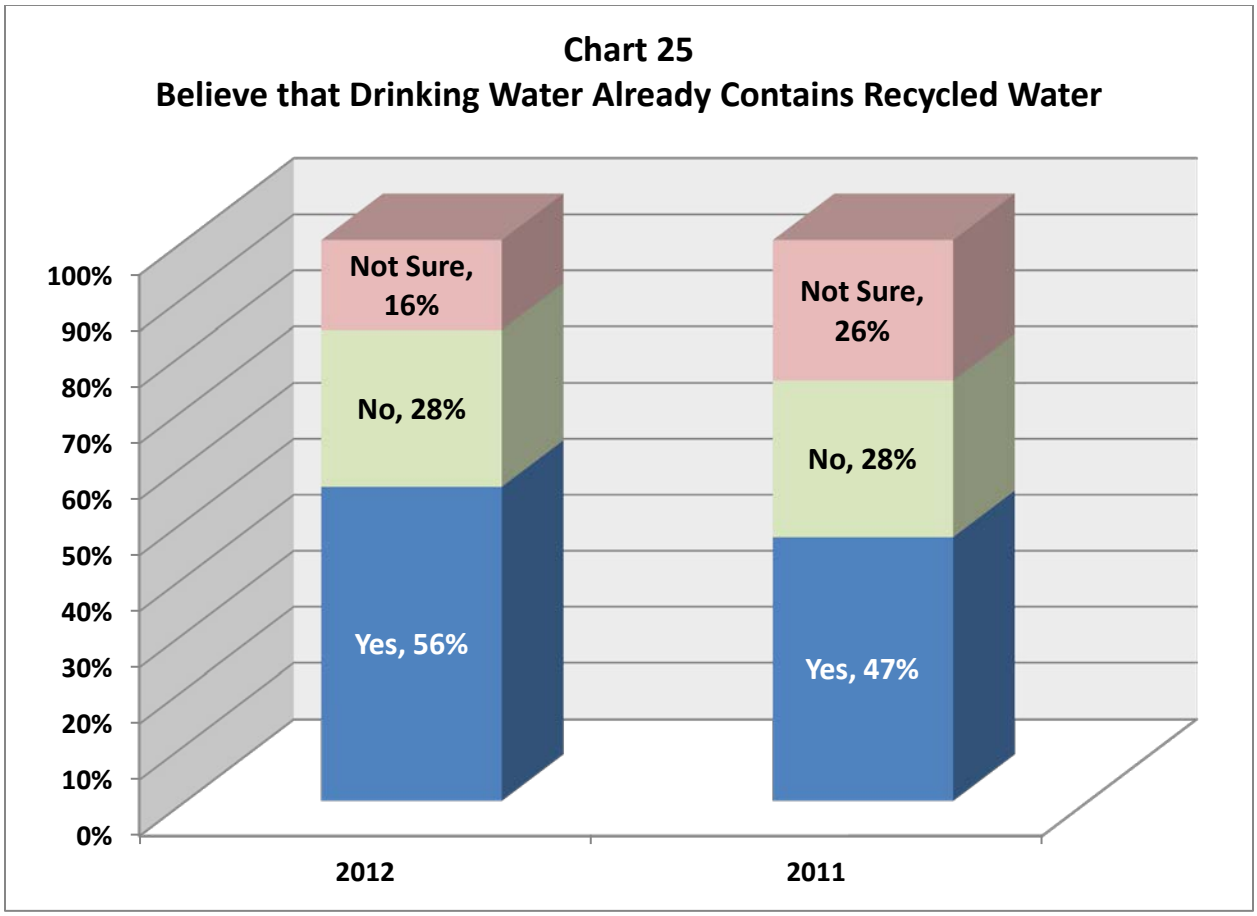


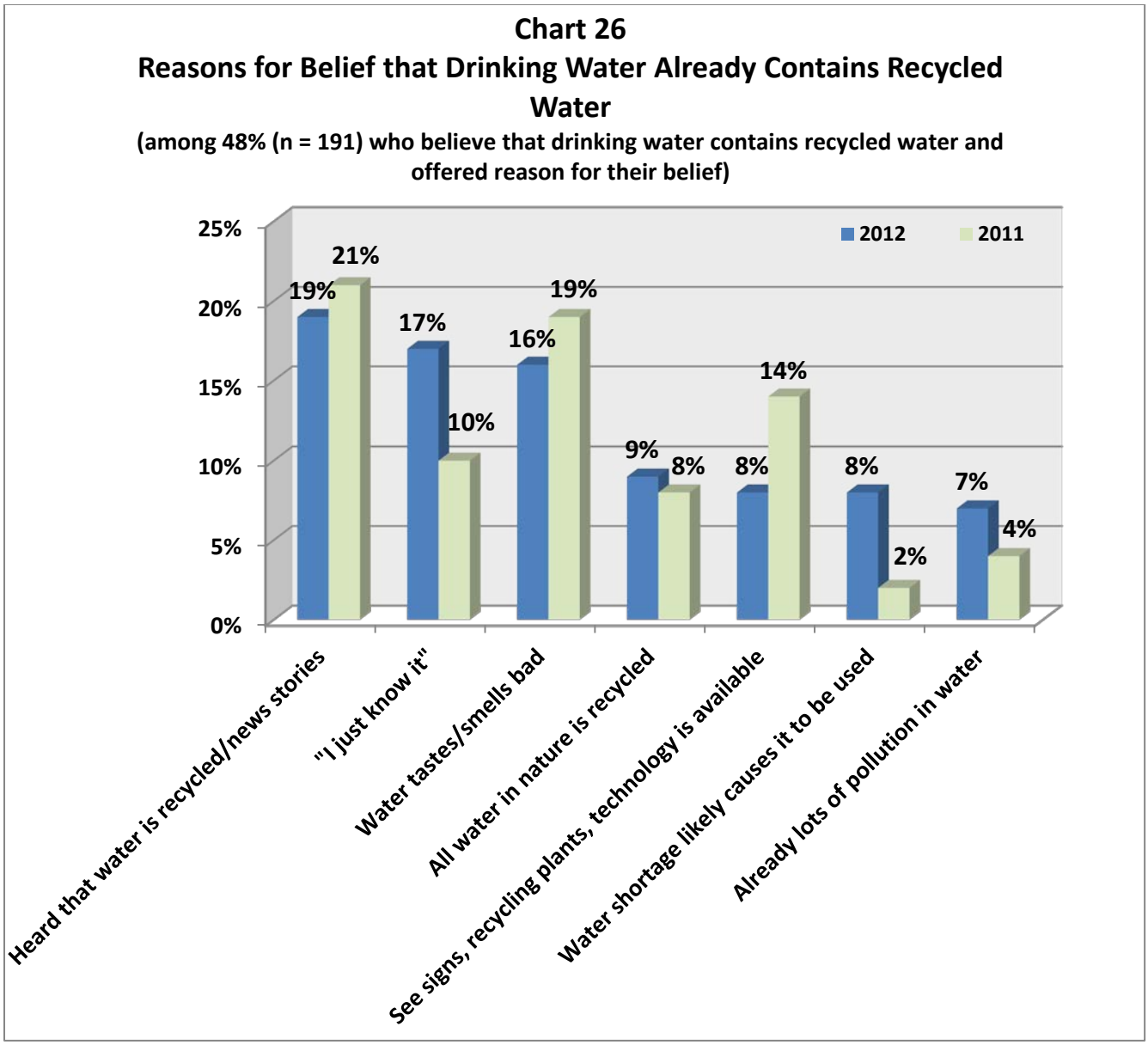
Chart 25 indicates that nearly three-fifths of the respondents (56 percent) believe that drinking water already contains recycled water. This reflects a clear upward movement in the percentage of those who hold this belief – 47 percent in 2011.

Several differences exist among groups related to their opinion as to whether or not drinking water already contains recycled water. The groups with the highest percentages indicating that drinking water already contains recycled water are as follows:

- Those who do not pay their own water bill (76 percent) versus those who do pay their own bill (63 percent).
- Renters (77 percent) versus homeowners (62 percent).
- Younger residents--ages 18-34 (79 percent) in contrast to 65 years of age or older (49 percent).
- Residents of San Diego County for 30 years or less (74 percent) versus residents of 31 years or more (57 percent).

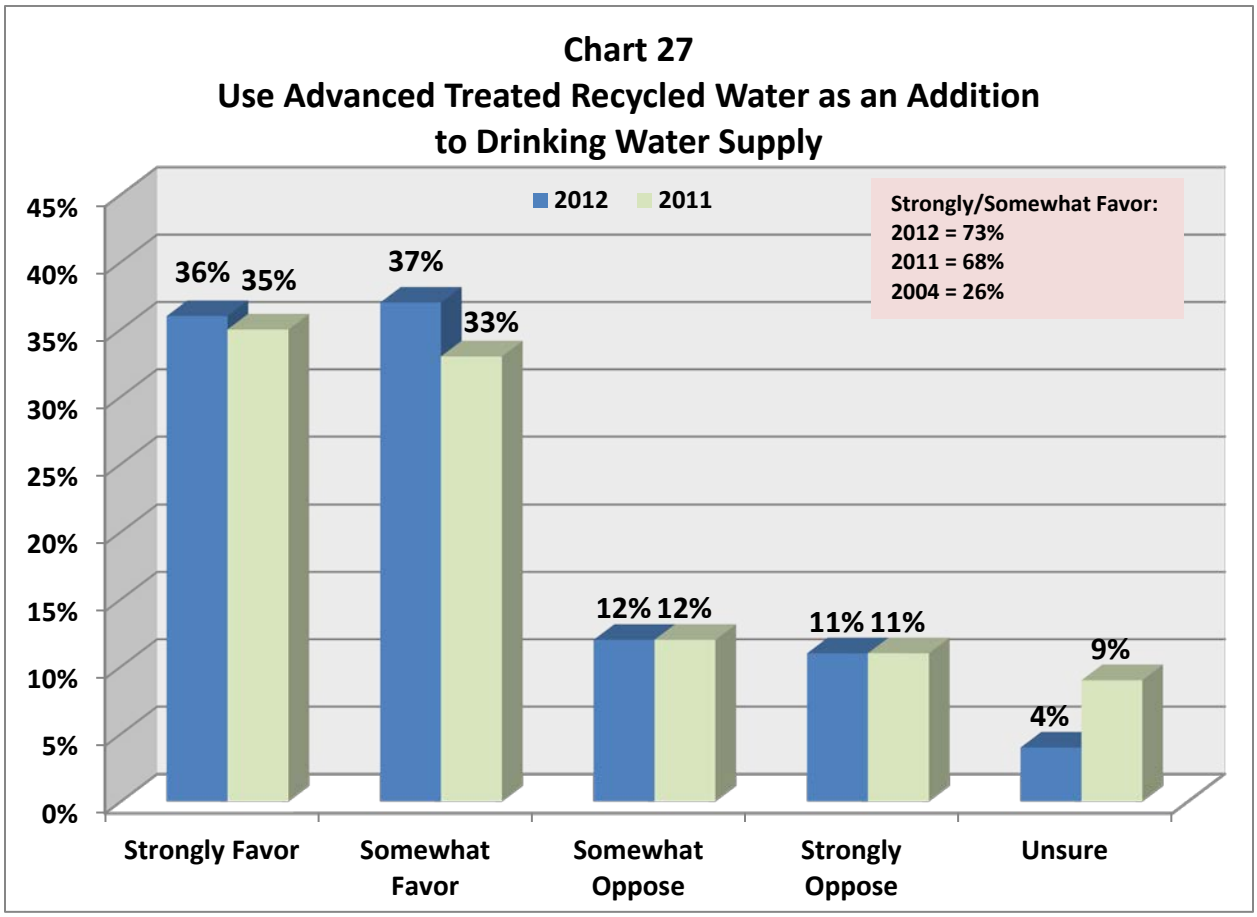


Among the 56 percent of respondents who think that drinking water contains recycled water, three primary reasons are provided to explain why they feel this way. Respondents think that they hear from news stories that water is recycled (19 percent), they "just know it" (includes hunches and common sense) (17 percent), and water tastes and smells bad (16 percent). In 2011, hearing about recycled water from news stories was also the most dominant reason (21 percent). The reason "just know it" increased in importance by 7 percent from the 10 percent reported in 2011. The perception that the water tastes or smells bad and the indication that all water in nature is recycled are given similar importance in both survey years as reasons for believing that drinking water already contains recycled water. Thinking that they see recycling plants and available technology (14 percent) was a dominant reason in 2011 but a much less important reason in 2012 (8 percent). The reasons associated with water shortages and water pollution have grown in importance since the 2011 survey (**Chart 26**).



Respondents were asked whether or not they would favor using advanced treated recycled water as an addition to the supply of drinking water and that such advanced techniques include ultra-filtration, reverse osmosis, and advanced oxidation. (upon request, one of these three advanced techniques would be explained to the respondent, but only 10 respondents asked). **Chart 27** indicates that nearly three-fourths (73 percent) of the respondents either strongly favor (36 percent) or somewhat favor (37 percent) advanced treated recycled water as an addition to the supply of drinking water. It is important to note that this represents a slight increase in support for advanced treatment over the 2011 survey where 68 percent

of the City respondents either strongly favored or somewhat favored advanced treated recycled water. It is particularly noteworthy that interest in using such advanced techniques has increased substantially since the 2004 survey when only 26 percent either strongly favored or somewhat favored such advanced treatment of recycled water.

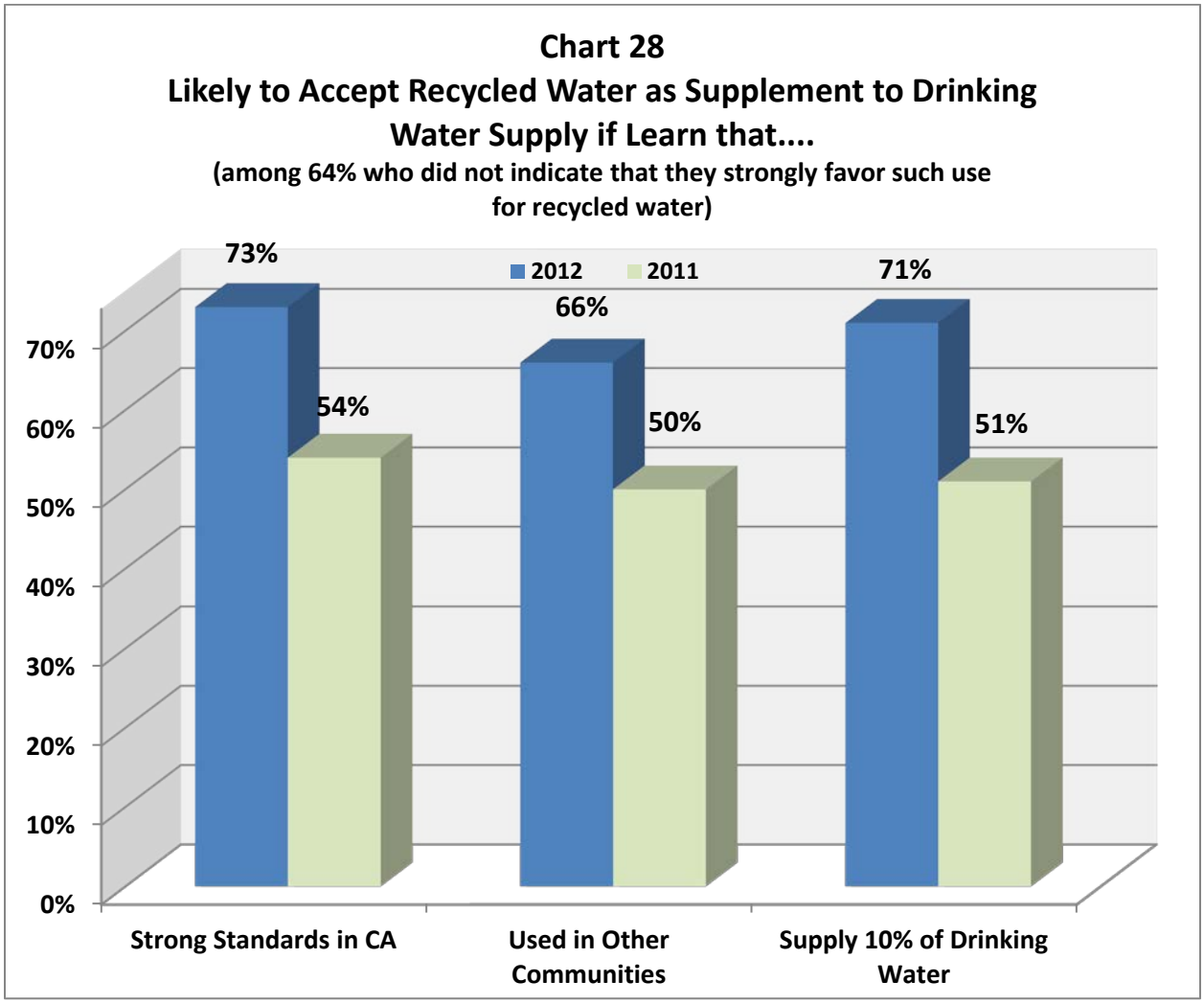


More strongly in favor of supplementing drinking water supplies with advanced treated recycled water are:

- Asians (68 percent strongly favor) versus all other groups—Blacks/African-Americans (49 percent, Whites (35 percent) and Hispanics/Latinos (30 percent).
- Drinkers of regular tap water often, sometimes or rarely (40 percent) versus those who never drink tap water (29 percent).

Respondents who did not already **strongly favor** the use of recycled water as an addition to the drinking water supply were asked if they would accept recycled water for drinking purposes if it were subject to such advanced treatment and if they learned certain facts about recycled water (**Chart 28).** The percentages reflect only those customers who formerly did not strongly favor the use of recycled water as an addition to the drinking supply but who changed their minds upon learning that:

- California drinking water standards are very strict and recycled drinking water would exceed those standards (73 percent). This represents a substantial increase from the results of the 2011 survey where an affirmative response of 56 percent was recorded.
- Recycled drinking water is used in other U.S. communities (66 percent); again, this represents a substantial (16 percent) increase over the 2011 survey result.
- Recycled drinking water could supply up to 10 percent of local supply (71 percent)--only 51 percent were influenced by this statement in 2011.



These findings show that approximately 70 percent of those who were originally not strongly in favor of using recycled water for drinking purposes, would find it acceptable if recycled water received advanced treatment and if certain other safety measures were assured. This is an increase of about 20 percent over the approximately 50 percent who changed their mind in 2011.

The message about California's strict drinking water standards carries more weight with the following groups:

- Higher income residents (mean income for those who are now more likely to support recycled water as an addition to drinking water is $87,400 versus those who are not similarly influenced -- $56,700).
- Larger households of 3 or more persons (80 percent) versus 1-2 person households (66 percent).
- Single family dwellers (76 percent) as opposed to those who live in apartments (61 percent).

The message about the use of recycled water in other U.S. communities is influential to

- Those who earn $75,000 or more annually (83 percent) versus those who earn less than $75,000 (62 percent).

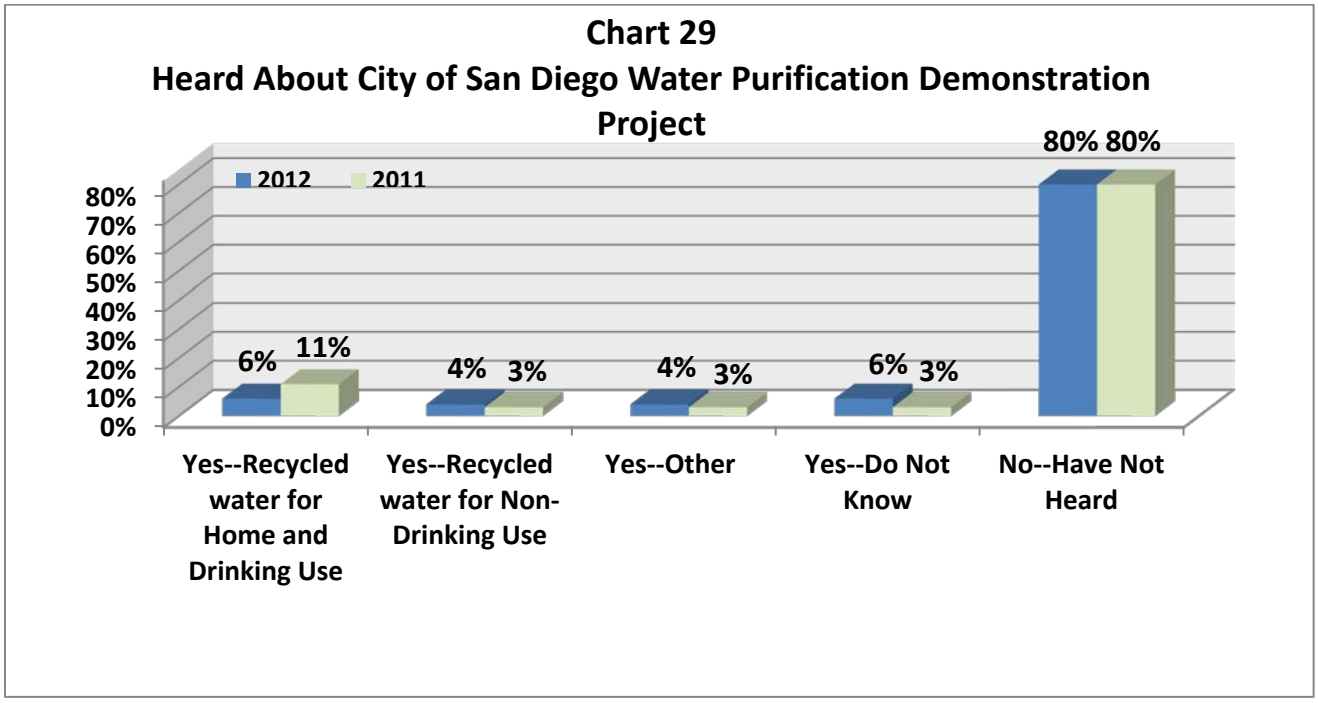
The message about the use of recycled water to supply 10 percent of our drinking water supply is influential to

- Those who often, sometimes or rarely drink regular tap water (77 percent) versus those who never drink regular tap water (61 percent).
- Residents of San Diego County for 10 years or less (85 percent) versus those who have resided in the County for 11 or more years (69 percent).

Table 2 shows that movement toward being more in favor of the use of recycled water for drinking water purposes differs, as would be expected, depending upon the degree to which the respondent was initially opposed or in favor of using recycled water for this purpose in the first place. Omitting all of those who were strongly in favor to begin with, it can be seen that the more in favor a respondent was initially, the easier it is for this information to sway his or her opinion. Among those who were previously somewhat in favor of recycled water being added to the drinking water supply, 83-to-90 percent are influenced by this information to be more in favor of this use of recycled water -- a stronger response than in 2011 where 65-to-72 percent shifted their opinion. In the current survey, 58-to-75 percent of those who are somewhat opposed can be positively influenced to accept recycled water for drinking purposes – again a stronger response than found in 2011 (38-to-50 percent).

Table 2 Shift in Opinion Using Recycled Water (Percentages Represent Respondents Now Likely to Accept Recycled Water for Drinking Water Purposes)				
	Formerly Somewhat in Favor	Formerly Somewhat Opposed	Formerly Strongly Opposed	Don't Know/ Unsure
California drinking water standards are very strict and recycled drinking water would exceed those standards	89%	75%	12%	78%
Recycled drinking water is used in other U.S. communities	83%	58%	12%	72%
Recycled drinking water could supply up to 10 percent of local supply	90%	60%	12%	78%

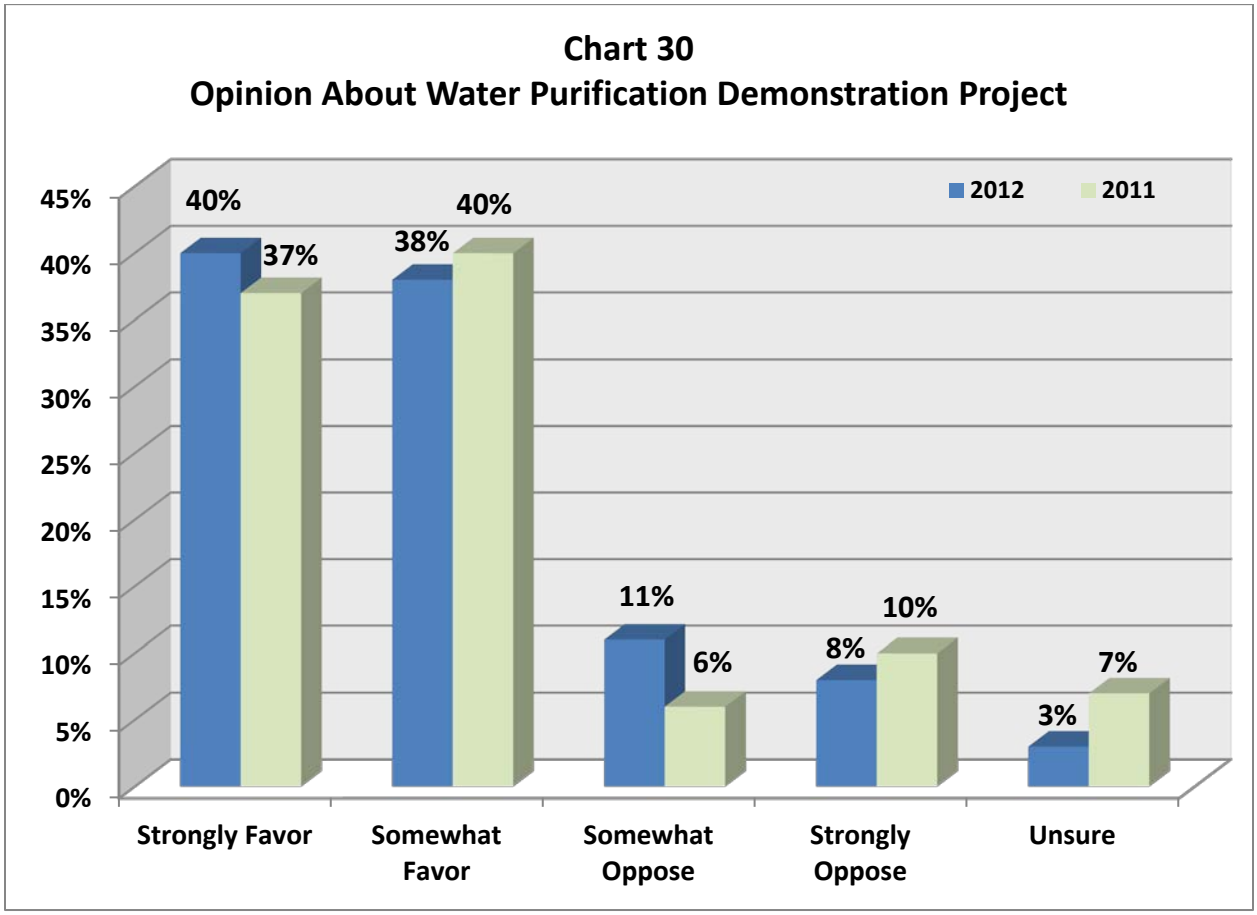
City of San Diego Water Purification Demonstration Project: Chart 29 shows that 80 percent of San Diego City residents have not heard of the City of San Diego Water Purification Demonstration Project. This is precisely consistent with the results of the 2011 survey. In the current survey, among the 20 percent who have heard about this project, 6 percent know that it involves recycled water for drinking and household purposes – a decline of 5 percent from the 11 percent who correctly identified the purpose of the project in 2011. In 2012, 4 percent believe that the project involves recycled water for a purpose other than household and drinking use and this is consistent with the 3 percent who believed this in 2011.



Knowledge of the Water Purification Demonstration Project is highest among:

- Ages 55 and older (32 percent) versus those 54 years of age and younger (13 percent).
- Land line telephone users (23 percent) versus those who use only cell phones (10 percent).

Respondents were subsequently informed about the nature and purpose of the Water Purification Demonstration Project. When so informed, residents expressed substantial support for the Project. **Chart 30** shows that 78 percent of residents either strongly favor (40 percent) or somewhat favor (38 percent) the goals of the Project. This response represents strong approval for the use of recycled water for drinking purposes and precisely parallels the high level of support in 2011 for the Water Purification Demonstration Project.



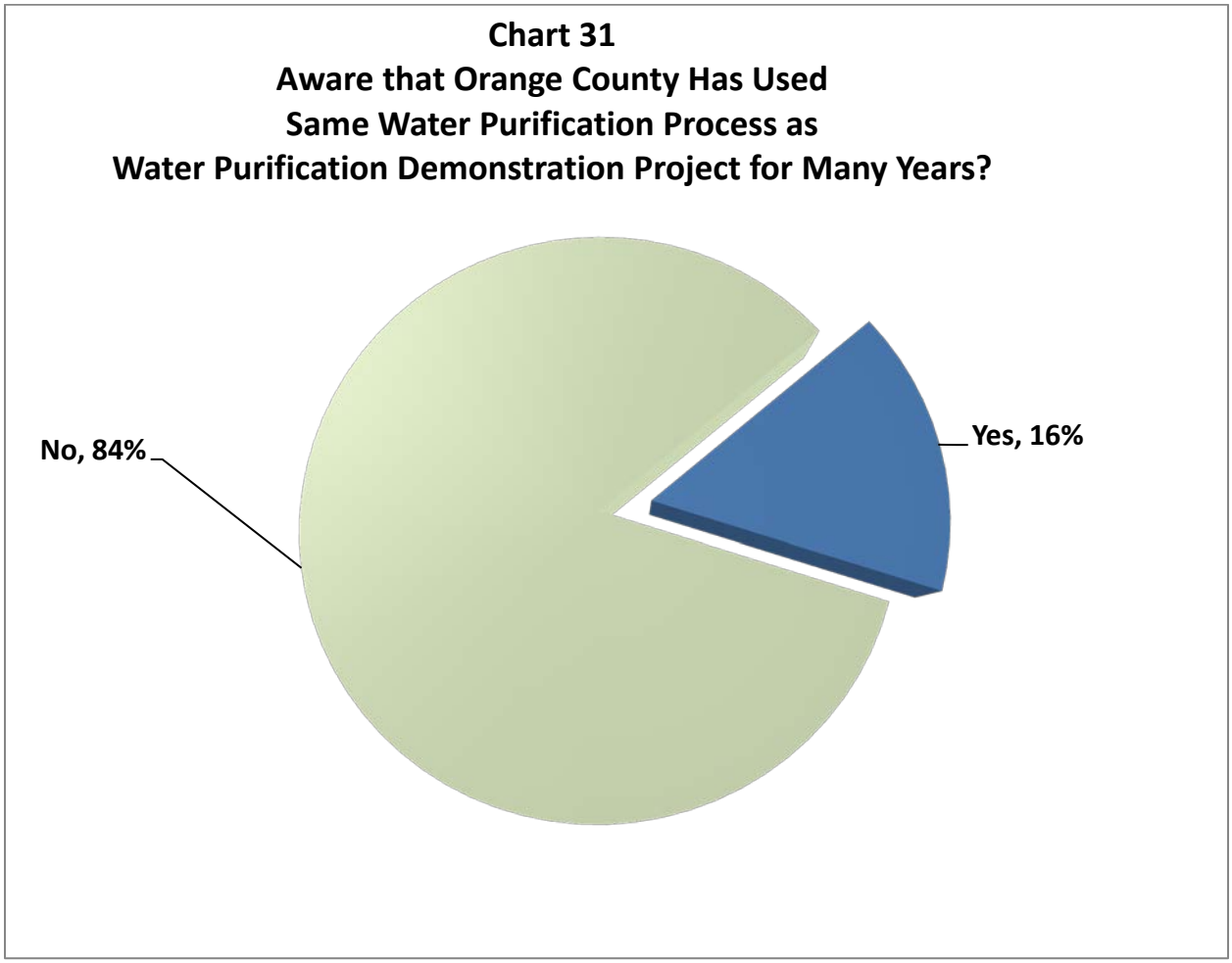
Groups that strongly or somewhat favor the Water Purification Demonstration Project are:

- Asians (58 percent) versus Blacks/African-Americans (23 percent). Whites (44 percent) and Hispanics/Latinos (38 percent) are close to the overall average percentage.

- Those who often or sometimes drink tap water (84 percent) versus those who rarely or never drink tap water (75 percent).

Chart 31 shows that 16 percent of the City of San Diego respondents are aware that Orange County has used the same water purification process as the City of San Diego's Water Purification Demonstration Project for many years.

- Awareness that Orange County has used the same water purification process for several years is highest among those who often, sometimes or rarely drink tap water (18 percent) in contrast to those who never drink tap water (9 percent).



Water Rates

Over two-fifths (45 percent) of respondents feel that the cost of water is too expensive. This represents a decline from the 2011 survey period among those who feel the cost of water is too expensive -- in 2011, 52 percent indicated water was too expensive. This result points to a trend toward an enhanced understanding of and tolerance for the cost of water. The dominant causes for increases in water rates are seen by residents as more water being consumed by customers and less rain in San Diego—neither of which is correct.

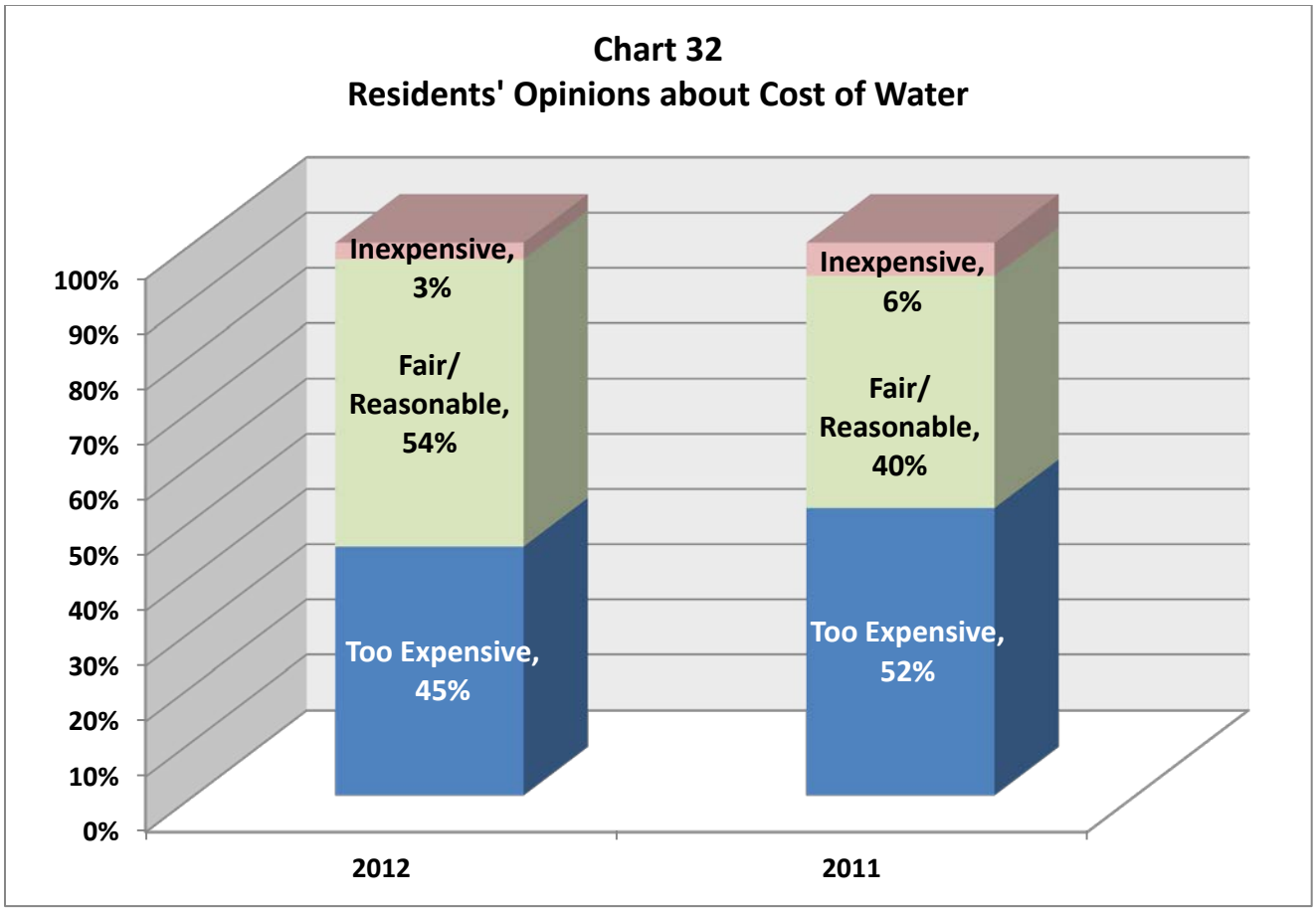
Over three-fifths of respondents feel that increases in water rates are necessary to maintain reliability of the water supply while one-third of the respondents feel that increased water rates are not necessary and should be stopped. This represents a distinct shift from the 2011 survey results toward an understanding and a tolerance of water rate increases. In the 2011 survey, there was a near equal split in opinion about the necessity of water rate increases to pay for projects designed to improve water supply reliability.

However, despite this seeming acceptance of water rates, almost two-thirds indicated that they were very concerned or somewhat concerned about continued increases in these rates. This level of concern is consistent with the results of the 2011 survey.

Chart 32 demonstrates that, despite its high degree of valuation discussed earlier in this report, over two-fifths (45 percent) of respondents feel that the cost of water is too expensive. This represents a decline from the 2011 survey period among those who feel the cost of water is too expensive -- in 2011, 52 percent indicated water was too expensive. In the current survey, another 54 percent feel that the cost is fair and reasonable. This represents a 14 percent increase from 2011 to 2012 regarding those who feel that the cost of water is fair and reasonable. There is a clear trend toward an understanding of and/or a tolerance of the cost of water.

The following groups are more likely to feel that the cost of water is too expensive:

- Residents who have lived in the County for 10 years or more (48 percent) as opposed to those who have been in the County for less than 10 years (32 percent).
- Homeowners (47 percent) as opposed to renters (40 percent).
- Residents with a lower income – residents who earn less than $75,000 feel that the cost of water is too expensive (46 percent) versus those who earn $100,000 or more (34 percent).
- Those who drink bottled water often (52 percent) versus those who never drink bottled water (25 percent).
- In the reverse, those who never drink tap water find water to be more expensive (58 percent) than do those who drink tap water often, sometimes or rarely (40 percent).



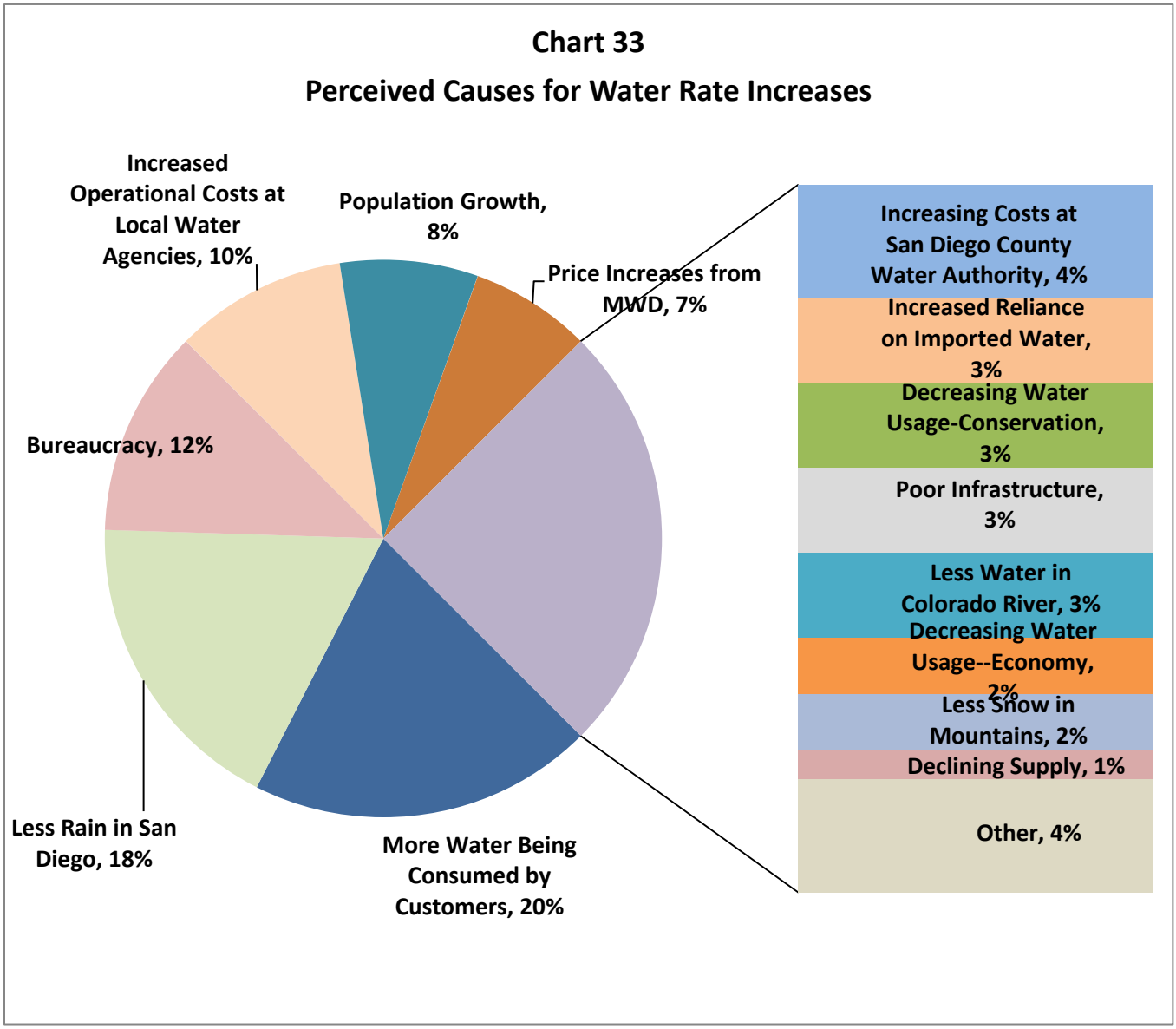
The perceived causes for water rate increases are shown in **Chart 33**. The dominant causes in the view of the respondents are more water being consumed by customers (20 percent) and less rain in San Diego (18 percent)—neither of which are correct as primary causes. Bureaucracy (12 percent) and increased operational costs at local water agencies (10 percent) follow in the order of importance.

There are significant differences among groups regarding the biggest causes of water rate increases:

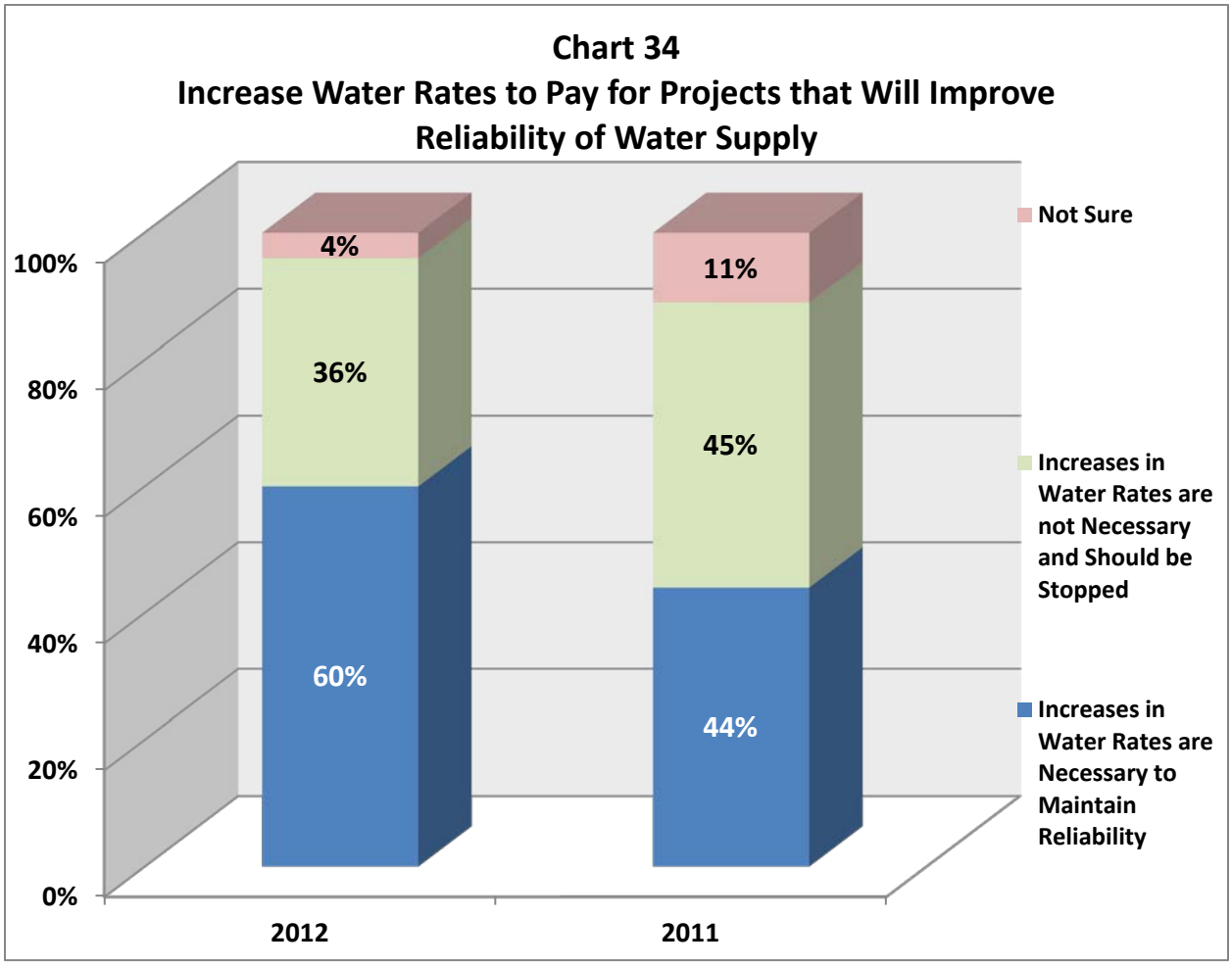
- Homeowners and Renters differ on the following perceived causes:
    - Bureaucracy (owners 17 percent—renters 9 percent)
    - Increased operating costs at local water agencies (owners 11 percent—renters 5 percent).
    - Price increases from MWD (owners 9 percent—renters 3 percent)
    - More water being used by customers (renters 25 percent—owners 18 percent)
    - Population growth (renters 11 percent—owners 6 percent)
    - Decreased usage due to conservation (renters 7 percent—owners 2 percent)
- Older residents consider the following as bigger causes of water rate increases:
    - Increased costs at San Diego County Water Authority (61 years of age)
    - Price increases from MWD (59 years of age)

- Bureaucracy (57 years of age)
- Less water in Colorado River (55 years of age)
- Reliance on imported water (54 years of age)

- Younger residents consider the following as bigger causes of water rate increases:
  - Economy (41 years of age)
  - More water used by customers (44 years of age)
  - Low/Declining water supply (47 years of age)
  - Less water used because of conservation (47 years of age)
  - Less rain in San Diego (48 years of age)



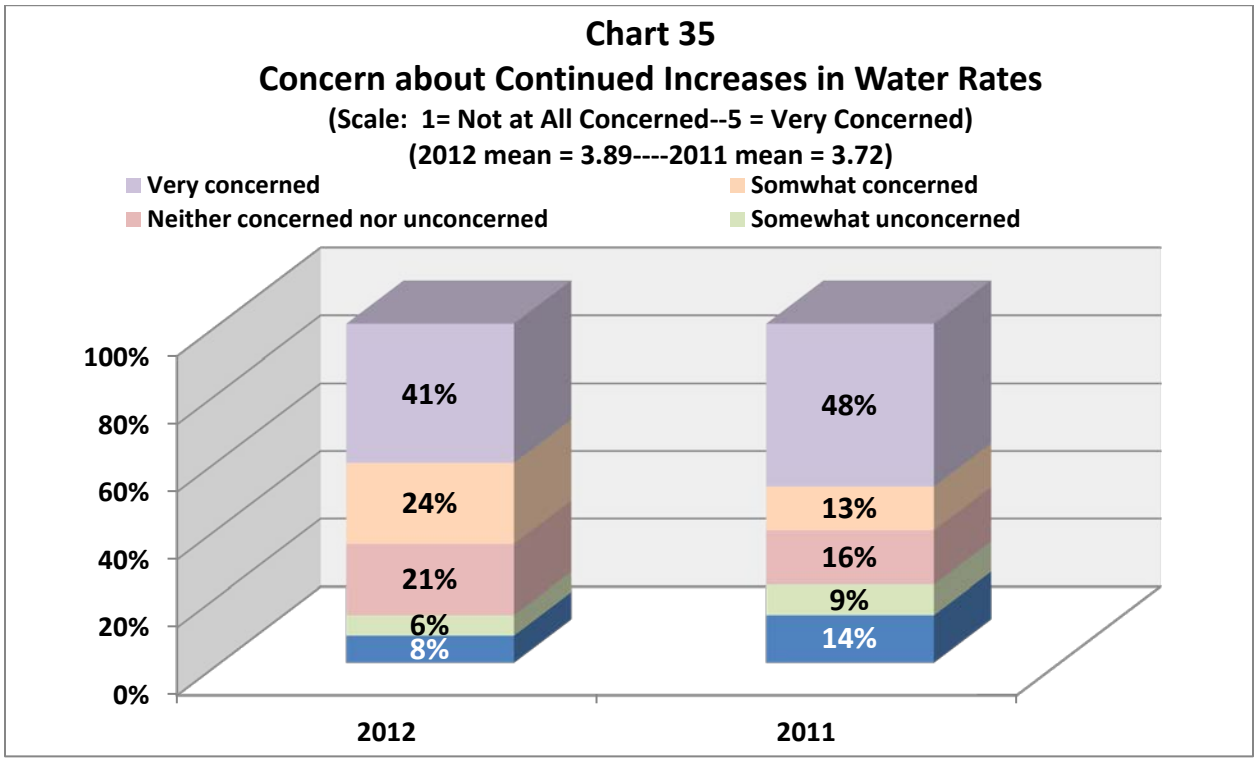
Two hypothetical arguments were put forth about whether or not increased water rates are necessary to maintain an adequate water supply. One argument was that "Mr. Smith says that increases in water rates are necessary to maintain reliability of the water supply" and the other was that "Ms. Jones says that increasing water rates are not necessary and should be stopped." Three-fifths of respondents (60 percent) feel that increases in water rates are necessary to maintain reliability of the water supply (Mr. Smith's argument) while well over one-third of the respondents (36 percent) feel that increased water rates are not necessary and should be stopped (Ms. Jones' argument) (**Chart 34**). This represents a distinct shift from the 2011 survey results and again reaffirms the trend that the population is expressing a greater tolerance for and acceptance of water rate increases. In the 2011 survey, the there was a near equal split in opinion about the necessity of water rate increases to pay for projects designed to improve water supply reliability.



The following groups are more likely to think that water rate increases are necessary to maintain the reliability of the water supply:

- Shorter term residents of the County (less than 10 years – 78 percent versus 10 years or more – 57 percent).
- Residents with incomes of $75,000 or more (72 percent) versus those with incomes below $75,000 (56 percent)
- Residents with at least one year of post-graduate education (74 percent) in contrast to college degree or less (59 percent)
- Those who often, sometimes or rarely drink tap water (68 percent) versus those who never drink tap water (46 percent)

Chart 35 reports the level of resident concern regarding the prospect of continued increases in water rates. This concern was measured on a 5-point scale, where 1 = not at all concerned to 5 = very concerned. Three fifths (65 percent) recorded ratings of very concerned (41 percent) and somewhat concerned (24 percent) despite their seeming acceptance of higher rates. The mean rating is 3.9, which represents a high level of concern. This level of concern is consistent with the results of the 2011 survey where 61 percent were either very concerned or somewhat concerned about continued increases in water rates and where the mean rating was 3.7.



The following groups are either very concerned or somewhat concerned about increases in water rates:

- Homeowners (71 percent) versus renters (51 percent).
- Residents of single family homes (73 percent) versus those who are apartment dwellers (35 percent).
- Longer term residents of 31 years or more exhibit the greatest level of concern about increases in water rates (very or somewhat concerned = 73 percent versus 30 years or less = 59 percent).
- Households that pay for their water (71 percent) versus households that do not pay for water (51 percent).

2010 San Diego State University Research Study
Executive Summary

Executive Summary

Water Purification Demonstration Project: A Community Study

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Community-Based Service Learning Project

Every semester at San Diego State University, students enrolled in Journalism 581, Public Relations Research Methods, conduct a community-based service learning project for organizations on the SDSU campus or a non-corporate client in the larger community. The purpose of community-based service learning projects is to provide students with hands-on experience conducting a full-scale research project while providing a product of benefit to the sponsoring organization. The sponsoring client provides a stipend through the SDSU Research Foundation to provide logistical and material support for the project. Past clients have included Birch Aquarium, Scripps Healthcare, the San Diego County Water Authority, and Sharp Mesa Vista. These projects have been conducted for 30 years.

The Community Study

The City of San Diego Public Utilities Department contacted SDSU to see if the Water Purification Demonstration Project would serve as a useful focus for a community-based service learning project for the public relations research methods course. After discussing the parameters of the study, it was agreed in July, 2010 that the Water Purification Demonstration Project would serve as a useful focus for the class project.

Research Questions and Information Needs

In discussions with the Community Outreach Specialist of the Public Utilities Department, a number of research questions and information needs were identified. How much do San Diegans know about the water supply for the city? Do San Diegans know how much of our potable water is imported from outside the county? What do San Diegans know about water purification in general and about the Water Purification Demonstration Project specifically? What is the relationship between knowledge about water purification and opinions about the Water Purification Demonstration Project? How do demographics (e.g., age, income,

ethnicity, and gender) influence what San Diegans know and how they feel about water purification.

Research Methodology

One goal of the course is to show students how to combine qualitative research methods (e.g., focus groups, depth interviews, participant observation) with quantitative research methods (e.g., telephone and online surveys) to provide better information to client organizations. Therefore, students conducted face-to-face depth interviews with a dimensional sampling of San Diegans, as well as telephone interviews with San Diegans, using random digit dialing (RDD). RDD ensures that both listed and unlisted numbers are included in the sample.

Methods: Depth Interviews

In the fall semester, 2010, 63 students were enrolled in the public relations research methods course. This included 52 undergraduates and 11 graduate students. The class was divided into 11 self-selected "consulting groups." Each consulting group constructed a depth interview guide (DIG), which is a series of semi-structured open-ended probes similar to the probes used in focus group studies. The instructor reviewed and edited each DIG. Student consulting groups then used the edited version of the DIG to conduct 45- to 60-minute face-to-face interviews with San Diegans. Each DIG was unique to the consulting group that developed it. However, all DIGs focused on a set of information needs articulated by the client organization. These included: (1) to determine awareness of the need to develop local, reliable water sources, (2) to determine awareness of the Water Purification Demonstration Project, (3) to determine the level of understanding of the advanced purification process (3-step process), (4) to determine the level of awareness of the fact that San Diego's regular drinking water supply already contains recycled water, (5) to learn about the concerns that San Diegans have about using purified recycled water (which might include safety or quality), (6) to learn about attitudes towards the addition of purified recycled water to local reservoirs if a full-scale project of reservoir augmentation were to be approved by the city council, and (7) to explore the linkage between knowledge and opinions about water purification.

Findings: Depth Interviews

From the 63 depth interviews conducted in October, 2010, the following tentative results emerged. First, San Diegans are woefully uninformed about sources of potable water in the City of San Diego and increasing limitations on imported water supplies.

Second, San Diegans were quite unfamiliar with the terminology that "insiders" (e.g., Public Utilities Department) use to discuss water quality and supply. One participant, for example, defined *potable water* as water one uses to water household plants. More complex terminology, such as reverse osmosis, microfiltration, ultraviolet treatment, and peroxide treatment, was not comprehensible for the vast majority of people interviewed. Very few of the depth interview participants had heard anything about the Water Purification Demonstration Project. Third, a number of participants said that they disliked the taste of tap water in San Diego, including people who had never actually consumed San Diego tap water. This information was used by the research consulting groups to develop drafts of telephone questionnaires, based on revised information needs provided by the client organization.

Methods: Telephone Survey

Based on the information gleaned from the depth interviews, 11 draft questionnaires were prepared by the student consulting groups. The professor reviewed the questionnaires generated by the students and constructed a master questionnaire from student input. The master questionnaire (length=10 minutes) was then vetted to the client organization and revised. Graduate students in the class then conducted a pilot test of the questionnaire. Minor technical problems with flow and vocabulary were identified during the pilot test. These problems were corrected and the questionnaire was duplicated on paper. The questionnaire was also converted to a Web-based questionnaire (using Survey Monkey, a commercial online survey vendor). A list of random digit telephone numbers for the City of San Diego was purchased from Scientific Telephone Surveys, a vendor in Orange County. In November, 2010, students dialed 11,414 telephone numbers. To qualify, respondents were required to be (1) 18 or older and (2) residents of the City of San Diego. The questionnaire was also translated into Spanish and back translated to ensure accuracy. Students who were sufficiently bilingual were referred to households where an initial contact indicated that the residents were Spanish speaking only. After eliminating disconnects, business and government numbers, households with language barriers, and no answers after at three attempts, the original sample was reduced to a valid sample of 5,478. Of those, the response rate was 11%, the refusal rate was 22%, and the noncontact rate was 67%. A total of 626 eligible respondents were interviewed; the margin of error (95% confidence interval) is +/- 4 percentage points. The data was entered into an Excel database from Survey Monkey, which was

used by students as an input tool. These data were then uploaded into a data file compatible with the Statistical Package for the Social Sciences (SPSS), Version 18 for Macintosh. In general, older people and women are more likely to respond to telephone interviews. Therefore, the professor weighted the data file to match the City of San Diego with regard to gender and age, based on known population distributions from the U.S. Bureau of the Census. Thus, the sample matches the population of San Diego with regard to age and gender.

Findings: Demographics From Telephone Survey

Regarding gender, the sample was 51% male; average age was 43.8 years (median=40.3 years). Average income was $96,880 (median=$75,000). Regarding education, fewer than 16% had earned a high school diploma or less. Another 31% had attended some college or earned a 2-year or technical degree. About 31% had earned a 4-year degree. Nearly 22% had attended graduate school or had earned an advanced degree. Regarding ethnicity, 62% reported that they were white/Caucasian, 18% indicated that they were Hispanic or Latino, 85 reported that they were Asian American and another 8% reported that they were African American. Only 2% reported that they were Native American and 1% reported that they were Hawaiian or Pacific islanders. Average length of residency was 24.8 years (median=21.0 years). About 83% were registered to vote. Democrats outnumbered Republicans 31% to 24%, with 15% reporting that they were independents. The balance of the sample was affiliated with minor parties, declined to answer the question, or were not registered to vote.

Findings: Awareness of WPDP

According to the survey, 78% of respondents had not heard of the Water Purification Demonstration Project (WPDP). Of those who had heard of the WPDP, 8% said that the WPDP had something to do with converting wastewater to drinking water. About 9% mentioned "toilet to tap" explicitly. The remaining 5% who said that they had heard of the WPDP said they could not recall what they had heard.

Findings: Opinions About the WPDP

Respondents were read a brief, 47-word description of the WPDP. Then they were asked their opinion of the Project, based on the description and/or any prior knowledge they had about it. About 63% of respondents said they favored the Project, either somewhat or strongly.

Findings: Linkage Between Knowledge and Opinion

Based on the depth interviews, the research class hypothesized that opinions of the WPDP might be linked to the level of knowledge about the Project: The more knowledgeable a San Diegan becomes about the Project, the more favorably they will view the Project. This is a basic theory of information processing, applied to a specific case. Respondents were read four brief information modules related to water purification. These information modules dealt with (1) the purity of water generated by the WPDP treatment process, (2) a brief description of the 3-step water purification process, (3) the utilization of similar technology in other communities (e.g., Orange County), and (4) the current utilization of recycled water in San Diego from communities upstream. Consistent with the class hypothesis, greater knowledge of water purification tended to correlate with more favorable views of water purification.

Trusted Sources of Information

From the depth interviews, the research class learned that a number of participants were distrustful of sources of information about water supply and especially water quality. One goal of the study was to determine the types of information sources that San Diegans trust with regard to water quality and safety. About 67% of respondents indicated that they would trust "a great deal" a "scientist who is a water quality expert." About 33% said they would trust a health department official "a great deal."

Stakeholder Interviews (Spring 2010-Spring 2011)

WATER PURIFICATION DEMONSTRATION PROJECT
STAKEHOLDER INTERVIEWS (SPRING 2010-SPRING 2011)

STAKEHOLDER INTERVIEWS COMPLETED: 105

- American Consulting Council/ Simon Wong Engineering
- American Society of Landscape Architects
- Asia Media, Inc.
- Asian Business Association
- Bayview Baptist Church
- Bethel Baptist Church
- Black American Political Action Committee
- Blacks in Government
- California Curl and Monitor (San Diego Monitor)
- Care View Medical Group
- Casa Familiar
- Catfish Club of San Diego
- Central Commercial District Revitalization Corp.
- Chicano Federation
- City Heights Community Planning Group
- Clean TECH San Diego
- Coalition of Neighborhood Councils
- El Latino Newspaper
- Fairmount Park Association
- Faith Chapel Church of God in Christ
- Filipino Press
- Filipino-American Chamber of Commerce
- Food and Beverage Association San Diego
- Fountain of Life Church of God in Christ
- General Dynamics NASSCO
- Geocon, Inc.
- Golden Hill Community Development Corp.
- Greater Skyline Hills Neighborhood Council
- Green Chamber of San Diego County
- Homefront San Diego
- House of Metamorphosis
- Jackie Robinson Family YMCA
- Jamacha Neighborhood Council
- Japan Society of San Diego & Tijuana
- Japanese American Citizens League
- Japanese Friendship Garden
- Kaiser of San Diego
- Korean Chamber of Commerce
- La Prensa Newspaper
- La Raza Lawyers
- Lao Community Culture Center
- Local Initiatives Support Corporation
- MAAC Project
- Mabuhay Alliance
- Macedonia Baptist Church
- MANA de San Diego
- Mt. Carmel Church
- Mt. Erie Baptist Church - Pastors on Point
- Mt. Zion Baptist Church
- Neighborhood House Association
- New Life Baptist Church
- New Paradise Baptist Church
- Nu-Way Christian Ministry
- Otay Mesa Chamber of Commerce
- Pilgrim Progressive Baptist Church
- Qualcomm
- Ridgeview Neighborhood Council
- San Diego and Imperial Counties Labor Council
- San Diego Asian Film Foundation
- San Diego Association of Realtors
- San Diego Building Industry Association
- San Diego Chinese Historical Museum
- San Diego Convention & Visitors Bureau (CONVIS)
- San Diego County Building and Construction Trades Council
- San Diego County Community College District
- San Diego County Farm Bureau
- San Diego County Hispanic Chamber of Commerce
- San Diego County Hotel-Motel Association
- San Diego County Medical Society
- San Diego County NAACP
- San Diego County Veterinary Medical Association
- San Diego Oceans Foundation

- San Diego PTA Unified Council
- San Diego Regional Economic Development Corp.
- San Diego State University
- San Diego Travel Association
- San Diego Unified School District
- San Diego Vietnamese Federation
- San Ysidro Business Association
- San Ysidro Chamber of Commerce
- San Ysidro Health Center
- Scripps Health
- Sempra Energy
- Sierra Club
- South Bay Community Services
- South County Economic Development Council
- Southeastern Economic Development Corp
- St Rita's Catholic Parish
- St. Charles Church
- St. Stephen's Church of God in Christ
- The Greater San Diego Business Association
- The Nature Conservancy
- The San Diego Foundation
- The San Diego Junior Chamber JAYCEES
- The Star News
- Tieng Nuoc Toi Radio, KSON 97.3
- Union of Pan Asian Communities
- United States Green Building Council
- United States Navy League, San Diego Council
- Urban League of San Diego County
- Vietnamese Community Association
- Vietnamese Lions Club
- Volunteer San Diego
- World Trade Center San Diego
- YMCA of San Diego County

Water Purification Demonstration Project

Stakeholder Interview Summary Report

Issues Covered in Interviews

- Level of awareness of water supply issues
- Opinions about need for additional water supplies
- Level of awareness of existing water recycling programs
- Concerns about existing water recycling programs
- Familiarity with indirect potable reuse, reservoir augmentation, or the Water Purification Demonstration Project
- Reasons for support/opposition to indirect potable reuse
- Level of confidence in the City's ability to operate a reservoir augmentation project
- Sources for water-related information
- Methods of communicating with stakeholder groups

Summary of Feedback Received

Water supply
Most of the participants interviewed had a general understanding about the sources of San Diego's water supply. A few interviewees were unsure or requested more information about the source of San Diego's water supply. Many individuals were aware that around 80 percent of San Diego's drinking water supply comes from imported sources and that San Diego has limited local water sources. There was also a general awareness about water supply challenges, such as drought, pumping restrictions, and cost increases. While the understanding of local sources and distribution ranged from basic to very technical, few were uninformed or had no understanding of where their water comes from.

The need for more water
While opinions varied on how to produce or sustain more water in San Diego, most of those interviewed agreed that San Diego needs more water for the future. Options suggested included conservation, desalination, recycled water distribution system expansion, grey water or other natural systems, and indirect potable reuse. None of the participants thought that the status quo was acceptable and all agreed that something has to be done to increase the amount of water available to San Diegans in the future. Controlling population growth was seen as an alternative solution to developing more water sources. A few did not have enough information to comment on the need for water.

Awareness of recycled water
Most of those interviewed were familiar with the recycled water distribution system, but several respondents had limited or no knowledge of it. Of those familiar with the system, most only identified it as "purple pipe." Some lacked an understanding of the water quality and/or treatment of recycled water. Nonetheless, water recycling was viewed by many as necessary in San Diego. A common question was whether the recycled water distribution system can be expanded.

Concerns about the use of recycled water
Water quality and public health or safety, were the top concerns reported by interviewees about both the current and future uses of recycled water. The cost of potable and recycled water was a concern to some of the groups, in particular industrial groups that rely on affordable water to support business and industrial growth. Nevertheless, concerns about cost were primarily deemed irrelevant if the demand for water exceeds San Diego's supply.

Prior knowledge of indirect potable reuse, advanced water treatment or reservoir augmentation
Many of those interviewed had some prior knowledge of indirect potable reuse (IPR) or reservoir augmentation. Participants typically referred to the project as the "Toilet to Tap" project at some point during the interview. While a few participants understood that the moniker is misleading, many participants only had an understanding of the project as "Toilet to Tap." This illustrates the public identity issues and challenges with the project. Also, while a few of the participants were aware of other IPR projects like the Orange County Groundwater Replenishment System, very few participants had a clear understanding of the water purification process or advanced treatment technology.

Support using recycled water for reservoir augmentation as an option
Most stakeholders personally supported reservoir augmentation and the Demonstration Project, but would require more information or would need authorization from their organizational board to formalize their support. A few participants said they are advocates of the project and would be willing to sign a letter of support. Of those that said they did not support the project, most cited concerns about safety. Several people, whether they supported the project or not, also stated a desire to see more data related to the project. Others said they would only approve of potable reuse as a last resort if the City had no other water supply options available.

Confidence in the City's ability to provide safe drinking water through reservoir augmentation
The majority of participants reported medium to high confidence in the City's ability to provide safe drinking water through reservoir augmentation. Some rated their confidence as low, claiming concerns about project budgeting, water rates, response times in case of a problem with the water, human error, and City leadership. On the other hand, many participants responded that the City has provided safe drinking water with the current treatment technology, so they do not doubt the City can continue to provide safe drinking water in the future.

Trusted sources of information on water related issues
A variety of sources were cited by participants when asked where they receive information about water related issues. Newsletters and online media were common sources of information. Other sources of information such as newspapers, radio, trade journals, and word of mouth were mentioned by participants. The San Diego County Water Authority and other water agencies were also cited by some as a source of information. There was a frustration among many with what they perceived as inconsistency in the information or lack of information about water in San Diego.

Many of the participants said the Water Authority and the City of San Diego were the most trusted sources for information on water issues, although a few people expressed that the Water Authority and the City were the sources they would be least likely to trust. Nongovernmental organizations, water experts, community leaders and the media were also listed by some as their most trusted sources.

Information requested by respondents and methods of communication

Most participants requested facts and data from the studies associated with the Demonstration Project including the limnology study, environmental impacts, water quality, job creation, and costs related to both the Demonstration Project and a possible full-scale project. Participants also wanted information on how the cost of reservoir augmentation compares to other water supply options, such as desalination, expanding the recycled water distribution system and continuing to import water. Other requests included information on timelines, health and safety issues, and which areas in the City would receive purified water. Organization leaders also wanted general and simplified information to share with their members who may not be well versed on water issues.

When asked to suggest methods of communicating with stakeholder groups, most organizations interviewed said that they have a website and newsletter and would be happy to share information about the project in some format to their constituents. Also, many participants requested a project presentation or facility tour. Some participants suggested community events and conferences to highlight the project.

AWP Facility Tour Feedback Analysis

The AWP Facility tour feedback analysis can be found in Appendix H, Section 3 – Community Outreach and Tours.

Outreach Metrics Report (March 1, 2010-December 31, 2012)

Water Purification Demonstration Project Outreach Metrics (DRAFT)
(March 1, 2010 - December 31, 2012)

	Goal	Status	2010	Q1 2011	Q2 2011	Q3 2011	Q4 2011	Q1 2012	Q2 2012	Q3 2012	Q4 2012	Total
Research												
Stakeholders interviewed:			99	4	2	N/A	N/A	N/A	N/A	N/A	N/A	105
· Environmental group leaders	5 interviews	Met goal	5	0	0	N/A	N/A	N/A	N/A	N/A	N/A	5
· Multi-cultural groups/orgs	45 interviews	Exceeded goal	60	0	0	N/A	N/A	N/A	N/A	N/A	N/A	60
· Business associations	5 interviews	Exceeded goal	5	1	1	N/A	N/A	N/A	N/A	N/A	N/A	7
· Faith-based organizations	5 interviews	Exceeded goal	16	0	0	N/A	N/A	N/A	N/A	N/A	N/A	16
· Senior/service advocacy groups	3 interviews	Exceeded goal	3	0	0	N/A	N/A	N/A	N/A	N/A	N/A	3
Materials and Tools												
Project newsletters	3/year	Met goal	1	1	1	0	1	1	0	1	1	7
E-updates to key stakeholders	Bi-monthly average	Met goal	1	1	1	1	3	1	0	1	1	10
Project website updates	As needed	As needed	17	7	7	24	16	25	13	5	9	123
Website visits/month	N/A	Tracked website visits	3,414	1,587	1,476	2,847	607*	2,326	1,820	2,275	2,438	19,070 visits
Information/interest cards collected from groups	80%		81	162	104	68	2	402	198	11	28	1,056

	Notes
Research	
Stakeholders interviewed: · Environmental group leaders · Multi-cultural groups/orgs · Business associations · Faith-based organizations · Senior/service advocacy groups	105 stakeholder interviews were conducted. Stakeholder interviews ended in early 2011. In addition to these groups, stakeholder interviews have been conducted with federal elected officials, Native American tribes, utility agencies and a number of organizations in the fields of agriculture, real estate/construction, health care, military, education, and hospitality. For the federal elected officials, M. Steirer met with the staff for senators Boxer and Feinstein and representatives Davis, Bilbray and Filner on Sept. 15 & 16, 2010.
Materials and Tools	
Project newsletters	Published and distributed newsletters on November 29, 2012; July 26, 2012; Jan. 19, 2012; Nov. 1, 2011; June 30, 2011; March 31, 2011; and December 20, 2010. Distribute newsletter through website, email blasts, and making printed copiesavailable at tours, presentations, events, and other opportunities as needed.
E-updates to key stakeholders	Distributed e-updates on Dec. 14, 2012 (holiday e-card; 3,867 contacts); Aug. 7, 2012 (CBS8 coverage; 3,751 contacts); Feb. 10, 2012 (NYT coverage; 2,525 contacts); Dec. 15, 2011 (holiday e-card; 2,236 contacts); Dec. 9, 2011 (social media update; 2,228 contacts); Nov. 7, 2011 (10 News coverage; 2364 contacts); July 18, 2011 (AWP Facility tour invitation; 1,740 contacts); May 31, 2011 (1,209 contacts); February 28, 2011 (808 contacts); and November 23, 2010.
Project website updates	Updated on a regular basis, including project materials, links & resources, news & publications, public involvement information, site layout, tour dates, etc. Between October and December 2012, updated the public involvement and media articles pages.
Website visits/month	December 2012: 702; November 2012: 717; October 2012: 1,019; September 2012: 754; August 2012: 752; July 2012: 769; June 2012: 517; May 2012: 595; April 2012: 708; March 2012: 690; February 2012: 817; January 2012: 819; December 2011: 448; November 2011: N/A (Due to City software licensing, web stats did not track November); October 2011: 159 (Due to City software licensing, web stats only tracked Oct. 1-9); September 2011: 774; August 2011: 1,173; July 2011: 1,180; June 2011: 497; May 2011: 447; April 2011: 532; March 2011: 597; February 2011: 467; January 2011: 523; December 2010: 458 visits; November 2010: 728 visits; October 2010: 638 visits; September 2010: 714 visits; August 2010: 876 visits
Information/interest cards collected from groups	Between October and December 2012, collected 28 cards from community events and speakers bureau presentation. Prior to October 2012, received interest cards from speakers bureau presentations, stakeholder interviews, community events, facility tours, EIS, SDSU research class and other outreach.

	Goal	Status	2010	Q1 2011	Q2 2011	Q3 2011	Q4 2011	Q1 2012	Q2 2012	Q3 2012	Q4 2012	Total
Brief city council district offices	N/A	Briefed mayor and 7 councilmembers.	8	2	1	4	1	3	0	3	2	24 tours/ briefings
Informational items distributed at presentations and stakeholder interviews	1 to each attendee	Distributed informational items	1,397	~300	~350	~480	~120	~190	~170	~140	~350	~3,497
Virtual AWP Facility tour DVDs distributed	N/A	Distributed DVDs and video	N/A	N/A	N/A	N/A	10	~40	0	0	0	~62
Community Outreach and Tours												
Present to chambers of commerce throughout the region	80%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Present to city boards and commissions	100%	Regularly updated NR&C and IROC	7	3	2	2	2	2	2	2	2	24

	Notes
Brief city council district offices	Briefed new councilmembers from districts 5 and 7 in November 2012. In August 2012, provided tours to Councilmember-elect Mark Kersey and staff from Councilmember Alvarez's office. In July 2012, provided tour to staff from Councilmember DeMaio's office. In February 2012, provided AWP Facility tour for CD 4 and 6 Councilmembers and staff. CD 4 posted tour photos on district website. In January 2012, provided AWP Facility tour for CD 7 Councilmember and staff. In December 2011, provided tour of the AWP Facility for CD 4 staff. Provided tours of the AWP Facility for Mayor Sanders and Councilmembers from CD 1, 2, 3, and 8. Briefed CD 8 councilmember in June 2011 in preparation for his speaking role at media day at the AWP Facility. M. Steirer briefed new council members in CD 6 and 8 in January 2011 and provided them with outreach materials and data for their council district. Contacted all council district offices in July 2010 and on the mayor's docket briefing on July 22, 2010.
Informational items distributed at presentations and stakeholder interviews	Fact sheet, FAQ, and info cards were made available to each presentation attendee. (Speakers bureau flier, project newsletter, tour flier, speaker's bio and evaluation form were given only to the point of contact for presentations.)
Virtual AWP Facility tour DVDs distributed	Prior to June 2012, distributed DVDs to OzWater'12 Conference; University of New South Wales/national demonstration education and engagement program; Brisbane water officials; the offices of Senator Vargas; Senator Kehoe; Senator Wyland; Assemblymember Garrick; Assemblymember Hueso; Assemblymember Fletcher; members present during the March 20, 2012, hearing of the Assembly Water, Parks, and Wildlife Committee; San Diego City Councilmembers, Mayor and library PIO; and SDCWA board members. Posted on website, intranet, CityTV and YouTube.
Community Outreach and Tours	
Present to chambers of commerce throughout the region	Present to chambers upon request.
Present to city boards and commissions	Currently plan to meet with NR&C and IROC. Between October and December 2012, provided updates to IROC Outreach and Communications Subcommittee in October and December 2012. Previously, provided updates to NR&C in September, July, May, April and March 2012; October, September, August, May, April, March, and February 2011; and December, October, September, June, April, March, and February 2010. Updated IROC Public Outreach, Education & Customer Service Subcommittee in March 2012 and October 2011. Provided update to IROC E&T Subcommittee in January 2011.

	Goal	Status	2010	Q1 2011	Q2 2011	Q3 2011	Q4 2011	Q1 2012	Q2 2012	Q3 2012	Q4 2012	Total
Community events	1/council district/ year	Participated in all council districts.	2	5	8	3	4	4	13	2	1	42
Orange County Groundwater Replenishment System & West Basin tours	As needed; up to 4/year	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Urban Water Cycle tours	As needed	Conducted tours	N/A	6	11	0	N/A	N/A	N/A	N/A	N/A	17
Advanced Water Purification Facility tours	6/month	Exceeded goal	N/A	N/A	9	79	36	32	34	27	26	243

	Notes
Community events	Hosted informational booths at numerous community events and engaged a number of booth visitors in discussing the project and signing interest cards. The number of overall event attendees and visitors engaged by project staff are listed below. Between October and December 2012, participated in the Filipino-American Festival (11,500 attendees; 259 booth visitors).Prior to July 2012, participated in the San Diego Horticultural Society meeting (300 attendees; 50 booth visitors); Mira Mesa Town Council Street Fair (3,000 attendees; 150 booth visitors); Juneteenth Celebration (2000 attendees; 68 booth visitors); Allied Gardens SpringFest (15,000 attendees; 175 booth visitors); Scripps Ranch Community Fair (2500 attendees; 120 booth visitors); Fiesta de los Penasquitos (18,000 attendees; 77 booth visitors); Clairemont Garden Tour & Expo (600 attendees; 20 booth visitors); Logan Heights Library Earth Day Event (71 attendees; 20 booth visitors); BD Biosciences Earth Day Fair (150-200 attendees; 26 booth visitors); Take Your Sons and Daughters to Work Day (250 attendees; 45 booth visitors); Scripps Research Institute Employee Fair (2000 attendees; 52 booth visitors); City of San Diego Celebrate the Earth (1,000 attendees; 12 booth visitors); EarthFair (60000 attendees; 196 booth visitors); Linda Vista Multicultural Festival (20000 attendees; 368 booth visitors); Qualcomm Earth Day Event (2,000 attendees; 182 booth visitors); the SDSA High Tech Fair (3,000 attendees; 700 booth visitors); Greater San Diego Science and Engineering Fair (750 fair participants; over 100 judges); San Diego Science Festival Expo Day (27,000 attendees; 740 booth visitors); and Rolando Street Fair (8,000 attendees; 79 booth visitors); the Girl Scouts World of Water Workshop (120 attendees; 49 booth visitors), Serra Mesa Community Fair (5,000 attendees; 140 booth visitors), Wesley Methodist Church Health Fair (300 attendees overall, 65 booth visitors), FilAmFest (12,000 attendees overall; 339 booth visitors); Politifest (500 attendees; 50 booth visitors), Mira Mesa Town Council Street Fair (10,000 attendees overall, 200 booth visitors), Fiesta del Sol (60,000 attendees), RiverFest (6,000 attendees), Sally Ride Science Festival (145 attendees), Take Your Daughters and Sons to Work Day (100 attendees), EarthFair (60,000 attendees), Qualcomm Earth Day Fair (1,000 attendees), Lao New Year Fair (2,500 attendees), Science Expo (30,000 attendees), Heritage Festival (11,000 attendees), Chinese New Year Fair (25,000 attendees), Tet Festival (20,000 attendees), Multicultural Festival (20,000 attendees), Executive Square Green Fair, and Little Italy FESTA. Provided materials for distribution at National Public Works Week and Scripps Ranch Green Fair. Continuing to schedule future events.
Orange County Groundwater Replenishment System & West Basin tours	Scheduled upon request. GWRS tour brochures and sign-up forms are provided at AWP Facility tours.
Urban Water Cycle tours	47 guests visited Point Loma Wastewater Treatment Plant and 25 guests visited Alvarado Water Treatment Plant between January and June 2011. Urban Water Cycle tours ended prior to AWP Facility tours.
Advanced Water Purification Facility tours	Hosted 243 tours for a total of 3,244 guests. Between October and December 2012, hosted 26 tours for 462 guests, including members of the general public as well as California-Nevada AWWA Conference guests, water experts from Spain, Public Utilities Department staff, UCSD Medical School students, San Jose Silicon Valley Chamber of Commerce members, middle and high school students, SDSU students, Sustainable Scripps Ranch members, CARCD conference attendees, and California Department of Public Health staff. Entire list of tours available in tour database. Tour feedback available in feedback database.

	Goal	Status	2010	Q1 2011	Q2 2011	Q3 2011	Q4 2011	Q1 2012	Q2 2012	Q3 2012	Q4 2012	Total
Open house training for tour guides	1 prior to opening	Exceeded goal	N/A	N/A	2	N/A	N/A	N/A	N/A	N/A	N/A	2
Social Media, Conferences and Awards												
Present at water industry trade show/conferences	1/year	Exceeded goal	3	2	2	3	4	3	9	4	3	33
Add/update contact database	Monthly or as needed	Updated as new contacts arrive	833 new contacts	640 new contacts	185 new contacts	477 new contacts	390 new contacts	536 new contacts	998 new contacts	81 new contacts	100 new contacts	3,890 contacts
Presentations to all water and wastewater agency boards	All that may get IPR water	100% of agencies	19	0	0	0	1	0	8	0	0	24
Presentations to all cities in the county that would receive water from the AWPF.	100%	N/A	10	0	0	0	0	0	0	0	0	10 cities
Social media monitoring:	N/A	In progress										
Posts/tweets			0	2	0	35	116	306	133	175	149	916
Comments/Mentions			0	0	0	8	11	34	14	15	5	87
Retweets			0	0	0	2	2	20	6	13	11	54

	Notes
Open house training for tour guides	Katz & Associates conducted a presentation skills training for tour guides on June 23, 2011. L. Macpherson held a training meeting on June 2, 2011, to review tour guide script and tour set-up.
Social Media, Conferences and Awar	
Present at water industry trade show/conferences	Developed and submitted abstracts for upcoming conferences. Between October and December 2012, presented at the California Lake Management Society conference in San Diego in October 2012 and presented at the CA-NV AWWA conference in San Diego in October 2012 (two different presentations). Prior to this quarter, presented at the 2012 Annual WateReuse Symposium in Florida in September 2012 (two different presentations), both CA-NV AWWA Desalination Committee Workshops in Foster City and Fountain Valley in August 2012, WateReuse Association webinar in June 2012, WESTCAS conference in June 2012, AWWA ACE 12 in Dallas in June 2012 (three different presentations), WateReuse Reuse & Desalination Research Conference in San Diego in June 2012 (three different presentations), Ozwater'12 in May 2012, WateReuse California conference in Sacramento in March 2012 (presented and hosted a poster display), ASCE Region 9 Annual California Infrastructure Symposium in Sacramento in February 2012, 2011 Potable Reuse Conference in November 2011 in Florida (three different presentations), WEFTEC 11 conference in October 2011 in Los Angeles, ACWA Continuing Legal Education workshop in September 2011 in San Diego, WateReuse Symposium in September 2011 in Phoenix (two different presentations), AWWA ACE 2011 in June 2011 in Washington, D.C. (two different presentations), WateReuse California Annual Conference in March 2011 in Dana Point, the Utilities Management Conference in February 2011, the WateReuse Symposium in September 2010 in Denver, AWWA ACE 2010 in June 2010, and WateReuse California annual conference in March 2010 (presented and staffed an exhibit).
Add/update contact database	Added 100 contacts between October and December 2012. The total number of contacts is 3,890.
Presentations to all water and wastewater agency boards	Invited SDCWA Board of Directors and all member agency GMs, board members and chief engineers to a tour of the AWP Facility in May 2012. Representatives from 13 agencies attended. Presented to the CWA board in December 2011. Presented to Olivenhain Municipal Water District on Nov. 17, 2010. Presented to the SDCWA board meeting on Aug. 26, 2010. The 36-member Water Authority board represents 24 agencies. Presented to the SDCWA member agency GM meeting on Aug. 17, 2010.
Presentations to all cities in the county that would receive water from the AWPF.	Made a full presentation to Metro JPA on Dec. 2, 2010. Cities of Chula Vista, Coronado, Del Mar, El Cajon, Imperial Beach, La Mesa, Lemon Grove, National City, Poway, and San Diego were present. County of San Diego, Otay Water District, Metro TAC and IROC were also present. M. Steirer presented briefly to Metro JPA on Aug. 5, 2010.
Social media monitoring:	PIOs and staff monitor the project Facebook and Twitter sites. Between October and December, the City posted 83 wall updates to Facebook and 66 tweets to Twitter. The public posted 1 comment on Facebook and 4 mentions and 11 retweets on Twitter about the Demonstration Project. In total, the project has made 916 posts or tweets. The public has posted 87 comments or mentions on Facebook and Twitter and 54 retweets on Twitter.
Posts/tweets	
Comments/Mentions	
Retweets	

	Goal	Status	2010	Q1 2011	Q2 2011	Q3 2011	Q4 2011	Q1 2012	Q2 2012	Q3 2012	Q4 2012	Total
Awards earned	N/A	Earned local and national awards.	0	0	0	1	0	1	0	1	1	4
Media Outreach												
Media contact database: create and update	N/A	N/A	82	81	81	81	81	87	87	87	240	270 contacts
Post news articles on project website	Update monthly	Ongoing	20	3	3	10	8	11 posted; 13 pending	13	1	1	83 posted
News releases	3/year	Exceeded goal	N/A	N/A	1	2	2	9	1	3	2	20 releases
Project briefings with editorial staff – community and special interest newspapers	80%	N/A	N/A	N/A	N/A	4	0	1	0	1	0	6
Project briefings with editorial staff – daily papers	100%	Met goal	N/A	N/A	4	3	0	3	0	0	0	9
Template article to community and special interest papers	50% publication rate	Met goal	N/A	N/A	N/A	10	1	7	1	1	0	20 covered

	Notes
Awards earned	Recognized in December 2012 by ACWA as a Best in Blue 2012 finalist for achieving communications excellence. Received the 2012 WateReuse Association Small Project of the Year award in September 2012. Project Director Marsi Steirer received the 2012 WateReuse California Recycled Water Advocate of the Year award in March 2012. Received the 2011 WateReuse Association Public Education Program of the Year award in September 2011.
Media Outreach	
Media contact database: create and update	Have 270 media contacts in all.
Post news articles on project website	Posted 86 related media clips on the project's News and Publications Page. Between October and December 2012, posted KPBS (San Diego seeks a swifter current for water recycling).
News releases	Between October and December 2012, distributed news releases to SDSU and Scripps Ranch for inclusion in their newsletters. Covered in Scripps Ranch Newsletter in December. Prior to October 2012, distributed news release regarding WateReuse Association award, Drinking Water Week and the tour open house in May 2012. Pitched story and provided news releases about tour visits to 13 community papers. Distributed releases in July and September 2011 to entire distribution list. Mayor's Office distributed advisory about AWP Facility opening in June 2011.
Project briefings with editorial staff – community and special interest newspapers	Since 2010, met and/or spoke with reporters from San Diego Monitor, Mission Valley News, Tieng Nuoc Toi Radio (Vietnamese radio), Filipino Press, Epoch Times and GrokSurf blog. [Some of these briefings overlap with the AWPF reporter tour metric.]
Project briefings with editorial staff – daily papers	Since 2010, met and/or spoke with reporters from San Diego Union-Tribune, New York Times and the Atlantic/Wall Street Journal. Previously met and/or spoke with reporters and editors from San Diego Union-Tribune (twice), North County Times, Voice of San Diego, KPBS (twice), and New York Times. [Some of these briefings overlap with the AWPF reporter tour metric.]
Template article to community and special interest papers	Prior to October 2012, distributed template article about the AWP Facility to San Diego Horticultural Society and covered in August 2012 newsletter. Distributed template article about preliminary testing and monitoring results to WateReuse Association's San Diego chapter and covered in May 2012 newsletter. Distributed updated template article about AWP Facility to 82 publications in February 2012. Scoop San Diego/Mission Valley News, ecoBLOGic, WateReuse Association, Alpine Community Network newsletter, Beach and Bay Press, and My Clean Water Act covered the Demonstration Project based on the template article. In March 2012, provided AWP Facility template article to Councilmembers Zapf and Young to include in their newsletters. Council President Young covered the Demonstration Project in his newsletter. US Mayor covered the AWP Facility in December 2011 based on the updated project template article distributed in November 2011. Distributed original template article about the project opening in July 2011 to media list, trade journals and stakeholder newsletters. Mission Times Courier, the Mission Valley News, the La Jolla Light and sister papers, the Emerald News, the San Diego Metro, SCAP Monthly Update, Desalination & Water Reuse, WateReuse Association, WaterTechOnline.com, ACWA News, and AWWA Streamlines covered the AWP Facility based on the template article.

	Goal	Status	2010	Q1 2011	Q2 2011	Q3 2011	Q4 2011	Q1 2012	Q2 2012	Q3 2012	Q4 2012	Total
Advertise AWPF tours in community and ethnic papers	N/A	N/A	N/A	N/A	1	6	0	0	1	1	0	9
Story ideas to science and environmental reporters (print, radio and television), as well as to reporters who write about more general issues	3/year	Exceeded goal	1	2	3	0	1	2	0	2	1	12
AWPF tour for all science and environmental reporters (print, radio and television) , as well as to reporters who write about more general issues	100% attend	N/A	N/A	N/A	1	5	0	3	1	2	1	13
Project articles in stakeholder publications or websites	4/year	Have not met goal	0	0	0	3	0	3	0	0	0	4
PSA production for city cable channel	3 over project life	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Speakers Bureau												
Presentation skills training for all members	N/A	N/A	3	0	1	0	0	1	0	0	0	5
Include presentation contact information on all materials and website	N/A	Included on all info. materials	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Information/Interest cards distributed to members of groups having presentation	100%	100%	59	9	12	13	4	5	7	10	13	132

	Notes
Advertise AWPF tours in community and ethnic papers	Between July and September 2012, advertised AWP Facility tours in the VOSD Monthly magazine. Prior to July 2012, advertised AWP Facility tours on the Voice of San Diego website and emails (June 2012), and in We Chinese in America (August 2011), Filipino Press (August 2011), La Prensa (July 2011), El Latino (July 2011), San Diego Monitor (July 2011), Giving Back Magazine (July 2011), and Voice and Viewpoint (June 2011).
Story ideas to science and environmental reporters (print, radio and television), as well as to reporters who write about more general issues	Worked with reporters to develop "Changing Public Perceptions" (OpFlow, December 2012), "You are Drinking What?" (Wall Street Journal, August 24, 2012), "Wade in the Water" segment (KFMB, August 6, 2012), "As 'Yuck Factor' Subsides, Treated Wastewater Flows From Taps" (New York Times, Feb, 10, 2012) and "Where toilet-to-tap fears circle the drain" (San Diego Union-Tribune, Jan. 21). Prior to January 2012, worked with reporters to develop "Future of Water on Display" (US Mayor, Dec. 19, 2011), "Will Mayor sip purified sewage?" (Voice of San Diego, June 30, 2011), "Wastewater getting new life across county" (UT, May 15, 2011), "San Diego launches landmark water project" (UT, June 30, 2011), "From Toilets to Tap" (USA Today, March 3, 2011), "The yuck factor: Get over it" (UT, Jan. 23, 2011), and "New Source of Drinking Water Hinges on Pilot Project" (UT, Oct. 11, 2010).
AWPF tour for all science and environmental reporters (print, radio and television) , as well as to reporters who write about more general issues	Between October and December 2012, provided AWP Facility tour to Tom Fudge of KPBS (December 10, 2012) . Prior to October 2012, provided tours or visits of the AWP Facility to KFMB, San Diego Monitor, Voice of San Diego, Mission Valley News, Epoch Times, New York Times (twice – reporter and photographer), Filipino Press, Tieng Nuoc Toi Radio (Vietnamese radio), and San Diego Union-Tribune (twice). Held a news conference and offered a tour for media, including science and environmental reporters, on June 30. Local media attended, including Daily Transcript, Voice of San Diego, and television stations (KUSI, KGTV, KFMB, KNSD and Univision).
Project articles in stakeholder publications or websites	Distributed updated AWP Facility tour template article to stakeholders in February 2012. San Diego Coastkeeper and I Love a Clean San Diego published articles. Distributed facility opening article to stakeholder contacts in July 2011. San Diego Coastkeeper and Equinox Center published articles in their newsletters.
PSA production for city cable channel	Will use virtual tour video footage to develop a PSA.
Speakers Bureau	
Presentation skills training for all members	Conducted workshops on June 28, May 25, and May 24, 2010. Held meetings on June 1, 2011 and January 10, 2012, to update speakers bureau staff on AWPF tour promotion and presentation slide edits.
Include presentation contact information on all materials and website	Included the following language: For more information, please call (619) 533-7572 or email purewatersd@sandiego.gov.
Information/Interest cards distributed to members of groups having presentation	Cards were available to all speakers bureau presentation attendees.

Water Purification Demonstration Project Outreach Metrics (DRAFT)
(March 1, 2010 - December 31, 2012)

	Goal	Status	2010	Q1 2011	Q2 2011	Q3 2011	Q4 2011	Q1 2012	Q2 2012	Q3 2012	Q4 2012	Total
Categorize presentations by council district	N/A	Presented in all districts										
Council District 1			6	1	1	4	1	0	0	1	1	15
Council District 2			11	3	3	3	0	0	0	1	3	23
Council District 3			3	1	3	0	0	0	3	0	0	10
Council District 4			3	0	2	2	0	0	2	5	2	16
Council District 5			5	0	0	0	0	0	0	1	3	9
Council District 6			7	1	1	0	2	2	0	0	1	14
Council District 7			10	2	1	0	0	2	0	0	0	15
Council District 8			7	1	1	0	0	0	0	0	0	9
Outside City Boundaries			15	2	1	4	1	1	1	3	3	31
Total			59	9	12	13	4	5	7	10	13	132
Evaluation forms received from groups having presentations	50%	Received 29%.	14	4	9	6	0	2	2	2	2	41
Speaker tracking forms collected	100%	Received 67%.	42	8	11	10	2	3	7	3	0	86
Type of groups that received presentations:		Presented to all types of identified groups										
Environmental	80%		3	1	1	0	0	0	0	2	1	8
Multicultural groups/orgs	50%		3	0	2	0	0	0	0	2	0	7
Business associations/BIDs	50%		3	0	0	0	0	0	0	0	1	4
Senior/service groups	30 groups		0	0	0	0	0	0	1	0	0	1
Civic/social clubs	80%		3	1	5	5	2	1	1	1	0	19
City planning groups	80%		16	2	3	0	0	0	0	2	2	25
Community/recreation councils	80%		17	3	1	3	0	0	4	2	4	34
Religious	N/A		1	0	0	0	0	0	0	0	0	1
Medical	N/A		0	0	0	0	0	0	0	0	0	0
Water Industry	N/A		7	0	0	3	2	1	1	1	2	17
School	N/A		1	1	0	1	0	2	0	0	3	8
Government/Internal City	N/A		5	1	0	1	0	1	0	0	0	8

	Notes
Categorize presentations by council district	Completed 132 presentations, 13 of which were between October and December 2012. Some presentations may be categorized in more than one district.
Council District 1	
Council District 2	
Council District 3	
Council District 4	
Council District 5	
Council District 6	
Council District 7	
Council District 8	
Outside City Boundaries	
Total	
Evaluation forms received from groups having presentations	From the 13 presentations completed between October and December 2012, two evaluation forms were received. 41 forms have been received in all.
Speaker tracking forms collected	From the 13 presentations completed between October and December 2012, 0 speaker tracking forms were received. 86 forms have been received in all.
Type of groups that received presentations:	132 presentations in all have been completed.
Environmental	
Multicultural groups/orgs	
Business associations/BIDs	
Senior/service groups	
Civic/social clubs	
City planning groups	
Community/recreation councils	
Religious	
Medical	
Water Industry	
School	
Government/Internal City	

Water Purification Demonstration Project Outreach Metrics (DRAFT)
(March 1, 2010 - December 31, 2012)

	Goal	Status	2010	Q1 2011	Q2 2011	Q3 2011	Q4 2011	Q1 2012	Q2 2012	Q3 2012	Q4 2012	Total
Stakeholder/Partner Communications												
American Assembly group outreach letter	N/A	Completed in 2010	63	63	63	63	63	63	63	63	63	63 members
Project inquiries received by phone and e-mail and responded to	Track number	Tracked all calls and emails.	2	20	8	61	17	22	26	21	5	182
Internal Department Communication												
Post project updates on the public utilities section of city employee intranet site	2/year	Exceeded goal	N/A	N/A	2	2	2	1	0	1	2	10
Provide one staff education session at employee mtgs/training to each key division of PUD that has public contact	1/year	Exceeded goal	6	0	0	10	0	3	1	0	4	24
Article published in Pipeline	1/year	Exceeded goal	1	1	3	2	1	3	1	0	2	14

	Notes
Stakeholder/Partner Communications	
American Assembly group outreach letter	Sent follow-up email in March 2012 to members reminding them to tour the facility or register for a presentation. Invited members to tours of the AWP Facility in June 2011. Sent outreach letter on Nov. 18, 2010.
Project inquiries received by phone and e-mail and responded to	Does not include those that contacted staff regarding tour reservations.
Internal Department Communication	
Post project updates on the public utilities section of city employee intranet site	Between October and December 2012, posted the Fall 2012 Pure News and an invitation to tour the AWP Facility on the Public Utilities intranet page. Prior to October 2012, posted the Summer 2012, Winter 2012, Fall 2011, Summer 2011, Spring 2011, and Winter 2011 Pure News, the video of the virtual AWP Facility tour and an invitation to tour facility on the Public Utilities intranet site.
Provide one staff education session at employee mtgs/training to each key division of PUD that has public contact	Between October and December 2012, conducted two AWP Facility tours for EMTS Public Utilities staff in October and two AWP Facility tours for Public Utilities staff in December 2012. Prior to July 2012, conducted a tour for the Public Utilities Mentorship program in April 2012, conducted 11 City-employee-only tours. Presented project at the Engineering and Program Management division meeting in August 2011, the Customer Care Solutions Project Team meeting in January 2011, the Public Utilities Executive Team meeting in September 2010, the Employee Services and Internal Controls division meeting in October 2010, three sessions at the Wastewater Fall Classic Annual Training Tailgate in October and November 2010, and the Long-Range Planning & Water Resources division meeting in spring 2010.
Article published in Pipeline	WPDP outreach was covered in December, November, April, March, February and January 2012 issues, October, August, July, June, May, April and March 2011 issues and the December 2010 issue.

Appendix H: Public Outreach and Education

Section 2: Education and Outreach Materials and Tools

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Fact Sheet

Fact Sheet

Water Reuse Program

Water Purification Demonstration Project

The City of San Diego • Public Utilities Department

Water Purification | Demonstration Project

Recycled Water

The City of San Diego has limited local water sources and relies on importing approximately 85 to 90 percent of its water supply. In the past, importing water from the Colorado River and Northern California has been a low-cost, reliable option, but environmental stresses and court-ordered pumping restrictions have continued to reduce the amount of water that can be delivered to San Diego. These circumstances and the threat of further limitations on our water supplies have intensified the need for new sources of water. As part of the City's effort to provide a local and sustainable water supply, the Water Purification Demonstration Project is examining the use of water purification technology to provide safe and reliable water for San Diego's future.

The Demonstration Project is the second phase of a process evaluating ways for the City to increase its use of recycled water. The first phase was the City's 2005 Water Reuse Study that identified reservoir augmentation as the preferred option for developing recycled water sources. The Demonstration Project will determine if reservoir augmentation is a feasible option for San Diego.

Reservoir augmentation is a multi-step process that includes:

- Using water purification technology on recycled water
- Sending the purified water to a reservoir to blend with existing water supplies
- Treating the blended water again to be distributed as drinking water

The Demonstration Project is underway and will conclude in early 2013. During this time, the Advanced Water Purification Facility will operate for approximately one year and will produce 1 million gallons of purified water per day. A study of the San Vicente Reservoir is being conducted to test the key functions of reservoir augmentation and to determine the viability of a full-scale project. No purified water will be sent to the reservoir during the demonstration phase.

The City of San Diego's water resource strategy includes planning, conservation, recycled water, groundwater, water reuse, and watershed and resource protection to help meet future water needs.

An independent advisory panel of experts is providing oversight on project research to determine (1) if the purification process satisfies all water quality, safety and regulatory requirements of the California Department of Public Health, and (2) the behavior of the reservoir and what will happen if the purified water is added. A summary report detailing the results of the Demonstration Project will be provided to the Mayor and City Council. If deemed technically feasible, and following Mayoral and City Council authorization, a full-scale reservoir augmentation project would be implemented.

Potential benefits of implementing Reservoir Augmentation in San Diego:

- Provide a local and sustainable supply of purified drinking water for San Diego
- Improve the quality of water in the San Vicente Reservoir
- Decrease dependence on imported water
- Increase utilization of recycled water
- Provide a supply of water that uses less energy than imported water
- Have a positive impact on the environment by producing less discharge into the ocean and working toward lower carbon emissions

In an effort to keep San Diego citizens informed about this important project, the public outreach program is offering free tours of the Advanced Water Purification Facility and project presentations will be made to groups upon request. For more information, please call (619)533-7572 or email purewatersd@sandiego.gov. To register for a tour please visit www.purewatersd.org.

The City of San Diego

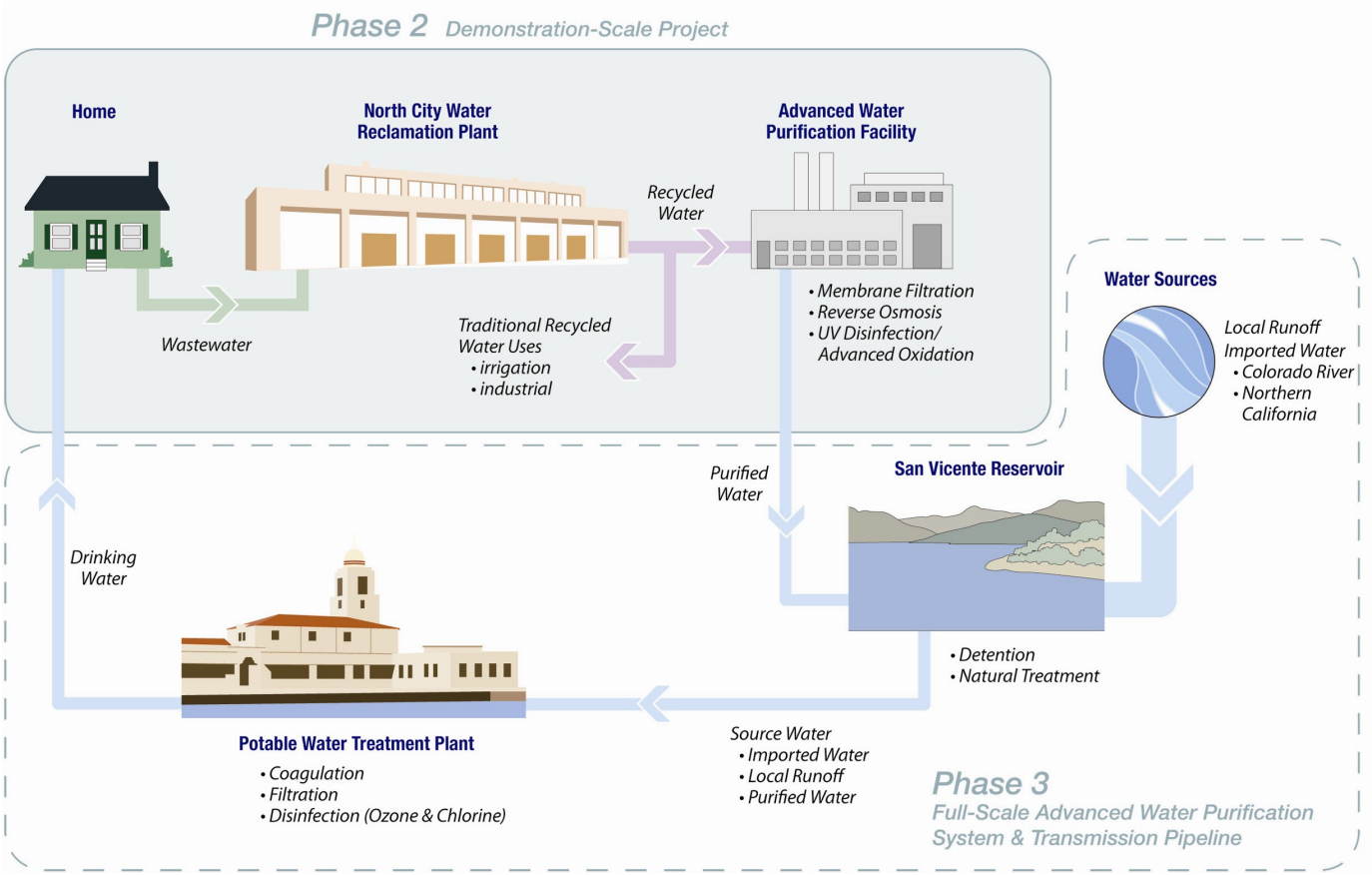
City of San Diego PUBLIC UTILITIES Water & Wastewater

City of San Diego Public Utilities Department • Long-Range Planning & Water Resources Division
600 B Street, Suite 600, San Diego, CA 92101 • (619)533-7572 www.purewatersd.org

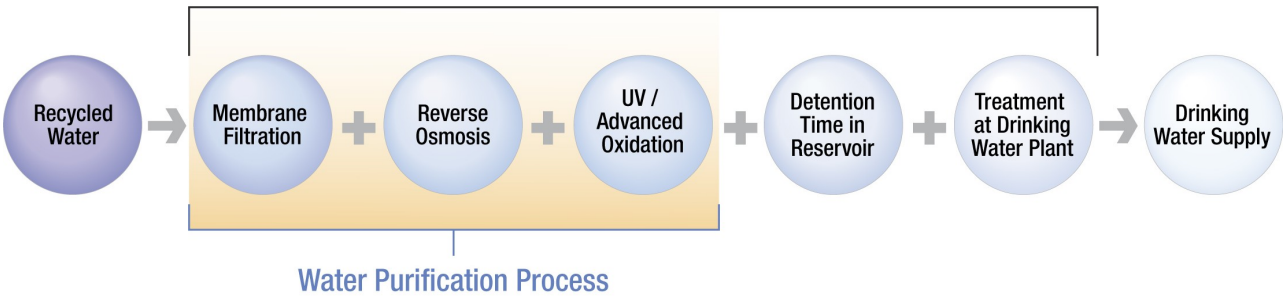
Printed on recycled paper. This information is available in alternative formats upon request.

Public Information Office 5/25/11

Water Purification Demonstration Project
Advanced Water Purification Process



Multi-Barrier Water Treatment Steps



The multiple barrier approach is a proven means to protect public health. Each barrier or step must have frequent and continuous water quality monitoring. Safeguards are built into the process to insure that a failure or error at any given treatment step would not compromise public health.

Fact Sheet

Water Reuse Program

Proyecto de Demostracion de Purificacion de Agua

The City of San Diego • Public Utilities Department

Water Purification | Demonstration Project

Agua Reciclada

La Ciudad de San Diego cuenta con limitados recursos de agua, y tiene que importar aproximadamente entre el 85 y el 90 por ciento de su suministro de agua. En el pasado, la opción de importar agua del Río Colorado y del Norte de California ha sido una opción confiable y baja en costo, pero los retos ambientales y las restricciones impuestas por los tribunales relativas a la posibilidad de bombeo, han contribuído a una reducción adicional sobre la cantidad de agua que puede ser distribuída a San Diego. Dichas circunstancias y la amenaza de limitaciones adicionales sobre nuestro suministro de agua han intensificado la necesidad de identificar nuevas fuentes de agua. Como parte del esfuerzo de la Ciudad en proveer un suministro de agua local y confiable, el Proyecto de Demostración de Purificación de Agua analiza el uso de tecnología avanzada de purificación de agua para proveer agua confiable y segura para el futuro de San Diego.

El Proyecto de Demostración es la segunda fase de un proceso que evalúa las formas en qué la Ciudad puede incrementar su uso de agua reciclada. La primera fase consistió en el Estudio de Reuso de Agua de la Ciudad del 2005, misma que identificó como opción preferida la de aumentar el nivel de agua en los embalses artificiales como vía para desarrollar fuentes de agua reciclada. El Proyecto de Demostración determinará si el aumentar la capacidad de los embalses artificiales es una opción factible para San Diego.

El aumentar el agua en los embalses artificiales es un proceso de múltiples pasos que incluye:

- Utilizar tecnología avanzada de purificación de agua para aguas residuales altamente tratadas.
- Enviar el agua purificada para almacenarse en un embalse artificial para ser mezclado con suministros de agua actuales
- Tratar el agua mezclada nuevamente para ser distribuido como agua potable

Actualmente se lleva a cabo el Proyecto de Demostración, el cual concluirá a principios del 2013. Durante dicho período, las Instalaciones Avanzadas de Purificación de Agua operarán durante aproximadamente un año y producirán 1 millón de galones de agua purificada al día. Se está realizando un estudio del Emabalse Artificial San Vicente para evaluar las funciones claves relacionadas con aumentar la capacidad del agua en los embalses arificiales así como determinar la viabilidad de un proyecto a gran escala. No se enviará agua purificada al embalse artificial durante la fase de demostración.

The City of San Diego's water resource strategy includes planning, conservation, recycled water, groundwater, water reuse, and watershed and resource protection to help meet future water needs.

Un panel asesor independiente integrado por expertos supervisará la investigación del proyecto para determinar si (1º.) el sistema de purificación satisface todos los requisitos de calidad, seguridad y normatividad del agua del Departamento de Salud Pública de California, y (2º.) el comportamiento del embalse artificial y de lo que ocurriría si se agregase el agua purificada. Un informe resumido que detalla los resultados del Proyecto de Demostración se entregará al Alcalde y al Cabildo de la Ciudad de San Diego. Si se considera técnicamente factible y es seguido por la autorización de parte del Alcalde y del Cabildo, se llevaría a cabo un proyecto para aumentar la capacidad del agua en un embalse artificial a gran escala.

Posible beneficios generados al aumentar el agua en los embalses artificiales en San Diego:

- Proveer una fuente local y sustentable de agua potable de alta calidad para San Diego.
- Incrementar el uso de agua reciclada.
- Reducir la dependencia sobre al agua importada.
- Proveer un abastecimiento de agua que utiliza menos energía que el agua importada.
- Mejorar la calidad del agua en el Embalse Artificial de San Vicente.
- Surtir un impacto positivo sobre el medio ambiente al producir menos descarga al mar y trabajar para reducir las emisiones de carbón.

Para mantener informados a los ciudadanos sandieguinos sobre este importante proyecto, el programa de difusión pública ofrecerá recorridos de cortesía de las Instalaciones Avanzadas de Purificación del Agua, y se podrán organizar presentaciones sobre el proyecto a grupos que así lo soliciten. Para mayor información, favor de comunicarse al (619) 533-7572 o enviar un correo electrónico a purewatersd@sandiego.gov.

THE CITY OF SAN DIEGO

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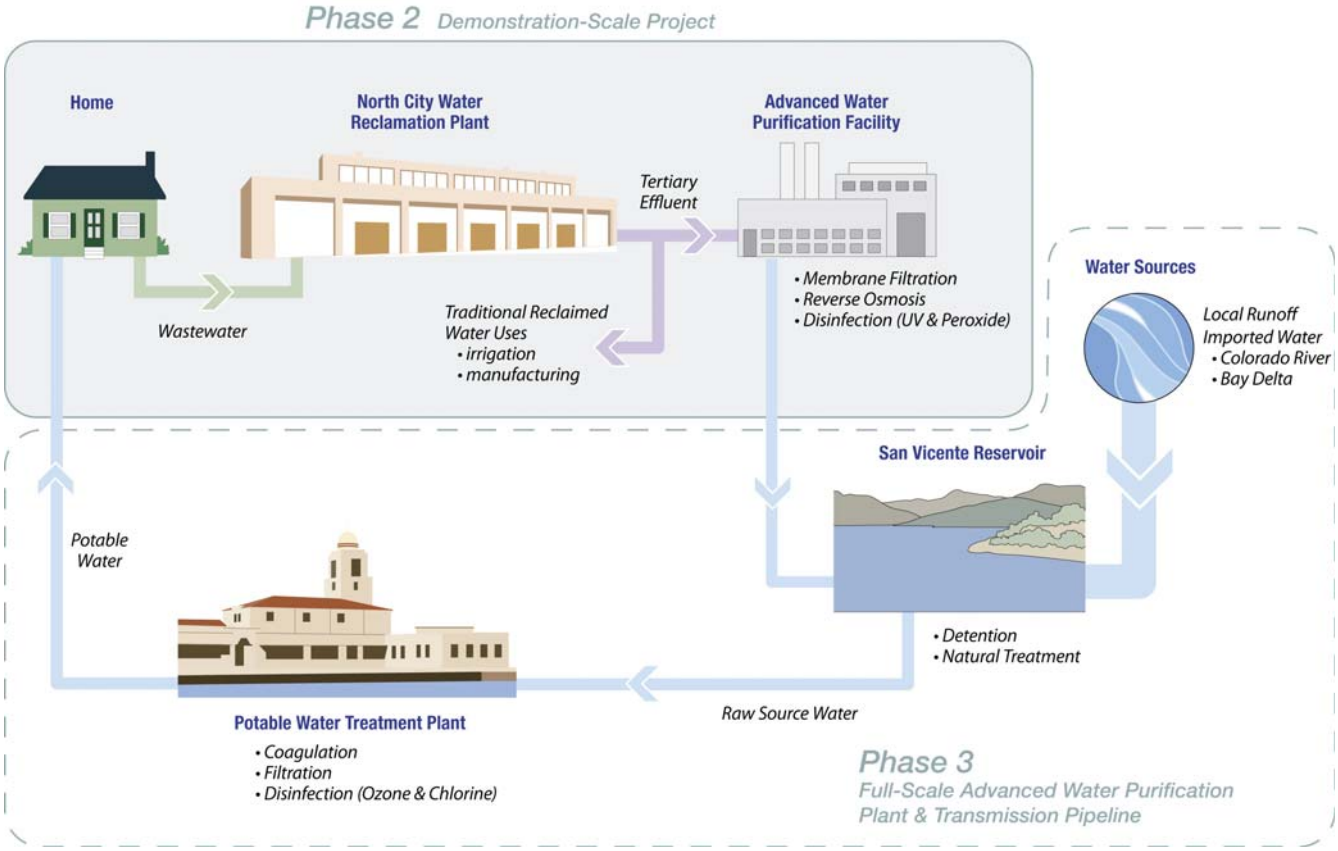
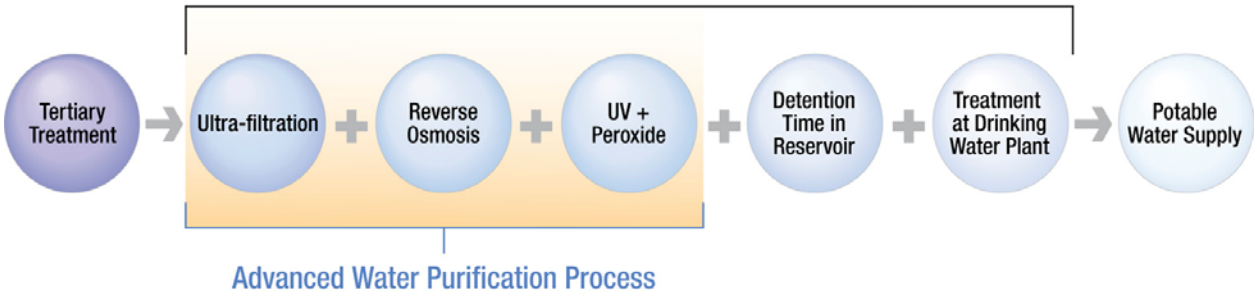
Public Information Office 2/4/11

Proceso Avanzado de Purificacion del Agua



Toda el agua potable se recicla en algún momento. El agua Purificada a Niveles Avanzados se aproxima a la calidad de agua destilada y es más limpia que el agua que actualmente se encuentra en el Embalse Artificial de San Vicente.

Pasos para la Purificación Avanzada del Agua



Fact Sheet

Water Reuse Program

Dự án lọc nước thí điểm
Bản thông tin chung về các giai đoạn

The City of San Diego • Public Utilities Department

Water Purification | Demonstration Project

Recycled Water

Thành phố San Diego có rất ít nguồn cung cấp nước tại địa phương và phụ thuộc vào việc nhập khẩu khoảng 85% đến 90% trong tổng số lượng nước cần để cung cấp. Trong thời gian qua, việc nhập khẩu nước từ sông Colorado và phía Bắc tiểu bang California là một lựa chọn có chi phí thấp, đáng tin cậy; tuy nhiên, những yếu tố gây bất lợi đến môi trường cùng với lệnh giới hạn việc bơm nước từ tòa án đã liên tục làm giảm đi lượng nước có thể đưa vào San Diego. Những thực trạng như vậy và nguy cơ có các hạn chế khác ảnh hưởng đến nguồn cung cấp nước cho San Diego đã làm nhu cầu về việc có những nguồn nước khác thay thế trở nên cấp thiết hơn. Dự án lọc nước thí điểm, một phần trong nỗ lực của Thành phố nhằm tạo nguồn cung cấp nước dài hạn ngay tại địa phương, sẽ xem xét việc sử dụng công nghệ lọc nước tiên tiến để cung cấp nguồn nước an toàn và lâu dài trong tương lai cho San Diego.

Dự án thí điểm là giai đoạn thứ hai của quá trình đánh giá các phương thức giúp Thành phố gia tăng khả năng sử dụng nguồn nước tái chế. Giai đoạn đầu, được thực hiện vào năm 2005 thông qua "*Chương trình nghiên cứu khả năng tái sử dụng nguồn nước*" của Thành phố, đã xác định việc gia tăng lượng nước trong hồ chứa là lựa chọn được ưu tiên dành cho việc phát triển các nguồn nước tái chế. Dự án thí điểm này sẽ quyết định liệu việc tăng lượng nước trong hồ chứa có phải là một lựa chọn khả thi cho San Diego.

Gia tăng lượng nước trong hồ chứa là một quá trình có nhiều bước gồm:

- Sử dụng công nghệ lọc nước tiên tiến để làm sạch nước thải đã qua xử lý kỹ
- Đưa nguồn nước đã được lọc sạch vào hồ chứa để hòa chung với nguồn nước hiện có
- Xử lý lại nguồn nước đã pha trộn để làm nước sinh hoạt đưa đi phân phối

Dự án thí điểm đang được tiến hành và sẽ kết thúc vào đầu năm 2013. Trong thời gian này, hệ thống lọc nước thí điểm (Water Purification Demonstration Facility) sẽ hoạt động trong khoảng thời gian một năm và sẽ sản xuất một triệu galông (gallon) nước được lọc sạch mỗi ngày. Một cuộc khảo sát nghiên cứu về khu vực hồ chứa nước San Vicente (the San Vicente Reservoir) đang được tiến hành để kiểm tra những bước vận hành quan trọng trong quá trình làm tăng lượng nước trong hồ chứa và để đánh giá tính khả thi của toàn bộ dự án. Trong giai đoạn thí điểm, nước sau khi được lọc sạch sẽ không được đưa vào hồ chứa.

A water resource strategy that includes planning, conservation, recycled water, groundwater, water reuse, and watershed and resource protection is helping to meet future water needs.

Một ủy ban cố vấn độc lập gồm các chuyên gia đang giám sát việc nghiên cứu dự án để xác định (1) liệu hệ thống lọc nước có thỏa mãn các yêu cầu về chất lượng, độ an toàn và các quy định của Sở Y Tế tiểu bang California, và xác định (2) trạng thái của hồ chứa và những gì sẽ xảy đến nếu đưa thêm nước được lọc sạch vào hồ chứa. Một bản báo cáo tóm lược gồm chi tiết kết quả của dự án thí điểm sẽ được đệ trình lên ngài Thị trưởng và Hội đồng thành phố San Diego. Nếu được xem là khả thi về mặt khoa học kỹ thuật, và được Hội đồng thành phố và Thị trưởng chấp thuận thì toàn bộ các bước trong dự án bổ sung thêm lượng nước trong hồ chứa sẽ được thực hiện.

Những lợi ích tiềm năng khi thực hiện việc tăng lượng nước trong hồ chứa tại San Diego:

- Cung cấp cho San Diego nguồn nước sinh hoạt chất lượng cao, lâu dài và có sẵn tại địa phương
- Tăng cường hiệu quả sử dụng nước tái chế
- Bớt phụ thuộc vào nước nhập khẩu
- Tạo ra một nguồn cung cấp nước sử dụng ít năng lượng hơn so với nước nhập khẩu
- Cải thiện chất lượng nước trong hồ chứa San Vicente
- Có tác động tích cực đối với môi trường nhờ xả ít chất thải ra biển hơn và góp phần làm giảm chất khí thải carbon

Với nỗ lực nhằm thông báo đến cư dân thành phố San Diego về dự án quan trọng này, chương trình tiếp cận cộng đồng sẽ tổ chức các buổi tham quan (tour) miễn phí "Hệ thống lọc nước thí điểm" (Water Purification Demonstration Facility); và sẽ có những buổi thuyết trình về dự án này cho từng nhóm theo yêu cầu. Để biết thêm thông tin, xin gọi số máy (619) 533-7572 hoặc gửi email theo địa chỉ purewatersd@sandiego.gov.

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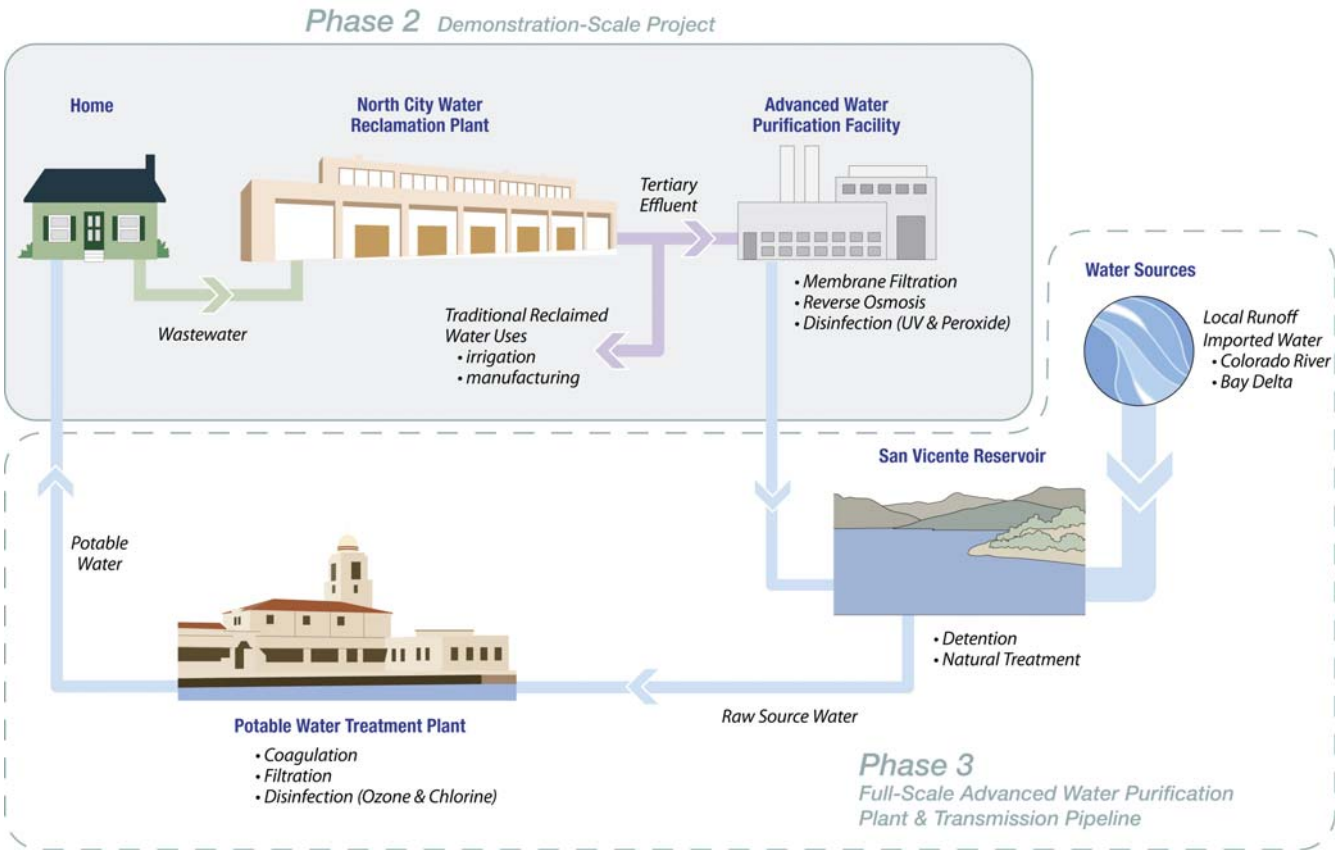
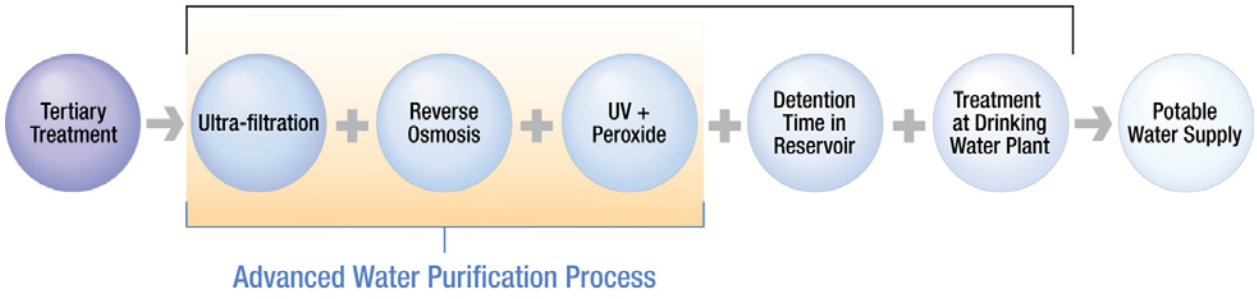
Public Information Office 2/7/11

Water Purification Demonstration Project
Advanced Water Purification Process



Multi-Barrier Water Treatment Steps



The multiple barrier approach is a proven means to protect public health. Each barrier or step must have frequent and continuous water quality monitoring. Safeguards are built into the process to insure that a failure or error at any given treatment step would not compromise public health.

Quick Facts Document

Quick Facts

Water Reuse Program

Water Purification Demonstration Project

The City of San Diego • Public Utilities Department

Water Purification | Demonstration Project

Recycled Water

San Diego's water supply:

- 85-90 percent imported from Northern California and the Colorado River
- Environmental stresses & pumping restrictions make importing water unreliable & expensive
- A 2005 Water Reuse Study identified reservoir augmentation as the preferred option for further developing recycled water sources

Reservoir augmentation:

- Uses water purification technology on recycled water
- Blends purified water with existing supplies in a local reservoir
- Treats the blended water further before distribution as drinking water

San Diego's Water Purification Demonstration Project (Demonstration Project):

- A test project examining the use of water purification technology
- Will determine if reservoir augmentation is a feasible option for San Diego
- Uses a multi-barrier approach in which safeguards insure that a failure at any treatment step would not compromise public health
- Purified water is not added to the drinking water system during this test phase; instead it is returned to the recycled water system

Advanced Water Purification Facility:

- Purifies one million gallons of recycled water per day as part of the Demonstration Project
- Treats recycled water with a multi-barrier process of membrane filtration, reverse osmosis and ultraviolet light/advanced oxidation
- Has hosted numerous tours for local and international visitors since June 2011

The City of San Diego's water resource strategy includes planning, conservation, recycled water, groundwater, water reuse, and watershed and resource protection to help meet future water needs.

Potential benefits of implementing reservoir augmentation in San Diego:

- Provide a local and sustainable supply of purified drinking water
- Improve the quality of water in the San Vicente Reservoir
- Decrease dependence on imported water
- Increase use of recycled water

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Public Information Office 3/8/12

Frequently Asked Questions (FAQ)

FAQ

Water Reuse Program

Water Purification Demonstration Project

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Water Purification | Demonstration Project

North City Water Reclamation Plant

Does San Diego need more water?
Water is essential to our quality of life. The City of San Diego imports approximately 85 to 90 percent of its water supply from Northern California and the Colorado River. For the past few years, California has been affected by a historic dry period and a drought on the Colorado River. In addition, legal and regulatory decisions to protect endangered species in the Sacramento – San Joaquin Delta have resulted in restrictions on the amount of water that can be imported from Northern California. Population projections predict the City will need more water in the future than is used today. Since San Diego is at the end of the imported water pipeline, and receives an average of 10 inches of rain each year, we need to develop local water supplies to secure a reliable supply of water for present and future City of San Diego water customers.

Why can't we just conserve enough water to meet future needs?
Using water wisely through conservation practices should always be the first step in preserving the City's precious water supplies. The average water demand (which includes local surface water, imported water, conservation and recycled water) for the City of San Diego for the last six fiscal years has been approximately 260,000 acre-feet per year. The City's conservation programs have helped reduce its dependence on imported water by saving more than 34,000 acre-feet of drinking water a year. That's enough water to meet the needs of 68,000 average families of four for one year. Nonetheless, by 2030 the City will need an additional 43,000 acre-feet of water per year to meet the needs of current and future public utilities customers. So while conservation is important, efforts to save water need to be combined with other sustainable strategies if we are to have enough water for all of our needs.

The City of San Diego's water resource strategy includes planning, conservation, recycled water, groundwater, water reuse, and watershed and resource protection to help meet future water needs.

Doesn't the City already recycle water?
Yes. The City of San Diego operates two water recycling facilities capable of treating 45 million gallons per day of wastewater to secondary and tertiary treatment levels. Recycled water treated to a secondary level is safe for distribution into the environment, while recycled water treated to a tertiary level undergoes further treatment so the water is safe for use in irrigation and industrial purposes.

The recycled water produced by these plants is primarily used for irrigation and industrial purposes. A separate distribution system of "purple pipes" is required to keep the recycled water separate from drinking water pipelines. Constructing additional purple pipe distribution systems is costly. Also, using recycled water for irrigation is seasonal – it is not used in rainy periods or when it is cooler. This means less than half of all wastewater available for recycling is beneficially reused. The remainder of recycled water is treated to a secondary level and discharged into the ocean. Because of the cost and the limited use of existing recycled water, the City is examining other ways to use more recycled water, including reservoir augmentation.

Does the City plan to use more recycled water?
Yes, the City has a recycled water master plan and is always looking for ways to reuse existing water supplies. In 2005 the City conducted a comprehensive, balanced, impartial and science-based Water Reuse Study of all recycled water opportunities. The study included a public

- more -

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Public Information Office 5/25/2011

participation component and concluded that Indirect Potable Reuse through Reservoir Augmentation was the preferred method of implementing the expanded use of recycled water in San Diego.

The Water Reuse Study was the first phase of the City's plan to expand the use of recycled water. The second phase is now underway to examine the feasibility of reservoir augmentation through a demonstration project.

What is Reservoir Augmentation?
Reservoir augmentation is a multi-step process that is being examined by the Water Purification Demonstration Project. It includes using advanced water purification processes on recycled water which can be blended with existing "raw" water supplies. The Demonstration project will not send purified recycled water to a local reservoir. The concept of Reservoir Augmentation is to add purified recycled water to a local reservoir which can be treated to drinking water standards and distributed to the public.

What is the Water Purification Demonstration Project?
The Demonstration Project is the second phase of the City's plan to expand the use of recycled water. It will evaluate the use of advanced water purification technology and the feasibility of producing water that can be sent to blend with existing water in a local reservoir. The Demonstration Project includes a study of San Vicente Reservoir, research to determine a pipeline alignment, a public outreach education program and the construction and operation of a pilot scale advanced water purification facility.

Is this project toilet-to-tap?
Although "toilet-to-tap" has been used to describe this project in the past, it is not an accurate description. The notion that wastewater can be sent directly to drinking water taps is inaccurate. "Toilet-to-tap" is misleading because it ignores key treatment steps and strict testing requirements that are involved in the recycling process. In California, all forms of water are highly regulated and monitored to ensure safety. Since there is no new water on Earth, all water goes through a natural cycle and is essentially recycled water before it is treated and tested before being sent to drinking water taps. This project is strictly a demonstration and at no point during the demonstration phase will recycled water be distributed to drinking water taps.

What is the latest in water purification technology?
The Demonstration Project is using a state-of-the-art purification process that purifies treated wastewater to a level similar to distilled water quality. This process includes membrane filtration, reverse osmosis, and advanced oxidation through the use of ultraviolet light and hydrogen peroxide. The resulting purified water is of higher quality than existing raw water sources and can be used as a locally controlled source to augment reservoir supplies.

Is reservoir augmentation safe?
Yes. There are many public health protection steps that must be taken before highly purified recycled water can be used for reservoir augmentation. A state-of-the-art process of water purification produces water that is similar to distilled water quality. After this water is put in the reservoir, it blends with existing supplies of untreated or raw water. All water that is distributed to public drinking water taps must meet strict state and federal drinking water standards. Water stored in open reservoirs (lakes) is processed through a drinking water treatment plant. After this final treatment, the water meets drinking water standards before it can be distributed to homes and businesses. The water treatment and distribution system is also monitored regularly to ensure safety.

Will recycled water be added to our drinking water now?
No. The Demonstration Project will test the key functions of reservoir augmentation on a small scale and no recycled water will be sent to the reservoir or distributed to customers during the demonstration phase. The City will operate a pilot scale facility for at least one year to analyze water quality and monitoring methods. At the same time, an independent advisory panel of experts will provide oversight of project research to determine if the treatment system meets all water quality, safety and regulatory requirements necessary to determine the viability of a full-scale project.

What are the benefits of reservoir augmentation?
Reservoir augmentation can provide a locally controlled, drought-proof supply of high-quality water. If implemented, a full-scale project will increase the utilization of recycled water and save energy by reducing San Diego's dependence on imported water. Reservoir augmentation could also improve the water quality in the San Vicente Reservoir and have a positive impact on the environment by producing less discharge into the ocean.

Would you like to know more?
In an effort to keep San Diegans informed about this important project, the public outreach program is offering free tours of the Advanced Water Purification Facility and project presentations will be made to groups upon request.

For more information, please call (619)533-7572 or email purewatersd@sandiego.gov.

To register for a tour, please visit www.purewatersd.org.

FAQ

Water Reuse Program

Proyecto de Demostracion de Purificacion de Agua

The City of San Diego • Public Utilities Department

Water Purification | Demonstration Project

North City Water Reclamation Plant

Requiere San Diego de un mayor abastecimiento de agua?
El agua es esencial para nuestra calidad de vida. La Ciudad de San Diego (Ciudad) importa aproximadamente entre el 85 y el 90 por ciento de su suministro de agua del Norte de California y del Río Colorado. Durante los últimos años, California ha sido afectado por un período histórico árido, así como por una sequía en el Río Colorado. Adicionalmente, las decisiones legales y normativas a favor de la protección de las especies en peligro de extinción en la Delta San Joaquin – Sacramento, han generado restricciones sobre la cantidad de agua que se podrá importar del Norte de California. Proyecciones demográficas pronostican que la Ciudad necesitará más agua en futuro que la cantidad que se consume hoy día. Siendo que San Diego se encuentra al final del sistema de conducción de agua importada, y que, en promedio, recibe 10 pulgadas de lluvia cada año, tendremos que desarrollar todas las posibles fuentes de agua locales para garantizar un suministro confiable de agua para residentes y negocios sandieguiños actuales y futuros.

Porqué no podemos simplemente conservar más agua?
El primer paso en la protección de nuestro suministro local de agua siempre debe ser consumir menos agua por medio de la conservación. Los programas de conservación de la Ciudad han logrado reducir nuestra dependencia sobre el agua importada generando ahorros de más de 33,000 pies-acre de agua potable en forma anual, que resulta ser cantidad suficiente para satisfacer las necesidades de aproximadamente 66,000 familias típicas durante un año. Sin embargo, reconociendo la importancia de la conservación, las iniciativas para generar ahorros en el consumo del agua tendrán que combinarse con otras estrategias sustentables para cubrir las necesidades de agua que San Diego tendrá en un futuro.

Actualmente recicla agua La Ciudad?
Sí. la Ciudad opera dos instalaciones para producir agua reciclada, mismas que son capaces de tratar 45 millones de galones de aguas negras a niveles secundarios y terciarios. Agua reciclada tratada a niveles secundarios se puede descargar al medio ambiente, mientras que agua tratada a niveles terciarios pasa por un tratamiento adicional, es entonces donde el agua se puede utilizar para riego y usos industriales.

El uso primordial de el agua reciclada producida en estas plantas es para uso de riego o industrial. La distibucion de agua reciclada requiere de un sistema de conducción independiente del sistema de agua potable, para diferenciarlo, la tubería de agua reciclada es morada, construir otro sistema de agua es costoso. Ademas, el uso de agua reciclada para riego es por temporadas, existe menos uso durante época de lluvia o de frio. Esto significa que menos de la mitad de aguas negras disponible se usa y es tratada a niveles terciarios, el resto solo es tratada a niveles secundarios y tirada al mar. Por el costo y el uso limitado de el aguay reciclada, la Ciudad esta analizando otras formas de usar agua reciclada, incluyendo la posibilidad de mandar agua reciclada a las presas.

The City of San Diego's water resource strategy includes planning, conservation, recycled water, groundwater, water reuse, and watershed and resource protection to help meet future water needs.

Cuenta la Ciudad con un plan de consumo de agua reciclada?
Sí, la Ciudad cuenta con un plan maestro para el uso de agua reciclada, y siempre está al pendiente de identificar formas en que se pueda reutilizar el suministro de agua existente. En el 2005 la Ciudad realizó un Estudio de Reuso de Agua que abarco todas las oportunidades para reutilizar el agua reciclada, basado en una metodología científica que fuera completa, equilibrada e imparcial. El estudio integró un componente de participación pública y concluyó que la Reutilización Indirecta de Agua Potable a base de Aumentar los Niveles de Agua en las Presas, sería el método preferido para ampliar el mayor uso de agua reciclada en San Diego.

- more -

THE CITY OF SAN DIEGO

City of San Diego PUBLIC UTILITIES Water & Wastewater

City of San Diego Public Utilities Department • Long-Range Planning & Water Resources Division
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El Estudio de Reuso de Agua representó la primera etapa del plan de la Ciudad en ampliar el uso de agua reciclada. La segunda fase actualmente se realiza con un proyecto de demostracion donde se analiza la factibilidad de aumentar los niveles de agua en las presas.

En qué consiste el Aumentar los Niveles de Agua en una presa?
El proceso de aumentar los niveles de agua en las presas abarca múltiples pasos, mismos que actualmente están siendo analizados por el Proyecto de Demostración de Purificación de Agua. Incluye utilizar procesos avanzados de purificación de agua utilizando agua reciclada que podrá mezclarse con los suministros de aguas crudas actuales. El proyecto de Demostración no enviará agua reciclada purificada a una presa local. El concepto de aumentar los niveles de agua en una presa es agregar agua reciclada purificada a una presa local que podrá ser sometido a un tratamiento para cumplir con estándares locales de agua potable y ser distribuida al público.

En qué Consiste el Proyecto de Demostracioń de Purificación de Agua?
El Proyecto de Demostración es la segunda fase del plan de la Ciudad en ampliar el uso de agua reciclada. Este evaluará el uso de tecnología avanzada para la purificación de agua y la factibilidad de producir agua que podrá ser distribuída para mezclarse con agua actual en una presa local. El Proyecto de Demostración incluye un estudio de la Presa de San Vicente, investigación para determinar la alineación con el sistema de conducción, un programa de difusión al publico y la construcción y operación de una instalación avanzada de purificación de agua a nivel piloto.

Es este proyecto "del escusado a la llave" (toilet- to-tap)?
Aunque el uso de "del escusado a la llave" ("toilet- to- tap")el escusado a la llave") ha sido usado en el pasado par describir este proyecto , la descripción no es correcta. La idea que las aguas negras se puedan enviar directamente a la llave de agua potable es errónea tratándose de cualquier proyecto de agua reciclada, ya que deja fuera los pasos claves de tratamiento así como los análisis rigurosos requeridos. En California, todo tipo de agua es altamente regulada y monitoriada para asegurar la salud publica. Ya que no hay nuevas fuentes de agua en el mundo, toda el agua pasa por un proceso natural y básicamente es agua reciclada antes de ser tratada y analisada antes de ser enviada a la llaves de agua. Este proyecto es estrictamente un proyecto de demostración y en ningún momento se enviara agua reciclada a las llaves de agua.

Cual es la tecnología mas avanzada de la purificación de agua ?
La purificación de agua avanzada es un proceso vanguardista que purifica las aguas negras sumamente tratadas hasta lograr un nivel de calidad similar a el de agua destilada. Este proceso incluye filtración por membranas, ósmosis inversa, y la desinfección a través del uso de luz ultra violeta y peróxido. El agua purificada que resulte es de mayor calidad que las fuentes actuales de aguas crudas, y podrá utilizarse como una fuente localmente controlada para incrementar el abastecimiento de agua en las presas.

Es un proceso seguro ell aumentar los niveles de agua en las presas?
Sí. Existen muchos pasos para la protección de la salud pública que deberán cumplirse antes de que el agua reciclada altamente purificada se pueda utilizar en aumentar los niveles de agua en las presas. Un proceso con tecnología de punta en la purificación de agua produce agua que cumple con niveles de calidad de agua destilada. Después de que está agua se envía a la presa, se mezcla con el abastecimiento de agua actual de aguas crudas o no tratadas. Toda el agua que se distribuya a las llaves de agua deberá cumplir con estrictos estándares de agua potable a nivel estatal y federal. El agua es almacenada en depósitos abiertos (lagos) y se procesa a través de una planta de tratamiento de agua potable que elimina todas las sustancias nocivas. Después del tratamiento final, el agua cumplirá con estándares de agua potable antes de que pueda ser distribuida a casas residenciales o negocios. El sistema de tratamiento y conducción de agua se monitorea regularmente para garantizar la seguridad publica.

Se incorporará el agua reciclada a nuestra agua potable ahora?
No. El Proyecto de Demostración analizará las funciones claves mediante las cuales se aumentará el nivel de agua en las presas a pequeña escala y no se enviará agua reciclada a ninguna presa ni se distribuirá a los clientes durante la fase de demostración. La Ciudad operará esta instalación a escala piloto por lo menos durante un año para analizar las operaciones. Al mismo tiempo, un panel asesor independiente integrado por expertos supervisará la investigación del proyecto para determinar si el sistema de tratamiento cumple con todos los requisitos de calidad de agua, seguridad y los reglamentos necesarios para determinar si un proyecto a gran escala sería viable.

Cuáles son las ventajas de aumentar los niveles de agua en los reservorios?
El aumentar los niveles de agua en las presas ofrece maneras de control local, contra sequias el suministro de agua de alta calidad. Si esto es implementado, un proyecto a gran escala, incrementara la utilización de agua reciclada y generara ahorros de energía al reducir la dependencia que San Diego tiene sobre al agua importada. El aumentar los niveles de agua en las presas también podría mejorar la calidad de agua en el Presa San Vicente así como generar un impacto positivo al medio ambiente al producir menos descarga de aguas negras parcialmente tratadas al mar.

Desea mayor información?
El personal de la ciudad quiere llegar con su mensaje al mayor número de sandieguinos y presentarles información sobre el Proyecto de Demostración a su organización.

FAQ

Water Reuse Program

Dự án lọc nước thí điểm
Các câu hỏi thường gặp

The City of San Diego • Public Utilities Department

Water Purification | Demonstration Project

North City Water Reclamation Plant

Thành phố San Diego có cần thêm nước?
Nước là yếu tố không thể thiếu cho chất lượng cuộc sống. Thành phố San Diego nhập khẩu từ miền Bắc tiểu bang California và sông Colorado khoảng 85% đến 90% trong tổng lượng nước cần để cung cấp. Trong vài năm qua, tiểu bang California đã bị ảnh hưởng bởi thời kỳ khô hạn hiếm thấy từ trước đến nay và một đợt hạn hán xảy đến cho sông Colorado. Bênh cạnh đó, những quyết định pháp lý và mang tính bắt buộc để bảo vệ các loài động thực vật đang bị đe dọa tại vùng châu thổ Sacramento - San Joaquin (Sacramento - San Joaquin Delta) đã dẫn đến hạn chế về lượng nước có thể được nhập khẩu từ miền Bắc California. Những thống kê dự đoán về dân số cho thấy Thành phố sẽ cần nhiều nước hơn trong tương lai so với lượng nước được sử dụng hiện nay. Vì San Diego nằm ở khu vực cuối của đường ống dẫn nước nhập khẩu, và có lượng mưa trung bình mỗi năm vào khoảng 10 inch, chúng ta cần phải phát triển tất cả các nguồn cung cấp nước có thể sử dụng được ngay tại địa phương để bảo đảm việc cung cấp nước lâu dài cho dân cư và các doanh nghiệp trong hiện tại và tương lai ở San Diego.

Tại sao chúng ta không thể tiết kiệm nước nhiều hơn (như là một cách để có thêm nước)?
Sử dụng nước ít hơn bằng cách tiết kiệm luôn là bước đầu tiên trong việc bảo vệ nguồn cung cấp nước địa phương của chúng ta. Những chương trình tiết kiệm nước của Thành phố đã giúp giảm sự phụ thuộc của chúng ta vào nước nhập khẩu bằng cách tiết kiệm được hơn 33 ngàn acre-feet (33,000 acre-feet) nước dùng cho sinh hoạt một năm, đủ để đáp ứng nhu cầu sử dụng nước cho một năm của khoảng 66 ngàn hộ gia đình. Tuy nhiên, trong lúc việc bảo tồn nước là quan trọng, những nỗ lực để tiết kiệm nước cần được kết hợp với các chiến lược dài hạn khác để đáp ứng nhu cầu sử dụng nước của San Diego trong tương lai.

Không phải là Thành phố đã sử dụng nước tái chế rồi?
Đúng. Thành phố San Diego điều hành hai hệ thống hiện đại tái xử lý nước có khả năng sản xuất gần 45 triệu gallon nước tái chế một ngày nhằm mục đích phục vụ cho trồng trọt và các hoạt động công nghiệp. Việc phân phối nước tái chế đòi hỏi một hệ thống đường ống dẫn riêng bao gồm những ống màu tím để phân biệt với các đường ống dùng để dẫn nước sinh hoạt. Hệ thống phân phối nước tái chế của thành phố hiện đang tiếp tục được mở rộng. Tuy nhiên, việc sử dụng nước tái chế cho trồng trọt chỉ mang tính mùa vụ; do đó, lượng nước dư được thải ra biển trong suốt những mùa mưa. Xây dựng hệ thống dẫn nước với đường ống màu tím lại tốn kém, do vậy thành phố đang xem xét những phương cách khác để sử dụng được nhiều nước tái chế hơn, trong đó gồm có cả việc tăng lượng nước tích trữ trong hồ chứa.

The City of San Diego's water resource strategy includes planning, conservation, recycled water, groundwater, water reuse, and watershed and resource protection to help meet future water needs.

Thành phố hiện đã có kế hoạch cho việc sử dụng nước tái chế chưa?
Có, Thành phố có một kế hoạch tổng thể về sử dụng nước tái chế và luôn tìm cách để tái sử dụng nguồn nước hiện có. Năm 2005, Thành phố tiến hành một cuộc nghiên cứu tái sử dụng nước chi tiết toàn diện, khách quan, dựa trên các thông số và mang tính khoa học nhằm xem xét tất cả những cơ hội sử dụng nước tái chế. Cuộc nghiên cứu thăm dò đó có cả phần tham gia của công chúng và đi đến kết luận rằng "Kế hoạch gián tiếp dùng lại nguồn nước lưu động" (Indirect Potable Reuse) hay còn được gọi là "Tăng lượng nước được tích trữ trong hồ chứa" là phương pháp ưu tiên để thực hiện quá trình mở rộng việc sử dụng nước tái chế tại San Diego.

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Điều gì đã được thực hiện từ khi có cuộc nghiên cứu tái sử dụng nước vào năm 2005?
Cuộc nghiên cứu tái sử dụng nước là giai đoạn đầu trong kế hoạch của Thành phố nhằm mở rộng việc sử dụng nước tái chế. Giai đoạn thứ hai đang được tiến hành để kiểm tra tính khả thi của việc tăng lượng nước tích trữ trong hồ chứa thông qua một dự án thí điểm.

"Tăng lượng nước tích trữ trong hồ chứa" là một quá trình như thế nào?
Việc tăng lượng nước tích trữ trong hồ chứa là một quá trình gồm nhiều bước đang được khảo sát thông qua Dự án lọc nước thí điểm. Quá trình đó bao gồm việc sử dụng các quy trình lọc nước tiên tiến để làm cho nước tái chế có thể pha trộn được với nguồn nước "tự nhiên" hiện có. Dự án thí điểm sẽ không đưa nước tái chế được lọc sạch vào một hồ chứa nào tại địa phương. Khái niệm của quy trình "Tăng lượng nước tích trữ trong hồ chứa" là nhằm đưa thêm nước tái chế sau khi được tinh lọc vào hồ chứa địa phương để có thể được xử lý theo tiêu chuẩn nước sinh hoạt và phân phối cho cộng đồng.

"Dự án lọc nước thí điểm" thực ra là gì?
Dự án thí điểm là giai đoạn thứ hai trong kế hoạch của Thành phố nhằm mở rộng việc sử dụng nước tái chế. Dự án sẽ đánh giá việc sử dụng công nghệ lọc nước tiên tiến và tính khả thi của việc xử lý nước để có thể đưa vào pha trộn với nước hiện có trong hồ chứa địa phương. Dự án thí điểm bao gồm nghiên cứu đánh giá hồ chứa nước San Vicente, nghiên cứu để xác định đường liên kết ống dẫn nước, chương trình tiếp cận cộng đồng nhằm phổ biến thông tin, và xây dựng cũng như vận hành thử nghiệm một hệ thống lọc nước tiên tiến.

Có phải đây là dự án biến nước thải thành nước dùng trong sinh hoạt?
Không, dự án này hoàn toàn là một khảo sát thí điểm và sẽ không có lượng nước tái chế nào được phân phối đến nguồn nước dùng cho sinh hoạt vào bất kỳ thời điểm nào trong quá trình của dự án. Hơn nữa, việc tin rằng nước thải có thể được đưa trực tiếp đến các vòi nước dùng cho sinh hoạt là hiểu biết sai lệch về bất kỳ dự án nước tái chế nào vì nhận định như vậy đã bỏ qua các bước xử lý then chốt và các quy định kiểm tra nghiêm ngặt. Tại California, tất cả các loại nước đều được quy định và giám sát chặt chẽ để đảm bảo độ an toàn. Do không có nguồn nước mới trên trái đất, tất cả các loại nước trải qua một quá trình xử lý theo tự nhiên và được tái sinh một cách tất yếu trước khi được xử lý và kiểm tra thông qua một số quy trình, rồi sau đó được đưa đến các vòi nước dùng sinh hoạt hằng ngày.

Thế nào là "Lọc nước tiên tiến"?
Lọc nước tiên tiến là một quá trình phức tạp về mặt kỹ thuật để thanh lọc kỹ lưỡng nước thải đạt đến chất lượng nước cất. Quá trình này bao gồm xử lý qua màng lọc, thẩm thấu ngược, và khử trùng thông qua việc sử dụng tia cực tím và chất per-oxyt. Nước tinh khiết sau khi xử lý có chất lượng cao hơn nguồn nước "tự nhiên" hiện có và có thể sử dụng như nguồn nước được kiểm soát tại địa phương để tăng thêm nguồn cung cấp nước cho hồ chứa.

Việc tăng lượng nước tích trữ trong hồ chứa có an toàn không?
Có. Có rất nhiều bước bảo vệ sức khỏe cộng đồng phải được thực hiện trước khi nước tái chế được tinh lọc kỹ, có thể được sử dụng để đưa vào hồ chứa làm tăng lượng nước tích trữ. Một quá trình lọc nước dùng kỹ thuật cao sẽ tạo ra nguồn nước có chất lượng như nước cất. Sau khi loại nước này được đưa vào hồ chứa, nó được pha trộn với nguồn nước tự nhiên sẵn có chưa qua xử lý hay còn gọi là nước "thô". Toàn bộ lượng nước được đưa đến các vòi nước phục vụ cho sinh hoạt của người dân phải đáp ứng các tiêu chuẩn nghiêm ngặt về nước uống của tiểu bang và liên bang. Nước được lưu trữ trong các hồ chứa lộ thiên được xử lý qua một nhà máy xử lý nước dùng sinh hoạt nhằm loại bỏ tất cả các chất có hại. Sau bước xử lý cuối cùng, nguồn nước sẽ đáp ứng được tiêu chuẩn của nước uống trước khi nó có thể được phân phối cho các gia đình và doanh nghiệp. Việc xử lý nước và hệ thống phân phối cũng được giám sát định kỳ thường xuyên để đảm bảo độ an toàn.

Có phải nguồn nước tái chế sẽ được bổ sung vào nước sinh hoạt của chúng ta hiện nay?
Không. Dự án thí điểm sẽ kiểm tra các bước vận hành quan trọng của quá trình tăng cường lượng nước tích trữ cho hồ chứa trên một quy mô nhỏ và sẽ không có lượng nước tái chế nào được đưa vào hồ chứa hay phân phối cho người sử dụng trong giai đoạn thí điểm. Thành phố sẽ điều hành một hệ thống thử nghiệm trong vòng ít nhất một năm để phân tích các hoạt động. Đồng thời, một hội đồng tư vấn độc lập bao gồm các chuyên gia cũng giám sát việc nghiên cứu của dự án để xem xét liệu hệ thống xử lý có đáp ứng được các yêu cầu về chất lượng nước, độ an toàn và quy định pháp lý cần thiết để quyết định tính khả thi của toàn bộ dự án đầy đủ các giai đoạn.

Có những lợi ích gì trong việc tăng lượng nước tích trữ trong hồ chứa?
Việc tăng lượng nước tích trữ trong hồ chứa có thể tạo ra một nguồn cung cấp nước chất lượng cao có thể kiểm soát tại địa phương và chống lại hạn hán. Nếu được thực hiện, một dự án hoàn chỉnh với đầy đủ các giai đoạn sẽ làm tăng khả năng sử dụng nước tái chế và tiết kiệm năng lượng bằng cách giảm sự phụ thuộc của San Diego vào nguồn nước nhập khẩu. Tăng lượng nước tích trữ trong hồ chứa cũng có thể cải thiện chất lượng nước ở khu vực hồ chứa San Vicente và có một tác động tích cực đến môi trường nhờ xả ít chất thải hơn ra biển.

Bạn cần biết thêm thông tin?
Nhân viên làm việc cho Thành phố đang tiếp cận với càng nhiều cư dân San Diego càng tốt để trình bày về dự án thí điểm này. Chúng tôi mong muốn được đến tận nơi để cung cấp cho bạn thêm thông tin về việc tăng lượng nước tích trữ trong hồ chứa. Xin vui lòng gọi đến số điện thoại (619) 533-7572 hoặc vào trang web của dự án tại địa chỉ www.purewatersd.org để biết thêm thông tin.

Information (Fact) Card

THE CITY OF SAN DIEGO

Water Purification | Demonstration Project

www.purewatersd.org

Potential benefits of the Demonstration Project

- Provide a local and sustainable supply of high-quality drinking water for San Diego
- Increase utilization of recycled water
- Decrease reliability on imported water
- Provide a supply of water that uses less energy than imported water
- Improve the quality of water in the San Vicente Reservoir
- Have a positive impact on the environment by producing less discharge into the ocean & working toward lower carbon emissions

2011 City of San Diego Public Utilities

Did You Know...

1. San Diego needs to develop local, reliable and sustainable sources of water to lessen our dependence on imported water due to multiple factors affecting California's water supply.
2. The Water Purification Demonstration Project is examining the use of advanced water purification technology on high-quality recycled wastewater to determine the feasibility of a full-scale reservoir augmentation project in the future.
3. The water produced by the purification process goes through multiple steps of advanced treatment and will be tested to meet all water quality, safety and regulatory requirements.*

* No purified water will be added to the San Vicente Reservoir or San Diego's drinking water system during the Demonstration Project.

(619) 533-7572

purewatersd@sandiego.gov

City of San Diego
PUBLIC UTILITIES
Water & Wastewater

Printed on recycled paper. This information is available in alternative formats upon request.

Interest and Information Card

The latest version of the card is displayed. Similar cards with varying formatting were developed for events.

Water Purification | Demonstration Project

THE CITY OF SAN DIEGO

City of San Diego PUBLIC UTILITIES Water & Wastewater

INFORMATION CARD

Please check all that apply:

- ☐ I am **interested** in the Water Purification Demonstration Project as a reliable local water source.
- ☐ I would like a project representative to make a **presentation to my organization**.
- ☐ I would like to receive **periodic updates** about the Demonstration Project.
- ☐ I **support** the City of San Diego pursuing the Demonstration Project.

Please send information to:

Name:_____ Organization: _____

Address: _____

City: _____ State: _____ Zip: _____

Phone: _____ E-mail: _____

purewatersd@sandiego.gov • (619) 533-7572 • www.purewatersd.org

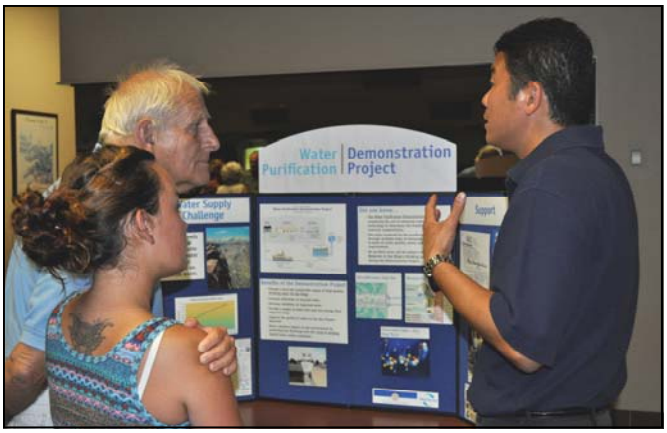
Website

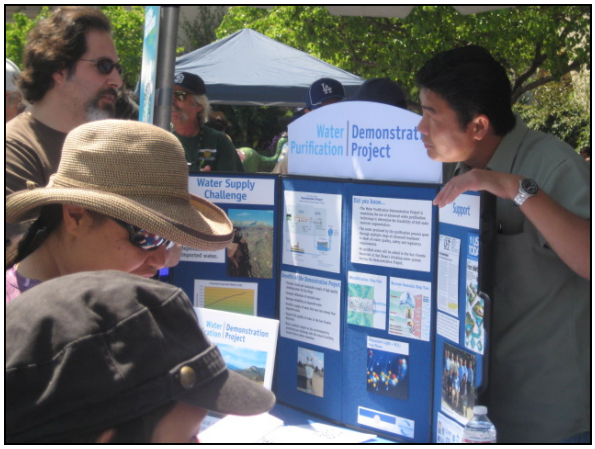
The screenshot is from February 2012 of the home page for the Water Purification Demonstration Project website.

WATER PURIFICATION DEMONSTRATION PROJECT
WEBSITE HOME PAGE (WWW.PUREWATERSD.ORG)

Photographs

Community Events





Advanced Water Purification Facility Tours

eUpdate

E-Update

Water Reuse Program

Water Purification Demonstration Project

The City of San Diego • Public Utilities Department

Water Purification | Demonstration Project

The City of San Diego's water resource strategy includes planning, conservation, recycled water, groundwater, water reuse, and watershed and resource protection to help meet future water needs.

The City of San Diego's Water Purification Demonstration Project is underway to examine the use of advanced water purification technology on high quality recycled wastewater. The Demonstration Project will determine the feasibility of a full-scale reservoir augmentation project, which would diversify San Diego's water supply, reduce its dependence on imported water and provide a safe source of drinking water for residents.

The San Diego Public Utilities Department invites you to visit the Water Purification Demonstration Project website at www.purewatersd.org to learn more. The project's public education and outreach program is offering informative presentations to all groups upon request and free tours of the Advanced Water Purification Facility following its completion in 2011. For more information, please call (619) 533-7572 or email purewatersd@sandiego.gov.

We hope that you will become informed and get involved in this important project for San Diego's future!

THE CITY OF SAN DIEGO

City of San Diego PUBLIC UTILITIES Water & Wastewater

Recycled Water

WPDP

In the News

New Source of Drinking Water Hinges on Pilot Project (PDF)

San Diego Union Tribune, October 11, 2010

City of San Diego Public Utilities Department • Long-Range Planning & Water Resources Division
600 B Street, Suite 600, San Diego, CA 92101 • (619)533-7572 www.purewatersd.org

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The City of San Diego

City of San Diego PUBLIC UTILITIES Water & Wastewater

The City of San Diego | Public Utilities Department

E-Update #2 February 2011

Under Construction

In January, work crews poured the foundation for the new Advanced Water Purification Facility (AWP Facility) located at the North City Water Reclamation Plant. Construction on the testing facility will continue throughout the spring.

Upon completion of the AWP Facility in summer 2011, the City will begin demonstrating advanced purification technology for approximately one year. During the demonstration period, 1 million gallons of purified water per day will be produced. The public will have the opportunity to visit the facility throughout the testing phase. To schedule a tour, please call (619) 533-7572 or email purewatersd@sandiego.gov.

In the News

The Yuck Factor: Get Over It

San Diego Union-Tribune, January 23, 2011

Upcoming Event

The Demonstration Project staff will be hosting an informational booth at the following community event:

San Diego Science Festival - Expo Day
Saturday, March 26, 10 a.m. - 5 p.m.
Petco Park

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E-Update #3 May 2011

Coming Attraction

The City of San Diego opens the doors this summer to its Advanced Water Purification Facility (AWP Facility). Located at the North City Water Reclamation Plant, this facility is part of the City's Water Purification Demonstration Project, which is examining the use of water purification technology on recycled water.

The AWP Facility will operate for one year and will produce approximately 1 million gallons of purified water every day. Purified water will not be added to the drinking water supply during this testing period; it will be added to the existing recycled water distribution system. Members of the public are invited to tour the AWP Facility and see how this technology can transform wastewater into one of the purest sources of water in San Diego.

Keep an eye out for an email in June inviting you to sign up for a tour!

In the News

From Toilets to Tap
USA Today, March 3, 2011

Wastewater Getting New Life Across County
San Diego Union-Tribune, May 15, 2011

Recent Events

The Demonstration Project staff recently hosted informational booths at the San Diego Science Festival Expo Day, Lao New Year Festival, Qualcomm Earth Day Fair, EarthFair, City of San Diego Take Your Son or Daughter to Work Day, Sally Ride Science Festival and RiverFest. Thank you to everyone who visited our booths. We hope to see you at future community events!

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AWP Facility Tour

Dear Danielle,

The City of San Diego opens the doors this summer to its Advanced Water Purification Facility (AWP Facility). You are invited to tour the AWP Facility, where you will see how this technology can transform wastewater into one of the purest sources of water in San Diego. If you are one of the few guests who has already previewed this facility, now is the time to encourage friends and family to register for a tour.

Located at the North City Water Reclamation Plant, this facility is part of the Water Purification Demonstration Project, which is examining the use of water purification technology for San Diego's future water supply. The AWP Facility will operate for one year and will produce approximately 1 million gallons of purified water every day. Purified water will be added to the recycled water distribution system and not to the drinking water supply during this demonstration phase.

Register Today

- Register for a tour of the Advanced Water Purification Facility at www.purewatersd.org/tours.shtml.
- Email purewatersd@sandiego.gov or call (619) 533-6638 to schedule a presentation for your organization.

I hope that you will take advantage of this exclusive opportunity. I look forward to your participation in the AWP Facility tour!

Sincerely,
Marsi A. Steirer
Water Purification Demonstration Project Director
City of San Diego, Public Utilities Department

The Demonstration Project has been funded in part by grants from the U.S. Bureau of Reclamation and from a Proposition 50 grant administered by the California Department of Water Resources.

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Dear Danielle,

As part of sweeps week, ABC affiliate 10 News in San Diego is promoting a segment scheduled to air tonight at 5 p.m. called "Toilet to Tap Reality." If you miss the segment when it airs, it should be viewable online following the broadcast. This segment proposes to examine the process of purifying recycled water at the Orange County Groundwater Replenishment System in relation to how a similar process may eventually be used in San Diego.

Learn More

If you are interested in learning more about water purification in San Diego, call the City's Water Purification Demonstration Project information line at (619) 533-7572 or visit the project website at www.purewatersd.org. An excellent way to learn more about the project is through a tour of the Advanced Water Purification Facility at North City Water Reclamation Plant. Reservations can be made online. Speakers bureau presentations to your organization are also available by calling (619) 533-6638.

For those who want to find out more about what Orange County is already doing for water purification, visit www.gwrsystem.com/.

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The City of San Diego | Public Utilities Department

Dear Danielle,

Find Us, "Like" Us & Follow Us!

We hope you have been following our project updates on Facebook and Twitter, and now the Water Purification Demonstration Project is sharing videos on YouTube. Please take a moment to subscribe to our YouTube page where you can take a virtual tour of the Advanced Water Purification Facility and see what goes on inside our water purification equipment.

Click the image to view the virtual tour:

Water Purification Demonstration Project

@PureWaterSD

PureWaterSD

Sincerely,
Marsi A. Steirer
Water Purification Demonstration Project Director
City of San Diego, Public Utilities Department

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Happy Holidays

A special greeting to express our sincere appreciation for your interest in, and support of, the Water Purification Demonstration Project.

Wishing you a happy holiday season and a healthy and prosperous New Year,

The Water Purification Demonstration Project Team

In acknowledgement of the City's ongoing drive for sustainability, we have opted to further reduce our paper usage and send you this eCard.

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February 2012

Demonstration Project Goes National

First it was USA Today. Then TIME. Now the New York Times has taken notice.

The New York Times

Today's New York Times cover story "As 'Yuck Factor' Subsides, Treated Wastewater Flows From Taps" highlights the nationwide interest in water purification as part of the solution for limited water supplies. The story features San Diego's Water Purification Demonstration Project along with several full-scale projects already in place.

As 'Yuck Factor' Subsides, Treated Wastewater Flows From Taps

The Demonstration Project is exploring the use of advanced water purification technology on recycled water to determine the feasibility of a full-scale reservoir augmentation project in the future. Currently, no purified water is being added to the drinking water supplies; instead the water is being returned to the City's recycled water distribution system.

Read the full story here. Already saw the story? Get involved in the conversation on Twitter and Facebook!

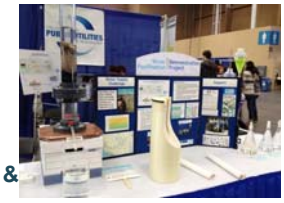
National Research Council Report

Read the latest report from the National Research Council on the expansion of water reuse (the full report and a report in brief are offered on this page):

Water Reuse: Expanding the Nation's Water Supply Through Reuse of Municipal Wastewater

It's All About the Science

SDSA High Tech Fair



Students and other visitors at the San Diego Science Alliance High Tech Fair learned about the water purification process at the Public Utilities Department's informational booth.

San Diego Festival of Science & Engineering EXPO Day

The Demonstration Project team is planning to make another science-related appearance at the San Diego Festival of Science & Engineering EXPO Day in PETCO Park on Saturday, March 24. Be sure to stop by our booth!

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Community Involvement February 2012

Dear [NAME],

Education and community involvement are at the forefront of our mission to inform San Diegans about the benefits of the Water Purification Demonstration Project. Many community groups and organizations have taken advantage of the project's speakers bureau and nearly 2,000 people have toured the Advanced Water Purification Facility.

To keep members of City of San Diego informed about this important project, we would like to present the Demonstration Project at one of your upcoming meetings and invite you to sign up for a tour. Your group will learn about San Diego's water supply challenges and the City's efforts to pursue locally controlled, sustainable water supply options.

The Water Purification Demonstration Project is examining the use of advanced purification technology on recycled water as an option to supply safe and reliable water for San Diego's future.

Schedule a Presentation

Please call (619) 533-6638 or reply to this email to schedule a presentation.

We are happy to answer any questions you may have, and we hope to speak to your group about the Water Purification Demonstration Project in the near future.

Tour the Advanced Water Purification Facility

In addition to presentations, free tours of the Demonstration Project's Advanced Water Purification Facility are also available. Guests are guided on a walking tour through the water purification facility to view the treatment process and compare samples of water. Interested community members may register for a tour online.

Spread the News

Water issues impact everyone. Share information about the Demonstration Project with City of San Diego. A template article is available for inclusion in your organization's newsletter or community paper. Please email us if you need the document in another format or would like photos to include with the article.

Also available is a flier publicizing the presentations and tours. Please share it with members of your organization.

Wrong Contact?

Although we do our best to update our contact information, we are aware that people often change roles within an organization or leave an organization. If you are not the appropriate person to schedule a presentation or tour, please let us know who we should contact.

Many thanks,
Water Purification Demonstration Project
PureWaterSD.org

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Water Purification Demonstration Project

The City of San Diego | Public Utilities Department

March 2012

Dear [NAME],

In 2004, you participated in the City of San Diego Water Reuse Study American Assembly Workshops in which participants endorsed reservoir augmentation as the preferred option for developing recycled water sources. In response to the Water Reuse Study, the Water Purification Demonstration Project is underway to examine the use of advanced purification technology on recycled water as an option to supply safe and reliable water for San Diego's future.

Education and community involvement are at the forefront of our mission to inform San Diegans about the Water Purification Demonstration Project. Many community groups and organizations have taken advantage of the project's speakers bureau and nearly 2,000 people have toured the Demonstration Project's Advanced Water Purification (AWP) Facility.

Since you played such a vital role in the Water Reuse Study, we want to ensure you remain informed about the project. Below are some ways for you to remain involved and to share project information with friends and colleagues.

Schedule a Presentation

If you are a member of an organization, **please call (619) 533-6638 or reply to this email** to schedule a presentation.

We are happy to answer any questions you may have, and we hope to speak to your group about the Water Purification Demonstration Project in the near future.

Tour the Advanced Water Purification Facility

In addition to presentations, free tours of the Demonstration Project's Advanced Water Purification Facility are also available. Guests are guided on a walking tour through the water purification facility to view the treatment process and compare samples of water. Interested community members may register for a tour online.

Spread the News

Water issues impact everyone. Share information about the Demonstration Project with your organization or business. A template article is available for inclusion in your organization's newsletter or community paper. Please email us if you need the document in another format or would like photos to include with the article.

Also available is a flier publicizing the presentations and tours. Please share it with colleagues, friends and family.

Show Your Support

If you are interested in further supporting water purification, you are welcome to write a letter of support. A sample letter of support can be found here for your reference.

Thank You

We appreciate the time and energy you put into participating in the Water Reuse Study American Assembly Workshops. We hope you remain involved in the Demonstration Project.

Many thanks,
Water Purification Demonstration Project
PureWaterSD.org

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April 20, 2012

Dear Danielle,

To celebrate Earth Day on April 22, 2012, the Water Purification Demonstration Project team will be participating in the following community events this weekend:

Linda Vista Multicultural Festival
Saturday, April 21, 10 a.m. - 5 p.m.
Linda Vista Road (between Comstock St. and Ulric St.)

Logan Heights Library Earth Day Event
Saturday, April 28, 11 a.m. - 1 p.m.
Logan Heights Branch Library, 567 S. 28th Street, San Diego

San Diego Earth Fair
Sunday, April 22, 10 a.m.- 5 p.m.
Balboa Park

Please stop by our booth to learn about how the City is examining the use of purification technology to provide a local and reliable source of Earth's most precious resource: water.

We will also be attending the following events next week:
Scripps Research Institute Employee Fair
City of San Diego Take Your Sons and Daughters to Work Day
BD Biosciences Earth Day Event

Upcoming Open House

On Saturday, May 12, the Water Purification Demonstration Project will host an Open House event at the Advanced Water Purification Facility to celebrate Drinking Water Week. A total of six tours will be held every half hour from 10 a.m. until 12:30 p.m. Invite your colleagues, family and friends to join us for a tour, refreshments and givaways. Please register for the event by May 7 at purewatersd.org/tours.shtml.

Drinking Water Week 2012

Learn More

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Dear Danielle,

In case you missed it yesterday, Larry Himmel's Neighborhoods of CBS 8 visited the City of San Diego's Advanced Water Purification Facility. Watch the clip on the CBS 8 website.

Learn More

If you are interested in learning more about water purification in San Diego, visit the project website at www.purewatersd.org.

Experience the project firsthand with a tour of the Advanced Water Purification Facility. Reservations can be made online.

Speakers bureau presentations are also available for organizations by calling (619) 533-6638.

Upcoming Events

Visit the Demonstration Project's informational booths at the following events:

San Diego Horticultural Society meeting
Monday, August 13
6 - 8 p.m.
Del Mar Fairgrounds

New ERAA Back to School Conference, Rally for Education and Festival
Saturday, August 25
1-3 p.m.
Lincoln High School

The Demonstration Project has been funded in part by grants from the U.S. Bureau of Reclamation and from a Proposition 50 grant administered by the California Department of Water Resources.

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One of the greatest joys of this season is the opportunity to say THANK YOU and to wish you the very best for the New Year,

The Water Purification Demonstration Project Team

In acknowledgement of the City's ongoing drive for sustainability, we have opted to further reduce our paper usage and send you this eCard.

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Pure News

Pure News

Winter 2010

Water Reuse Program

Water Purification Demonstration Project

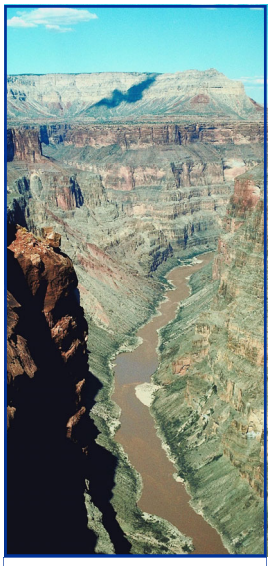
The City of San Diego • Public Utilities Department

Welcome to Pure News!

Welcome to Pure News, a newsletter to keep you informed about the latest happenings with the City of San Diego's Water Purification Demonstration Project. Please invite your friends and colleagues to sign up to receive this newsletter and other project-related updates at www.purewatersd.org.

Do you know where your water comes from?

San Diego is renowned for its sunny skies and ideal climate. What many may not know is that because of the region's semi-arid climate, the City of San Diego has limited local water sources and relies on importing approximately 85 to 90 percent of its water supply each year.



Colorado River

In the past, importing water from the Colorado River and Northern California has been a low-cost, dependable option, but these water sources have become less reliable and more expensive in recent years. Environmental stresses, including the ongoing drought in the Colorado River basin and reduced snow pack and runoff in Northern California, have decreased the available water supply. In addition, court-ordered pumping restrictions to protect threatened fish species have severely reduced the amount of water that can be delivered by the California State Water Project. This has a significant effect on San Diego, which sits at the end of the various pipeline systems that deliver the imported water. These conditions have intensified the need to identify new, locally controlled water sources.

To address this critical water supply situation, the City is actively pursuing ways to diversify San Diego's water supply options. One of these options is water conservation. The City declared a Level 2 Drought Alert in effect as of June 2009, which enforces many mandatory water restrictions and water conservation practices. Water customers in the City of San Diego have done a great job from July 2009 to June 2010, reducing water use by 11.6 percent compared to July 2008 to June 2009. Although conserving water is an important aspect of the City's water supply initiative, conservation alone is not enough. Therefore, the City is implementing a three-phase Water Reuse Program to explore local solutions for San Diego's future water supply reliability.

Sacramento–San Joaquin Delta

As the City continues to diversify San Diego's water supply portfolio and increase the amount of water available to us in the future, efforts are focused on providing information about the water supply to residents of San Diego. To learn more about the City's current water supply situation, drought conditions, conservation practices and water reuse options, please visit www.sandiego.gov/water.

Water Purification | Demonstration Project

Did you know...

Why can't we just conserve enough water to meet future needs?

Using water wisely through conservation practices should always be the first step in preserving the City's precious water supplies. The average water demand (which includes local surface water, imported water, conservation and recycled water) for the City of San Diego for the last six fiscal years has been approximately 260,000 acre-feet per year. The City's conservation programs have helped reduce its dependence on imported water by saving more than 34,000 acre-feet of drinking water a year. That's enough water to meet the needs of 68,000 average families of four for one year. Nonetheless, by 2030 the City will need an additional 43,000 acre-feet of water per year to meet the needs of current and future water customers. So while conservation is important, efforts to save water need to be combined with other sustainable strategies if we are to have enough water for all of our needs.

A look at new, local options for water

Today, the majority of San Diego's water supply comes from imported sources that are becoming more expensive and less reliable. In 2004, the City launched a three-phased Water Reuse Program (Program) to address the water supply crisis by exploring local solutions for future water supply reliability.

Phase one of the Program was the City's 2005 Water Reuse Study (Study). The Study provided a comprehensive evaluation of all viable options to maximize the use of recycled water produced by the City's two water reclamation plants. In addition, the Study analyzed and researched the health effects of various water reuse options. The Study concluded that reservoir augmentation at the City's San Vicente Reservoir is the preferred option for maximizing the use of the City's recycled water supply. Reservoir augmentation is a multi-step process that includes sending the advanced purified water to a reservoir to blend with existing water supplies and then treating the blended water again to be distributed as drinking water. A broad-based group of City residents participated in an American Assembly process to review the Study findings. The American Assembly reached the same conclusion that reservoir augmentation was the most viable use of highly treated recycled water for San Diego and that it could provide a local, reliable supply of water crucial to the City's future.

San Vicente Reservoir

Based on the final draft report that summarized the Study results, the San Diego City Council commissioned the second phase of the Program: the Water Purification Demonstration Project (Demonstration Project). The purpose of this phase is to further explore the option of reservoir augmentation by demonstrating the project on a small scale. The Demonstration Project, which is currently underway, is examining the use of advanced water purification technology to purify highly treated recycled wastewater that could potentially be added to the "raw" water (water prior to being treated) in a local reservoir. During this testing phase, purified water will not be added to the drinking water supply.

An Advanced Water Purification Facility (AWPF) is being built in Sorrento Mesa, a community in the northern region of the City, and will operate for about one year to produce approximately 1 million gallons of purified water per day. A study of the San Vicente Reservoir is also being conducted to test the key functions of reservoir augmentation and an independent advisory panel of experts is providing oversight on project research. The research will determine if the purification system satisfies all water quality, safety and regulatory requirements of the California Department of Public Health, and what will happen if the purified water is added to the reservoir. The Demonstration Project is scheduled to conclude at the end of 2012.

If the Demonstration Project meets regulatory requirements and provides evidence that a full-scale project would be viable, the mayor and city council will decide whether to implement a full-scale reservoir augmentation project. This would potentially be the third and final phase of the Water Reuse Program. In this potential phase, the advanced treated water would be added to the San Vicente Reservoir. The blended water from the reservoir would go to the Alvarado Water Treatment Plant where it would be treated for potable use. This water would become part of the drinking water supply for the City of San Diego.

Visit www.purewatersd.org to learn more about the Demonstration Project.

Did you know...

Doesn't the City already recycle water?

Yes. The City of San Diego operates two water recycling facilities capable of treating 45 million gallons per day of wastewater to secondary and tertiary treatment levels. Recycled water treated to a secondary level is safe for distribution into the environment, while recycled water treated to a tertiary level undergoes further treatment so the water is safe for use in irrigation and industrial purposes.

The recycled water produced by these plants is primarily used for irrigation and industrial purposes. A separate distribution system of "purple pipes" is required to keep the recycled water separate from drinking water pipelines. Constructing additional purple pipe distribution systems is costly. Also, using recycled water for irrigation is seasonal – it is not used in rainy periods or when it is cooler. This means less than half of all wastewater available for recycling is beneficially reused. The remainder of recycled water is treated to a secondary level and discharged into the ocean. Because of the cost and the limited use of existing recycled water, the City is examining other ways to use more recycled water, including reservoir augmentation.

Demonstrating Advanced Water Purification Technology

A key component of the Demonstration Project is the Advanced Water Purification Facility (AWPF). Construction on the AWPF will begin in early 2011. Following testing, the AWPF is expected to be operational in spring 2011.The facility will be located at the North City Water Reclamation Plant and will be the centerpiece of the Water Purification Demonstration Project.

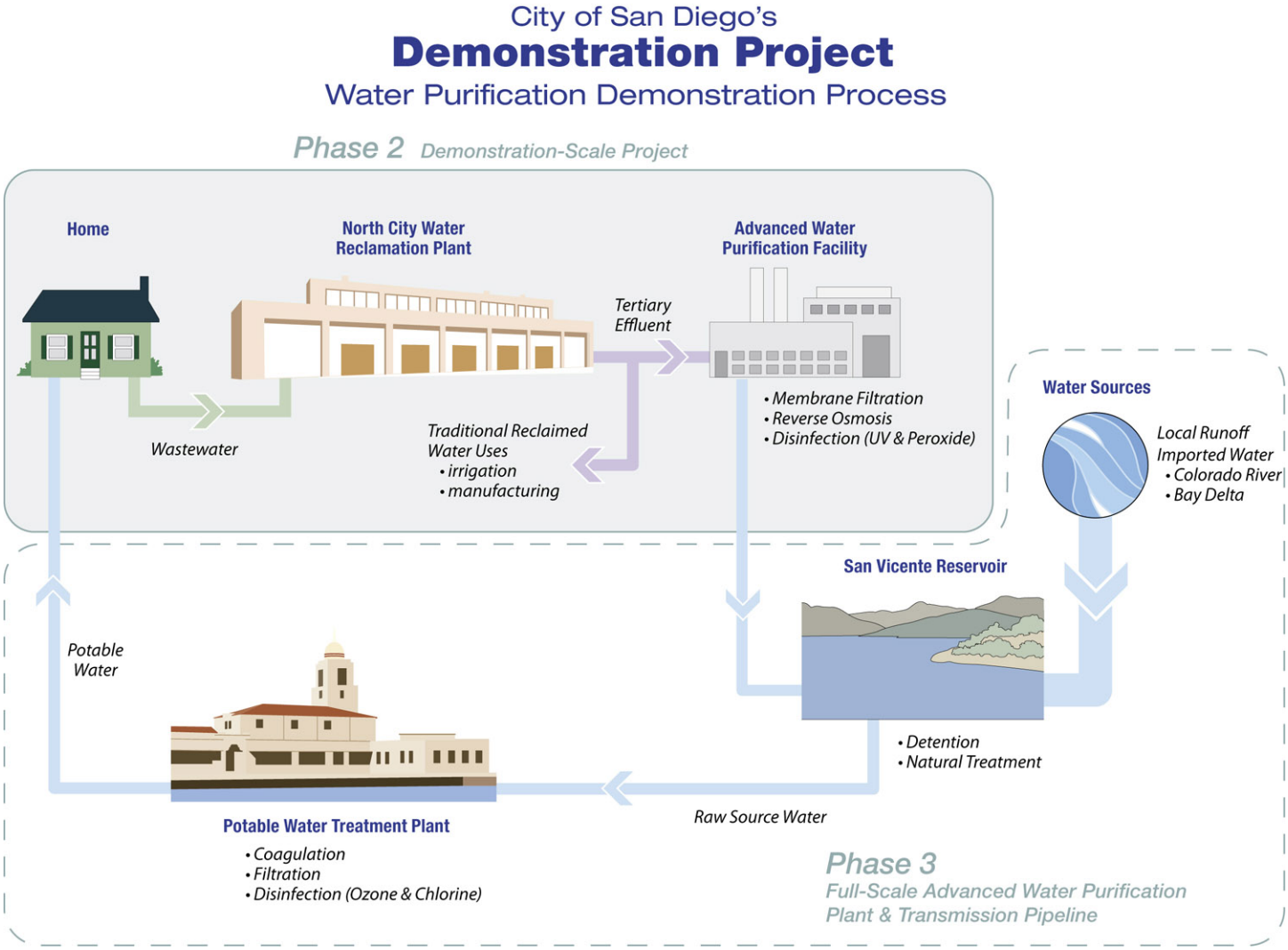
The AWPF is very different from a wastewater treatment facility. First, the water entering the AWPF has already been "reclaimed" through a series of treatment processes. At the North City Water Reclamation Plant, sewage is screened multiple times before being chemically treated to a safe level for discharging into the environment. After these treatment steps the wastewater is considered recycled water and is safe enough to be used for all irrigation and industrial purposes.

North City Water Reclamation Plant

At the AWPF, the City will start with recycled water and, using advanced water purification technology, will purify it to a level equivalent to distilled water. Advanced water purification technology includes membrane filtration, reverse osmosis, and disinfection by ultraviolet light and hydrogen peroxide. The resulting purified water is of higher quality than any of the City's existing raw water supplies.

The AWPF will produce approximately 1 million gallons of purified water per day for about a year. During the demonstration phase, the water produced at the facility will be used for irrigation, the same way the existing recycled water is used. It will not be added to the existing drinking water supply during the demonstration phase.

Free tours of the AWPF will be offered to the public when construction is complete. Details will be posted on www.purewatersd.org as the facility completion date nears.



Community Involvement

A major component of the Water Purification Demonstration Project is an extensive public education and outreach program that is being implemented throughout the City of San Diego. This program includes public presentations, the distribution of information at community events and on the project website, and tours of the AWPF once it is completed in the spring of 2011.

Since its launch in July, the Demonstration Project speakers bureau has been actively seeking opportunities to make presentations to civic, business and community groups as a way to engage the public and gather feedback on project information. Information about the project is presented by a member of the City's Demonstration Project team and includes information about San Diego's need for a local and reliable water supply, the purpose of the Demonstration Project, a description of the advanced water purification process, and the potential use of advanced purified water for reservoir augmentation in the future. Presentations are followed by an opportunity to ask questions or focus on an area of interest to a particular group.

To schedule a presentation for your organization or business, please contact the speakers bureau at (619) 533-6638 or email purewatersd@sandiego.gov. A calendar of upcoming presentations that are open to the public is available on the project website, which also includes more detailed project information and a list of past presentations.

Upcoming Events

Learn more about the Demonstration Project at one of the following community events. Project team members will be present to answer questions about the project and to share the latest project news.

13th Annual San Diego Multicultural Festival
Martin Luther King Jr. Promenade
(Downtown San Diego along Harbor Drive across the street from the Convention Center)
Saturday, Jan. 15
www.ccdc.com

6th Annual San Diego Lunar New Year Tet Festival 2011
Balboa Park
Saturday, Jan. 29
www.sdtet.com

Stay tuned for tours of the
Advanced Water Purification Facility
beginning in Spring 2011

North City Water Reclamation Plant

THE CITY OF SAN DIEGO

PureWaterSD.org

Visit our project website to sign up for email versions of Pure News and to keep informed about this important project.

City of San Diego PUBLIC UTILITIES Water & Wastewater

Pure News

Water Reuse Program

Water Purification Demonstration Project

Spring 2011

The City of San Diego • Public Utilities Department

Water Purification | Demonstration Project

Pure News: Issue 2

Welcome to Pure News, a newsletter to keep you informed about the latest happenings with the City of San Diego's Water Purification Demonstration Project.

Why rain isn't enough

Every winter after a storm, you hear the same question: with all this rain, why doesn't San Diego have enough water?

The answer is related to San Diego's climate and population. From year to year, San Diego's rainfall is anything but dependable. In the past decade, rainfall in the City of San Diego has been as low as 4 inches to as high as 14 inches, which is not enough to meet the demands of San Diego's population. Since rainfall is so varied, so is runoff into the City's nine reservoirs where raw water is stored. Lower Otay Reservoir, the City's oldest, has records dating back more than 100 years, which tell the story of San Diego's water runoff challenges. Years go by with little runoff – some years none at all – and then there are wet years that fill the reservoir with water, followed again by very dry years.

"Normal rainfall in the San Diego region can range from very dry to very wet," said Jeff Pasek, San Diego Public Utilities Department Watershed Manager. "If you look at the records of rainfall and runoff over the years, you'll see extremes in fluctuation. We can't count on any certain amount of rainfall."

The situation is exacerbated by the City's ever-growing population. San Diego's system of local reservoirs was built from about 1900 to 1950. These reservoirs amply supplied San Diego through the first half of the last century, but because of population growth, the demand for water has quadrupled over the last 60 years. San Diegans have diligently conserved water over the past 20 years, steadying the water demand despite continued population growth. Nevertheless, even if rainfall in the San Diego region was consistently above average, the local runoff would not be enough to sustain the City.

Even in a wet year, natural runoff accounts for a small percentage, roughly 15 percent, of San Diego's annual water supply; the rest has to be imported. Countywide, the

Continues on Page 3

Did you know...

Does San Diego need more water?

The City of San Diego imports approximately 85 percent of its water supply from Northern California's Bay-Delta and the Colorado River. For the past few years, California has been affected by a historic dry period and a drought on the Colorado River. Legal and regulatory decisions to protect endangered species have resulted in restrictions on the amount of imported water from Northern California. Population projections predict the City will need more water in the future than is used today. For all of these reasons, the City needs to develop local water supplies to secure a reliable supply for present and future City of San Diego water customers.

AWPF construction begins!

In January, work crews poured the foundation for the new Advanced Water Purification Facility (AWP Facility) located at the North City Water Reclamation Plant. Construction on the testing facility will continue throughout the spring.

The Advanced Water Purification Facility's canopy is now installed.

Ahrens Corporation completed construction on the concrete pad for the AWP Facility in January 2011. The facility canopy, which will cover the advanced water treatment equipment, was completed in late February.

Upon completion of the AWP Facility this summer, the City will begin testing advanced purification technology for approximately one year. During the demonstration period, 1 million gallons of purified water per day will be produced. Concurrently, the San Vicente Reservoir is being studied to examine the viability of adding the advanced purified water to the reservoir to augment drinking water supplies. Other studies, including cost analysis, will be completed at the same time. Together these studies and tests will determine if the project concept is feasible for full scale.

In the community

If you've been to a community event recently, there's a good chance the Water Purification Demonstration Project was there, too. Beginning in early 2011, the Demonstration Project team staffed informational booths at several community events.

In January and February, the Demonstration Project staff teamed up with the City's Conservation team to reach out to San Diegans with important messages about water at the San Diego Multicultural Festival, the San Diego Lunar New Year Tet Festival and the San Diego Chinese New Year Food and Cultural Fair. In February and March, the Demonstration Project team struck out on their own to participate in the Heritage Weekend Festival and the San Diego Science Festival Expo Day.

Guests visit the Demonstration Project booth at the Tet Festival.

Hundreds of passersby stopped by the booth to learn more and ask questions about the Demonstration Project. Staff explained the details of the project and provided fact sheets to them. After learning about the project, these visitors were invited to spin the prize wheel for a chance to win the Demonstration Project's highly coveted reusable tote bag. Many interested participants (including some of you who are reading this right now) signed up to receive email updates about the project.

"By participating in these events, we are able to talk to a wider variety of San Diegans, not just those who have an interest in water issues," said Alma Rife, Public Information Officer for the Demonstration Project. "These events have been great opportunities to share information about the Demonstration Project and eliminate misinformation and confusion about it."

In April and May, the Demonstration Project staff will be at the Lao New Year at Market Creek Plaza on Saturday, April 2, and the EarthFair in Balboa Park on Sunday, April 17. Hope to see you there!

Why rain isn't enough *(Continued from Page 1)*

portion of water supply from local runoff is even lower. This supply is not only low because of the fluctuating amount of rainfall, but also because San Diego's watersheds extend less than a thousand square miles from the western slopes of our mountains to the coastal plain. When compared to the watershed of the Colorado River – hundreds of thousands of square miles in seven states with the snowcap of the Rocky Mountains draining into it – the San Diego watersheds are not a very big area to capture water.

When San Diego does get rain, most of the rain runoff in the region occurs in the back country and mountains, and flows down streams to be captured in reservoirs. San Diego's reservoirs are sized and situated to capture almost all of the runoff that's available from rain events. If all the reservoirs are full, they can hold nearly two years' worth of water supply for the City. Just this winter, Barrett and Hodges reservoirs received so much runoff they filled and overflowed into the ocean. However, because major rainstorms are infrequent, the reservoirs are not often full or even close to full. In fact, the last time all of San Diego's reservoirs were completely full was 1983.

Compared to cities that sit next to the Great Lakes, the Mississippi River or atop massive aquifers, San Diego's water supply has always been rather precarious. That's part of life in Southern California. Rainfall is iffy, rivers are scanty, watersheds are small, reservoirs are few and groundwater is limited. Since San Diego cannot depend on local rainfall, the City must depend on importing about 85 percent of its water supply. As imported supplies become more expensive and less reliable, it is time to diversify San Diego's local water sources to supplement the small supply produced by the rain.

Treating water right: Part I

When it comes to wastewater treatment, there is no "one-size-fits-all" approach. In fact, there are several levels for "cleaning" wastewater. Regulatory requirements determine which level of treatment the wastewater will undergo: primary, secondary or tertiary treatment. Tertiary treated water is considered "recycled water" and can be used for many applications.

Point Loma Wastewater Treatment Plant

At San Diego's Point Loma Wastewater Treatment Plant, sewage goes through what is called "advanced primary treatment." In this process, water is separated from grit or large particles. Following grit removal, the wastewater is pumped into sedimentation tanks. With the assistance of chemical treatment, solids or "primary sludge" settle to the bottom of the tanks and "scum" (primarily cooking grease and oil) float to the surface. At this point, approximately 80 percent of the suspended solids have been removed. The waste is separated from the water and is disposed offsite. After a final screening, the treated wastewater is discharged from the Point Loma Wastewater Treatment Plant through a long pipeline 4.5 miles out into the ocean.

Wastewater may continue on to secondary treatment. If this occurs, bacteria are added to the wastewater. Air is pumped into this mixture, and the bacteria ingest and digest the organic solids. Next, the wastewater is pumped into secondary clarifiers,

Continues on Page 4

Terms to Know

Potable Water:
Water that has been treated to drinking water standards. This is the water delivered to consumers' taps.

Raw Water:
Water from rain, snow, rivers, and lakes/reservoirs that has not been treated at a drinking water plant.

Storm Water:
Urban runoff water from rainfall and irrigation. In most of San Diego, this water is untreated and flows into creeks, bays, lagoons, and ultimately the ocean.

Wastewater:
Water collected in the sewer system from residences and business. It is mostly water with some impurities.

Treating water right *(Continued from Page 3)*

North City Water Reclamation Plant

where the bacteria and digested solids settle to the bottom as "secondary sludge." Similar to primary treatment, the sludge is removed for further treatment, and the treated wastewater can either be moved along to tertiary treatment to produce reclaimed water or may be discharged.

After going through primary and secondary treatment processes, tertiary-treated wastewater is produced by filtering to remove any remaining solids, chlorination to disinfect, and demineralization to reduce the amount of salt in the water. The resulting product is known in California as "recycled water." Recycled water produced at the North City Water Reclamation Plant is safe for industrial uses and outdoor irrigation.

Water treatment doesn't end there. Stay tuned because in the next Pure News we will talk about how recycled and raw water can go through additional treatment steps.

Schedule a presentation for your group or organization
Contact the speakers bureau at (619) 533-6638 or email purewatersd@sandiego.gov.

Upcoming Events

Learn more about the Demonstration Project at one of the following community events. Project team members will be present to answer questions about the project and to share the latest project news.

Lao New Year
Market Creek Plaza
(310 Euclid Avenue, San Diego, 92114)
Saturday, April 2
10 a.m. - 6 p.m.
www.LCCCSD.com

EarthFair
Balboa Park
Sunday, April 17
10 a.m. - 5 p.m.
www.earthdayweb.org/

Coming soon:
Tours of the Advanced Water Purification Facility.
Watch for an email in the coming months.

North City Water Reclamation Plant

THE CITY OF SAN DIEGO

PureWaterSD.org

Visit our project website to sign up for project updates.

City of San Diego PUBLIC UTILITIES Water & Wastewater

Pure News

Summer 2011

Water Reuse Program

Water Purification Demonstration Project

The City of San Diego • Public Utilities Department

Pure News: Issue 3

Welcome to Pure News, a newsletter to keep you informed about the latest happenings with the City of San Diego's Water Purification Demonstration Project.

Get a Glimpse of the Future at the Advanced Water Purification Facility

The City of San Diego opens the doors this summer to its Advanced Water Purification Facility (AWP Facility). Starting in June, groups and individuals can tour the site of a small-scale, state-of-the-art treatment facility that could contribute to the future of San Diego's water supply. This facility, located at the North City Water Reclamation Plant, represents the focal point of the City of San Diego's Water Purification Demonstration Project (Demonstration Project). It has been under construction since early 2011.

Here visitors will learn about the advanced technologies being demonstrated by the City to purify one million gallons of recycled water per day. The purification process employs three treatment methods: microfiltration/ultrafiltration, reverse osmosis, and advanced oxidation with ultraviolet disinfection and hydrogen peroxide. More simply put, the AWP Facility is demonstrating the purification of water using technology that is able to produce one of the most pristine sources of water available anywhere.

Visitors will learn how such purity is established through this multi-barrier approach of consecutive treatment steps, which work together to remove or destroy all unwanted materials in the water. Each barrier includes frequent, continuous water quality monitoring and safeguards built into the process to ensure that an error at any given treatment step is caught and corrected to protect public health.

Why here, and why now? California's water supply is subject to climate variations, droughts and regulatory restrictions, all of which affect the amount of water delivered to San Diego at the end of the pipelines that carry water imported from hundreds of miles away. The City needs to develop local, reliable sources of water to lessen its dependence on imported supplies. The Demonstration Project is exploring this proven technology that is already used to produce purified water for a full-scale project in Orange County.

With this effort, the City of San Diego joins other cities and water agencies throughout the United States and around the world, standing on the leading edge of water technology. Visitors will end their tour of the AWP Facility with a better understanding of the promise of these technologies to help ensure a drought-proof water supply independent of less reliable and constrained imported water sources.

Water Purification | Demonstration Project

About the Tours

Guests who participate in the AWP Facility tour will gain a better understanding of the Demonstration Project and what role the facility plays in this testing phase.

Following an introductory presentation, guides will lead a walking tour through the facility. Guests will see the microfiltration/ ultrafiltration, reverse osmosis and UV disinfection/advanced oxidation equipment up close. At the end of the tour, guests can view the purified water produced at the facility and will have a chance to compare it to drinking water and recycled water samples.

To register for a tour, visit www.purewatersd.org/tours.shtml. If you would prefer to schedule a presentation for your organization, email purewatersd@sandiego.gov or call (619) 533-6638. We hope you will take advantage of this unique opportunity to visit the AWP Facility.

The Urban Water Cycle

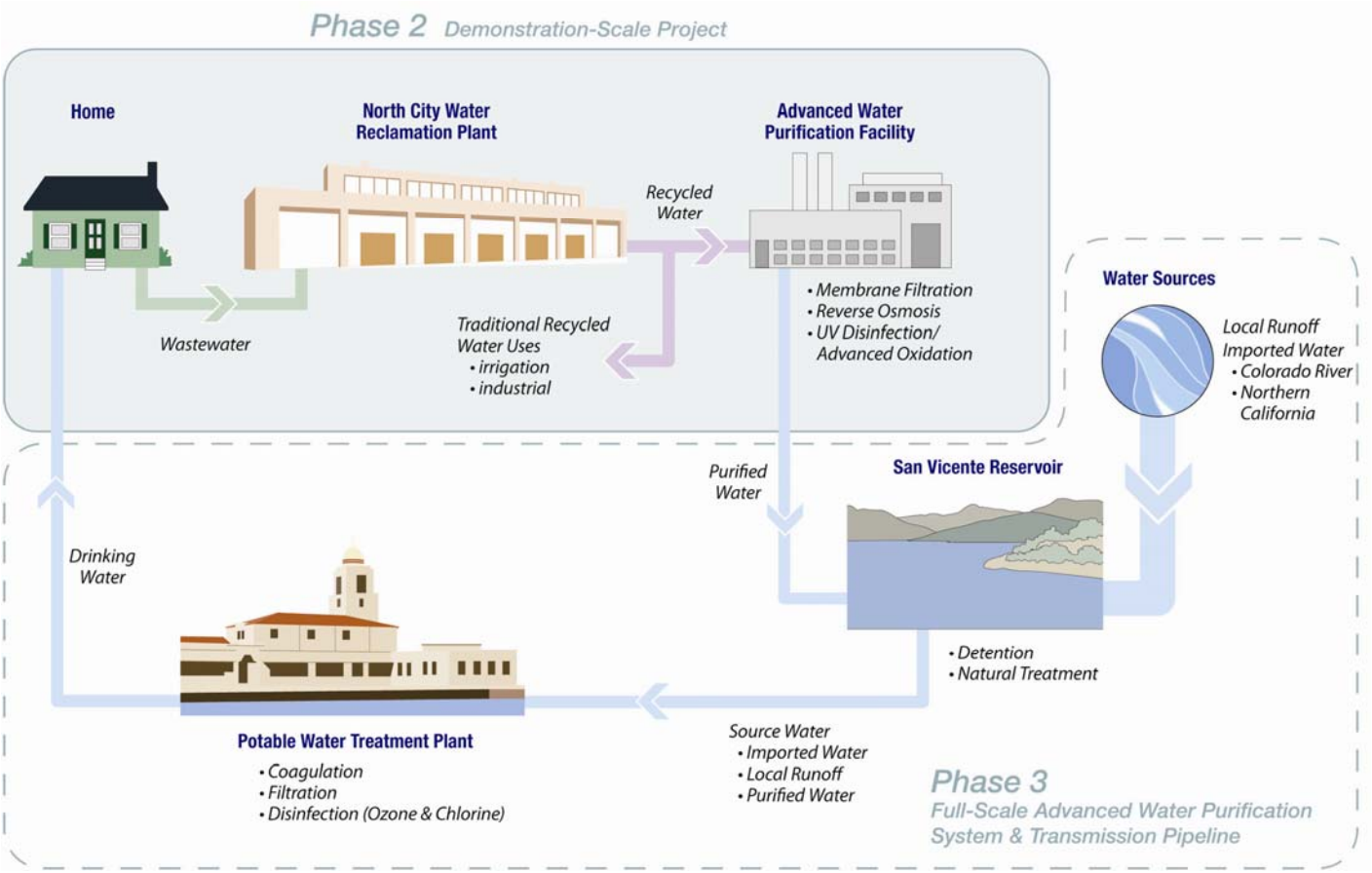
When we think back to our fourth grade science lessons about the natural cycle of water, it becomes clear that all water is as old as the Earth itself. This means that all water is naturally recycled - including the water we drink. The urban water cycle is a similar, man-made system that works to create the continuous movement of water to import and export our local supply of one of the Earth's most precious resources: water.

Modern technology has enhanced the urban water cycle with the ability to clean up and recycle the water we use. Recycled water can be treated to various levels for use in irrigation and manufacturing, and the most advanced water treatment can purify recycled water for drinking. This technology can be especially beneficial in a city like San Diego that has limited local water sources and relies on importing approximately 85 percent of its water supply.

San Diego's urban water cycle features multiple water treatment facilities that make up an extensive treatment system that water travels through before reaching your faucet. Water treatment plants, such as the Alvarado Water Treatment Plant, provide drinking water treatment. The treated water is then distributed to residents and businesses all over the City.

The Point Loma Wastewater Treatment Plant handles wastewater treatment and disposal for the City of San Diego. In addition to this wastewater treatment plant, the City has two wastewater reclamation plants: the North City and South Bay water reclamation plants. Instead of simply disposing treated wastewater, these plants treat the wastewater even further to produce recycled water. Recycled water is distributed through designated "purple pipes" and is used for irrigation and industrial purposes.

The newest member of San Diego's urban water cycle is the state-of-the-art Advanced Water Purification Facility (AWP Facility) that purifies the recycled water produced at the North City Water Reclamation Plant. The AWP Facility is demonstrating the latest in water purification technology as part of the Water Purification Demonstration Project. The outcome of the Demonstration Project will determine whether or not the City will close the loop on its urban water cycle to provide a source of purified water to supplement drinking water supplies. In a world where water reuse is inevitable and water purification technology is available, enhancing the urban water cycle is the key to a sustainable future.



Permanent Water-Waste Restrictions Still in Place

New Watering Times Started June 1

When the San Diego City Council approved Mayor Sanders' proposal in May to end mandatory water-use restrictions, the move did not affect several water-waste restrictions that remain permanent year-round. Water-waste restrictions refer to City restrictions on wasteful water use. Starting on June 1, one of the permanent restrictions--the timing for when landscape watering is allowed -- shifts to after 6 p.m. and before 10 a.m.

"San Diegans have done a tremendous job by saving water when we were faced with mandatory cutbacks," said Mayor Jerry Sanders, who has demonstrated both at home and at work that water conservation is a priority. "While the drought may be officially over, waste is never an option. Using water wisely throughout the year needs to remain a permanent way of life," added Mayor Sanders.

The City's permanent water-waste restrictions also address issues such as excessive irrigation, washing *Continues on Page 4*

Treating water right: Part II

Terms to Know

Drinking Water:
Water that has been treated to federal and state drinking water standards. This is the water delivered to consumers' taps. Also called potable water.

Raw Water:
Water from rain, snow, rivers, lakes, and reservoirs that has not been treated at a drinking water plant. San Diego's raw water is primarily imported from sources such as the Colorado River or collected in the City's reservoirs from rainfall.

Recycled Water:
Wastewater that has undergone a high level of treatment at a reclamation facility so that it can be reused for irrigation and industrial purposes.

Storm Water:
Urban runoff water from rainfall and irrigation. In most of San Diego, this water is not treated and flows into creeks, bays, lagoons, and ultimately the ocean.

Wastewater:
Water collected in the sewer system from the drains of residences and business. Wastewater is more than 99% water along with impurities.

In the Spring 2011 edition of Pure News, we explained the process for treating wastewater. In this edition, we will focus on drinking water treatment.

Since approximately 85 percent of the City of San Diego's drinking water is imported from unreliable and increasingly expensive sources, San Diego is considering purification of recycled water to develop a new, local source of drinking water. Through the Water Purification Demonstration Project (Demonstration Project), the City is demonstrating water purification technology that purifies recycled water even further. This technology includes membrane filtration, reverse osmosis, and disinfection through the use of ultraviolet light and hydrogen peroxide. The resulting purified water is of higher quality than our imported water and local runoff. During this demonstration phase, the water produced at the AWP Facility will not be added to any drinking water supplies, but will instead be added to the recycled water system. If the concept proves feasible and is approved by the City Council, the City would then build a full-scale water purification project to blend purified water with raw water in San Vicente Reservoir.

Alvarado Water Treatment Plant

All of San Diego's drinking water, which includes water from San Vicente Reservoir, undergoes drinking water treatment. This is the final step of treatment before arriving at the tap. At the water treatment plant, any particles are removed and contaminants are eliminated through the combined processes of flocculation, sedimentation, filtration, chlorination and ozonation. Before the water is sent to homes and businesses around San Diego, it is tested to make sure it meets all health and safety requirements set forth by the U.S. Environmental Protection Agency and the California Department of Public Health. Thanks to these behind-the-scenes treatment processes, San Diegans can dependably turn on their faucet for reliable, clean water.

Learn more about water sources, treatment and distribution at "Source to Tap" (www.sandiego.gov/water/quality).

Permanent Water-Waste Restrictions Still in Place *(Continued from Page 3)*

down sidewalks and patios, overfilling swimming pools and using re-circulating pumps on decorative fountains. Additional restrictions pertain to car washing, cooling systems and hospitality industry water use. To help customers eliminate water waste, the City's Public Utilities Department offers a number of programs and services, providing the tools needed to save water and money. Some examples include the following:

- Free residential and commercial water surveys through the Public Utilities Department can pinpoint water-saving options at your home or business, including identifying possible leaks. Call (619) 570-1999, email water@sandiego.gov or visit the City's website.
- Citizens can play an important role in preserving our water and maintaining our water system by reporting any water leaks. Water loss is often caused by leaks from service lines, main breaks and fire hydrants knocked over by a vehicle. The City counts on residents to help proactively identify and report all types of leaks or other problems on the City water system. To report leaks, call the City's 24-hour emergency hotline at 619-515-3525.
- Customers are also encouraged to report water waste. Just send the City the location, date and time the waste was observed. Customers can provide their contact information for follow-up questions or remain anonymous. Either send an email to waterwaste@sandiego.gov or call (619) 515-3500 (press 5) or (619) 533-7485.

For more information on the City's permanent water-waste restrictions and a comprehensive listing of available conservation resources and tips, visit WasteNoWater.org or call the Public Utilities Department at (619) 515-3500.

Upcoming Event

Learn more about the Demonstration Project at the following community event. Project team members will be present to answer questions about the project and to share the latest project news.

Fiesta del Sol
Cesar Chavez Park on San Diego Bay
Saturday, August 13
11 a.m. - 7 p.m.
www.fiestadelsolsandiego.org/

To schedule a presentation for your organization, email purewatersd@sandiego.gov or call (619) 533-6638. Visit www.purewatersd.org/tours.shtml to sign up for a tour of the AWP Facility.

Not receiving email updates from the Demonstration Project? Sign up at www.purewatersd.org or email purewatersd@sandiego.gov.

THE CITY OF SAN DIEGO

PureWaterSD.org

Visit our project website to sign up for project updates.

City of San Diego PUBLIC UTILITIES Water & Wastewater

Pure News

Water Reuse Program

Water Purification Demonstration Project

Fall 2011

The City of San Diego • Public Utilities Department

Water Purification | Demonstration Project

Pure News: Issue 4

Welcome to Pure News, a newsletter to keep you informed about the latest happenings with the City of San Diego's Water Purification Demonstration Project.

A new site to see in San Diego

San Diego Mayor Jerry Sanders, Councilmember David Alvarez, Public Utilities Director Roger Bailey, and Water Purification Demonstration Project Director Marsi Steirer welcomed media to the AWP Facility on June 30.

Since the Advanced Water Purification (AWP) Facility opened for tours in July, City staff has hosted more than 102 tours for approximately 1,200 people. The City is pleased to welcome community members and others who have toured the AWP Facility. People from all over San Diego have visited and many guests bring their family, friends and co-workers. Various groups from graduate school classes to the Audubon Society to senior citizen organizations to a fifth grade science class have toured the facility. It's not just local folks who visit, though. Because many countries around the globe are interested in water purification technology as a potential solution to water supply issues, international visitors have come all the way from Mexico, Vietnam, Australia and Eurasian countries.

In early July, elected officials, water agency boards, and community group representatives were among the visitors. Elected official visitors include San Diego Mayor Sanders, San Diego Councilmembers Alvarez, Faulconer, Gloria, and Lightner, and the mayors of Del Mar and Solana Beach. In addition, staff from the offices of U.S. Senator Boxer, U.S. Representative Issa, State Senator Anderson, and Assemblymember Jones have also toured the facility. Staff from the San Diego Regional Water Quality Control Board, California Department of Health, U.S. Bureau of Reclamation, U.S. Environmental Protection Agency, U.S. Department of the Interior, and the U.S. Office of Management and Budget have also visited.

Students from the Elementary Institute of Science compare beakers filled with tap, recycled and purified water.

If you haven't already, we hope you will tour the AWP Facility by registering at www.purewatersd.org/tours.shtml. If you can't make it out to the facility, you can watch a video about the purification process online at www.purewatersd.org. Another option to learn more about the Demonstration Project is to schedule a speaker's bureau presentation for your group or organization by calling (619) 533-6638 or emailing purewatersd@sandiego.gov. Through these and other methods, the City wants to provide opportunities for San Diegans to learn more about the water purification process.

City of San Diego Water and Wastewater Treatment Facilities

Drinking Water Treatment Plant:

Alvarado, Miramar, & Otay Water Treatment Plants

Cleans water from rain, snow, rivers, lakes, and reservoirs to a level safe for drinking. The water from these plants is then sent to faucets around San Diego.

Wastewater Treatment Plant:

Point Loma Wastewater Treatment Plant

Treats wastewater from homes and businesses and releases the cleaned wastewater into the ocean.

Water Reclamation Plant:

North City Water Reclamation Plant & South Bay Water Reclamation Plant

Treats wastewater from homes and businesses to a level that is safe enough to be reused for irrigation and industrial purposes.

Advanced Water Purification Facility:

AWP Facility at North City Water Reclamation Plant

Purifies the recycled water produced at a water reclamation plant using micro/ultrafiltration, reverse osmosis and ultraviolet disinfection/advanced oxidation. Currently this water is sent back to the recycled water system for irrigation and industrial purposes. If it is approved for a full-scale project, the purified water would be added to San Vicente Reservoir.

San Diego recycles...its water

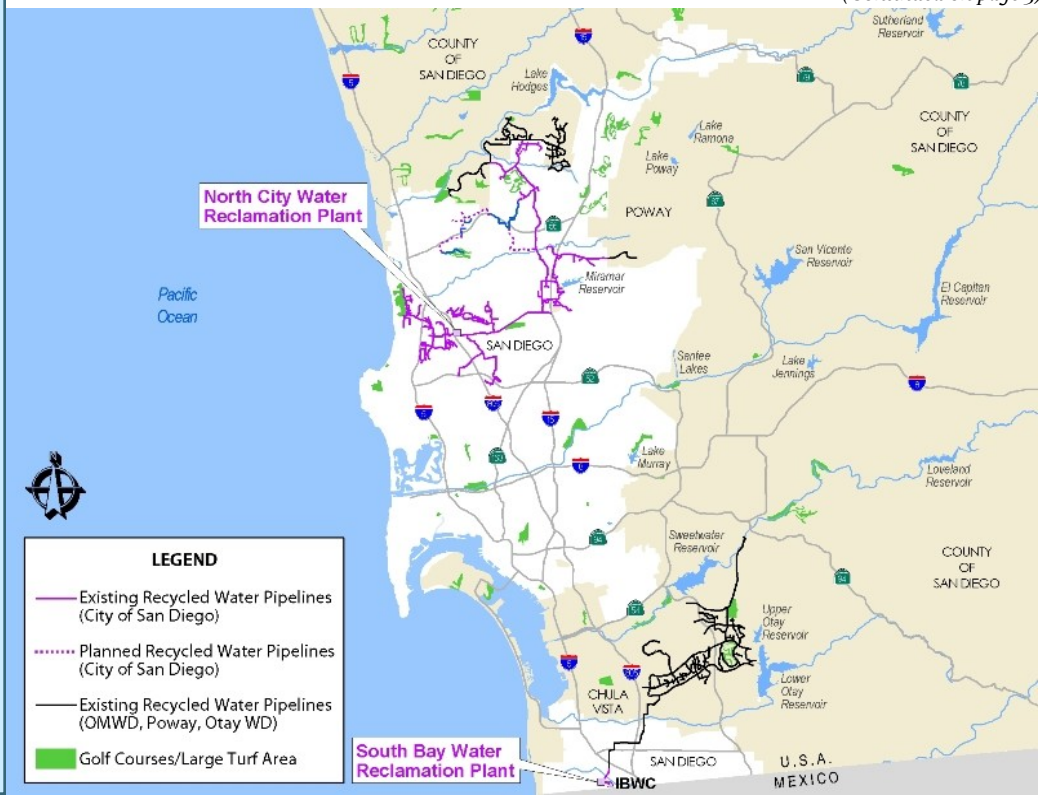
Have you ever driven by a San Diego golf course and thought about how much water must be used to keep a golf course green? This question might occur to many people as San Diegans are reminded of the importance of water conservation. While it may seem like a lot of water, there is a good chance that the water you see coming out of golf course sprinklers is recycled water. This type of water is an essential part of San Diego's diverse "water portfolio."

Recycled water is wastewater that has been treated to meet standards for use in a range of non-drinking applications. Landscape irrigation is the single largest use for recycled water within the City of San Diego. Recycled water is also used for industrial processes, cooling towers, soil compaction, dust suppression, and toilet flushing. It is reliable, drought-proof, good for the environment and has the added bonus of being a locally controlled water resource that is dependable year-round.

Two plants are responsible for producing recycled water for the northern and southern regions of the City: the North City Water Reclamation Plant built in 1997 and the South Bay Water Reclamation Plant built in 2002. Together, they have the capacity to treat up to 45 million gallons of wastewater per day. The City is not alone in recycling its wastewater—other water agencies in San Diego County also produce recycled water for irrigation and industrial purposes.

This year, recycled water has come to serve another function as the source water for San Diego's Water Purification Demonstration Project. That's right! The water that is

(Continued on page 3)



San Diego recycles… its water *[continued from page 2]*

being purified to a level similar to distilled water quality is already treated before it undergoes a three-step purification process at the Advanced Water Purification Facility.

And since the Demonstration Project is just that—a demonstration--the purified water is currently being put back into the recycled water system. So while you won't be able to drink it, those thirsty blades of grass on the 14th hole will.

For more information about the City 's Recycled Water Program visit sandiego.gov/water/recycled.

Limnology study: A look at the San Vicente Reservoir

Why send the purified water to a reservoir?

Reservoir augmentation allows the water to be diluted with the existing water supply as part of the multi-barrier treatment process. The detention time in a reservoir is one of the many safeguards built into the process to insure that a failure or error at any given treatment step would not compromise public health. The reservoir also provides further, natural treatment by exposing the water to sunlight and allowing it to blend with minerals existing in the reservoir.

Why San Vicente Reservoir?

Following the completion of the San Vicente Dam Raise in 2014, the San Vicente Reservoir will be the largest reservoir in the San Diego region at 247,000 acre-feet. Blending the purified water in a large reservoir allows it to be diluted with San Diego's imported water supply before being treated again for use as drinking water.

While the Advanced Water Purification Facility has been the center of attention since it opened in July, there is additional and equally important behind-the-scenes work being done on the Water Purification Demonstration Project. If approved to be a full-scale project, the City of San Diego would add purified water to San Vicente Reservoir, a process known as reservoir augmentation. Therefore, a scientific undertaking, called a limnology study, is now being conducted to examine the key functions of the reservoir as it pertains to its physical, geological, and biological attributes. Although no purified water is being added to the reservoir during the study, a computer model of San Vicente is being used to determine the behavior of the reservoir and what will happen if purified water is added.

> ...a computer model of San Vicente is being used to determine the behavior of the reservoir and what will happen if purified water is added.

The reservoir aspect of the Demonstration Project is unique to San Diego's approach. Water purification technology has been established in areas around the world and is being used in California, specifically at the 70-million-gallon-per-day Groundwater Replenishment (GWR) System in Orange County. One way that a full-scale project in San Diego would differ from the GWR System is that Orange County injects its purified water into existing groundwater basins as part of the multi-barrier treatment process before the water becomes part of their drinking water supply. San Diego does not have large groundwater basins, so the City is working with the San Diego Regional Water Quality Board and the California Department of Public Health to consider blending the purified water with surface water and develop the necessary regulations to do so. The project and regulators want to validate that the purified water has no negative effect on the reservoir as a source of water supply to the City or on the ecological balance of the reservoir and its surrounding environment.

The limnology study uses a state-of-the-art computerized model of the San Vicente Reservoir to predict the behavior of the reservoir throughout the year. The model is calibrated and validated using existing data from testing and monitoring the actual reservoir.

San Vicente Reservoir

A reason to celebrate

Demonstration Project Director Marsi Steirer accepts the WateReuse Association Public Outreach and Education award in September.

One of the goals of the Water Purification Demonstration Project is to inform the public about the science behind the water purification process. In September, the WateReuse Association recognized the City of San Diego's outreach efforts in achieving this goal by honoring the Demonstration Project with the **2011 WateReuse Association Public Outreach and Education award**. The City appreciates the WateReuse Association's recognition of the Demonstration Project team's efforts to keep the public informed and involved in this important project for San Diego's future.

The Demonstration Project team earned this award by providing information to thousands of San Diegans over the last year through nearly 100 speakers bureau presentations, more than 100 tours of the City's treatment facilities, informational booths at nearly two dozen community events, approximately 100 meetings with leaders of various organizations and communities throughout San Diego, and information shared through print and electronic materials.

Sharing information about San Diego's need for more local water supply sources cannot be done alone. We are grateful to those of you who have taken the time to listen to our messages, tour our facilities, invite staff to present at your organizations' meetings, read our informational materials, provide us with valuable feedback, and share this information. with friends and family. Our work is far from over, but with your help, we hope to reach all San Diegans.

To schedule a presentation for your organization, email purewatersd@sandiego.gov or call (619) 533-6638.
Visit www.purewatersd.org/tours.shtml to sign up for a tour of the AWP Facility.

@PureWaterSD

Get the latest online

For our smartphone-savvy readers, we have included quick response (QR) barcodes in this newsletter, so you can quickly and easily follow us on Twitter or Facebook. Just use your barcode-scanning app of choice, and scan the barcodes to the left and right. You'll be an official Demonstration Project fan in no time!

Not receiving email updates from the Demonstration Project? Sign up at www.purewatersd.org or email purewatersd@sandiego.gov.

SanDiegoWPDP

The City of San Diego

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City of San Diego PUBLIC UTILITIES Water & Wastewater

City of San Diego Public Utilities Department • Long-Range Planning & Water Resources Division
600 B Street, Suite 600, San Diego, CA 92101 • (619)533-7572 • www.purewatersd.org

Pure News

Water Reuse Program

Water Purification Demonstration Project

Winter 2012

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Pure News: Issue 5

Welcome to Pure News, a newsletter to keep you informed about the latest happenings with the City of San Diego's Water Purification Demonstration Project.

Putting the AWP Facility to the Test

What's being tested

Below are a few of the many parameters being tested at the AWP Facility:

Conductivity: corresponds to the concentration of dissolved salts and metals

Nitrogen: an element that can promote algae growth in a reservoir

Total organic carbon: a measurement of the amount of natural and synthetic organic materials dissolved in water

Turbidity: a measurement of water clarity

Ultraviolet transmittance: the ability of an ultraviolet light to pass through water

To ensure water quality, monitoring is essential at any water treatment facility. At the Advanced Water Purification Facility, automated and manual testing is regularly performed in order to ensure the water purification process is properly functioning and the water produced meets all safety regulations.

One method of ensuring the integrity of the equipment is the use of automated meters. There are more than a dozen meters throughout the facility that continuously measure various water quality parameters throughout the treatment process. In the event an anomaly is detected, the monitoring system would either trigger an alarm or automatically shut down the plant. In a full-scale plant, this would prevent any water that does not meet the water quality requirements from being added to the San Vicente Reservoir.

Operators also manually test water from sampling ports to verify the equipment is functioning correctly. The water samples are tested to ensure that contaminants are removed and that the water meets drinking water standards. These compounds include all of those regulated under the federal and state drinking water acts, as well as unregulated contaminants of emerging concern, such as pharmaceuticals and personal care products. Laboratory analysis is able to detect many compounds in concentrations as low as 5 parts per trillion. One part per trillion is comparable to one drop of water in 20 Olympic-size swimming pools.

Reverse osmosis sampling station

In addition to monitoring water quality, each piece of equipment undergoes specific tests. For example, an automatic pressure decay test is performed daily on the membrane filters. This test is sensitive enough to detect even one broken fiber and helps confirm that more than 99.99 percent of all solid particles are consistently removed by the membranes. The integrity of the reverse osmosis is confirmed by continuous tracking of water quality levels before entering and after exiting the equipment. If the quality of the water produced by the reverse osmosis units were to decline, operators can test each individual pressure vessel to locate the membrane breach. At the ultraviolet disinfection/advanced oxidation stage, the amount of power being applied tells operators whether the lamps are functioning properly. Operators also measure the hydrogen peroxide dose rate to verify that the appropriate amount of hydrogen peroxide is used.

The testing and monitoring performed at the Demonstration Project's AWP Facility not only ensures the safety of the water produced at the facility, but has the added benefit of allowing the City to determine which equipment is the most effective for purifying water. Similar water quality monitoring performed at the demonstration-scale facility would be provided at a full-scale facility. If a full-scale facility were approved, the City's priority would be to ensure only the purest and safest water is added to the San Vicente Reservoir. Additionally, all of the City's drinking water is and will continue to be tested at the City's drinking water plants before being sent to customers' taps.

Water Purification Demonstration Project: 2011 YEAR-IN-REVIEW

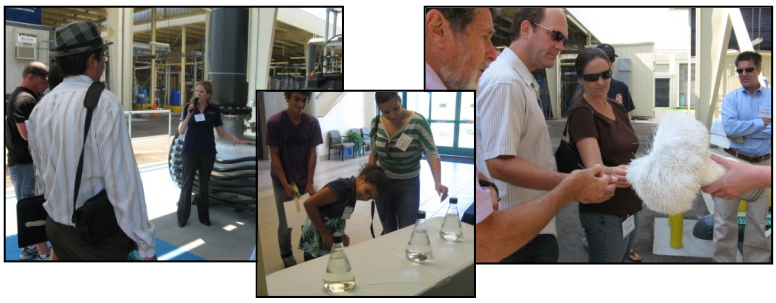
It has been an exciting and eventful year for the Water Purification Demonstration Project. In an effort to demonstrate that water purification can be a reliable, sustainable source of local water for San Diego, the project team strives to inform San Diegans about this important project. To this end, the project team reaches out to community members throughout the City by providing informational presentations, inviting residents to tour the Advanced Water Purification (AWP) Facility, and ensuring accessibility to information on the project website and social media platforms. The Demonstration Project and the AWP Facility have received positive feedback from project stakeholders in San Diego and internationally from Mexico, Vietnam, Australia, the United Kingdom, and Eurasian countries. Take a look at some of our 2011 highlights, including the unveiling of the state-of-the-art AWP Facility:

Before

After

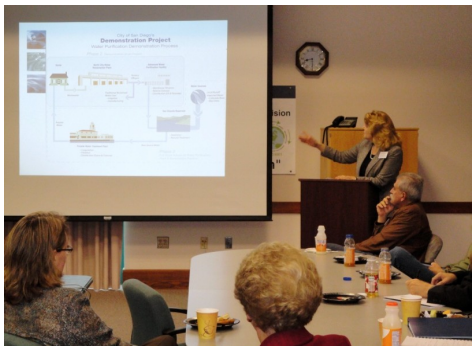
After months of planning, design and construction, the AWP Facility was completed and began operation in June 2011.

The AWP Facility kicked off public tours with a visit from Mayor Jerry Sanders, Public Utilities Director Roger Bailey, Project Director Marsi Steirer, Councilmember David Alvarez and many local media outlets.



The Demonstration Project team has hosted more than 100 tours for over 1,500 people since the AWP Facility opened its doors. The facility has attracted San Diego residents, government leaders, and stakeholders from around the world.

Hundreds of San Diegans learned about water purification at the Demonstration Project's informational booths at citywide community events. The City hosted exhibits at the San Diego Multicultural Festival, Earth Fair, Science Expo Day, Tet Festival, FilAmFest, and a dozen other events.



More than 100 groups throughout San Diego have invited the Demonstration Project speakers bureau to present to their members. To schedule a speaker for an organization's meeting, email purewatersd@sandiego.gov or call (619) 533-6638.

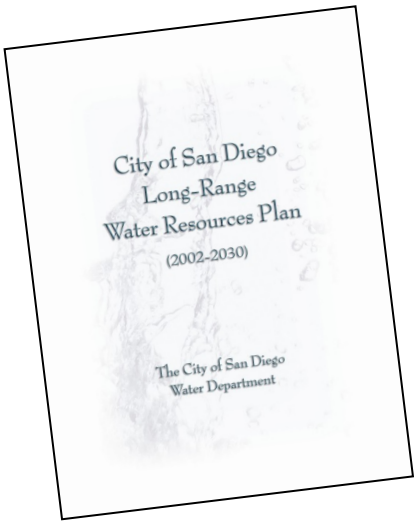
Many media outlets have covered stories on the Demonstration Project, including the Union-Tribune, USA Today, Huffington Post and TIME Magazine.

In September, the WateReuse Association honored the Demonstration Project with the 2011 WateReuse Association Public Education Program of the Year award.

Thank you to all who have taken the time to become informed and involved in this important project for San Diego's future.

Planning for a Sustainable Future

In an area where water is so scarce, strategic planning is essential to ensure water sustainability. The City of San Diego's 1997 Strategic Plan for Water Supply prompted the City to be more engaged in the planning and development of its water supply in order to become less reliant on imported water. Previously, the City depended almost entirely on the San Diego County Water Authority (SDCWA) to plan for and acquire necessary water supplies.



2002 Long-Range Water Resources Plan

In 2001, the City, with the assistance of a citizen's advisory committee, initiated an update of its Long-Range Water Resources Plan (Long-Range Plan), which was adopted by the City Council in 2002. The objectives of the Long-Range Plan were to extend water demand projections through 2030 and to develop a decision-making framework for evaluating water supply options to meet these demands. The water supply options identified in the Long-Range Plan included water conservation, water reclamation, groundwater desalination, groundwater storage, ocean desalination, marine transport, Central Valley water transfers, and imported supply. Various water supply options were evaluated. It was determined that no single supply source would be sufficient to meet the City's future water demand.

2012 Long-Range Water Resources Plan

In April 2011, the City began work on the 2012 Long-Range Water Resources Plan (2012 Plan) to update the 2002 Long-Range Plan. In developing the 2012 Plan, the City has convened a stakeholder committee, who will provide guidance and input on alternative strategies for meeting San Diego's water needs through 2035. The 2012 Plan will address various concerns, including those related to population growth, water resource diversification, climate change and other issues affecting water reliability. The 2012 Plan is anticipated to be complete in summer 2012.

Point Loma Wastewater Treatment Plant

2010 Urban Water Management Plan

While the Long-Range Plan provides a foundation for water options for San Diego, other planning is continually taking place. The City's 2010 Urban Water Management Plan (UWMP) describes long-term resource planning responsibilities to ensure adequate water supplies are available to meet existing and future demands. For the UWMP, the City coordinated with SDCWA and with local water agencies and cities that receive water from the City. The 2010 UWMP assesses current demands, lays out supply expectations over a 20-year period, and details plans for various drought scenarios.

Recycled Water Study meeting

Recycled Water Study

In addition to sustaining water supplies, the City is examining ways to limit the discharge of wastewater from the Point Loma Wastewater Treatment Plant (WWTP). In order to do this, the City is conducting a Recycled Water Study to identify opportunities and provide recommendations to increase recycling of wastewater, reduce wastewater discharged into the ocean, lessen the complexity of secondary upgrades to Point Loma WWTP, and determine implementation costs. This study is the result of a cooperative agreement the City entered with two local environmental groups in 2009. The agreement requires the City to conduct the Recycled Water Study and find ways to minimize Point Loma WWTP discharges by maximizing reuse. In return, the environmental groups supported the City's waiver application to operate the Point Loma WWTP as an advanced primary treatment plant. A final Recycled Water Study project report is expected to be complete in spring 2012.

One component of the Recycled Water Study is the completion of the 2010 Recycled Water Master Plan Update (2010 RWMP). The City must update its Recycled Water Master Plan every five years to define, encourage, and develop the use of recycled water. If all of the projects identified in the Recycled Water Study are not pursued, the 2010 RWMP evaluates other opportunities to maximize the reuse of water for non-potable purposes.

◆ ◆

Thanks to these and other long-range water resource plans, the City has expanded its recycled water system, developed the Water Purification Demonstration Project, dramatically increased water conservation, and continued to ensure safe and reliable water for San Diego. With the continued development and implementation of these and other plans, San Diegans can count on a reliable source of water for years to come.

California's Bay-Delta: Fragile and Tapped Out

Few places in the world are as essential to their region as the Sacramento-San Joaquin Bay-Delta is to the State of California. Located on the western edge of the Central Valley where the Sacramento and San Joaquin rivers feed into the San Francisco Bay, the Bay-Delta is a capillary-like expanse of natural and manmade channels that serve as the heart of California's ecosystem and economy. Depending on the current water situation, San Diego relies on the Bay-Delta for anywhere from 25 to 60 percent of its water supply.

The Bay-Delta is also an estuary, funneling freshwater runoff from the Sierra Nevada mountain range to the ocean, resulting in a beautiful, sensitive and complex ecology. This watery marsh creates a fertile peat soil that supports California's agricultural industry. Some of the freshwater that flows into the estuary is diverted to provide drinking water to communities statewide. Water imported from today's Bay-Delta system is fully allotted with no additional water available for future demands. Local supplies must support future water demands.

In recent years, attention has focused on the fragility of the Bay-Delta system. The levee system created in the late 19th century to reclaim farmland, control flooding, and divert water for local irrigation and consumption purposes is very delicate as a result of soil erosion and deferred maintenance. During the last century, nearly 200 Delta levee failures led to island inundations. In 1998, exterior levee breaches inundated over 22,000 acres of land and threatened State Water Project and Central Valley Project facilities.

Additionally, there are concerns that human activities are causing declines in fish populations. One species impacted is the delta smelt. This two-inch fish is considered an environmental indicator—meaning the health of the delta smelt population might be a reflection of the health of the Delta itself. In 2009 the California Fish and Game Commission reclassified the delta smelt from "threatened" to "endangered." In an effort to address the declining population of the delta smelt and other indicator fish species, court-ordered pumping restrictions have curtailed how much water gets sent through the California Aqueduct to Central and Southern California.

This means that a once reliable source of San Diego's water supplies now faces challenges limiting its accessibility. San Diego is particularly vulnerable to a shortage of imported water due to its limited local groundwater and surface water supplies. Developing local water supplies is critical to our economy and quality of life. One of these potential local water sources is purified water, which is the process being examined by the Water Purification Demonstration Project. By purifying recycled water and augmenting local reservoirs, the City can ensure a sustainable water source for San Diego, mitigate its dependence on imported Bay-Delta water, and lessen the environmental impact to a magnificent natural resource.

Did You Know?

Why do we need more water after the recent rain?

Even though winter rain helps, San Diego is located in a semi-arid desert climate and periodic droughts are inevitable in California. It is always important to use water wisely. Developing local reliable water sources, along with conservation efforts, are key components in San Diego's plan for a sustainable future.

@PureWaterSD

To schedule a presentation for your organization, email purewatersd@sandiego.gov or call (619) 533-6638.

SanDiegoWPDP

Get the latest online

For our smartphone-savvy readers, use your barcode-scanning app of choice to scan the quick response (QR) barcodes to the left and right. You'll be an official Demonstration Project fan in no time!

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Pure News

Water Reuse Program

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Summer 2012

The City of San Diego • Public Utilities Department

Pure News: Issue 6

Welcome to Pure News, a newsletter to keep you informed about the latest happenings with the City of San Diego's Water Purification Demonstration Project.

Moving Right Along

It's hard to believe it has been one year since the Advanced Water Purification (AWP) Facility began operation in June 2011. This demonstration facility purifies one million gallons of recycled water a day for testing and analysis before being diverted back to the City's recycled water system. The purification process uses microfiltration and ultrafiltration, reverse osmosis, and ultraviolet disinfection with advanced oxidation. The AWP Facility will continue to operate and offer tours through next year.

Although the AWP Facility is the centerpiece of the Demonstration Project, other behind-the-scenes work has been taking place as part of the project. For more than two years, staff have been conducting a study of the San Vicente Reservoir, working with California Department of Public Health and the San Diego Regional Water Quality Control Board to define regulatory requirements, and determining the cost of a full-scale project.

A final report compiling the results of the project's components is scheduled for completion at the year's end. The report will be available to the public following its release to the Mayor and City Council.

Pulling Out All the Stops for Purified Water

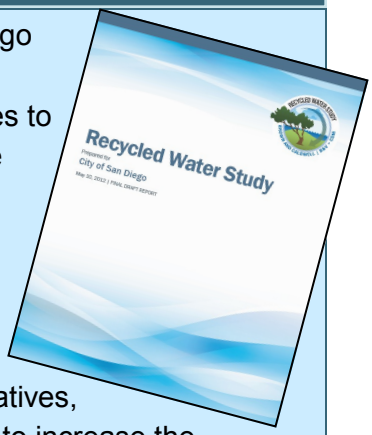
When it comes to water purification, many people refer to it as "toilet-to-tap." Although that is a catchy alliteration, it fails to indicate the comprehensive treatment process of purifying recycled water. In fact, recycled water would go through multiple treatment steps before reaching customers' faucets in a full-scale project. These steps provide multiple safety barriers so that public health is protected.

Pre-AWP Facility Barrier: Recycled Water

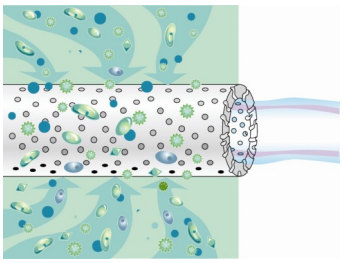
Before the purification process, wastewater from homes and businesses is treated at a water reclamation facility to a level suitable for irrigation, manufacturing and other non-drinking purposes. This treated water is called recycled water and is safe for human contact. The Water Purification Demonstration Project further treats the recycled water at the AWP Facility.

(Continued on page 2)

Expanding Recycled Water Use



In 2009, the City of San Diego launched a Recycled Water Study to look at opportunities to maximize wastewater reuse and reduce the amount of treated wastewater discharged into the ocean via Point Loma Wastewater Treatment Plant. The Study features reuse alternatives, including water purification, to increase the use of recycled water and to decrease the City's reliance on imported water. A report on the Study's findings was presented to the San Diego City Council on July 17. They are also available online at sandiego.gov/water/waterreuse/pdf/recycledfinaldraft120510.pdf.

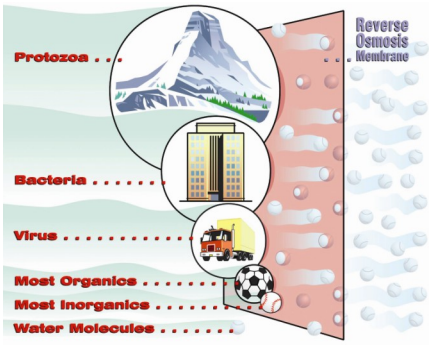


AWP Facility Barrier 1: Membrane Filtration

The first step upon entering the AWP Facility is membrane filtration. Recycled water is pushed by pumps through the membrane filtration's thousands of hollow fibers. These fibers have very fine pores that filter out bacteria, protozoa and particles. Microfiltration and ultrafiltration are two types of membrane filtration.

AWP Facility Barrier 2: Reverse Osmosis

The water treated by membrane filtration then enters the reverse osmosis units. In this step, water is pumped through semi-permeable membranes which let water molecules pass through, but blocks microorganisms, such as viruses.



AWP Facility Barrier 3: Ultraviolet Disinfection/Advanced Oxidation

After reverse osmosis, hydrogen peroxide is mixed into the water before undergoing ultraviolet treatment. The added hydrogen peroxide reacts with ultraviolet light to form powerfully reactive molecules that destroy any remaining organic matter in the water. This advanced oxidation process completely disinfects the water of any remaining organisms in addition to destroying any remaining contaminant chemicals.

Post-AWP Facility Barrier: San Vicente Reservoir

Now that the water has gone through membrane filtration, reverse osmosis, and ultraviolet disinfection with advanced oxidation, the resulting water is similar to distilled water quality. During the Demonstration Project, this water is returned to the recycled water distribution system for irrigation and industrial uses; it is not currently added to the drinking water supply. If a full-scale water purification project were approved, the purified water would be sent to San Vicente Reservoir via a 23-mile pipeline.

At San Vicente Reservoir, the purified water would mix with and be diluted by the existing water supply. The reservoir also provides further treatment by exposure to sunlight and other natural cleansing processes.

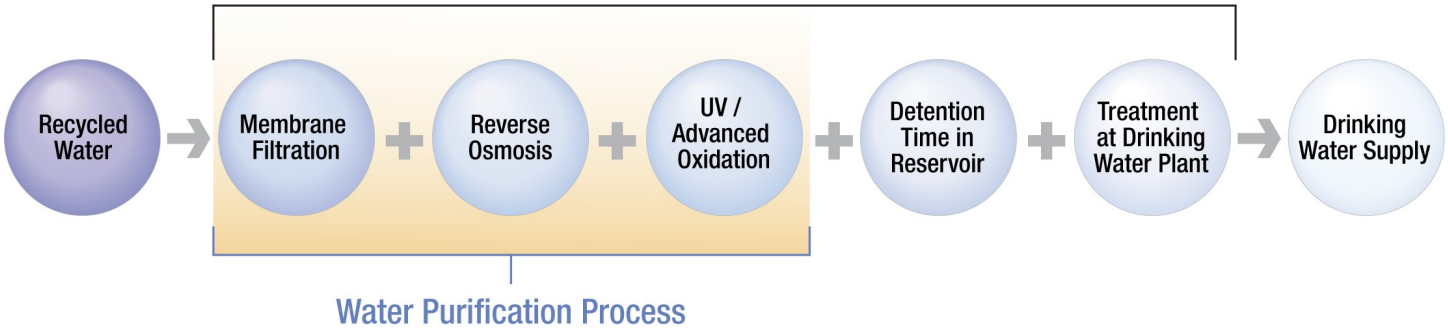
Post-AWP Facility Barrier: Drinking Water Treatment Plant

The final step for the blended water (raw water from the reservoir and the purified water) before reaching customers would be a drinking water treatment plant. There the blended water would undergo additional treatment to make it safe to drink.

Testing & Monitoring

Throughout the entire process, water would be tested and monitored to ensure contaminants are removed and the final product meets state regulations. If any anomalies were detected with the water quality at any point, the process would be halted and the water would not reach customers. Although the multiple barrier process may seem excessive, these safeguards ensure that San Diegans would receive the highest quality and safest water possible.

Multi-Barrier Water Purification Steps



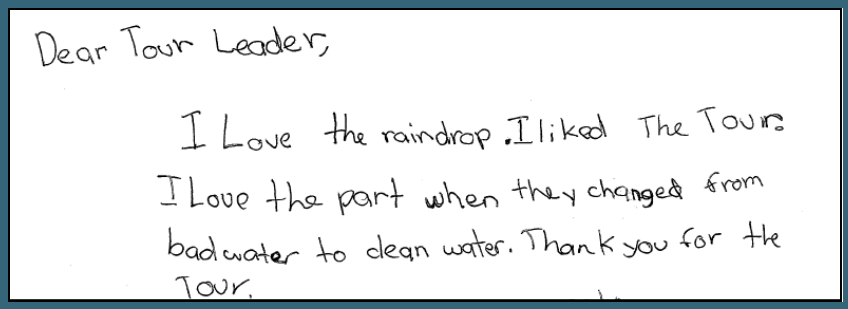
Celebrating a Year of Tours

When the AWP Facility opened in June 2011, the City supplemented its existing outreach program with something more tangible: a tour experience. From the very first tours of the facility, tour guides have engaged visitors and explained the need for a local and reliable water supply, led them through an up-close experience with the water purification equipment, and challenged them with a quiz comparing purified water to tap and recycled water. Almost 200 tours later, the tour program continues to provide guests a unique insight into water purification.

Nearly 2,500 guests have toured the AWP Facility since its opening. Visitors range from members of the public to elected officials; from elementary school classes to fourth-year medical students; from Girl Scout troops to professional societies; from people who live down the street from the facility to people all the way from Australia, the UK, India, and other countries.

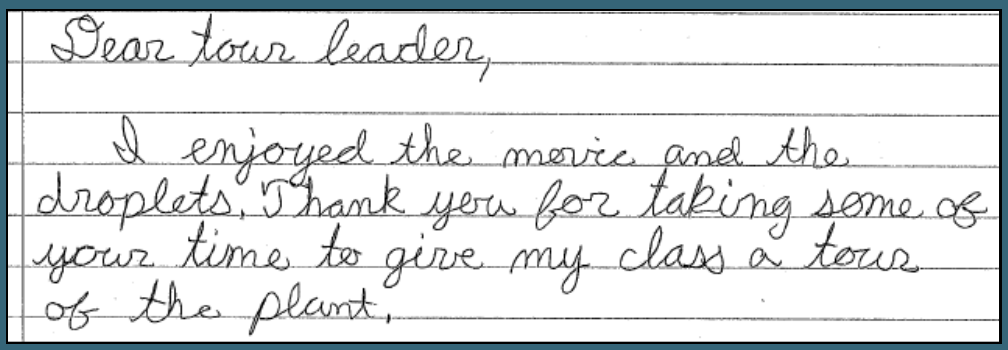
The Demonstration Project has welcomed many San Diegans to the AWP Facility, and it's not stopping yet. Tours are expected to continue through summer 2013. So gather your friends, family, neighbors, coworkers and organizations to come for a look at what may be one of San Diego's future water sources. To register for a tour, visit purewatersd.org/tours.shtml. If you can't make it out for a tour, staff would be happy to make a presentation to your organization. Contact purewatersd@sandiego.gov to schedule a presentation or to register a large group for a tour. Hope to see you soon!

Out of the Mouths of Babes:



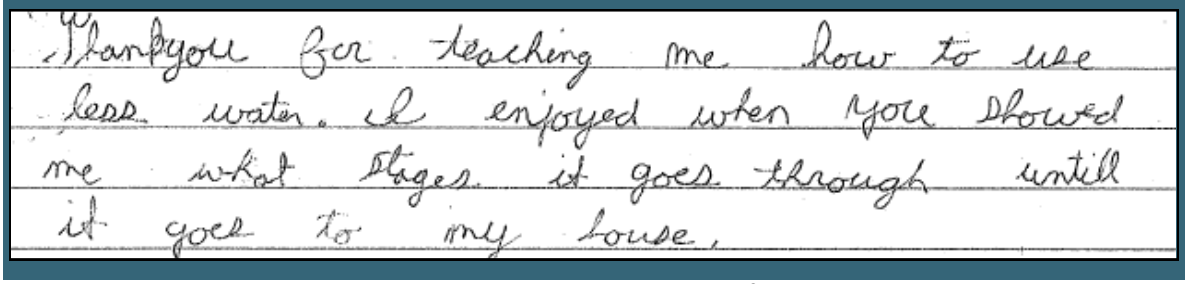
Dear Tour Leader,

I Love the raindrop. I liked The Tour. I Love the part when they changed from badwater to clean water. Thank you for the Tour.

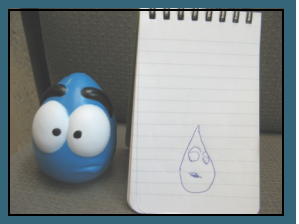


Dear tour leader,

I enjoyed the movie and the droplets. Thank you for taking some of your time to give my class a tour of the plant.



Thankyou for teaching me how to use less water. I enjoyed when you showed me what stages it goes through untill it goes to my house.



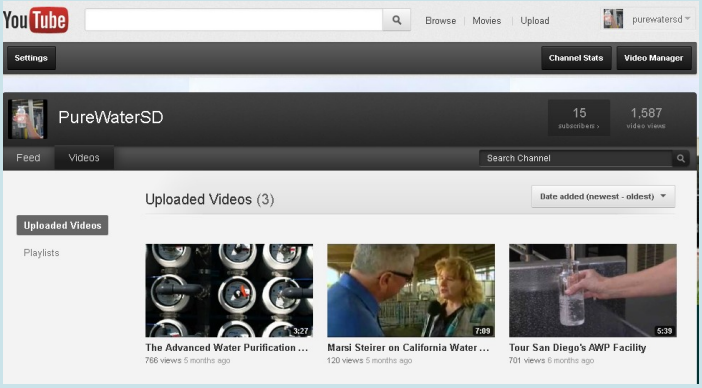
Get Social

The Demonstration Project is social-media savvy! We are on Facebook, Twitter and YouTube and want your participation. By "liking," following, and subscribing to the Demonstration Project on Facebook, Twitter, and YouTube, you can interact with the Demonstration Project team and find out what's going on with the future of San Diego water.

Find us on Facebook at **facebook.com/SanDiegoWPDP**. There you can read the latest information about the project, view photos of the AWP Facility and tour participants, ask questions of the Demonstration Project team and find links to interesting articles about water issues in California and around the globe. Our Facebook page is a great first step to learning about the Demonstration Project.

Follow us on Twitter **@PureWaterSD** to not only keep current on the Demonstration Project, but to also participate in the dialogue of the sustainable water community. Tweet at us for a direct reply, and retweet to your followers what you find interesting.

Subscribe to our YouTube page at **youtube.com/PureWaterSD** and view a virtual tour of the AWP Facility. You can also watch how TM the multi-barrier filtration process works to produce clean, clear water from recycled water. There is also a clip from California's Gold with Huell Howser featuring project director Marsi Steirer explaining the water purification process. Comment on the videos and let us know what you think.



Your participation on our social media platforms ensures your active contribution toward the future of San Diego's water supply. We look forward to hearing from you!

@PureWaterSD

SanDiegoWPDP

Get the latest online

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Pure News

Water Reuse Program

Water Purification Demonstration Project

Fall 2012

The City of San Diego • Public Utilities Department

Water Purification | Demonstration Project

Pure News: Issue 7

Welcome to Pure News, a newsletter to keep you informed about the latest happenings with the City of San Diego's Water Purification Demonstration Project.

San Diego Is Leading the Way

San Diego is paving the way for water purification not just locally, but also nationally and internationally. As water supplies shrink worldwide and with growing interest in sustainable water programs, water purification is gaining momentum as a potential solution to depleted water resources. There are great examples of full-scale water purification facilities operating successfully, such as Singapore's NEWater and Orange County's Groundwater Replenishment System. For cities and water agencies around the world, however, San Diego's Water Purification Demonstration Project exemplifies a key step in the development of a full-scale water purification project.

Orange County's water purification facility

Visitors from all over the world have come to San Diego to learn more about the Demonstration Project , which includes the installation and operation of a one-million-gallon-a-day Advanced Water Purification (AWP) Facility, a study of the San Vicente Reservoir, a pipeline alignment assessment and an extensive public outreach and education program. Since opening in June 2011, the AWP Facility has welcomed guests from nearly 20 countries, including Mexico, Australia, Vietnam, Spain, India, China, the United Kingdom, Iraq, Brazil and Ukraine. There are also many American visitors, including guests from Arizona; Florida; Massachusetts; Texas; Utah; Washington, D.C. and cities throughout California. These guests come to get ideas on how to implement water purification in their own locales.

The project has also received industry awards recognizing its achievements. The WateReuse Association, an international group of organizations and individuals working together to improve and increase local water supplies, honored the Demonstration Project with the 2012 WateReuse Small Project of the Year Award. The award provides industry recognition for successful small (less than five-million-gallons-a-day capacity) projects that have made significant contributions to advancing water reuse. Last year, the WateReuse Association recognized the Demonstration Project's outreach program as the 2011 WateReuse Public Education Program of the Year.

While it is important to have national and international recognition, the purpose of this project is to determine whether water purification is a feasible option for expanding San Diego's local water resources. The public outreach program's goal is to provide information about the project to as many San Diegans as possible. The outreach team will continue to encourage residents to learn about the project through presentations and facility tours throughout 2013. Request a presentation by emailing PureWaterSD@sandiego.gov or by calling 619-533-6638. Sign up for a tour online at www.purewatersd.org/tours.shtml.

San Vicente Reservoir Limnology Study:
An overview of the study and what it has shown

If the Demonstration Project advances to a full-scale project, purified water would be added to the untreated or “raw” water that is already stored in the San Vicente Reservoir. Part of the research conducted during the Demonstration Project was a limnology study, or a scientific study of the biological and physical features of the reservoir. Primarily, the project team needed to gain a good understanding of what effect– if any – purified water would have on the other water in the reservoir.

Although water purification technology is widely recognized as capable of purifying recycled water into drinkable water, regulatory agencies require that purified water be retained in an “environmental buffer,” such as a groundwater basin or a surface water reservoir, before it becomes part of the drinking water supply. Adding purified water to an environmental buffer provides a public health barrier: dilution with other water sources and retention time that allows for additional natural treatment.

San Vicente Reservoir would serve as an effective environmental buffer for a full-scale project in San Diego. The reservoir stores a large volume of water capable of providing adequate dilution and retention of the purified water and, most importantly, exhibits seasonal stratification (see Page 3). A three-dimensional hydrodynamic model of the reservoir was developed by experts from the firm Flow Science, and was reviewed and accepted by the Demonstration Project’s Independent Advisory Panel (IAP).

San Vicente Reservoir has been studied many times in the past. In fact, tracer studies of the reservoir were conducted in the 1990s. A tracer study involves putting an element in the water at a specific point and tracing its path through the reservoir. This provides an understanding of how water mixes in the reservoir. These tracer studies provided good background for the current study, which involved running the three-dimensional hydrodynamic model 18 times. The project team - with input from the IAP and regulators - selected eight modeling scenarios that represent the full range of operational conditions the full-scale reservoir augmentation project could encounter. The key findings are:

- The addition of purified water to San Vicente Reservoir would not affect the natural hydrologic characteristics of the reservoir (the natural dilution and retention in the reservoir).
- Dilution and retention of purified water in San Vicente Reservoir would constitute a substantial environmental barrier, sufficient to meet regulatory requirements.
- For all anticipated reservoir operating scenarios and purified water entry locations, the reservoir would dilute the purified water by a factor of at least 200 to one at all times.
- The addition of purified water would not negatively affect any aspect of water quality in San Vicente Reservoir. Independent of the Demonstration Project, the San Vicente Dam has been raised to a height of 337 feet. The expanded reservoir will hold over 240,000 acre-feet of water (more than double its original 90,000 acre-feet), which will improve the overall water quality in the reservoir. The addition of purified water will have no effect on these improvements.

What is a three-dimensional hydrodynamic model?

"Hydrodynamics" is the movement of water. The three-dimensional hydrodynamic model of San Vicente Reservoir is a computer-based model that simulates and predicts the movement of water in all three directions within the reservoir: up and down, left to right, and fore and back. The model incorporates solar heating, wind speed and direction, water inflows and outflows, evaporation and rainfall, and air temperature. Equations in the model calculate heating and cooling, mixing, and dilution of the reservoir water.

BREAKING NEWS: The California Department of Public Health, a key regulator in this project, provided written approval of the City’s proposed reservoir augmentation concept in September 2012, stating that the City’s concept “will not compromise the quality of the water derived from San Vicente Reservoir.”

What is reservoir stratification?

Reservoir stratification – the formation of layers of water within a reservoir – is a natural phenomenon that occurs in nearly all reservoirs in western North America, including San Vicente Reservoir. Consistent and predictable stratification has been observed over more than twenty years of monitoring at San Vicente Reservoir. During the period of stratification, which lasts for about eleven months each year, surface water is heated by the sun. Because this warm water is less dense than cooler water it "floats" in the top-most layer of the reservoir. The denser, cooler water remains in the lower layer of the reservoir. During stratification, any dissolved or suspended constituents in the surface water do not readily mix with the water and constituents in the deep water. In winter the surface water cools, causing water temperature in the reservoir to equalize so that the surface and deep water mix, or destratify. The fully destratified condition lasts for a few weeks to a month and typically occurs during January or February. The natural stratification and mixing of San Vicente Reservoir is an important phenomenon because it determines the extent and timing of dilution and retention provided by the reservoir.

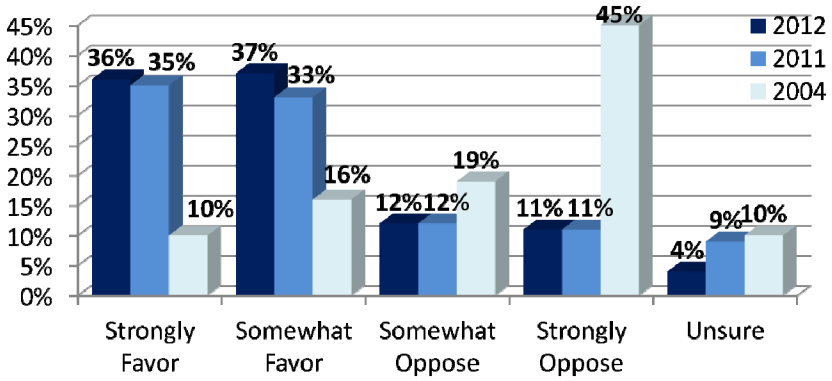
Understanding Local Water Attitudes

To get a better idea of public opinions regarding water issues throughout the county, the San Diego County Water Authority regularly conducts public opinion polls. For 2004, 2011, and 2012, the City of San Diego requested a sample of City residents be polled to ensure we have a good base knowledge about water attitudes in the City, including opinions regarding the use of water purification to create new water supplies.

The results from the latest research study are now available and show a steady increase in acceptance of water purification. Some of the questions and findings are below:

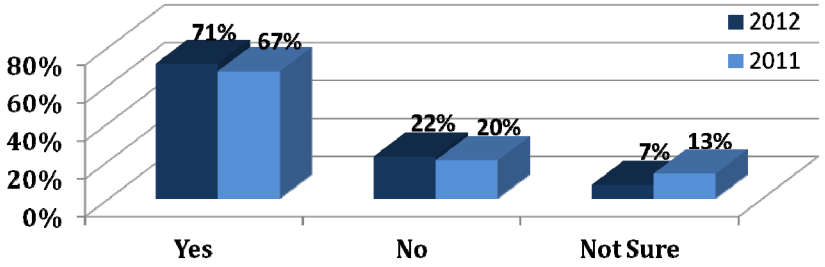
How would you feel about using advanced treated recycled water as an addition to the supply of drinking water?

- In 2004, only 26 percent favored using advanced treated recycled water (or purified water) to help diversify the City's water supply
- In 2012, favorability jumped to nearly three-fourths of City residents



Do you believe that it is possible to further treat recycled water currently used for irrigation to make the water pure and safe for drinking?

- The 2011 survey found 67 percent of the nearly 400 respondents felt that it is possible to further treat recycled water for drinking purposes
- A year later, 71 percent believe it is possible



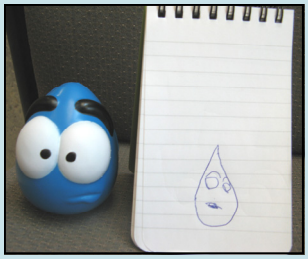
Despite these positive findings, many respondents were still unaware that San Diego is testing water purification locally. Additionally, the majority of respondents also did not know that Orange County's drinking water supply is supplemented with purified water produced using the same purification process being tested by the Demonstration Project. The Demonstration Project team continues to educate San Diegans about this test phase to increase local knowledge about water supply challenges and the science of water purification.

The entire public opinion poll findings can be found online at www.sandiego.gov/water/waterreuse/pdf/sdcwasurvey2012.pdf.

Year in Review: Building on the Momentum of 2012

This has been a productive and exciting year for the Demonstration Project. Our staff is grateful to the people of San Diego who helped spread the word about the project. We are proud to have spent almost every day in 2012 engaging curious and enthusiastic groups, decision makers and community members in the Water Purification Demonstration Project through tours, presentations, events and social media.

Since the tour program began in mid-2011, we have led over 225 AWP Facility tours for more than 3,000 participants. While we were honored to have visitors from as far away as Australia and Iraq tour the facility, some of our favorite guests have been children who asked thoughtful questions and got us to look at water purification in a whole new light. From drawings about the very curious "Wobbly the Waterdrop" to asking important questions about the water they are already drinking, educating young people is an important element of the project's outreach efforts. We have hosted 2nd graders who are just learning the terms associated with water purification, medical students who are interested in the technology, Girl Scout and Boy Scout troops, rotary clubs, senior groups and members of the military.



In addition to the tours, our speakers bureau has presented information about water purification to more than 120 groups and organizations in San Diego County. We have also participated in over 40 community events in each of San Diego's City Council Districts, as well as shared project updates and connected one-on-one with interested parties through active pages on Facebook and Twitter.

Decisions made about water supply sources today will determine how reliable San Diego's water supplies are in the future. Therefore, it is important to the Demonstration Project team that we share information with as many San Diego residents as possible about our future water needs and the role of this project.

Thanks again for making 2012 a great year for the Demonstration Project. We look forward to building on our momentum and continuing to share information about water purification at more events, presentations and tours in the coming months. Additionally, a final report wrapping up all of the project's findings is due out in 2013. Until then, we wish you and yours a happy holiday season. See you in 2013!

@PureWaterSD

SanDiegoWPDP

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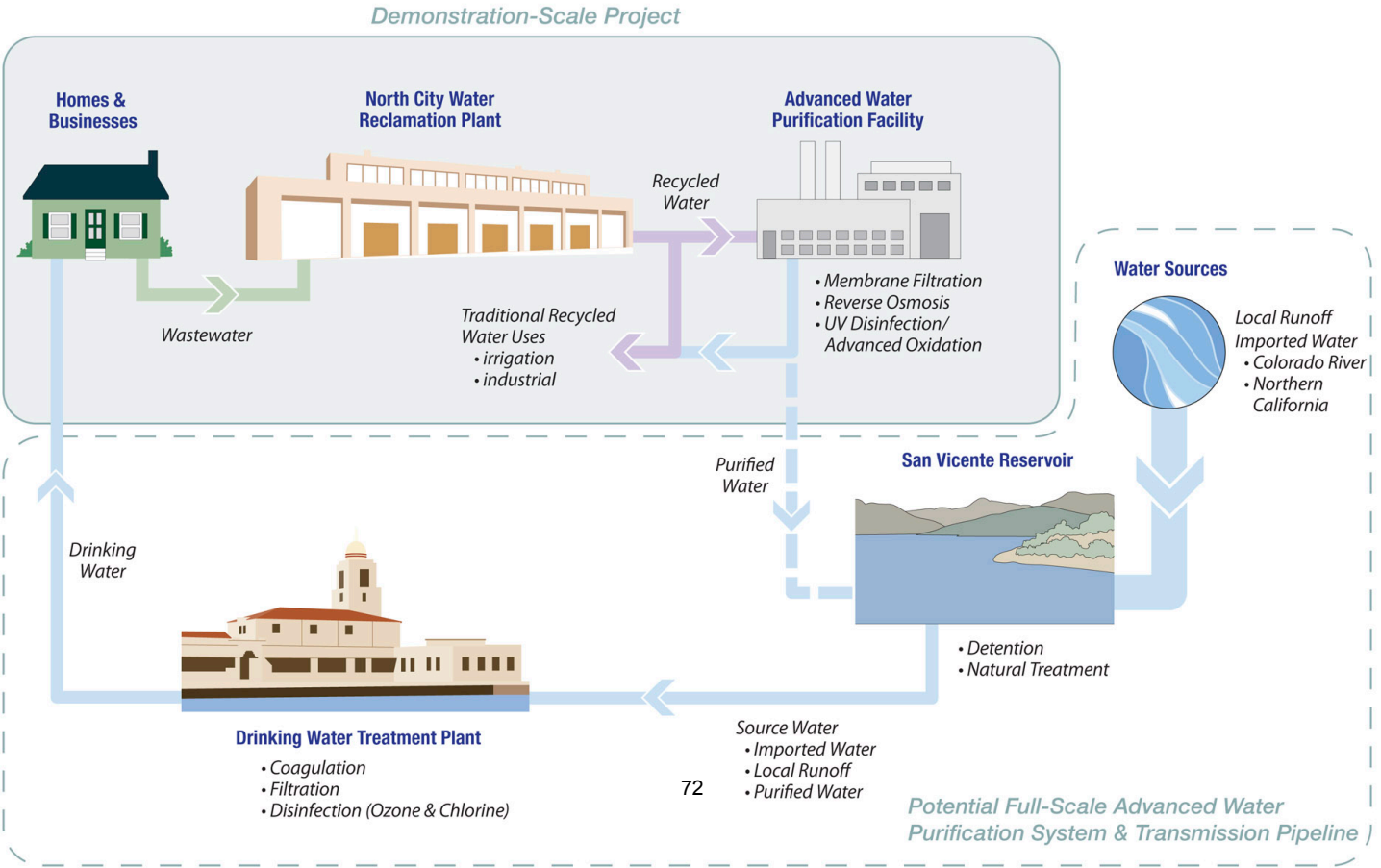
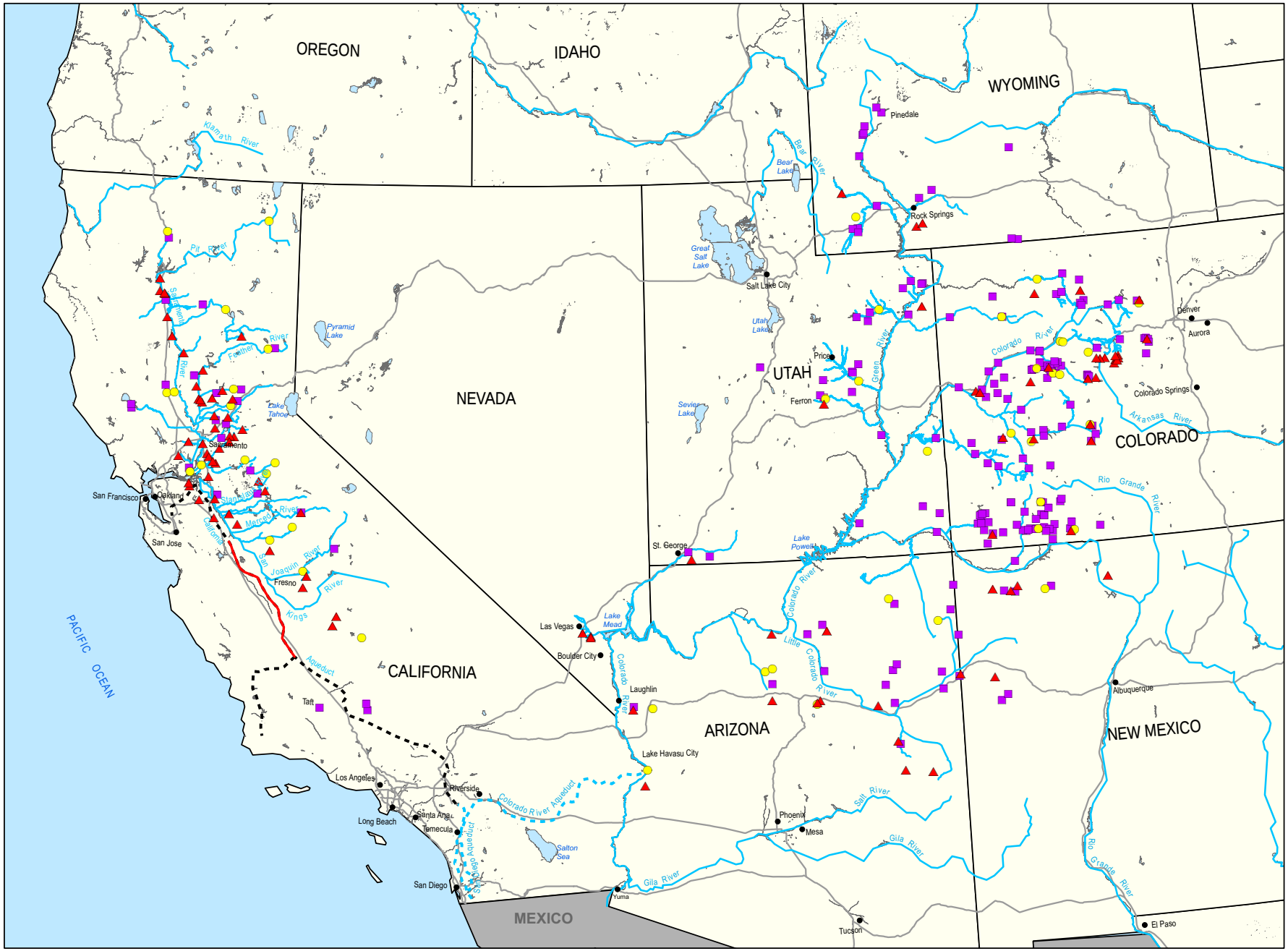
Poster Boards

City of San Diego's

Water Purification Demonstration Project

Purification Process





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Geographic Data based on maps obtained from The National Atlas of the United States of America & Environmental Systems Research Institute, Inc. (ESRI) data.

SanGIS

N

0 20 40 80 120 160 Miles

LEGEND

- 1.0> MGD
- .5 - <1.0 MGD
- <.5 MGD
- FREEWAYS
- RIVERS
- COLORADO/SAN DIEGO AQUEDUCT
- SWP AQUEDUCT
- STATE-FEDERAL WATER PROJECT

MGD = Flow in million gallons per day *
Facility locations are approximate

* Source for flow rate: Colorado Salinity Forum Oct 31, 2008 & California Department of Water Resources & U.S Environmental Protection Agency

Note:
At any given time many of the permits identified in this map are being reviewed, reissued, and/or terminated, and new discharge permits are being filed, this data must be considered as being subject to frequent changes

City of San Diego
PUBLIC UTILITIES
Water & Wastewater

Municipal Wastewater NPDES Facilities

Colorado River & State Water Projects

N:\Resources & Planning\Water Purification Demonstration Project\Public Outreach\Outreach Materials\Graphics\Discharge Map NPDES Facilities_2011.pdf coordinates_1/24/11.mxd

In the World of Water, We are All Downstream

Timeline for Potable Reuse Projects in U.S.

1960 1970 1980 1990 2000 2010

1962
LACSD Montebello Forebay Groundwater Recharge Project

1976 - 2008
OCWD Water Factory 21 Seawater Barrier

1978
Upper Occoquan Service Authority WRF (UOSA WRF) in Fairfax, Virginia starts operation to improve water quality in the Occoquan Reservoir, a major potable water source

1985
Hueco Bolson Recharge Project in El Paso, TX

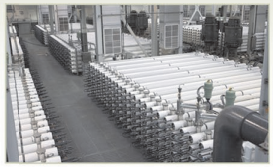
1995
LACDPW West Coast Basin Seawater Barrier

2005
IEUA Chino Basin Recycled Water Groundwater Recharge Project

2005
Los Angeles County Dept. of Public Works (LACDPW) Alamitos Seawater Barrier

2005
UOSA WRF capacity is expanded to 54 MGD

2006
LACDPW Dominguez Gap Seawater Barrier



2008
OCWD GWR System Seawater Barrier & Groundwater Recharge Project starts and Water Factory 21 is discontinued

2011
Prairie Waters Project in Aurora, CO anticipated to start operation of indirect potable reuse

2011
San Diego Water Purification Demonstration Project in San Diego, CA anticipated to start operation of indirect potable reuse demonstration project

2011
El Monte Groundwater Recharge Project in San Diego County, CA anticipated to start operation of indirect potable reuse

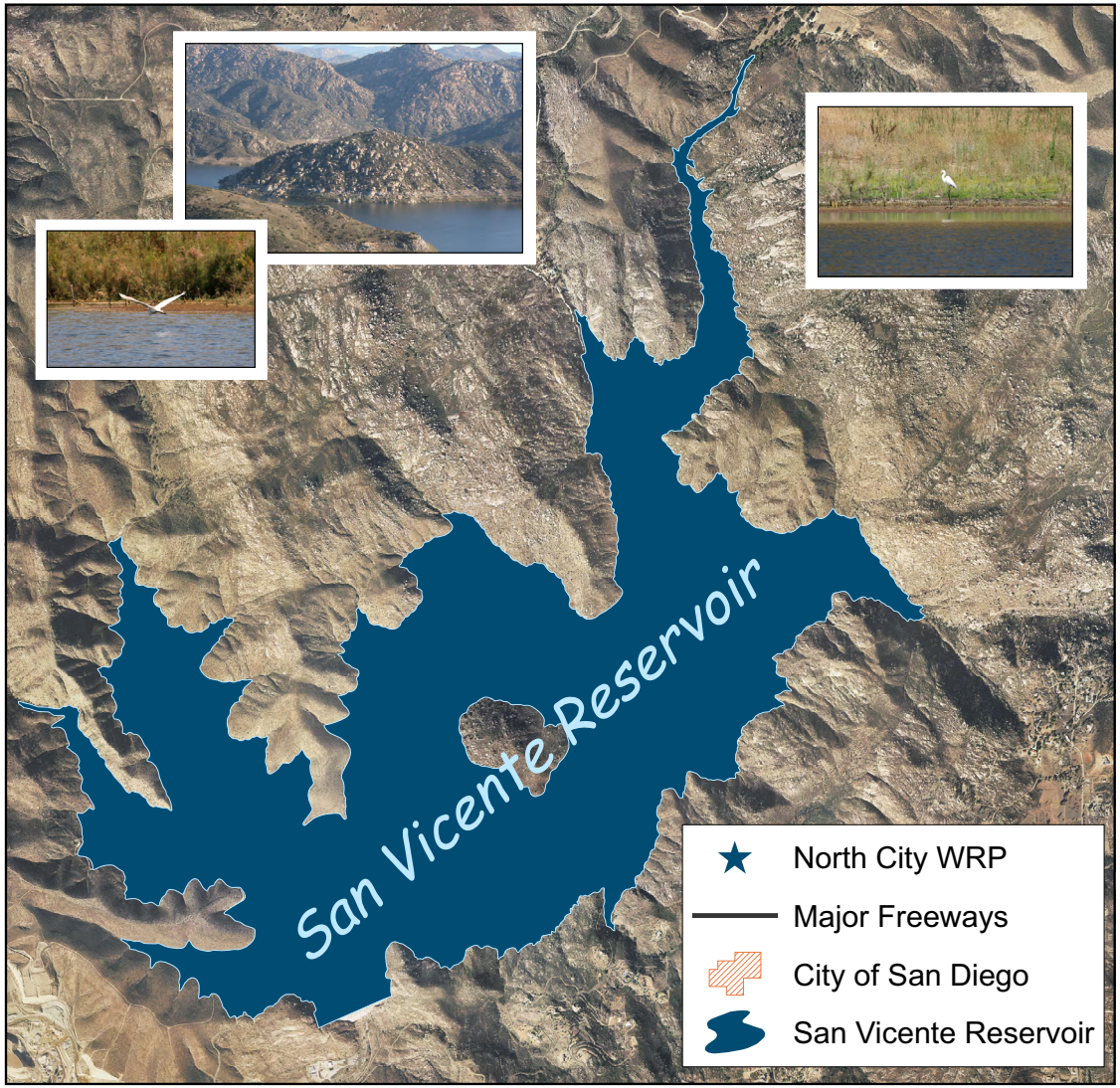
Potable Reuse Project Details

Project	Level of Treatment	Start Year	WRF Rated Capacity (MGD)	Actual Delivery
LACSD Montebello Forebay Groundwater Recharge Project[1] Los Angeles County, CA	Tertiary with Soil Aquifer Treatment	1962	47.5	50,000
OCWD Water Factory 21 Seawater Barrier Orange County, CA	Tertiary with Microfiltration and Reverse Osmosis	1976	15	17,000
UOSA Occoquan Reservoir Indirect Potable Reuse[2] Fairfax, VA	Tertiary with High-lime Process, Chlorination & Dechlorination	1978	54	47,000
Hueco Bolson Recharge Project El Paso, TX	Tertiary with Activated Carbon, Lime Process, Ozone Disinfection	1985	10	2,000
LACDPW West Coast Basin Seawater Barrier[3] Los Angeles County, CA	Tertiary with Microfiltration, Reverse Osmosis & UV	1995	30	5,000
LACDPW Alamitos Seawater Barrier[4] Los Angeles County, CA	Tertiary with Microfiltration, Reverse Osmosis & UV	2005	3	3,000
IEUA Chino Basin Groundwater Recharge Project[5] San Bernardino County, CA	Tertiary with Soil Aquifer Treatment	2005	84.4	10,000
LACDPW Dominguez Gap Seawater Barrier[6] Los Angeles County, CA	Tertiary with Microfiltration and Reverse Osmosis	2006	4.5	1,000
OCWD GWRS Seawater Barrier & Groundwater Recharge Project Orange County, CA	Tertiary with Microfiltration, Reverse Osmosis & AOP	2008	70	75,000
Aurora Prairie Waters Project Aurora, CO	Riverbank Filtration, Advanced UV Oxidation, GAC Adsorption	2011	50	10,000
Helix WD El Monte Groundwater Recharge Project[7] San Diego County, CA	Tertiary with Microfiltration, Reverse Osmosis, Advanced UV Oxidation	2011	x	5,000
San Diego Water Purification Demonstration Project[8] San Diego, CA	Tertiary with Microfiltration, Reverse Osmosis, Advanced UV Oxidation	2011	1	N/A

Notes:

1 Recycled water is provided by Sanitation Districts of Los Angeles County's Whittier Narrows and San Jose Creek (100 MGD) WRFs.
2 Recycled water is provided by the regional Upper Occoquan Service Authority's WRF.
3 Recycled water is provided by Water Replenishment District that is purchased from West Basin MWD Edward C. Little WRF. It is blended with MWD imported water.
4 Recycled water is provided by the Water Replenishment District of Southern California's Long Beach WRF (Tert.) and Leo J. Vander Lans WTF (Adv).
5 Recycled water is provided by four Inland Empire Utility Agency water reclamation facilities; Regional Plants Nos. 1, 4 and 5 and the Carbon Canyon WRF.
6 Recycled water is provided by the Los Angeles County Flood Control District's Terminal Island Treatment Facility.
7 Recycled water to be provided by the Padre Dam Municipal Water District or the City of San Diego.
8 Recycled water to be provided by the City of San Diego North City WRF. As this is a demonstration facility only, no water will be delivered for indirect potable consumption.

North City Water Reclamation Plant to San Vicente Reservoir



0 0.25 0.5 1 1.5 Miles

North City Water Reclamation Plant to San Vicente Reservoir

City of San Diego PUBLIC UTILITIES Water & Wastewater

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Prepared by City of San Diego Public Utilities Department
Watershed and Resource Protection Team, June 29, 2011

Bookmarks

Three types of bookmarks were produced for the Demonstration Project.

Did you know...

THE CITY OF SAN DIEGO

City of San Diego
PUBLIC UTILITIES
Water & Wastewater

- San Diego needs local, reliable and sustainable sources of water to lessen our dependence on imported water.

- The Water Purification Demonstration Project is examining the use of advanced water purification technology to determine the feasibility of full-scale reservoir augmentation.

- The water produced by the purification process goes through multiple steps of advanced treatment to meet all water quality, safety and regulatory requirements.

- No purified water will be added to the San Vicente Reservoir or San Diego's drinking water system during the Demonstration Project.

CITY OF SAN DIEGO

Water Purification | Demonstration Project

www.PureWaterSD.org

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Water Purification Demonstration Project

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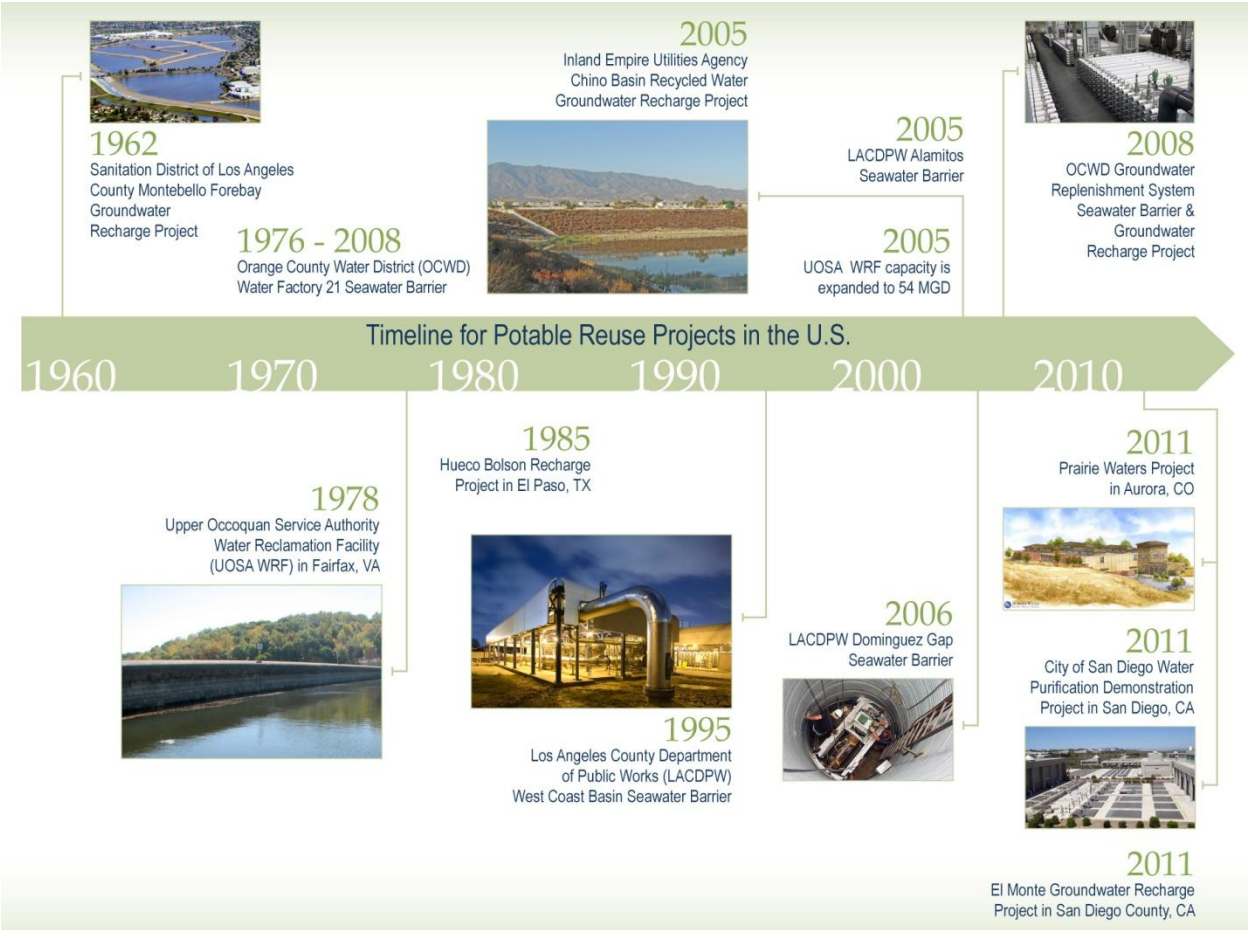
White Papers

POTABLE REUSE PROJECTS IN THE UNITED STATES

The water cycle—the continuous movement of water from ocean to air and land and back to the ocean—is as old as the earth itself. The basic underlying principle is simple: All water is recycled. There is no new water.

Throughout the developed world, wastewater has been collected and treated for return to the environment where it receives further treatment thanks to sunlight, time, and nature, prior to being used again. Today, nature cannot keep up with all the water needs of people, industry and agriculture, especially in arid regions like Southern California. As a result, human beings have accelerated this process with advanced water purification systems which, combined with natural treatment occurring in groundwater or surface water bodies, make up *potable reuse*. Advanced water purification includes additional treatment beyond tertiary for further removing constituents of concern to public health. This may include membrane filtration, reverse osmosis and advanced oxidation (WateReuse, n.d.).

This white paper presents key potable reuse projects that have been implemented in the United States beginning in the 1960s. It should be noted that almost all of these projects occur in areas with limited or no surface water reservoir storage capacity and, as such, the treated water is used to recharge groundwater aquifers. Projects that discharge into rivers or reservoirs (surface water augmentation) include the Upper Occoquan Service Authority project in Fairfax, Virginia and the Prairie Waters Project in Aurora, Colorado. A summary timeline and key fact tabulation is presented below.



Potable Reuse Project Details

Project	Level of Treatment	Start Year	WRF Rated Capacity (MGD)	Actual Delivery (AFY)
LACSD Montebello Forebay Groundwater Recharge Project[1], Los Angeles County, CA	Tertiary with Soil Aquifer Treatment	1962	47.5	50,000
OCWD Water Factory 21 Seawater Barrier, Orange County, CA	Tertiary with Microfiltration and Reverse Osmosis	1976	15	17,000
UOSA Occoquan Reservoir Indirect Potable Reuse[2], Fairfax, VA	Tertiary with High-lime Process, Chlorination & Dechlorination	1978	54	47,000
Hueco Bolson Recharge Project, El Paso, TX	Tertiary with Activated Carbon, Lime Process, Ozone Disinfection	1985	10	2,000
LACDPW West Coast Basin Seawater Barrier[3], Los Angeles County, CA	Tertiary with Microfiltration, Reverse Osmosis & UV	1995	30	5,000
LACDPW Alamitos Seawater Barrier[4], Los Angeles County, CA	Tertiary with Microfiltration, Reverse Osmosis & UV	2005	3	3,000
IEUA Chino Basin Groundwater Recharge Project[5], San Bernardino County, CA	Tertiary with Soil Aquifer Treatment	2005	84.4	10,000
LACDPW Dominguez Gap Seawater Barrier[6], Los Angeles County, CA	Tertiary with Microfiltration and Reverse Osmosis	2006	4.5	1,000
OCWD GWRS Seawater Barrier & Groundwater Recharge Project, Orange County, CA	Tertiary with Microfiltration, Reverse Osmosis & AOP	2008	70	75,000
Aurora Prairie Waters Project, Aurora, CO	Riverbank Filtration, Advanced UV Oxidation, GAC Adsorption	2011	50	10,000

Notes:
[1] Recycled water is provided by Sanitation Districts of Los Angeles County's Whittier Narrows and San Jose Creek (100 MGD) WRFs.
[2] Recycled water is provided by the regional Upper Occoquan Service Authority's WRF.
[3] Recycled water is provided by Water Replenishment District that is purchased from West Basin MWD Edward C. Little WRF. It is blended with MWD imported water.
[4] Recycled water is provided by the Water Replenishment District of Southern California's Long Beach WRF (Tert.) and Leo J. Vander Lans WTF (Adv).
[5] Recycled water is provided by four Inland Empire Utility Agency water reclamation facilities; Regional Plants Nos. 1, 4 and 5 and the Carbon Canyon WRF.
[6] Recycled water is provided by the Los Angeles County Flood Control District's Terminal Island Treatment Facility.

Following are brief descriptions of key groundwater replenishment and surface water augmentation projects using advanced purified water that are currently in operation.

Los Angeles, California: Montebello Forebay Groundwater Recharge Project
The Sanitation Districts of Los Angeles County (LACSD) manage the Montebello Forebay Groundwater Recharge Project, one of the oldest ongoing natural groundwater recharge projects in the nation. LACSD has managed the project, located in southeastern Los Angeles County, since 1962.

The Montebello Project provides advanced secondary treatment (partial denitrification) and tertiary filtration/disinfection for an average of 45 MGD of water prior to spreading in basins in the Montebello Forebay area of the Los Angeles Central groundwater basin. This advanced purified water makes up about 35 percent of the total recharge to the groundwater basin, while imported water purchased from the Metropolitan Water District of Southern California and storm water runoff make up the remainder of the water used to replenish the basin, which provides water for 3.7 million people.

The Montebello Project is important because its long duration—40 years—has allowed numerous health studies that confirm the safety of groundwater replenishment projects. A heavily peer-reviewed health

effects study conducted in 1976 found no measurable health issues among the people consuming the water. In 1996 and 1999, the Rand Corporation conducted epidemiological studies on the Montebello project examining the health outcomes of about 900,000 people. The conclusion reached by the Rand researchers was that after 30 years of consumption of advanced purified recharge water there was no association between project water and any ill health effects.

Fairfax, Virginia: Upper Occoquan Service Authority, Millard H. Robbins, Jr. Water Reclamation Facility
After an intensive study conducted in 1970 of water quality problems in the Occoquan Reservoir, a major source of drinking water for Northern Virginia, the Occoquan Policy (Policy) mandated the creation of an advanced water purification facility to replace the 11 secondary treatment plants discharging to the reservoir. The Policy also mandated the creation of an independent ongoing program of water quality surveillance. The Upper Occoquan Service Authority (UOSA) was created to meet the water recycling mandate of the Policy. The Occoquan Watershed Monitoring Laboratory met the requirement for independent surveillance.

The UOSA regional advanced water purification facility includes lime clarification, carbon adsorption, filtration, and chlorine disinfection. Originally a 27 MGD facility, UOSA WRF was expanded to 54 MGD in the 1990s and discharges to a final effluent reservoir prior to release to Bull Run, a tributary of the Occoquan Reservoir, about 20 river miles upstream of the water treatment plant intake. During times of normal precipitation, the advanced purified water from the UOSA WRF makes up about five percent of the total inflows to the reservoir, with percentages much higher (up to 90%) during times of drought.

Orange County, California: Water Factory 21 and Groundwater Replenishment System

Water Factory 21

From its inception in 1976, Water Factory 21 was the most recognized and highly-regarded water purification program in the water industry worldwide. It was the first project in California to use advanced water purification technologies, including reverse osmosis, to enhance secondary effluent to drinking water standards. Advanced purified water was injected into the Orange County groundwater basin in a series of wells used as a barrier against the intrusion of seawater into the basin. For over 30 years, Water Factory 21 protected the integrity of the large groundwater basin that serves northern and central Orange County while also helping to increase the reliability of the region's water supply. Water Factory 21 had a design capacity of 15 million gallons per day (MGD).

Groundwater Replenishment System

The Groundwater Replenishment System (GWRS) has been operational in Orange County since January of 2008. The GWRS replaced Water Factory 21 and expanded using a combination of membrane filtration, reverse osmosis, and advanced oxidation to address a new generation of emerging contaminants, including pharmaceuticals. The 70 MGD project, expandable to 100 MGD, purifies water to state and federal drinking water standards prior to serving the seawater injection barrier and a spreading basin recharging the Orange County groundwater basin. The underground basin provides more than half the water used by northern and central Orange County.

El Paso, Texas: Hueco Bolson Recharge Project

In order to decrease the rate at which the fresh water reserves of the Hueco Bolson were being depleted, El Paso Water Utilities looked to artificially recharge the aquifer using advanced purified water. The Hueco Bolson aquifer provides about 40 percent of the municipal water supply needs of El Paso, Texas and the surrounding area. It also supplies 100 percent of the municipal supply for Ciudad Juarez, Mexico and Fort Bliss, Texas. The Hueco Bolson receives limited natural recharge due to the arid climate. The 10 MGD Fred Hervey Reclamation Plant and the associated Hueco Bolson Recharge Project started full operation in 1985 and treats up to 7.5 MGD to drinking water standards for groundwater injection. The reclamation plant uses a 10-step treatment process including activated carbon, lime clarification, filtration and ozone disinfection.

Scottsdale, Arizona: City of Scottsdale Water Campus

Meeting the water supply demands of a growing city led to the creation of the Water Campus in Scottsdale, Arizona. Since 1998, the Water Campus has produced 12 MGD of tertiary treated recycled water that is used for golf course irrigation during the summer months. In winter, when irrigation is reduced, 10 MGD receives advanced purification at a state-of-the-art facility where microfiltration, reverse osmosis, and disinfection purify the water to drinking water standards before recharge into the local groundwater basin.

Los Angeles County-Area, California: Seawater Barrier Projects

Seawater intrusion is a natural and typical occurrence for all coastal aquifers around the world. Due to the severe over-draft of groundwater for potable and agricultural purposes in the Central and West Coast Basins (CWCB), seawater intrusion is contaminating the groundwater with salt and poses a serious threat to the local potable water source. To address this issue, fresh water consisting of imported and recycled water is injected into a well to build up pressure such that it overcomes the pressure of the intruding seawater, thereby blocking the intrusion. The Water Replenishment District of Southern California (WRD) currently manages three seawater intrusion barriers systems within Los Angeles County, all of which are operated by injecting imported potable or advanced purified water into a series of wells to maintain a freshwater barrier to protect against seawater intrusion. It is important to note that all seawater barrier projects are, in fact, potable reuse projects as well, as the injected water does eventually migrate into the drinking water source in the aquifer.

West Coast Seawater Barrier

The West Basin Municipal Water District's Edward C. Little Water Recycling Facility (ELWRF) in El Segundo, California, has been on-line since 1995. Secondary effluent from the City of Los Angeles Hyperion Treatment Facility is treated at the ELWRF to produce five different qualities of custom-made recycled water for irrigation, commercial and industrial use and groundwater recharge. For recharge, secondary treated effluent is purified by micro-filtration, reverse osmosis, and disinfected with UV disinfection. The advanced purified water is mixed with imported water prior to injection into the groundwater basin (West Coast) via a 100-well seawater barrier. Approximately 5,000 acre-feet of advanced purified water is injected into the seawater barrier annually.

Alamitos Seawater Barrier

The Alamitos Seawater Barrier receives recycled water from the Long Beach Water Reclamation Plant (LBWRP) that provides primary, secondary and tertiary treatment for 25 million gallons of wastewater per day. The plant serves a population of approximately 250,000 people. Approximately 5 million gallons per day of recycled water is reused at over 40 reuse sites for landscape irrigation of schools, golf courses, parks, and greenbelts by the City of Long Beach and the re-pressurization of oil-bearing sediment off the coast of Long Beach. A portion of the recycled water produced from the LBWRP undergoes advanced treatment at the Leo J. Vander Lans Advanced Water Treatment Facility. The facility uses microfiltration, reverse osmosis, and ultraviolet disinfection to produce high quality water that is blended with imported water and pumped into the Alamitos Seawater Barrier to protect the groundwater basin from seawater contamination. The WRD purchases all of the water injected into the barrier, except for about 2,500 acre-feet per year that is purchased by the Orange County Water District. In total, approximately 3,000 acre-feet of advanced purified water is injected into the seawater barrier annually.

Dominguez Seawater Barrier

The Dominguez Gap Barrier currently receives approximately 1,000 acre-feet per year of advanced purified water from the Los Angeles County Flood Control District (LACFCD) Terminal Island Water Reclamation Plant/Advanced Water Treatment Facility. They also operate and maintain the barrier. The plant treats wastewater from over 130,000 people and 100 businesses in the heavily industrialized Los Angeles Harbor area, including the communities of Wilmington, San Pedro, and a portion of Harbor City. The advanced purification facility can treat up to 4.5 MGD of tertiary effluent with microfiltration followed by reverse osmosis and chlorine disinfection. The advanced purified water meets all drinking water quality standards. It is also used as valuable boiler feed water for local industries in the Harbor area and offsets millions of gallons of potable water each day.

San Bernardino County, California: Chino Basin Groundwater Recharge Project

Water recycling is a critical component of the water resources management strategy for the Chino Basin in Southern California. Inland Empire Utilities Agency (IEUA) has implemented an aggressive water recycling program to complement dwindling imported water to meet its expanding needs. IEUA produces a very high quality recycled water that can be used for a wide variety of applications, including groundwater recharge, industrial process water, and irrigation of golf courses, freeway landscaping, pasture for animals and food crops. Presently, about 15 percent of the 60 MGD of water currently generated by the agency's four water recycling plants is reused locally each day. Recycled water received tertiary filtration and UV disinfection prior to conveyance and blending with stormwater flows in spreading basins prior to percolation into the groundwater basin.

Aurora, Colorado: Prairie Waters Project

Colorado's arid environment and cycles for drought make a drought-protected water supply a priority for many Colorado cities. Out of this need, the City of Aurora, Colorado developed the Prairie Waters Project. Anticipated to begin operation in 2011, the Prairie Water Project will increase the City's water supply by 20 percent, delivering up to 10,000 acre-feet (about 3.3 billion gallons) of advanced purified water per year. The project will draw river water from the South Platte River, a receiving water of treated wastewater effluent from wastewater treatment plants located upstream. The river water will be drawn through the sand and gravel of the riverbank and pumped to a 50 MGD water purification facility that treats the water using softening, advanced ultraviolet oxidation, filtration and granulized activated carbon adsorption. The advanced purified water will then be discharged into the Aurora Reservoir, the City's raw water storage reservoir. Water from the reservoir is treated again prior to distribution into the potable water distribution system.

SIDEBAR

Planned Versus Unplanned Potable Reuse Projects

Indirect potable reuse—using water a second time as a drinking water supply—occurs on both a planned and unplanned basis. San Diego's Water Purification Demonstration Project will demonstrate the safety associated with *planned* indirect potable reuse, which means that wastewater is purified to an extremely high level. The process includes state-of-the-art technological processes, including a combination of membrane filtration, reverse osmosis, and advanced oxidation.

Unplanned indirect potable reuse takes place on nearly every river system throughout the world, including the United States. Water that moves from an upstream community to one downstream varies in water quality depending on the quality of wastewater discharged along the way. So, treated wastewater is already being provided to many communities as part of their drinking water.

In the case of the City of San Diego, imported water from the Colorado River and Northern California contains treated wastewater discharged from a total of over 345 municipal wastewater facilities. All imported water and water collected in San Diego's reservoirs from rainfall is untreated or "raw" water. Before any of that water is sent to your tap, it is treated in a water treatment plant to ensure it is safe and healthy to drink – and that it meets all drinking water standards. San Diego could not exist without these imported water sources, which contain treated wastewater.

References

WateReuse. (n.d.). WateReuse Association website online glossary. Accessed on June 13, 2011.
http://www.watereuse.org/information-resources/about-water-reuse/glossary-1

CITY OF SAN DIEGO WATER PURIFICATION DEMONSTRATION PROJECT
ADVANCED WATER PURIFICATION

It is commonly known that human activities over the years have resulted in contamination of our water bodies worldwide. Whether it's runoff from agricultural farms or health and beauty products we use daily to improve the quality of our lives, contaminants find their way into water bodies as a result of human activities. Many of these water bodies are used as public water supply sources. Recently, the public has become more aware about human activities and the associated impact of contaminants from those activities on water supplies, as well as the potential impacts of exposure to contaminants on both humans and wildlife. For more than a decade, water professionals and regulators have studied various contaminants, which are sometimes called "constituents of emerging concern" (CECs), because of their consistent occurrence in source waters throughout the United States and internationally.

While the presence of CECs is of concern, many of these compounds are not being detected as a result of recent events. Instead, the elevation of the level of compounds is a result of the improvement of our ability to detect them in the environment. In fact, our ability to detect CECs has outstripped our knowledge of what kind of impact they might actually have on humans. *Detection of these compounds does not necessarily imply a risk*. For example, typical concentrations of pharmaceuticals found in water supplies are millions of times lower than one therapeutic dose of that same pharmaceutical. In fact, the highest concentration of any pharmaceutical detected in U.S. drinking waters is approximately 5,000,000 times lower than the therapeutic dose (AWWA, 2008). Nonetheless, strategies have been developed to manage potential risks to the public.

The primary objective of water and wastewater treatment is to protect human health and promote economic vitality while minimizing adverse ecological impacts from the use of the water. Improved public health protection, through effective drinking water treatment, is one of the outstanding civil engineering accomplishments of the twentieth century. At the same time, advances in wastewater treatment have greatly reduced the ecological impacts of wastewater discharges.

While wastewater treatment has been shown to be an effective barrier at reducing CECs, many agencies have embraced the advanced purification of water that will find its way back to a public water supply. Advanced water purification has been proven to positively remove CECs and provide a superior water quality that meets all drinking water standards.

What is Advanced Water Purification?

Advanced Water Purification (AWP) is a state-of-the-art process that further purifies highly treated wastewater. After the wastewater is biologically treated and filtered, the water is considered to be high quality but is not considered suitable for drinking water. AWP involves several additional treatment steps that scientists and health professionals recognize will produce a very high quality water supply. The high quality of this water is achieved by filtering the water through membranes that remove CECs, which are much larger in size than the very small pores in the membrane material. A subsequent step involves advanced oxidation, the combination of hydrogen peroxide and ultraviolet light, which provides one of the most powerful oxidants on the planet to provide an additional barrier and disinfect the purified water. Analysis of the water produced by this process indicates that advanced water purification facilities consistently produce water with significantly lower concentrations of constituents than raw (untreated) imported water supplies.

What type of treatment is provided by Advanced Water Purification in the Demonstration Project?

This advanced water purification process includes membrane filtration (microfiltration and/or ultrafiltration), reverse osmosis, ultraviolet light disinfection, and advanced oxidation. These

technologies have been utilized in the water industry for many decades, and are proven barriers that remove CECs and safeguard public health.

Microfiltration and Ultrafiltration

Microfiltration (MF) and ultrafiltration (UF) are types of filters that utilize fibers that resemble a sponge-like material when magnified. The pores, or openings in the fibers that allow the water to pass through, are 0.2 microns, which is approximately 300 times finer than one human hair. MF and UF are very effective at removing materials in the water, but not good at removing dissolved compounds or CECs. These filters are used to "polish" the water. This improves the operation of the reverse osmosis system that is very effective at removing CECs and dissolved materials.

Reverse Osmosis

Reverse osmosis is a membrane filtration method that removes compounds that are very small, such as dissolved salts, by using pressure to push water through a semi-permeable membrane, leaving other unwanted materials behind. The reverse osmosis membrane is designed to allow only water to pass through while preventing the passage of dissolved materials, such as salt. While these membranes have been used for years to desalinate seawater, they are also being used today to purify water by removing CECs from reuse supplies. The membrane essentially acts like a very fine filter that separates out any remaining minerals and pollutants, salts, viruses, bacteria, metals, pesticides and other materials, resulting in very high quality water. Many bottled water companies use reverse osmosis because of its proven purifying capability.

Ultraviolet Light Disinfection

Following reverse osmosis, water is treated by ultraviolet (UV) light as an additional barrier to CECs. The system is designed to deliver a dose of UV light significantly higher than natural UV from sunlight. This breaks the chemical bonds of the compound into their more natural elements like carbon or nitrogen. The UV system also provides disinfection of the water. Hospitals and dental offices utilize UV light to sterilize instruments.

Advanced Oxidation

The addition of hydrogen peroxide before the UV process creates an additional step called advanced oxidation, providing an additional or backup barrier to CECs. Many of the operating AWP facilities use advanced oxidation to target chemicals typically not found in reuse waters in San Diego. The other intended use of advanced oxidation is as a safety net to address any remaining trace chemicals, which are in extremely low concentrations and thus difficult to detect even with the improvements in analytical testing.

Water Quality Testing

Awareness of our impact on the environment has increased over the years, but this is particularly true in the last 10 years with the improved sensitivity in analytical testing. Decades ago, compounds could only be detected at the parts-per-million levels (one part compound to one million parts water). In the last ten years this has advanced to parts-per-billion. Now, with very sensitive equipment, we are able to detect compounds at the parts-per-trillion level, and are near the parts-per-quadrillion boundary. In fact, lab technicians have to wear special gloves, clothing and breathing filters in order avoid contaminating the samples of water they are testing. While this low level of detection is necessary for analytical purposes, it is not always necessary to determine a human health impact. Experts agree that just because a compound is detected doesn't mean there is an associated health concern.

While humans worldwide have sent many compounds into the environment, many of these compounds are of little health or environmental concern. For those compounds that are a health or environmental concern, the risk of their presence is balanced by the extremely low concentrations at which they occur. Improvements in wastewater treatment have resulted in a very effective barrier to the CECs that that are introduced into the water. Advanced water purification has been proven to be an extremely effective system at providing a superior quality of water that meets all drinking water standards.

If the Demonstration Project were to result in a decision to implement a full-scale project that would augment San Vicente Reservoir with purified water from the AWP, it would have one benefit that other similar projects do not possess. All of the other projects in Southern California use the purified water to supplement groundwater supplies and then pump that groundwater directly to the consumer's taps. A full-scale reservoir augmentation project would send the purified water from the AWP to the San Vicente Reservoir where it would blend with untreated water stored there. Ultimately the blended water would be sent to one of the City's water treatment facilities where it will be further treated before being sent into our drinking water system.

SIDEBAR

What can you do to help reduce pharmaceuticals in water supplies?

Pharmaceuticals and personal care products are products used by individuals for personal health or cosmetic reasons. They comprise a diverse collection of thousands of chemical substances, including prescription and over-the-counter therapeutic drugs, fragrances, soaps, lotions, and cosmetics. These products are considered pollutants when they enter the wastewater stream through such means as bathing or flushing unused or expired medications down the toilet. Many cities have established "take back" centers or, as with the City and County of San Diego, an annual "Take Back Day", for unused medications. Additionally, the City of San Diego Environmental Services Department recommends that medications and pharmaceuticals be securely packed and disposed of in the trash: http://www.sandiego.gov/environmental-services/ep/medical.shtml. You can help reduce pollution in our water supplies by returning unused or expired medicine to a center or by properly disposing in a landfill rather than flushing it down your toilet.

References

American Water Works Association (AWWA). 2008. *Statement of Dr. Shane Snyder, Southern Nevada Water Authority before the Senate Subcommittee on Transportation Safety, Infrastructure Security, and Water Quality on Pharmaceuticals in the Nation's Water: Assessing Potential Risks and Actions to Address the Issue.* April 15. Accessed on May 12, 2011. http://www.awwa.org/files/GovtPublicAffairs/AWWA2008FlyinTestimonyPharmaceuticals.pdf

Water Bill Insert

The latest version of the insert from March 2012 is displayed. A similar version was distributed in July 2011.

Open for Tours

Water Purification | Demonstration Project

City of San Diego PUBLIC UTILITIES Water & Wastewater

The Advanced Water Purification Facility is part of the City's Water Purification Demonstration Project, which is examining the use of advanced water purification technology on recycled water.

Tours Available

Explore San Diego's first water purification testing facility on a guided tour.

Experience the water purification process:

- See how wastewater becomes purified water
- See what other places are already drinking purified water
- See the comparison among purified, drinking, and recycled water

Signing up is easy:

- Email your request to PureWaterSD@sandiego.gov
- Call (619) 533-4631
- Register online at www.PureWaterSD.org/tours.shtml

Can't tour in person?

Schedule a presentation for your organization — email: PureWaterSD@sandiego.gov or call (619) 533-6638

www.PureWaterSD.org

THE CITY OF SAN DIEGO

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Abierto al Publico

Water Purification | Demonstration Project

City of San Diego PUBLIC UTILITIES Water & Wastewater

El Tratamiento Avanzado de Purificacion de Agua es parte del projecto de Demostracion de Purificacion de Agua, el cual esta investigando las tecnologias mas avanzadas para la purificacion de agua reciclada.

Recorridos disponibles

Explore en San Diego la primer instalacion de prueba de purificacion de agua en una visita con guia.

Conosca por experiencia propia el proceso de purificacion de agua:

- Vea como agua de desague se convierte en agua purificada
- Vea en que otros lugares se usa agua purificada como agua potable
- Vea la diferencia entre agua purificada, agua potable y agua reciclada

Apuntense Hoy:

- Visite www.purewatersd.org/tours.shtml para registrarse a un recorrido
- Mande un correo electronico a purewatersd@sandiego.gov o llame al (619) 533-4631

No puede asistir en persona?

Visite www.purewatersd.org para ver un guia virtual

Programe una presentacion para su organizacion- mande un correo electronic a purewatersd@sandiego.gov o llame al (619) 533-6638

www.PureWaterSD.org

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THE CITY OF SAN DIEGO

AWP Facility Brochure

Demonstration Project Components

The Advanced Water Purification Facility is one component of the Demonstration Project. Additional components include a study of San Vicente Reservoir to determine the potential of augmenting the reservoir with purified water, an economic and energy analysis, and defining regulatory requirements. In addition, an independent advisory panel of experts provides oversight and guidance. The purified water will not be added to the San Vicente Reservoir during the demonstration phase; instead it will be added to the existing recycled water distribution system. For more information about the project or to schedule a speakers bureau presentation for your organization, visit www.purewatersd.org.

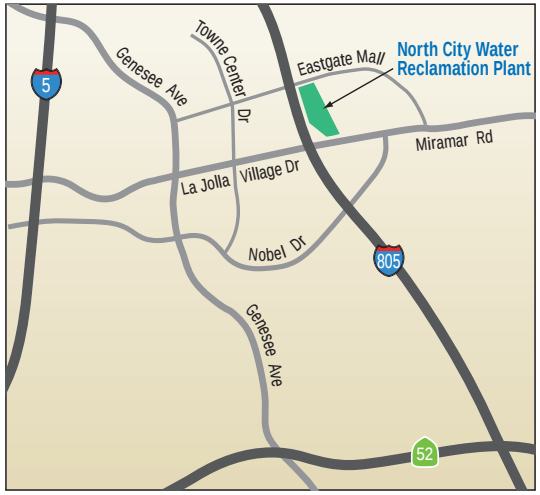
Take a Look

You are invited to tour the Advanced Water Purification Facility, the test facility for California's first indirect potable reuse via reservoir augmentation pilot project. During the walking tour you will see water purification technology up close and compare samples of purified water produced at the facility to tap and recycled water—the difference is clear.

Tours are held Tuesdays and Thursdays and on occasional evenings and Saturdays. To tour the facility, please register at www.purewatersd.org/tours.shtml or call (619) 533-4631.

Tasting is Believing

Orange County's Groundwater Replenishment System (GWR) is a full-scale advanced water purification facility located in Fountain Valley, California. The GWR System uses the same purification process being examined by the Demonstration Project to supply a safe and reliable water source to over 500,000 residents. As a full-scale facility, guests touring the GWR System are able to drink the purified water. To register for a tour, visit www.GWRSystem.com.



To tour the facility, please register at www.purewatersd.org/tours.shtml or call (619) 533-4631.

City of San Diego
PUBLIC UTILITIES
Water & Wastewater

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Public Utilities Department
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Project Information Line: (619) 533-7572
Project Speakers Bureau Line: (619) 533-6638
Email: purewatersd@sandiego.gov
Website: www.PureWaterSD.org

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A look at the technology behind the

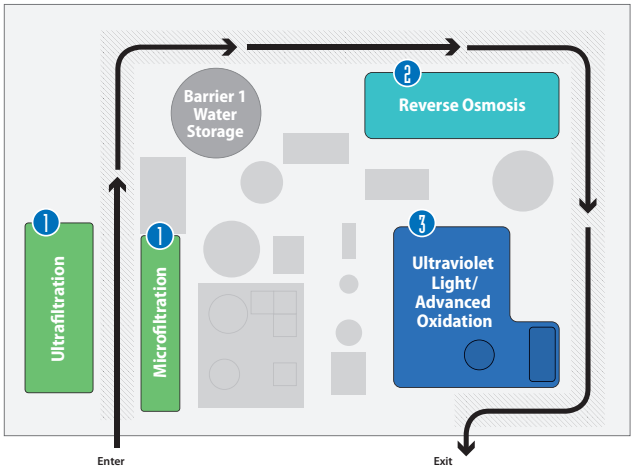
Water Purification | Demonstration Project

Exploring local resources to ensure a sustainable water supply

The City of San Diego

Innovation for Future Water Supply

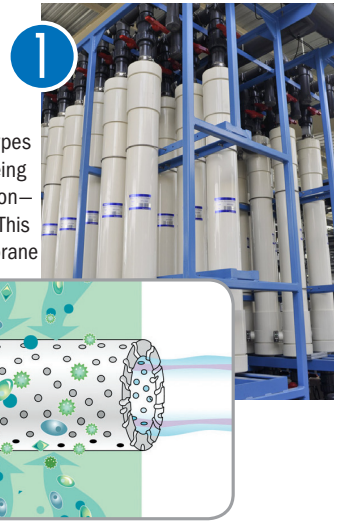
The Advanced Water Purification Facility is the focal point of the City of San Diego's Water Purification Demonstration Project (Demonstration Project). This project is vital to San Diego's future and is a critical step towards developing a local, sustainable and reliable water supply. This state-of-the-art facility, located at the North City Water Reclamation Plant, is using the most advanced technologies to purify one million gallons of recycled water per day.



The Purification Process

The City of San Diego currently uses recycled water for irrigation and industrial purposes. The Demonstration Project is a pilot study to determine the feasibility of further purifying recycled water to supplement local drinking water supplies through reservoir augmentation. The project will determine if the purified water meets water quality, safety and regulatory requirements. The purification process uses the multi-barrier approach of consecutive treatment steps, which work together to remove or destroy unwanted materials. Each barrier includes frequent and continuous water quality monitoring. Safeguards are built into the process to ensure that an anomaly at any given treatment step would not compromise public health. Here is a look at the process:

Membrane Filtration — Barrier 1



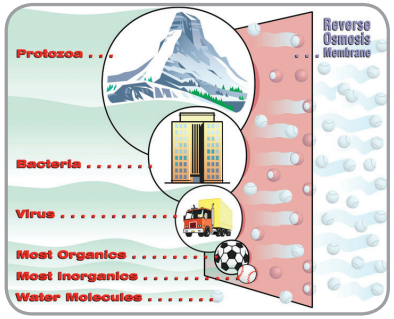
The first step in the water purification process is membrane filtration. Two types of membrane filtration systems are being tested—microfiltration and ultrafiltration—to determine which is most effective. This treatment step uses a series of membrane filtration canisters that remove contaminants in the already-treated recycled water.

Inside the membrane filtration canisters are hollow fibers that block unwanted materials like suspended solids, bacteria and protozoa from passing through. The filters are extremely efficient and are tested daily to confirm their consistent removal of contaminants. After undergoing membrane filtration, the clouded appearance of the recycled water is converted into a clear solution that contains dissolved organic material and salts.

Reverse Osmosis — Barrier 2

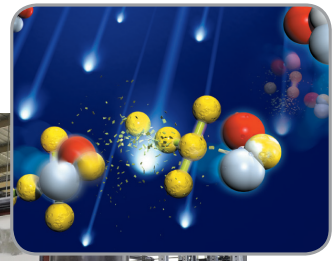
Reverse osmosis is the second and most essential step in the purification process. Water is forced under high pressure through membranes that remove salt and microorganisms, including viruses and bacteria.

Reverse osmosis purifies the water to a level similar to distilled water quality. This process is used by the bottled water industry.



Ultraviolet Disinfection/Advanced Oxidation — Barrier 3

Step three of the purification process is advanced oxidation through the use of ultraviolet (UV) light and hydrogen peroxide. Inside the vessel shown to the right is a high intensity light, similar to extremely concentrated sunlight, that provides disinfection. Hydrogen peroxide is added and reacts with the light to form powerfully reactive molecules like those used by nature to clear pollutants from the atmosphere. These molecules provide further disinfection and destroy any remaining contaminants in the water by breaking them down into harmless compounds.



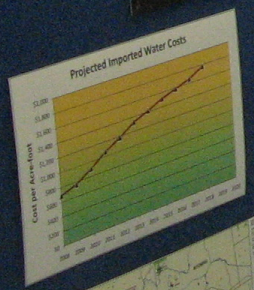
San Diego is among many innovative cities exploring water purification technology to purify wastewater for use as drinking water.

Display Board

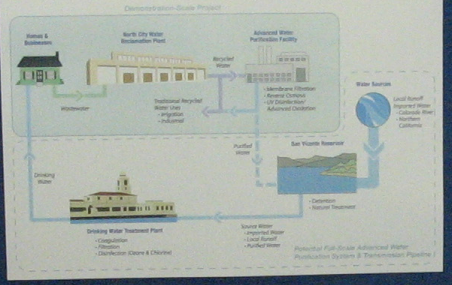
Water Purification | Demonstration Project

Water Supply Challenge

San Diego needs local, reliable and sustainable sources of water to lessen our dependence on imported water.



City of San Diego's
Water Purification Demonstration Project
Purification Process



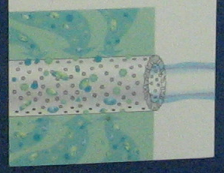
Benefits of the Demonstration Project

- Provide a local and sustainable supply of high-quality drinking water for San Diego
- Increase utilization of recycled water
- Decrease reliability on imported water
- Provide a supply of water that uses less energy than imported water
- Improve the quality of water in the San Vicente Reservoir
- Have a positive impact on the environment by producing less discharge into the ocean & working toward lower carbon emissions

Did you know...

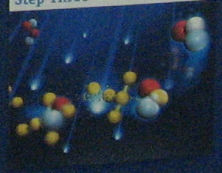
- The Water Purification Demonstration Project is examining the use of advanced water purification technology to determine the feasibility of full-scale reservoir augmentation.
- The water produced by the purification process goes through multiple steps of advanced treatment to meet all water quality, safety and regulatory requirements.
- No purified water will be added to the San Vicente Reservoir or San Diego's drinking water system during the Demonstration Project.

Microfiltration: Step One



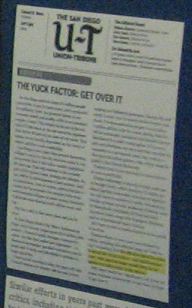
Reverse Osmosis: Step Two

Ultraviolet Light + H_2O_2: Step Three



The City of San Diego | Public Utilities

Support



Similar efforts in years past were dubbed by critics, including this editorial page, as "toilet-to-tap" technology. But this editorial board has come to accept the latest science — and real-life experience — that says this water would likely be the purest and safest water in the system.

Independent Advisory Panel

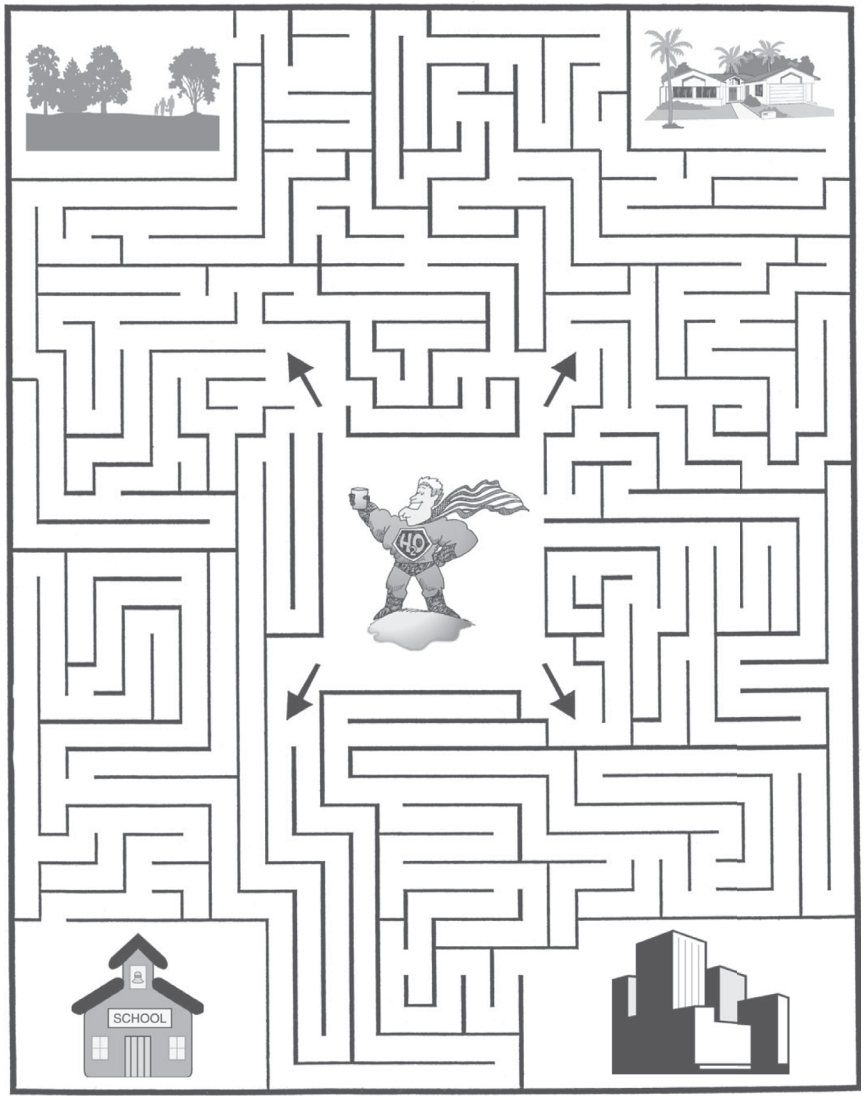
Water Reliability Coalition

Water Purification | Demonstration Project
www.purewatersd.org

Children's Activity Page

Maze

Help our water superhero find his way to the park, home, school and business.



Water Purification Demonstration Project Activity Page

Test your Demonstration Project knowledge!

Water is essential for life. We need it for cooking, cleaning, bathing, watering lawns, and drinking! In San Diego, most of our water is imported, or brought in, from Northern California and the Colorado River. Importing water costs a lot of money. Also, many other people use the water before it gets to San Diego.

The City of San Diego is looking at ways to create a local water supply. With the Water Purification Demonstration Project, the City is testing whether the water San Diegans flush down their drains can be cleaned and used for drinking again. This activity page will help you learn more about the Water Purification Demonstration Project.

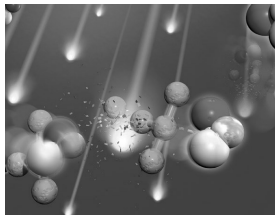
Match the Technology

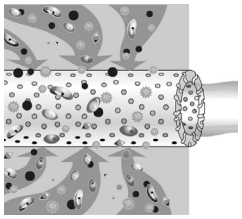
Three technologies used in the Water Purification Demonstration Project are described below. Write the name of the technology underneath the matching picture.

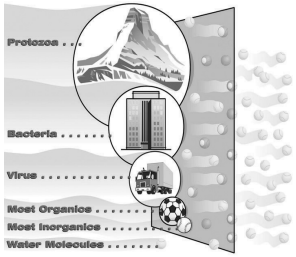
Membrane filtration: Consists of “straws” with holes in the side that suck in the water and keep out the contaminants. The Demonstration Project uses microfiltration and ultrafiltration.

Reverse osmosis: Forces water through several sheets of thin plastic membranes to filter out anything bigger than a water molecule, such as minerals and contaminants. The RO membranes are like microscopic strainers.

Ultraviolet disinfection/advanced oxidation: Intense light, like sunlight, that works with hydrogen peroxide to zap any remaining contaminants in the water.

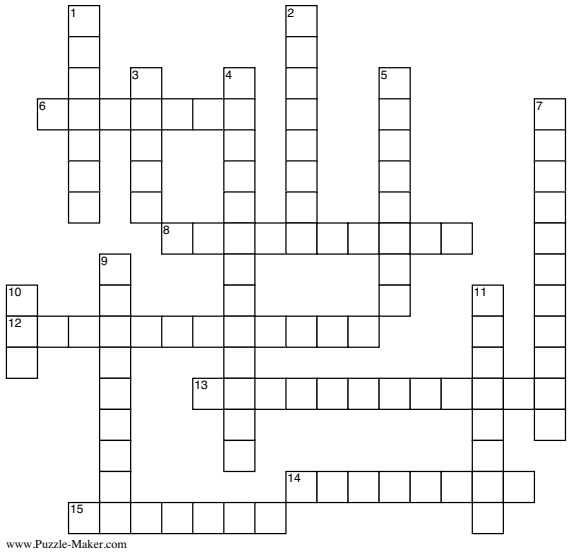






_____ _____ _____

Crossword Puzzle



Determine the word that best fits the clues and definitions provided. Fill the word in the crossword puzzle.

ACROSS

6 _____ water. Another name for "drinking water."

8 Untreated water collected in the sewer system from residences and businesses (e.g., from bathtubs, showers, bathroom sinks, clothes washers, toilets, kitchen sinks, and dishwashers).

12 A reduction in water waste. Saving water.

13 Removing or destroying microorganisms in water that may be harmful to humans.

14 _____ water. Wastewater that has undergone a high level of treatment at a reclamation facility so that it can be reused for a variety of purposes, such as irrigation and industrial use. This is the water that comes into the AWP Facility.

15 A period of time when rainfall is far below average.

DOWN

1 Reverse _____ (RO). A high-pressure membrane filtration process that forces water through several sheets of thin plastic membranes to filter out minerals and contaminants. The RO membranes are like microscopic strainers.

2 _____ filtration. A filtration process used to separate particles from the water. The Demonstration Project uses microfiltration and ultrafiltration.

3 _____ cycle. The movement of water as it evaporates from rivers, lakes or oceans, returns to the earth as precipitation, flows into rivers and evaporates again. This cycle is aided in urban areas by modern technology, which includes wastewater and drinking water treatment facilities.

4 Water Purification _____ Project. This test project is examining the use of water purification technology to provide safe and reliable water for San Diego's future.

5 _____ water. A water source that begins in one region and is transferred to another region. For example, San Diego's water comes from Northern California or the Colorado River.

7 A substance found in the water. Can be safe or unsafe.

9 A manmade lake or tank used to collect and store water.

10 Abbreviation for personal care products. Products that can be found in wastewater such as shampoos, fragrances, soap, and deodorant.

11 _____ water. The water that the AWP Facility produces. It starts as recycled water and is treated with membrane filtration, reverse osmosis and ultraviolet disinfection/advanced oxidation.

Word Search

Words related to the Water Purification Demonstration Project are hidden in the puzzle to the right. Find the Word Bank words in the puzzle. Words may go right, left, up, down, and diagonal.

WORD BANK:

ADVANCED
DEMONSTRATION
DISINFECTION
MEMBRANE
MICROFILTRATION
PURE
RECYCLED
REVERSE OSMOSIS
ULTRAVIOLET
WATER

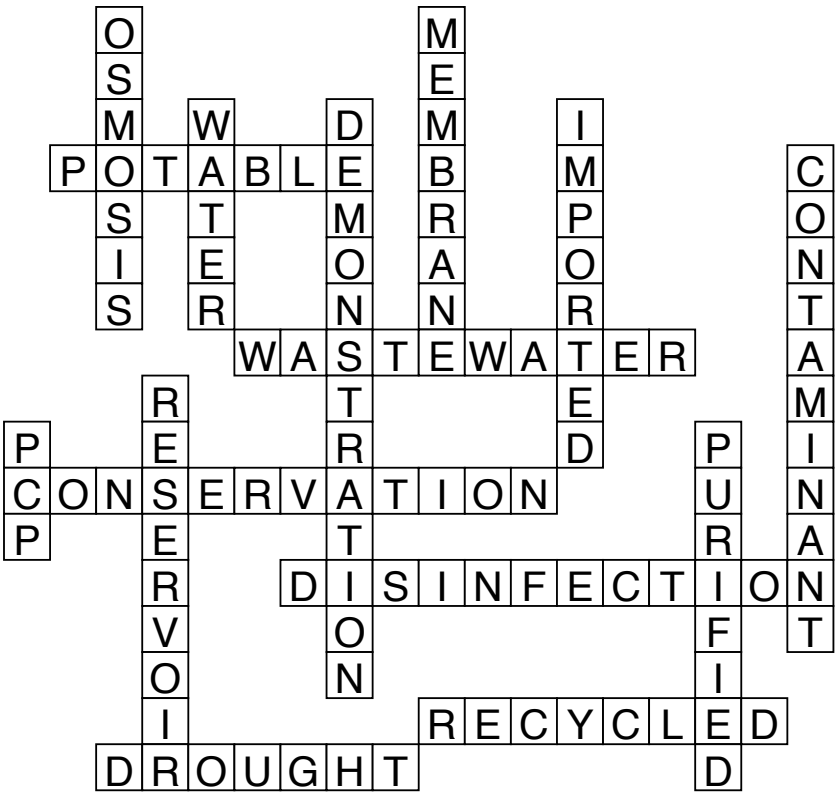
C	R	G	B	M	S	M	E	Y	Y	J	F	T	B	M
N	I	E	C	K	L	L	F	A	Y	B	E	K	I	T
O	O	C	C	V	Q	M	V	H	N	L	G	C	L	W
I	U	I	R	Y	T	I	F	H	O	R	R	L	O	W
T	M	T	T	U	C	C	H	I	F	O	A	B	A	X
C	D	C	L	A	A	L	V	Y	F	C	M	T	F	T
E	D	Z	M	J	R	A	E	I	C	U	E	F	X	L
F	E	R	U	P	R	T	L	D	A	R	M	Z	M	K
N	H	A	C	T	O	T	S	D	R	Q	B	U	I	W
I	E	K	L	C	R	K	T	N	U	R	R	Q	U	Y
S	W	U	M	A	B	C	R	Y	O	O	A	M	V	A
I	S	Z	T	Q	X	E	N	M	C	M	N	S	T	I
D	S	I	S	O	M	S	O	E	S	R	E	V	E	R
F	O	A	D	V	A	N	C	E	D	V	J	D	Y	K
N	G	D	S	E	Y	I	P	F	C	I	K	Q	S	I

Water Quiz

Below are statements about water. Some are true. Some are false.
Circle T if a statement is true and F if a statement is false.

	True/False
1. The water coming out of your faucet contains molecules that the dinosaurs drank.	T F
2. Most of San Diego's water supply comes from local rainfall.	T F
3. San Diego is at the end of the pipeline when importing water from the Colorado River and Northern California.	T F
4. The City of San Diego's "purple pipes" carry recycled water to use on lawns and for industries.	T F
5. Recycled water from the purple pipes is safe to drink.	T F
6. The Water Purification Demonstration Project is testing whether San Diego can purify recycled water and add the purified water to a local reservoir.	T F
7. A reservoir is a manmade lake or tank used for storing water.	T F
8. The Demonstration Project is using membrane filtration, reverse osmosis and ultraviolet disinfection to purify recycled water.	T F
9. San Diego is the first in the nation to use water purification technology.	T F
10. If you drink tap water at Disneyland, you are most likely drinking purified water.	T F

Solutions



Word Search:

```
+ + + + + + + + + + + + T + M
N + + + + + + + + + + + E + I +
O O + + + + + + + + + L + C + +
I + I + R + + + + O + R M + +
T + + T + E + + I + O + E + +
C + + + A + C V + F + + M + +
E + + + + R A Y I + W + B + +
F + + + + R T L C A + + R + +
N + + + T + T S T L + + A + +
I + + L + R + E N + E + N + +
S + U + A + R + + O + D E + +
I + + T + + + + + + M + + + +
D S I S O M S O E S R E V E R
+ O + + A D V A N C E D D + +
N + + + + + E R U P + + + + +
```

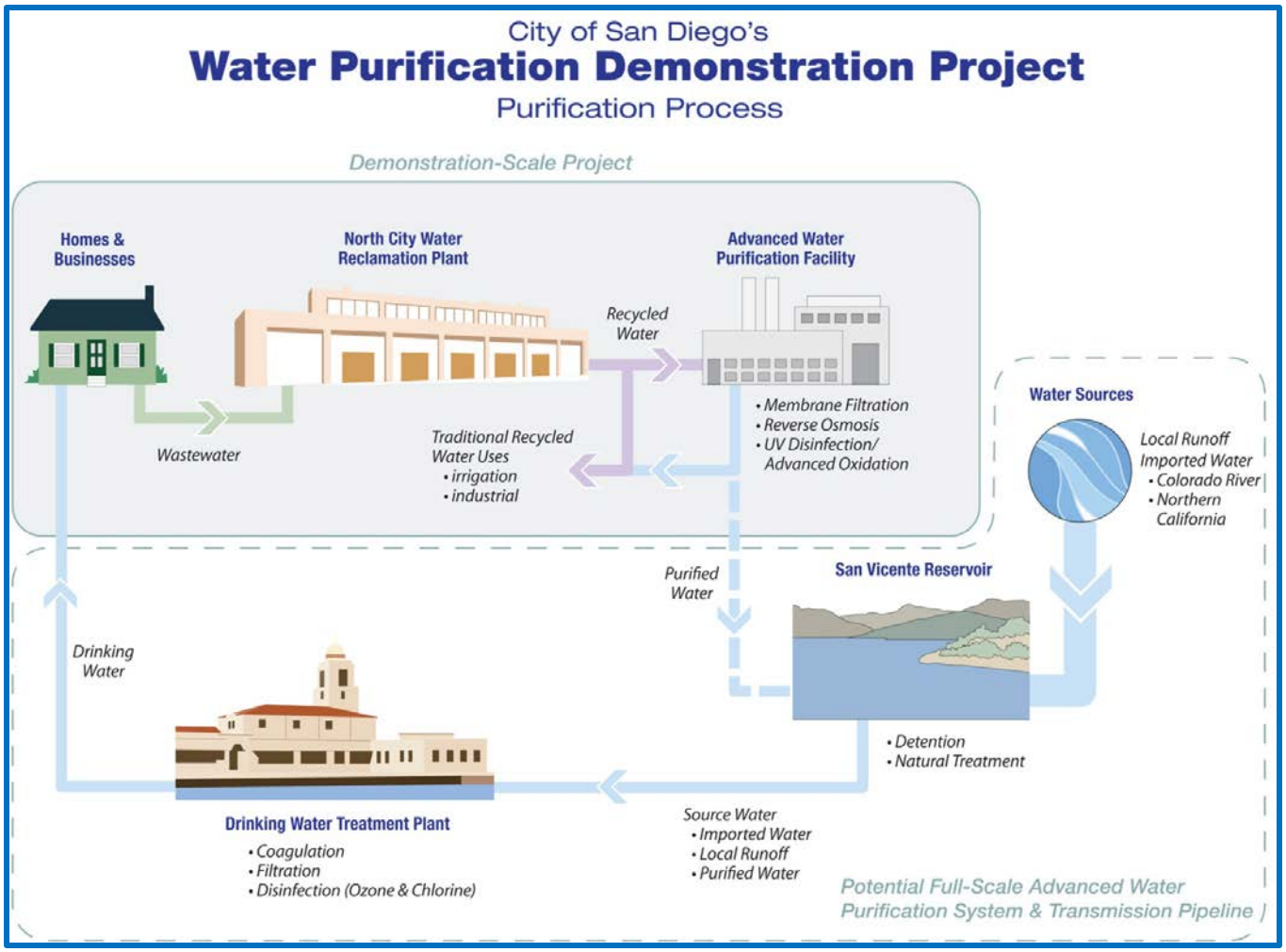
(Over,Down,Direction)
ADVANCED(5,14,E)
DEMONSTRATION(13,14,NW)
DISINFECTION(1,13,N)
MEMBRANE(13,4,S)
MICROFILTRATION(15,1,SW)
PURE(10,15,W)
RECYCLED(5,4,SE)
REVERSEOSMOSIS(15,13,W)
ULTRAVIOLET(3,11,NE)
WATER(11,7,SW)

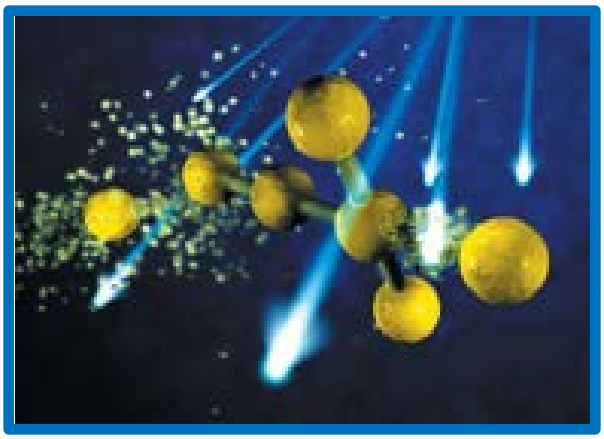
Water Quiz:

1. T, **2.** F, 80% is imported, **3.** T, **4.** T, **5.** F, recycled water needs further treatment to be safe for drinking, **6.** T, **7.** T, **8.** T, **9.** F, other communities have used this technology for years, **10.** T

Necesitamos agua potable para bebe, conicna, bañarnos, limpiar y regar. En San Diego, la mayoria de el abua proviene del norte de California y del rio Colorado. Como cuesta mucho dinero comprar esta agua, San Diego necesita su propia agua.

La cuidad de San Diego esta buscando mas agua y hacienda pruebas al agua que los san dieguinos mandan al drenaje par aver si se puede limpiar y usarse para usos domesticos. Esta pagina de actividades te ayudara a entender como funciona esto.





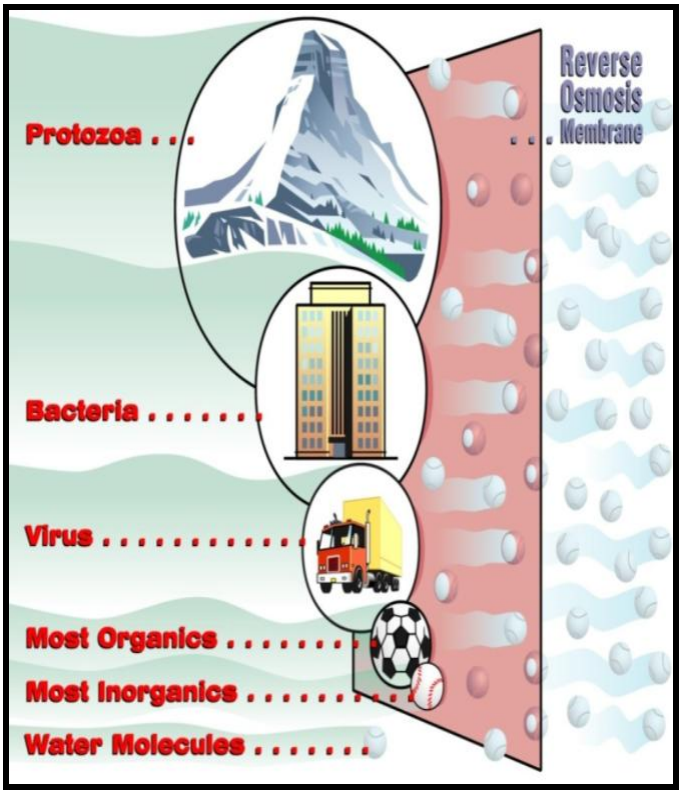
Iguala la Tecnologia

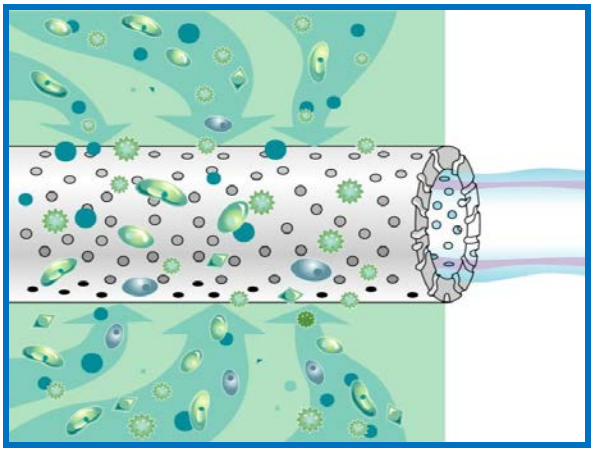
Descrito abajo son 3 tipos de tecnologia usadas en el projecto de Demostracion de Agua Purificada. Escribe el nombre de la tecnologia al lado de la foto.

Filtración de membrane- popotes con agujeros en los lados que chupan el agua dejando fuera contaminantes.

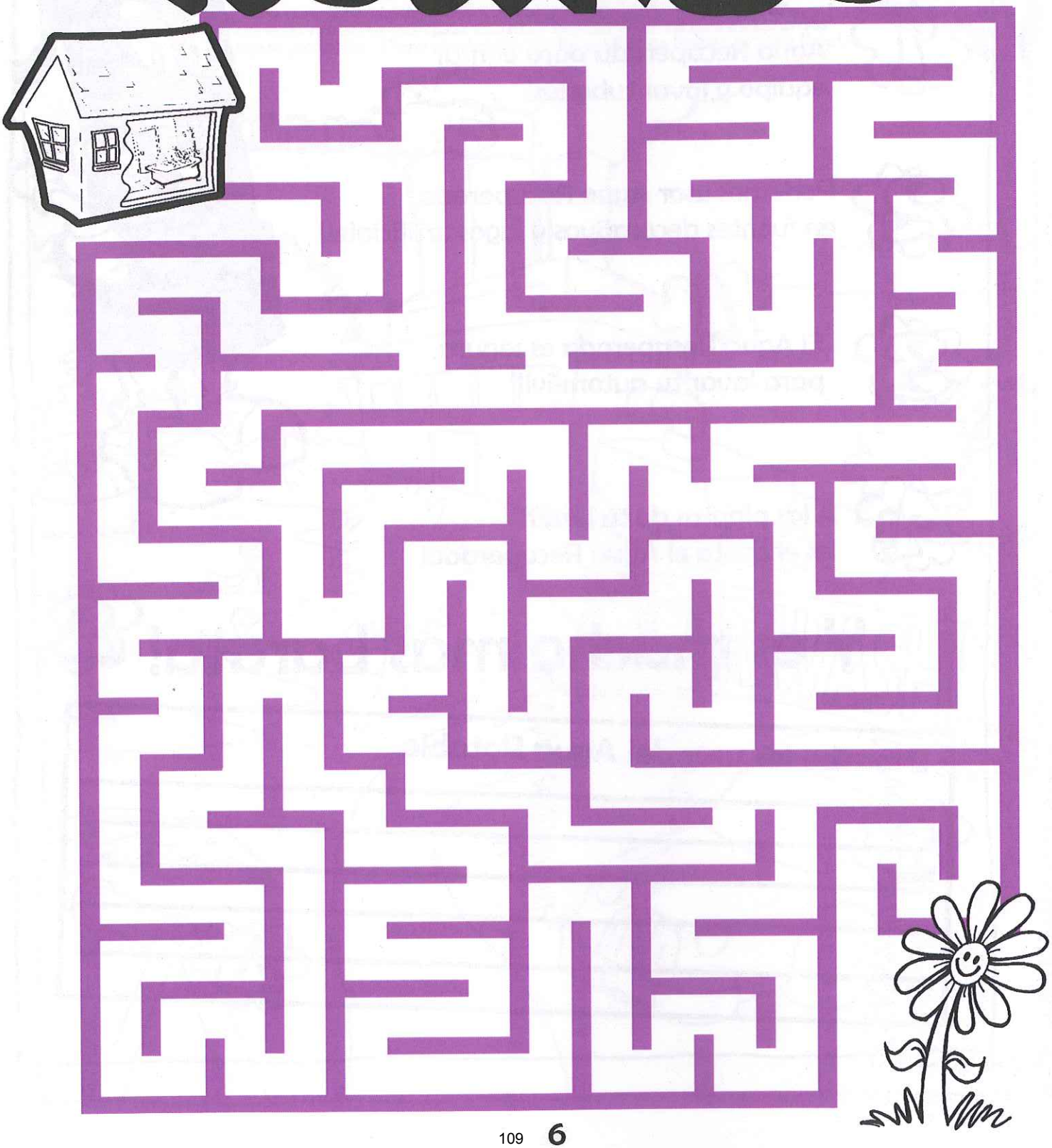
Osmosis Reversa- forza agua a travez de capas delgadas de membranas de plastic para filtrar cualquier cosa mas grande que una molecula de agua, como minerales y contaminantes. La osmosis inversa funciona como coladores microscopicos.

Desinfección ultravioleta/ oxidación avanzada- luz intense, como la luz natural, que trabaja con agua oxigenada para eliminar cualquier contaminante restante en el agua.





EL LABERINTO MORADO



PALABRAS RECUPERADAS

R	E	S	E	R	V	A	X	R	W	R	A
E	Z	S	X	E	W	Q	X	Z	Q	W	G
C	X	I	H	C	K	F	P	X	K	Z	U
L	L	U	V	I	A	E	I	Z	X	W	A
A	Q	Z	I	C	X	R	P	Z	W	X	N
M	X	Q	R	L	W	T	A	N	Q	U	E
A	Y	X	R	A	Q	I	S	Q	J	W	G
D	X	Q	I	R	Q	L	K	H	X	Q	R
A	T	X	G	Q	X	I	X	Z	L	Q	A
Q	X	Q	A	Y	Q	Z	X	W	X	W	X
X	K	T	R	A	T	A	D	A	X	Z	K
X	Q	W	X	Q	X	R	X	Y	Z	Q	R

RESERVA
LLUVIA
TANQUE
TRATADA
RECLAMADA
IRRIGAR
RECICLAR
FERTILIZAR
AGUA NEGRA
PIPAS

Iremos en la busqueda de las Palabras Recuperadas
Encuentra las palabras de la derecha en la sopa de letras
y encierralas en un circulo.
Pueden estar en forma horizontal ó vertical.

Videos

Demonstration Project videos can be found on the project's website. The videos and links are as follows:

- Virtual AWP Facility tour video
  http://granicus.sandiego.gov/ASX.php?publish_id=1257&sn=granicus.sandiego.gov
- Water purification process animation video
  http://granicus.sandiego.gov/ASX.php?publish_id=1207&sn=granicus.sandiego.gov
- The Science Behind the Water Purification Process (testimonial video)
  http://granicus.sandiego.gov/MediaPlayer.php?publish_id=1413
- The Benefits of the Water Purification Process (testimonial video)
  http://granicus.sandiego.gov/MediaPlayer.php?publish_id=1412
- Overcoming The Yuck Factor (testimonial video)
  http://granicus.sandiego.gov/MediaPlayer.php?publish_id=1417
- Support for the Demonstration Project (testimonial video)
  http://granicus.sandiego.gov/MediaPlayer.php?publish_id=1416

Appendix H: Public Outreach and Education

Section 3: Community Outreach and Tours

Community events **2**
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Tour flier (half page) 8
Facility graphics and layout 10
Tour list 12
Tour Thank You e-blast 18
Feedback form 20
Feedback from tour guests 22
Feedback analysis 24

Community Events: Events Database

A list of events in which the Demonstration Project team participated.

WATER PURIFICATION DEMONSTRATION PROJECT
COMMUNITY EVENT INVOLVEMENT (OCTOBER 2010 – OCTOBER 2012)

- **Little Italy Festa** (Sunday, October 10, 2010)
- **Executive Square Green Fair** (Friday, October 29, 2010)
- **13th Annual San Diego Multicultural Festival** (Saturday, January 15, 2011)
- **Vietnamese Tet Festival** (Friday, January 28 - Sunday, January 30, 2011)
- **San Diego Chinese New Year Fair** (Saturday, February 12 - Sunday, February 13, 2011)
- **Heritage Weekend Festival and Parade** (Saturday, February 26, 2011)
- **Science Festival Expo** (Saturday, March 26, 2011)
- **Lao New Year** (Saturday, April 02 - Sunday, April 03, 2011)
- **EarthFair** (Sunday, April 17, 2011)
- **Qualcomm Earth Day Fair** (Friday, April 22, 2011)
- **City of San Diego's Take Your Daughters and Sons to Work Day** (Thursday, April 28, 2011)
- **Sally Ride Science Festival** (Saturday, May 14, 2011)
- **Scripps Ranch Green Fair** (Sunday, May 15, 2011)
- **RiverFest** (Sunday, May 15, 2011)
- **City of San Diego's National Public Works Week** (Monday, May 16 - Friday, May 20, 2011)
- **Fiesta Del Sol** (Saturday, August 13 - Sunday, August 14, 2011)
- **Mira Mesa Street Fair** (Saturday, September 17, 2011)
- **Politifest** (Saturday, September 17, 2011)
- **Filipino American Arts & Culture Festival (FilAm Fest)** (Saturday, October 01, 2011)
- **Wesley Methodist Church's Health Fair** (Saturday, October 08, 2011)
- **Serra Mesa Community Fair** (Saturday, October 15, 2011)
- **Girl Scouts World of Water Workshop** (Saturday, October 22, 2011)
- **SDSA High Tech Fair** (Tuesday, February 07 - Wednesday, February 08, 2012)
- **Greater San Diego Science and Engineering Fair** (Wednesday, March 21, 2012)
- **San Diego Science Festival Expo Day** (Saturday, March 24, 2012)
- **Rolando Street Fair** (Sunday, March 25, 2012)
- **Qualcomm Earth Day Event** (Wednesday, April 18, 2012)
- **Linda Vista Multicultural Festival** (Saturday, April 21, 2012)
- **EarthFair** (Sunday, April 22, 2012)
- **City of San Diego Celebrate the Earth** (Monday, April 23, 2012)
- **Scripps Research Institute Employee Fair** (Wednesday, April 25, 2012)
- **Take Your Sons and Daughters to Work Day** (Thursday, April 26, 2012)
- **BD Biosciences Earth Day Fair** (Friday, April 27, 2012)
- **Logan Heights Library Earth Day Event** (Saturday, April 28, 2012)
- **Clairemont Garden Tour & Expo** (Saturday, May 05, 2012)
- **Fiesta de los Penasquitos** (Sunday, May 06, 2012)
- **Scripps Ranch Community Fair** (Sunday, May 06, 2012)
- **Allied Gardens SpringFest** (Saturday, May 12, 2012)
- **Juneteenth Celebration** (Saturday, June 16, 2012)
- **San Diego Horticultural Society** (Monday, August 13, 2012)
- **Mira Mesa Street Fair** (Saturday, September 15, 2012)
- **Filipino American Arts & Culture Festival (FilAmFest)** (Saturday, October 06, 2012)

Community Events: Event Welcome e-blast

A template for the e-blast sent to Demonstration Project booth visitors at community events.

Having trouble viewing this email? Click here

You're receiving this email because you have expressed interest in the City of San Diego's Water Purification Demonstration Project. Please confirm your continued interest in receiving email from us. To ensure that you continue to receive emails from us, add purewatersd@sandiego.gov to your address book today.

You may unsubscribe if you no longer wish to receive our emails.

Water Reuse Program

Water Purification Demonstration Project

Quick Links

Water Purification Demonstration Project

City of San Diego

Sign up for emails

Forward email to a friend

Contact Us

(619) 533-7572

Water Purification | Demonstration Project

The City of San Diego's water resource strategy includes planning, conservation, recycled water, groundwater, water reuse, and watershed and resource protection to help meet future water needs.

The City of San Diego

City of San Diego PUBLIC UTILITIES Water & Wastewater

The City of San Diego | Public Utilities Department

June 26, 2012

Dear [NAME],

Thank you for visiting our City of San Diego Water Purification Demonstration Project booth at the [EVENT] on [DATE]. As part of the City's effort to provide a local and sustainable water supply, the Demonstration Project is examining the use of water purification technology to provide safe and reliable water for San Diego's future.

Based on the information card you completed at the event, we have added you to our project's email list. We will keep you updated about the latest happenings with the Water Purification Demonstration Project. Your information will be used only for this project's outreach. Please be sure to add us to your safe senders so you can continue to receive our emails. If at any time you are no longer interested in learning about our project, please click "Unsubscribe" at the bottom of our emails.

Sincerely,

Danielle Thorsen
Community Outreach Specialist
San Diego Public Utilities Department
600 B Street, Suite 600
San Diego, CA 92101
Office: (619) 533-6606
DThorsen@sandiego.gov

Learn More

Tour the Advanced Water Purification Facility to get a closer look at water purification in action. Sign up for a tour at purewatersd.org/tours.shtml.

Can't make it out for a tour? Email purewatersd@sandiego.gov to request a Demonstration Project presentation for your group or to ask any project-related questions.

The Demonstration Project has been funded in part by grants from the U.S. Bureau of Reclamation and from a Proposition 50 grant administered by the California Department of Water Resources.

AWP Facility Tour Program: Tour Flier (full page)

Water Purification | Demonstration Project

A Site to See

Tours Available

Explore San Diego's first water purification testing facility on a guided tour.

Experience the water purification process:

- See how wastewater becomes purified water
- See what other places are already drinking purified water
- See the comparison of purified water, drinking water, and recycled water

Signing up is easy:

- Email your request to PureWaterSD@sandiego.gov
- Call (619) 533-4631
- Register online at www.PureWaterSD.org/tours.shtml

Scan this code to connect to our tour page!
How? Use your smartphone with a QR code reader. Open the code reader app and scan the code using your phone's camera.

Can't tour in person?

- View a virtual tour online at www.PureWaterSD.org
- Schedule a presentation for your organization — email PureWaterSD@sandiego.gov or call (619) 533-6638

AWP Facility Tour Program: Tour Flier (half page)

Open for Tours

Water Purification | Demonstration Project

Tours Available

Explore San Diego's first water purification testing facility on a guided tour.

Experience the water purification process:

- See how wastewater becomes purified water
- See what other places are already drinking purified water
- See the comparison of purified water, drinking water, and recycled water

Signing up is easy:

- Email your request to PureWaterSD@sandiego.gov
- Call (619) 533-4631
- Register online at www.PureWaterSD.org/tours.shtml

Can't tour in person?

- View a virtual tour online at www.PureWaterSD.org
- Schedule a presentation for your organization — email PureWaterSD@sandiego.gov or call (619) 533-6638

The City of San Diego

City of San Diego PUBLIC UTILITIES Water & Wastewater

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This information is available in alternative formats upon request.

AWP Facility Tour Program: Facility Graphics and Layout

AWP Facility Layout and Graphics

AWP Facility Tour Program: Tour List

List of tours from June 2011 through December 2012.

AWP Facility Tours
(June 2011 - December 2012)

Date	Time	Tour Group	Attendance
06/06/11	All day	Independent Advisory Panel	29
06/08/11	8:30 - 9:30 a.m.	Public Utilities Executive Staff	15
06/09/11	10 - 11 a.m.	Public Utilities Staff	9
06/09/11	11 a.m. - 12 p.m.	Public Utilities Staff	9
06/29/11	9 - 10 a.m.	American Assembly & Water Reliability Coalition	6
06/29/11	10 - 11 a.m.	American Assembly & Water Reliability Coalition	7
06/29/11	11 a.m. - 12 p.m.	American Assembly & Water Reliability Coalition	8
06/29/11	1 - 2 p.m.	American Assembly & Water Reliability Coalition	4
06/29/11	2 - 3 p.m.	American Assembly & Water Reliability Coalition	2
07/05/11	10 - 11 a.m.	Elected officials and water industry members	4
07/05/11	11 a.m. - 12 p.m.	Elected officials and water industry members	6
07/05/11	2 - 3 p.m.	Elected officials and water industry members	2
07/06/11	10 - 11 a.m.	Elected officials and water industry members (Councilmember Alvarez)	10
07/06/11	11 a.m. - 12 p.m.	Elected officials and water industry members	4
07/07/11	10 - 11 a.m.	Elected officials and water industry members	4
07/07/11	2 - 3 p.m.	Elected officials and water industry members (Councilmember Faulconer)	15
07/08/11	All day	Recycled Water Study	10
07/12/11	10 - 11 a.m.	Elected officials and water industry members	12
07/12/11	11 a.m. - 12 p.m.	Elected officials and water industry members	5
07/12/11	1 - 2 p.m.	Elected officials and water industry members	5
07/12/11	3:30 - 4:30 p.m.	Mayor's Office	13
07/14/11	10 - 11 a.m.	Elected officials and water industry members	11
07/14/11	1 - 2 p.m.	Elected officials and water industry members	4
07/14/11	2 - 3 p.m.	Elected officials and water industry members	11
07/19/11	10 - 11 a.m.	General public	9
07/19/11	11:30 a.m. - 12:30 p.m.	General public	10
07/20/11	11 a.m. - 12 p.m.	Elementary Institute of Science	16
07/21/11	10 - 11 a.m.	General public	18
07/21/11	11:30 a.m. - 12:30 p.m.	General public	4
07/23/11	11 a.m. - 12 p.m.	National University	14
07/26/11	10 - 11 a.m.	General public	14
07/26/11	11:30 a.m. - 12:30 p.m.	General public	6
07/27/11	5 - 6 p.m.	CWEA	13
07/27/11	6 - 7 p.m.	General public	11
07/28/11	10 - 11 a.m.	General public	9
07/28/11	11:30 a.m. - 12:30 p.m.	SABIT Group	13
08/02/11	10 - 11 a.m.	General public	19
08/02/11	11:30 a.m. - 12:30 p.m.	General public	12
08/04/11	10 - 11 a.m.	General public	10
08/04/11	11:30 a.m. - 12:30 p.m.	General public	10
08/04/11	2 - 3 p.m.	Councilmember Lightner	9
08/09/11	10 - 11 a.m.	General public	13
08/09/11	6 - 7 p.m.	General public	13
08/11/11	10 - 11 a.m.	General public	13
08/11/11	11:30 a.m. - 12:30 p.m.	General public, IEA	21
08/16/11	10 - 11 a.m.	General public	5
08/16/11	11:30 a.m. - 12:30 p.m.	General public	6
08/17/11	10 - 11:30 a.m.	WateReuse Association	30
08/18/11	10 - 11 a.m.	General public	12
08/18/11	11:30 a.m. - 12:30 p.m.	General public	6
08/20/11	11 a.m. - 12 p.m.	General public	17

AWP Facility Tours
(June 2011 - December 2012)

Date	Time	Tour Group	Attendance
08/22/11	3 - 4 p.m.	Councilmember Gloria	2
08/23/11	10 - 11 a.m.	General public	12
08/23/11	11:30 a.m. - 12:30 p.m.	General public	12
08/25/11	10 - 11 a.m.	General public	13
08/25/11	11:30 a.m. - 12:30 p.m.	General public	7
08/30/11	10 - 11 a.m.	General public	14
08/30/11	11:30 a.m. - 12:30 p.m.	General public	15
08/31/11	3 - 4:30 p.m.	Ambler Tours	47
08/31/11	5 - 6 p.m.	Audubon Society	12
09/01/11	8:30 - 9:30 a.m.	U.S. Bureau of Reclamation	5
09/01/11	10 - 11 a.m.	General public	13
09/01/11	11:30 a.m. - 12:30 p.m.	General public	5
09/02/11	9 - 10 a.m.	U.S. Bureau of Reclamation	5
09/06/11	10 - 11 a.m.	City of San Diego staff	9
09/06/11	1 - 2 p.m.	City of San Diego staff	14
09/06/11	9 - 10 a.m.	City of San Diego staff	8
09/06/11	11 a.m. - 12 p.m.	City of San Diego staff	10
09/08/11	11:30 a.m. - 12:30 p.m.	General Public	8
09/09/11	4:15 p.m.	Water Education Foundation	42
09/13/11	10 - 11 a.m.	General public	6
09/14/11	9 - 10 a.m.	Kipp Elementary School	65
09/14/11	11:30 a.m. - 12:30 p.m.	Home school group	21
09/15/11	9:30 - 11 a.m.	Kipp Elementary School	36
09/15/11	11:30 a.m. - 12:30 p.m.	General public	1
09/15/11	6 - 7 p.m.	General public	4
09/19/11	2 - 3 p.m.	Home school group	5
09/20/11	10 - 11 a.m.	General public	16
09/20/11	1 - 2 p.m.	Scripps Intitute of Oceanography	17
09/22/11	10 - 11 a.m.	General public	10
09/22/11	11:30 a.m. - 12:30 p.m.	General public	16
09/24/11	11 a.m. - 12 p.m.	General public	7
09/27/11	9 - 10 a.m.	City of San Diego staff	11
09/27/11	10 - 11 a.m.	City of San Diego staff	11
09/27/11	11 a.m. - 12 p.m.	City of San Diego staff	20
09/27/11	1 - 2 p.m.	City of San Diego staff	5
09/29/11	10 - 11 a.m.	General public	10
09/29/11	11:30 a.m. - 12:30 p.m.	General public	5
10/03/11	11 a.m. - 12 p.m.	City of San Diego staff	11
10/04/11	9:30 - 11 a.m.	High Tech High School	41
10/06/11	10 - 11 a.m.	General Public	6
10/08/11	11 a.m. - 12 p.m.	General Public	10
10/08/11	12:30 - 1:30 p.m.	Elementary Institute of Science	7
10/11/11	9 - 10 a.m.	Asian Business Association	6
10/13/11	10 - 11 a.m.	City of San Diego staff	11
10/17/11	10 - 11 a.m.	San Diego County Grand Jury	10
10/17/11	11 a.m. - 12 p.m.	Coachella Valley Water District	5
10/18/11	6 - 7 p.m.	Boy Scouts Den	17
10/19/11	1 - 2 p.m.	Mesa College Sustainability Class	13
10/19/11	3 - 4 p.m.	Thomas Jefferson School of Law Environmental Class	12
10/20/11	10 - 11 a.m.	General Public	3
10/27/11	10 - 11 a.m.	General Public	5

AWP Facility Tours
(June 2011 - December 2012)

Date	Time	Tour Group	Attendance
11/01/11	9:30 - 11 a.m.	Pacific Beach Elementary School	42
11/03/11	11:30 a.m. - 12:30 p.m.	General Public	6
11/05/11	10 - 11 a.m.	General Public	5
11/05/11	11:30 a.m. - 12:30 p.m.	Cub Scouts	32
11/08/11	10:30 a.m. - 12:30 p.m.	King-Chavez High School	59
11/09/11	10 - 11 a.m.	Assemblymember Fletcher and General Public	7
11/09/11	11 a.m. - 12 p.m.	Home school group	26
11/09/11	1 - 2 p.m.	UCSD Medical School and United Utilities	18
11/10/11	10 - 11 a.m.	SDSU Water Quality Investigation class	11
11/10/11	11:30 a.m. - 12:30 p.m.	Southwestern College class	14
11/17/11	11:30 a.m. - 12:30 p.m.	General Public	5
11/29/11	10 - 11 a.m.	General Public	10
11/29/11	11:30 a.m. - 12:30 p.m.	General Public	9
11/29/11	2 - 3 p.m.	La Jolla Village Greening Taskforce	21
12/02/11	11 a.m. - 12 p.m.	City of Los Angeles and General Public	4
12/02/11	12:30 - 1:30 p.m.	Catfish Club	13
12/08/11	10 - 11:30 a.m.	Pacific Beach Elementary School	42
12/10/11	10 - 11 a.m.	General Public	17
12/10/11	11:30 a.m. - 12:30 p.m.	Boy Scouts Den and Girl Scouts Troop	19
12/13/11	9:30 - 10:30 a.m.	Mexican government delegation	6
12/28/11	10 - 11 a.m.	Council District 4 staff	5
12/29/11	9:30 - 11:30 a.m.	Indian Nationals	2
01/09/12	10 - 11 a.m.	Conservation Action Committee	24
01/10/12	9:30 - 11:30 a.m.	San Diego Community College Older Adult Program	62
01/12/12	11:30 a.m. - 12:30 p.m.	Scripps Research Institute Toastmasters and Public	13
01/13/12	1:30 - 2:30 p.m.	Councilmember Emerald and Assemblymember Block's staff	10
01/17/12	10 - 11 a.m.	General Public	7
01/18/12	10 - 11 a.m.	UCSD Medical School	7
01/21/12	10 - 11 a.m	Association of Hazardous Materials Professionals (PSW CHMM)	8
01/21/12	11:30 a.m. - 12:30 p.m.	416th Civil Affairs Battalion (Airborne)	25
01/24/12	11:30 a.m. - 12:30 p.m.	Allied Gardens Optimist Club and General Public	11
01/26/12	1:30 - 2:30 p.m.	California Water Environment Association and General Public	8
01/27/12	9:30 - 10:30 a.m.	Santa Clara Valley Water District	4
02/07/12	10 - 11 a.m.	General Public	10
02/09/12	10 - 11 a.m.	General Public	6
02/09/12	11:30 a.m. - 12:30 p.m.	General Public	1
02/11/12	10 - 11 a.m.	General Public	21
02/11/12	11:30 a.m. - 12:30 p.m.	Society of Women Engineers and General Public	13
02/21/12	10 - 11 a.m.	Iraqi Delegation	6
02/23/12	10 - 11 a.m.	General Public	7
02/28/12	11:30 a.m. - 12:30 p.m.	Francis Parker Upper School AP Environmental Science Class	17
03/01/12	10 - 11 a.m.	General Public	5
03/10/12	10 - 11 a.m.	Cuyamaca College	34
03/10/12	12 - 1 p.m.	Mensa Playgroup	17
03/15/12	11:30 a.m. - 1:30 p.m.	American Society of Mechanical Engineers	10
03/16/12	9 - 10 a.m.	Council President Young and Councilmember Zapf	4
03/16/12	11 a.m. - 12 p.m.	Point Loma Rotary Club	17
03/16/12	1 - 2 p.m.	Assemblymember Toni Atkins	2
03/20/12	10 - 11 a.m.	City of San Diego staff	17
03/20/12	11 a.m. - 12 p.m.	City of San Diego staff	17
03/22/12	11:30 a.m. - 12:30 p.m.	General public	4

AWP Facility Tours
(June 2011 - December 2012)

Date	Time	Tour Group	Attendance
03/27/12	10 - 11:15 a.m.	White Sands La Jolla	11
03/29/12	10 - 11 a.m.	General Public	4
03/29/12	11:30 a.m. - 12:30 p.m.	General public	11
04/02/12	9:30-10:30	Public Utilities Mentorship Group	11
04/03/12	10 - 11 a.m.	San Diego Job Corps	33
04/03/12	11:30 a.m. - 12:30 p.m.	General public	8
04/05/12	10 - 11 a.m.	General public	6
04/11/12	6 - 7 p.m.	General public	6
04/12/12	10 - 11 a.m.	SDSU Osher Institute	23
04/12/12	11:30 a.m. - 12:30 p.m.	General public	5
04/14/12	10 - 11 a.m.	Boy Scouts	18
04/14/12	11:30 a.m. - 12:30 p.m.	Presbyterian Windjammers	16
04/24/12	11:30 a.m. - 12:30 p.m.	General public	10
04/26/12	10 - 11 a.m.	UCSD Pharmacology Lab	14
05/01/12	10 - 11 a.m.	SCAP Water Issues Committee	10
05/01/12	11:30 a.m. - 12:30 p.m.	National University	9
05/01/12	1:30 - 2:30 p.m.	Brazilian delegates	2
05/03/12	3 - 4 p.m.	Bureau of Reclamation & Senate Committee	4
05/12/12	10 - 11 a.m.	Girl Scouts	14
05/12/12	10:30 - 11:30 a.m.	General public	9
05/12/12	11 a.m. - 12 p.m.	General public	9
05/12/12	12:30 - 1:30 p.m.	General public	6
05/17/12	10-11 a.m.	Comision Estatal de Servicios Publicos de Tijuana	14
05/22/12	10-11 a.m.	Environmental Health Advisory Board	7
05/24/12	10-11 a.m.	All Hallows Academy	24
05/25/12	9:45-10:45 a.m.	Congressman Bob Filner	2
05/29/12	9:30-10:30 a.m.	Lincoln High School	16
05/29/12	11 a.m.-12 p.m.	All Hallows Academy	28
05/31/12	10-11 a.m.	SDCWA and Member Agency Officials	14
06/03/12	1:30-3:30 p.m.	WateReuse Conference Attendees	30
06/05/12	11:30 a.m. - 12:30 p.m.	General Public	16
6/122012	10-11 a.m.	General Public	6
06/14/12	11:30 a.m. - 12:30 p.m.	General Public	10
06/20/12	6 p.m. - 7 p.m.	Sustainability Committee	18
06/21/12	11:30 a.m. - 12:30 p.m.	General Public	6
06/23/12	10-11 a.m.	General Public	15
06/26/12	11-12 p.m.	General Public	8
07/16/12	12:30 - 1:30 p.m.	Assemblymember Atkins Stakeholder	8
07/16/12	1:30 - 2:30 p.m.	SDCWA Mentorship Group	8
07/18/12	11-12 p.m.	Retirement Club	16
07/19/12	9:30 -10:30 a.m.	General Public	21
07/20/12	10 a.m. - 1 p.m.	CUWA Board	8
07/21/12	10-11 a.m.	General Public	4
07/24/12	6-7 p.m.	General Public	3
07/26/12	11:30 a.m. - 12:30 p.m.	Councilmember DeMaio staff and General Public	5
08/07/12	11:30 a.m. - 12:30 p.m.	EMWD and General Public	14
08/10/12	11:30 a.m. - 12:30 p.m.	International Symposium	16
08/16/12	11:30 a.m. - 12:30 p.m.	Torrey Pines Ski Club	9
08/18/12	10-11 a.m.	Girl Scouts	13
08/18/12	11:30 a.m. - 12:30 p.m.	General Public	6
08/22/12	6:30 p.m. - 7:30 p.m.	Coalition of Neighborhood Councils	12

AWP Facility Tours
(June 2011 - December 2012)

Date	Time	Tour Group	Attendance
08/27/12	3-4 p.m.	Australian delegates and Councilmember-elect Kersey	3
08/29/12	11:30 a.m. - 12:30 p.m.	Women's Environmental Council	15
08/30/12	3 - 4 p.m.	South Jordan, Utah, & Councilmember Alvarez's staff	10
09/13/12	10-11 a.m.	San Diego Christian Home School Group	27
09/13/12	11:30 a.m. - 12:30 p.m.	General Public	6
09/22/12	11:30 a.m. - 12:30 p.m.	General Public	14
09/26/12	9:30 a.m. - 10:30 a.m.	Kipp Adelante Preparatory Academy	33
09/26/12	10:30 a.m. - 11:30 a.m.	Kipp Adelante Preparatory Academy	28
09/26/12	11:30 a.m. - 12:30 p.m.	Kipp Adelante Preparatory Academy	24
09/26/12	1 p.m. - 2 p.m.	General Public	4
09/27/12	11:30 a.m. - 12:30 p.m.	Olympian High School	12
09/29/12	8 a.m. - 9 a.m.	Healthy Hair Project and Business Bootcamp	25
09/29/12	9:30 a.m. - 10:30 a.m.	SDSU Dept of Geography Water Resources class	11
10/06/12	11 a.m. - 12 p.m.	Cuyamaca College	22
10/09/12	8:30 - 11:30 a.m.	CA-NV AWWA Conference	25
10/09/12	2 - 5 p.m.	Profs. Mujeriego and Asano	2
10/11/12	1 p.m. - 2 p.m.	EMTS (Public Utilities employees)	30
10/11/12	2 p.m. - 3 p.m.	EMTS (Public Utilities employees)	18
10/17/12	11 a.m. - 12 p.m.	UCSD Medical Students	12
10/18/12	10 a.m. - 11 a.m.	Intetnational Society of Automation EXPO	5
10/18/12	11:30 a.m. - 1 p.m.	Kearny High School AP environmental science class	42
10/25/12	3 - 4 p.m.	San Jose Silicon Valley Chamber of Commerce	27
10/26/12	9:30 - 10:30 a.m.	San Diego County of Educators	18
10/30/12	10 - 11:30 a.m.	Serra High School AP Environmental Science class	32
11/01/12	10 - 11:30 a.m.	Serra High School AP Environmental Science class	51
11/02/12	10 - 11 a.m.	Museum School, 6th grade class	32
11/03/12	10 - 11 a.m.	Sustainable Scripps Ranch	9
11/08/12	10 - 11:30 a.m.	SDSU Water Quality Investigation class	19
11/09/12	9:45-11:15	Museum School, 7th grade class	29
11/09/12	11:30 a.m. - 12:30 p.m.	SDSU ASCE members	5
11/14/12	9:30 a.m. - 10:30 a.m.	California Association of Resource Conservation District conference attendees	9
11/14/12	11 a.m. - 12 p.m.	General Public	5
11/28/12	2 p.m. - 3 p.m.	General Public	4
11/28/12	3:30 p.m. - 4:30 p.m.	Girl Scouts	15
12/04/12	10:30 - 11:30 a.m.	California Department of Public Health	18
12/07/12	11:30 a.m. - 12:30 p.m.	UCSD and Public Utilities staff	6
12/08/12	10 a.m. - 11 a.m.	Girl Scouts	14
12/13/12	10 a.m. - 11 a.m.	Public Utilities Staff	6
12/13/12	11 a.m. - 12 p.m.	Public Utilities Staff	7

Total number of tour attendees: **3244**

AWP Facility Tour Program: Tour Thank You e-blast

A template for the e-blast sent to AWP Facility tour guests following their visit.

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You're receiving this email because you have expressed interest in the City of San Diego's Water Purification Demonstration Project. Please confirm your continued interest in receiving email from us. To ensure that you continue to receive emails from us, add purewatersd@sandiego.gov to your address book today.

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Water Reuse Program

Water Purification Demonstration Project

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Water Purification | Demonstration Project

The City of San Diego's water resource strategy includes planning, conservation, recycled water, groundwater, water reuse, and watershed and resource protection to help meet future water needs.

THE CITY OF SAN DIEGO

City of San Diego PUBLIC UTILITIES Water & Wastewater

The City of San Diego | Public Utilities Department

Dear (Contact First Name),

Thank you for visiting the City of San Diego's Advanced Water Purification Facility on [DATE]. As you witnessed firsthand during the tour, the City's Water Purification Demonstration Project is examining the use of water purification technology to provide safe and reliable water for San Diego's future.

Visit our Facebook page to view your group's photo from the tour. If you were unable to join us for your scheduled tour on [DATE], we hope you will join us for an upcoming tour by registering at purewatersd.org/tours.shtml.

If you have friends or family who may be interested in learning more about this potential source of water, please encourage them to register for a tour at purewatersd.org/tours.shtml. We also welcome you to email us at purewatersd@sandiego.gov to request a presentation about the project for your group or organization.

Want to support a full-scale water purification project in San Diego? Contact us to learn more.

Thank you again for your interest in the Demonstration Project. We hope that you found the tour to be valuable and informative.

Sincerely,
Marsi A. Steirer
Water Purification Demonstration Project Director
City of San Diego, Public Utilities Department

The Demonstration Project has been funded in part by grants from the U.S. Bureau of Reclamation and from a Proposition 50 grant administered by the California Department of Water Resources.

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AWP Facility Tour Program: Feedback Form

City of San Diego PUBLIC UTILITIES Water & Wastewater

Water Purification | Demonstration Project

Tour Survey

Date: _____

Thank you for attending today's tour. Please take a moment to give us feedback that will help us improve our tour program. Check the box that best applies under each question.

1) How informative was the tour?

☐ Not informative ☐ Informative ☐ Very informative

2) Before the tour, how would you rate your understanding of the water purification process?

☐ Poor ☐ Fair ☐ Good ☐ Excellent

3) After taking the tour, how would you rate your understanding of the water purification process?

☐ Poor ☐ Fair ☐ Good ☐ Excellent

4) How would you rate your tour experience overall?

☐ Poor ☐ Fair ☐ Good ☐ Excellent

DT 6/28/11

5) What was the most valuable information you gained from the tour?

_____

_____

_____

_____

6) This tour would have been even better if…

_____

_____

_____

_____

7) Additional comments or questions:

_____

_____

_____

8) Your ZIP code:_____

9) Organization(s) to which we should offer a tour or presentation:

_____

Contact:_____

Thank you. We value your feedback.

AWP Facility Tour Program: Feedback from Tour Guests

A sampling of quotes from the feedback tour guests emailed following their tour experience.

AWP Facility Tour Feedback Excerpts

Thank you and your staff for your forward looking needs of our environment.

It gives me hope that there are young people like yourselves that understand the pressing issues of saving limited resources.

Thank you so much for the free tour of the Water Purification Demonstration Project. My husband and I enjoyed it very much and are looking forward to having some of your lovely water in our tap water…

I want to thank you for an excellent tour this morning. The leaders were very knowledgeable, clear, and friendly. The demonstration project is quite impressive, and I now understand why we San Diegans should welcome well-treated water being added to the San Vicente Reservoir.

Although I personally am very familiar with the project most of our members were not and I think they learned a lot. You did an excellent job of explaining the project.

[J]udging from our informal discussion immediately after the tour- I would say it was very much appreciated. Much valuable information was shared, presented clearly, on a subject of utmost importance to the public's health.

Thank you SO much for having us! The consensus is that the students enjoyed the field trip. I'm a bit surprised considering it was educational. Just goes to show that the people on your end did a great job in relating it to the audience.

I think ALL schools should be made aware of and encouraged to tour your facility.

What a great tour you put on Thursday ... I've been for recycling of the water since the Ron Coss days. Hearing about it is fine, but actually seeing it work is amazing. The tour guides all did such a great job, really shows the pride in work. kudos to the whole gang up there.

Prior to the presentation, I hadn't considered where the upstream, land locked cities dump their treated sewer water. Seeing so many treatment plants along the feeders to Southern California water source made me realize the water treatment proposed for San Diego, is in fact already in place.

AWP Facility Tour Program: Feedback Analysis

TOUR FEEDBACK REPORT

July 2011–
December 2012

Advanced Water Purification Facility

An analysis of responses from Advanced Water Purification Facility tour participants to question and comment prompts on a self-administered post-tour survey card.

BACKGROUND AND PURPOSE

The Advanced Water Purification (AWP) Facility is the centerpiece of the Water Purification Demonstration Project's outreach efforts. Since its opening in June 2011, the AWP Facility has hosted tours for individuals both local and international.

Prior to the end of every tour, participants are encouraged to fill out a survey card in order to determine what aspects of the tour are successful and what aspects need refinement. Based on the results, the outreach team can then adjust the tour experience to reflect the needs of the participants and promote a better understanding of the AWP Facility and the Demonstration Project as a whole.

The survey card includes four quantitative questions (1-4) in which the participants must choose from scaled, pre-selected responses and three open-ended questions (5-7) in which the participants are free to answer in their own words. Additional demographic and outreach suggestion questions (8-9) conclude the survey card. A sample of the card is provided below.

Tour Survey

Date: _____

Thank you for attending today's tour. Please take a moment to give us feedback that will help us improve our tour program. Check the box that best applies under each question.

1) How informative was the tour?
☐ Not informative ☐ Informative ☐ Very informative

2) Before the tour, how would you rate your understanding of the water purification process?
☐ Poor ☐ Fair ☐ Good ☐ Excellent

3) After taking the tour, how would you rate your understanding of the water purification process?
☐ Poor ☐ Fair ☐ Good ☐ Excellent

4) How would you rate your tour experience overall?
☐ Poor ☐ Fair ☐ Good ☐ Excellent

Water Purification | Demonstration Project

5) What was the most valuable information you gained from the tour?
_____
_____
_____
_____

6) This tour would have been even better if…
_____
_____
_____
_____

7) Additional comments or questions:
_____
_____
_____

8) Your ZIP code:_____

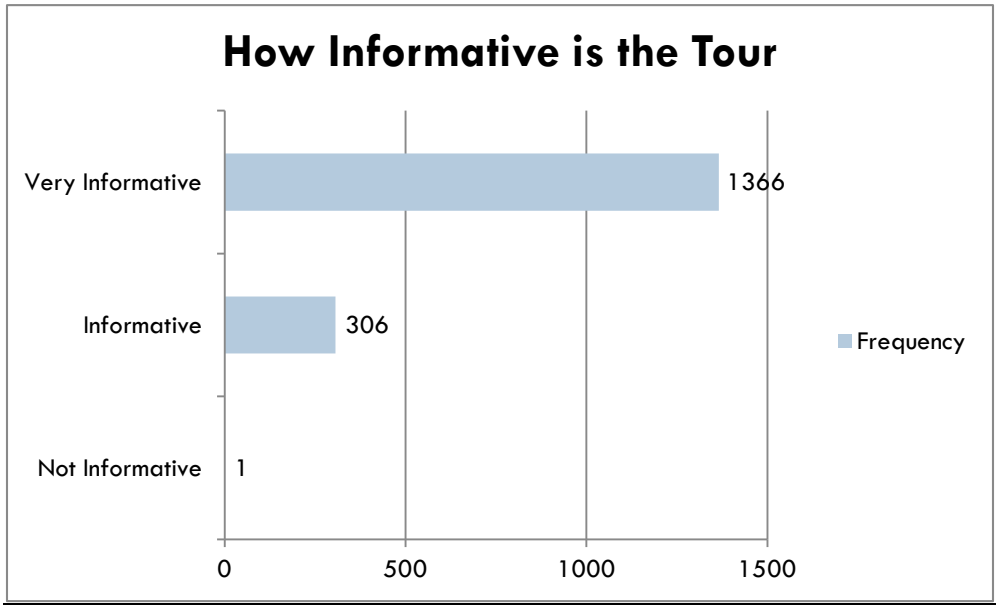
9) Organization(s) to which we should offer a tour or presentation:
_____

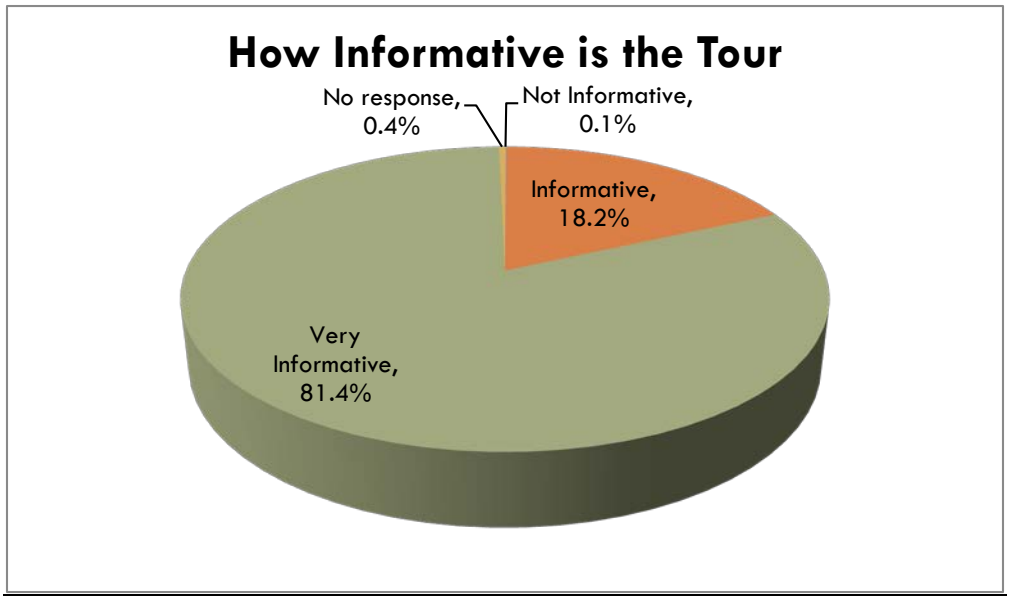
Contact:_____

Thank you. We value your feedback.

QUESTION ONE, 'HOW INFORMATIVE WAS THE TOUR?'

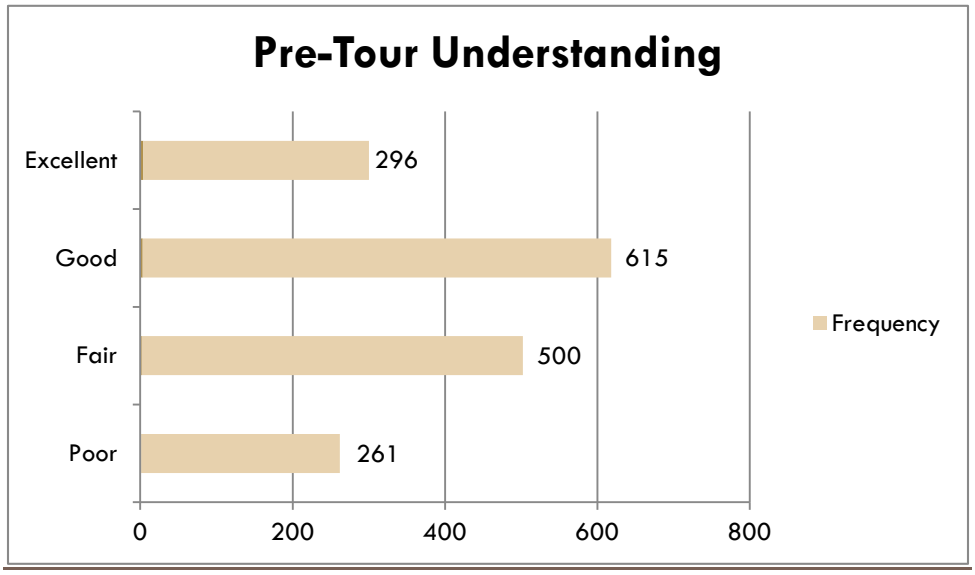
JULY 2011- DECEMBER 2012 CUMULATIVE RESULTS

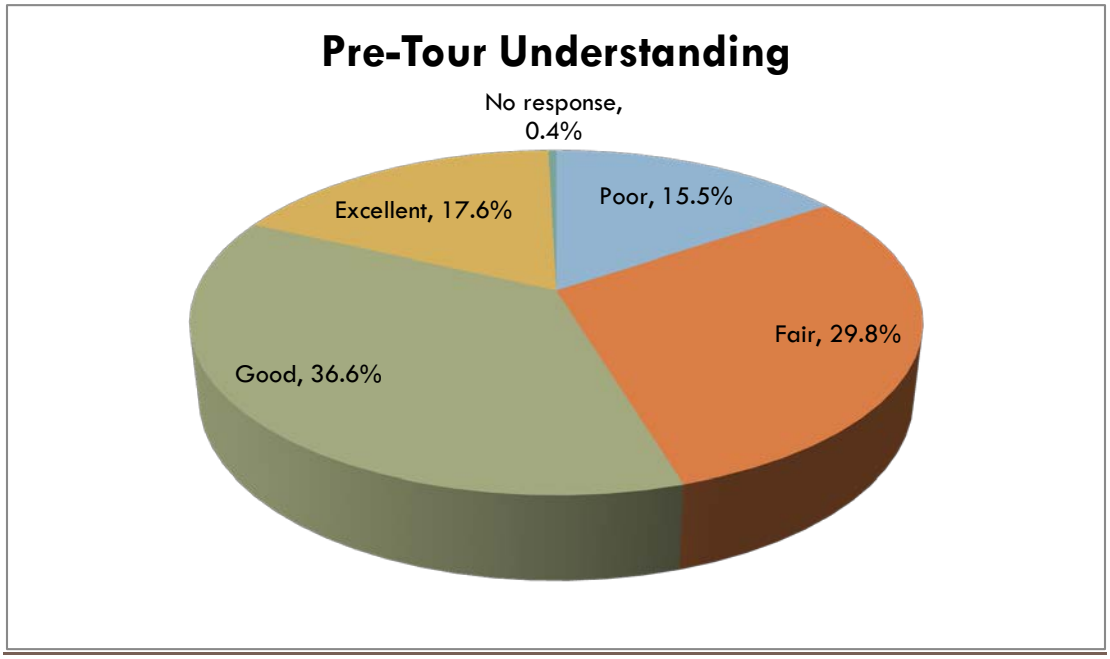




QUESTION TWO, 'BEFORE THE TOUR, HOW WOULD YOU RATE YOUR UNDERSTANDING OF THE WATER PURIFICATION PROCESS?'

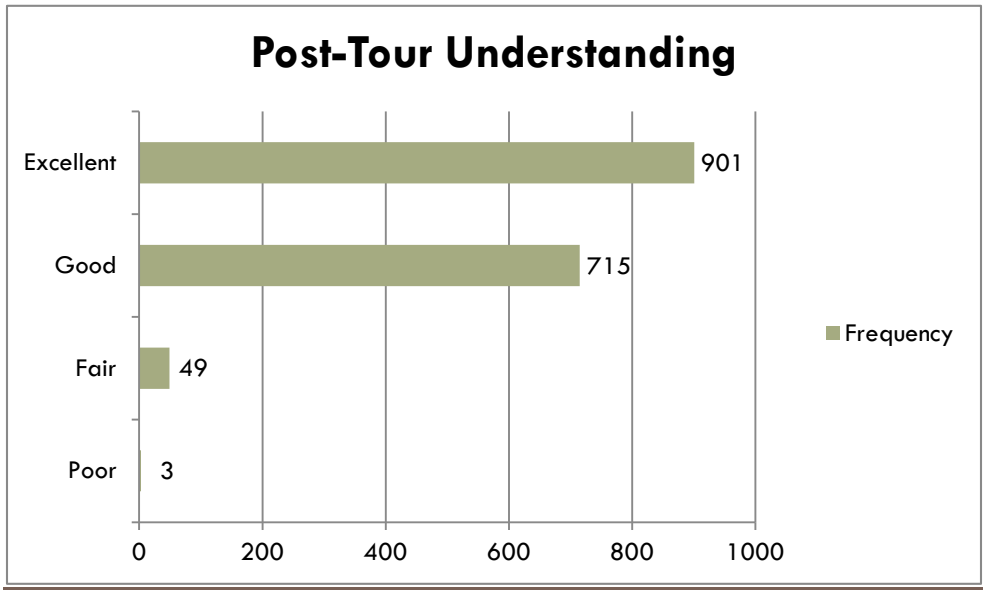
JULY 2011- DECEMBER 2012 CUMULATIVE RESULTS

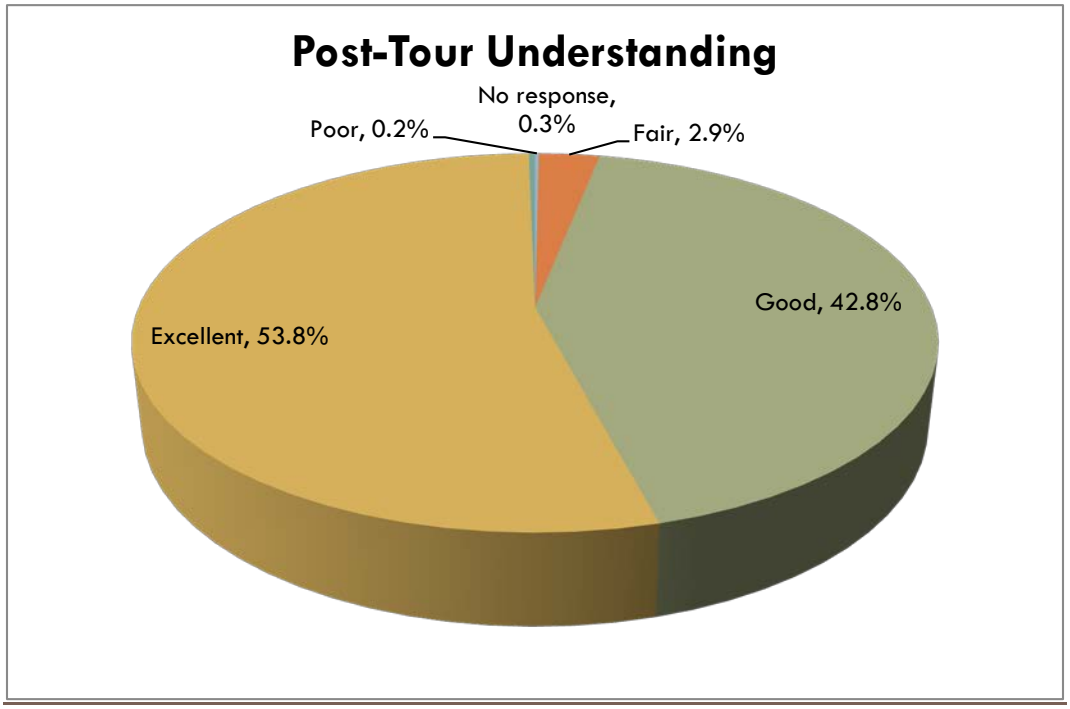




QUESTION THREE, 'AFTER TAKING THE TOUR, HOW WOULD YOU RATE YOUR UNDERSTANDING OF THE WATER PURIFICATION PROCESS?'

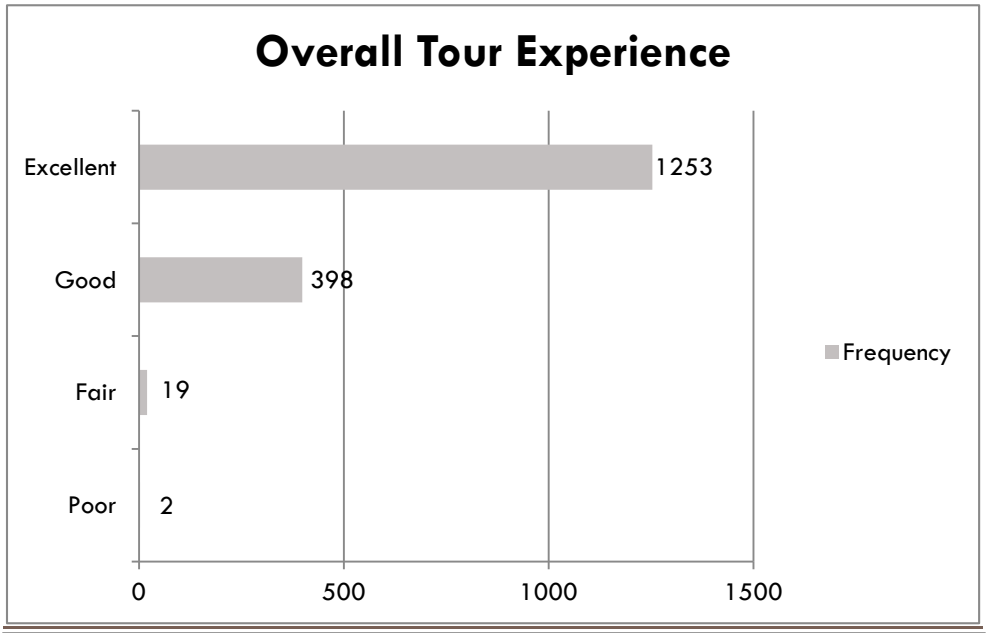
JULY 2011- DECEMBER 2012 CUMULATIVE RESULTS

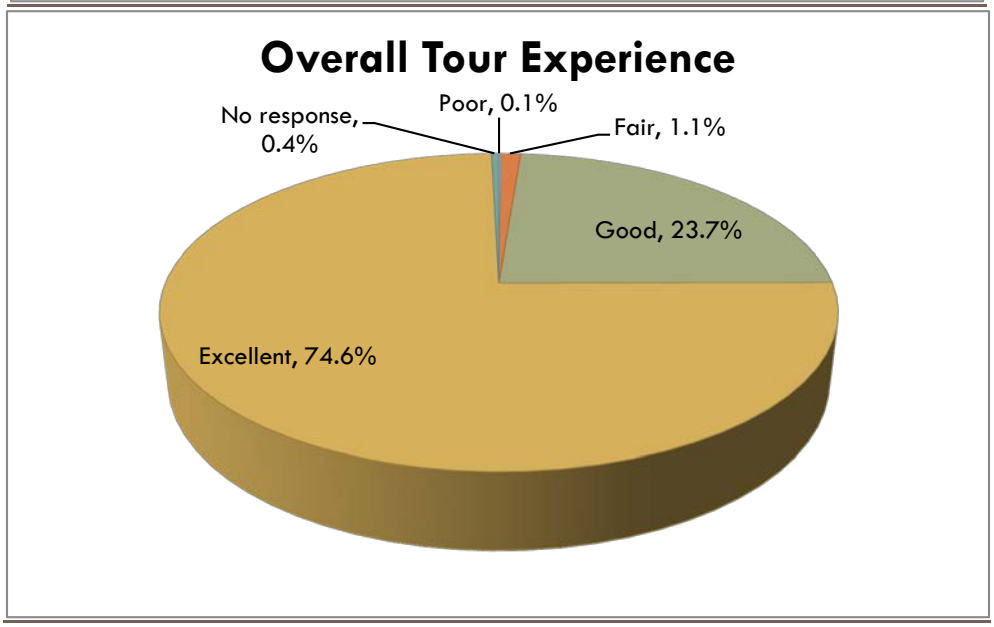




QUESTION FOUR, 'HOW WOULD YOU RATE YOUR TOUR EXPERIENCE OVERALL?'

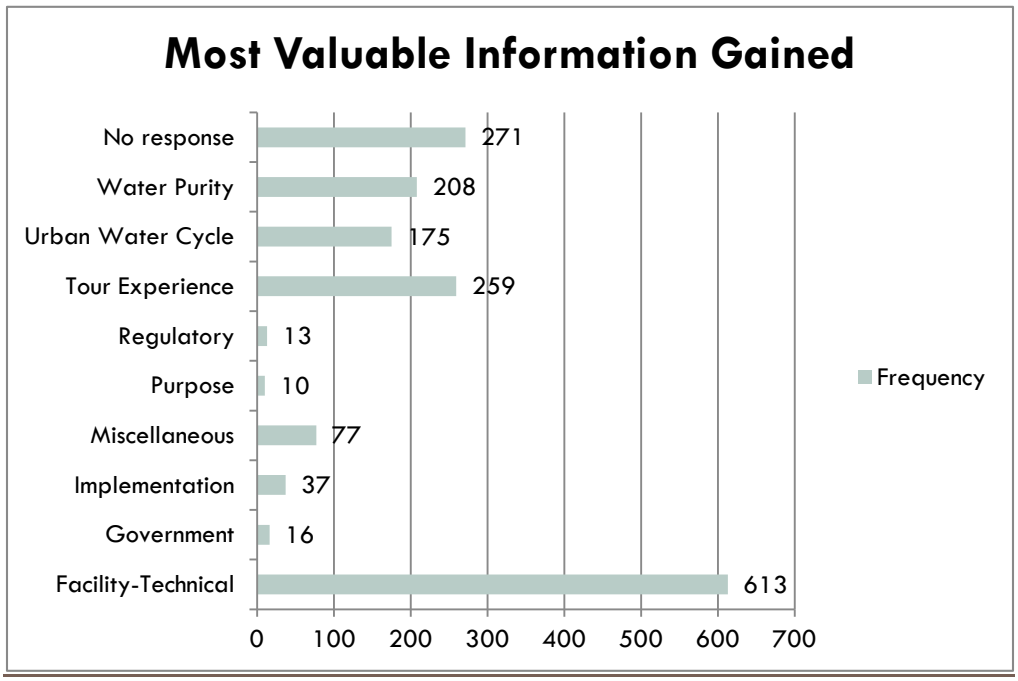
JULY 2011- DECEMBER 2012 CUMULATIVE RESULTS

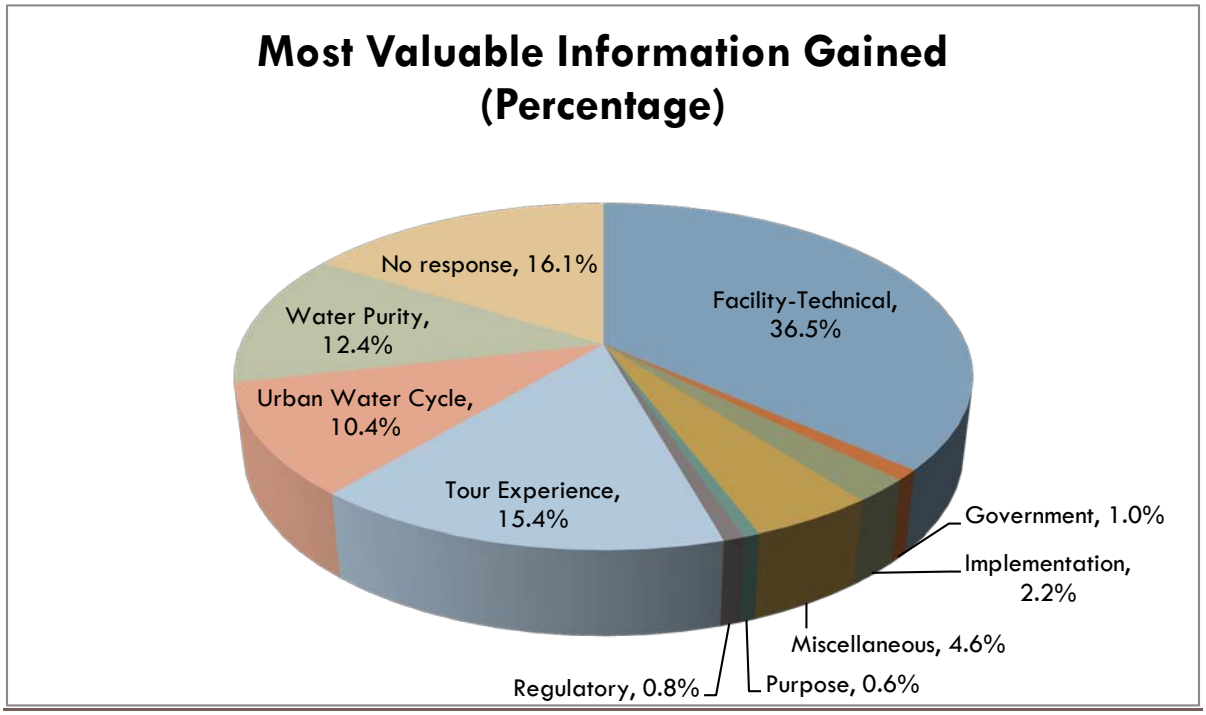




QUESTION FIVE, 'WHAT WAS THE MOST VALUABLE INFORMATION YOU GAINED FROM THE TOUR?'

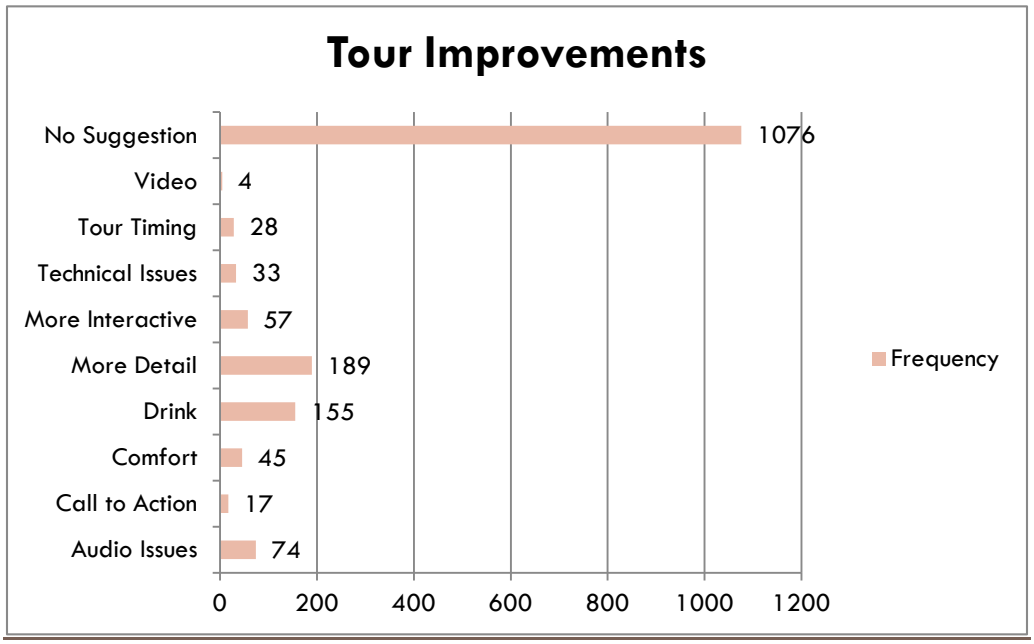
JULY 2011- DECEMBER 2012 CUMULATIVE RESULTS

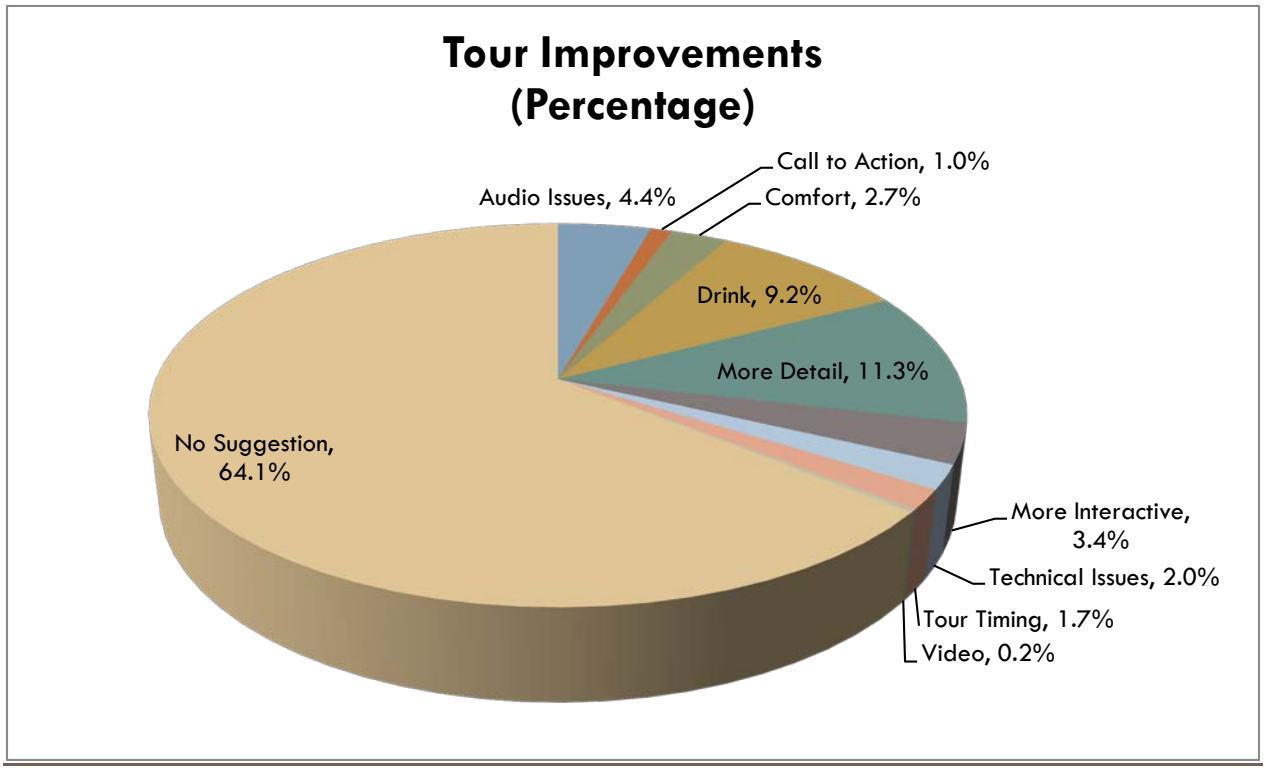




QUESTION SIX, 'THIS TOUR WOULD HAVE BEEN BETTER IF…'

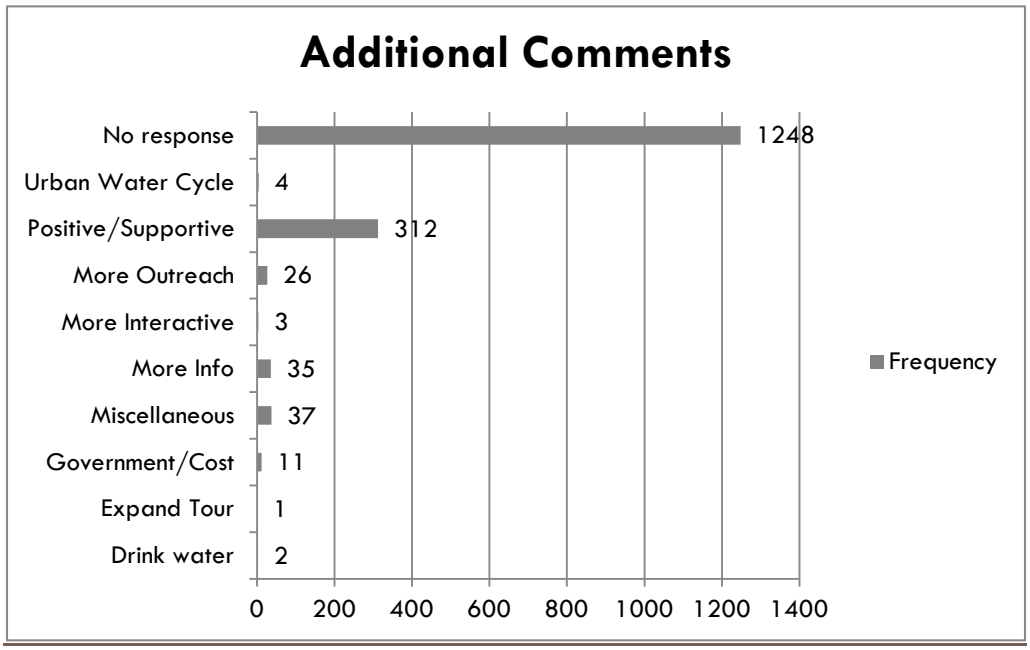
JULY 2011- DECEMBER 2012 CUMULATIVE RESULTS

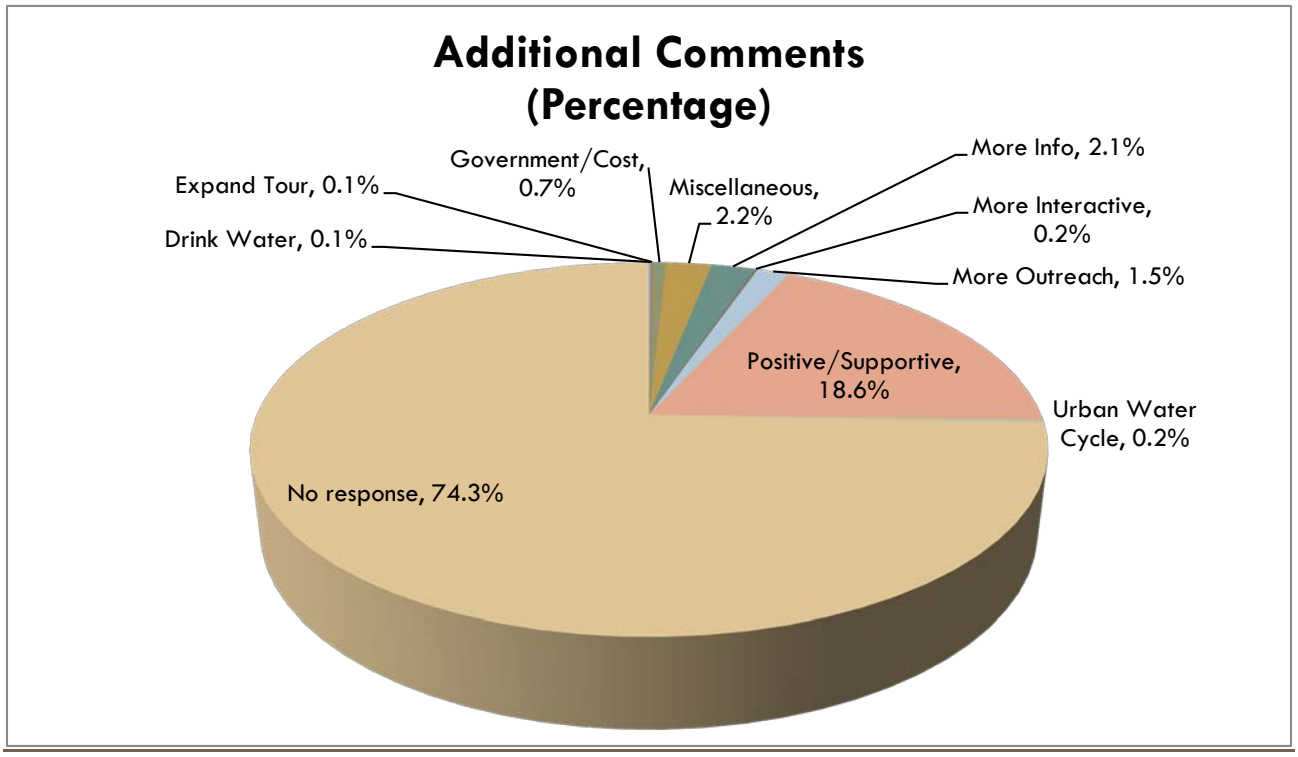




QUESTION SEVEN, 'ADDITIONAL COMMENTS OR QUESTIONS'

JULY 2011- DECEMBER 2012 CUMULATIVE RESULTS





SUMMARYOF RESULTS

QUESTIONS 1-4

The first set of questions (1-4) is quantitative and feature scaled, pre-selected answers from which tour participants could choose from. These questions aimed to measure tour participants' feelings on the informational content of the tour as well as their overall tour experience. Questions two and three measured participants' pre-tour and post-tour understanding of the water purification process to gauge if the tour experience served to heighten their understanding.

Between July 2011 and December 2012, a vast majority of those who participated in the tour of the AWP Facility rated the tour as "very informative." Only one response out of 1,679 responses characterized the tour as "not informative."

In evaluating their existing knowledge, 54 percent of participants characterized their pre-tour understanding of water purification as either "good" (36.6 percent) or "excellent" (17.6 perecent) while nearly 97 percent of respondents characterized their post-tour understanding as "good" (42.8 percent) or "excellent" (53.8 percent). The numbers show a positive correlation between the tour experience and a rise in understanding of the water purification process.

The vast majority of participants (nearly 75 percent) rated their tour experience as "excellent."

QUESTIONS 5-7

The second set of questions (5-7) is qualitative or open-ended and participants answered them in their own words. Their responses were then assigned categories based on content (see Tour Feedback Report Appendices A, B, and C) in order to analyze any trends in their responses.

The majority of participants stated that the most valuable information they gained from the tour was knowledge of the water purification process and being able to see, up close, the water purification equipment functioning.

When asked how they would improve their tour experience, the majority of participants gave either no suggestion or general positive feedback.

When asked for additional comment, the majority of participants offered either no response or general positive feedback.

Overall feedback, both quantitative and qualitative, was positive and encouraging from the beginning of the tour program. In analyzing the monthly trends, the numbers showed no major issues to reconcile and no cause for major tour improvements. Participants generally found the tour to be educational, interesting and a positive experience.

APPENDIX A - EXPLANATORY KEY FOR OPEN-ENDED QUESTION #5

'WHAT WAS THE MOST VALUABLE INFORMATION YOU GAINED FROM THE TOUR'

Response Category	Definition
Water Purity	Any mention of the purity, safety or clarity of the product water
Tour Experience	Includes mentions of "downstream," videos, guide knowledge and any mention towards the overall tour as an educational experience
Facility-Technical	Any mention of the actual equipment and/or knowledge gained by seeing and interacting. Also refers to the mention of the process of water purification
Government	Any mention of government (particularly the City) involvement with the project
Urban Water Cycle	Any mention of the water cycle (natural or urban), where our water comes from, where it goes, recycled water, reclamation, etc.
Implementation	Any mention of implementation or timeline for the project, long-term planning, cost-savings of implementation
Regulatory	Any mentions of regulations or policies
Purpose	Learning of the purpose for the Demonstration Project or of a full-scale project
Miscellaneous	Does not fall in a category or is not a relevant response

APPENDIX B – EXPLANATORY KEY FOR OPEN-ENDED QUESTION #6

'THIS TOUR WOULD HAVE BEEN BETTER IF…'

Response Category	Definition
Audio Issues	Any mention of problems hearing the tour guides due to PA speaker volume or jets flying overhead
Comfort	Any preference for bigger or smaller tour groups. Any mention of preference for refreshments.
Drink	Requests to drink IPR finished water and/or compare it with other waters (bottled, distilled, etc.)
Technical Issues	Mentions of concerns or incidents of operational or tour procedure issues.
Video	Any mention of the videos viewed during the presentation phase of the tour
Tour Timing	Any mention of the speed of the tour or length of the tour
More Detail	Requesting more information on contaminants, Orange County IPR, project costs, job creation, urban water cycle and environmental impact
More Interactive	Any mention of eliminating portions of the tour, use of language that is too technical or requesting a more hands-on experience
Call to Action	Any mentions of political involvement, social issues or informing the public to "take action"
No Suggestion	No response, unrealistic suggestions and/or positive feedback.

APPENDIX C - EXPLANATORY KEY FOR OPEN-ENDED QUESTION #7 'ADDITIONAL COMMENTS OR QUESTIONS:'

Response Category	Definition
Positive Supportive	Complimentary messages or messages that express satisfaction with the tour and encouragement for the project
Urban Water Cycle	Any mention of the water cycle, natural or urban, where our water comes from, where it goes, RW, reclamation, etc.
Gov't/Cost	Any mention of government, regulation or any other governing body or organization involved with the project, or any desire for more information about cost
More Outreach	Comments that request the tour be given to more people or more widely promoted
More Info	Mention of wide variety of more information requested
Expand Tour	Any mention of the tour being longer or actually touring the whole reclamation plant
Drink Water	Mention that they wanted to taste the finished product water
Miscellaneous	Any other response that did not fit in another response category
More Interactive	Mentions of ways to improve the tour to be more engaging or "hands-on"
No Response	"No comment" or left blank

Appendix H: Public Outreach and Education

Section 4: Social Media, Conferences and Awards

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2012 WateReuse Project of the Year award 16

Social Media Editorial Calendar

A sample of the December 2012 editorial calendar used to determine Facebook and Twitter postings. Editorial calendars were produced monthly beginning in October 2011.

Water Purification Demonstration Project
Social Media Message Calendar: December 2012

Dec.	Facebook & Twitter
1	x
2	x
3	There is no water to waste, just wasted water. Make a conscious effort to conserve water in your home or business. Some simple tips to save water: http://www.sandiego.gov/water/pdf/conservation/waystosavewater.pdf
4	The Demonstration Project welcomes representatives from the California Department of Public Health to the AWP Facility. We have given over 130 presentations to groups around San Diego. If you would like to schedule a speaker to educate your group on the future of San Diego water, email purewatersd@sandiego.gov or call the hotline at (619) 533-6638.
5	"In time and with water, everything changes" Leonardo da Vinci
6	Brackish water? Advanced oxidation? Decode these and other water purification terms here: http://www.sandiego.gov/water/waterreuse/pdf/100908wpdglossary.pdf
7	While the daily recommended amount of water is eight cups per day, not all of this water must be consumed in the liquid form. Nearly every food or drink item provides some water to the body.
8	x
9	x
10	"Water is the basis of life and the blue arteries of the earth! Everything in the non-marine environment depends on freshwater to survive." –Sandra Postel
11	Water treatment has been around since ancient civilizations. Brush up on a brief history of drinking water treatment at http://www.epa.gov/ogwdw/consumer/pdf/hist.pdf
12	The Demonstration Project welcomes students from Madison High School to the AWP Facility.
13	Interested in getting involved with the WPDP? Check out the Public Involvement page of our website to learn how: http://bit.ly/RoG3le
14	In the world of water, we are all downstream: past, present and future.
15	x
16	x
17	[Provide update about the final report.]
18	"Water is the lifeblood of our bodies, our economy, our nation and our well-being"-Stephen Johnson, former EPA administrator
19	Find answers to frequently asked questions about the quality of your water. http://www.sandiego.gov/water/quality/faqs.shtml
20	"In an age when man has forgotten his origins and is blind even to his most essential needs for survival, water along with other resources has become the victim of his indifference." – Rachel Carson
21	Wishing you and yours a very happy holiday season and a happy new year! See you in 2013.
22-31	x

Facebook

The screenshot of the Demonstration Project's Facebook page was taken in January 2013.

WATER PURIFICATION DEMONSTRATION PROJECT
FACEBOOK PAGE (WWW.FACEBOOK.COM/SANDIEGOWPDP)

Twitter

The screenshot of the Demonstration Project's Twitter page was taken in January 2013.

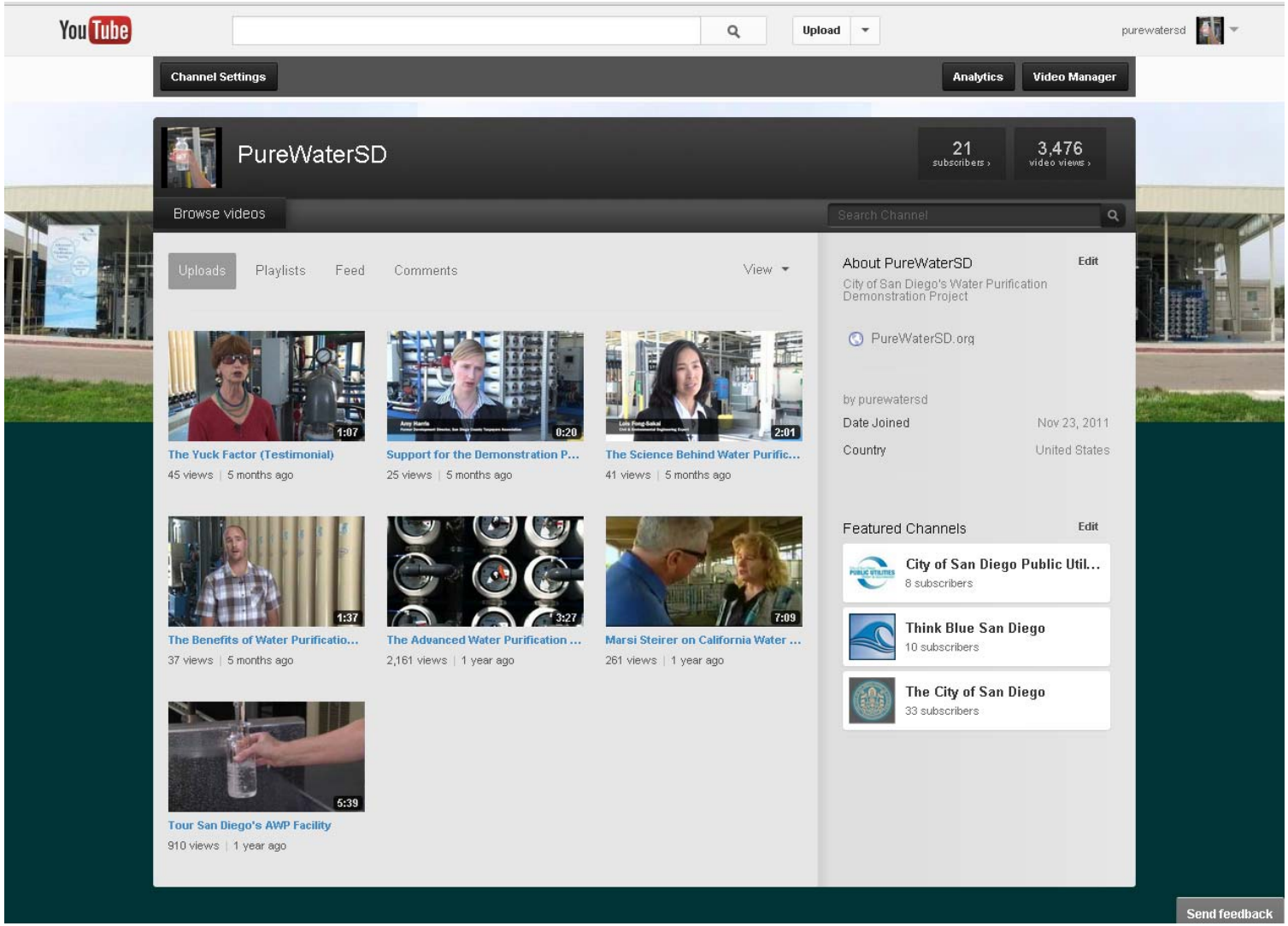
WATER PURIFICATION DEMONSTRATION PROJECT
TWITTER PAGE (WWW.TWITTER.COM/PUREWATERSD)

YouTube

The screenshot of the Demonstration Project's YouTube page was taken in January 2013. A snapshot of the project's YouTube video analytics is also included.

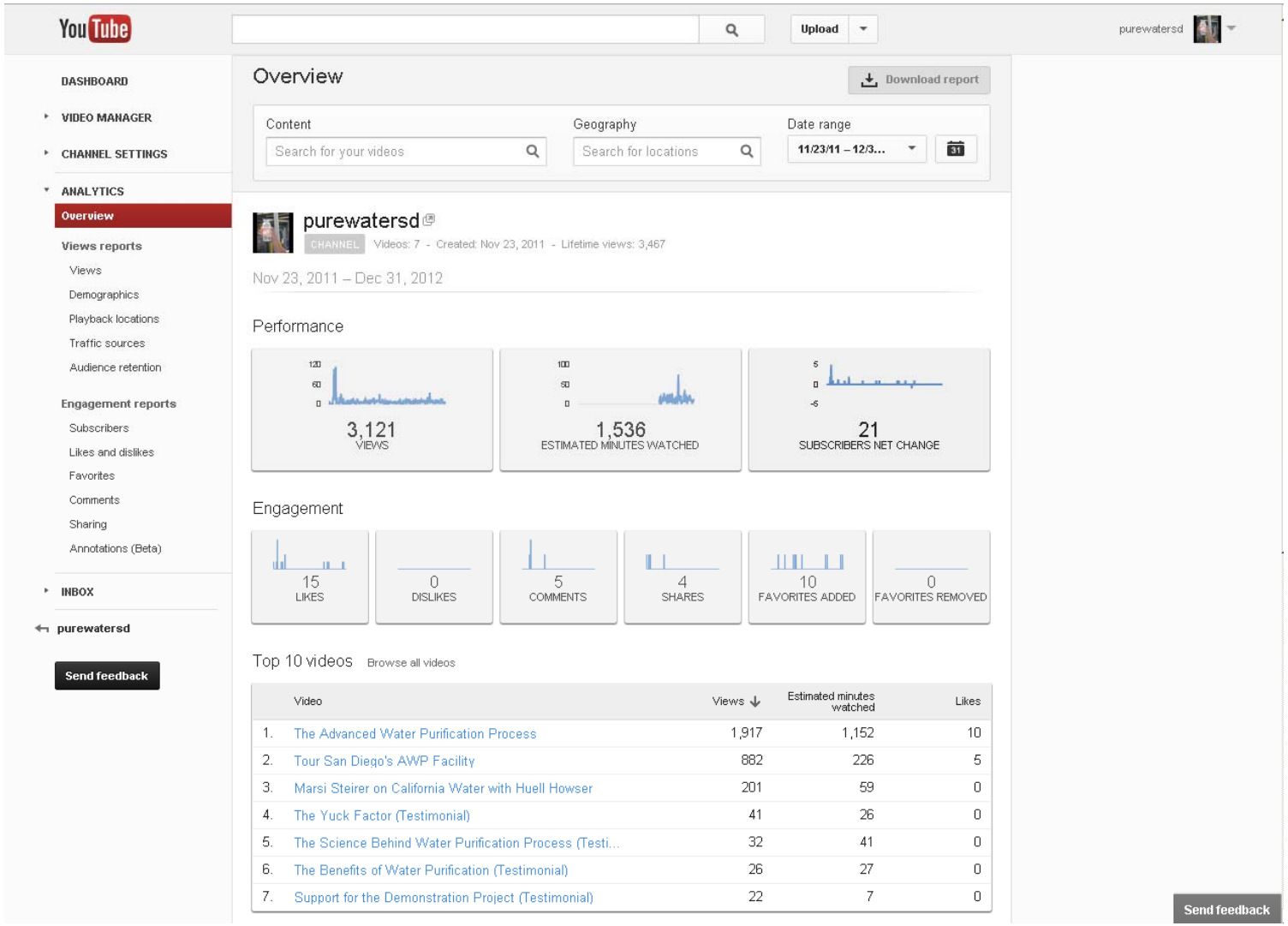
WATER PURIFICATION DEMONSTRATION PROJECT

YOUTUBE PAGE (WWW.YOUTUBE.COM/PUREWATERSD) AND ANALYTICS



WATER PURIFICATION DEMONSTRATION PROJECT

YOUTUBE PAGE (WWW.YOUTUBE.COM/PUREWATERSD) AND ANALYTICS



Conferences: Conference List

A list of conferences at which the Demonstration Project team presented project information

Water Purification Demonstration Project
Conference Involvement (March 2010 - December 2012)

Conference	Location	Date	Abstract Title	Topic	Presenter
2010 WateReuse California Annual Conference	San Diego, CA	March 7-9, 2010	City of San Diego's Indirect Potable Reuse/Reservoir Augmentation Demonstration Project	General	Marsi
AWWA ACE 10	Chicago, IL	June 20-24, 2010	Managing Water Resources in a Sustainable Manner	General	Marsi
25th Annual WateReuse Symposium	Washington, D.C.	Sep. 12-15, 2010	Developing a Model Solution for Sustainability through Water Reuse	Technical	Marsi
2011 Utilities Management Conference	Denver, CO	Feb. 8-11, 2011	City of San Diego Water Purification Demonstration Project	Technical	Marsi
2011 WateReuse California Annual Conference	Dana Point, CA	March 20-22, 2011	Evaluating the Feasibility of a New Local Water Supply for San Diego	Technical	Anthony
AWWA ACE 11	Washington, D.C.	June 11-12, 2011	Changing Public Perception with Education and Information	Outreach	Marsi
AWWA ACE 11	Washington, D.C.	June 11-12, 2011	Is Advanced Purified Water Feasible?	Technical	Marsi
26th Annual WateReuse Symposium	Phoenix, AZ	Sept. 11-14, 2011	Development of a Comprehensive T&M Plan	Technical	Jay
26th Annual WateReuse Symposium	Phoenix, AZ	Sept. 11-14, 2011	Changing Public Perception with Education and Information	Outreach	Marsi
ACWA's 2011 Continuing Legal Education for Water	San Diego, CA	Sept. 22-23, 2011	City of San Diego Water Purification Demonstration Project	Outreach	Marsi
WEFTEC 11	Los Angeles, CA	October 15-19, 2011	City of San Diego Water Purification Demonstration Project	Technical	Joseph
2011 Potable Reuse Conference	Hollywood, FL	Nov. 13-15, 2011	City of San Diego Water Purification Demonstration Project	Outreach	Marsi
2011 Potable Reuse Conference	Hollywood, FL	Nov. 13-15, 2011	"Seeing is Believing" for the Water Purification Process	Outreach	Patsy
2011 Potable Reuse Conference	Hollywood, FL	Nov. 13-15, 2011	Performance & Reliability Monitoring of Advanced Water Treatment Unit Processes for Indirect Potable Reuse—A Stepping Stone for Potable Reuse	Technical	Jay
ASCE Region 9 Annual California Infrastructure Symposium	Sacramento, CA	February 28, 2012	City of San Diego Water Purification Demonstration Project	General	Marsi
2012 WateReuse California Annual Conference	Sacramento, CA	March 25-27, 2012	City of San Diego Advanced Water Purification Facility Tour Experience	Outreach	Marsi
2012 WateReuse California Annual Conference	Sacramento, CA	March 25-27, 2012	City of San Diego Update of the Water Purification Demonstration Project	Technical	Anthony
Ozwater'12 (Australian Water Association)	Sydney, Australia	May 8-10, 2012	Overcoming Barriers to the Acceptance of Potable Reuse as an Alternative Water Source	Outreach	Marsi
16th Annual Water Reuse & Desalination Research Conference	San Diego, CA	June 4-5, 2012	Development of a Three Dimensional Hydrodynamic Model to Assess Indirect Potable Reuse/Reservoir Augmentation in San Vicente Reservoir	Technical	Jeff
16th Annual Water Reuse & Desalination Research Conference	San Diego, CA	June 4-5, 2012	Practice What You Find: Tailoring Outreach Efforts Based on Research Findings	Outreach	Marsi
16th Annual Water Reuse & Desalination Research Conference	San Diego, CA	June 4-5, 2012	Evaluation of Performance Monitoring Methods for AWP Processes: City of SD AWP Demonstration Project	Technical	Bill/Jay
AWWA ACE 12	Dallas, TX	June 10-14, 2012	City of San Diego Advanced Water Purification Facility Tour Experience	Outreach	Marsi
AWWA ACE 12	Dallas, TX	June 10-14, 2012	City of San Diego Update of the Water Purification Demonstration Project	Technical	Marsi
AWWA ACE 12	Dallas, TX	June 10-14, 2012	Comparing Multiple MF/UF and RO Systems for Indirect Potable Reuse in Side-by-Side Comparison	Technical	Greg W.
Western Coalition of Arid States (WESTCAS) 2012 Annual Conference	San Diego, CA	June 18-20, 2012	San Diego Water Purification Demonstration Project	General	Marsi
WateReuse Foundation Webcast - Panel Discussion	Marsi's office	June 26, 2012 at 2PM	WateReuse Association Webcast - Accelerating the Progress of Potable Reuse	Outreach	Marsi
CA-NV AWWA Desalination Committee Workshop	Foster City, CA	August 21, 2012	San Diego Water Purification Demonstration Project	Outreach	Alma
CA-NV AWWA Desalination Committee Workshop	Fountain Valley, CA	August 23, 2012	San Diego Water Purification Demonstration Project	Outreach	Alma
27th Annual Water Reuse Symposium	Hollywood, FL	September 9-12, 2012	"Seeing is Believing" for the Water Purification Process	Outreach	Marsi
27th Annual Water Reuse Symposium	Hollywood, FL	September 9-12, 2012	Evaluation of Performance & Reliability of Advanced Water Purification Processes: City of San Diego Advanced Water Purification Demonstration Project	Technical	Jay D.
California Lake Management Society	San Diego, CA	Oct 4 - 5, 2012	San Diego's Water Purification Demonstration Project: Changing Public Perception of IPR/RA	Technical	Marsi
CA-NV AWWA 2012 Annual Fall Conference	San Diego, CA	Oct. 8 - Oct 11, 2012	The City of SD's Water Purification Demonstration Project	Outreach	Marsi
CA-NV AWWA 2012 Annual Fall Conference	San Diego, CA	Oct. 8 - Oct 11, 2012	A Comparison of Operating Conditions and Performance of Indirect Potable Reuse Facilities for San Diego's Demonstration Plant	Technical	Greg W./Jen T.

Conferences: Conference Poster

Poster displayed at various conferences

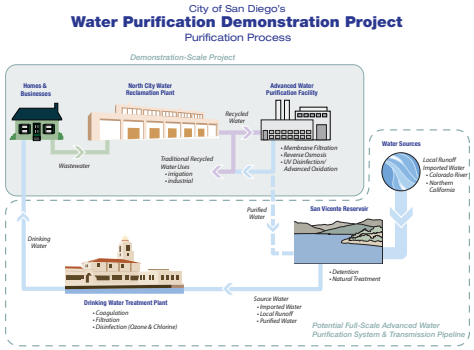
THE CITY OF SAN DIEGO

Water Purification | Demonstration Project

City of San Diego PUBLIC UTILITIES Water & Wastewater

The City of San Diego is evaluating the feasibility of using advanced water treatment technology on recycled water for augmentation of supplies in a local reservoir. The newly purified water would undergo additional treatment before it is added to the drinking water supply.

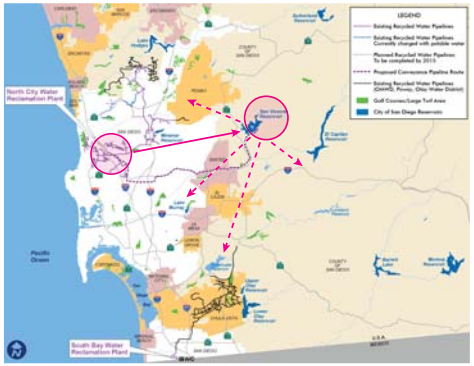
The intent of the Water Purification Demonstration Project is to establish the technical, water quality, environmental, public outreach, regulatory, and funding requirements necessary to implement a full-scale project.



Water Purification Demonstration Project Tasks

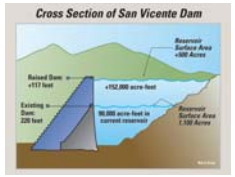
- Operate and test a 1 MGD demonstration-scale Advanced Water Purification Facility.
- Conduct a limnology and reservoir detention study of the San Vicente Reservoir.
- Conduct an energy and economic analysis.
- Conduct a public outreach and education program.
- Define regulatory requirements for a potential full-scale project.

Demonstration Project Concept



San Vicente Reservoir Limnology and Detention Study

- Construction timeline: 2009 – 2013
- 3D model of San Vicente was developed to evaluate the hydrodynamic & water quality effects of using purified water to augment the reservoir.
- Augmentation would improve water quality.

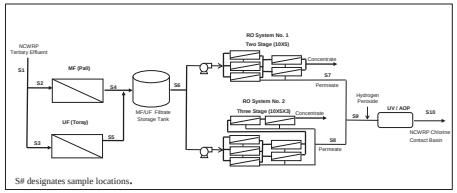


Public Outreach & Education

- Speakers Bureau
- Website/Social Media
- AWP Facility Tours

Advanced Water Purification (AWP) Facility

- Operating in accordance with a Testing & Monitoring Plan.
- Equipment selected is scalable for future full-scale facility.
- Purified water used to supplement recycled water system.



AWP Facility Process Schematic

Membrane Filtration

- Microfiltration & ultrafiltration situated side-by-side to test effectiveness prior to reverse osmosis.
- Pressurized hollow fiber membranes.
- MF nominal pore size of 0.10 microns.
- UF nominal pore size of 0.02 microns.

Reverse Osmosis (RO)

- RO set to test two configurations, 0.5 MGD side-by-side to quantify trade-offs:
  - Greater rejection and lower feed pressure
  - Comparison of 2-stage vs. 3-stage configurations
- RO Train 1 has lower pressure membranes (2-stage).
- RO Train 2 has higher pressure and higher rejection membranes (3-stage).
- Energy recovery devices.

Ultraviolet Light/Advanced Oxidation Process (UV/AOP)

- RO permeate feeds UV/AOP.
- Hydrogen peroxide 30% is injected upstream of UV at 3 mg/L.
- UV system utilizes low pressure/high output lamps.
- Single reactor, 72 lamp configuration.

Water Quality

- Purified water tested for more than 300 compounds.
- Compounds tested have regulatory limits for meeting drinking water standards.
- Tested for compounds under consideration for regulation, including chemicals of emerging concern.

Quarterly Results

- Exceptional overall water quality
- Purified water met drinking water standards

Visit: www.purewatersd.org

www.facebook.com/SanDiegoWPDP

@PureWaterSD

YouTube PureWaterSD

Awards

Photographs of the WateReuse Association awards won by the Demonstration Project in 2011 and 2012

WateReuse Awards

Appendix H: Public Outreach and Education

Section 5: Media Outreach

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"Spiderman" (Web banner) 17
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Template Article

The template article regarding the AWP Facility opening was prepared and distributed to local publications in July 2011. Updated variations were produced and distributed to additional publications as needed.

Future of water on public display at San Diego's Water Purification Demonstration Project

by Marsi A. Steirer, Water Purification Demonstration Project Director,
City of San Diego, Public Utilities Department

The City of San Diego opens the doors this summer to a facility that is testing whether it could provide a new local source of water for San Diego. Located in northern San Diego, the Advanced Water Purification Facility is a small-scale, state-of-the-art water purification facility that purifies one million gallons of recycled water every day to a level similar to distilled water quality.

The facility is one component of the City's Water Purification Demonstration Project that is examining the safety and cost of purifying recycled water. If this project is approved to go full-scale, the purified water would blend with the City's imported supplies at San Vicente Reservoir and would become part of the City's drinking water supply. As another component of the Demonstration Project, the City is studying San Vicente Reservoir and the potential effects of adding purified water to it. During the year-long test phase, purified water will not be sent to San Vicente Reservoir or the City's drinking water system; instead, the purified water will be added to the City's recycled water system.

San Diego is testing water purification as a means to develop a locally controlled, supplemental water supply. San Diego's semi-arid region is at the end of pipelines that import water from hundreds of miles away. The City needs to develop local, reliable water sources to lessen its dependence on expensive and limited imported water supplies.

"Our City has been both creative and aggressive in trying to diversify our water supply. The less we rely on importing water from outside San Diego County, the more we control our own destiny," San Diego Mayor Jerry Sanders said. "A locally produced supply of water could be an important option for us."

All wastewater in San Diego undergoes treatment to remove harmful contaminants, making it safe enough to be discharged into the ocean. Some wastewater is diverted to the City's recycled water facilities, where it is further treated and then used for irrigation and industrial purposes. A portion of the recycled water produced at the North City Water Reclamation Plant will be sent to the Advanced Water Purification Facility.

At the facility, the recycled water undergoes the multi-barrier purification process, which includes membrane filtration, reverse osmosis, and advanced oxidation with ultraviolet disinfection and high-strength hydrogen peroxide. The multi-barrier approach of consecutive treatment steps work together to remove or destroy all unwanted materials in the water and produces one of the most pristine supplies of water available anywhere. Each step in the

process also includes continuous water quality monitoring. The City thoroughly examines the safety of the water through laboratory tests and computer analysis to ensure that it meets public health standards.

The data from the Demonstration Project will be thoroughly examined, and the results will determine the safety and cost of a full-scale water purification and reservoir augmentation project. After the test phase is complete, the City Council and Mayor will decide whether to implement a full-scale project.

"This Demonstration Project will provide the answers San Diego needs before taking the next step with purified water," said Mayor Sanders. "We owe it to our citizens to see if we can come up with an alternative source of local, safe and relatively inexpensive drinking water."

The same water purification process is already used around the world. Just north of San Diego, Orange County operates the world's largest water purification plant. The Orange County Groundwater Replenishment System produces up to 70 million gallons a day of ultra clean water to provide safe and reliable drinking water for nearly 600,000 residents. The purified water is produced from secondary-treated wastewater and injected into the county's drinking water aquifer.

Visitors are welcome and encouraged to tour the Advanced Water Purification Facility through summer 2012. Guests who participate in the AWP Facility tour will gain a better understanding of the Demonstration Project and what role the facility plays in this testing phase. Following an introductory presentation, tour participants will take a walking tour through the facility to view the water purification technology equipment up close. At the end of the tour, guests will view the purified water produced at the facility. To register for a tour, visit www.purewatersd.org/tours.shtml. For more information about the City of San Diego's Water Purification Demonstration Project, visit www.purewatersd.org, email purewatersd@sandiego.gov, or call (619)533-7572.

###

Press Release: Drinking Water Week

This press release was distributed to community publications in May 2012 to publicize the AWP Facility open house tours in honor of national Drinking Water Week 2012.

THE CITY OF SAN DIEGO
PUBLIC UTILITIES

FOR IMMEDIATE RELEASE
May 4, 2012

MEDIA CONTACTS:
Alma Rife
(619) 533-5477

City's Water Purification Demonstration Project Celebrates Drinking Water Week with Open House Tours

City Studying Feasibility of Purifying Wastewater for Drinking Water

SAN DIEGO – The City of San Diego's Water Purification Demonstration Project will commemorate Drinking Water Week 2012 by offering free open house tours of its Advanced Water Purification Facility in northern San Diego on Saturday, May 12. Back-to-back tours will be offered from 10:30 a.m. to 12:30 p.m. Registration for the open house tours closes on Wednesday, May 9. Register for a tour at **www.purewatersd.org/tours.shtml**.

"Drinking Water Week is a unique opportunity for water professionals and the communities they serve to join together to recognize the vital role water plays in our daily lives," said San Diego Public Utilities Director Roger Bailey. "With limited local drinking water supplies and a reliance on importing approximately 85 percent of its water, San Diego is extremely aware of the need for secure, local drinking water. The Water Purification Demonstration Project plays an important role in exploring advanced technology to augment San Diego's water portfolio."

The Demonstration Project is examining the cost and safety of purifying recycled water as a means to develop a locally controlled, supplemental drinking water supply. The Advanced Water Purification Facility is a small-scale facility that purifies one million gallons of recycled water every day. Currently, the purified water produced at the facility is returned to the recycled water distribution system for irrigation and industrial purposes. If all regulatory requirements are met, funding is identified and approval is granted by Mayor and Council, a full-scale water purification facility could provide San Diego with a new source of local drinking water.

During the facility tours, guests will learn what the Demonstration Project is about and what role the Advanced Water Purification Facility plays in this testing phase. Following an introductory presentation, participants take a walking tour through the facility to view the water purification technology equipment up close and hear more about how the purification process works. At the end of the tour, guests are challenged to decipher samples of purified, recycled and tap water. Since opening in June 2011, more than 2,000 people have toured the facility.

For more information about the Water Purification Demonstration Project, visit **www.purewatersd.org** or email **purewatersd@sandiego.gov**.

# # #

Press Release: WateReuse Association Award

This press release was distributed to local publications in September 2012 to publicize the Demonstration Project winning the WateReuse Association's Small Project of the Year Award. A similar release was distributed the previous year when the Demonstration Project won the WateReuse Association's Public Education Program of the Year Award.

THE CITY OF SAN DIEGO
PUBLIC UTILITIES

FOR IMMEDIATE RELEASE
September 18, 2012

MEDIA CONTACT:
Alma Rife
(619) 533-5477

City's Water Purification Demonstration Project Honored with National Award

Project Receives 2012 Small Project of the Year

SAN DIEGO – Last week, the WateReuse Association honored the City of San Diego's Water Purification Demonstration Project with the "2012 WateReuse Small Project of the Year Award" at its 27th Annual Symposium in Florida. Since the Demonstration Project began in 2009, the City's Public Utilities Department has been examining the use of water purification technology to potentially provide safe and reliable water for San Diego's future. This comprehensive pilot program includes operating a test facility, studying the impact of adding purified water to San Vicente Reservoir, completing a cost and energy analysis, and conducting a public outreach and education program to inform San Diegans about the science of water purification.

"The Demonstration Project is playing an important role in determining whether purified water can be a viable option for supplementing San Diego's limited water supplies," said Roger Bailey, Director of the City's Public Utilities Department. "We are truly honored to be recognized for our ongoing work in exploring new water supply solutions for San Diego," added Bailey.

The award provides industry recognition for successful small (less than five-million-gallons-a-day capacity) projects that have made significant contributions to advancing water reuse. The City of San Diego Public Utilities Department is receiving this award for its continued dedication to water reuse and its successful implementation of the Water Purification Demonstration Project. Last year, the WateReuse Association recognized the Demonstration Project's outreach program as the 2011 WateReuse Public Education Program of the Year.

Members of the public are encouraged to register to tour the Demonstration Project's Advanced Water Purification Facility, which explains the project in more detail and provides an up-close look at the test facility. To register, visit the project website at **www.purewatersd.org/tours.shtml**. For a presentation to community, civic or business organizations, email **purewatersd@sandiego.gov** or call **(619) 533-6638**.

The WateReuse Association is a national, nonprofit organization whose mission is to advance the beneficial and efficient uses of high-quality, locally-produced, sustainable water sources for the betterment of society and the environment through advocacy, education and outreach, research, and membership. Across the United States and the world, communities are facing water supply challenges due to increasing demand, drought, depletion and contamination of groundwater, and dependence on a single source of supply.

# # #

Press Release: AWP Facility Tour Group Visits

This is a template of a press release distributed to organizations following their tours of the AWP Facility. These news releases were for publicizing the tour program in organizations' newsletters.

THE CITY OF SAN DIEGO
PUBLIC UTILITIES

FOR IMMEDIATE RELEASE
[DATE]

MEDIA CONTACTS:
Alma Rife
(619) 980-9560

[ORGANIZATION] Tours
City's Water Purification Demonstration Project

City Studying Feasibility of Purifying Wastewater for Drinking Water

SAN DIEGO – [Members of ORGANIZATION] toured the City of San Diego's Advanced Water Purification Facility on [DATE]. Located in northern San Diego, the Advanced Water Purification Facility is a small-scale facility that purifies one million gallons of recycled water every day to a level similar to distilled water quality.

The facility is one component of the City's Water Purification Demonstration Project that is examining the safety and cost of purifying recycled water. If the project is approved to go full-scale, the purified water would blend with the City's imported supply of raw or untreated water stored in the San Vicente Reservoir. After being treated again at the Alvarado Water Treatment Plant, water from San Vicente Reservoir would become part of the City's drinking water supply. As another component of the Demonstration Project, the City is studying San Vicente Reservoir and the potential effects of adding purified water to it. During the year-long test phase, purified water will not be sent to San Vicente Reservoir or the City's drinking water system; instead, the purified water will be added to the City's recycled water system used for irrigation and industrial purposes.

[INSERT QUOTE FROM ATTENDEE]

Since opening in June 2011, more than [ATTENDANCE NUMBER] people have toured the facility. The [ORGANIZATION] is one of many groups that have toured the facility to better understand the science of water purification. On the tour, guests become familiar with the Demonstration Project and what role the Advanced Water Purification Facility plays in this testing phase. Following an introductory presentation, tour participants take a walking tour through the facility to view the water purification technology equipment up close and hear more about how the purification process works. At the end of the tour, guests see for themselves the purity of the water produced at the facility and compare samples of purified, recycled and tap water.

To register for a tour of the Water Purification Demonstration Project, visit the project website at **www.purewatersd.org/tours.shtml**. For a presentation to your organization, email **purewatersd@sandiego.gov** or call **(619) 533-6638**.

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Advertisement: Open for Tours (English)

This advertisement was published in the Voice & Viewpoint (June 2011), Giving Back Magazine (July 2011), San Diego Monitor (July 2011), Filipino Press (August 2011) and We Chinese in America Weekend (August 2011).

Water Purification | Demonstration Project

OPEN *for Tours*

The City of San Diego opens the doors this summer to its Advanced Water Purification Facility at the North City Water Reclamation Plant. Join us for a tour of the facility and see how this technology can transform wastewater into one of the purest sources of water in San Diego.

Sign Up Today:

- Visit www.purewatersd.org/tours.shtml to register for a tour.
- Email purewatersd@sandiego.gov or call (619) 533-6638 to schedule a presentation for your organization.

THE CITY OF SAN DIEGO

City of San Diego
PUBLIC UTILITIES
Water & Wastewater

Advertisement: Open for Tours (Spanish)

This advertisement was published in El Latino (July 2011) and La Prensa (July 2011).

Water Purification | Demonstration Project

ABIERTO *para Recorridos*

Este verano la ciudad de San Diego abrira las puertas de las instalaciones del Tratamiento Avanzado de Purificacion de Agua(AWP) en la planta de tratamiento North City Water Reclamation Plant. Acompañanos a recorrer las instalaciones y ver como esta tecnologia puede transformar aguas negras en una de las fuentes de agua mas pura en San Diego.

Apuntense Hoy:

- **Visite www.purewatersd.org para registrarse a un recorrido.**
- **Mande un correo electronico a purewatersd@sandiego.gov o llame al (619) 533-6638 para programar una presentacion a su organizacion.**

THE CITY OF SAN DIEGO

City of San Diego
PUBLIC UTILITIES
Water & Wastewater

Advertisement: Top 5 Reasons to Tour

This advertisement was published in the Voice of San Diego monthly publication (July 2012).

Top 5 Reasons to Tour San Diego's Water Purification Facility

1. **It's fun**
2. **It's free**
3. **It's educational**
4. **It makes you think**
5. **It makes you say "wow"**

Join the thousands who've already seen how wastewater is transformed into purified water.

Water Purification | Demonstration Project

Visit PureWaterSD.org for reservations.

Advertisements: Purely Amazing and Spiderman

The “Purely Amazing” advertisement was featured in two Voice of San Diego e-blasts (July 2012). The Spiderman three-panel rotating graphics advertisment was featured on the Voice of San Diego website (June 2012).

Email Advertisement

Web Advertisement

Three-panel rotating graphics

Media Coverage List (2010-2012)

The following document lists all of the known media coverage of the Water Purification Demonstration Project from 2010 to 2012.

Water Purification Demonstration Project
Media Coverage (2010-2012)

Category	Article Title	Publication Name/ Organizational Affiliation	Date of Coverage
Online	Public Comment: Sewage Recycling	Voice of San Diego	1/21/2010
TV Online	Toilet to Tap Back on the Drawing Board	San Diego 6 News	1/26/2010
Newspaper	Coalition Has Hand in Water Recycling Plan, Council Advances Recycling Project	San Diego Union Tribune	1/27/2010
Online	Toilet-to-Tap Campaign Approved by Council	San Diego News Room	1/28/2010
Online	City Water Usage Up	Voice of San Diego	2/9/2010
Online	Mayor Supports Sewage Recycling Pilot	Voice of San Diego	2/11/2010
Online	Let's Use the Water We Have	San Diego News Room	3/9/2010
Online	The Future of Indirect Potable Reuse	San Diego News Network	3/10/2010
Online	A Guide to Purified Sewage	Voice of San Diego	4/26/2010
Blog	A Primer/Refresher on San Diego's Water Purification Demonstration Project	GrokSurf's San Diego	7/7/2010
Magazine	Council Approves Wastewater Treatment Project	San Diego Metropolitan Magazine	7/28/2010
Radio	Political Analysis: The Legacy of Toilet-to-Tap	KPBS	8/4/2010
Radio	What Role Could Water Reclamation Play in San Diego's Future?	KPBS	8/5/2010
Online	San Diego's Progress with Water Reuse	San Diego News Room	8/6/2010
Online	San Diego to Test Alternative Water Source	San Diego News Room	8/20/2010
Online	Fact Check: The Real Price of Purified Sewage	Voice of San Diego	9/16/2010
Blog	Should San Diego Ozonate its Wastewater for IPR?	GrokSurf's San Diego	10/5/2010
Newspaper	New Source of Drinking Water Hinges on Pilot Project	San Diego Union Tribune	10/11/2010
Blog	"Toilet to Tap"	3-Waters	1/6/2011
Newspaper	City Engineers Tell La Jollans about Water Purification	La Jolla Light	1/12/2011
Newspaper	The Yuck Factor: Get Over It	San Diego Union Tribune	1/23/2011
Blog	La Jolla Residents Get a Distilled Water Lesson	Distilled Water Company	1/24/2011
Newspaper	From Toilets to Tap	USA Today	3/3/2011
Blog	From Wastewater to Drinking Water	State of the Planet/The Earth Institute	4/4/2011
Newspaper	Wastewater Getting New Life Across the County	San Diego Union Tribune	5/15/2011
Online	The Emotion of Wastewater	The Huffington Post	6/12/2011
Online	Will San Diego's Mayor Drink Purified Sewage?	Voice of San Diego	6/30/2011
TV Online	Year Long Study Will Determine if Wastewater Can Be Properly Treated for Drinking	10 News	6/30/2011
TV Online	Can San Diego Go From Toilet to Tap?	NBC News	6/30/2011
Online	Mayor Kicks Off Pilot Project to Test Possible New Source of Drinking Water	SanDiego.gov	6/30/2011
Online	Water Reliability Coalition Supports Water Purification Pilot Project	San Diego Coastkeeper	6/30/2011
Online	City Tests System of Turning Wastewater into Drinking Water	San Diego News Room	6/30/2011
Online	City to Test System that Makes Wastewater Drinkable	10 News	6/30/2011
Newspaper	San Diego Launches Landmark Water Project	San Diego Union Tribune	6/30/2011
Blog	San Diego Reuse Water Purification Plant Opens	OB Rag	7/1/2011
Newsletter		Emerald News	7/1/2011
Newspaper	Purify "Brown" Water to Solve SD Water Crisis	Daily Aztec/San Diego State University	7/10/2011
Newspaper	City Gives Water Reclamation Plant Tours	San Diego Metropolitan Magazine	7/20/2011

Water Purification Demonstration Project
Media Coverage (2010-2012)

Category	Article Title	Publication Name/ Organizational Affiliation	Date of Coverage
Newspaper	City offering tours of water purification plant	La Jolla Light	7/25/2011
Newsletter	Utility Briefs	AWWA Streamlines	7/26/2011
Newsletter	City of San Diego Speculates on Future of New Source of Local Water	ACWA News	7/29/2011
Online	Future of Water on Public Display for San Diego's Water Purification Demonstration Project	WaterTechOnline.com	7/29/2011
Newsletter	San Diego's Pro-active Approach-Tests New Water Facility	SCAP Monthly Update	8/1/2011
Blog	Join us when we tour San Diego's cutting-edge new IPR Demonstration Project	Know Your h2o	8/2/2011
Online	Fact Check: Cleaner Water than Orange County?	Voice of San Diego	8/2/2011
Online	Public Invited to Tour City's Water Purification Demonstration Project	WaterTechOnline.com	8/3/2011
Radio	Recycling Water: A Clear Solution for San Diego	KPBS	8/3/2011
Online	San Diego IPR open to public tours	Desalination and Water Reuse Quarterly	8/4/2011
Blog	Water Recycling: Creating Water So Pure You Can Drink It	San Diego Coastkeeper	8/6/2011
Blog	Breaking the Taboo on "Toilet to Tap"	Ecocentric/TIME Magazine	8/10/2011
Blog	San Diego, Drink It In…	CleanTech Insights	8/26/2011
Blog	Indirect Potable Reuse: It Works!	San Diego Coastkeeper	9/1/2011
Online	Local Experts Discuss Region's Local Water Supply	San Diego News Room	9/14/2011
Online	City's Water Purification Demonstration Project Honored with National Award	SanDiego.gov	9/16/2011
Blog	San Diego's Water Purification Demonstration Project Wins Award	San Diego Surfrider Foundation	9/19/2011
Newsletter	City's Water Purification Demo Project Honored with National Award	San Diego Chapter newsletter/WateReuse Association	10/1/2011
Newspaper	Whets Public's Appetite for More Information	Mission Times Courier	10/7/2011
Online	City Opens Doors to Water Purification Demonstration Project	WaterWorld	10/13/2011
Newspaper	San Diego Frames Water Policy for the Future	San Diego Union Tribune	10/19/2011
Newspaper	A Big Win in the War for Water	San Diego Union Tribune	12/9/2011
Newspaper	City Endorses Plan to Convert Sewage into Drinking Water	North County Times	12/10/2011
Newspaper	Future of Water on Display at San Diego's Water Purification Demonstration Project	U.S. Mayor	12/19/2011
Online	San Diego's Advanced Treatment Facility Viewable on YouTube	Desalination and Water Reuse Quarterly	12/30/2011
Newspaper	Water Recycling Key to U.S. Future	San Diego Union Tribune	1/10/2012
Newsletter	SOS Toastmasters Tours City's Water Purification Demonstration Project	SOS Toastmasters	1/15/2012
Newspaper	Where Toilet to Tap Fears circle the drain	San Diego Union Tribune	1/21/2012
Newspaper	As 'Yuck Factor' Subsides, Treated Wastewater Flows From Taps	New York Times	2/9/2012
Blog	Water Recycling Makes National News	E-Bulletin/California Water Environment Assoc.	2/13/2012
Blog	Spacewater Recycling: Getting Around the Yuck Factor	Water Management:	2/23/2012
Blog	San Diego's Indirect Potable Reuse Proposal Without the Hype	GrokSurf's San Diego	2/27/2012
Blog	Ultra-purified Recycled Water Cleaner Than Imported Water	San Diego Coastkeeper	2/27/2012
Newspaper	Future of Water on Public Display for San Diego's Water Purification Demonstration Project	Mission Valley News/Scoop San Diego	2/27/2012
Blog	San Diego's Indirect Potable Reuse Proposal Without the Hype	Aquafornia.com	2/28/2012
Online	City Officials Put Future of Water on Display at SD facility	SDnews.com	2/29/2012
Blog	San Diego Uses Advance Oxidation to Recycle Wastewater	Spartanwatertreatment.com	2/29/2012

Water Purification Demonstration Project
Media Coverage (2010-2012)

Category	Article Title	Publication Name/ Organizational Affiliation	Date of Coverage
Newspaper	City Officials Put Future of Water on Display at SD facility	Beach and Bay Press	3/1/2012
Newsletter	Future of Water on Display for San Diego's Water Purification Demonstration Project	San Diego Chapter newsletter/WateReuse Association	3/1/2012
Newsletter	Future of Water on Display for San Diego's Water Purification Demonstration Project	Alpine community newsletter	3/5/2012
Online	Students Tour City Water Purification Facility	Francis Parker School website	3/5/2012
Newsletter	[Photo with Caption]	District 4 newsletter	3/21/2012
Blog	Future of Water on Display for San Diego's Water Purification Demonstration Project	My Clean Water Act	3/28/2012
Blog	Future of Water on Display for San Diego's Water Purification Demonstration Project	I Love a Clean San Diego	3/28/2012
Newsletter	Recycled Water is Coming to San Diego	District 6 newsletter	4/1/2012
Newspaper	Taking the Waste Out of Wastewater	New York Times/Sunday Review	4/21/2012
Radio	Mares: Recycled Water	Vermont Public Radio/Commentary Series	4/23/2012
Newspaper	City's Water Purification Demonstration Project Celebrates Drinking Water Week with Open House Tours	Scoop San Diego	5/4/2012
Online	Sewage Plan Envisions Massive Expansion of Wastewater Recycling	Voice of San Diego	5/21/2012
Newspaper	Boosting Reservoirs with Purified Wastewater?	San Diego Union Tribune	5/22/2012
Online	Final Draft of San Diego Water Reuse Scheme Published	Desalination and Water Reuse Quarterly	5/25/2012
Newspaper	Bill Seeks to Streamline Recycled Water Regulations	San Diego Union Tribune	5/27/2012
Blog	San Diego: Improving the Flow to use recycled wastewater	Aquafornia.com	5/28/2012
TV	Reusable Water Not Cheaper: Report	NBC San Diego	5/29/2012
Online	Purifying Sewage: Where the Mayoral Candidates Stand	Voice of San Diego	5/29/2012
Newspaper	Recycling Sewage to Drinking Water Could Save City of San Diego Money: Study	North County Times	6/2/2012
Newspaper	Toilet to Tap Helps Conservation Efforts	San Diego Union Tribune	7/14/2012
Online	In San Diego, Recycled Water Quickly Wins Fans (And They Don’t Even Have It Yet)	National Geographic Daily News	8/30/2012
TV	Wade in the Water	Larry Himmel's In the Neighborhood/CBS8	8/6/2012
Newsletter	San Diego's Water Purification Demonstration Project Showcases Future of Water, Offers Tours	Let's Talk Plants!/San Diego Horticultural Society	8/6/2012
Newsletter	Tour of the Water Purification Facility	Torrey Pines Ski Club newsletter	9/1/2012
Newspaper	San Diego Monitor News' Business Bootcamp Group Visits AWP Facility	San Diego Monitor	10/5/2012
Newsletter	Take a Pure Tour	Waste No Water Newsletter/City of San Diego Water Conservation	Fall 2012
Journal	Changing Public Perception About Water Purification	AWWA Opflow	12/1/2012
Newsletter	Water Purification Tour	Scripps Ranch Newsletter	12/1/2012
Radio	San Diego Seeks a Swifter Current for Water Recycling	KPBS	12/10/2012

Media Clips

A collection of media clips about the Demonstration Project can be found online at www.sandiego.gov/water/waterreuse/demo/articles.shtml or by visiting www.purewatersd.org and clicking on the “News and Publications” link.

Appendix H: Public Outreach and Education

Section 6: Speakers Bureau

Speakers bureau PowerPoint presentation **2**
Speakers bureau flier **16**
Speakers bureau completed presentations **18**

Speakers Bureau PowerPoint Presentation

Slides from the regular presentation are included. Other variations of the presentation include a video and a shortened version.

Water Purification Demonstration Project

www.purewatersd.org

What you should know…

- San Diego needs to develop local, reliable sources of water.
- The Water Purification Demonstration Project is examining the use of advanced purified water.
- The purified water goes through multiple advanced treatment steps.
- No purified water is added to the drinking water system during the Demonstration Project.

www.purewatersd.org

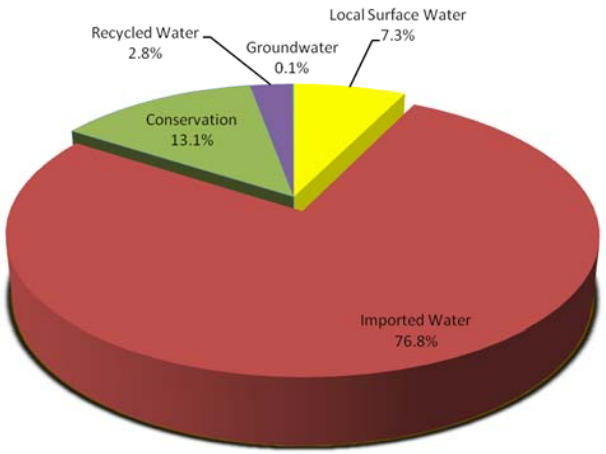
Water Supply Challenges

- Rising costs of imported water
- Pumping restrictions
- Population growth
- Earthquakes

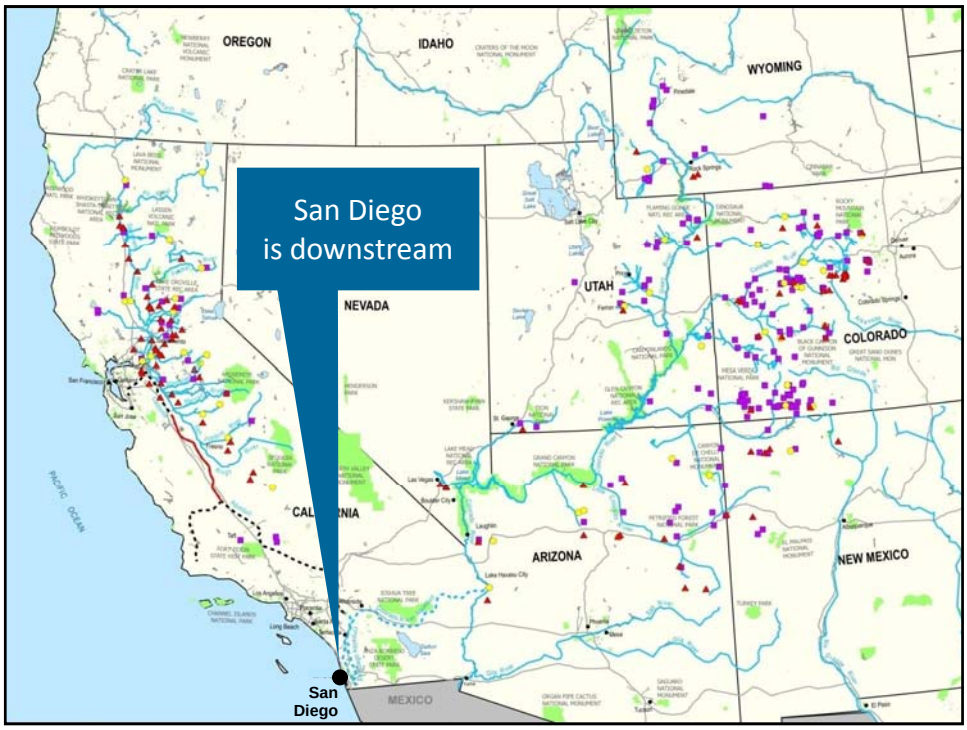
SAN DIEGANS WASTE NO WATER ALL DAY. EVERY DAY.

www.purewatersd.org

WATER SUPPLY: FY 2012
SEVEN YEAR HISTORICAL AVERAGE



California Water Projects
Federal Water Projects
Central Valley Project
Coachella Canal
All American Canal
State Water Projects
Local Water Projects
Mokelumne Aqueduct
Hetch Hetchy Aqueduct
Los Angeles Aqueduct
Colorado River Aqueduct
Bay-Delta
Redding
Sacramento
San Francisco
Fresno
Los Angeles
San Diego
Colorado River


San Diego is downstream
OREGON
IDAHO
WYOMING
NEVADA
UTAH
COLORADO
ARIZONA
NEW MEXICO
MEXICO
PACIFIC OCEAN
San Diego

What is being done…

- Water Conservation
- Groundwater Development
- Recycled Water
- The Water Reuse Program

www.purewatersd.org

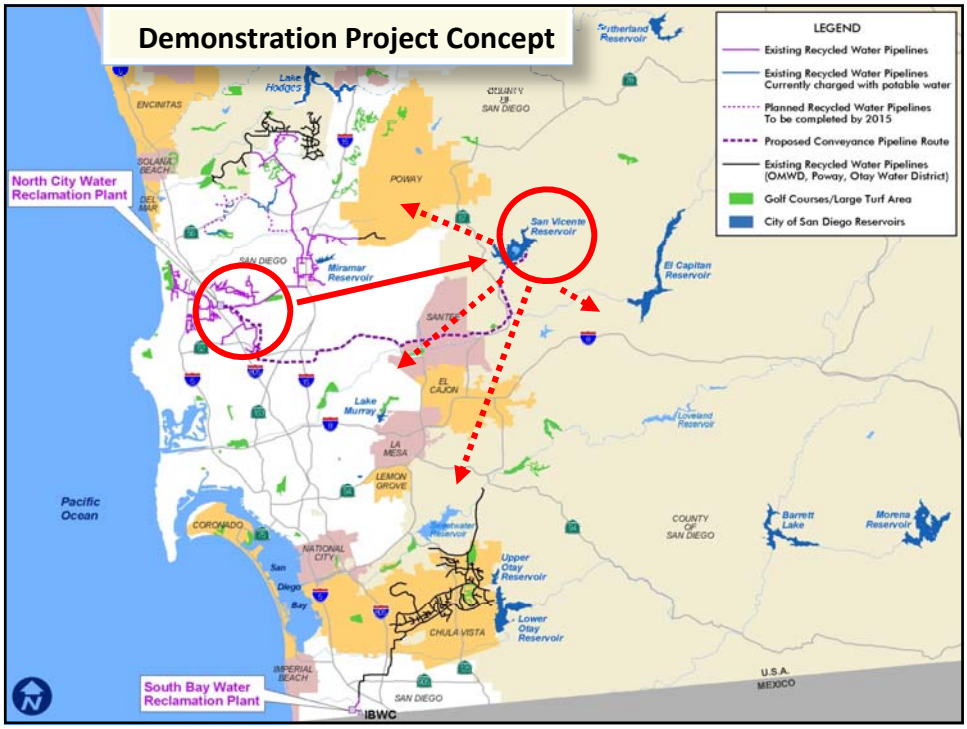
Project Components

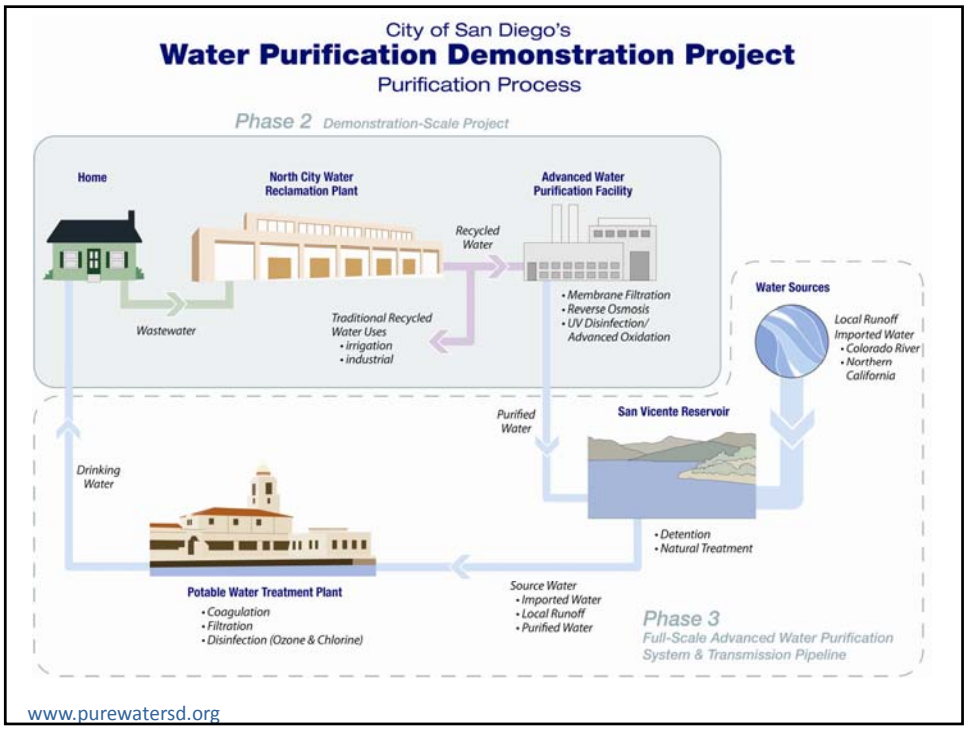
- Operate 1 MGD facility
- San Vicente Reservoir study
- Define regulatory requirements
- Conduct energy and economic analysis
- Public education and outreach

Outcomes

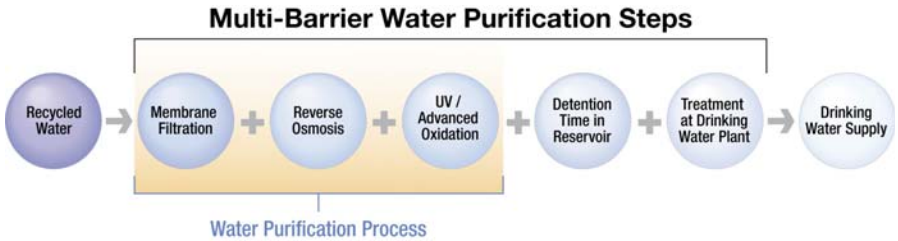
- Validate treatment process
- Gain regulatory approval
- Evaluate cost
- Public acceptance

www.purewatersd.org


Demonstration Project Concept
LEGEND
Existing Recycled Water Pipelines
Existing Recycled Water Pipelines Currently charged with potable water
Planned Recycled Water Pipelines To be completed by 2015
Proposed Conveyance Pipeline Route
Existing Recycled Water Pipelines (OMWD, Poway, Otay Water District)
Golf Courses/Large Turf Area
City of San Diego Reservoirs
North City Water Reclamation Plant
South Bay Water Reclamation Plant
Pacific Ocean
Lake Hodges
ENCINITAS
SOLANA BEACH
DEL MAR
POWAY
SAN DIEGO
Miramar Reservoir
San Vicente Reservoir
El Capitan Reservoir
Lake Murray
EL CAJON
LA MESA
LEMON GROVE
CORONADO
NATIONAL CITY
San Diego Bay
Upper Otay Reservoir
Lower Otay Reservoir
CHULA VISTA
IMPERIAL BEACH
IBWC
Barrett Lake
Morena Reservoir
U.S.A.
MEXICO


City of San Diego's
Water Purification Demonstration Project
Purification Process
Phase 2 Demonstration-Scale Project
Home
North City Water Reclamation Plant
Advanced Water Purification Facility
Recycled Water
Wastewater
Traditional Recycled Water Uses
• Irrigation
• Industrial
• Membrane Filtration
• Reverse Osmosis
• UV Disinfection/ Advanced Oxidation
Water Sources
Local Runoff
Imported Water
• Colorado River
• Northern California
Purified Water
San Vicente Reservoir
Drinking Water
• Detention
• Natural Treatment
Potable Water Treatment Plant
• Coagulation
• Filtration
• Disinfection (Ozone & Chlorine)
Source Water
• Imported Water
• Local Runoff
• Purified Water
Phase 3
Full-Scale Advanced Water Purification System & Transmission Pipeline
www.purewatersd.org

Water Purification Process

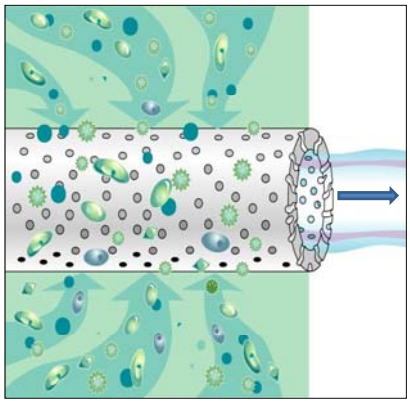


Microfiltration & Ultrafiltration

Reverse Osmosis

Ultraviolet Light / Hydrogen Peroxide

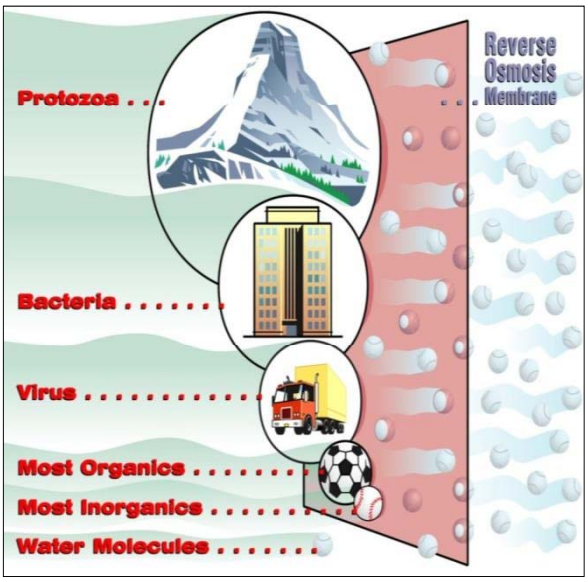
Membrane-filtration: Step One



- Hollow fiber with holes in the sides
- Used to make baby food, purify medicines, fruit juices and more
- Excellent pre-filter before reverse osmosis

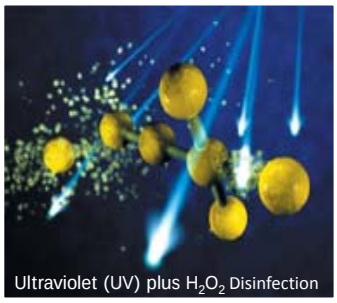
www.purewatersd.org

Reverse Osmosis: Step Two



- Same technology used by bottled water companies
- Forces water under high pressure through sheets of plastic membrane
- Demineralizes and purifies water

Ultraviolet Light plus H_2O_2: Step Three


Ultraviolet (UV) plus H_2O_2 Disinfection

- High-intensity light and hydrogen peroxide
- Creates advanced oxidation reaction, essentially destroys anything in the water

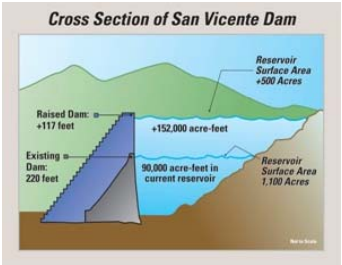
www.purewatersd.org

Water Purification: a proven technology

Upper Occoquan Service Authority

Leader in Water Reclamation and Reuse

San Vicente Limnology and Reservoir Detention Study



- Dam to be raised 117 feet
- Currently 90,000 acre-feet
- After dam raise 242,000 acre-feet
- Construction duration 2009 – 2013
- Augmentation would improve water quality

Project Benefits

- Local and sustainable supply of drinking water
- Increased use of recycled water
- Decreased dependence on imported water
- Less energy than imported water
- Improved quality of reservoir water
- Positive impact on environment

www.purewatersd.org

Independent Advisory Panel

Panel included:

- Ph.D's (9)
- Experts in water quality & treatment technology
- Experts in regulatory issues
- Local stakeholders
- O. C. Groundwater Replenishment System management

Public Outreach & Education

- Speakers Bureau
- Community Events
- Facility Tours

www.purewatersd.org

Open for Tours - A Site to See

Register online at www.PureWaterSD.org

Final Report

- Results of the Demonstration Project will be available in a comprehensive report.
- City Council will decide whether to accept the report, which could pave the way for the development of a full-scale water purification project in San Diego.

Water Quality Results

- Exceptional overall water quality, met all project treatment goals
- Purified water met all drinking water standards
- Equipment at each step in the treatment process is performing properly

WRC
WATER RELIABILITY COALITION

WWW.SDWATERSUPPLY.COM

Friends of Infrastructure

- BIOCOM
- Building Industry Association of San Diego
- Building Owners and Managers Association, San Diego Chapter
- Citizens Coordinate for Century 3
- Coastal Environmental Rights Foundation
- Empower San Diego
- Endangered Habitats League
- Environmental Health Coalition
- Friends of Infrastructure
- Industrial Environmental Association
- National Association of Industrial and Office Properties
- San Diego and Imperial Counties Labor Council
- San Diego Audubon Society
- San Diego Regional Economic Development Corporation
- San Diego Coastkeeper
- San Diego County Apartment Association
- San Diego County Taxpayers Association
- San Diego Regional Chamber of Commerce
- San Diego River Park Foundation
- Surfrider Foundation, San Diego Chapter
- Sustainability Alliance of Southern California
- Utility Consumers' Action Network

Turning the Tide

2008...

The San Diego Union-Tribune.

UNION-TRIBUNE EDITORIAL

No toilet-to-tap

Special water rate hike unwarranted

September 8, 2008

High gasoline prices, rising food costs and upwardly adjustable mortgage payments may be sapping your paycheck, but they have not deterred the City Council from voting today on a special water rate hike for the infamous toilet-to-tap scheme.

At issue is an untested process to take sewage effluent, treat it heavily and then dump it into the San Vicente Reservoir, the source of much of San Diego's drinking water. This would mean, quite literally, taking your toilet water and returning it to your tap. Yet advocates of the plan abhor the apt toilet-to-tap sobriquet, preferring instead to call it "indirect potable reuse."

But no matter what euphemism you employ, the project is a colossal waste of ratepayer dollars and, just as important, fraught with serious public health concerns.

Over Mayor Jerry Sanders' well-justified veto, the City Council is rushing head long to build a $12 million toilet-to-tap demonstration plant that may or may not meet the approval of the California Department of Health, which must sign off on it. Toward that end, the City Council will vote today on a special water rate increase of 2.3

...2011

Edward R. Moss, Publisher
Jeff Light, Editor

THE SAN DIEGO UT UNION-TRIBUNE

EDITORIAL

THE YUCK FACTOR: GET OVER IT

As San Diego sprawls above 3.5 million people countywide in just 10 more years, and a projected 4.4 million by 2050, the greatest threat to our economic health and quality of life is an uncertain supply of water. This urban cul-de-sac at the bottom of California is at the tail end of the pipelines that deliver 80 percent or more of our water. That means we are heavily dependent on the mercy of others, and that is not comforting.

San Diegans have more than proved themselves willing to conserve; the city uses less water in real terms today than it did with a smaller population 20 years ago. That will continue to be a crucial part of the region's water strategy for decades. So, too, will be the development of new sources, such as desalination. And, of course, political battles to rescue the Sacramento-San Joaquin Delta from environmental collapse in order to keep Northern California water flowing south will be unremitting.

But the reality is

scaping and industrial processes, then purify and scrub it some more to nearly distilled water standards. The demonstration project is to produce 1 million gallons a day for a year, during which it will be continually monitored and studied, but not distributed for public consumption. If it proves safe and affordable, the city could then consider its expansion to a permanent plant that could produce up to 16 million gallons a day, which would be piped to San Vicente Reservoir.

Frankly, there is not that much to demonstrate at least scientifically.

Similar technology is already in large use in Orange County, which produces 70 million gallons a day of purified wastewater and injects it into the county's groundwater basin.

Information

Visit: www.purewatersd.org

Email: purewatersd@sandiego.gov

Call: (619) 533-7572

Speakers Bureau Flier

Schedule your presentation today!

City of San Diego
PUBLIC UTILITIES
Water & Wastewater

City of San Diego

Water Purification Demonstration Project

Did you know?

The City of San Diego imports approximately 85 to 90 percent of its water supply and recent court ordered restrictions have reduced the amount of water that reaches San Diego.

What is being done?

San Diego's Water Purification Demonstration Project is examining the use of advanced water purification technology on high quality recycled wastewater to provide a safe, local and sustainable water supply for the future.

We would like to make a presentation to your group

The presentation will include:

- San Diego's need for a local, reliable water supply
- The purpose of the Water Purification Demonstration Project
- The advanced water purification process
- The potential use of advanced purified water for Reservoir Augmentation in the future

Recycled Wastewater

Please contact the Speakers Bureau Program to schedule a presentation

City of San Diego
Public Utilities Department

Speakers Bureau Program

Phone: (619) 533-6638

Email: purewatersd@sandiego.gov

Visit **www.purewatersd.org** for more information.

Speakers Bureau Completed Presentations
(March 2010 – December 2012)

A list of the groups that received Demonstration Project speakers bureau presentations.

WATER PURIFICATION DEMONSTRATION PROJECT
SPEAKERS BUREAU (MARCH 2010 – DECEMBER 2012)

TOTAL COMPLETED PRESENTATIONS	**132**
(Through December 2012)	

COMPLETED PRESENTATIONS

WateReuse Association (CA Section)	March 9, 2010
Independent Rates Oversight Committee	May 10, 2010
American Water Works Association	June 21, 2010
Industrial Environmental Association	July 8, 2010
U.S. Bureau of Reclamation	July 13, 2010
SD County Water Authority Capital Improvement Program	July 13, 2010
Tierrasanta Community Council	July 21, 2010
Johnson & Johnson	July 28, 2010
Mt. Zion Baptist Church, Missionary Department	August 4, 2010
San Diego Metro Wastewater Joint Powers Authority	August 5, 2010
Otay Mesa Property Owners	August 5, 2010
Fox Canyon Neighborhood Association	August 10, 2010
Otay Mesa Nestor Community Planning Group	August 11, 2020
Greater Golden Hill Planning Group	August 11, 2010
SD County Water Authority General Managers	August 17, 2010
Otay Mesa Community Planning Group	August 18, 2010
Pacific Beach Town Council	August 18, 2010
Catfish Club	August 20, 2010
Serra Mesa Community Council	August 25, 2010
SD County Water Authority Board	August 26, 2010
San Carlos Area Council	September 1, 2010
Rancho De Los Penasquitos Town Council	September 2, 2010
Normal Heights Community Planning Group	September 7, 2010
Rancho De Los Penasquitos Planning Board	September 8, 2010
Serra Mesa Recreation Council	September 8, 2010
Tierrasanta Recreation Council	September 9, 2010
La Jolla Town Council	September 9, 2010
Redwood Village Community Council	September 13, 2010
Allied Gardens Recreation Council	September 13, 2010
Lake Murray-San Carlos Recreation Council	September 15, 2010
SD County Medical Society	September 15, 2010

WATER PURIFICATION DEMONSTRATION PROJECT
SPEAKERS BUREAU (MARCH 2010 – DECEMBER 2012)

Allied Gardens Kiwanis Club	September 16, 2010
BOMA San Diego, Government Affairs Committee	September 20, 2010
Mission Valley Community Council	September 21, 2010
San Diego Community Planners Committee	September 28, 2010
Public Utilities Executive Team	September 29, 2010
SD Coastkeeper's Legislative Summit	September 30, 2010
City Heights Area Planning Committee	October 4, 2010
Miramar Ranch North Planning Committee	October 5, 2010
Ocean Beach Planning Board	October 6, 2010
City of San Diego Public Utilities Department, Employee Services and Internal Controls	October 7, 2010
East Village Business Improvement District	October 7, 2010
Southeastern San Diego Planning Group	October 11, 2010
University Community Planning Group	October 12, 2010
North Bay Community Planning Group	October 20, 2010
Peninsula Lions Club	October 20, 2010
Rancho Bernardo Community Planning Group	October 21, 2010
East Village Community Action Network	October 21, 2010
Ocean Beach Community Development Corporation	October 26, 2010
California Water Environment Association	October 28, 2010
South County Economic Development Council	October 29, 2010
National Association for the Advancement of Colored People	November 4, 2010
Clairemont Town Council	November 4, 2010
Mission Bay Park Committee	November 9, 2010
La Jolla Shores Association	November 10, 2010
Rolando Community Council	November 16, 2010
Olivenhain Municipal Water District	November 17, 2010
Del Mar Rotary	November 18, 2010
San Diego Metro Wastewater Joint Powers Authority	December 2, 2010
U.S. Environmental Protection Agency/ Australian Government Representatives	December 6, 2010
Mission Valley Planning Group	January 5, 2011
La Jolla Community Planning Association	January 6, 2011
Pacific Beach Kiwanis Club	January 13, 2011
El Cerrito Community Council	January 20, 2011

WATER PURIFICATION DEMONSTRATION PROJECT
SPEAKERS BUREAU (MARCH 2010 – DECEMBER 2012)

Customer Care Solutions	January 25, 2011
Del Cerro Action Council	January 27, 2011
Barrio Logan Project Area Committee	February 16, 2011
Point Loma High School	February 25, 2011
SD County Water Authority, Conservation Action Committee	March 14, 2011
Uptown Planners	April 5, 2011
Blacks in Government	April 6, 2011
Girl Scouts Eco-Action Workshop	April 9, 2011
Black American Political Action Committee	April 16, 2011
American Society of Civil Engineers, Pipeline Group	April 21, 2011
Point Loma Rotary	April 29, 2011
Fairmount Park Neighborhood Association	May 19, 2011
Point Loma Kiwanis Club	June 7, 2011
Allied Garden Optimist Club	June 9, 2011
Del Mar Mesa Planning Group	June 9, 2011
Sunrise Optimist Club	June 14, 2011
San Ysidro Planning Group	June 20, 2011
La Jolla Kiwanis Club	July 8, 2011
Elementary Institute of Science	July 20, 2011
Ramona Kiwanis Club	August 6, 2011
Del Mar/Solana Beach Optimist Club	August 17, 2011
Ocean Beach Town Council	August 24, 2011
City of San Diego Engineering and Program Management	August 30, 2011
Torrey Pines Rotary	August 31, 2011
La Jolla Golden Triangle Rotary	September 2, 2011
Jamacha Community Council	September 12, 2011
San Diego County Water Authority "Water Talks"	September 13, 2011
Bankers Hill Neighborhood Association	September 19, 2011
Scripps Institute of Oceanography Symposium	September 20, 2011
ACWA Continuing Legal Education Workshop	September 22, 2011
El Cajon Lions Club	October 3, 2011
6th Annual Joint ACWA Regions Fall Event	October 19, 2011
SD County Water Authority Board	December 8, 2011
CONVAIR/220 Amateur Radio Club	December 14, 2011
SDSU, College of Extended Studies	January 6, 2012

WATER PURIFICATION DEMONSTRATION PROJECT
SPEAKERS BUREAU (MARCH 2010 – DECEMBER 2012)

American Society of Civil Engineers, General Members	January 24, 2012
St. Therese Academy, 6th Grade Class	March 14, 2012
Mission Lions Club	March 19, 2012
Assembly Water Parks & Wildlife Committee Hearing	March 20, 2012
Sweetwater Valley Civic Association	April 4, 2012
San Diego Therapeutic Recreation Services	April 6, 2012
University Heights Community Association	May 3, 2012
U.S. International Boundary and Water Commission Citizen's Forum	May 10, 2012
City Heights Town Council	June 5, 2012
Coalition of Neighborhood Councils	June 11, 2012
Emerald Hills Town Council	June 12, 2012
Skyline-Paradise Hills Community Planning Committee	July 10, 2012
Industrial Environmental Association, Water Committee	July 12, 2012
Coalition of Neighborhood Councils	July 23, 2012
Broadway Heights Community Council	July 26, 2012
San Diego Green Building Council	August 15, 2012
Mira Mesa Community Planning Group	August 20, 2012
Eco Rotary Club Solana Beach	August 30, 2012
African American Genealogist Research Group	September 8, 2012
The Palavra Tree	September 11, 2012
San Diego County Water Authority, Water Planning Committee	September 27, 2012
Rancho Bernardo Recreation Council	October 3, 2012
Carmel Mountain Ranch Community Committee	October 10, 2012
Chollas View Neighborhood Council	October 23, 2012
Annual Environmental Summit Conference	October 23, 2012
The Southern California Water Dialogue	October 24, 2012
La Jolla Village Community Council	October 24, 2012
Skyline Hills Recreation Council	October 25, 2012
UCSD Occupational/Environmental Health Class	October 30, 2012
San Pasqual/Lake Hodges Planning Group	November 1, 2012
Cuyamaca College Water Resources Management Class	November 26, 2012
International Right of Way Association	November 28, 2012
Madison High School Engineering Classes	December 4, 2012

Appendix H: Public Outreach and Education

Section 7: Internal Department Communications

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December 2012 33

Pipeline Newsletter Article: December 2010

A Look at New, Local Options for Water

Today, the majority of San Diego's water supply comes from imported sources that are becoming more expensive and less reliable. In 2004, the City launched a three-phased Water Reuse Program (Program) to address the water supply crisis by exploring local solutions for future water supply reliability

Phase one of the Program was the City's 2005 Water Reuse Study (Study). The Study provided a comprehensive evaluation of all viable options to maximize the use of recycled water produced by the City's two water reclamation plants. In addition, the Study analyzed and researched the health effects of various water reuse options. The Study concluded that reservoir augmentation at the City's San Vicente Reservoir is the preferred option for maximizing the use of the City's recycled water supply. Reservoir augmentation is a multi-step process that includes sending the advanced purified water to a reservoir to blend with existing water supplies and then treating the blended water again to be distributed as drinking water. A broad-based group of City residents participated in an American Assembly process to review the Study findings. The American Assembly reached the same conclusion that reservoir augmentation was the most viable use of highly treated recycled water for San Diego, and that it could provide a local, reliable supply of water crucial to the City's future.

Based on the final draft report that summarized the Study results, the City Council commissioned the second phase of the Program: the Water Purification Demonstration Project (Demonstration Project). The purpose of this phase is to further explore the option of reservoir augmentation by demonstrating the project on a small scale. The Demonstration Project, which is currently underway, is examining the use of advanced water purification technology to purify highly treated recycled wastewater that could potentially be added to the "raw" water (water prior to being treated) in a local reservoir. No purified water will be sent to the reservoir during the demonstration phase.

An Advanced Water Purification Facility is being built and will operate for about one year to produce approximately 1 million gallons of purified water per day A study of the San Vicente Reservoir is also being conducted to test the key functions of reservoir augmentation and an independent advisory panel of experts is providing oversight on project research. The research will determine if the purification system satisfies all water quality, safety and regulatory requirements of the California Department of Public Health, and what will happen if the purified water is added to the reservoir. The Demonstration Project is scheduled to conclude at the end of 2012.

If the Demonstration Project meets regulatory requirements and provides evidence that a full-scale project would be viable, the City may implement a full-scale reservoir augmentation project. This would potentially be the third and final phase of the Water Reuse Program. In this potential phase, the advanced treated water would be added to the San Vicente Reservoir. The blended water from the reservoir would go to a drinking water treatment plant where it would be treated and become part of the City's drinking water supply.

A major component of the Demonstration Project is an extensive education and outreach program, which includes public presentations, the distribution of information at community events and on the project web site, and tours of the Advanced Water Purification Facility once it is completed in the spring of 2011. Visit www.purewatersd.org to view informational materials and to learn more about outreach activities related to the Demonstration Project.

60 Days without a Sewer Overflow and a New Record in Sight

A stretch of 60 consecutive days without a sanitary sewer overflow has Wastewater Collection Division staff on target for another record-breaking year There were no spills in the entire system from early September through November 4, 2010, a mark unequalled in modern WWC history. The total from 2009 was 38 spills, compared to the benchmark year of 2000 when there were 365 spills system-wide. Look for the full story in the January issue of *Pipeline*.

Check Out What's New on Department's Intranet Site

A new feature called "Department Fact Sheets" has been added to the Employee Resources section of the Department Intranet: http://publicutilities. There are fact sheets on the Department, providing an overview of the complex systems we operate and maintain, on rate-related information that may help our customers better understand why rate increases occur and how to keep their bills down, as well as various programs and resources.

Pipeline Newsletter Article: March 2011

Serious About Service

Congratulations to the following Public Utilities Department employees for their continued outstanding service to the City.

Edison Lomibao	35	Darlene Morrow-Truver	30
Ahmad Rashada	25	Jimmy Evans	25
Nancy Garcia	25	Kenneth Stanley	25
Rodrigo Rocha	25	Steven Meyer	25
David Schlickman	25	Maureen Brungardt	25
Danilo Manglicmot	25	James Wiley	25
Richard Hopson	20	Karen Anderson	20
Manuel Delao	20	David Koonce	20
Michael Vogl	20	Freddie Wilkins	20
Carmel Wong	20	Walter Cooke	20
Henrietta Crowder	20	Gregory Diaz	20
Josue Bueno	20	Viviana Castellon	20
David Haney	20	David Venable	20
Albert Gatavasky	20	Gonzalo Gonzales	20
Kristen Ikeda	20	Michael Joslyn	20
Cha Moua	20	Victor Van Wey	20
Andre Macedo	20	Kris Witczak	20
Neil Tran	20	Skyla Wallmann	20
Raul Romero	20	Michael Elling	20
Salvador Sandoval	20	Timothy Labadie	20
Stacy Carey	20	Mitch Dornfeld	20
Curt Deloatch	15	Jacqueline Hall	15
Jennise Milton	15	Harold Harris	15
Virginia Basilan	15	Elvira Baluyot	15
Jose Guerrero	15	Marc Hall	15
Yolanda Reynoso-Martin	15	Margarita Vasquez	15
Zohra Alexander	15	Alejandro Serafico	15
David Marlow	15	Oscar Rafael	15
Reynaldo Sacro	15	Carlos Nunez	15
Nestor Abiva	15	Alberto Ragucos	15
Eddy Mata	15	Rosalito Cataulin	15
Roberto Cuevas	15	David Mills	15
Rae Brown	15	Hector Martinez	15
Navareto Alfaro	15	Laura Gaugh	15
Erica Tilaro	10	Vichai Stanley	10
Norma Quintero	10	Jaime Jacinto Jr	10
Kenneth Hood	10	Danilo Pareja	10
Ellen Hutter	10	Deloris Torres	10
Carmel Honeycutt	10	Maria Carmela De Jesus	10
June Olson	10	Minh Phan	10
Douglas Campbell	10	Greg Schlimme	10
Denise Lopez	10	Dan Daft	10
Mike Daoud	10	Enrique Blanco	10
Li Johnson	10	Irma Bolio	10
Adriano Feit	10	Paul Powell	10
Dellanira Bravo	10	Matthew Tomas	10
William Eames	10		
James Mikulovsky	5	Colette Parker	5
Daniel Sanchez	5	Juan Roman Magdaraog,	5
Reynaldo Novencido	5	Yosef El Talmas	5

USA TODAY

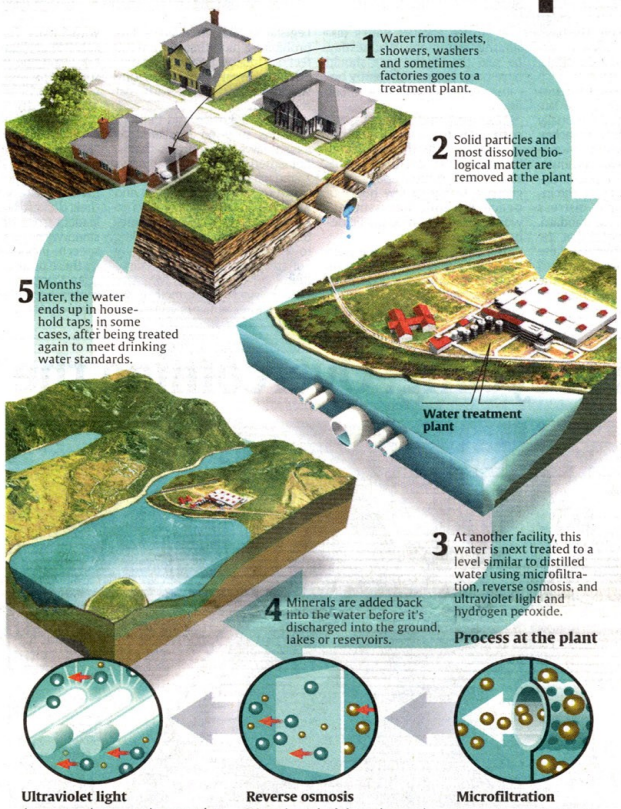
NO. 1 IN THE USA • USATODAY.COM

THURSDAY, MARCH 3, 2011

COVER STORY

From toilets to tap

As water becomes more precious, more drinking water will come from treated sewage. Here's how it works.



Sources: Orange County Water District, PUB (Singapore's water agency), Water technology expert Andrew Benedek, San Diego Public Utilities Department
Reporting by Kathy Chu, USA TODAY; graphic by Karl Gelles, USA TODAY

By Kathy Chu
USA TODAY

SINGAPORE — This island nation is aggressively promoting a solution to the water scarcity that vexes countries worldwide: recycling toilet water to drink.

It's an idea that many people find revolting. But, in Singapore at least, the nearly 5 million residents largely seem to have accepted it as necessary.

"In the past, we had to get water from another country, but what happens if the ties between the two countries are jeopardized?" asks Khaiting Tan, 20, a student at Nanyang Technological University in Singapore. "It's better to be self-reliant."

Once heavily dependent on neighboring Malaysia for its water supply, Singapore is unapologetically recycling sewage and other wastewater in a way that the city-state believes will help make it self-sufficient. The treated water — which Singapore claims is nearly as pure as distilled water — is used largely for industrial purposes, including making semiconductors and powering air-conditioning systems. But increasingly, it's also running out of Singaporeans' taps.

Wastewater has long been recycled for agricultural and industrial purposes. But only a few places in the world, including Singapore, have been bold enough to add it to the drinking water supply. The technology — if it gains wider public acceptance — could change the face of potential water-rights disputes in places such as the Unit-

Please see COVER STORY next page ►

San Diego's and other cities' Indirect Potable Reuse Projects make the front page, above-the-fold coverage in *USA TODAY*. To check out the full article, visit the following link:http://www.usatoday.com/money/industries/environment/2011-03-03-1Apurewater03_CV_N.htm

Pipeline Newsletter Article: April 2011

PIPELINE
PUBLIC UTILITIES MONTHLY UPDATE
April 2011

Message from the Director

Over the last couple of years, we've been taking a hard look at our department, branches, divisions and programs. During these difficult economic times, it is important for every facet of the City to be as efficient as possible. The Public Utilities Department needs to streamline and improve. As a result, we are consistently assessing what we do, why we do it, and whether we can do it better.

It's not an easy process, and some choices have been difficult. However, the end result will be an improved Public Utilities Department that better serves our customers.

Already much has been done. Following the merger of Water and Wastewater, an internal study found many ways we could cut costs and work better together. Some recent changes are described in this issue of Pipeline. We overhauled the Department's Rewards & Recognition program (see page 3), and we're redoing the lobby of MOC to provide better customer service (see page 2). An update to the Bid to Goal program can be found on page 4.

More changes will be coming, and we will do our best to keep you informed on a regular basis. I thank all employees for their hard work and their patience. As always, your ideas on how we can function better and more efficiently are important and welcome. Please make your suggestions to your supervisors for consideration.

Roger Bailey

April 15 - Tennis Tournament Sign-Up Deadline

Please see story on page 2 of this newsletter for more details about this event.

April 17 - Earth Fair

The annual Earth Fair will be held in Balboa Park from 10 a.m. to 5 p.m. The event regularly attracts around 70,000 people. If you're among them, stop by the Public Utilities booth and say hello to co-workers from Water Conservation, Wastewater Operations, and the Water Purification Demonstration Project outreach team. Construction & Maintenance will also be providing a water wagon.

April 28 - Take Your Sons & Daughters to Work

The annual Take Your Sons & Daughters to Work Day will be hosted by the City of San Diego and the National Management Association, City of San Diego chapter. In an effort to promote careers in government, the Public Utilities Department will participate in this event by hosting a booth display of services (programs/operations/equipment) in the Concourse Plaza between 11 a.m. and 1 p.m.

If you would like to attend this event's activities in the Concourse Plaza, you must request pre-approval from your supervisor and utilize annual leave to cover the time you are away from work (excluding your normal lunch break time).

For additional information about Take Your Sons & Daughters to Work Day, contact Margaret Wyatt, Human Resources Section Manager, at 858-29-26467 or 619-961-6696.

Pipeline Newsletter Article: May 2011

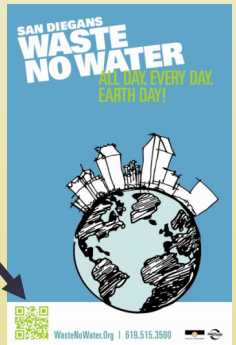
Out & About

Take Your Daughters & Sons to Work

In an effort to promote careers in government, the National Management Association hosted the City's annual "Take Your Daughters & Sons to Work Day," targeted to girls and boys ages 8 through 12, on Thursday, April 28, 2011. Staff from Wastewater, Conservation and the Water Purification Demonstration Project were on hand to inform visitors of the department's efforts and initiatives.

Earth Fair

On April 17, Department staff participated in the annual Earth Fair in Balboa Park. The event drew roughly 60,000 attendees interested in environmental sciences and sustainability practices. Water and Wastewater staff hosted a booth to educate the public on the latest programs, projects, and rebates. In an effort to minimize the distribution of paper materials guests with smart phones were able to scan a posted bar code and access department materials online.



= Scannable bar code

Pipeline Newsletter Article: June 2011

PIPELINE
PUBLIC UTILITIES MONTHLY UPDATE

June 2011

A Message from the Director

There is always something new and interesting going on in the Public Utilities Department, but what's going on at the North City Water Reclamation Plant this month promises to have a profound effect on our future water supplies. Marsi Steirer, Deputy Director of the Long-Range Planning and Water Resources Division, explains: "We are excited to begin operations this June at the Advanced Water Purification Facility (AWP Facility). Located at the North City Water Reclamation Plant, this facility is part of the City's Water Purification Demonstration Project, which is examining the use of water purification technology on recycled water. Additional components of the Demonstration Project include a study of San Vicente Reservoir to determine the potential of augmenting the reservoir with purified water, an analysis of the cost to operate the facility, an independent advisory panel of experts to provide oversight on the entire process, and ongoing public outreach activities. The AWP Facility will operate for one year and will produce approximately 1 million gallons of purified water every day. The process includes three treatment barriers that are being tested and monitored at the AWP Facility: membrane filtration, reverse osmosis and advanced oxidation with ultraviolet disinfection and hydrogen peroxide. Purified water will be added to the recycled water distribution system and not to the drinking water supply during this testing period."

Pipeline Newsletter Article: July 2011

PIPELINE
PUBLIC UTILITIES MONTHLY UPDATE
July 2011

Message from the Director

Roger Bailey

Late in June, the Mayor announced that our Department would be absorbing $8.75 million in costs rather than passing them onto our customers (see announcement below). This means during the next fiscal year, we in the Public Utilities Department are going to have to be even more vigilant in our efforts to continually improve and become more efficient.

We have done great things in the two years since the merger of the Water Department and the Wastewater Department. Our workforce has shrunk significantly. I am well aware that we are being asked to do more with less. Fortunately, our ethic of finding increased efficiencies, of seeking out new ways to do our jobs better and faster, continues to pay off for our Department and for the citizens of San Diego.

We have completed a very successful year and we have many exciting programs on the very near horizon. We continue to reap prestigious local and national awards (check out our awards page at http://www.sandiego.gov/publicutilities/pdf/100927departmentawards.pdf), our Field Academy, Management Academy and Mentorship Programs continue to thrive and we keep getting great suggestions through our STAR Program.

Coming up this month, we will launch Customer Care Solutions, an entirely new billing system that will allow us to help customers quicker and with more information and give customers new ways to see and pay their bills. We also are well under way with our Water Purification Demonstration Project. This includes free tours at the Advanced Water Purification Facility at the North City Water Reclamation Plant.

I would like to thank everybody for working hard at finding better and more efficient ways to do our jobs and fulfill our mission to ensure the quality, reliability and sustainability of our water and wastewater services for the benefit of ratepayers and all the citizens of San Diego. It is because of all your effort and ability that we are able to help San Diegans by keeping the cost of water as low as possible.

MAYOR JERRY SANDERS
FACT SHEET

CITY WILL NOT RAISE WATER RATES ON SAN DIEGANS DESPITE LATEST RATE HIKE BY WHOLESALERS

Public Utilities Department will absorb additional $8.75 million cost

The city will not raise water rates next fiscal year even though the city's water wholesaler voted today to increase the price of water by more than seven percent, Mayor Jerry Sanders announced today. The city will be forced to pay an additional $8.75 million in wholesale water costs next fiscal year as a result of today's vote by the San Diego County Water Authority, whose rates were hiked by the Metropolitan Water District in Los Angeles.

"The cost of water is an enormous concern for everyone in this city, from the families trying to keep their households solvent to the businesses struggling through the worst economy since the 1930s," the mayor said. "We are doing everything in our power to postpone any future water-rate increases as long as possible."

To prevent any rate increases for Fiscal Year 2012, the city's Public Utilities Department is taking a variety of steps to pay for the increased price of its wholesaler water. These measures include everything from maximizing the use of local water supplies to keeping vacant jobs open as long as possible. San Diego reservoirs are higher than normal because of the wet winter and cool spring, meaning the city has the option of buying less water from its wholesalers.

Pipeline Newsletter Article: August 2011

PIPELINE

PUBLIC UTILITIES MONTHLY UPDATE

August 2011

Roger Bailey

A Message from the Director

As we continue to move forward in this new fiscal year, I would like to reaffirm the importance of customer service. Our jobs exist for the sole purpose of ensuring excellence in the delivery of water, wastewater and recycled water services for San Diego residents and businesses. It's that simple.

We do a tremendous job of this and I cannot thank you enough for taking this role very seriously every day. While we are public servants who derive satisfaction from making a difference in our community, we must continue to raise the bar for ourselves when it comes to customer service.

One of the primary ways we interact with our customers is through our Customer Support Division and the Department's billing system. Providing accurate, efficient and easy billing options for our customers is a crucial part of our service delivery.

I am very pleased to report that we have successfully transitioned to a new Customer Care system based in SAP that is providing many new enhancements for our customers. While most of San Diego was enjoying time with family and friends over the long Fourth of July holiday weekend, a crack team of Department staff, consultants and others were working tirelessly on the final details of a two-year effort to launch the new system. The proverbial switch was flipped at 8:00am on July 5 and the new system is now providing enhanced options for our customers. This project was managed extremely well and that speaks volumes for all of those who dedicated their talents to this significant effort.

Speaking of dedication, another recent coup for the Department was the opening of the Water Purification Demonstration Project. This vital project has been a goal for the Department for several decades. As the Mayor led a press conference for television, radio and print media, with the Advanced Water Purification facility actually purifying water in the background, it was apparent to all present that we are progressing toward developing more sustainable water supplies for future generations of customers. The public will continue to learn more about this project through tours and our active speakers bureau.

Please enjoy reading more about these and other accomplishments, updates and news in this issue of *Pipeline*. Again, thank you for making customer service a priority every day.

Roger

Mark Your Calendars

August 11
Junior Lifeguards Enviro Day
Santa Clara Recreation Center
7:30am to 7:30pm
(sandiego.gov/lifeguards/junior/)

August 11
Wipeout on ABC Network Television
See Dept Staffer Compete for $50K
8:00pm on Channel 10
(abc.com/wipeout)

August 13 and 14
Fiesta del Sol
Barrio Logan
Cesar Chavez Park
11am to 7pm
(fiestadelsolsandiego.org)

Throughout August
10 am to 11am, Monday thru Friday
Drip Irrigation Mini Clinics
Home Depot - Sports Arena Store
(619-224-9200)

Public Utilities staff are participating in or sponsoring each of these vents.

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Customer Care System Now Live!

New Department Billing System to Serve as Foundation for Future Billing Citywide

The Customer Support Division successfully activated the Customer Care Solutions system on July 5, 2011. The Customer Care Solutions (CCS) system will allow customers to have more access to their account information, more and easier ways to pay their bills. Additionally, CCS will allow our Customer Care Agents to better assist customers, as they now have SAP applications that will mirror the information viewed by customers through the online customer portal.

For a historical overview of the project and more recent activities, including customer outreach, please access Customer Care Solutions page at sandiego.gov/publicutilities/ccs.shtml. To access the Customer Care Center, with links to instructional materials and the Public Utilities Customer Portal please access sandiego.gov/customercare/, or click on the "Pay Your Water & Sewer Bill Online" link from the Customer Care Solutions page, or any of the Departments internet sites (e.g., Public Utilities Department, Water Department or Metropolitan Wastewater Department).

Many of our Public Utilities Department Employees are also Public Utilities Customers. You are encouraged to enroll in the new Customer Care Solutions system. Our goal is to get the majority of our customers to an online invoicing and bill payment option, and having you make the switch will greatly help move us towards this target!

Have more questions? Please contact CCS Program Manager Jane Arnold at JArnold@sandiego.gov.

Out with the old...

In with the new...

We're Getting More "Social"

PIO Team Adds to Department Social Media Presence

SD Public Utilities has expanded farther into the social media universe. Now all your news and information about "San Diegans Waste No Water" campaign, the Water Purification Demonstration Project and general happenings around the Department are at your fingertips.

"Like" us on Facebook with the following pages:
City of San Diego Public Utilities
San Diegans Waste No Water
Pure Water SD (Water Purification Demonstration Project)

Follow us on Twitter with the following pages:
@SanDiegansWasteNoWater
@PureWaterSD (Water Purification Demonstration Project)
.

Got it? After you're done with all your "liking" and following, spread the word by tweeting, retweeting and sharing our pages with your friends and family. And if you have no idea what the heck this all means, contact your respective Branch PIOs to get squared away. More social media enhancements coming soon.

Water Purification Debuts

Mayor Holds Press Conference to Announce Opening of Demonstration Project

Deputy Director Marsi Steirer holds up a container of purified water as Mayor Sanders, Councilmember Alvarez and Department Director Roger Bailey look on

On a hot day at the end of June, media outlets from television, radio and print converged onto the North City Water Reclamation Plant (North City WRP) as Mayor Sanders officially unveiled the Advanced Water Purification Facility (AWP Facility) to the public. Also there to support the unveiling was Councilmember David Alvarez and the Public Utilities Department's own Director Roger Bailey and Deputy Director Marsi Steirer.

Under construction since early 2011, the AWP Facility is the focal point of the City's Water Purification Demonstration Project and was well-received by the attending press. *The Voice of San Diego* said the water produced by the AWP Facility looked "alluring" and is "as clean as mankind knows how to get it." Local blogger and San Diego water watchdog George Janczyn of Groksurf.com called the mood around the AWP Facility "celebratory."

The unveiling coincided with the launch of a tour program at the facility. Starting in early June, North City WRP staff and other select guests served as a test audience for dry run tours. The tour program officially launched in July, starting with tours for stakeholders, community leaders, elected officials and water industry experts. Beginning in mid-July the tour program opened up to guests from the general public.

The tour experience educates visitors about the Demonstration Project with a special focus on the AWP Facility's science of purifying recycled water with membrane filtration, reverse osmosis, and UV disinfection with advanced oxidation. Visitors to the facility are greeted in the lobby of the North City WRP, where they are exposed to informational materials and displays about the Demonstration Project. The tour begins with a brief presentation examining San Diego's need for additional water supplies and explaining how water purification could potentially provide San Diego with an independent source of water.

The presentation concludes with a video illustrating just how the technology used at the AWP Facility removes or destroys unwanted materials in the water. Participants then walk through the facility to see the facility equipment up close and view the final product water.

Public Utilities Department staff members are invited to tour the AWP Facility during specially designated City staff open houses. The first of these open house events will take place on September 6. To register, please visit https://apps.sandiego.gov/ereg/purewatersd/courses.php?grp=staff. Supervisor approval is required to attend the tours.

Additional City staff open house tours of the AWP Facility will be available on a regular basis through summer 2012. The Demonstration Project staff is looking forward to City employees learning about water purification during the City staff tours.

Associate Civil Engineer Fabiola Amarillas gives an interview in Spanish for Univision Television

Deputy Director Marsi Steirer provides project details for local television

Project signage enhances the public tour experience

Pipeline Newsletter Article: October 2011

Water Purification Demonstration Project Honored with National Award

Project Director, Marsi Steirer, gleefully accepts award.

The WateReuse Association recognized the Water Purification Demonstration Project for the "2011 WateReuse Public Education Program of the Year Award" at its 26th Annual Symposium in Arizona. Along with examining the use of advanced water purification technology to potentially provide safe and reliable water, the Department has also embarked on a program to educate residents by offering free public tours of the Advanced Water Purification Facility, speaker presentations to interested groups and opportunities to learn about the Demonstration Project at community events throughout San Diego.

Staff members are encouraged to bring family and friends for a tour. To register, visit purewatersd.org, email purewatersd@sandiego.gov or call (619) 533-6638.To better accommodate staff, evening and weekend tours are offered monthly.

San Diego's Fourth Annual Water For People Fall Luncheon

Raising funds for worldwide initiatives

The San Diego Committee of Water For People invites you to its 4th Annual Fall Luncheon on Thursday, October 27th from 11:30AM - 1:00PM at the Admiral Baker Golf Course Club House. The Water For People community will gather to celebrate what has become the most distinguished fundraising event for the organization in the California – Nevada area. All are welcome and encouraged to register online at http://2011wfpluncheon.eventbrite.com.

Water For People (WFP) is a non-governmental organization founded in 1991 by the American Water Works Association. The international, humanitarian organization focuses on improving the quality of life in developing countries by supporting the development of locally sustainable drinking water resources, sanitation facilities and health and hygiene education programs. WFP now works in rural areas of 11 countries where the need is greatest for water and sanitation solutions.

Water Purification Demonstration Project team member, Jennifer Farrow, traveled to Bolivia to assist in the search for clean water.

Pipeline Newsletter Article: January 2012

Fifteen Hundred and Counting!

Catfish Club Member Marks 1,500th Tour Participant at AWP

Members of the Catfish Club take the AWP tour at North City

On December 2, the Water Purification Demonstration Project reached a new milestone when it welcomed its 1,500th tour guest to the Advanced Water Purification (AWP) Facility. Lucky number 1,500 was a member of the Catfish Club, a group that provides a forum on topics critical to the success of diversity in San Diego. Including the Catfish Club's visit, Demonstration Project staff has hosted more than 120 tours since opening in July 2011.

The Demonstration Project continues to examine the use of water purification technology on recycled water to determine the feasibility of a full-scale reservoir augmentation project in San Diego. The tour program has proven to be a successful way to inform the public about the science behind the water purification process.

Guests who participate in the AWP Facility tour gain a better understanding of the Demonstration Project and what role the facility plays in this testing phase. People from all over San Diego have visited and many guests have brought their family, friends and co-workers. Various groups from graduate school classes to the Audubon Society to senior citizen organizations to a fifth grade science class have toured the facility. Elected officials, including San Diego Mayor Sanders and San Diego Councilmembers Alvarez, Faulconer, Gloria, and Lightner, have also been among the visitors. It's not just local folks who visit, though. Because many countries around the globe are interested in water purification technology as a potential solution to water supply issues, international visitors have come all the way from Mexico, Vietnam, Australia and Eurasian countries to see water purification technology in action.

City staff visited the AWP Facility during specially designated tours in the fall. Additional City staff tours will be posted as they become available at https://apps.sandiego.gov/ereg/purewatersd/courses.php?grp=staff. For those that have already toured, please encourage friends and family to join a public tour by registering online at www.purewatersd.org/tours.shtml or request a presentation for your organization by emailing purewatersd@sandiego.gov or calling (619)533-6638.

B2G Update

Auditor Expected on Board in February

The Department is completing several steps in the annual Bid to Goal (B2G) program cycle. Currently, the Department is in the process of selecting an auditor who will review the FY10 B2G goal attainment results, savings calculations, Employee Efficiency Incentive Reserve (EEIR)/Assurance fund activity, and employee eligibility. We anticipate an auditor will be on board in February 2012. After the audit is complete, the Department should be able to begin to process payments. Keep checking the Pipeline for the latest B2G information. If you have any questions, contact Liz Barat at ebarat@sandiego.gov or 858-292-6474.

SURVEY

Continued from page 1

them as a tool to identify areas where employees feel we are doing well, as well as identify areas where employees feel we could improve. Next, in spring of 2012, a Peer Review Team comprised of executives from Water and Wastewater utilities around the country will use our Self-Assessment report as a starting point for an in-depth review and benchmarking of our utility.

Detailed information on the QualServe program can be found at the following site: http://www.awwa.org/Resources/utilitymanage.cfm?ItemNumber=624&navItemNumber=3769

If you have any other questions, contact Liz Barat at ebarat@sandiego.gov or 858-292-6474.

WPDP Video Debuts

Virtual Tour of Advanced Water Purification Facility Featured

Department PIO staff worked with CityTV to create a new video featuring Deputy Director Marsi Steirer as host and narrator of a virtual tour of the Advanced Water Purification Facility at the North City Water Reclamation Plant.

The video was developed to increase awareness of the Water Purification Demonstration Project, serve as an alternative for those unable to take the actual tour and serve as a catalyst to increase public participation in the project. The video is available on the project page at purewatersd.org (on our website) and is also available on YouTube (search for PureWaterSD).

"Winning..."

California Water Environment Association Honors Department

From left to right: Denis Pollak CWEA, Stan Griffith Deputy Director, Wastewater Collection Division, Ann Sasaki Assistant Director, Public Utilities Department, Rick Lewis, Bev Stumman, Duane Johnson of CWEA and Michael Rosenberg Principal Water Utility Supervisor, Wastewater Collection Division

On December 15, the Wastewater Collections Division was bestowed two awards from the California Water Environment Association. One award was for hosting a collection system workshop with the Southern Section Collection Systems Committee of the association, in which 15 cities participated. The second award was given to Deputy Director Stan Griffith for his support and leadership in the wastewater collection field.

PIPELINE
PUBLIC UTILITIES MONTHLY UPDATE

From the Editor's Desk:

Pipeline is the monthly internal newsletter of the City of San Diego's Public Utilities Department. The aim of ***Pipeline*** is to keep employees up-to-date on the people, places and events in our Department. ***Pipeline*** is distributed to Department staff and others in the City interested in Public Utilities news. The newsletter is produced on a rotation basis by the Department's Public Information Officers.

January Editor: Eric Symons

January Contributors: Roger Bailey, Liz Barat, Arian Collins, Brian Drummy, Laura Durbin, Kurt Kidman, Terrell Powell, Alma Rife, Michael Rosenberg and Danielle Thorsen.

February Editor: Arian Collins

If you have any story ideas and photos for the **February issue of *Pipeline***, contact Arian Collins in the Public Information at (619) 527-3121 or email him. **Please provide content by 1/23/12 (the sooner the better)**.

What to Contribute for Future Issues? We're looking for constructive questions for the Director (which will remain anonymous), photos of the month that relate to the department, staff news, section, division, or department events, spotlights on operations, customer recognition, upcoming partner events, Department fundraisers, interesting factoids and statistics about operations, etc. **This is your staff newsletter so all of your contributions and suggestions are greatly appreciated!**

Our Mission:

To ensure the quality, reliability, and sustainability of water, wastewater and recycled water services for the benefit of the ratepayers and citizens served.

Our Vision:

We are an industry leader in the delivery of water, wastewater and recycled water services

Our Guiding Principles:

Service Excellence
Environmental Stewardship
Fiscal Responsibility
Continuous Improvement
Innovative Use of Technology
Sustainable Growth and Prosperity
Safe Work Environment
Dedicated to Employee Development

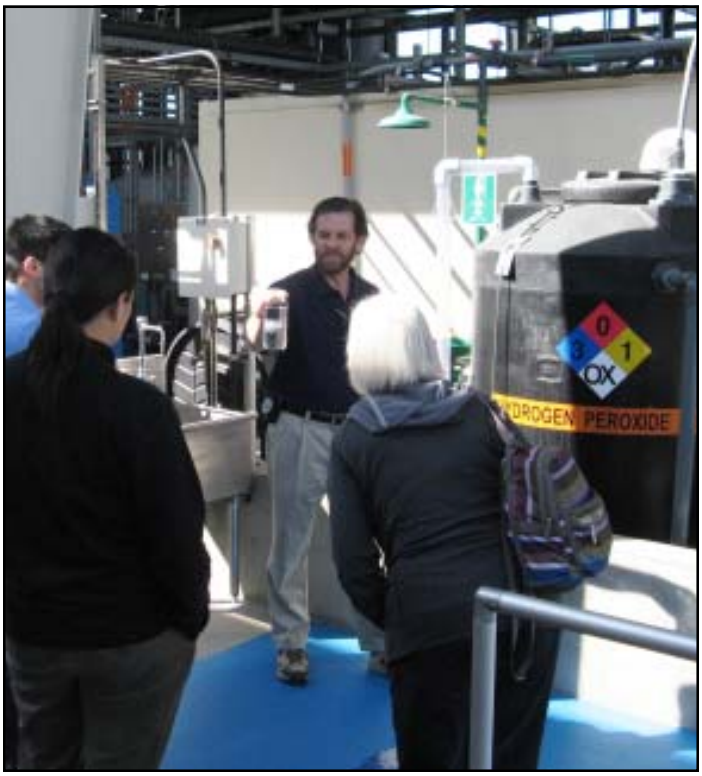
Pipeline Newsletter Article: February 2012

AWP Facility Tour Program Gaining Momentum

Nearly 200 people have already toured the Advanced Water Purification Facility in 2012. The tour educates visitors about the Demonstration Project with a special focus on the AWP Facility's science of purifying recycled water with membrane filtration, reverse osmosis, and UV disinfection with advanced oxidation. Some of the groups to visit the AWP Facility in January included the Conservation Action Committee, Santa Clara Valley Water District, San Diego Community College Older Adults Program, the Army Reserves, and UCSD School of Medicine. On Jan. 13, Councilmember Marti Emerald, her staff, and a representative from State Assemblymember Marty Block's office also visited the AWP Facility.

The tours continue to garner positive feedback from attendees. The *San Diego Union-Tribune* covered the tours in the Jan. 22 article "Water purification tour tries to make process crystal clear." A tour guest responded with a letter to the editor stating, "I toured the Advanced Water Purification Facility ... and was impressed with the overall operation and results that I saw… [T]here is no danger or need for 'queasy stomachs' regarding the introduction of purified water into the San Diego water supply."

A UCSD School of Medicine professor who toured with her students on Jan. 18 said, "The students were very interactive, raising many questions and issues. I have found this type of student response is an excellent indicator of the value of the experience. Hopefully the tours and the knowledge that the students acquired will assist them in both their personal lives and in the guidance they provide their patients regarding the important decisions we all will be making in terms of the community's use and reuse of our limited water resources."



UCSD medical students tour the Advanced Water Purification Facility.

AWWA QualServe Self-Assessment Survey: Wrap-up and Next Steps

A big thank you to all employees who participated in the American Water Works Association (AWWA) QualServe Self-Assessment Survey. Your opinion on how our utility performs in various aspects of our industry is valued and appreciated. This month, the survey results will be aggregated into a final report for our Department by AWWA. Our Executive Team will be reviewing the results and using them as a source of data to identify areas where employees feel we are doing well, as well as identify areas where employees feel we could improve. This spring, a Peer Review Team comprised of executives from Water and Wastewater utilities around the country will use our Self-Assessment report as a starting point for an in-depth peer review and benchmarking of our utility. Detailed information on the QualServe program can be found at the following site: www.awwa.org/Resources/utilitymanage.cfm?ItemNumber=624&navItemNumber=3769. If you have any other questions about the Self-Assessment, contact Liz Barat at ebarat@sandiego.gov or 858-292-6474.

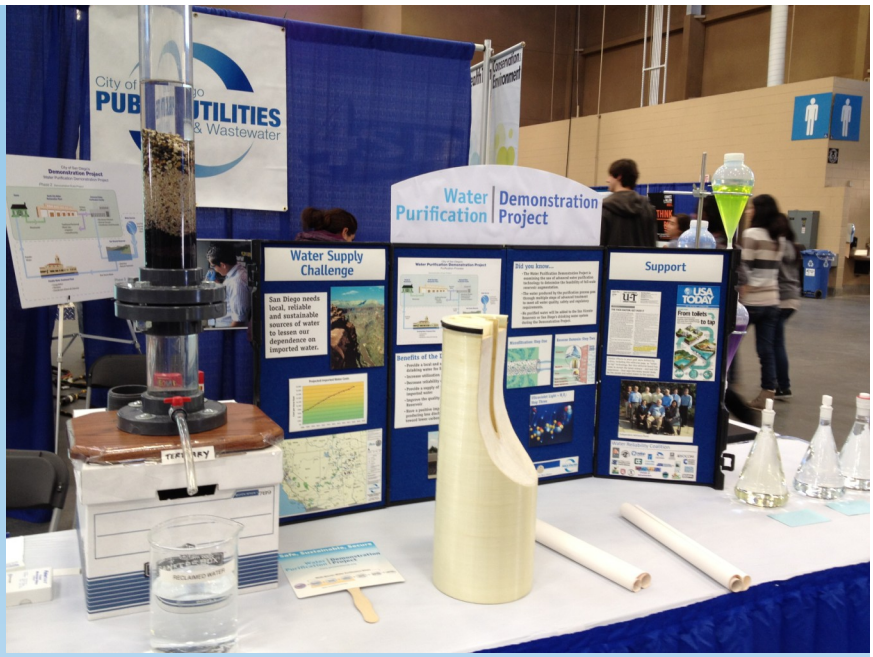
Department Staff Can Take Tour March 20

Public Utilities Department staff members are invited to tour the AWP Facility during tours specifically designed for City staff on March 20. To register, please visit https://apps.sandiego.gov/ereg/purewatersd/courses.php?grp=staff. Supervisor approval is required to attend the tours. City employees are asked to not register for the general public tours in order to conserve space on those tours for community members. For those that have already toured, please encourage friends and family to join a public tour by registering online at www.purewatersd.org/tours.shtml or request a presentation for your organization by emailing purewatersd@sandiego.gov or calling 619-533-6638.

The Demonstration Project will also be featured at the Public Utilities Department's exhibit at the San Diego Science Alliance High Tech Fair on Feb. 7 and 8 from 5 to 8 p.m. in Wyland Hall at Del Mar Fairgrounds. City staff interested in attending the High Tech Fair can learn more and register online at http://sdsa.org/programs/high-tech-fair/programs/high-tech-fair/programs/high-tech-fair/high-tech-fair.

Pipeline Newsletter Article: March 2012

Making a Difference



On February 7th and 8th members of the Environmental Monitoring and Technical Services Division (EMTS) participated for the fourth consecutive year in the San Diego Science Alliance High Tech Fair. The goal of the fair is to enlighten 7th-12th grade students to the world of science and the possibilities of a scientific career.

The EMTS exhibit featured a demonstration of the recycled water treatment process with discussion of the beneficial reuses of recycled water, and included a real-time view of the role of microorganisms in the wastewater treatment process. The exhibit showcased the City of San Diego's Water Purification Demonstration Project, which is examining the use of advanced water purification technology to provide safe and reliable water for San Diego's future. The exhibit allows students to explore and enjoy seeing 'real life' applications of what they may be learning in the classroom.

Fair attendees were intrigued by the microorganisms found in the activated sludge treatment process, especially the hard-to-find but amazing, Water Bear. Upon completion of the ten minute presentation, students, parents, and teachers alike expressed support of the Water Purification Demonstration Project's ability to produce high-quality drinking water. Their toilet-to-tap concerns had floated away!

The High Tech Fair is a collaborative effort between the Science Alliance, the San Diego County Office of Education and San Diego City Schools. It includes over 50 exhibitors from local cutting-edge STEM organizations and nearly 3000 students in attendance. EMTS staff members, Victoria Santibanez, Alejandra Molloy, Erica Fitzgerald, Eric Clark, Greg Schlimme, and Doug Campbell, prepared and hosted the exhibit.

Partnership for Safe Water Directors' Award

Otay operations staff modeling award shirts. From left: Julieanna Piatek, Cory Boyd, Tom Watson, Jeff Cekander, Glenda Evans, Brandon Krumenacker, Julio Gonzalez, Israel Jazo, Jim McVeigh, Jesus Meda, Jamie Garcia, Jim Fisher, Roger Bailey, Ephraim Delarosa, Jonathan McDowell and Gabe Soltero.

The Otay Water Treatment Plant recently earned its fourth consecutive Partnership for Safe Water Directors' Award. The award program is a nationally recognized effort sponsored by the country's leading drinking water agencies, including the Environmental Protection Agency and the American Water Works Association. The Partnership is a voluntary program in which a water treatment plant strives to provide the safest water possible – not just meet the standards. This award recognizes Otay staff for its hard work and accomplishment in water treatment plant optimization.

PIPELINE
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March Editor: Alma Rife
March Contributors: Liz Barat, Melissa Oates, Alma Rife, Doug Campbell, Arian Collins.
April Editor: Eric Symons

If you have any story ideas or photos for the **April issue**, contact **Eric Symons** at (619) 980-2784 or email him at esymons@sandiego.gov. **Please provide content by 3/22/12.**

What to Contribute for Future Issues? We're looking for constructive questions for the Director (which will remain anonymous), photos of the month that relate to the department, staff news, section, division, or department events, spotlights on operations, customer recognition, upcoming partner events, Department fundraisers, interesting factoids and statistics about operations, etc. **This is your staff newsletter so all of your contributions and suggestions are greatly appreciated!**

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Continuous Improvement
Innovative Use of Technology
Sustainable Growth and Prosperity
Safe Work Environment
Dedicated to Employee Development

Pipeline Newsletter Article: April 2012

Tweeting, Posting and Uploading, Oh My!

Department Expands Social Media Presence with YouTube and Twitter

The External Affairs section is continuing to expand our social media presence with the development of a new Department YouTube channel and Twitter account. Through the YouTube channel, which can be searched as SDPublicUtilities, the Public Information staff will be showcasing a series of videos that will focus on Department operations, services and programs. In addition, the channel currently features videos from partner organizations that relate to our services.

The new Twitter account, @SDPubUtilities, is a must to follow for interesting news and tidbits about all things Public Utilities.

Combined, the Department now has three Facebook pages (become a "fan" of City of San Diego Public Utilities, San Diegans Waste No Water and Water Purification Demonstration Project), three Twitter accounts (same subjects) and two YouTube Channels (SDPubUtilities and Purewatersd).

Check out the new YouTube Channel (from home of course) and follow us on Twitter. While External Affairs staff are constantly monitoring for items to tweet, post, and upload, please share your ideas as well. Simply contact a Department PIO if you have suggestions for content.

We can even post or retweet information and resources from our many partner organizations, so forward content, links, photos, video ideas, etc to a PIO in External Affairs.

SDPublicUtilities is the address for the Department's new YouTube channel

@SDPubUtilities is the address for the Department's Twitter account

Busy, Busy Bee!

Testifying Before the State Assembly, Giving Tours and Winning Awards Keeps This DD on the Move

Department Deputy Director Marsi Steirer testified at the March 20 California State Assembly Water, Parks and Wildlife Committee's informational and oversight hearing on Untapped Potential: Water Reuse for California's Future Water Supply Reliability. As one of only three California case studies presented at this hearing, the Committee is recognizing San Diego's leadership promoting potable reuse.

This hearing could lay policy groundwork in support of streamlined permitting of future purified water projects, offering communities across California additional local water supply options.

Deputy Director Marsi Steirer gives Councilmember Todd Gloria and members of his staff a tour of the Advanced Water Purification Facility (one of 42 tours Marsi has given so far).

California WateReuse Association President Paul Jones stands with Deputy Director Marsi Steirer, who was awarded the WateReuse Advocate of the Year at the association's annual conference in Sacramento.

According to the nomination, Marsi "...has been a tireless champion of potable reuse as a valuable local water supply option and has managed to keep the concept alive at city hall despite facing many challenges.

In 2004, Steirer managed the Water Reuse Study, which picked up the pieces from the previous unsuccessful attempt to be the first city in California to augment a surface water reservoir with highly treated recycled water. She managed the successful stakeholder process that resulted in a recommendation that the City move forward with reservoir augmentation.

Undaunted by the political 'buzzsaw' she encountered when the final report was released, Steirer worked with City Council members and a broad-based coalition of environmental, business, taxpayer advocacy and technology groups to bring it forth from the life-support phase to a 1 million-gallon-a-day demonstration project.

Steirer is also at the helm of a comprehensive public outreach program and a series of technical studies for the project."

Congrats Marsi!

Pipeline Newsletter Article: November 2012

Department wins AMWA 2012 Achievement Award

On October 22nd, San Diego Public Utilities won the Platinum Award for Utility Excellence from The Association of Metropolitan Water Agencies (AMWA) at its 2012 annual meeting in Portland, Oregon. Director Roger Bailey accepted the award on behalf of the Department.

Director Roger Bailey accepting the Department's Achievement Award from AMWA President Pat Mulroy

"I was proud to accept this award on behalf of all the employees of San Diego Public Utilities who work hard each and every day to ensure that we are the very best at what we do and are an industry leader. We are truly 'excellent'. "

San Diego Public Utilities was one of ten national winners—and the only agency in California—to receive the Platinum Award for Utility Excellence while four others won the Gold Award for Exceptional Utility Performance.

"AMWA's 2012 award winners are industry-leading water systems with innovative managers and dedicated workforces who create sustainable utilities marked by high quality, affordable water, responsive customer service and attention to resource management and environmental protection," said AMWA President Pat Mulroy, General Manager, Las Vegas Valley Water District. "The accomplishments of these exceptionally well-run public utilities should be a source of pride for the communities they serve."

The Attributes of Effective Utility Management are industry standards and cover utility performance in areas of product quality, customer satisfaction, employee and leadership development, operational optimization, financial viability, infrastructure stability, operational resiliency, community sustainability, water resource adequacy, and stakeholder understanding and support.

AMWA recognized that the Department prides itself in continual improvement and has established goals, objectives and initiatives that challenge employees to be optimally efficient. During FY2010 and FY2011 additional initiatives regarding Bond Refinancing and State Revolving Fund loans have generated savings of $107.8M over 30 years.

Through award winning projects, like the Water Purification Demonstration Project, the Department pursues innovative ways of creating new local water supplies to address the increasing demands and needs of the public. Revenue producing initiatives that help alleviate the rates of the citizens are continuously explored, such as the Beneficial Use of Digester Gas Project which has led to the production of a renewable energy source.

> "AMWA's 2012 award winners are industry -leading water systems with innovative managers and dedicated workforces . . . The accomplishments of these exceptionally well-run public utilities should be a source of pride for the communities they serve."
>
> *—Pat Mulroy, AMWA President*

These efforts illustrate the Department's commitment to providing the standard of excellence on which the residents of San Diego depend.

Pipeline Newsletter Article: December 2012

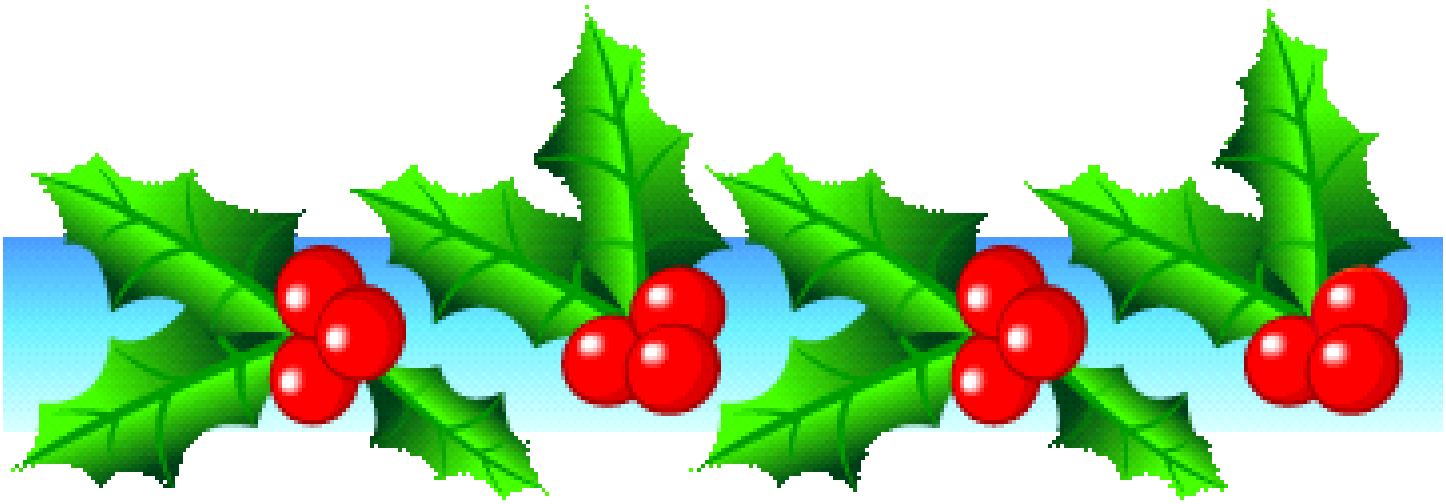
Last call for Staff to Tour AWP Facility

Public Utilities Department staff members are invited to tour the Advanced Water Purification (AWP) Facility on Thursday, Dec. 13 at 10 a.m., 11 a.m. or 1 p.m. More than 3,000 people have toured the AWP Facility since opening in June 2011. The tour experience educates visitors about the Demonstration Project with a special focus on the AWP Facility's science of purifying recycled water using membrane filtration, reverse osmosis, and UV disinfection with advanced oxidation. The purpose of the Demonstration Project is to determine whether purifying recycled water and adding it to the San Vicente Reservoir is a viable option for supplementing San Diego's local water supplies.

Long-Range Planning & Water Resources engineer Bill Pearce, left, conducts a tour of the AWP facility.

The Demonstration Project team is currently preparing a final report on the project's findings. The team has conducted a variety of activities, including constructing and operating a one-million-gallon-per-day AWP Facility, studying the potential effects of adding purified water to the San Vicente Reservoir, conducting a pipeline alignment assessment, determining economic and energy needs, developing regulatory requirements, and educating the public about the water purification process. Findings from the project components will be compiled in a final report, which will be available to the public in early 2013.

As the project winds down, this may be one of the last opportunities for staff to tour the facility. To reserve your spot, please visit https://apps.sandiego.gov/ereg/purewatersd/courses.php?grp=staff. **Registration closes on Dec. 7.** Supervisor approval is required to attend the tours. City employees are asked to not register for the general public tours in order to conserve space on those tours for community members. For those that have already toured, please encourage friends and family to join a public tour by registering online at www.purewatersd.org/tours.shtml or request a presentation for your organization by emailing purewatersd@sandiego.gov or calling (619)533-6638.



Advanced Water Purification Facility Study Report

January 2013

Indirect Potable Reuse/Reservoir Augmentation Demonstration Project
Advanced Water Purification Facility

THE CITY OF SAN DIEGO

City of San Diego
PUBLIC UTILITIES
Water & Wastewater

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AWP Facility Study Report

Acknowledgements

This Advanced Water Purification (AWP) Facility Study Final Report summarizes the results of the City of San Diego's AWP Facility Study, conducted as part of the City's multi-faceted Water Purification Demonstration Project (Demonstration Project) to evaluate the feasibility of indirect potable reuse through reservoir augmentation to provide safe and reliable water for San Diego. The combined contributions of the project team, regulatory agency representatives, Independent Advisory Panel members, and local stakeholders were invaluable completing this project. This page recognizes the efforts of participants that contributed substantially to this effort.

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Abbreviations, Acronyms, and Glossary

Abbreviations and Acronyms

Ace-K	acesulfame-k
ADI	acceptable daily intake
AWP	advanced water purification
AWP Facility	advanced water purification facility
Basin Plan	Water Quality Control Plan for the San Diego Basin
Bay-Delta	Sacramento-San Joaquin Bay-Delta
BDCM	bromodichloromethane
CDPH	California Department of Public Health
CEC	constituent of emerging concern
CIP	clean in place
City	City of San Diego
cm	centimeter
CTR	California Toxics Rule
CWA	Clean Water Act
DBCM	dibromochloromethane
DCS	distributed control system
DEET	N,N-diethyl-meta-toluamide
C	Celsius
Demonstration Project	Water Purification Demonstration Project
DLR	CDPH detection limit for reporting
DP	distribution panel
DWEL	Drinking Water Equivalent Level
DWR	California Department of Water Resources
EDR	electrodialysis reversal
EEO	electrical energy per order
ENR	Engineering News Record
EPA	U. S. Environmental Protection Agency
ft^2	square feet
gfd	gallons per day per square foot
gpm	gallons per minute
H_2O_2	hydrogen peroxide
HAA5, Total	Haloacetic Acids
HMI	human machine interface
HP	horsepower
HVAC	heating, ventilating, and air conditioning
I&C	instrumentation and controls
IAP	Independent Advisory Panel
in^2	square inches
IPR	indirect potable reuse
IPR/RA	indirect potable reuse/reservoir augmentation
IRWM	Integrated Regional Water Management
KV	kilovolts
KVA	kilovolts-amperes
kW	kilowatt
kWh	kilowatt-hours
kWh/d	kilowatt-hours per day
kWh/yr	kilowatt-hours per year

L	liter
LPHO	low pressure high output
LRL	laboratory reporting level
LSI	Langelier Saturation Index
MCL	maximum contaminant level
MDL	method detection limit
MF	microfiltration
m	meter
MCC	motor control center
MG	million gallons
mg/L	milligrams per liter
mg/L-N	milligrams per liter as nitrogen
mg/L-P	milligrams per liter as phosphorus
mgd	million gallons per day
mL	milliliter
mL/min	milliliters per minute
min	minute
mJ/cm^2	millijoules per square centimeter
MPN	most probable number
mV	millivolt
µg/L	micrograms per liter
µg/L-P	micrograms per liter as phosphorus
µS/cm	microsiemens per centimeter
N/A	not applicable
North City	North City Water Reclamation Plant
ND	not detectable or not quantifiable
NDEA	N-Nitrosodiethylamine
NDMA	N-Nitrosodimethylamine
ng/L	nanograms per liter
NL	notification level
NPDES	National Pollution Discharge Elimination System
NR&C	Natural Resources and Culture Committee
NTU	Nephelometric Turbidity Units
O&M	operation and maintenance
ORP	oxidation reduction potential
pCi/L	picocuries per liter
PLC	programmable logic controller
Point Loma	Point Loma Wastewater Treatment Plant
ppb	parts per billion
ppm	parts per million
ppt	parts per trillion
psi	pounds per square inch
PVC	polyvinyl chloride
PVDF	polyvinylidene fluoride
Q1	Quarter 1
Q2	Quarter 2
Q3	Quarter 3
Q4	Quarter 4
QA/QC	quality assurance/quality control
RA	Reservoir Augmentation
Regional Board	San Diego Regional Water Quality Control Board
RfDs	Reference Doses

RO	reverse osmosis
SDG&E	San Diego Gas & Electric
SDI	silt density index
SIP	State Board Policy for Implementation of Toxics Standards for Inland Surface Water, Enclosed Bays, and Estuaries of California
South Bay	South Bay Water Reclamation Plant
State Board	State Water Resources Control Board
STD	standard deviation
T&M Plan	Testing and Monitoring Plan
TCEP	tris (2-chloroethyl) phosphate
TCPP	tris (1-chlor-2-propyl) phosphate
TDI	tolerable daily intake
TDS	total dissolved solids
THMs	trihalomethanes
Title 22	Title 22 of California Code of Regulations
TOC	total organic carbon
UCMR	Unregulated Contaminant Monitoring Rule
UF	ultrafiltration
UV	ultraviolet light
UV254	UV 254 Absorbance
UVT	ultraviolet light transmittance
VOC	volatile organic compound
Water Authority	San Diego County Water Authority
WSE	water surface elevation

Glossary

1, 4- Dioxane: A chemical contaminant primarily used as an industrial stabilizer to enhance performance of solvents in manufacturing processes. Commonly used in food and food additives or in personal care products such as cosmetics, deodorants, soaps and shampoos. Currently there is not a federal or state MCL; however, the CDPH has established a notification level of 1 ppb. CDPH also specifies in the 2011 Draft Groundwater Recharge Reuse Regulations that AOP systems required for direct injection applications can be designed to achieve 0.5 log removal of 1,4-dioxane. Alternatively, AOP sizing can be based on demonstrated log removals of select indicator compounds from different functional groups.

Advanced Oxidation: A set of chemical treatment processes designed to destroy organic material through the breakdown of their molecular structure. The advanced oxidation process used at the AWP Facility employs ultraviolet light and hydrogen peroxide, which break down into natural elements, such as carbon, hydrogen and nitrogen.

Advanced Water Purification Facility (AWP Facility): A facility that produces purified water by utilizing advanced treatment technologies: membrane filtration (microfiltration [MF] or ultrafiltration [UF]), reverse osmosis (RO), disinfection, and advanced oxidation.

Advanced Water Purification (AWP) Facility Study: One element of the multi-faceted Demonstration Project. The AWP Facility Study included two primary elements: (1) the design, installation, and operation of a one million gallon per day (mgd) Demonstration Facility located at North City and (2) a conceptual design and cost estimate for a potential Full-Scale Facility.

Advanced Water Purification (AWP) Facility Study Report: Final report documenting the observations and findings of the AWP Facility Study.

Analyte: a chemical substance that is the subject of chemical analysis.

Backwash: The process of reversing the direction of flow through a filtration system in order to remove contaminants that had been filtered out in a water purification process, e.g. membrane filtration. The backwash process is necessary in order to maintain the treatment capacity of membrane filtration.

Bacteriophage: Viruses present among coliform bacteria. Have a high presence in wastewater.

Ballast: An electronic device on the UV system designed to generate a constant UV intensity and maximize UV lamp life.

Blending: Mixing or combining one water source with another such as purified water with raw water sources.

California Groundwater Recharge Reuse Draft Regulations: The November 21, 2011 Groundwater Recharge Reuse Draft Regulations, which are used as a guidance document for the conceptual design of the Full-scale Facility since regulations for reservoir augmentation with purified water do not yet exist. Also referred to as the draft groundwater recharge regulations.

Clean in place: The in-situ chemical cleaning of membranes that consists of soaking membranes in one or more chemical solutions (typically acid and caustic solutions) to remove accumulated foulants and restore permeability.

Concentrate: A continuous waste stream, typically containing concentrated dissolved solids, from the membrane process.

Constituent: In water, a constituent is a dissolved chemical element or compound or a suspended material that is carried in the water.

Constituents of Emerging Concerns (CECs): CECs are not regulated and include commonly used pharmaceuticals, personal care products, flame retardants and unregulated pesticides.

Contaminant: An organic or inorganic substance found in the water. Some contaminants have a health effect in people consuming the water, and thus is regulated in drinking water. Not all contaminants are unsafe. Iron and manganese are contaminants, but in excess simply causing staining. See Maximum Contaminant Level.

Critical alert limit: Measurement of a critical limit parameter that requires urgent corrective action in order for the corresponding critical control point to function as intended.

Critical control point: A point or step within the AWP Facility process train at which critical limit parameters can be monitored in order for corrective actions to be taken should critical alert limits be exceeded.

Critical limit parameter: A parameter that indicates whether or not a control measure is within the alert limit or critical alert limit for the corresponding critical control point.

Demonstration Facility: The one-mgd advanced water purification facility that was designed, installed, and operated as part of the City's Water Purification Demonstration Project.

Detection limit for the purposes of reporting (DLR): The DLR is a parameter that is set by regulation for each reportable analyte. It is not laboratory-specific and it is independent of the analytical method used (in cases where several methods are approved). The DLR cannot be changed by the laboratory. It is expected that a laboratory can achieve a reporting limit that is lower than or equal to the DLR set by the California Department of Public Health (CDPH).

Disinfection: The removal, inactivation or destroying of microorganisms present in a water supply that may be harmful to humans. Commonly used disinfectants include chlorine (and its derivatives), ultraviolet (UV) light, and ozone. Chlorine and its derivatives are used to disinfect drinking water because they provide residual disinfection that protects the water as it goes through the pipes to homes and businesses.

Disinfection byproduct: A compound that is formed through the reaction of a disinfectant (chlorine, ozone, chlorine dioxide, hydrogen peroxide) with organic or inorganic material present in the water. Some disinfection byproducts have been found to be harmful to human health and are regulated by the EPA or under consideration for future regulation.

Drinking water: Water that meets federal drinking water standards as well as state and local water quality standards so that it is safe for human consumption. Water treatment facilities that produce drinking water require a state permit. Also referred to as potable water.

Drought: A defined period of time when rainfall and runoff in a geographic area are much less than average.

Endocrine disrupting compounds (EDCs): A chemical substance or mixture that alters the normal hormone functions in humans and animals. These chemicals can come from pharmaceuticals and personal care products such as detergent and synthetic hormones. They may also come from some industrial wastes and pesticides. EDCs are also contained in natural agricultural products such as soybeans, alfalfa, and natural hormones in animals.

Effluent: The water leaving a water or wastewater treatment process or facility. If effluent has been treated to a high enough standard, it may be considered to be recycled water and can be used for beneficial purposes.

EEO-electrical energy per order: The amount of energy required to destroy 1 log order (i.e. 90%) of a given contaminant per 1000 gallons of water treated. EEO values are both reactor and water quality specific and used to baseline differences in reactor configurations and UV lamp intensities to establish comparative removals of a given constituent such as NDMA and 1,4- dioxane.

Environmental Impact Statement / Environmental Impact Report (EIS/EIR): Detailed analysis of impacts of a project on all aspects of the natural and human environment. An EIS is required by the federal National Environmental Policy Act (NEPA) for federal permitting or use of federal funds. An EIR is required by the California Environmental Quality Act (CEQA) for local projects.

Filtrate: A continuous stream of water that passes through a filter.

Filtration: A process that separates small particles from water by using a porous barrier to trap the particles and allow the water to pass through.

Flux: The unit rate at which water passes through the membrane expressed as flow per unit of membrane area (e.g., gallons per square foot per day (gfd)).

Fouling: The accumulation of contaminants on the membrane surface, within membrane pores, or media surface that inhibits the passage of water.

Full-Scale Facility: The proposed AWP Facility for the full-scale IPR/RA project. The Full-Scale Facility will have a capacity of 18 mgd and annual average purified water production of 15 mgd.

Groundwater recharge: Naturally or artificially adding water back into a groundwater basin.

Hydrogen peroxide: Chemical added in the UV disinfection/advanced oxidation step.

Imported water: A water source that originates in one hydrologic region and is transferred to another hydrologic region. In San Diego's case, water is imported from Northern California or the Colorado River and travels to this region in large above ground aqueducts or underground pipelines.

Imported raw aqueduct water: The raw imported water conveyed to the City's three water treatment plants for treatment prior to being introduced into the City's drinking water distribution system. For the AWP Facility Study, imported raw aqueduct water specifically refers to the imported water that was sampled at the Miramar Water Treatment Plant, per the Testing and Monitoring Plan.

Indicator Compounds or Indicator Organisms: A common method to evaluate water or wastewater quality using representative chemicals or organisms that are characteristic of a larger group of related chemicals or organisms. Coliform bacteria are common indicator organisms, and trihalomethanes, benzene, and NDMA are examples of indicator compounds.

Indirect potable reuse (IPR): The process of blending purified water into a natural water source (groundwater basin or reservoir) that can be used as a source of drinking water.

Influent: Flow entering a process.

Inorganic chemicals: Inorganic chemicals are substances that do not contain both carbon and hydrogen. Generally, inorganic chemicals are minerals. Most minerals are not a cause for concern in water. Water contains many natural minerals from the rocks the water has come into contact with on its journey to the water treatment plant. Nutrients, such as phosphorus and nitrogen, and metals, such as calcium, iron, sodium, potassium, and zinc, are inorganic chemicals. Some inorganic chemicals, when they are too abundant, are considered contaminants in water.

Integrity monitoring: Performance evaluation of a treatment process in order to verify that the process meets its intended treatment performance on a continuous basis.

Laboratory reporting level (LRL): The lowest concentration at which an analyte can be quantified and reported with an acceptable degree of accuracy. Laboratory reporting levels can vary based on the analytical method used, the laboratory, and the concentration being tested.

Maximum Contaminant Level (MCL): The highest allowable amount of a contaminant in drinking water mandated by the Safe Drinking Water Act, established by the U.S. Environmental Protection Agency as a regulatory standard.

Membrane filtration: A type of filter used to separate particles from the water. Membrane filters are characterized by the pore openings size from the largest to the smallest pore size: microfiltration, ultrafiltration, and nanofiltration. Membrane filters remove suspended solids, bacteria, protozoa, and other material from water.

Method detection limit (MDL): The lowest concentration at which an analyte can be detected in a sample and reported with greater than 99 percent certainty using a particular analytical method.

Microfiltration (MF): A low-pressure membrane filtration process where tiny, hollow straw-like membranes separate small suspended particles, bacteria and other materials out of the water. MF provides the most efficient preparation of water for reverse osmosis. MF is used in commercial industries to process food, fruit juices and soda beverages; in computer chip manufacturing; and to sterilize medicines that cannot be heated.

Micron: Equal to one-millionth of a meter or 1/25,400 of one inch. The eye can see particles only to about 40 microns. Used to describe the size of bacteria.

Non detectable and non quantifiable (ND): Laboratory sample results of a constituent reported as less than the laboratory reporting level or method detection limit (MDL).

Nitrosodimethylamine (NDMA): A semi-volatile, yellow, oily liquid of low viscosity that has been extensively used in industry for several decades (USEPA, 2001). NDMA is found at low levels in numerous items of human consumption including cured meat, fish, beer, and tobacco smoke. Currently there is not a federal or state MCL; however, the CDPH has established a notification level of 10 ng/L. Until revision of the Draft Groundwater Recharge Reuse Regulations in 2011 CDPH required that AOP systems required for direct injection applications be designed to achieve 0.5 log removal of 1,4-dioxane and 1.2 log removal of NDMA.

Non-potable water: Water that is not suitable for drinking because it has not been treated to drinking water standards.

North City Water Reclamation Plant (North City): Wastewater treatment plant that produces recycled water through a series of processes: primary treatment (screening and sedimentation), secondary treatment (aeration and clarification), and tertiary treatment (filtration and disinfection).

National Pollutant Discharge Elimination System (NPDES): A federal permit authorized by the Clean Water Act, Title IV, which is required for discharge of pollutants to navigable waters of the United States, and includes any discharge to surface waters: lakes, streams, rivers, bays, the ocean, wetlands, storm sewer, or tributary to any surface water body.

Organic chemicals: Chemicals that contain both carbon and hydrogen. There are millions of organic compounds, both naturally occurring and man-made. Naturally occurring organic compounds include amino acids (the building blocks of proteins), sugars, fats, hormones, and vitamins. All living matter is made up of natural organic chemicals. Synthetic (manmade) organic chemicals have been developed because they exhibit features that are valuable to us. These synthetic organic chemicals include herbicides, insecticides, pharmaceuticals, food coloring and flavors, personal care products, dyes, paints, adhesives, detergents, polymers, and plastics.

Osmotic pressure: The amount of pressure that must be applied to stop the natural osmosis-driven flow of water across a semi-permeable membrane.

Oxidation: A treatment step often used in disinfection, where chlorine, hydrogen peroxide, ozone, or another oxidizing agent is added to water to produce a chemical reaction that removes or aids in removal of harmful substances.

Pathogens: Disease-causing organisms. The general groupings of pathogens are viruses, bacteria, protozoa, and fungi.

Permeate: A continuous stream of water that passes through membrane. Typically used for water that passes through a reverse osmosis membrane (i.e., reverse osmosis permeate). Also referred to as filtrate or product.

Personal care product: Products that can be found in wastewater such as shampoos, fragrances, soap, and deodorant.

Pharmaceutically-active compound: Hormone-based compounds found within EDCs. Examples of these compounds include antibiotics, anti-epileptic medications, heart medications, pain medications, and cancer medications, along with veterinary drugs and feed additives used for livestock.

Phenolic Compounds: A class of aromatic organic compounds commonly used in the manufacture of plastics, cosmetics, and antiseptics, and as preservatives for wood and rubber. Several of these compounds are regulated for surface water (11 compounds), drinking water (1 compound), and air (5 compounds), based on observed toxicity. Phenolic compounds are commonly found in bottled water and are sometimes classified as endocrine disrupting compounds.

Point Loma Wastewater Treatment Plant (Point Loma): Advanced primary wastewater treatment plant that discharges treated wastewater into the Pacific Ocean.

Potable water: See drinking water.

Purified water: Recycled water that has been treated to an advanced level beyond tertiary treatment, so that it can be added to water supplies ultimately used for drinking water. The treatment includes membrane filtration with microfiltration (MF) or ultrafiltration (UF), reverse osmosis (RO), and advanced oxidation that consists of disinfection with ultraviolet light (UV) and hydrogen peroxide (H_2O_2). Purified water may be discharged into a groundwater basin or surface water reservoir that supplies water to a drinking water treatment facility.

Quarterly Testing Reports: Four quarterly testing reports were prepared to summarize the testing data collected at the Demonstration Facility. Quarterly Testing Report No. 4 includes all of the data collected at the Demonstration Facility and is included as an appendix to the AWP Facility Study Report.

Raw water: Water that has not been treated for use. Examples of raw water are water in the Colorado River aqueduct, the State Water Project aqueduct, open reservoirs (whether filled with imported water or runoff), rivers, naturally occurring lakes and some well water.

Reactor: A vessel or tank where physical or chemical treatment processes occur.

Reclaimed water: See recycled water.

Recovery: The volumetric percent of feed water that is converted to filtrate or permeate.

Recycled water: Treatment of wastewater beyond secondary treatment using tertiary filtration and chlorination. Water treated to this tertiary level is considered to be recycled water, which is suitable for many beneficial uses including irrigation or industrial processes. Recycled water meets treatment and reliability criteria established by Title 22, Chapter 4, of the California Code of Regulations.

Reservoir: A manmade lake or tank used to collect and store water.

Reservoir augmentation (RA): The process of adding purified water to a surface water reservoir. The purified water undergoes advanced treatment (membrane filtration, reverse osmosis and UV disinfection/advanced oxidation). The purified water is then blended with untreated water in a reservoir. The blended water is then treated and disinfected at a conventional drinking water treatment plant and is distributed into the drinking water delivery system. Also known as surface water augmentation.

Reverse osmosis (RO): A high-pressure membrane process that forces water through the molecular structure of several sheets of thin plastic membranes to filter out minerals and contaminants, including salts, viruses, pesticides, and other materials. The RO membranes are like microscopic strainers -- bacteria and viruses as well as inorganic and most organic molecules cannot pass through the membranes.

Scaling: The precipitation or crystallization of salts on a surface (e.g., on the feed side of a membrane).

Stage: A group of membrane units operating in series. In a two-stage configuration, concentrate from the first stage travels to the second where more water is produced.

Storage: Water held in a reservoir for later use.

Surface water: Water located on the Earth's surface in a river, stream, lake, pond or surface water reservoir.

Surrogate Compounds or Surrogate Parameters: A common method used to evaluate water quality using a compound or parameter viewed as representative of a non-related class of chemicals or organisms. Surrogates are used when the analytes of interest are more difficult to quantify and measure through standard laboratory practices. Examples of surrogate parameters include turbidity, conductivity, UV254, and total organic carbon.

Tertiary effluent prior to chlorination: Tertiary effluent prior to chlorination is wastewater that has undergone primary treatment, secondary treatment, and tertiary filtration, but has not been disinfected with chlorine. This is the feed water to the AWP Facility. Sometimes referred to as recycled water even though it has not been disinfected.

Testing and Monitoring Plan (T&M Plan): This plan was prepared as part of the AWP Facility Study to outline the testing and monitoring that was conducted at the Demonstration Facility. The plan was reviewed and commented on by the Independent Advisory Panel (IAP), the California Department of Public Health (CDPH), and the San Diego Regional Water Quality Control Board (Regional Board). More information about the T&M Plan is included in Section 2 and the plan is included as an appendix.

Total dissolved solids (TDS): The concentration of mineral salts dissolved in water. Salinity may be measured by weight (TDS) or by electrical conductivity. Salinity and TDS are both measures of the amount of salt dissolved in water, and the terms are often used interchangeably. Generally, salinity is used when referring to water with a lot of salt (e.g., seawater), whereas TDS is used to refer to water with little salt (e.g., freshwater).

Total organic carbon (TOC): A measure of the amount of carbon that is bound in organic molecules, including all natural and man made chemicals.

Transmembrane pressure: The difference in pressure from the feed (or feed-concentrate average) to the permeate across the membrane.

Turbidity: A measure of suspended solids in water; cloudiness.

Ultrafiltration (UF): Identical to microfiltration, except membrane pore size is smaller.

Ultraviolet (UV) disinfection and advanced oxidation: During ultraviolet disinfection, water is exposed to ultraviolet (UV) light, just like instruments in medical and dental offices, to provide disinfection. Additionally, ultraviolet light combined with hydrogen peroxide creates an advanced oxidation reaction that eliminates any remaining compounds in water by breaking them down into harmless compounds.

Vessel Array: Physical arrangement of pressure vessels in a reverse osmosis (RO) system. For example, a 10 by 5 by 3 vessel array indicates a three-stage RO system with 18 total vessels: stage one has 10 vessels, stage two has 5 vessels, and stage three has 3 vessels.

Wastewater: Untreated water collected in the sewer system from residences and businesses (e.g., from bathtubs, showers, bathroom sinks, clothes washers, toilets, kitchen sinks, dishwashers, and industrial processes). It consists of mostly water with some impurities. Also known as sewage.

Water Purification Demonstration Project (Demonstration Project): The second phase of the City of San Diego's Water Reuse Program. During this phase the Demonstration Facility will operate for approximately one year and will produce one million gallons of purified water per day. A study of the

San Vicente Reservoir is being conducted to test the key functions of reservoir augmentation and to determine the viability of a full-scale project. No purified water was sent to the reservoir during the demonstration phase.

Water Purification Demonstration Project (Demonstration Project) Report: Final report documenting the findings of the Demonstration Project.

Water purification process: The process of using water purification technology on recycled water to produce a water supply that can be used for reservoir augmentation and ultimately for drinking water purposes. The process of water purification starts with recycled water, which has already been treated to produce a supply of water safe enough for irrigation and industrial purposes. This recycled water is further treated with water purification technology. The resulting purified water can be used to augment local reservoir supplies, which would be treated once more at a potable water treatment plant to produce drinking water.

Water purification technology: The technology used for purifying treated wastewater, including membrane filtration with microfiltration (MF) or ultrafiltration (UF), reverse osmosis (RO), and ultraviolet (UV) disinfection and advanced oxidation.

Water reuse: The planned use of recycled water that would otherwise return to the natural hydrologic (water) system for a specific beneficial purpose.

Water Measurement Terms

Milligrams per liter (mg/L) also known as parts per million (ppm): A measurement describing the amount of a substance (such as a mineral, chemical or contaminant) in a liter of water; a unit used to measure water concentrations (parts of something per million parts of water). One part per million is equal to one milligram per liter. (This term is becoming obsolete as instruments measure smaller particles.) This is equivalent to one drop of water diluted into 50 liters (roughly the fuel tank capacity of a compact car) or about thirty seconds out of a year.

Micrograms per liter (µg/L) also known as parts per billion (ppb): A frequently used measurement for water concentration (parts of something per billion parts of water). One part per billion is equivalent to one second of time in 32 years or one drop of water in a typical backyard swimming pool (a typical residential swimming pool is 30 feet by 15 feet with an average depth of 6 feet or 60 cubic meters). One thousand parts per billion is equal to one part per million.

Nanograms per liter (ng/L) also known as parts per trillion (ppt): A very high level of measurement for water concentration (parts of a constituent per trillion parts of water). This is equivalent to one drop of water diluted into 20 London Olympics swimming pools (2,500 cubic meters times 20 = 50,000 cubic meters) or about three seconds out of every 100,000 years.

Million gallons per day (mgd): This term is used to describe the volume of water treated and distributed from a treatment plant daily.

Acre foot (AF): A unit of water commonly used in the water industry to measure large volumes of water. It equals the volume of water required to cover one acre to a depth of one foot. An acre-foot is 325,851 gallons and is considered enough water to meet the needs of two families of four with a house and yard for one year.

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Advanced Water Purification Facility Study Report

Executive Summary

The City of San Diego (City) has limited local water sources and relies on importing approximately 85 percent of its water supply. In the past, importing water from the Colorado River and Northern California has been a reliable option, but environmental stresses, court-ordered pumping restrictions in Northern California, and a historic dry period and drought on the Colorado River have reduced the amount of water that can be delivered to San Diego. These circumstances and the possibility of further limitations have intensified the need for new sources of water that are under local control.

As part of the City's effort to provide a local and sustainable water supply, the Water Purification Demonstration Project (Demonstration Project) evaluated the feasibility of indirect potable reuse through reservoir augmentation (IPR/RA) to provide safe and reliable water for San Diego. The Demonstration Project results will help the City to determine if IPR/RA is a feasible option for San Diego, and if the City should move forward with implementation.

One component of the multi-faceted Demonstration Project was the Advanced Water Purification (AWP) Facility Study. The AWP Facility Study included two primary elements: (1) the design, installation, operation, and testing of a one million gallon per day (mgd) Demonstration Facility located at the North City Water Reclamation Plant (North City) and (2) a conceptual design and cost estimate for a potential Full-Scale Facility (18-mgd capacity and 15-mgd annual average purified water production).

The following summarize the key findings of the AWP Facility Study, which are further discussed in this report:

- Over 9,000 water quality tests were performed throughout the testing period that demonstrated that the water purification process can reliably produce purified water that consistently meets all drinking water quality standards and anticipated reuse regulations.
- Beyond the 231 monitored constituents related to existing or anticipated regulations, 127 additional unregulated constituents were monitored (111 when accounting for duplication with regulated constituents), including unregulated constituents identified for monitoring by the U.S. Environmental Protection Agency (EPA) and other constituents and constituents of emerging concern (CECs) identified in the Testing and Monitoring Plan. Of the 111 additional constituents sampled, only six were found to be quantifiably detected in the purified water at any time.
- Sixteen constituents were monitored as potential performance indicators and removals generally exceeded 95 percent by reverse osmosis, and in some cases greater than 99.9 percent, indicating the integrity and performance reliability of the RO process. The advanced oxidation process was shown to further remove or destroy these constituents to below quantifiable levels.
- Water quality goals included nutrients, which are specific to Reservoir Augmentation. The Demonstration Facility produced water that was below the established water quality goals for nutrient removal. This information was used for the Demonstration Project to make conclusions about maintaining reservoir water quality.

- Energy consumption was monitored at the Demonstration Plant. Power costs make up a substantial portion of the operation and maintenance cost (O&M) costs (33 percent). Testing showed that utilizing a two-stage RO configuration equipped with energy recovery devices can reduce the energy consumption by up to 16 percent compared to operating full-scale facilities that use a three-stage configuration without energy recovery.
- The estimated capital cost for an 18-mgd Full-Scale Facility (excluding the purified water pump station and pipeline) is $144,700,000. The estimated annual O&M cost is $8,145,000.
- Almost 3,000 visitors toured the Demonstration Facility during the 13.5 month start up and testing period, supporting the City's goal to educate the public about the Demonstration Project.

ES.1 AWP Facility Study Background

The primary purpose of the City's Demonstration Facility is to demonstrate the feasibility of water purification technologies to produce purified water that can be sent to the San Vicente Reservoir, a raw water reservoir, to blend with existing water supplies. Prior to distribution to City water customers, water from the reservoir is treated at a drinking water treatment plant. To achieve this primary purpose, the following objectives were defined for the Demonstration Facility and the AWP Facility Study:

- Demonstrate the feasibility of an AWP Facility to reliably produce purified water that is consistently in compliance with all drinking water quality standards.
- Implement a monitoring plan for CECs that is tailored to the wastewater received at North City.
- Demonstrate integrity monitoring techniques and performance reliability measures for the treatment equipment.
- Generate data to be able to make conclusions on maintaining reservoir water quality.
- Assess energy consumption and develop energy conservation opportunities.
- Develop recommendations for design and operation of a Full-Scale Facility that assures only safe purified water leaves the plant.
- Develop a cost estimate for a Full-Scale Facility.
- Educate the public about the Demonstration Project through community outreach, informational materials, and AWP Facility tours.

Figure ES-1 represents the IPR/RA concept for the City's potential full-scale project and a schematic of the demonstration-scale project. The figure shows that wastewater, generated at our homes and businesses, is currently treated at North City to recycled water quality standards. The City uses the recycled water for traditional recycled water uses that include irrigation and industrial use. For the Demonstration Project, a portion of this recycled water is directed to the Demonstration Facility where it is treated by membrane filtration, reverse osmosis, and advanced oxidation. Since this is a demonstration project, the purified water is sent to the recycled water system. If the project is approved for full-scale, the purified water would be conveyed to the San Vicente Reservoir, as represented by the dashed arrow. After detention time in the reservoir, the water would be treated at

one of the City's drinking water treatment plants before being introduced into the drinking water distribution system to be used in our homes and businesses.

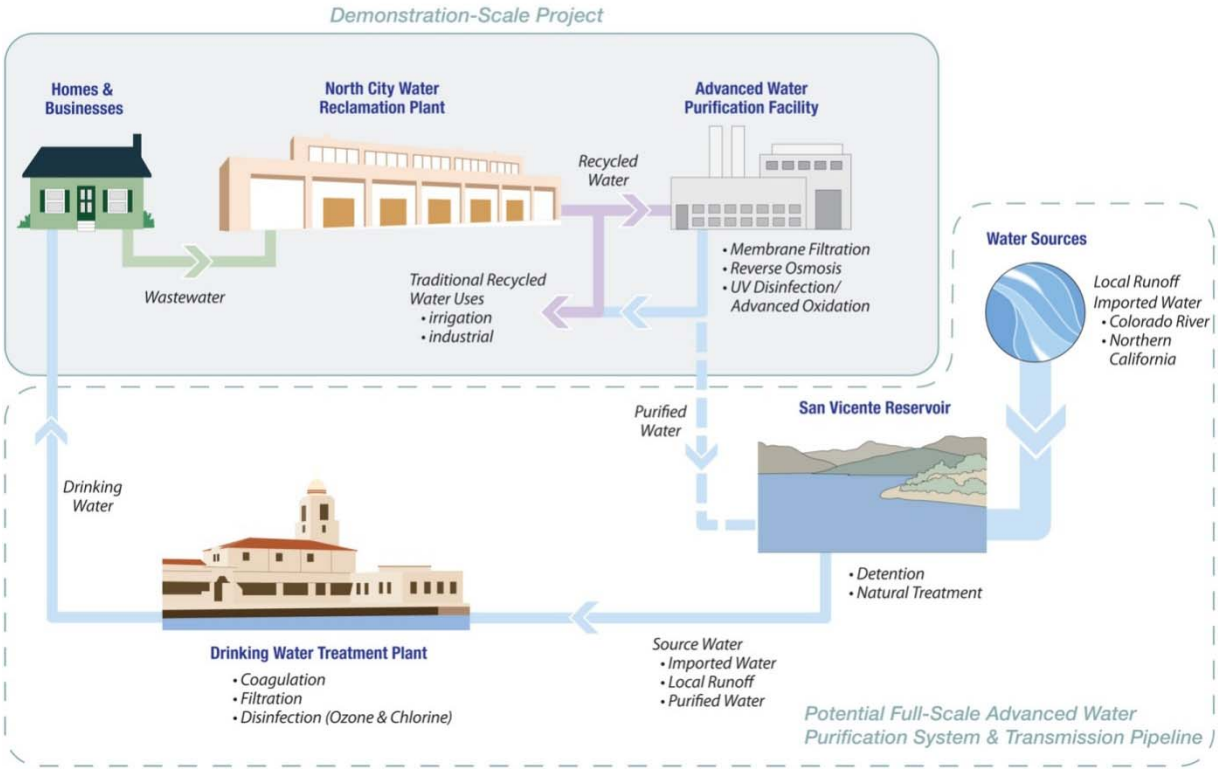


Figure ES-1
Demonstration-Scale and
Potential Full-Scale IPR/RA Projects Schematic

This AWP Facility Study Report summarizes the results and conclusions from the Demonstration Facility, and includes a conceptual design and cost estimate for a Full-Scale Facility. The overall Demonstration Project is summarized in the Demonstration Project Report. Additional discussion on the background of the overall Demonstration Project and the AWP Facility Study is presented in Section 1.

ES.2 Demonstration Facility Description and Observations

This section includes a description of the Demonstration Facility and an overview of the observations made during operations. This information is presented in more detail in Section 2.

ES.2.1 Demonstration Facility Description

The one-mgd Demonstration Facility is located at and treats recycled water produced by North City (tertiary effluent prior to chlorination) using the following water purification processes:

- Membrane filtration: parallel microfiltration (MF) and ultrafiltration (UF) systems
- Reverse osmosis (RO) system with two parallel trains to test two different configurations: two-stage (Train A) and three-stage (Train B)

- Ultraviolet (UV) light disinfection and advanced oxidation system

As shown in Figure ES-1, during the demonstration phase the purified water is returned to the North City recycled water system and is used for irrigation and industrial purposes. Figure ES-2 presents a flow diagram of the Demonstration Facility processes.

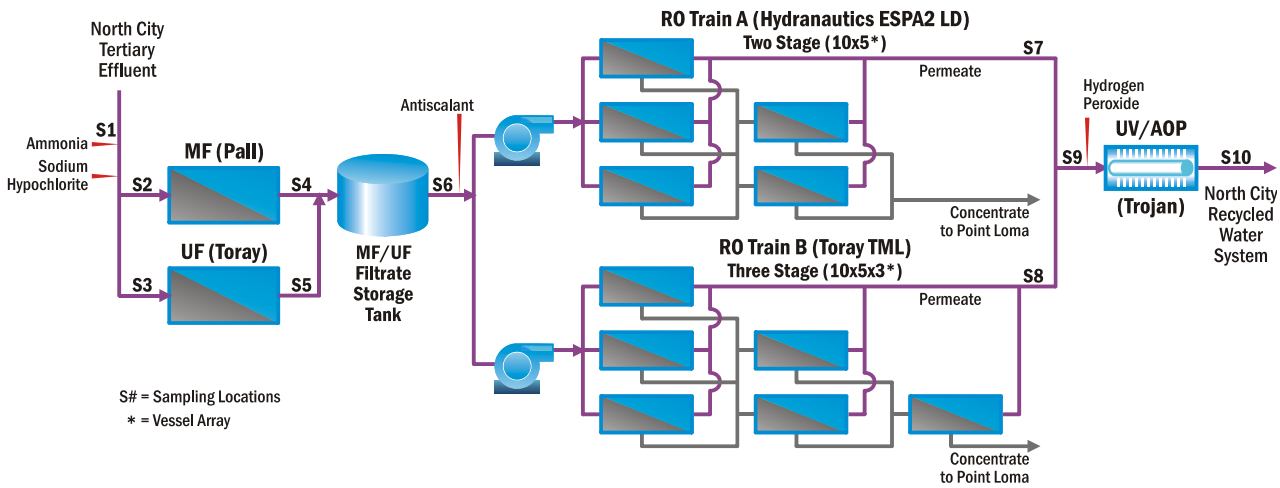


Figure ES-2
Demonstration Facility Processes

The Demonstration Facility was designed, installed, operated, and tested between 2010 and 2012, which is shown graphically in Figure ES-3. The facility start-up period was 1.5 months (mid-June 2011 through the end of July 2011) with full operational testing continuing for one year (August 2011 through July 2012). The results and conclusions from this 13.5-month period are the focus of this report. The Demonstration Facility is continuing to operate after the testing period for tours.

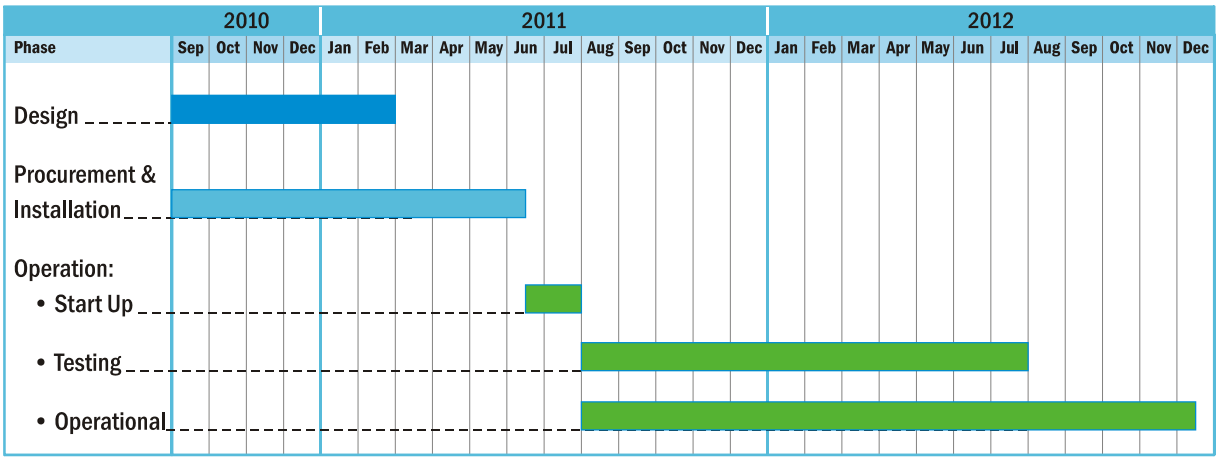


Figure ES-3
Demonstration Facility Schedule

During the testing period of the Demonstration Facility, the purified water and the integrity of the water purification processes were tested to determine the effectiveness of the processes in removing contaminants. Operational data were gathered and analyzed to refine O&M cost estimates for a Full-Scale Facility.

ES.2.2 Demonstration Facility Public Outreach and Tours

One of the objectives of the Demonstration Facility was to support public education and outreach activities to acquaint San Diego residents and stakeholders with the concepts and processes related to IPR/RA. The Demonstration Facility was designed and constructed to facilitate public tours as part of the City's ongoing Education and Outreach program.

The Demonstration Facility tours fulfilled four critical purposes:

- Introduce and graphically illustrate the water purification processes and technologies.
- Show how North City, the potential Full-Scale Facility, the approximately 23-mile pipeline, the San Vicente Reservoir, and the City's drinking water treatment plants work together to provide multiple barriers of protection.
- Communicate information about expert oversight and continuous monitoring of treatment processes to enhance public trust in the reliability of these facilities to provide a safe and clean supply of water.
- Place the water purification process in a water cycle context to reframe mental models about how water is continuously used and reused.

The Demonstration Project Public Education and Outreach program is summarized in the Demonstration Project Report.

ES.2.3 Summary of Operations

The Final Testing and Monitoring Plan (CDM Smith/MWH, 2011) established the testing program and water quality goals for the Demonstration Facility. The Testing and Monitoring Plan was reviewed and commented on by the Demonstration Project's Independent Advisory Panel (IAP), the California Department of Public Health (CDPH), and the San Diego Regional Water Quality Control Board (Regional Board). As a result of the comments received, the Testing and Monitoring Plan was expanded to include sampling for additional water quality parameters and increased frequency and number of samples for constituents that were identified in the draft plan. These comments and a description of how the comments were addressed are included as an appendix to the Testing and Monitoring Plan (the Testing and Monitoring Plan is included as Appendix A to this report). The first quarter testing and monitoring results were presented to the IAP in December 2011. As a result of the comments received, the third and fourth quarter sampling was focused on improving the correlation of indicator compounds for performance and integrity monitoring.

Full-time operation of the Demonstration Facility began on June 16, 2011. The operation and testing results were presented in quarterly reports over the operating period as summarized in Table ES-1. The data collected in previous quarters were included in subsequent reports (e.g., Quarterly Testing Report No. 3 includes data from Quarter 1 [Q1] through Quarter 3 [Q3]) and Quarterly Testing Report No. 4 and this report include all of the operations and testing results gathered over the one year operational testing period.

Table ES-1 Demonstration Facility Testing Periods

Testing Period	Testing Quarter	Operating Period		Report Date
		Test Period Start	Test Period End	
Testing Period 1	Quarter 1 (Q1)	6/16/2011	10/31/2011	December 2011
Testing Period 2	Quarter 2 (Q2)	11/1/2011	2/10/2012	March 2012
Testing Period 3	Quarter 3 (Q3)	2/11/2012	5/14/2012	June 2012
Testing Period 4	Quarter 4 (Q4)	5/15/2012	7/31/2012	September 2012

The following subsections summarize the operations of the membrane filtration, reverse osmosis, and UV disinfection and advanced oxidation systems.

ES.2.3.1 Membrane Filtration

The membrane filtration equipment used at the Demonstration Facility included two parallel 0.63-mgd systems, each treating half the facility flow. One system was a Pall MF system utilizing membranes with a nominal pore size of 0.1 micron, while the second system was an engineered UF system utilizing Toray membranes with a nominal pore size ten times smaller at 0.01 micron. Although both systems were expected to be efficient in removal of suspended solids, bacteria, and protozoa as the first step in the multi-barrier process, previous testing of UF membranes suggested that the smaller pore size might provide better treatment, but with potentially higher energy requirements (Reardon et al, 2006). Therefore, side-by-side testing was performed to determine the feasibility of using either MF or UF for the Full-Scale Facility.

Based on the similarities in operational performance and water quality performance, both MF and UF are suitable systems for membrane filtration in a Full-Scale Facility. For the Full-Scale Facility, pilot testing of the specific MF and UF systems being considered should be conducted to confirm recommended operating conditions and to allow the City to select the membrane filtration system on a lifecycle basis.

The results of the testing showed the following:

- **Recovery:** The MF system operated at a recovery of 93 percent, and the UF system operated at 95 percent recovery.
- **Chemical Cleaning:** Two chemical cleanings were conducted on both the MF and UF systems during Testing Periods 1 through 3, and one was conducted on the UF system during Testing Period 4. These cleanings were effective at restoring the performance to the level observed when the membranes were new.
- **Energy Use:** The side-by-side testing showed that the smaller pore size on the UF membrane did not result in higher pressure/energy requirements. The MF and UF system pressures and resulting energy consumption were essentially equal.
- **Water Quality:** Water quality monitoring of the MF and UF systems showed that both consistently produced water with similar concentrations for key water quality parameters including turbidity, total organic carbon (TOC), and UV 254 absorbance (UV254). Pathogen testing indicted that both MF and UF removed protozoa and bacteria to undetectable

concentrations. The MF was shown to remove more than 99 percent of the measured virus. The UF provided even greater virus removal, which was attributed to its smaller pore size.

ES.2.3.2 Reverse Osmosis

Two reverse osmosis configurations were tested for energy consumption and fouling characteristics: Train A, a two-stage configuration; and Train B, a three-stage configuration. Each RO train was equipped with an energy recovery device designed to transfer energy from the concentrate to the feed of the last stage, reducing the total energy required to treat the water and improving the flow balance between the stages. The different configurations were tested to compare hydraulic conditions and potential operating advantages of one configuration over the other. The two-stage configuration was anticipated to use less energy than the three-stage configuration; however, the three-stage configuration is more commonly used at other AWP facilities.

Two types of membranes were also tested to determine if one had higher removal of targeted constituents compared with the other (focusing primarily on expected differences in total nitrogen rejection).

The results of the testing showed:

- **Recovery:** For the first 8.5 months, both Trains A and B were operated at 80 percent recovery. For the last 3.5 months, both Trains A and B were operated at 85 percent recovery. Testing showed that both the two-stage and three-stage configurations can reliably operate at 85 percent recovery, although the rate of fouling in the final stage was higher for the three-stage configuration than the two-stage configuration.
- **Chemical Cleanings:** Per manufacturers' recommendations, two chemical cleanings were performed for Trains A and B.
- **Energy Use:** The power monitors on the RO system Train A (two-stage) and Train B (three-stage) showed that the three-stage configuration required on average 8 percent more energy than the two-stage configuration. An interstage boost from the energy recovery device resulted in an additional 8 percent energy reduction for Train A and 5 percent for Train B.
- **Water Quality:** The two types of membranes consistently produced water with nearly identical water quality characteristics. Nitrate rejection had been expected to be higher for the Train B membranes than the Train A, however, actual rejection was better than expected for Train A, and lower than expected in Train B, resulting in identical total nitrogen concentrations from both trains.

ES.2.3.3 Ultraviolet Disinfection and Advanced Oxidation

During the testing period, the UV disinfection and advanced oxidation system, which includes ultraviolet light and hydrogen peroxide, was operated to achieve a target 1.2-log (94 percent) removal of N-Nitrosodimethylamine (NDMA) and 0.5-log (68 percent) removal of 1,4-dioxane based on the 2008 CDPH Groundwater Replenishment Reuse Draft Regulations. While the NDMA removal requirement was removed in the most current draft regulations released in November 2011, the permit for the Full-Scale Facility will include NDMA permit limits based on the California Toxics Rule (CTR). Throughout the testing period, the UV disinfection and advanced oxidation process achieved the target NDMA and 1,4-dioxane removal defined in the 2008 and 2011 CDPH Groundwater Replenishment Reuse Draft Regulations.

The average electrical energy per order (EEO) value predicted for NDMA was 0.26 kWh/1000 gallons/log removal; however, when directly measured during the testing period, the EEO was better than projected ranging from 0.18 to 0.21 kWh/1000 gallons/log removal. This EEO is similar to the tested EEO of 0.19 to 0.23 kWh/1000 gallons/log removal for the UV disinfection and advanced oxidation system at the West Basin Municipal Water District's Edward C. Little Water Recycling Facility, a full-scale AWP Facility. The EEO observed for 1, 4-dioxane destruction ranged from 0.5 to 0.7 kWh/1,000 gallons/log removal with a peroxide dose of 2.5 mg/L. This EEO is similar to the EEO of 0.5 kWh/1,000 gallons/log removal reported by the Orange County Water District after initial testing at their Groundwater Replenishment System.

ES.2.4 Water Quality and Regulatory Relevance

This section discusses the water quality monitoring objectives and goals for the Demonstration Project, the regulatory relevance of the water quality monitoring results for regulated constituents, a summary of the water quality monitoring results for other non-regulated constituents, and results of the integrity and reliability monitoring conducted at the Demonstration Facility.

ES.2.4.1 Water Quality Monitoring Objectives and Goals

Water quality tests were performed before and after each water purification process (membrane filtration, RO, and advanced oxidation) and imported aqueduct water. Over 9,000 tests were performed to measure 342 constituents. These constituents included all 231 regulated constituents and 111 unregulated constituents, which are considered to be of potential concern for indirect potable reuse facilities.

The Testing and Monitoring Plan also identified 21 key water quality parameters to serve as a primary focus of the water quality testing, with project specific goals established for each parameter. These key constituents were identified because they can be challenging to remove by the treatment processes employed or because they are widely used parameters to measure performance of water treatment processes. Additionally, nutrients are a specific concern when introducing purified water to the San Vicente Reservoir, and five specific nutrient goals were identified as part of the key water quality parameters. A comparison of these key water quality results and the Demonstration Facility goals is presented in Table ES-2. The table shows that the average concentrations of all constituents measured in the purified water are below the established Demonstration Facility goals.

Table ES-2 Comparison of Key Water Quality Results and Demonstration Goals

Constituent		Units	Laboratory Reporting Level	Purified Water			Water Quality Goal[b]
				Number of Samples	Average Concentration[a]	Maximum Concentration	
Removal Challenge	Bromoform	µg/L	0.5	9	ND	ND	0.5
	Methylene Chloride	µg/L	0.50	9	ND	0.59	4.7
	Trihalomethanes, Total	µg/L	2.0	9	ND	ND	80
	Bromodichloromethane	µg/L	0.5	9	ND	0.7	0.56
	Dibromochloromethane	µg/L	0.5	9	ND	ND	0.5
	Haloacetic Acids (HAA5)	µg/L	1	9	ND	ND	60
	N-Nitrosodiethylamine (NDEA)	ng/L	2	12	ND	4.9	10
	N-Nitrosodimethylamine (NDMA)	ng/L	2	12	ND	5.5	2
	1,4-Dioxane	µg/L	0.5	16	ND	ND	1
	1,2-Dichloroethane	µg/L	0.5	16	ND	ND	0.5
	Boron	mg/L	0.01	28	0.23	0.29	1.0
Common Parameters	Total Organic Carbon[d]	mg/L	0.3	97	ND	ND	0.5
	Total Dissolved Solids	mg/L	10	29	14	19	300
	Chloride	mg/L	0.5	29	3.1	4.3	50
	Sulfate	mg/L	0.5	28	ND	1.1	65
	Turbidity	NTU	-	298	0.05	0.10	0.2
Nutrients	Nitrate as N	mg/L	0.11	74	0.65	1.2	1
	Nitrite as N	mg/L	0.09	71	ND	0.1	1
	Ammonia as N (unionized)	mg/L	varies[c]	71	<0.007[c]	0.027[c]	0.025
	Phosphorus, Total	mg/L	0.01	66	0.02	0.42	0.10
	Nitrogen, Total	mg/L	0.1	74	0.8	1.3	1

Notes:

a. Average concentration calculation assumes non-quantifiable results are half of the laboratory reporting level and non-detectable results are half of the method detection limit.

b. See Testing and Monitoring Plan, Table 5-2 (Appendix A).

c. Unionized values of ammonia were estimated based on EPA's *Aqueous Ammonia Equilibrium – Tabulation of Percent Un-ionized Ammonia (EPA-600/3-79-091)* using average values of temperature and pH measured on-site.

d. Laboratory results showed a single positive result of 1.4 mg/L on January 12, 2012. However, online monitoring for that same day recorded that the TOC was <0.1 mg/L. See Section 2.5.1 for more information on the online monitoring of TOC.

Acronyms:

ND – Not detectable or not quantifiable, shown for all values below laboratory reporting level
mg/L – milligrams per liter, equivalent to parts per million (ppm)
µg/L – micrograms per liter, equivalent to parts per billion (ppb)
ng/L – nanograms per liter, equivalent to parts per trillion (ppt)
NTU – Nephelometric Turbidity Units

ES.2.4.2 Water Quality Monitoring Results – Regulated Constituents

A full-scale IPR/RA project will be subject to requirements put forth by CDPH and the Regional Board. At this time, definitive requirements have not been established. However, results from the water quality monitoring show that the Demonstration Facility produced purified water that reliably met drinking water quality standards. The water also met all water quality requirements of the 2008 and 2011 CDPH Groundwater Replenishment Reuse Draft Regulations.

Water quality monitoring results relative to the current regulations and guidelines are summarized in Table ES-3:

- **Federal and State Drinking Water Maximum Contaminant Levels (MCLs)**
    - **Primary MCLs:** Results from the water quality monitoring show that the purified water consistently meets all primary MCLs established at both the federal and state levels. The federal drinking water MCLs are established by the U.S. Environmental Protection Agency (EPA) and the state MCLs are established by CDPH.
    - **Secondary MCLs:** The purified water met all numerical secondary drinking water MCLs, which are established for non-health based concerns.
    - **Microbial:** Microbial tests were all non-detect in the purified water.
- **CDPH Notification Levels:** During the testing period, the 30 constituents for which CDPH has established Notification Levels were monitored quarterly. Results from the monitoring show that the purified water was consistently below all the Notification Levels established by CDPH. These are advisory levels that require actions on the part of a water agency should concentrations in drinking water exceed the Notification Levels.
- **Groundwater Replenishment Reuse Draft Regulations:** The most recent Groundwater Replenishment Reuse Draft Regulations were issued in November 2011 as part of an informal stakeholder process prior to CDPH initiating a formal rulemaking process to adopt the regulations. Additionally, CDPH is currently developing draft regulations for the use of recycled water for surface water augmentation that have not been released for public review. For the time being, a reasonable assumption is that the CDPH water quality and treatment conditions for a groundwater recharge project that uses 100 percent purified water for groundwater recharge can be used as possible CDPH requirements for this project. Purified water from the Demonstration Facility met all of the water quality requirements in these draft regulations.
- **Regional Board Requirements for the Reservoir:** The San Diego Regional Board's Water Quality Control Plan (Basin Plan) has been established to preserve and enhance water quality and protect the beneficial uses of all regional water bodies. All of the requirements of the Basin Plan have not been defined for the Full-Scale Facility; however, it is expected that the Full-Scale Facility must comply with the Basin Plan numeric and narrative water quality objectives and the CTR criteria for Priority Pollutants. CTR is a federal regulation established to protect both aquatic life and human health by limiting surface water discharges based on 105 priority toxic pollutants. During the testing period, general parameters of the Basin Plan numeric objectives were sampled on a weekly, bi-weekly or monthly basis and Priority Pollutant testing was conducted quarterly. Results from the monitoring show that the purified water produced at the Demonstration Facility consistently met the Basin Plan objectives for those parameters that

have been defined. In addition, requirements have not yet been defined for the CTR, due to uncertainty regarding the applicability of mixing zones. The City will assess the water quality results of the Demonstration Facility and the final permit limits based on the remaining Basin Plan objectives and CTR criteria when they are established.

Table ES-3 Water Quality Monitoring Results of Regulated Constituents

Regulating Authority	Regulation and Guideline Group	Number of Constituents / Parameters	Total Number of Tests[1]	Purified Water Results
Federal and State MCLs	Primary Drinking Water MCL [2]	90	1,781	√ Meets all
	Secondary Drinking Water MCL [3]	18	1,290	√ Meets all
	Microbial [4]	4	1,547	√ Non-Detect
CDPH	CDPH Notification Level [5]	30	716	√ Below all
	CDPH Groundwater Replenishment [6]	142	2,244	√ Meets all
Regional Board	Regional Board Requirements for the Reservoir [7]	143	4,404	√ Meets all
	Total Number of Constituents / Parameters[8]	231[8]	7,523[8]	----------

Notes:

[1] The total number of tests represents the approximate number of tests conducted at all sample locations shown in Figure ES-2 and the Imported Raw Aqueduct Water.

[2] Maximum Contaminant Levels and Regulatory Dates for Drinking Water U.S. EPA VS. California November 2008.

[3] California Code of Regulation: Title 22, Division 4, Environmental Health Chapter 15. Domestic Water Quality and Monitoring Regulations Article 16. Secondary Water Standards. Purified water met all Federal and State Secondary MCLs with the exception of pH and corrosivity. The potential Full-Scale Facility would include post treatment to meet these requirements.

[4] EPA Total Coliform Rule (published 29 June 1989/effective 31 December 1990). Samples from the Demonstration Facility were analyzed for the following microbial contaminants: Total coliform, Fecal Coliform, and Viruses (Somatic and Male Specific Bacteriophage).

[5] Drinking Water Notification Levels and Response Levels: An Overview. CDPH Drinking Water Program Last Update: December 14, 2010.

[6] 2011 CDPH Groundwater Replenishment Reuse Draft Regulations. Purified water meets all numerical water quality requirements for indirect potable reuse via groundwater replenishment.

[7] EPA Numeric Criteria for Priority Pollutants Toxic Pollutants for the State of California Rule. Regional Board San Diego Basin Plan Numeric objectives; note, some objectives have not been defined.

[8] Because some constituents and parameters are in multiple regulations / guidelines the total of unique parameters is less than the sum.

ES.2.4.3 Water Quality Monitoring Results – Non-regulated Constituents

Additional non-regulated constituents were monitored at various locations in the purification process and the imported raw aqueduct water. These constituents are grouped into two main categories: those included in the 2012 EPA Unregulated Contaminant Monitoring Rule (UCMR3) and other CECs, such as pharmaceutical compounds and personal care products. In addition, lithium was monitored in the purified water, based on the recommendation of the Demonstration Project Independent Advisory

Panel, and six nitrosamine compounds were monitored beyond the two nitrosamine compounds (NDMA and N-Nitrosodiethylamine [NDEA]) already being tested for in the routine water sampling. All together, 127 non-regulated constituents were evaluated, 111 when accounting for duplication with regulated constituents.

Of the 111 additional non-regulated constituents sampled for at the Demonstration Facility, only six were found to be quantifiably detected in the purified water at any time, including three constituents from the UCMR3 list and three CECs. These six constituents are discussed further in Section 2 of this report. Table ES-4 provides a summary of the six constituents, including average and maximum values measured in both the purified water and imported raw aqueduct water. The following sections present the results for these compounds grouped as UCMR3 constituents and CECs.

Summary of UCMR3 Sampling Results

Results from the testing period show that 27 of the 30 compounds included in the UCMR3 were consistently below quantifiably detectable levels in the purified water. Three constituents, bromochloromethane, hexavalent chromium, and strontium, were quantifiably detected in the purified water. The first two of these constituents can be considered disinfection byproducts and may have been formed at low levels within the treatment processes. The third constituent is a naturally occurring metal used as a dietary supplement and in manufacturing. Additional information on these three constituents is presented in Section 2.4.4.

Summary of CEC Sampling Results

The CEC results in Table ES-4 (the last three constituents shown in the table) are presented in the units of nanogram per liter (ng/L). Analogies commonly used to describe the quantity represented by a concentration of one ng/L are 1 penny in 10 billion dollars or one drop in 20 Olympic-size swimming pools. When assessing low level CEC results such as these it is important to keep in mind that analytical variability and influence of false positive/negative results becomes a more significant issue at such minute levels. Technologies were not available to measure compounds at these low concentrations a decade ago, and there is still considerable debate about the significance of such low measured concentrations.

Results showed the RO and advanced oxidation process are effective at removing the majority of the CECs present in the North City tertiary effluent, and advanced oxidation further reduced the remaining constituents. For constituents found in significant concentrations in the tertiary effluent, the purification process achieved greater than 98 percent removal. Only three CECs were detected at quantifiable concentrations in the purified water. These compounds were iohexal, acesulfame-k, and triclosan. Additional information on these three constituents is discussed in Section 2.4.4.

Drinking Water Equivalent Levels

Since these UCMR3 and CEC constituents do not have regulatory limits, it can be difficult to interpret these water quality results. One method to interpret the results is to compare concentrations to the constituent's Drinking Water Equivalent Level (DWEL) or to an EPA identified Health Reference Level, when such information is available. DWELs and Health Reference Levels both represent an acceptable concentration in drinking water, assuming an average person consumes two liters of water (about 8.5 cups) per day over 70 years. DWELs are developed from tolerable daily intakes (TDIs) or acceptable daily intakes (ADIs), or EPA identified References Doses (RfDs), which all describe a daily dose below which risks to public health are judged to be minimal, assuming repeated daily exposure over a lifetime through consumption of drinking water. DWELs or Health Reference Levels were available for

all of the six constituents quantifiably detected in the purified water, with detected values between 18 times and 10 million times lower thant the associated DWEL or Health Reference Level.

Additional information on these six constituents and the potential significance of the measured concentrations are discussed Section 2.4.4.

Table ES-4 Summary of Other Non-regulated Constituents in Purified Water and Imported Raw Aqueduct Water (Detected Constituents of 111 Monitored)

Constituent	Classification/ Common Use	Units	Laboratory Reporting Level	Purified Water			Imported Raw Aqueduct Water		
				Number of Samples	Average Concentration[a]	Maximum Concentration	Number of Samples	Average Concentration[a]	Maximum Concentration
Bromochloromethane	UCMR3 Disinfection byproduct	µg/L	0.06	4	0.23	0.25	4	ND	0.08
Chromium (VI)[b]	UCMR3 Disinfection byproduct, industrial byproduct	µg/L	0.02	4	0.09	0.16	4	0.05	0.05
Strontium	UCMR3 Naturally occurring metal, Dietary Supplement	µg/L	0.3	4	ND	0.37	4	405	610
Acesulfame-K	CEC Sugar Substitute	ng/L	20	9	ND	50	4	343	370
Iohexal	CEC X-ray contrast agent	ng/L	10	9	ND	19	4	43	55
Triclosan	CEC Antibacterial	ng/L	10	9	ND	19	5	ND	ND

Notes:

a. Average concentration calculation assumes non-quantifiable results are half of the laboratory reporting level and non-detectable results are half of the method detection limit.

b. Three Chromium (VI) samples were sent to another lab and all results were below the detection limit of 0.0059 µg/L. The CDPH Detection Limit for purposes of Reporting (DLR) is 1 µg/L.

Acronyms:

ND – Not detectable or not quantifiable, shown for all values below laboratory reporting level
µg/L – micrograms per liter, equivalent to parts per billion (ppb)
ng/L – nanograms per liter, equivalent to parts per trillion (ppt)

ES.2.5 Integrity and Reliability Monitoring

Verifying the integrity and reliability of the water purification processes is critical to assure that only safe water leaves a Full-Scale Facility. To develop recommendations for monitoring at the Full-Scale Facility, the Demonstration Facility processes were evaluated closely. Integrity monitoring was conducted using a mix of direct and indirect methods during operations. In addition, a critical control-point monitoring plan was implemented to identify any changes in performance of the treatment processes that could adversely impact final water quality. Integrity monitoring and critical control point monitoring showed that the equipment remained intact, met the intended treatment performance on a continuous basis, and was reliable throughout the operational period. This evaluation process also made it possible to identify useful procedures for the Full-Scale Facility, as outlined in Section 4.3.

The critical control point monitoring implemented for the Demonstration Facility is summarized in Table ES-5. During the design phase for the Full-Scale Facility, the City would develop a similar on-line monitoring and response plan that provides sufficient features and assurances that any foreseeable malfunction could be promptly identified and appropriate responses applied.

Table ES-5 Summary of Demonstration Facility Critical Control Point Monitoring

Critical Control Point	Critical Limit Parameter	Monitoring Frequency	Alert Limit	Critical Limit	Example Corrective Actions
MF/UF	Pressure Decay	1 per day	Value above baseline that approaches critical limit.	0.4 psi / 5 min based on the maximum decay predicted to achieve 4-log removal Cryptosporidium	Confirm Results. Assess fiber breakage. Isolate/ repair/replace damaged membrane.
RO	TOC, Conductivity	Continuous	Percent change of measured concentration in combined RO permeate	Online permeate conductivity = 150 µS/cm. Online permeate TOC = 100 ppb or greater for five consecutive measurements.	Automatic shutdown (conductivity). Monitor individual RO trains. Verify analyzer accuracy. Conduct vessel probing.
UV	Reactor Power Level	Continuous	System ramps up 100% if 2 to 7 lamps fail or 1 to 3 ballasts fail	0% (8 or more lamp failures or 4 ballast failures)	System alarm. Automatic increase of reactor power to 100% or system shutdown. Check/ replace lamps and/or ballasts.
UV	Hydrogen peroxide dose rate/Continuous Flow Confirmation	1 per day by draw down Continuous flow confirmation	Minimum dose (~22 mL/min.) to provide 3 mg/L peroxide	0 mL/min indicating pump failure or loss of flow confirmation	Check dosing system. Recalibrate pump. Auto switch to standby pump.

Acronyms:

TOC – total organic carbon
mL/min – milliliters per minute
mg/L – milligrams per liter
psi – pounds per square inch
min – minute
µS/cm – microsiemens/centimeter
ppb – parts per billion, equivalent to micrograms per liter (µg/L)

The Demonstration Facility testing also included performance indicator monitoring to determine if any constituents could be used to indicate the treatment efficiency of the RO and advanced oxidation processes. Many of the constituents monitored at the Demonstration Facility were removed by the RO to levels at or below quantifiable limits, demonstrating strong performance of the RO process. Therefore, identifying usable performance indicators to accurately measure advanced oxidation removal was a challenge.

Sixteen constituents were monitored as performance indicators and removal generally exceeded 95 percent within the RO when sufficient quantities were present in the membrane filtration filtrate to calculate such removals. In some cases, greater than 99.9 percent removal was observed.

Surrogate compounds, such as TOC, conductivity, ammonia, monochloramines, and UV 254, may prove to be more reliable as CEC removal performance indicators due to their ease of measurement and their reliable presence in the water downstream of both the RO and advanced oxidation. For the RO process, the average removal results were: TOC = 99.6 percent, conductivity = 99.0 percent, and UV254 = 88.8 percent. For the advanced oxidation process, the average removal results were: UV254 = 68.7 percent and monochloramines = 72.8 percent.

The results of the performance indicator monitoring are summarized in Table ES-6.

Table ES-6 Performance Indicator Monitoring Results

Category	Compound	Units	Average RO Feed	Average RO Perm.	Average UV/AOP	RO Removal	UV/AOP Removal
CEC Potential Indicators	Acesulfame-K	ng/L	33,000	<27	<22	>99.9%	>16.5%
	Amoxicillin	ng/L	220	<6.4	<6.4	>97%	-
	Carbamazepine	ng/L	190	<5	<1.2	>99%	-
	Dilantin	ng/L	120	<13	<13	>88.8%	-
	Diuron	ng/L	77	<1.8	<5	>97.7%	-
	Fluoxetine	ng/L	84	<10	<10	>88%	-
	Lidocaine	ng/L	170	<1.1	<1.1	>99.3%	-
	Lopressor	ng/L	340	<20	<5.1	>97.6%	-
	NDMA	ng/L	3	<2	<0.96	>65.5%	-
	Primidone	ng/L	100	<4.8	<4.8	>95.4%	-
	Sucralose	ng/L	55,000	<100	<42	>99.9%	-
	Sulfamethoxazole	ng/L	950	<2.8	<2.8	>99.7%	-
	TCEP	ng/L	300	<10	<10	>98.3%	-
	TCPP	ng/L	2,000	<100	<100	>97.6%	-
	Triclosan	ng/L	48	<10	<10	>84.1%	-
	Trimethoprim	ng/L	330	<5	<5	>99.1%	-
Online Monitoring Surrogates	Conductivity	µS/cm	1,348	14	--	99.0%	--
	Monochloramine	mg/L	--	3.14	0.85	--	72.8%
	TOC	mg/L	7.2	0.031	--	99.6%	--
	UV254	cm^{-1}	0.158	0.018	0.006	88.8%	68.7%

Notes:

a. For calculating average concentrations, results reported below the laboratory reporting level were considered the value of the laboratory reporting level and for values reported below the method detection limit, the value of the method detection limit was used.

b. Dashes are shown for values that were not measured or could not be calculated.

Acronyms:

mg/L – milligrams per liter, equivalent to parts per million (ppm)
µS/cm – microSiemens per centimeter
cm^{-1} – centimeters to the negative first power
ng/L – nanograms per liter, equivalent to parts per trillion (ppt)

ES.3 Full-Scale Facility Considerations

This section describes design considerations for the Full-Scale Facility that were developed based on the Demonstration Facility operations. Since energy conservation will be a major focus of the Full-Scale Facility, design considerations related to energy conservation are summarized in Section ES.3.1. Other design considerations are summarized in Section ES.3.2. See Section 3 for more information.

ES.3.1 Energy Conservation

Water purification processes are energy intensive and power costs are a substantial part (33 percent) of the annual operations cost for an AWP facility. Therefore, one of the objectives of Demonstration Facility was to understand the power requirements of a Full-Scale Facility and identify potential energy conservation opportunities. These energy conservation opportunities are summarized below.

Membrane Filtration

- **AWP Facility Influent Pumps:** The pumps should be equipped with variable frequency drives making it possible to efficiently ramp up and ramp down pump speed.
- **Membrane Filtration Overall Power Requirements:** The membrane filtration system for the Full-Scale Facility should be selected based on a lifecycle cost evaluation that takes power usage into account. Candidate membrane filtration systems should be pilot tested to gather actual operational data to be used for the lifecycle bid evaluation.

Reverse Osmosis

- **Two-stage RO System:** The power monitors on the RO system Train A (two-stage) and Train B (three-stage) showed that the two-stage configuration required on average 8 percent less energy than the three-stage configuration. A two-stage RO system should be considered to reduce the overall Full-Scale Facility power usage.
- **Energy Recovery Devices:** Energy recovery devices used at the Demonstration Facility were shown to reduce the energy use by 8 percent. Manufacturer's projections were used to estimate the efficiency of the energy recovery devices for the Full-Scale Facility. Based on these projections, energy recovery devices are estimated to reduce energy use by 4 percent to 7 percent over the life of the membranes, which equates to a payback period of less than six years for the future Full-Scale Facility.

UV Disinfection and Advanced Oxidation

- **Electrical Energy per Order**: Multiple UV vessels in series should be considered to improve reactor hydraulics to further reduce the energy requirements. Candidate UV system suppliers should be pilot tested to gather actual operational data from alternative UV systems to be used for the lifecycle bid evaluation.
- **UV Reactor Controls:** The design for the Full-Scale Facility should optimize the UV system to provide effective treatment allowing power to increase only to the extent needed to respond to lamp and/or ballast failure.

ES.3.2 Other Full-Scale Facility Considerations

In addition to energy, additional design considerations for the Full-Scale Facility are summarized in Table ES-7.

Table ES-7 Other Full-Scale Facility Considerations

Design Consideration	Effect
Membrane Filtration System	
Evaluate multiple manufacturers	• Promote competitive bidding • Determine best available equipment
Increase flux rate	• Smaller facility footprint • Reduce capital cost • Increase fouling, operational pressure, and O&M costs
Use of chemically enhanced backwashes	• Decreased clean in place frequency • Increase chemical usage
Reverse Osmosis	
Evaluate multiple manufacturers	• Promote competitive bidding
85 percent recovery	• Maximize water production
Increase flux rate	• Smaller facility footprint • Reduce capital cost • May improve hydraulics and reduce fouling/scaling potential
Add pH suppression capability	• Reduce potential fouling if water quality changes
UV Disinfection and Advanced Oxidation	
Evaluate multiple manufacturers	• Promote competitive bidding • Determine best available equipment
Reduce hydrogen peroxide dose	• Reduce chemical usage

ES.4 Full-Scale Facility Conceptual Design

A conceptual design for the Full-Scale Facility was developed consistent with the water purification processes that were operated at the Demonstration Facility. The Full-Scale Facility conceptual design is described in detail in Section 4. The design consists of the following components:

- AWP Facility influent pump station.
- Membrane filtration (MF or UF) system, which includes pretreatment chemical addition (chloramination for biofouling control) and break tank.
- RO system, which includes RO transfer pumps, cartridge filters, RO feed pumps, RO pre-treatment chemical addition (antiscalant and sulfuric acid for scale control).
- UV disinfection and advanced oxidation using ultraviolet light with hydrogen peroxide.
- Post treatment/stabilization chemical addition (pH and LSI adjustment for corrosion control).
- Purified water pump station and approximately 23-mile pipeline to San Vicente Reservoir (see the Purified Water Conveyance System Final Conceptual Design Report for more information).

The City's Full-Scale Reservoir Augmentation Capacity Analysis Technical Memorandum (RMC, 2011) has defined a capacity for the Full-Scale Facility of 18 mgd, which considers the capacity of North City and the need to continue supplying recycled water to existing and planned customers. Design criteria and preliminary equipment layouts are presented for the 18-mgd capacity Full-Scale Facility in Section 4. The capital cost estimates presented in Section 5 are based on a capacity of 18 mgd, while the O&M cost estimates are based on an annual average production of 15 mgd.

The proposed project site will be located on the property immediately north of North City. Process areas not enclosed in a building will be installed under canopies. A pipe gallery/access tunnel will be provided under Eastgate Mall Road, connecting North City just west of the guard shack to the Full-Scale Facility.

North City treats wastewater flows that would otherwise be treated at the Point Loma Wastewater Treatment Plant (Point Loma). North City can divert flow to Point Loma and go offline any time either by ceasing diversion from the sewer or diverting off-specification water back to the sewer for treatment at Point Loma. The Full-Scale Facility will also have the capability to go offline by ceasing to receive recycled water from North City. Because the Full-Scale Facility has the ability to shut-down at any time, the conceptual facility design includes limited redundancy. The redundancy provided will allow the Full-Scale Facility to continue to operate at capacity when a single unit is offline for maintenance or cleaning.

Instrumentation and automation will be provided to continuously verify conditions are maintained for sustainable operation and effective treatment. The controls system is provided with this electronic monitoring so that if a problem is detected in the system, then the system will automatically shut itself down to prevent water that does not meet the water quality requirements from being introduced into the reservoir. Manual checks will also be made of water produced by individual units within each system to identify operational trends and detect anomalies that require attention. These electronic systems controls and manual procedures, in concert with the critical control point monitoring described in Section ES.2.5, will assure that only safe water leaves the Full-Scale Facility.

ES.5 Estimated Costs

This section summarizes the estimated capital and O&M costs for the Full-Scale Facility, as well as for the Full-Scale Project.

ES.5.1 Estimated Costs for the Full-Scale Facility

The estimated capital costs was prepared based on the conceptual design for an 18-mgd Full-Scale Facility and O&M cost estimates were based on an annual average production of 15 mgd. For the construction cost, Appendix D includes a breakdown of each of the process areas and buildings. The construction cost includes the contractor direct costs plus construction allowances, permits and sales tax.

The O&M cost estimate is based on the preliminary design criteria developed for the Full-Scale Facility (see Section 4) and considers power costs, chemical costs, equipment replacement costs, maintenance costs, and labor costs. The average power demand for the Full-Scale Facility (annual average purified water production of 15 mgd) is approximately 2.1 to 3.1 megawatts, and the estimated total annual power consumption is 18,200,000 to 27,400,000 kilowatt-hours per year (kWh/yr).

The estimated capital and O&M costs for the Full-Scale Facility are presented in Table ES-8 and Table ES-9, respectively. Additional detail is provided in Section 5.

The estimated O&M cost for the Full-Scale Facility was compared to the O&M cost of the Demonstration Facility. The estimated O&M costs for the Full-Scale Facility for most of the unit processes are within 5 to 30 percent of the O&M costs for the Demonstration Facility. The differences are within an appropriate level of contingency, since the Demonstration Facility was operated within the first year of the equipment and membrane life, and many variables are anticipated to change over the course of the facility operation as the membrane filtration and RO membranes age. Additional discussion of the differences between the assumptions for the Full-Scale Facility and the operations data collected at the Demonstration Facility are included in Section 5.

Table ES-8 Estimated Construction Cost for the Full-Scale Facility

Parameter	Capital Cost[2,3]
Construction Costs[4]	
AWP Facility Influent Pump Station	$2,800,000
Site Civil/Yard Piping[5,6]	$5,800,000
Operations, Maintenance, and Administration Building	$1,600,000
Membrane Filtration Break Tank and Pump Station	$4,000,000
Chemical Storage Area #1 (Pre-Treatment Chemical Facility)[7]	$2,400,000
Membrane Filtration Facility[8]	$25,300,000
Reverse Osmosis Facility[9]	$21,300,000
UV Disinfection and Advanced Oxidation System[10]	$9,900,000
Chemical Storage Area #2 (Post-Treatment Chemical Facility)[11]	$2,100,000
Construction Subtotal	**$75,200,000**
Contingency (30% of Construction Total)	$22,600,000
Overhead & Profit	$9,800,000
Insurance & Bond	$2,900,000
Construction Total	***$110,500,000***
Implementation Costs	
Engineering & Pre-Construction (20% of Total Construction Cost)	$22,100,000
Environmental Documentation	$1,000,000
Construction Management (10% of Total Construction Cost)	$11,100,000
Implementation Total	***$34,200,000***
Total Capital Cost (Construction Total + Implementation Total) [12]	**$144,700,000**

Notes:

1) This table presents costs for the Full-Scale AWP Facility only. For costs related to the Purified Water Pump Station and Purified Water Pipeline, refer to Table ES-10 and the Demonstration Project Report.
2) Includes installation costs and indirect costs (project management, field management and support, training, quality assurance and control, project safety, construction allowances, permits, and sales tax).
3) All costs are in February 2012 dollars. The Engineering News Record (ENR) Construction Cost Index is 9267.57 and the ENR Building Cost Index is 5144.49 for February 2012.
4) Construction duration is assumed to be 30 months. Based on a 40 hour work week with no overtime.
5) No rock excavation is assumed to be required. Only nominal dewatering is assumed to be needed. No consideration for contaminated soils or hazardous materials (e.g. asbestos, lead) is included. Site grading, drainage and containment are included with assumptions made based on the aerial photograph.
6) Includes pressure membrane filtration feed pipeline, gravity membrane filtration backwash, pressure RO concentrate pipelines, and chemical feed pipelines.
7) Includes sodium hypochlorite, ammonium hydroxide, sulfuric acid, and antiscalant.
8) Includes citric acid and sodium hydroxide system for membrane filtration chemical cleaning systems.
9) Includes cartridge filters and RO feed pumps.
10) Hydrogen peroxide system is included with the UV disinfection and advanced oxidation system.
11) Includes calcium chloride and sodium hydroxide.

Table ES-9 Estimated Annual O&M Costs for the Full-Scale Facility

Parameter	Annual O&M Cost[1]
Power Costs[2]	
AWP Facility Influent Pump Station	$306,000
Membrane Filtration System	$43,000
Reverse Osmosis System	$1,614,000
UV Disinfection and Advanced Oxidation System	$185,000
Miscellaneous Equipment	$7,000
Buildings	$481,000
Power Costs – Subtotal	***$2,636,000***
Chemical Costs	
Membrane Filtration Pretreatment	$223,000
Reverse Osmosis Pretreatment	$431,000
Hydrogen Peroxide for Advanced Oxidation	$216,000
Post Treatment	$358,000
Membrane Cleaning	$103,000
Chemical Costs – Subtotal	***$1,331,000***
Replacement of Consumables (Equipment Replacement)	
Membrane Filtration Membranes	$441,000
Reverse Osmosis Cartridge Filters and Reverse Osmosis Membranes	$319,000
UV Lamps and Ballasts	$281,000
Replacement of Consumables – Subtotal	***$1,041,000***
Maintenance Costs[3]	***$1,409,000***
Other Costs (Compliance Testing and Security)[4]	***$310,000***
Labor Costs[5]	***$1,418,000***
Total Annual O&M Cost	**$8,145,000**

Notes:

1) All costs are in February 2012 dollars.
2) Power cost is assumed to be $0.12 per kilowatt-hours (kWh).
3) Assumed to be 1.7% of the equipment construction cost based on a review of actual maintenance costs for the Orange County Water District's Groundwater Replenishment System.
4) The annual compliance testing cost is assumed to be $150,000/year. This is based on half of the Demonstration Facility compliance testing cost of $300,000/year.
5) Estimated staffing = 12 personnel plus outside lab allowance, based on information provided by the City. The estimated staffing of 12 personnel was based on assessment of the department wide resources and additional needs to support and integrate this new facility as part of the City's existing treatment facilities. However, it is anticipated that this labor estimate will be updated in the future when the full-scale facility is constructed and the evaluation of new treatment technology provided at that time.
6) This table presents costs for the Full-Scale Facility only. For costs related to the Purified Water Pump Station and Purified Water Pipeline, refer to Table ES-11 and the Demonstration Project Report.

ES.5.2 Estimated Costs for the Full-Scale Project

The estimated costs for the Full-Scale Project incorporate the Full-Scale Facility, Purified Water Pump Station, and the Purified Water Pipeline. Table ES-10 presents the estimated construction costs for the Full-Scale Project, Table ES-11 presents the estimated O&M costs for the Full-Scale Project, and Table ES-12 presents the estimated additional auxiliary program costs to support the Full-Scale Project. The Full-Scale Project and the associated costs are discussed in more detail in the Demonstration Project Report

Table ES-10 Estimated Construction Costs for the Full-Scale Project

Parameter	Capital Cost
Total Full-Scale Facility Capital Cost (Construction Total + Implementation Total)[1]	**$144,700,000**
Purified Water Pipeline System Construction Costs[2]	
Purified Water Pump Station	$8,000,000
Purified Water Pipeline	$114,200,000
Pipeline System Construction Total	***$122,200,000***
Pipeline System Implementation Costs	
Contingency (30% of Construction Total)	$36,700,000
Engineering & Construction Management (30% of Construction Total)[3]	$36,700,000
Environmental Documentation and Mitigation	$24,400,000
Land Acquisition	$4,500,000
Pipeline System Implementation Total	***$102,300,000***
Total Pipeline System Capital Cost (Construction & Implementation)[2]	**$224,500,000**
Total Capital Cost (Full-Scale Facility and Pipeline System)	**$369,200,000**

Notes:
1) Refer to Table ES-8 for a breakdown of the Full-Scale Facility construction costs.
2) From the Demonstration Project Report.
3) Includes costs associated with regulatory compliance and permitting.

Table ES-11 Estimated Annual O&M Costs for the Full-Scale Project

Parameter	Annual O&M Cost[1]
Full-Scale Facility[1]	$8,145,000
Treatment at North City to Support Full-Scale Facility[2]	$3,965,000
Purified Water Pump Station[2,3]	$1,885,000
Purified Water Pipeline[2,4]	$1,500,000
Total Annual O&M Cost	**$15,495,000**

Notes:
1) Refer to Table ES-9 for a breakdown of the Full-Scale Facility O&M costs.
2) From the Demonstration Project Report.
3) Includes power and maintenance.
4) Includes maintenance.

Table ES-12 Estimated Auxiliary Program Costs for the Full-Scale Project[1]

Parameter	Auxiliary Cost
Auxiliary Upfront Cost	
Source Control Program Upfront Cost[2]	$500,000
Auxiliary Annual Cost	
Source Control Program Annual Costs[3]	$50,000
Public Outreach Annual Program Costs[4]	$700,000

Notes:

1) From the Demonstration Project Report.
2) Source control upfront costs include a chemical inventory program and GIS tracking database (approximately $50,000), a pollutant prioritization program to be completed by existing City staff (approximately $50,000 for initial set-up work), and a local limits evaluation for North City (approximately $400,000). For additional information on source control program costs, refer to the Enhanced Source Control Plan for the Full-Scale Advanced Water Purification Facility Technical Memorandum (RMC, 2013).
3) Source control annual costs include $25,000/yr for annual updates to the chemical inventory program and GIS tracking database, an average of $10,000/yr for periodic updates to the pollutant prioritization program, and $15,000/yr, on average, for updates to the local limits analysis. For additional information on source control program costs, refer to the Enhanced Source Control Plan for the Full-Scale Advanced Water Purification Facility Technical Memorandum (RMC, 2013).
4) Public outreach annual costs include initial start-up of outreach efforts. Annual public outreach costs will be scaled back following full-scale reservoir augmentation project operations.

ES.6 Conclusions

The primary purpose of the City's Demonstration Facility was to demonstrate the feasibility of water purification technologies to produce purified water for the City to determine the feasibility of a full-scale IPR/RA project. A full-scale project would assist with the City's effort to provide a local and sustainable water supply. To achieve this primary purpose, the following objectives were defined for the Demonstration Facility and the AWP Facility Study:

- Demonstrate the feasibility of an AWP Facility to reliably produce purified water that is consistently in compliance with all drinking water quality standards.
- Implement a monitoring plan for constituents of emerging concern (CECs) that is tailored to the wastewater received at North City.
- Demonstrate integrity monitoring techniques and performance reliability measures for the treatment equipment.
- Generate data to be able to make conclusions on maintaining reservoir water quality.
- Assess energy consumption and develop energy conservation opportunities.
- Develop recommendations for design and operation of a Full-Scale Facility that assures only safe purified water leaves the plant.
- Develop a cost estimate for a Full-Scale Facility.
- Educate the public about the Demonstration Project through community outreach, informational materials, and AWP Facility tours.

The Demonstration Facility and AWP Facility Study met all of these established objectives and the results of this project are supporting the City's pursuit of a full-scale IPR/RA project. Table ES-13 summarizes how the each objective was met.

Table ES-13 Demonstration Facility and AWP Facility Study Objectives and Key Findings

Objectives	Key Findings
Demonstrate the feasibility of an AWP Facility to reliably produce purified water that is consistently in compliance with all drinking water quality standards.	Water quality monitoring throughout the testing period demonstrated that membrane filtration, followed by RO, and UV disinfection and advanced oxidation can reliably produce water that meets or exceeds all of the drinking water requirements and also provides multiple barriers for regulated and unregulated chemical and microbial constituents.
Implement a monitoring plan for constituents of emerging concern (CECs) that is tailored to the wastewater received at North City.	Key constituents and water quality goals for each were identified in the Testing and Monitoring Plan. The average concentration of each constituent measured in the purified water is below the established Demonstration Facility goals.
Demonstrate integrity monitoring techniques and performance reliability measures for the treatment equipment.	Sixteen constituents were monitored as performance indicators, and removal generally exceeded 95 percent in the RO. In some cases, greater than 99.9 percent removal was observed, demonstrating strong performance of the RO process. Five surrogate compounds were also identified. The RO process averaged 99 percent or greater removal for TOC and conductivity and 88.8 percent for UV254. The advanced oxidation process further removed UV254 by 68.7 percent and monochloramines by 72.8 percent.
Generate data to be able to make conclusions on maintaining reservoir water quality.	143 constituents/parameters were monitored based on anticipated Regional Board requirements for the San Vicente Reservoir. The results were used to conclude that the addition of purified water would not impair existing conditions of the San Vicente Reservoir, and could improve nutrient-related water quality issues as further discussed in the Demonstration Project Report.
Assess energy consumption and develop energy conservation opportunities.	Energy consumption was monitored at the Demonstration Plant and, combined with experience from other Full-Scale Plants, energy conservation opportunities for the Full-Scale Facility were recommended. Energy recovery devices tested at the Demonstration Facility were successful in reducing energy consumption and are estimated to reduce energy use at a Full-Scale Facility by 4 to 7 percent over the life of the membranes. Use of a two-stage RO configuration at the Full-Scale Facility instead of a three stage RO configuration will reduce energy consumption by approximately 8 percent, while producing the same quality and quantity of RO permeate.
Develop recommendations for design and operation of a Full-Scale Facility that assures only safe purified water leaves the plant.	Design criteria, purification process layouts, system controls, and monitoring for a Full-Scale Facility were developed to assure that only water that meets all drinking water standards leaves the plant.
Develop a cost estimate for a Full-Scale Facility.	Operational data and observations collected from the Demonstration Facility testing period were used to estimate construction costs and annual operation and maintenance costs for a Full-Scale Facility. For a Full-Scale Facility with 18-mgd capacity with an annual average production of 15 mgd, the estimated capital cost is $144,700,000, and the estimated annual O&M cost is $8,145,000.
Educate the public about the Demonstration Project through community outreach, informational materials, and AWP Facility tours.	Almost 3,000 visitors toured the Demonstration Facility during the 13.5-month start up and testing period.

Section 1
Introduction

This report summarizes the results of the City of San Diego (City) Advanced Water Purification (AWP) Facility Study, conducted as part of the City's multi-faceted Water Purification Demonstration Project (Demonstration Project). The Demonstration Project evaluated the feasibility of indirect potable reuse through reservoir augmentation (IPR/RA) to provide safe and reliable water for San Diego.

The AWP Facility Study included two primary elements: (1) the design, installation, operation, and testing of a 1 million gallon per day (mgd) Demonstration Facility located at the North City Water Reclamation Plant (North City) and (2) a conceptual design and cost estimate for a potential Full-Scale Facility (18-mgd capacity and 15-mgd annual average purified water production), which would be located north of North City. This introduction section includes background information on both the overall Demonstration Project and the AWP Facility Study, as well as an overview of this AWP Facility Study Report.

1.1 Demonstration Project Background

The City has limited local water sources and relies on importing approximately 85 percent of its annual water supply. In the past, importing water from the Colorado River and Northern California has been a reliable option, but environmental stresses, court-ordered pumping restrictions in Northern California, and a historic dry period and drought on the Colorado River have reduced the amount of water that can be delivered to San Diego. These circumstances and the possibility of further limitations have intensified the need for new sources of water that are under local control.

One such source being considered is the use of IPR/RA. IPR/RA is a multi-step process that uses water purification technologies to produce purified water from a wastewater source, sending this purified water to the San Vicente Reservoir to blend with existing water in the reservoir, treating the blended water at a drinking water plant, and then distributing the drinking water to City water customers. This form of potable reuse is considered "indirect" because of the environmental buffer and natural treatment which occur within the reservoir before the water is used as a source of drinking water supply.

The potential benefits of implementing an IPR/RA program in San Diego could include:

- Providing a local and sustainable supply of high-quality drinking water for San Diego,
- Improving the quality of water in the San Vicente Reservoir,
- Decreasing dependence on imported water,
- Increasing utilization of recycled water,
- Providing a supply of water that uses less energy than imported water, and
- Having a positive impact on the environment by producing less discharge into the ocean and working toward lower carbon emissions.

The IPR/RA concept for the City is shown in Figure 1-1. For the Demonstration Project, the one-mgd Demonstration Facility treats recycled water (tertiary effluent prior to chlorination) from North City using membrane filtration (microfiltration [MF] and ultrafiltration [UF]), reverse osmosis (RO), and ultraviolet (UV) light disinfection and advanced oxidation to produce purified water. During the demonstration phase, the purified water is returned to the North City recycled water system and is used for irrigation and industrial purposes.

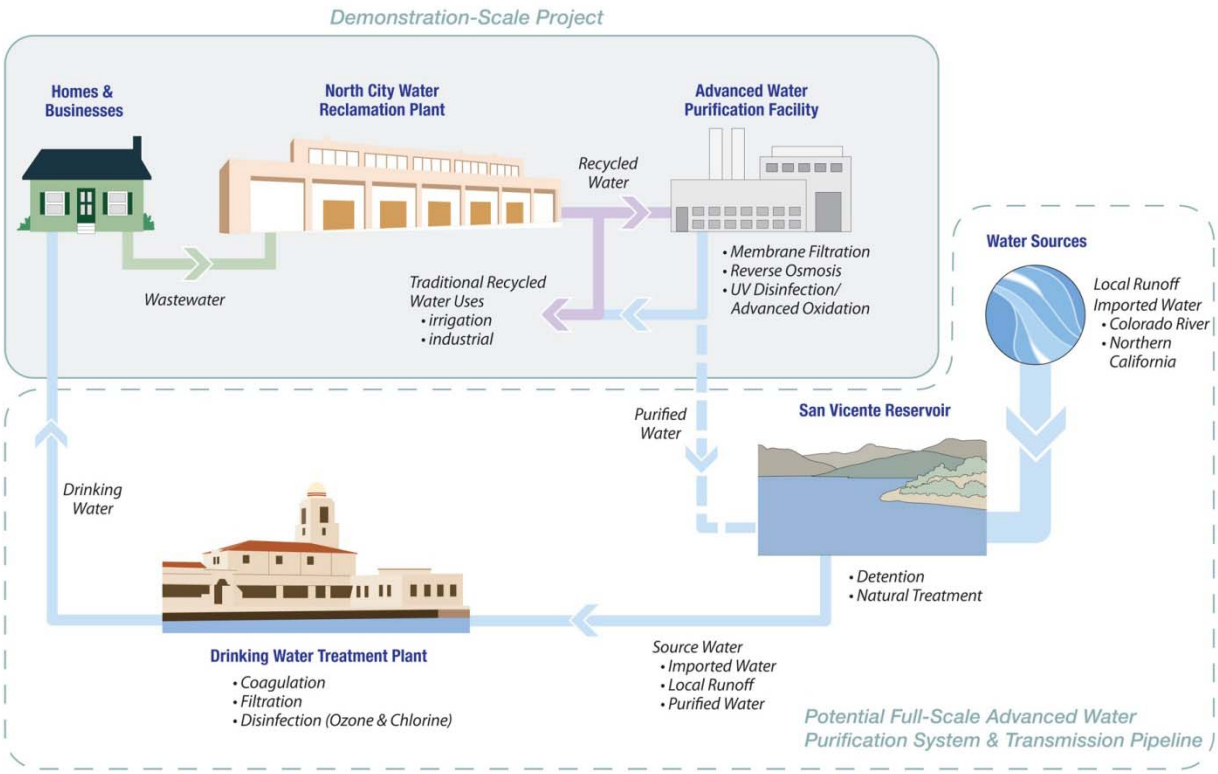


Figure 1-1
Demonstration-Scale and
Potential Full-Scale IPR/RA Projects Schematic

The City has initiated the Demonstration Project to evaluate the feasibility of using IPR/RA to provide a new source of local water to meet future water supply needs. The Demonstration Project is the second phase of the City's three-phase Water Reuse Program, which seeks to maximize the reuse of recycled water and purified water. The three phases are as follows:

- **Phase I:** In 2006, the City completed the Water Reuse study, which identified a series of strategies that could be implemented to increase water reuse in San Diego. The Water Reuse Study stakeholders and the San Diego City Council (City Council) independently identified augmentation of the City's San Vicente Reservoir with purified wastewater as their preferred alternative to meet the City's water reuse goals. On July 19, 2006, the City's Natural Resources and Culture Committee (NR&C) accepted the Final Draft Report of the Water Reuse Study (Phase I) as fulfilling City Resolution R-298781. On October 29, 2007, the City Council voted to accept the Water Reuse Study and directed the Mayor and City staff to implement actions to

demonstrate the feasibility of the IPR/RA concept. Through this and other City Council directives, the components of the Demonstration Project were clarified.

- **Phase II:** This phase of the City's Water Reuse Program is the Demonstration Project, in which the feasibility of augmenting San Vicente Reservoir supplies with purified water is being examined.
- **Phase III:** If IPR/RA is deemed feasible and approved by the Mayor and City Council, then Phase III will involve implementation of a full-scale IPR/RA project to augment the San Vicente Reservoir with purified water. The full-scale IPR/RA project would include construction of an 18-mgd Full-Scale Facility located north of North City and an approximately 23-mile pipeline that will transport the purified water to San Vicente reservoir for blending and retention prior to distribution to the region's drinking water treatment plants for further treatment. Implementation of the full-scale IPR/RA project is contingent on Mayoral and City Council authorization.

The majority of the costs associated with the Demonstration Project were funded by a temporary water rate increase, which was approved by City Council in November 2008. This temporary rate increase was in effect from January 2009 to August 2010 and collected funds to pay for the project. In addition, the Demonstration Project was partially funded by grants from the California Department of Water Resources' Integrated Regional Water Management Program through Proposition 50, and the United States Bureau of Reclamation in the approximate amount of $1.07 million and $2.95 million, respectively. The Demonstration Project has a total estimated cost of $11.8 million.

Components of the Demonstration Project include the following:

1. **Conduct a public outreach and education program:** In 2010, the City launched a comprehensive public outreach and education program for the Demonstration Project. The program included tours of the City's Demonstration Facility to educate City leadership, regulators, public, and other interested parties about advanced water purification and how a full-scale IPR/RA project would benefit the City.
2. **Design, construct, operate, and test a Demonstration Facility at North City:** This component of the Demonstration Project is included in the AWP Facility Study detailed in this report.
3. **Conduct a Limnology and Reservoir Detention Study for the San Vicente Reservoir:** A study of the San Vicente Reservoir was conducted to test the key functions of reservoir augmentation and to determine the viability of a full-scale project. The study evaluated dilution and established residence time and short-circuiting conditions of purified water in the reservoir.
4. **Define the regulatory requirements for a full-scale IPR/RA project:** Since the full-scale IPR/RA project would be the first of its kind in California, the regulatory requirements were defined as part of the Demonstration Project. The City has conducted meetings with the California Department of Public Health (CDPH) and the San Diego Regional Water Quality Control Board (Regional Board) to understand both the anticipated regulatory requirements and the approval process for the Full-Scale Facility.

5. **Convene an Independent Advisory Panel (IAP):** An IAP provided oversight on project research to determine (1) if the purification system satisfies all water quality, safety and regulatory requirements of the CDPH, and (2) the behavior of the reservoir and what will happen if the purified water is added. For the Demonstration Facility, the IAP reviewed and commented on the testing and monitoring plan, the testing results, and this AWP Facility Study report.

6. **Perform a pipeline alignment (water conveyance) study:** The Purified Water Conveyance System Final Conceptual Design Report was prepared to present the alignment and costs for conveying the purified water from the Full-Scale Facility to the San Vicente Reservoir.

7. **Perform an independent energy and economic analysis for water supply options in the City's Long-Range Water Resources Plan:** The City is updating their 2012 Long-Range Water Resources Plan (CDM Smith, 2012) to evaluate the City's water supply options. As part of this plan, IPR/RA was confirmed to be a cost-effective water supply option.

Through implementation of the steps outlined above, the Demonstration Project is being completed in 2012. The Demonstration Project Report will summarize all of the elements of the project and include a summary of the reports completed for the individual tasks:

- AWP Facility Study Report (the report presented herein)
- Limnology and Reservoir Detention Study
- Purified Water Conveyance System Final Conceptual Design Report
- 2012 Long-Range Water Resources Plan

At the conclusion of the Demonstration Project, the Demonstration Project Report will be presented to the Mayor and City Council. If deemed technically and financially feasible and following Mayoral and City Council authorization, a full-scale IPR/RA project would be implemented.

1.2 AWP Facility Study Background

The purpose of the AWP Facility Study was to provide operational information from a one-mgd Demonstration Facility, identifying recommendations for energy optimization and scale-up considerations for a future 18-mgd Full-Scale Facility, and developing a conceptual design and cost estimate for this Full-Scale Facility. The following specific objectives were defined for the project:

- Demonstrate the feasibility of an AWP Facility to reliably produce purified water that is consistently in compliance with all drinking water quality standards.
- Implement a monitoring plan for constituents of emerging concern (CECs) that is tailored to the wastewater received at North City.
- Demonstrate integrity monitoring techniques and performance reliability measures for the treatment equipment.
- Generate data to be able to make conclusions on maintaining reservoir water quality. Assess energy consumption and develop energy conservation opportunities.

- Develop recommendations for design and operation of a Full-Scale Facility that assures only safe purified water leaves the plant.
- Develop a cost estimate for a Full-Scale Facility.
- Educate the public about the Demonstration Project through community outreach, informational materials, and AWP Facility tours.

The one-mgd Demonstration Facility was designed, installed, operated, and tested between 2010 and 2012. During operation of the Demonstration Facility, the water was tested to evaluate the effectiveness of the treatment processes in removing constituents; operational data was gathered and analyzed to refine operation and maintenance (O&M) estimates for a Full-Scale Facility; and tours conducted as part of the public outreach effort.

The Demonstration Facility treats recycled water (tertiary wastewater effluent prior to chlorination) from North City to produce purified water. The Demonstration Facility uses water purification processes, including membrane filtration (MF and UF), RO, and UV disinfection and advanced oxidation. During the demonstration phase, the purified water was returned to the North City recycled water system and was used for irrigation and industrial purposes. No purified water was sent to the reservoir during the demonstration phase.

Figure 1-2 summarizes the schedule for design, testing, and operation of the Demonstration Facility. The facility was started up over a 1.5 month period (mid-June 2011 through the end of July 2011) and was tested for one year (August 2011 through July 2012). The results and conclusions from this 13.5-month period are the focus of this report. The Demonstration Facility is continuing to operate after the end of the testing period for tours.

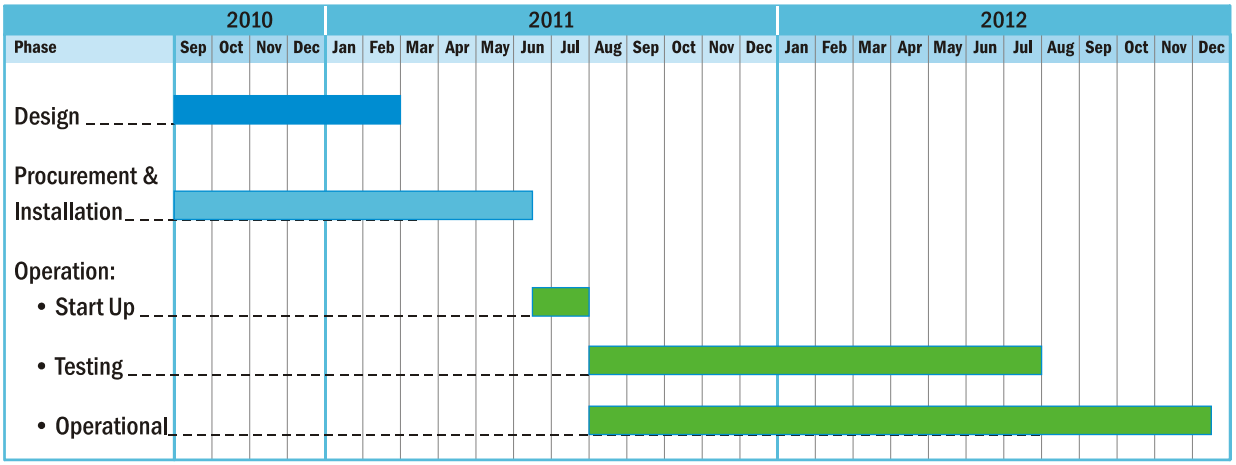


Figure 1-2
Demonstration Facility Schedule

1.3 Coordination with Other Activities and Deliverables

As a major component of the Demonstration Project, the AWP Facility Study was closely coordinated with other Demonstration Project activities and deliverables. The information was coordinated with the other project elements as follows:

- **Demonstration Project Report:** this AWP Facility Study Report is summarized in the Demonstration Project Report.
- **Purified Water Conveyance System Final Conceptual Design Report:** the Purified Water Conveyance System Final Conceptual Design Report presents the conceptual design for the purified water pump station and the approximate 23-mile pipeline to convey the purified water from the Full-Scale Facility to the San Vicente Reservoir. Information about the purified water pump station is included in Section 4. The pump station footprint is included on the Full-Scale Facility site plan (Figure 4-4) and the design criteria are included with the overall Full-Scale Facility design criteria (Figures 4-5 and 4-6).
- **Full-Scale Reservoir Augmentation Capacity Analysis Technical Memorandum:** the sizing of the Full-Scale Facility is documented in the Full-Scale Reservoir Augmentation Capacity Analysis Technical Memorandum. This document is included as an appendix to this AWP Facility Study Report for reference.

1.4 AWP Facility Study Report Overview

This report provides information on the Demonstration Facility and a conceptual design and cost estimate for the potential Full-Scale Facility. This AWP Facility Study Report is summarized in and appended to the Demonstration Project Report, which summarizes the overall results of the Demonstration Project. The remaining sections of this AWP Facility Study Report are organized into the following sections:

- Section 2 Demonstration Facility Description and Observations
- Section 3 Full-Scale Facility Considerations
- Section 4 Full-Scale Facility Conceptual Design
- Section 5 Full-Scale Facility Estimated Costs
- Section 6 References
- Appendices
  - A – Testing and Monitoring Plan
  - B – Quarterly Testing Report No. 4
  - C – Full -Scale Reservoir Augmentation Capacity Analysis Technical Memorandum
  - D – Estimated Capital Cost Process Area Breakdown
  - E – Estimated O&M Cost Process Area Breakdown
  - F – Demonstration Facility Power Consumption

Section 2

Demonstration Facility Description and Observations

This section provides a description of the Demonstration Facility, summarizes the operations and testing results, discusses the regulatory relevance of those results, and describes the integrity and reliability monitoring measures used to confirm that each water purification process functioned reliably. The information provides a basis for energy optimization and full-scale considerations discussed in Section 3 as well as the conceptual design and cost estimate for the Full-Scale Facility, presented in Sections 4 and 5, respectively.

2.1 Demonstration Facility Description

The Demonstration Facility was designed with a 1-mgd production capacity and consists of the following water purification processes: parallel membrane filtration processes; parallel-two stage and three-stage RO processes; and UV disinfection and advanced oxidation. A flow diagram of the Demonstration Facility and sampling locations (designated as S1 through S10) is provided in Figure 2-1.

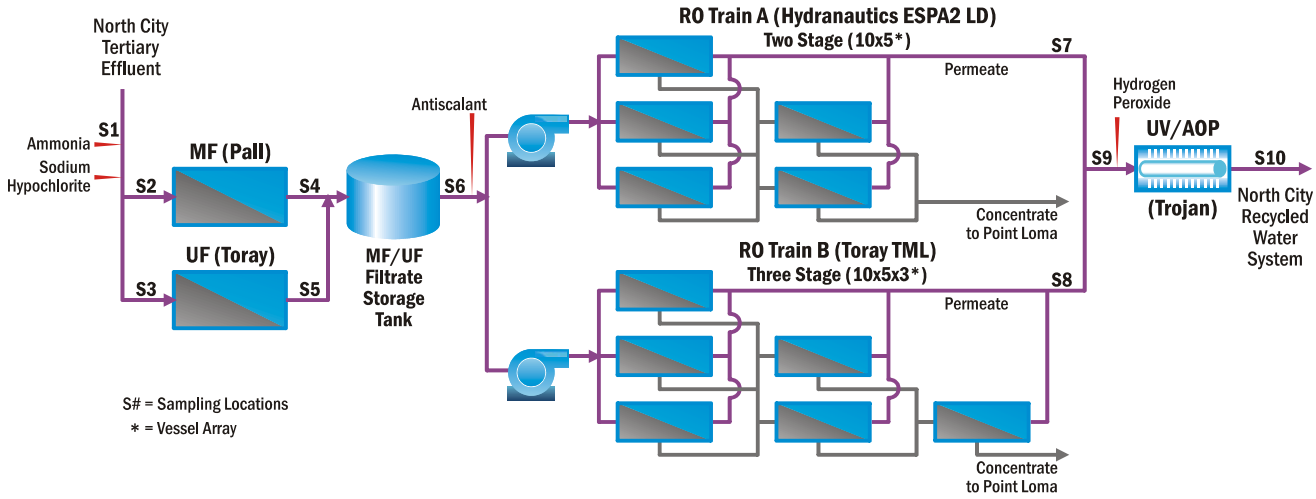


Figure 2-1
Advanced Water Purification Treatment Process

2.1.1 Demonstration Facility Location

The Demonstration Facility is located at North City located at 4949 Eastgate Mall, San Diego, California 92121. North City has a total design capacity of 30 mgd, but the current average annual demand of recycled water customers serviced by North City is only 7.3 mgd; thus, the plant's capacity is not fully utilized. The majority of current customers use the recycled water for irrigation, and the remainder for industrial purposes.

The Demonstration Facility is located on a concrete pad adjacent to the existing electrodialysis reversal (EDR) units #4 and #5. The Demonstration Facility pad area is 3,800 square feet (50 feet x 76 feet). The western edge of the pad houses the EDR #6 and was not part of the Demonstration Project. The operations trailer is located on the existing Research Pad, which has an area of 2,000 square feet (40 feet x 50 feet).

The Demonstration Facility is connected to the North City plant tertiary effluent by an 8-inch Schedule 80 polyvinyl chloride (PVC) pipe designed to deliver water to the Demonstration Facility at 980 gallons per minute (gpm) and a pressure between 40 to 50 pounds per square inch (psi). The water is delivered by the same pumps that feed EDRs #4, #5 and #6. Two drains are provided for liquid process and cleaning waste. The drains are routed in the Demonstration Facility and EDR #6 areas and then routed to discharge to an existing manhole and eventually discharged to Point Loma. Water produced by the Demonstration Facility is blended with North City tertiary effluent upstream of the chlorine contact tanks. The product water piping is routed overhead in the Demonstration Facility and EDR #6 areas and then routed below grade to discharge into the tertiary effluent line immediately upstream of the chlorine contact tanks.

2.1.2 Membrane Filtration

Membrane filtration is most commonly done using hollow fiber membranes, with each membrane fiber typically less than a millimeter in diameter and three to six feet in length. Filtration occurs across the surface of each individual membrane fiber. Tens of thousands of these fibers are packaged together and sold as removable membrane elements, typically within a self-contained pressure vessel. Dozens of these elements can then be manifolded together into a larger, modular operating unit, typically referred to as a membrane skid. A complete membrane system consists of the membrane skid or multiple skids, along with various ancillary equipment, often located off of the skid(s). Full scale facilities often contain multiple membrane skids, each operated independently through frequent backwash and production cycles.

The membrane filtration equipment used at the Demonstration Facility includes two parallel 0.63-mgd systems, each treating half the facility flow. One system is a Pall MF system utilizing membranes with a nominal pore size of 0.1 micron, while the second system is a semi-universal UF system utilizing membranes with a nominal pore size ten times smaller at 0.01 micron. The UF system used Toray membranes but is capable of operating with membrane elements (filter modules) from multiple vendors. Selection of the two systems was based on review of other operational advanced purification facilities and on the City's goal of comparing alternative membrane filtration systems to develop the most efficient and effective approach for a potential Full-Scale Facility.

Design Flux and Materials

Membrane system filtration rate, or flux, represents the amount of permeate flow produced per day (gallons per day) per unit area of membrane (square feet [ft^2]). A membrane system containing 20,000 ft^2 of membrane area, which produces 1.0 million gallons per day, would be operating with a flux of 50 gallons per day per square foot (gfd). Membrane filtration systems for wastewater applications are generally designed to operate at relatively low fluxes (20 to 35 gfd), to reduce the rate of fouling on the membranes. Fouling occurs more frequently at higher fluxes, particularly when treating water containing relatively high organic content, as treated wastewater often does. The MF and UF systems used at the Demonstration Facility were operated at fluxes between 29 and 30 gfd.

In addition to flux, specific flux, also known as permeability, is flux per unit pressure (gfd/psi). The specific flux is generally corrected for temperature, based on the viscosity of the water. The reference temperature for membrane filtration is 20 degrees Celsius (C), while it is 25 degrees C for RO.

The majority of the wastewater membrane filtration facilities in California are currently using MF membranes, which are made from either chlorine resistant polyvinylidene fluoride (PVDF) material or from chlorine-sensitive polypropylene. Facilities using PVDF membranes include the Water Replenishment District Leo J. Vander Lans Water Treatment Facility in Long Beach, California, and the Scottsdale Water Campus in Scottsdale, Arizona. Facilities using PVDF membranes often utilize chlorine enhanced backwashes to reduce organic fouling and biological growth on the membranes. However, chlorine enhanced backwashes cannot be used at facilities employing membranes sensitive to chlorine (i.e. polypropylene). Facilities using such chlorine sensitive polypropylene membranes include the Orange County Water District's Groundwater Replenishment System and the West Basin Edward C. Little Water Reclamation Facility, both in California.

Most indirect potable reuse plants, including facilities in the United States, Singapore, and Australia, employing membrane filtration and RO as treatment processes, maintain a continuous chloramine residual through the entire treatment process to prevent biological growth on the membrane filters and the RO membranes. At the Demonstration Facility, a total chlorine residual between 3 and 4 milligrams/liter (mg/L) was maintained through the membranes to prevent such biological growth.

Standardization of Membrane Filtration Membranes

Three manufacturers currently supply approximately 90 percent of the municipal membrane filtration systems in the United States, including Siemens/Memcor, Pall Corporation, and GE/Zenon. These systems generally are not compatible with each other, due to differences in membrane module configurations, dimensions, piping, and flow configurations. Due to the proprietary nature and complexity of these systems, membrane selection is commonly completed during the preliminary design phase of a project, allowing better integration of the systems into the overall design.

As the industry has matured in recent years, the system designs have become more standard. Today GE/Zenon makes a pressurized UF membrane that is relatively compatible in size and configuration to the Pall system. In addition, alternative membrane manufacturers are supplying domestic facilities with membranes that are far more standardized than systems sold a decade ago. A semi-universal membrane unit, capable of operating with membranes from several different suppliers, is now possible to design or purchase from third party vendors. Such a design benefits treatment system owners during the design phase and during bidding.

The City therefore selected a non-proprietary system design to treat half of the flow at the Demonstration Facility in order to promote future competition for the potential Full-Scale Facility. This UF system for the Demonstration Facility was designed to be compatible with membranes from three alternative membrane suppliers: Pentair, Dow, and Toray. Membrane element design conditions for each of these suppliers are included in Table 2-1.

Table 2-1 Membrane Elements Considered in Design of Semi-Universal UF Skid Design

Model	Pentair Aquaflex	Dow SFD-2860	Toray HFU-2020
Length	2.2 m	2.0 m	2.2 m
Diameter	0.2 m (8-inch)	0.2 m (8-inch)	0.22 m (8.5-inch)
Area	55 m^2 (85,250 in^2)	77 m^2 (119,350 in^2)	72 m^2 (111,600 in^2)
Flow Configuration	Inside-out	Outside-in	Outside-in

Microfiltration System Design

The microfiltration system selected for the Demonstration Facility was a Pall Aria system which produced 0.63 mgd for the downstream RO process. The Asahi membranes used with the Pall system were PVDF material with a nominal pore size of 0.1 micron. These membranes were selected as a baseline to compare against the UF, based on their successful operation in wastewater applications with low membrane fouling and few fiber breaks. The MF membranes were operated at a flux of 29 gfd and recovery of 93 percent. While the system was designed to incorporate chemically enhanced backwashes, they were not used during the initial operation of the Demonstration Facility in order to reduce the amount of downtime for the membrane filtration unit. Chemical enhanced backwashes may be required in the future if more aggressive operating conditions are use (e.g. higher flux, higher recovery).

Ultrafiltration System Design

The Demonstration Facility uses Toray HFU membranes in the UF system, which also produced 0.63 mgd for the downstream RO membranes. The UF system operates in parallel to the MF system. Toray UF membranes were selected for the UF system because these membranes are CDPH-certified. The Toray UF membranes are PVDF material, similar to the Pall MF membranes, but have a nominal pore size ten times smaller than the MF membranes. Toray membranes can be used in a standardized skid configuration, which could accommodate UF membranes from Norit, Dow, or Toray. This provides flexibility with the Demonstration Facility if the City decides to test another UF manufacturer, and could also provide advantages for membrane replacement in the Full-Scale Facility. The Toray UF membranes are chlorine resistant PVDF material with a nominal pore size of 0.01 micron. The smaller pore size of the UF membrane allows for the removal of smaller constituents, such as viruses. The UF system was operated at a flux of 30 gfd and 95 percent recovery. While the system was designed to incorporate chemically enhanced backwashes, they were not used during the initial operation of the Demonstration Facility in order to reduce the amount of downtime for the membrane filtration unit. Chemically enhanced backwashes may be required in the future if more aggressive operating conditions are use (e.g. higher flux, higher recovery).

The Demonstration Facility was the first municipal installation in the United States to use the relatively new Toray HFUF (hollow fiber ultrafiltration); however, the membranes had previously been used at wastewater facilities in Asia, and are now currently being used for other facilities being built or in recent operation within the United States. Because of differences in port dimensions and locations, it will be necessary to change out portions of the piping if and when the membranes are changed to an alternative manufacturer in the future. In addition, the inside-out flow configuration for the Pentair system will require modifications in the controls. The majority of the piping, controls, and the pumping system for the UF unit were designed to accommodate the alternative membrane suppliers.

2.1.3 Reverse Osmosis

Reverse osmosis membranes are most commonly manufactured as flat sheets, with a thin membrane layer coating a larger support structure used to resist the high pressures seen in reverse osmosis. Individual sheets are glued together in pairs to form membrane envelopes, with separation of dissolved ions occurring across the membrane surface. Desalinated water passes into the center of the membrane envelope, while salts and other contaminants remain on the outside of the membrane sheets. These sheets are typically rolled into spiral wound membrane elements, with hundreds of square feet of membrane area contained inside a single 8-inch by 40-inch element. The elements are most commonly loaded into pressure vessels in series, with six to eight elements per vessel. Multiple vessels are then manifolded together into a modular operating unit typically referred to as a train. Reverse osmosis facilities will operate with one or more membrane train, each operating independently through extended cleaning cycles.

The reverse osmosis equipment used at the Demonstration Facility included two parallel systems, each treating half the flow. Two alternative membranes were used, and two alternative RO configurations, one operated as a two-stage (Train A) and one as a three-stage (Train B) system. RO systems for wastewater applications are typically designed to operate at low fluxes, ranging from 10 to 12 gfd. These fluxes are more in line with traditional fluxes used at seawater desalination facilities than at brackish water plants; however, early operation at Water Factory 21 in California and other pilot studies suggested that the lower fluxes were needed to prevent fouling from high concentrations of organic material in the wastewater sources.

Design recoveries for RO units at all of the existing AWP facilities in California are 85 percent, but problems with scaling in downstream stages have resulted in some of these facilities operating at reduced recoveries—as low as 75 percent. A recovery of 80 percent was initially selected for the Demonstration Facility, which was the proven recovery demonstrated during the City's previous pilot testing of water purification processes (conducted in 2005-2006). As discussed in Section 2.3.2, the recovery was successfully increased to 85 percent to maximize water production.

Reverse Osmosis System Design

Similar to the membrane filtration system, two parallel reverse osmosis systems were used for the Demonstration Facility – one representing a baseline condition and the second representing an alternative design approach. Train A includes Hydranautics ESPA2-LD elements operated in a two-stage configuration, which was used as the baseline. ESPA2-LD membranes have a rated salt rejection of 99.6 percent, based on Hydranautics standard testing procedures, using a 1,500 mg/L sodium chloride solution and a 150 psi feed pressure. This train utilized seven elements per vessel within a 10 vessel by 5 vessel array. An Energy Recovery Incorporated turbocharger (also referred to as an energy recovery device) was used to recover residual energy from the second stage concentrate, boosting the pressure to the second-stage feed. The RO system was operated at 12 gfd at both 80 percent and 85 percent recovery.

The second parallel RO system (Train B) utilized Toray TML20 membranes in a three-stage RO configuration to improve system hydraulics at higher recovery rates. TML20 membranes have a rated salt rejection of 99.7 percent, based on Toray standard testing procedures, using a 2,000 mg/L sodium chloride solution and 225 psi feed pressure. Six element pressure vessels were used to reduce the differential pressure loss, with a 10 by 5 by 3 vessel array. An energy recovery device was used to recover residual energy from the third stage concentrate, boosting the pressure to the third stage feed.

The Toray TML20 membranes were projected to have a higher nitrogen rejection than the baseline ESPA2 membranes. Total nitrogen may be a controlling water quality limitation for reservoir augmentation, making the rejection of the RO membranes a critical evaluation parameter. A goal of 1.0 mg/L total nitrogen was set for the Demonstration Facility; however, the final requirement will be determined by the Regional Board. ESPA2 elements were not projected to meet this nitrogen goal, based on Hydranautics design software, however, the Toray membranes were projected to deliver considerably lower total nitrogen levels.

2.1.4 UV Disinfection and Advanced Oxidation

The RO permeate from the two RO trains are combined and treated through an advanced oxidation process, comprised of UV coupled with hydrogen peroxide. Trojan UVPhox, a low pressure and high output (LPHO) UV system was used to demonstrate the UV disinfection and advanced oxidation process. This reactor is the same model that is being used at the Groundwater Replenishment System in Orange County. The Trojan model used was selected based on discussions with Trojan, given the capacity of the Demonstration Facility. For more details on the selection of the reactor, see Appendix C, Attachment A of the Testing and Monitoring Plan (T&M Plan) (Appendix A).

There was an initial concern that the single reactor would not be as efficient as a full scale facility. Based on discussions with the manufacturer, this system was expected to be less efficient due to differences in hydraulic conditions, compared to a full scale system. However, based on results from the spiking experiment, the calculated electrical energy per order (EEO) values at the Demonstration Facility were similar to those predicted at Orange County's Groundwater Replenishment District, under similar conditions.

The advantages of LPHO UV, compared to medium pressure UV, include electrical efficiency, longer lamp life, and narrower UV wavelength targeted for microbial destruction. Trojan LPHO UV systems have a proven history with advanced water treatment in California with systems installed at the Orange County Water District's Groundwater Replenishment System, the West Basin Municipal Water District's Edward C. Little Water Recycling Facility, and the Water Replenishment's District Leo J. Vander Lans Advanced Water Treatment Facility.

2.1.5 Purified Water

The water that has been treated by the membrane filtration, RO, and UV disinfection and advanced oxidation processes is considered purified water. This purified water meets water quality requirements for full advanced treatment under the November 2011 Groundwater Replenishment Reuse Draft Regulations, including primary and secondary drinking water standards, total nitrogen, total organic carbon (TOC), and CDPH Notification Levels. If the IPR/RA project is approved for full-scale implementation, the purified water would be conveyed to the San Vicente Reservoir to supplement existing raw water supplies to the reservoir. Additional post-treatment through blending or adding stabilizing chemicals would be required for the Full-Scale Facility to address the aggressive nature of highly purified water. Since this project was for demonstration purposes only, the purified water produced by the facility was blended with existing recycled water and distributed through the existing recycled water system for irrigation and industrial uses. No water from the Demonstration Facility was used to supplement any drinking water supplies.

2.2 Demonstration Facility Public Outreach and Tours

One of the objectives of the Demonstration Facility was to support public education and outreach activities to acquaint San Diego residents and stakeholders with the concepts and processes related to IPR/RA. The Demonstration Facility, pictured in Figure 2-2, was designed and constructed to facilitate public tours as part of the City's ongoing Water Purification Education and Outreach program.

The Demonstration Facility tours fulfilled four critical purposes:

- Introduce and graphically illustrate the water purification processes and technologies.
- Show how North City, the potential Full-Scale Facility, the approximately 23-mile pipeline, the San Vicente Reservoir, and the City's drinking water treatment plant work together to provide multiple barriers of protection.
- Communicate information about expert oversight and continuous monitoring of treatment processes to enhance public trust in the reliability of these facilities to produce a safe and clean supply of water.
- Place the water purification process in a water cycle context to reframe mental models about how water is continuously used and reused.

The Demonstration Project Public Education and Outreach program is summarized in the Demonstration Project Report.

Figure 2-2
Demonstration Facility

2.3 Summary of Operations

The following subsection summarizes Demonstration Facility operation during the time period of 6/16/11 to 7/31/12. The facility start-up period was 1.5 months (mid-June 2011 through the end of July 2011) with full operational testing continuing for one year (August 2011 through July 2012). The results and conclusions from this 13.5-month period are the focus of this report. The Demonstration Facility is continuing to operate after the testing period for tours.

Each water purification process was operated continuously over this time period with minimal offline time due to routine maintenance, cleaning (membrane systems), and unscheduled minor repairs. Based on a comparison of actual time to run hours, the system was producing purified water 87 percent of the time during this period. Each of the water purification processes performed as required during this period of operation.

The operation and testing results were presented in quarterly reports over a 12-month testing period as summarized in Table 2-2:

Table 2-2 Demonstration Facility Testing Periods

Testing Quarter	Operating Period		Report Date
	Test Quarter Start	Test Quarter End	
Quarter 1 (Q1)	6/16/2011	10/31/2011	December 2011
Quarter 2 (Q2)	11/1/2011	2/10/2012	March 2012
Quarter 3 (Q3)	2/11/2012	5/14/2012	June 2012
Quarter 4 (Q4)	5/15/2012	7/31/2012	September 2012

The Quarterly Testing Report No. 4 includes the comprehensive water quality data for all Testing Periods and is provided in Appendix B.

2.3.1 Summary of Membrane Filtration Operation

The following includes a description of the membrane filtration system operation and a comparison of the operational and water quality performance of the two systems.

Microfiltration System

The Pall Aria MF system was operated for over 8,700 hours (12 months) under the operating conditions presented in Table 2-3. The feed water for the MF system was tertiary effluent prior to chlorination from North City. Membrane fouling was assessed during the operational period by monitoring the temperature corrected specific flux under constant flux operation. Figure 2-3 presents operational performance data including specific flux, flux, transmembrane pressure and temperature based on daily operational readings. These parameters are plotted versus run hours, the plot also includes dates at each 1,000 run hour interval. In general, the MF system experienced minimal membrane fouling. Following the initial operating period, a full chemical cleaning was conducted at run hour 2,277 (3.2 months). The chemical cleaning was effective at restoring the temperature corrected specific flux to values observed when the membranes were new. Following the initial chemical cleaning, the system was operated for an additional 3,962 hours (5.5 months). During this time, the specific flux was observed to remain constant prior to decreasing steadily around run hour 5,400. A second chemical cleaning was completed at run hour 6,239, which was effective at restoring the specific flux to values observed when the membranes were new.

Table 2-3 Summary of Pall MF System Operating Conditions

Parameter	Value
Target feed water chloramines dose	3 mg/L
Instantaneous flux	29 gfd
Average feed water recovery	93 percent
Backwash frequency	19 minutes or 10,000 or filtrate gallons
Backwash duration	96 seconds
Strainer backwash frequency	1,440 minutes
Pressure Decay Test frequency	24 hours

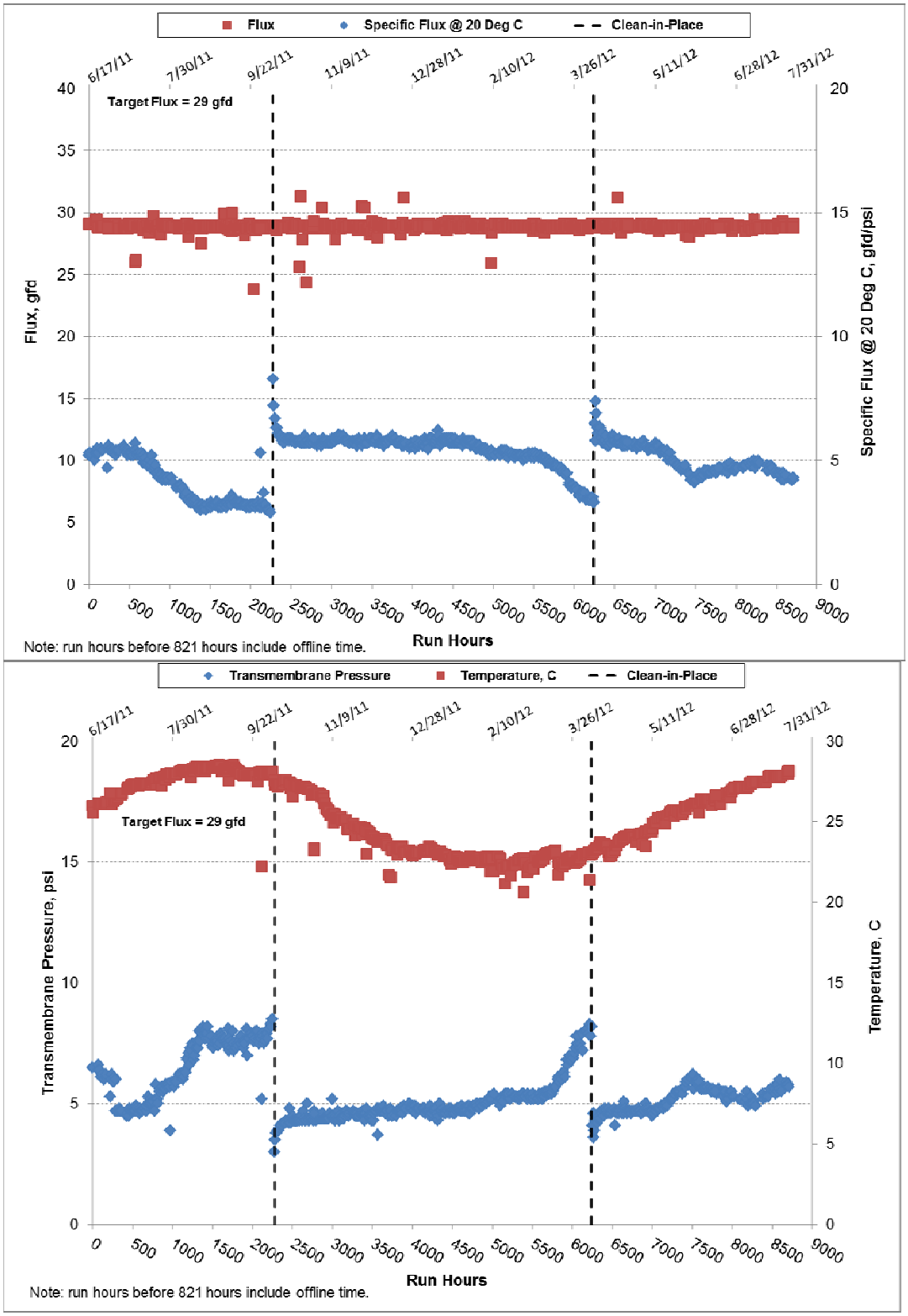


Figure 2-3
Summary of Pall MF System Operational Performance

Ultrafiltration System

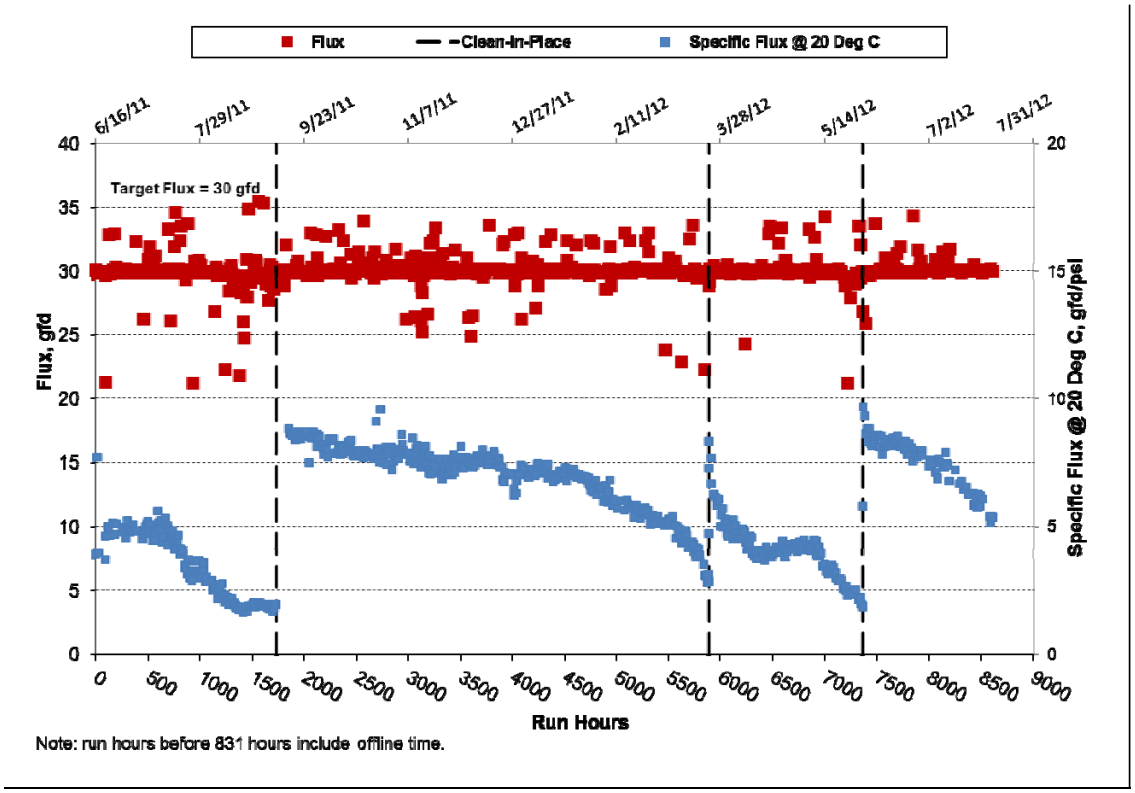
The Toray UF system was operated for over 8,600 hours (12 months) under the operating conditions provided in Table 2-4. The UF system was also fed from the tertiary effluent prior to chlorination produced by North City. Membrane fouling was assessed during the operational period by monitoring the temperature corrected specific flux under constant flux operation. Figure 2-4 presents operational performance data including specific flux, flux, transmembrane pressure and temperature based on daily operational readings. These parameters are plotted versus run hours; the plot also includes dates at every 1,000 run hour interval.

In general, the rate of decrease in specific flux for the UF system observed during the Q1 and Q2 Testing Periods showed minimal fouling; however, an increased rate of fouling was observed during the Q3 Testing Period. It is important to note the UF system was operated at a higher recovery than the MF system over the course of the operating period, resulting in overall less backwash waste flow. This higher recovery could therefore be partially responsible for the higher rate of observed fouling in the UF system.

Following the initial operating period, a chemical cleaning was conducted at run hour 1,729 (2.4 months). The chemical cleaning was effective at restoring the temperature corrected specific flux to values observed when the membranes were new. Following the initial chemical cleaning, the system was operated for an additional 4,156 hours (5.8 months). During this time, the specific flux was observed to remain steady prior to trending downward at a moderate rate around run hour 3,850. The rate of decline increased around run hour 4,540 and was consistent for the remainder of the operating period. A second chemical cleaning was completed at run hour 5,885, which was effective at restoring the specific flux to the previously observed post-clean value. The UF membranes fouled at a faster rate during the Q3 and Q4 Testing Periods than in the previous periods. A final chemical cleaning was conducted at run hour 7,360 (10.2 months).

Table 2-4 Summary of Toray UF System Operating Conditions

Parameter	Value
Target feed water chloramines dose	3 mg/L
Instantaneous flux	30 gfd
Average feed water recovery	95 percent
Backwash frequency	30 minutes
Backwash duration	195 seconds
Strainer backwash frequency	1,440 minutes
Pressure Decay Test frequency	24 hours



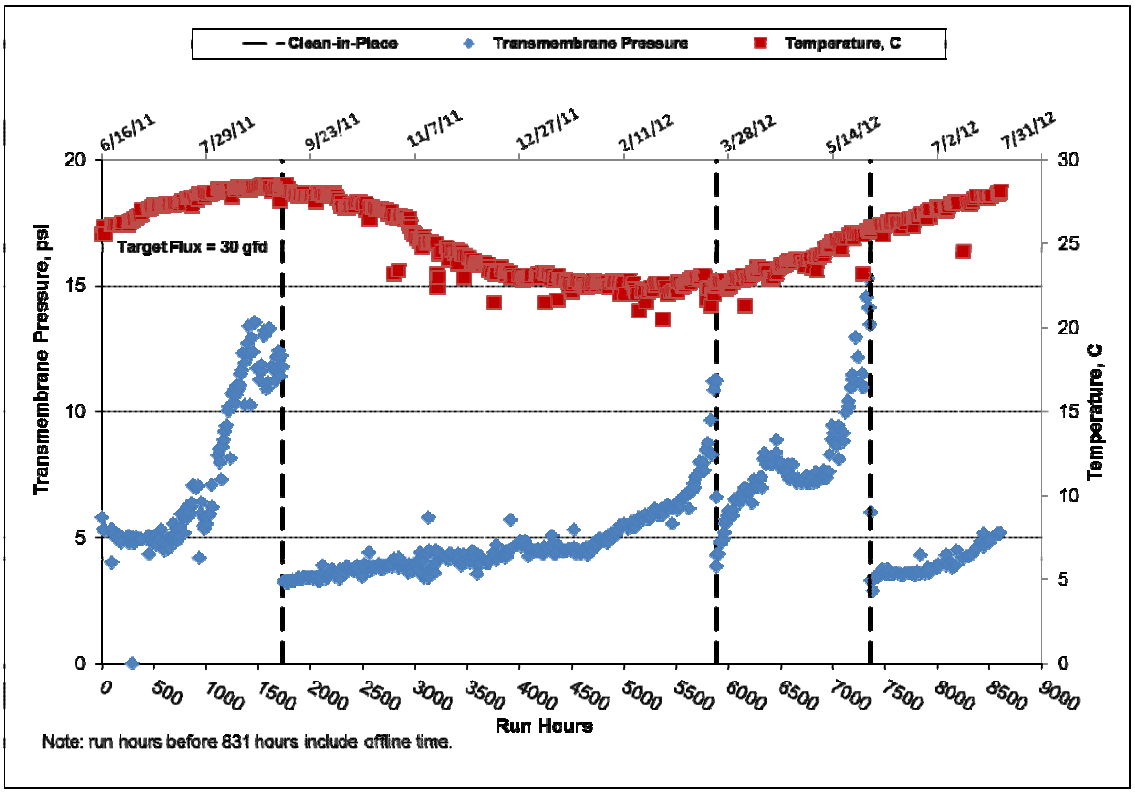


Figure 2-4
Summary of the Toray UF Operational Performance

Comparison of Membrane Filtration System Operation

The MF System (Pall) and UF system (Toray) were operated side by side for similar runtimes to compare the operational and water quality performance of the systems.

A summary of operational performance of the membrane filtration systems is provided in Table 2-5. Operating Period 1 is defined as the operational time period between the completion of the first and second chemical cleanings. During this time, the MF system operated for 5.5 months and the UF system for 5.7 months with similar fouling rates of 11 percent (decline in specific flux per month). During this time the UF system operated with a slightly lower average transmembrane pressure (4.6 psi vs. 5.0 psi); however, the UF system required a higher average feed pressure (16 psi vs. 15 psi), due to a higher permeate backpressure from the longer discharge piping between the UF system and the break tank. Backpressure on the UF averaged 11.3 psi, but averaged 8.5 psi for the MF system, located immediately adjacent to the break tank. The differences in feed pressure should therefore not be considered representative of the two systems, but are rather the result of the unique flow configuration of the intermediate piping downstream of each system.

Operational Period 2 is defined as the operational period following the completion of the second chemical cleaning. The MF system operated for over 3.4 months with a calculated fouling rate of 12 percent and did not require a third cleaning through the end of the 12 month testing period. In comparison, the UF system operated for 2 months before requiring cleaning during this operating period. During this time the fouling rate for the UF was 38 percent, which was significantly greater (> 3 times) than that observed on the MF system over a similar time period, and considerably greater than the fouling rate observed during Operational Period 1. The UF manufacturer recommended that an aggressive low pH (pH 1.5) cleaning be performed to try to decrease the unexpected transmembrane pressure rise seen during this operational period.

Operational Period 3 (UF only) is defined as the operational period following the completion of the third chemical cleaning. The UF system operated for 1.7 months with a lower fouling rate (26 percent vs. 38 percent) and much lower average transmembrane pressure (2.7 psi vs. 6.8 psi) than observed during Operational Period 2. The decrease in fouling is attributed to the lower target pH (1.5 vs. 3) used during the third cleaning as opposed to the target pH of the second cleaning.

Water quality monitoring of the membrane filtration systems showed that both consistently produced filtrate with similar water quality: turbidity (<0.1 NTU), TOC (6.5 mg/L), and UV 254 Absorbance (UV254) (0.17 cm^{-1}). With regards to pathogen removal, concentrations of total and fecal coliforms were consistently non detect (ND) in the filtrate from both systems; however, it was observed that the UF system achieved a slightly higher log removal of bacteriophage (viruses), than the MF system, which is attributable to the smaller pore size in the UF membranes. The average (n=20) log removal for somatic and male specific bacteriophage for the MF system were greater than 3.0 and 1.1, respectively. The average (n=20) log removal of somatic and male specific bacteriophage for the UF system were calculated as greater than 3.7 and 2.2, respectively. No quantifiable hits of either somatic or male specific bacteriophage were recorded in the UF product, suggesting that higher log removal values may have been observed had concentrations in the feed been higher. It should be noted that the composite reduction for the two types of viruses monitored was greater than 99 percent for both the MF and UF system.

Table 2-5 Summary of Membrane Filtration Operation

Operational Period following Chemical Cleanings	Run Time Hours (Months)	Average Feed Pressure (psi)	Average Filtrate Pressure (psi)	Total Delta H between Feed & Filtrate Pressure Transmitters (psi)	Average Transmembrane Pressure[1] (psi)	Fouling Rate (% decrease temp. corrected specific flux per month)
MF System						
Operating Period 1 (10/6/11 to 4/5/12)	3,962 (5.5)	15.0	8.5	1.5	5.0	11
Operating Period 2 (4/6/12 to 7/31/12)	2,444 (3.4)	15.2	8.6	1.5	5.1	12
UF System						
Operating Period 1 (9/8/11 to 3/22/12)	4,138 (5.7)	16.0	11.3	1.3	3.4	11
(Operating Period 2 (3/23/12 to 5/31/12)	1,472 (2)	19.4	11.3	1.3	6.8	38
Operating Period 3 (6/2/12 to 7/31/12)	1,225 (1.7)	15.3	11.3	1.3	2.7	26

Notes:

a. Transmembrane pressure was calculated as Average Feed Pressure minus Average Filtrate Pressure minus total Delta H (difference in elevation between feed and filtrate pressure transmitters).

b. Chemical cleanings performed on the MF system on 10/5/11 and 4/5/12.

c. Chemical cleanings performed on the UF system on 9/7/11, 3/22/12, and 5/31/12.

2.3.2 Reverse Osmosis

During the testing period the RO system (Trains A and B) was operated using combined filtrate from the membrane filtration systems for 8,500 hours (11.8 months) of runtime. The RO trains were operated under similar operating conditions for the entire testing period as shown in Table 2-6. Each RO train was also equipped with an energy recovery device that was designed to transfer pressure from the concentrate to the feed of the last stage. The RO trains were designed without the use of cartridge filtration as pre-treatment because of the controlled environment upstream of the RO system (closed membrane filtration break tank), which eliminated the introduction of particulates upstream of RO. Chloramines and antiscalant were applied upstream of RO to prevent biofouling and control scaling of the membranes.

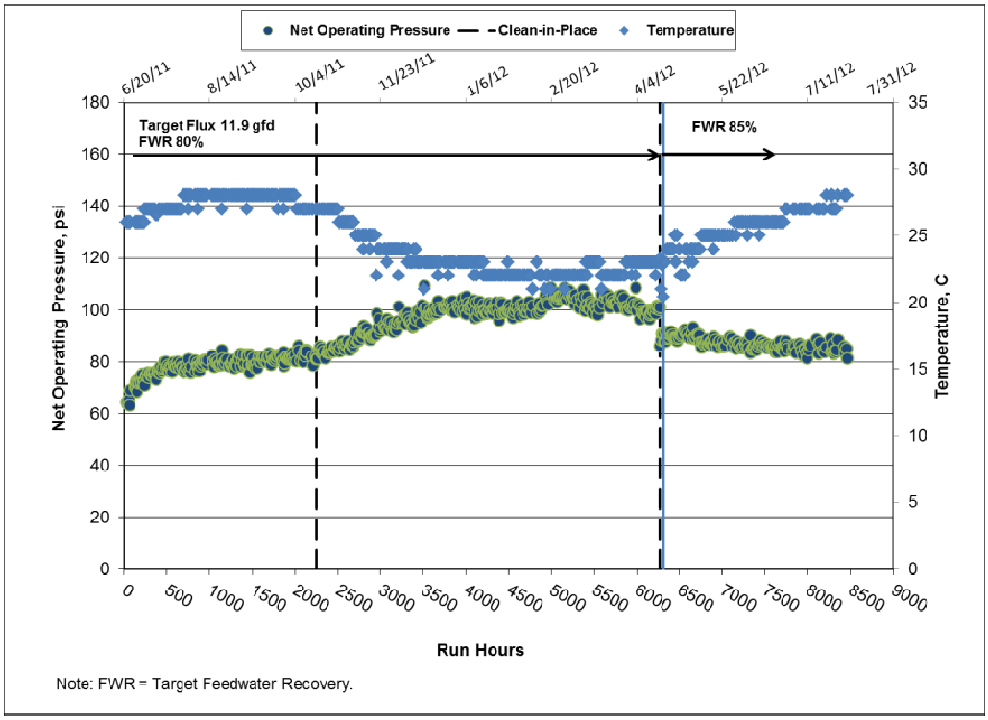
Table 2-6 Summary of the RO System Operating Conditions

Parameter	Value
RO Train A	
Antiscalant dose	3 mg/L
Average flux	11.9 gfd
Feed water recovery	80 to 85 percent
RO Train B	
Antiscalant dose	3 mg/L
Average flux	11.6 gfd
Feed water recovery	80 to 85 percent

RO Train A Operation

Operational performance parameters including net driving pressure, flux, specific flux, and feed water temperature for the RO system Train A are illustrated in Figure 2-5. Membrane fouling was assessed

during the operational period by monitoring the decline in temperature corrected specific flux, or permeability, under constant flux operation.



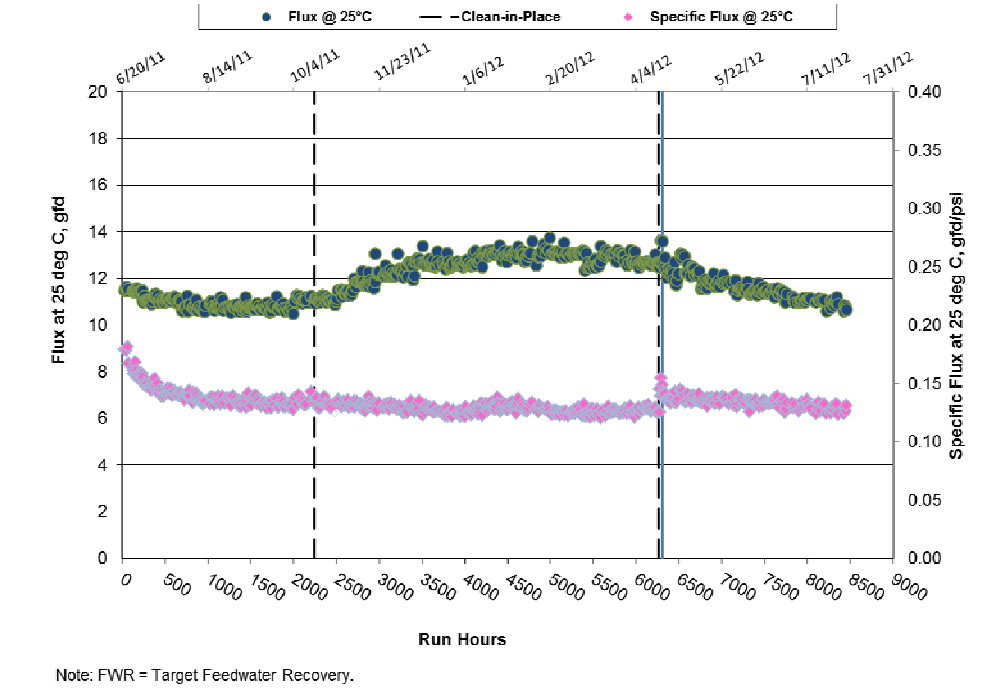


Figure 2-5
Membrane Performance of the RO System Train A

During the initial operation period, a decrease in the specific flux was observed prior to becoming level around run hour 900 (5 weeks). Since this decrease was predominantly in the first stage elements, it was believed that it may have been related to organic fouling or to biological regrowth. To prevent further fouling, the target feed water concentration of chloramines was increased from 1.5 to 3.0 mg/L. Following this adjustment, the membranes operated with little to no decrease in specific flux for approximately 1,345 hours of operation. A full chemical cleaning was performed on Train A on 10/14/11 (run hour 2,245). The membranes were cleaned in accordance to the manufacturer's protocol using caustic soda followed by citric acid. A summary of cleaning results for both RO Systems is provided in Table 2-7**.** Comparison of the specific flux measured before and after the cleaning of Train A on 10/14/11 indicates the cleaning had no effect on restoring the average membrane specific flux. These results suggest that the decrease in specific flux observed during the initial operation may have been related to conditioning of the membranes rather than entirely from membrane fouling. It is also possible that the cleaning procedures chosen were not sufficient to entirely remove the foulant layers.

Following cleaning, the system was restarted and the specific flux remained steady with little decline for the next 4,000 hours (5.5 months) of operation. On 4/26/12 a second chemical cleaning was performed before changing the RO recovery. During this cleaning, the order of cleaning chemicals was changed (citric acid followed caustic) and the soak and recirculation times were extended. Data collected before and after the chemical cleaning showed the specific flux was restored by about 15 percent.

Table 2-7 Summary of RO Membrane Cleaning Results

RO System	Date of Cleaning	Pre-Clean Temperature Corrected Specific Flux (gfd/psi@ 25 Deg C)	Post Clean Temperature Corrected Specific Flux (gfd/psi @ 25 Deg C)	Cleaning Effectiveness (% change in specific flux pre to post clean)	Cleaning Chemicals
Train A	10/14/11	0.14	0.14	0 %	Caustic followed by citric acid
Train A	4/26/12	0.13	0.15	15%	Citric acid followed by caustic
Train B	10/7/11	0.11	0.13	18%	Caustic followed by citric acid
Train B	4/18/12	0.12	0.14	17%	Citric acid followed by caustic
Train B (3rd Stage Only)	6/7/12	0.05	0.11	120%	Citric acid followed by caustic

Following completion of the chemical cleaning, the system was operated under the same target operating conditions as stated above with the exception that the feed water recovery FWR was increased to 85 percent at run hour 6,314. Following the adjustment, little to no fouling was observed as measured by the limited decline in overall specific flux for the remainder of the testing period. In all, the system operated for 2,144 hours (3 months) under these operating conditions without a cleaning. The fouling rate averaged 2 percent per month during these final 3 months of operation.

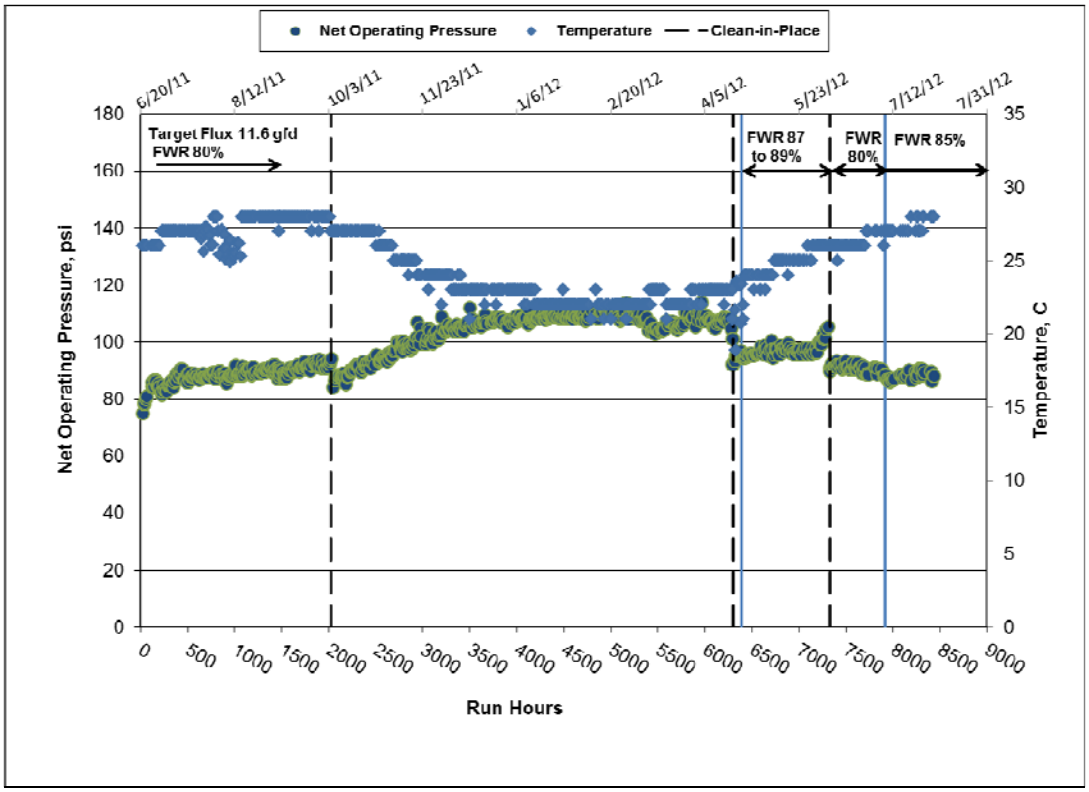
The performance of the RO Train A energy recovery device was also closely monitored over the testing period. During Q1 and Q2 Testing Periods, the energy recovery device performed far below optimal conditions. The device was removed from the system and sent to the manufacturer for repair. The unit was repaired and reinstalled at run hour 5,015. Comparison of performance data before and after the repair showed that the average boost pressure increased from 8.9 to 23 psi, which was within the range of the design projections of the energy recovery device. It was also observed that the average boost pressure dropped significantly (23 psi to 12 psi) when the recovery increased to 85 percent, because of the lower concentrate flows available to power the energy recovery device.

RO Train B Operation

Operational performance parameters monitored for the RO system Train B are shown in Figure 2-6. Membrane fouling was assessed during the operational period by monitoring the decline in temperature corrected specific flux under constant flux operation.

During the initial 160 hours (1 week) of operation, the specific flux (gfd/psi @25 degrees C) of the new Toray TML membranes declined steadily from an initial value of 0.15 to 0.13. The specific flux further declined slightly over the next 740 run hours to approximately 0.12 gfd/psi. The target feed concentration of chloramines was increased from 1.5 to 3.0 mg/L (same modification as Train A) at run hour 941. The specific flux remained steady with little or no decline for the next 1,126 hours (1.6 months) of operation.

A full chemical cleaning was performed on Train B at run hour 2,027. The membranes were cleaned in accordance with the manufacturer's protocol using both caustic soda and citric acid. Assessment of the membrane performance before and after the cleaning shows the cleaning was partially effective at restoring the specific flux in the second and third stage membranes. Following the cleaning, the specific flux remained steady with little to no decline for 4,253 hours (5.9 months) of operation. A second chemical cleaning was conducted at run hour 6,297. Due to the suboptimum effectiveness of the chemical cleaning conducted on all three stages of the RO system during the Q1 Testing Period (as well as the positive experience with RO Train A chemical cleaning), the cleaning protocol was modified to change the order of cleaning chemicals (citric acid followed caustic) and the soak and recirculation times were extended. Data collected before and after the cleaning showed the specific flux was restored by about 14 percent. The specific flux increased by 6 percent after the acid cleaning and an additional 8 percent after the caustic cleaning.



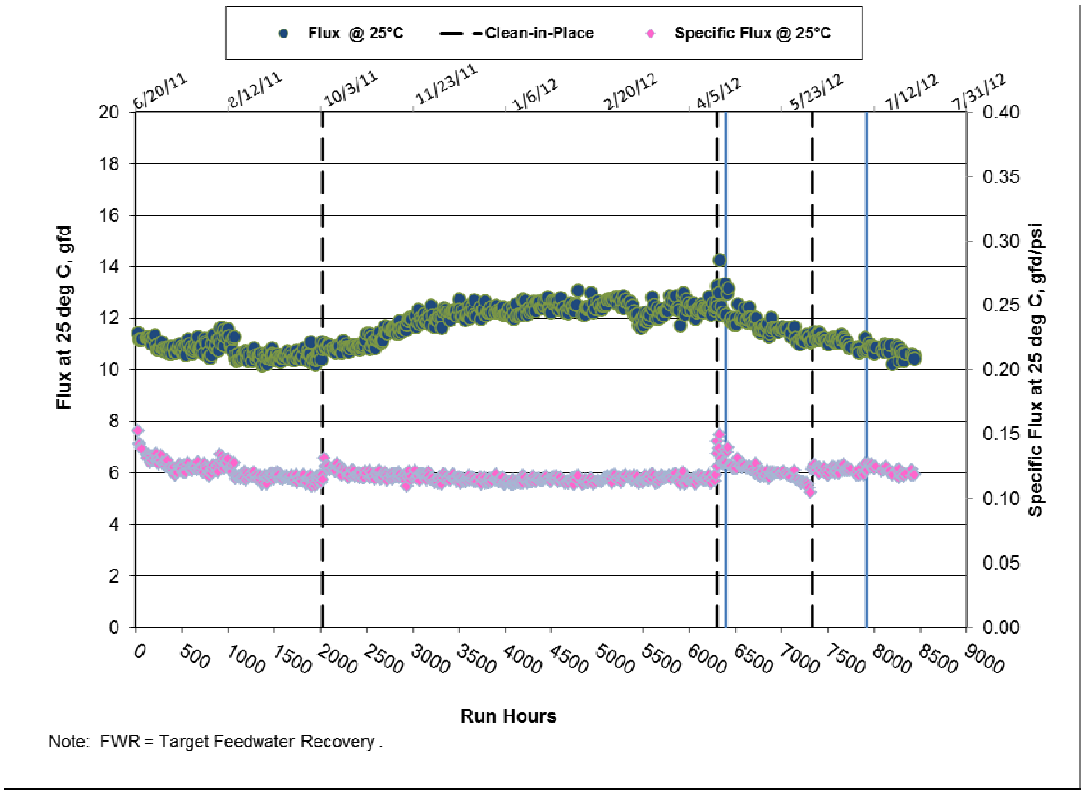


Figure 2-6
Membrane Performance of RO System Train B

Following completion of the chemical cleaning, the system was operated under the same target operating conditions as previously operated with the exception that the feed water recovery was increased to 85 percent at run hour 6,391. Since that change, little fouling was observed in either the first or second stage, however, significant scaling appears to have occurred within the third stage. By run hour 7,311, the third stage specific flux had dropped by 40 percent of the initial value observed at the start of 85 percent feed water recovery. In addition, the permeate conductivity of the third stage had increased by more than 158 percent. The increase in salt passage (higher permeate conductivity) and decrease in specific flux, are both indicators of inorganic scale formation in the final membrane stage. At this time, a chemical cleaning was conducted on the third stage membranes. Results of the cleaning show the cleaning was effective at restoring the specific flux to the values seen at the start of the 85 percent feed water recovery operation. After completion of this cleaning Train B was restarted at a target feed water recovery of 80 percent, while the cause of the scale formation was evaluated.

Because Train B scaled at a much faster rate than Train A during operation at 85 percent, an investigation was undertaken to identify the possible cause. The investigation included verification of the accuracy of the flow transmitters equipped on the RO skids as well as verifying the feed water recovery of the systems based on sulfate values measured in the feed, permeate, and concentrate. The flow transmitters equipped on both RO skids were checked against measurements using an ultrasonic flow meter provided by Toray. Comparing results showed the flow transmitters were within acceptable agreement with the ultrasonic flow meter with the exception of the concentrate flow transmitter on Train B, which read 22 percent higher than the flow measured by the ultrasonic meter. Based on this information, recovery calculations were revised to use the permeate and feed flow meters rather than the concentrate. In addition, sulfate mass balance calculations were performed, confirming the accuracy of the revised recovery calculations. It was therefore determined that Train B had operated at a feed water recovery between 87 and 89 percent instead of the targeted 85 percent feed water recovery during the time the scaling was observed. In order to rectify the issue, the scale factor on the concentrate flow meter was adjusted to accommodate the measured discrepancy. The feed water recovery was then returned to 85 percent at run hour 7,942. During the following 493 hours (3 weeks), the overall specific flux declined by approximately 9.9 percent and the third stage by 25 percent, which was still a significantly higher fouling rate than what was seen on RO Train A. Because a limited amount of run time was conducted on Train B at 85 percent recovery, it was recommended that further operation be conducted to more accurately assess the fouling rate at this recovery.

The performance of the RO Train B energy recovery device was also closely monitored over the testing periods. The average boost pressure during operation at a target feed water rate of 80 percent was 23 psi with a noticeable decrease at run hour 5,022. This decrease corresponds with a manual adjustment made on the concentrate valve to decrease the concentrate flow in order to maintain the target feed water recovery. Further adjustment was made to the concentrate valve at run hour 6,391 to increase the target feed water recovery to 85 percent. The average boost pressure measured during operation at 85 percent over the remainder of the testing period was 6.4 psi due to the lower concentrate flows available to power the device at 85 percent recovery.

Comparison of RO System Train A and Train B Operation

A comparison of operational performance of RO System Trains A and B is provided in Table 2-8.

Operating Period 1 is defined as the operational time period between the completion of the first and second chemical cleaning. During this time the systems operated for 5.6 months (Train A) and 5.9

months (Train B) with similar fouling rates of 1.4 percent and 1.6 percent (decline in specific flux per month), respectively. Train B operated with a higher feed pressure. The higher pressure required for Train B is attributed to the difference in configuration (three stages vs. two stages), as the specific flux were found to be similar for both membranes and were nearly identical for the first stage elements (see Table 2-8).

Table 2-8 Summary of the RO System Trains A and B Operation

Operational Period following Chemical Cleanings	Run Time Hours (Months)	Target Feed Water Recovery (%)	Average Feed Pressure (psi)	Net Driving Pressure(psi)	Average Specific Flux or Permeability (gfd/psi@25 Deg. C)	Fouling Rate (% decrease temperature corrected specific flux per month)
Train A (Two-stage)						
Operating Period 1 (10/16/11 to 4/16/12)	4,020 (5.6)	80%	133	98	1st Stage: 0.12 2nd Stage: 0.14	1.4
Operating Period 2 (4/19/12 to 7/31/12)	2,144 (3)	85%	124	87	1st Stage: 0.13 2nd Stage: 0.16	2.1
Train B (Three-stage)						
Operating Period 1 (10/6/11 to 4/17/12)	4,254 (5.9)	80%	139	104	1st Stage: 0.12 2nd Stage: 0.13 3rd Stage: 0.10	1.6
Operating Period 2 (4/23/12 to 6/7/12)	920 (1.3)	85%[1]	138	97	1st Stage: 0.13 2nd Stage: 0.14 3rd Stage: 0.10	15 (Stage 3 = 40)
Operating Period 3 [2] (6/8/12 to 7/9/12)	591 (0.8)	80	130	91	1st Stage: 0.12 2nd Stage: 0.13 3rd Stage: 0.10	2.1
Operating Period 4 (7/10/12 to 7/31/12)	493 (0.7)	85	130	88	1st Stage: 0.12 2nd Stage: 0.13 3rd Stage: 0.10	9.9

Note:

1. The actual feed water recovery during Operating Period 2 was determined to be between 87 to 89%.
2. No cleaning was performed between Operating Period 3 and Operating Period 4.

Specific flux for the first stage elements are presented in Figure 2-7. First stage permeability is impacted primarily by organic fouling, particulates, and biological growth and should not be impacted significantly by whether the membranes are operated in a two-stage or three-stage configuration. The first stage permeability therefore allows a direct comparison of the organic fouling rate between the TML20 and ESPA2 membranes for this feed water, along with a comparison of intrinsic resistance within the membranes (the membranes natural resistance to pushing water through). Specific flux decline for the two membranes was similar, with both showing a rapid initial decline during the first 20 days (500 hours) of operation, followed by relatively flat permeability (around 0.12 gfd/psi) until the membranes were cleaned after 260 days (6,250 hours). Fouling of the membranes was low compared with many operational AWP facilities.

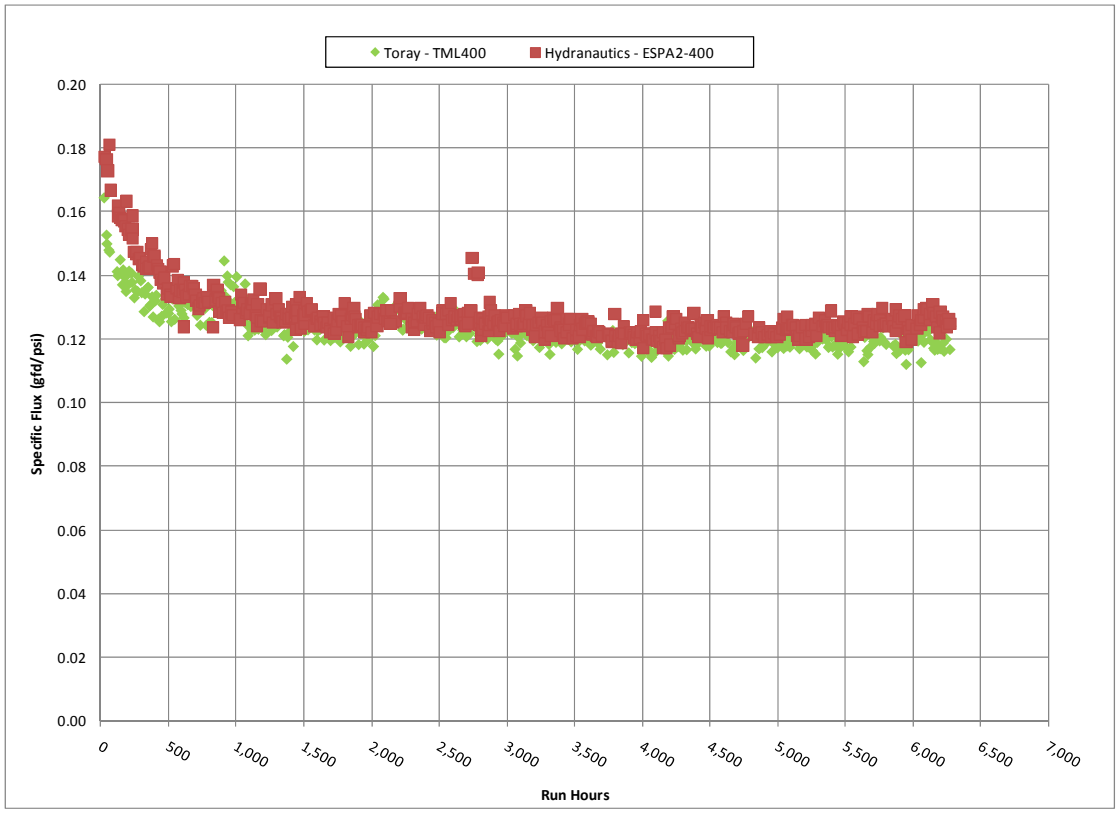


Figure 2-7
Membrane Permeability for RO System Trains A and B First-stage Membranes

Operational Period 2: is defined as the operational period following the completion of the second chemical cleaning, which was conducted at run hour 6,265 for Train A and run hour 6,297 for Train B. During this time the target feed water recovery for both systems was 85 percent. Following the second cleaning, Train A operated for 2,144 run hours (3 months) with little fouling (2.1 percent per month). However, Train B only operated for 920 run hours (1.3 months) due to the aforementioned issue with the concentrate flow meter which led to the system being operated above the target recovery (i.e. 87 to 89 percent). During this time fouling rate was 15 percent based on the decline in the overall specific flux, however the Stage 3 fouling rate was 40 percent. At this time, the third stage was cleaned.

Operational Period 3 (Train B only) is defined as the operational period following the cleaning of the third stage membranes. During this period the system was operated with a target recovery of 80 percent during which time the issue with the concentrate flow meter was investigated and resolved. During this period the system operated for 591 run hours with a modest fouling rate of 2.1 percent.

Operational Period 4 (Train B only) is defined as the operational period during which the system was operated at 85 percent recovery upon resolving the aforementioned issue with the concentrate flow meter. During this time the system operated for 493 run hours (0.7 months) with a measured fouling rate of 9.9 percent. Because a limited amount of run time was conducted on Train B at 85 percent

recovery, it is recommended that further operation be conducted to more fully assess the fouling rate at this recovery.

Table 2-9 presents the water quality data for RO System Trains A and B for several key water quality parameters. The two types of membranes were projected to differ on some water quality parameters, but both systems consistently produced permeate with similar water quality characteristics. Software projections for both membranes predicted less rejection of total dissolved solids (TDS) and chloride, with the Hydranautics ESPA2 elements (Train A) closer to projections for TDS and the Toray TML20 elements (Train B) closer for chlorides. Nitrate rejection was significantly under-estimated for the ESPA2 elements, projecting a total nitrogen concentration of 1.3 mg/L in the product, but measuring an average concentration nearly half of this, at 0.78 mg/L. In contrast, the TML20 software over estimated the nitrate rejection, predicting a total nitrogen of 0.3 mg/L, but measuring an average concentration more than double this, at 0.78 mg/L. Overall, there was very little difference between the permeate produced by the two RO membranes tested, in spite of the initial projections that had suggested much higher nitrogen removal with the TML20 elements.

Table 2-9 Comparison of RO System Trains A and B Permeate Water Quality

Contaminant	Units	Number of Samples (n)	Train A Permeate (Hydranautics ESPA2) (Average ±STD)	Train B Permeate (Toray TML) (Average ±STD)
Nutrients				
Ammonia, Total	mg/L-N	20	0.39 ±0.13	0.40 ±0.14
Nitrate	mg/L-N	20	0.38 ±0.09	0.40 ±0.09
Nitrite	mg/L-N	14	0.02 ±0.00	0.02 ±0.00
Nitrogen, Total	mg/L-N	20	0.78 ±0.12	0.77 ±0.09
Phosphorus, Total	µg/L-P	21	5 ±2	4 ±2
Inorganic				
TDS	mg/L	17	14 ±2	14 ±2
Sodium	mg/L	15	2.8 ±0.4	2.8 ±0.4
Chloride	mg/L	18	2.3 ±1.9	2.2 ±0.3
Boron	mg/L	15	0.22 ±0.02	0.22 ±0.02
Manganese	mg/L	15	0.002 ±0.001	0.002 ±0.001
Fluoride	mg/L	17	0.03 ±0.00	0.03 ±0.00
Organics				
TOC	mg/L	9	0.18 ±0.01	0.18 ±0.01
UV 254	cm-1	41	0.016 ±0.00	0.016 ±0.00
Microbial				
Total / Fecal Coliform	MPN/100 mL	73	<1	<1

Comparison of RO Configurations

Figure 2-8 presents the RO feed pressure for the two-stage and three-stage flow configurations. Since membrane permeabilities did not differ significantly between the two systems, the higher feed pressure seen with Train B (the Toray membranes) is the result of higher differential pressure losses associated with the three-stage operation. In a two-stage configuration, differential pressure loss occurs as water passes along the feed spacers of seven first-stage elements followed by seven second-stage elements, averaging 12 psi of loss within the first stage and 11 psi within the second. This pressure loss is partially overcome by an interstage boost from the energy recovery devices; however, the differential pressure loss still results in a decrease in net driving pressure and a lower water production in the tail end elements. For the three-stage configuration, differential pressure loss occurs

across three separate stages, although with only six elements in each stage, rather than the more typical seven elements used in the two-stage configuration. An average 11 psi of differential pressure loss occurred within the first stage, 15 psi in the second, and 13 psi in the third. As with the two-stage configuration, the differential pressure loss was partially overcome using an interstage boost from the energy recovery device.

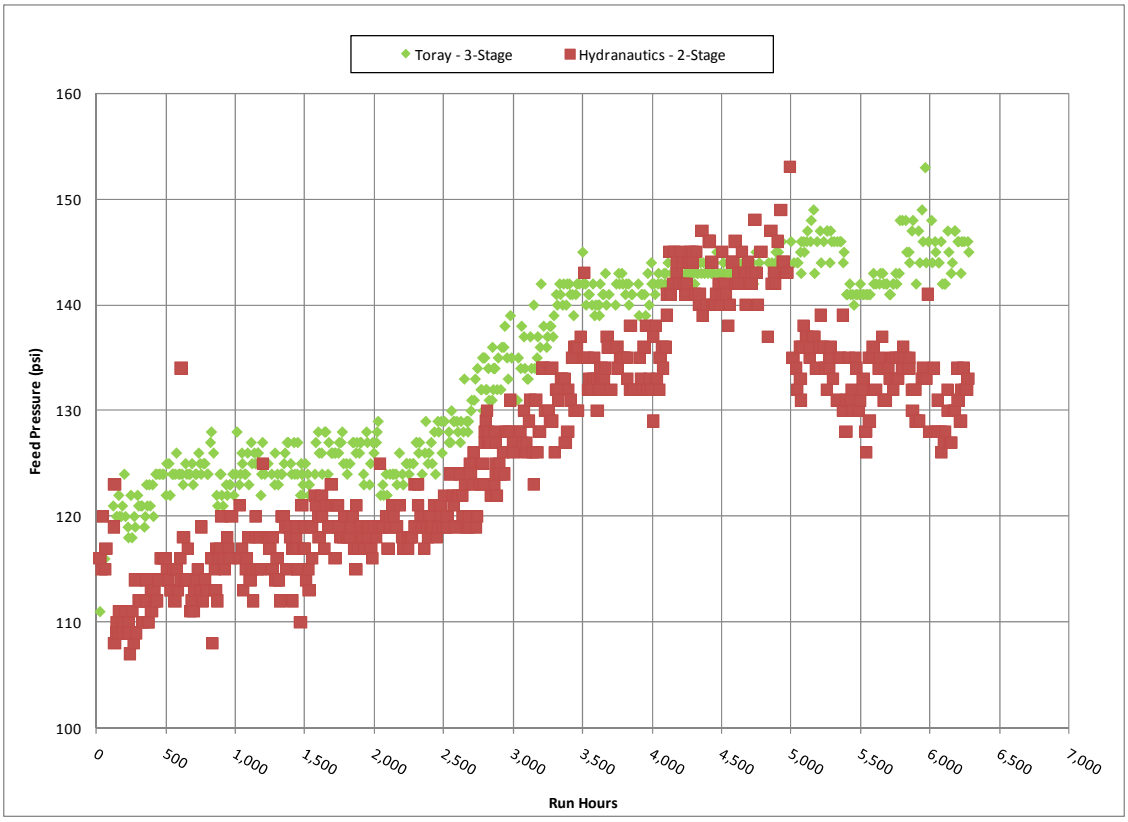


Figure 2-8
Feed Pressures for RO System Trains A and B

The operating results presented in Figure 2-8 demonstrate that the higher differential pressure loss experienced with the three-stage configuration resulted in a feed pressure between 10 to 15 psi higher than the two-stage configuration. This higher feed pressure relates directly to higher operating costs and energy demands for a three-stage configuration.

The rapid increase in feed pressure seen in the two-stage system after 170 days shown in Figure 2-7 resulted from removal of the energy recovery device for repair. The two-stage system operated at a feed pressure nearly identical to the three-stage system during the period in which no energy recovery device was used with the two-stage system, however, when the repaired energy recovery device was returned to service at 209 days, the feed pressure for the two-stage system dropped to approximately 15 psi below the three-stage system. Additional information on the comparison of the energy usage of the two-stage versus three-stage RO configuration is presented in Section 2.3.5.

2.3.3 UV Disinfection and Advanced Oxidation

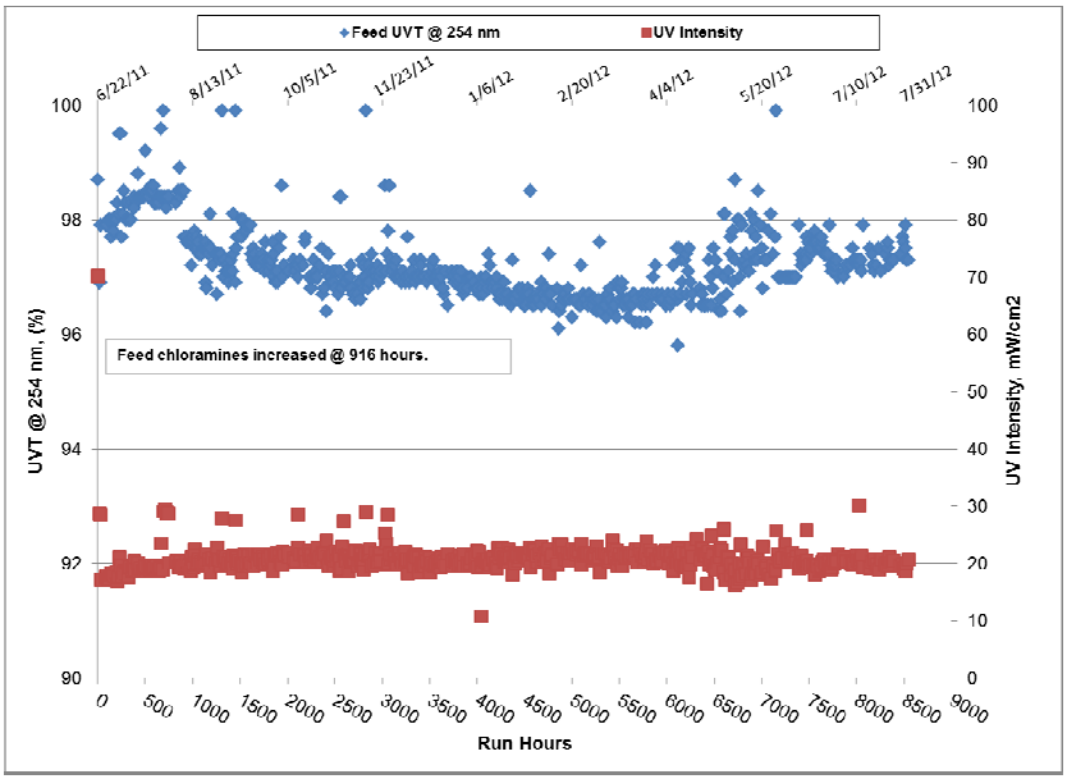
The UV disinfection and advanced oxidation system was operated to achieve a target log removal of NDMA and 1,4-dioxane of 1.2-logs and 0.5-logs, respectively, based on the 2008 CDPH Groundwater Replenishment Reuse Draft Regulations. After the commencement of this project, CDPH issued revised Groundwater Replenishment Reuse Draft Regulations (November 2011) that did not include the requirement for 1.2-log NDMA removal. The revised draft regulations maintained the requirement for 1,4-dioxane removal and included a requirement to meet the 10 nanogram per liter (ng/L) Notification Level for NDMA. However, testing conducted at the Demonstration Facility has shown that these low NDMA levels were met in the tertiary effluent before treatment, which means it may not ultimately be necessary to provide treatment for NDMA at the Full-Scale Facility. NDMA levels in the tertiary effluent are lower than other operating AWP facilities.

The target hydrogen peroxide dose applied to the UV disinfection and advanced oxidation feed water was held constant at 3 mg/L, targeting the required 0.5-log destruction of 1,4-dioxane. The ultraviolet light transmittance (UVT) at the 254 nanometer wavelength measured in the feed ranged from approximately 97 percent to 98.5 percent, which was determined to be impacted by the chloramines residual concentration. The Trojan control system adjusted the reactor power to maintain the target log removals using an algorithm, which takes into account feed flow, temperature, UVT, and lamp age.

Operating parameters monitored on the UV system for nearly 8,500 hours of operation are provided in Figure 2-9. The average reactor power level required to achieve the target NDMA removal as predicted by the Trojan control system was approximately 67 percent, which corresponds to an average power of 12.6 kilowatt (kW). A slight increase in the power required to achieve the target removal was observed to increase with an increase in runtime. The increased power was attributed to the decrease in temperature during the winter months as well as lamp aging, both of which increased the applied power to achieve a target contaminant removal. The average electrical energy per order (EEO) value as predicted by the Trojan algorithm and displayed on the human machine interface (HMI) over the testing period was 0.26 kilowatt-hours (kWh)/1,000 gallons/ log removal.

The UV system at the Demonstration Facility had five ballast failures which caused the reactor power to increase to 100 percent. The manufacturer indicated that the ballast failures were caused by failures in weak components of the faulty ballasts. The design of the Full-Scale Facility should include power monitoring of the Full-Scale Facility power sources to determine if a transient voltage surge suppressor should be included in the UV system design. Further discussion related to power optimization is provided in Section 3.1.3.

The EEO values and NDMA removal performance of the UV disinfection and advanced oxidation system were confirmed by conducting an initial spiking experiment. The spiking experiment was conducted by injecting a laboratory prepared NDMA stock solution to the UV and advanced oxidation feed water. The results of the spiking experiment are summarized in Figure 2-10. Overall the results showed that the Trojan system achieved NDMA removals between 1.5 to 2.1 log units over the span of power settings that were tested (60 percent to 100 percent). In addition, the system operated more efficiently than predicted by the Trojan algorithm. Calculated values of EEO based on results of the spiking experiment ranged from 0.18 to 0.21 kWh/1,000 gallons/log removal over the range of power settings tested. This EEO is similar to the tested EEO of 0.19 to 0.23 kWh/1,000 gallons/log removal for the UV disinfection and advanced oxidation system at the West Basin Municipal Water District's Edward C. Little Water Recycling Facility, a full-scale AWP Facility



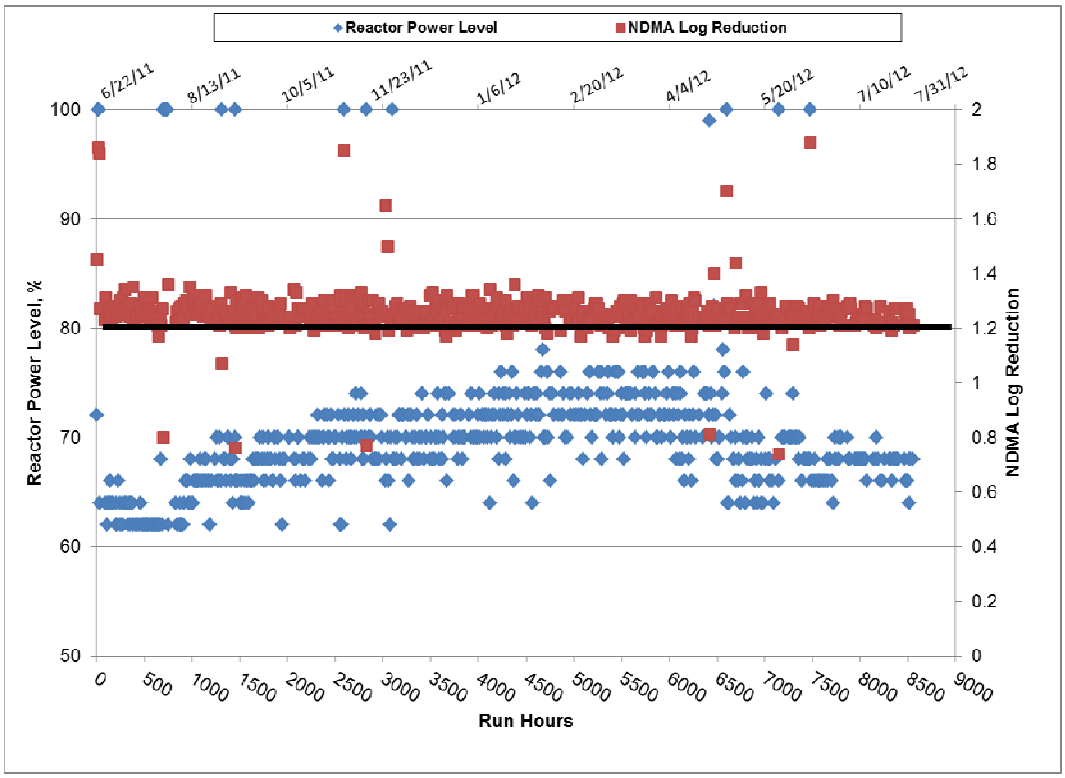


Figure 2-9
UV Disinfection and Advanced Oxidation Process System Performance

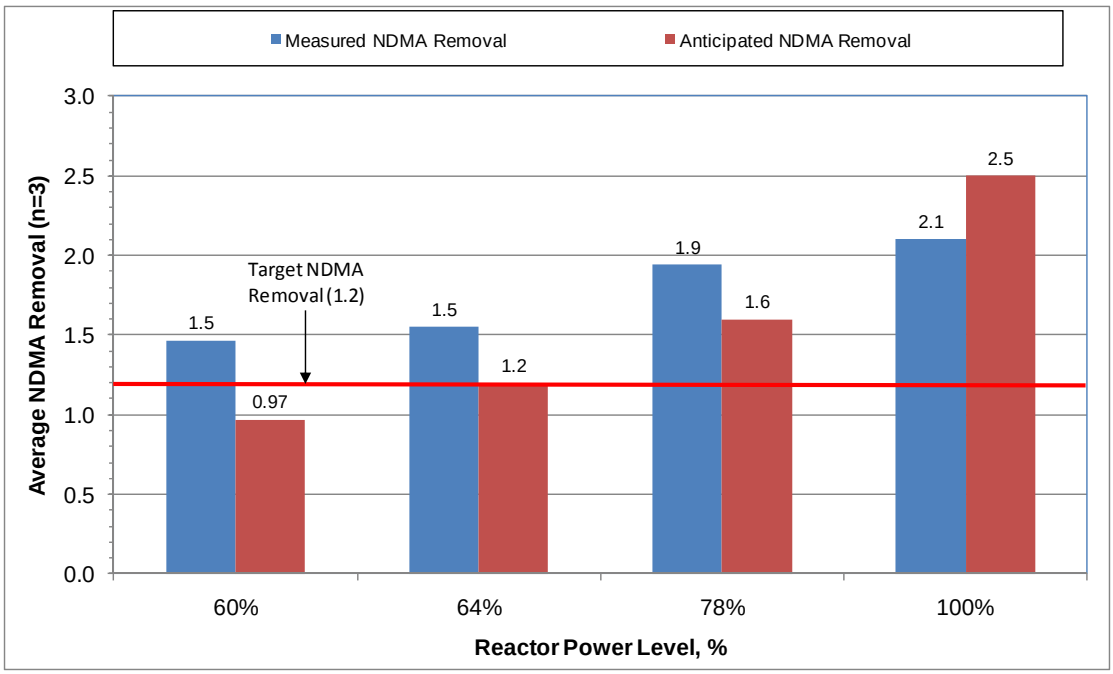


Figure 2-10
UV Disinfection and Advanced Oxidation NDMA Spiking Experiment Results

A second spiking experiment was conducted to demonstrate the performance of the reactor at removing both NDMA and 1,4-dioxane, the results of which are summarized in Figure 2-11. A laboratory-prepared 1,4-dioxane stock solution was injected into the UV and advanced oxidation feed water. The UV/AOP system achieved 0.6-log removal (74.9 percent) of 1,4-Dioxane under the design conditions. This exceeded the log-removal goal of 0.5 (68.7 percent) based on 2011 Groundwater Recharge Reuse Draft Regulations. Figure 2-11 plots log removal of 1,4-dioxane versus target peroxide dose for Tests 1 to 3. The results show a linear relationship between log removal and peroxide dose ($R^2 = 0.99$). Based on this relationship, a predicted target dose of 2.3 mg/L would be required to achieve 0.5 log removal of 1,4-dioxane. The significance of these results is that it may be possible to optimize the peroxide dose to reduce O&M costs of the UV/AOP if it is considered that there is a balance between electrical energy and peroxide dose needed to achieve the optimal operating conditions.

The EEO observed for 1,4-dioxane destruction ranged from 0.5 to 0.7 kWh/1,000 gallons/log reduction with a peroxide dose of 2.5 mg/L. This EEO is similar to the EEO of 0.5 kWh/1,000 gallons/log reduction reported by the Orange County Water District after initial testing at their Groundwater Replenishment System.

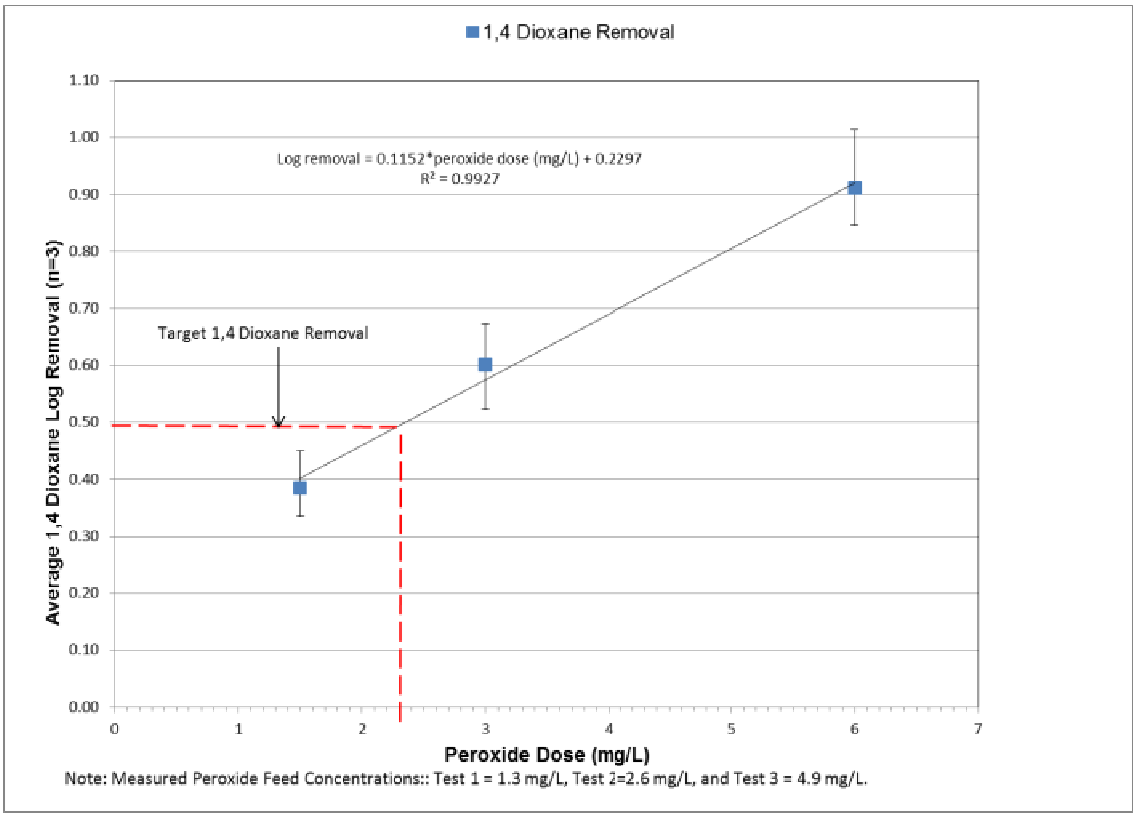


Figure 2-11
UV Disinfection and Advanced Oxidation 1,4 Dioxane Spiking Experiment Results

2.3.4 Chemical Consumption

The consumption of chemicals was monitored over the testing period. Key information and observations related to chemical consumption during the testing period for the various Demonstration Facility water purification processes are summarized below.

The Demonstration Facility used four chemicals during routine operations: ammonium hydroxide, sodium hypochlorite, antiscalant, and hydrogen peroxide. Table 2-10 provides specific information for each chemical used including target dose, location, stock concentration and purpose. Chemicals were fed into the process stream using diaphragm metering pumps. The speeds of the pumps are flow paced to maintain a constant dose when changes in flow occur. The most notable flow change throughout the Demonstration Facility operations was the feed flow when the MF or UF system goes into backwash or pressure decay test mode. Cylinder draw downs were completed daily to make sure that each chemical was being fed accurately and in the proper quantity.

Table 2-10 Summary of Chemicals used by the Demonstration Facility Water Purification Processes

Chemical	Stock Concentration (w/w)	Injection Location	Target Dose (mg/L)	Purpose
Ammonium hydroxide	19%	MF/UF Influent	1.5	To combine with sodium hypochlorite to form chloramines for membrane biofouling control.
Sodium hypochlorite	13%	MF/UF Influent	3.8	To combine with ammonia to form chloramines for membrane biofouling control.
Antiscalant	100%	RO Influent	3	To prevent scaling of RO membranes.
Hydrogen peroxide	30%	UV Influent	3	Reacts with UV light to form free hydroxyl radicals to provide advanced oxidation.

Monitoring of the chemical consumption of the Demonstration Facility water purification processes was conducted throughout the testing period. Table 2-11 provides information related to chemical usage for the MF, UF, RO and UV disinfection and advanced oxidation systems. The table provides the total amount of each chemical delivered during each testing period as well as the estimated average daily consumption per 1-mgd production of purified water.

The average daily consumption of each chemical represents the average of values determined from each testing period. During the Q1 Testing Period the daily consumption for each chemical was estimated based on full capacity production for a 24 hour period and the target dose rate. During the Q2 through Q4 Testing Periods, the actual average daily consumption usage of each chemical was determined by monitoring the level of each chemical storage tank before and after each delivery. The volume of each chemical used over the testing period was then calculated based on the difference in tank levels recorded at the beginning and end of the testing period, the total volume delivered over the testing period and the estimated storage capacity per foot of each chemical tank. The total calculated usage over the testing period was then divided by the total number of days in the testing period to estimate the average daily usage. No chemical usage above that expected was required during any of the testing periods.

Table 2-11 Summary of Chemical Consumption

Chemical	Total Amount Delivered Start up and Testing Period 1 5/3/11 to 10/31/11 (gallons)	Total Amount Delivered Testing Period 2 11/1/11 to 2/10/12 (gallons)	Total Amount Delivered Testing Period 3 2/11/11 to 5/14/12 (gallons)	Total Amount Delivered Testing Period 4 5/15/11 to 7/31/12 (gallons)	Estimated Average Daily Consumption per 1 mgd (gallons)
Ammonium hydroxide	1,593	1,007	1,208	928	11
Sodium hypochlorite	4,229	2,932	3,464	2,636	31
Antiscalant	440	275	220	164	3
Hydrogen peroxide	1,784	869	550	546	8

2.3.5 Energy Consumption

The power consumption of each Demonstration Facility water purification process was monitored during the demonstration period by taking daily readings of power consumption totals displayed on the Demonstration Facility control system. The totals are based on daily power logged by the individual power monitors (Electro Industries Model Shark 200) installed in each individual water purification processes (MF, UF, RO and UV disinfection and advanced oxidation systems). An

additional power meter was also installed to monitor the total power being used by the Demonstration Facility. The purpose of the main power meter was to capture the power usage of the entire Demonstration Facility, including MF, UF, RO and UV disinfection and advanced oxidation systems; chemical storage and feed systems for pre-treatment; and loads such as lights, air conditioning, and ancillary equipment (e.g., auto-samplers, TOC analyzer, etc.) plugged into the 120V receptacles. Table 2-12 summarizes the power monitors and associated equipment monitored by each power monitor.

Table 2-13 summarizes the monthly power usage by each water purification process for the days that the Demonstration Facility was in operation. Appendix F provides daily power totals logged from the main control system screen for each water purification process from 8/1/11 to 7/31/12.

The following observations were made regarding the Demonstration Facility power usage:

- Since the membrane filtration feed pumping was provided by the EDR feed pump located external to the Demonstration Facility, the power usage of the membrane filtration feed pumping was not monitored continuously. The power consumption of the EDR feed pump feeding the membrane filtration systems was monitored for three days and average daily power consumption was 960 kWh/d. The major power requirement for the membrane filtration systems is influent pumping.
- The UF power usage is consistently higher than the MF power usage, which was attributed to the oversized air compressor and other inefficient design components. The UF power usage is discussed in more detail below.
- Following the replacement of the inlet valve electro-pneumatic positioner with a pneumatic actuator on 1/18/12, the daily UF power totals were observed to increase by approximately 50 kWh/d.
- The measurements in the MF power monitor increased in October 2011 and April 2012 due to increased power usage required to heat the cleaning chemicals for the chemical cleanings conducted in those months. However, the increase in power usage of chemical cleanings was offset by reduced power usage from MF downtimes.
- Comparison of the sum of the individual power meters for the water purification processes to Demonstration Facility power meter show that the power usage for ancillary equipment not specific to MF/UF, RO or UV disinfection and advanced oxidation systems was approximately 3 percent to 4 percent of the total Demonstration Facility power usage.

Table 2-12 Demonstration Facility Power Monitors

Power Monitor		Equipment Monitored	Equipment Not Monitored
1	MF System	MF strainer MF skid including recirculation pump and reverse feed pump MF skid including hot water pump MF/UF/RO CIP tank heater MF air compressor system	MF control panel and MF air dryer are on 120 V power source and captured by the Demonstration Facility main power monitor
2	UF System	UF strainer UF skid including backwash pump UF air compressor system UF chemical transfer pumps	
3	RO Train A System	RO Train A including Train A feed pump	RO cleaning skid including permeate flush pump and cleaning pump are captured by the Demonstration Facility main power monitor
4	RO Train B System	RO Train B including Train B Feed pump	
5	UV Disinfection and Advanced Oxidation System	UV system Hydrogen peroxide feed pumps	
6	Demonstration Facility Main	All equipment located within Demonstration Facility, including: RO cleaning skid with permeate flush pump and cleaning pump; ancillary process equipment such as sodium hypochlorite feed pump, ammonium hydroxide feed pump, disinfection carrier water pump, sulfuric acid feed Pump, antiscalant feed pump, sump pump; analyzer equipment such as auto-samplers, TOC analyzer, etc.; lights; and air conditioning.	EDR feed pump for MF/UF feed pumping

Reference:

Indirect Potable Reuse/Reservoir Augmentation Demonstration Project Advanced Water Purification Facility at North City WRP, Approved for Construction Drawings, CDM Smith/MWH, February 2011, Drawings 28-E-3 and 28-E-4.

Table 2-13 Demonstration Facility Power Usage Monthly Summary

Month	Total Monthly Power Consumption (kWh) [8]									
	MF [1]	UF [2]	RO Train A	RO Train B	UV	Ancillary Loads [3]	Total including MF/UF Feed Pumping [4]	Total including MF/UF Feed Pumping [5]	Total without MF/UF Feed Pumping [6]	Total without MF/UF Feed Pumping [7]
Aug 2011	14,200	16,100	14,400	18,100	6,600		69,300		45,000	
Sep 2011	13,500	15,200	17,200	17,100	5,300		68,300		45,600	
Oct 2011	14,800	19,000	21,900	22,200	8,600		86,600		61,200	
Nov 2011	14,900	18,100	21,300	22,400	8,300		85,000		59,700	
Dec 2011	16,600	20,100	25,800	27,500	8,900	3,200	98,900	102,000	70,900	74,100
Jan 2012	16,600	20,800	25,400	27,100	8,800	3,200	98,600	102,000	70,400	73,600
Feb 2012	16,200	21,100	25,600	26,900	8,900	3,000	98,700	102,000	71,200	74,200
Mar 2012	17,800	21,600	24,700	26,600	8,900	3,300	99,500	103,000	70,400	73,700
Apr 2012	18,100	21,000	22,700	27,300	9,000	3,400	98,200	102,000	70,200	73,600
May 2012	15,000	17,300	19,100	21,700	7,500	2,500	80,700	83,000	56,000	58,600
June 2012	14,000	16,700	18,800	21,600	7,200	2,700	78,300	81,000	55,400	58,100
July 2012	14,400	17,200	19,200	22,500	9,100	2,400	82,400	84,000	58,000	59,200
Total Power (kWh)	**186,000**	**224,200**	**256,100**	**281,100**	**97,100**		**1,044,500**		**734,000**	
Total Flow Treated (MG)	**172**	**174**	**161**	**161**	**324**	**324**	**324**	**324**	**324**	**324**
Average Power Consumption per Flow (kWh/MG)	**1,100**	**1,300**	**1,600**	**1,700**	**300**		**3,200**		**2,300**	

Notes:

[1]Includes power measured by MF system power monitor, estimated power usage for MF feed pumping, and estimated power usage for MF control panel and MF air dryer that are powered through the 120V system. MF feed pumping is based on average feed flow of 570 gpm and 35-40 psi of pressure. Feed pressure was reduced at the PRV located upstream of MF. The MF control panel is estimated to use 14 kWh/day and the MF air dryer is estimated to use 2.9 kWh/day.

[2]Includes power measured by UF system power monitor and estimated power consumption for UF feed pumping. UF feed pumping is based on average feed flow of 552 gpm and 35-40 psi of pressure. Feed pressure was reduced at the PRV located upstream of UF.

[3] Includes power usage for: RO cleaning skid with permeate flush pump and cleaning pump; ancillary process equipment such as sodium hypochlorite feed pump, ammonium hydroxide feed pump, disinfection carrier water pump, sulfuric acid feed pump, antiscalant feed pump, sump pump; analyzer equipment such as auto-samplers, TOC analyzer, etc.; lights; and air conditioning.

[4]Total estimated power usage for UF, MF, RO and UV disinfection and advanced oxidation systems, including membrane filtration feed pumping. Does not include RO cleaning skid, ancillary process equipment, analyzer equipment, lighting and air conditioning.

[5]The total Demonstration Facility power usage measured by the main power monitor plus the estimated power usage for membrane filtration feed pumping. The main power monitor was installed on 11/8/11.

[6]Total estimated power usage for UF, MF, RO and UV disinfection and advanced oxidation systems. Does not include membrane filtration feed pumping. Does not include RO cleaning skid, ancillary process equipment, analyzer equipment, lighting and air conditioning.

[7]The total Demonstration Facility power usage measured by the main power monitor. Does not include the estimated power usage for membrane filtration feed pumping.

[8]For days that power totals were not recorded from the meters, power usage was estimated based on the estimated runtime and typical power usage over a 24-hour period.

Membrane Filtration Power Consumption

The detailed breakdown of monthly total membrane filtration power consumption is summarized in Table 2-14.

Table 2-14 Membrane Filtration Power Consumption

Month	MF					UF		
	MF Power Monitor[1]	MF Feed Pumping[2]	MF Control Panel[3]	MF Air Dryer[4]	Total MF	UF Power Monitor[5]	UF Feed Pumping[6]	Total UF
Aug 2011	1,621	12,114	361	72	14,168	3,953	12,190	16,143
Sep 2011	1,668	11,449	341	68	13,526	4,027	11,213	15,241
Oct 2011	2,438	11,953	356	71	14,818	5,561	13,460	19,021
Nov 2011	1,566	12,860	383	77	14,885	5,593	12,464	18,056
Dec 2011	1,811	14,271	425	85	16,591	6,337	13,753	20,090
Jan 2012	1,720	14,331	427	85	16,563	6,902	13,890	20,791
Feb 2012	1,737	13,948	415	83	16,184	7,554	13,519	21,073
Mar 2012	2,277	14,996	446	89	17,809	7,342	14,124	21,466
Apr 2012	3,401	14,210	423	85	18,119	7,225	13,773	20,998
May 2012	1,942	12,638	376	75	15,031	5,330	11,995	17,325
June 2012	2,057	11,469	341	68	13,935	5,294	11,448	16,741
July 2012	1,577	12,396	369	74	14,416	5,211	12,014	17,225
Total Power (kWh)	**23,816**	**156,633**	**4,663**	**933**	**186,044**	**70,327**	**153,843**	**224,170**
Total Flow Treated (MG)	**172**	**172**	**172**	**172**	**172**	**174**	**174**	**174**
Average Power Consumption per Treated Flow (kWh/MG)	**139**	**913**	**27**	**5**	**1,084**	**404**	**885**	**1,289**

Notes:
[1]Measured by MF system power monitor. MF power usage for membrane skids and ancillary equipment includes power usage from chemical cleaning system tank heater, which was also used for UF and RO cleanings. Therefore, MF power usage is slightly overestimated.
[2]Calculated value based on average feed flow of 570 gpm and 35-40 psi of pressure.
[3]MF control panel is powered through the 120V system. The MF control panel is estimated to use 14 kWh/day.
[4] MF air dryer is powered through the 120V system. The MF air dryer is estimated to use 2.9 kWh/day.
[5] Measured by UF system power monitor. UF power usage for membrane skids and ancillary equipment does not include power usage from chemical cleaning system tank heater (measured as part of MF system) or chemical cleaning system pumps (measured separately and accounted for as part of ancillary loads). Therefore, UF power usage is slightly underestimated.
[6]Calculated value based on average feed flow of 552 gpm and 35-40 psi of pressure.

Power Monitoring of the Membrane Filtration Feed Pump (EDR Feed Pump)

The power to pump the tertiary recycled water to the membrane filtration systems is separate from the power to the Demonstration Facility and not measured with the Demonstration Facility power monitor. The membrane filtration feed pump is shared with the City's EDR system and is set to pump at a discharge pressure of approximately 35 to 40 psi, which is later reduced down to 15.5 psi and 17.2 psi to meet the membrane filtration system influent pressure requirements (the estimated average feed pressure required for the MF and UF are 15.5 psi and 16.0 psi, respectively, after accounting for the backpressure on the UF system). The membrane filtration feed configuration in the Demonstration Facility is not reflective of the Full-Scale Facility influent pumping configuration, since

the Full-Scale Facility will be located north of North City and will have different head requirements (see Section 4).

The City performed short-term power monitoring of the EDR feed pump that supplies feed water to the membrane filtration systems to determine how much power was used to feed the membrane filtration systems at the Demonstration AWP Facility. An external power meter was connected to the feed pump for approximately nine days. Based on the total power recorded over this time period, the power usage of the feed pump per day was approximately 960 kWh/day to feed both membrane filtration systems. The membrane filtration feed pumping accounted for approximately 30 percent of the total Demonstration Facility power consumption.

Estimated Power Usage for Membrane Filtration Feed Pumping

Since approximately 18 to 25 psi of pressure was lost, on average, across the pressure reducing valves located upstream of the membrane filtration, a more realistic power requirement for membrane filtration feed pumping was estimated based on the average transmembrane pressure across the membrane filtration membranes that were measured during the Demonstration Facility testing period. Based on this calculation, the membrane filtration feed pumping was reduced to approximately 10 percent of the total Demonstration Facility power consumption. Table 2-15 shows a detailed breakdown of the membrane filtration power consumption with the EDR feed pump used for membrane filtration feed pumping.

Table 2-15 Average Power Consumption per Flow Treated for Membrane Filtration

Equipment	Average Power Consumption per Flow Treated (kWh/MG)			
	MF [1]		UF [2]	
	Pumping with EDR Feed Pump	Estimated Pumping based on transmembrane pressure	Pumping with EDR Feed Pump	Estimated Pumping based on transmembrane pressure
Feed Pumping	913 (Average Feed Pressure = 35-40 psi)	232 (Average Feed Pressure = 15.5 psi)	885 (Average Feed Pressure = 35-40 psi)	232 (Average Feed Pressure = 16.0 psi)
Membrane Skids and Ancillary Equipment	171	170	404	408
Total	**1,084**	**402**	**1,289**	**640**

Notes:
[1]MF power usage for membrane skids and ancillary equipment include power usage from the chemical cleaning system tank heater, which was also used for UF and RO cleanings. Therefore, MF power usage is slightly overestimated.
[2]UF power usage for membrane skids and ancillary equipment does not include power usage from the chemical cleaning system tank heater (measured as part of MF system) or the chemical cleaning system pumps (measured separately and accounted for as part of ancillary loads). Therefore, UF power usage is slightly underestimated.

Investigation of UF Power Usage

As shown in Table 2-15 and Appendix F, the UF system required approximately 18 percent more power than the MF system during the Demonstration Project. Table 2-15 shows that the difference in power consumption is greater (59 percent) once the influent pumping requirements are adjusted to eliminate excess pumping, as discussed above.

The City conducted additional power monitoring of the UF system with an external power meter to confirm the power usage. The power meter was connected to the main UF power supply for approximately 14 days. Based on the total power recorded over this time period, the power usage of

the UF system was determined to be approximately 200 kWh/day, which correlates to the values logged from the power monitor equipped on the system.

Next, the power usage of the air compressor on the UF system was monitored for nearly 14 days using the external power meter. Based on the total power recorded over this time period the power usage of the air compressor was determined to be 105 kWh/day, which is about half of the total UF power. It is expected that differences in the size and efficiency of the compressors equipped on the UF and MF systems may account for the discrepancy in power totals. The UF system air compressor is 40 HP and requires 50 amps while the MF system air compressor is about 8 horsepower (HP) and requires 7.9 amps. It seems that the UF system air compressor was oversized and the design could be optimized for the Full-Scale Facility.

Reverse Osmosis

Comparison of Two-stage versus Three-stage RO Systems

Two RO configurations were tested at the Demonstration Facility, two-stage and three-stage configurations, both incorporating energy recovery devices that were designed to provide approximately 23 psi of interstage boost. As previously discussed, the three-stage configuration (RO Train B) provided no improvement in performance over the two-stage configuration (RO Train A), but required a feed pressure 5 to 10 percent higher. As shown in Table 2-16 below, the three-stage configuration (RO Train B) required on average 9 percent more energy than a two-stage configuration (RO Train A).

Table 2-16 Comparison of Two-stage RO and Three-stage RO Power Consumption

Month	Total Monthly Power Consumption (kWh)		
	RO Train A [1] (Two-Stage Configuration)	RO Train B [2] (Three-stage configuration)	Ancillary Loads [3]
Aug 2011	14,400	18,100	
Sep 2011	17,200	17,100	
Oct 2011	21,900	22,200	
Nov 2011	21,300	22,400	
Dec 2011	25,800	27,500	3,200
Jan 2012	25,400	27,100	3,200
Feb 2012	25,600	26,900	3,000
Mar 2012	24,700	26,600	3,300
Apr 2012	22,700	27,300	3,400
May 2012	19,100	21,700	2,500
June 2012	18,800	21,600	2,700
July 2012	19,200	22,500	2,400
Total Power (kWh)	**256,100**	**281,100**	
Total Flow Treated (MG)	**161**	**162**	**324**
Average Power Consumption per Treated Flow (kWh/MG)	**1,600**	**1,700**	

Notes:
[1]Measured by RO Train A power monitor. Two-stage system. Energy recovery device is ERI Turbocharger LPT-250.
[2]Measured by RO Train B power monitor. Three-stage system. Energy recovery device is ERI Turbocharger LPT-150.
[3]Includes power usage for: RO cleaning skid with permeate flush pump and cleaning pump; ancillary process equipment such as sodium hypochlorite feed pump, ammonium hydroxide feed pump, disinfection carrier water pump, sulfuric acid feed pump, antiscalant feed pump, sump pump; analyzer equipment such as auto-samplers, TOC analyzer, etc.; lights; and air conditioning.

A two-stage configuration is currently used at the City of Los Angeles' Terminal Island AWP Facility, Water Replenishment District's Leo J. Vander Lans Water Treatment Facility, and one of the West Basin Municipal Water District's AWP facilities; however, a three-stage configuration is used at the Orange County Groundwater Replenishment System and another of the West Basin Municipal Water District's AWP facilities. The preliminary layout, design criteria, and cost estimate are based on a two-stage configuration, based on three quarters of operating data, which showed that a three-stage configuration required approximately 8 percent more energy with no improvement in performance over a two-stage configuration.

Evaluation of Energy Recovery Devices

Both RO trains are equipped with energy recovery devices to utilize wasted energy from the RO concentrate to boost feed pressures to the final stage. Energy recovery devices have been employed successfully at brackish water RO facilities in California and other western states, but have not yet been incorporated into an AWP Facility in the region. While energy recovery devices will reduce the required feed pressure and energy usage at an RO facility, the ability of the operational savings to offset the cost of the equipment will depend on the salinity of the water, the residual energy in the concentrate, and the efficiency of the energy recovery device. Because of the limited data available on full-scale operation of these devices in AWP facilities, a focus of the Demonstration Facility was to confirm the accuracy of projected energy recovery estimated using RO design models (IMSDesign v. 2009).

Table 2-17 presents information on the energy recovery devices used in the RO systems for the Demonstration Facility and the impacts these devices had on operating pressures. Section 3 includes additional information on the energy recovery devices. The average boost to the final stage shown in the table was measured directly from the systems; however, values for the two-stage configuration include only data from after 209 days of operation when the energy recovery device had been repaired. Initial operation with the energy recovery device only resulted in a 5 to 10 psi boost in interstage pressure for the two-stage system. After several months of trouble-shooting with the RO system supplier and ERD manufacturer, the device was removed and sent for testing and repairs. When the repaired device was returned to service, the interstage boost averaged 23 psi. The reduction in feed pressure listed in Table 2-17 for the two-stage system was calculated as the average feed pressure when the device was offline (between 170 and 209 days) minus the average feed pressure after the device was returned to service (after 209 days). The reduction in feed pressure for the three-stage system, in contrast, was calculated using an energy balance, the measured pressure boost to the final stage, and the flow ratio between the final stage and the first stage. Total energy reduction was calculated by dividing the calculated reduction in feed pressure by the measured feed pressure. The following formulas were used for these calculations:

Reduction in Feed Pressure (Three-stage)

$P_r = P_b * Q_{3f}/Q_{1f}$

where P_r = Reduction in feed pressure

P_{3b} = Boost pressure to third stage

Q_{3f} = Feed flow to the third stage (calculated from concentrate plus third-stage permeate flow)

Q_{1f} = Feed flow to the first stage

Total Energy Reduction

$E_r = (P_r/P_{1f})*100$

where E_r = Reduction in energy (%)

P_r = Reduction in feed pressure

P_{1f} = Feed pressure to the first stage

Concentrate Energy Recovered (Three-stage)

$E_{cr} = (P_b*Q_{3f}/(P_c*Q_c))*100$

where E_{cr} = Concentrate energy recovered (%)

P_{3b} = Boost pressure to third stage

Q_{3f} = Feed flow to the third stage

P_c = Final concentrate pressure

Q_c = Final concentrate flow

Table 2-17 Impact of Energy Recovery Devices on RO Operation

	RO Train A Two-Stage Configuration	RO Train B Three-Stage Configuration
Equipment Model Number	ERI Turbocharger LPT-250	ERI Turbocharger LPT-125
Average Boost to Final Stage	23 psi	24 psi
Reduction in Feed Pressure	10 psi	7.4 psi
Concentrate Energy Recovered	42%	27%
Total Energy Reduction	8%	5%

For the energy recovery devices used at the Demonstration Facility, the two-stage configuration resulted in a higher overall recovery of energy. An average of 42 percent of the hydraulic energy present in the concentrate stream was recovered in the interstage boost, compared with only 27 percent energy recovery achieved in a three-stage configuration. The energy recovery resulted in an overall energy savings of 8 percent and 5 percent for the two-stage and three-stage systems, respectively. Efficiencies of the energy recovery devices are impacted by operating pressures, concentrate and interstage flows and should not be assumed to remain constant over the full duration of plant operation.

UV Disinfection and Advanced Oxidation

The average reactor power level required to achieve the target NDMA removal as predicted by the Trojan control system was approximately 67 percent, which corresponds to an average power of 12.5 kW. The power required to achieve the target removal was observed to increase as runtime increased. The increased power was attributed to the decrease in temperature during winter months, as well as lamp aging, both of which increased the applied power to achieve a target contaminant removal. The average EEO value predicted over the testing period for NDMA was 0.26 kWh/1,000 gallons/ log removal. When measured during the testing period, however, the EEO was better than projected at 0.19 kWh/1,000 gallons/log removal. For the Full-Scale Facility, multiple UV vessels in series will likely be used to improve overall reactor hydraulics, further reducing the EEO.

2.4 Water Quality and Regulatory Relevance

This subsection includes a discussion of the water quality data collected during the operation of the Demonstration Facility and the regulatory relevance of the data in regards to future permitting of the Full-Scale Facility. Non-regulated water quality constituents are also discussed, in regards to potential health impacts associated with constituents monitored in the purified water.

2.4.1 Regulatory Background

As described in the T&M Plan (Appendix A), a future Full-Scale Facility will be subject to requirements put forth by CDPH and the Regional Board. At this time, specific requirements for reservoir augmentation have not been established by any state agencies, creating a degree of uncertainty regarding the ultimate requirements which will need to be met. For purposes of evaluating the regulatory relevance of the water quality observed at the Demonstration Facility, water quality goals were developed for the T&M Plan based on:

- Compliance with all federal (U.S. Environmental Protection Agency [EPA]) and state (CDPH) drinking water maximum contaminant levels (MCLs) and secondary maximum contaminant levels.
- Remaining below all CDPH notification levels (NLs).
- Compliance with all requirements of the August 2008 and November 2011 CDPH Groundwater Replenishment Reuse Draft Regulations. These draft requirements were used because CDPH has not issued draft regulations for surface water augmentation. (Note that in November 2011, after the Demonstration Facility design and T&M Plan were completed, CDPH released updated Groundwater Replenishment Reuse Draft Regulations. The goals included here-in comply with requirements from both the 2008 and the 2011 draft regulations.)
- Compliance with all established discharge requirements from the Regional Board, including Basin Plan Objectives, California Toxics Rule (CTR) requirements for freshwater and for human health, and State Board Policy for Implementation of Toxics Standards for Inland Surface Water, Enclosed Bays, and Estuaries of California (SIP). It should be noted here that not all requirements for the CTR or the nutrient limits of the Basin Plan have been firmly established for discharges to San Vicente Reservoir and some uncertainly therefore remains on these specific requirements.
- Compliance with project specific goals established for the Demonstration Facility.

Twenty-one key water quality parameters were identified to serve as a primary focus of the water quality testing, with project specific goals established for each parameter as listed in Table 2-18. These key constituents were identified because they can be challenging to remove by the treatment processes employed or because they are widely used parameters to measure performance of water treatment processes. Additionally, nutrients are a specific concern when introducing purified water to the San Vicente Reservoir, and five specific nutrient goals were identified as part of the key water quality parameters. Several of the water quality goals were based on CTR limits for consumption of water and organisms, without accounting for a mixing zone, as would typically be applied. The goals are considered conservative with respect to potential requirements of the CTR. Of particular note are the goals established for bromoform, bromodichloromethane, and dibromochlormethane, which are three of the four trihalomethanes that also regulated for drinking water with an MCL of 80 µg/L for

the sum of all four trihalomethanes. The goals listed in Table 2-18 for these three trihalomethanes are more than 100 times lower than this drinking water MCL and are based on CTR limits that may not be applicable once potential mixing zones are accounted for in the reservoir.

All water quality goals defined in the T&M Plan were reviewed and commented on by CDPH, the Regional Board, and the Demonstration Project Independent Advisory Panel. As a result of the comments received, the T&M Plan was expanded to include sampling for additional water quality parameters and increased frequency and number of samples for constituents that were identified in the draft plan. These comments and a description of how they were addressed are included as an Appendix to the T&M Plan.

Table 2-18 Demonstration Facility Project Specific Water Quality Goals

Constituent		Units	Water Quality Goal[a]
Removal Challenge	Bromoform	µg/L	0.5
	Methylene Chloride	µg/L	4.7
	Trihalomethanes, Total (TTHMs)	µg/L	80
	Bromodichloromethane	µg/L	0.56
	Dibromochloromethane	µg/L	0.5
	Haloacetic Acids (HAA5)	µg/L	<60
	N-Nitrosodiethylamine (NDEA)	ng/L	10
	N-Nitrosodimethylamine (NDMA)	ng/L	2
	1,4-Dioxane	µg/L	1
	1,2-Dichloroethane	µg/L	0.5
	Boron	mg/L	1.0
Common Parameters	Total Organic Carbon (TOC)	mg/L	0.5
	Total Dissolved Solids (TDS)	mg/L	300
	Chloride	mg/L	50
	Sulfate	mg/L	65
	Turbidity	NTU	0.2
Nutrients	Nitrate as N	mg/L	1
	Nitrite as N	mg/L	1
	Ammonia as N (unionized)[b]	mg/L	0.025
	Phosphorus, Total	mg/L	0.1
	Nitrogen, Total	mg/L	1

Note:

a. See T&M Plan, Table 5-2 (Appendix A).

b. Unionized values of ammonia are not directly measured, but are estimated using EPA's Aqueous Ammonia Equilibrium – Tabulation of Percent Un-ionized Ammonia (EPA-600/3-79-091) along with average values of temperature and pH.

2.4.2 Summary of Water Quality Testing

The T&M Plan outlined an extensive water quality monitoring plan for the Demonstration Facility. Water quality testing was conducted in the following seven constituent categories.

- *Routine Water Quality Monitoring.* This category consisted of nutrients (nitrogen and phosphorus); volatile organic compounds (trihalomethanes, methylene chloride, 1,2-dichloroethane); nitrosamines; 1,4-dioxane; and TOC. Sampling frequencies ranged from bi-weekly to monthly depending on the specific parameter.

- *Microbial Monitoring.* This category consisted of total coliform and fecal coliform, in which sampling was initially conducted daily and then weekly. Somatic and male specific bacteriophage (viruses) sampling was initially conducted weekly, then monthly.

- *Basin Plan Objectives Monitoring.* This category consisted of parameters with Basin Plan numeric objectives not addressed in other sampling categories: TDS, Chloride, Sulfate, Sodium, Iron, Manganese, Boron, Color, Fluoride, Phenolic compounds, pH, Temperature, Dissolved Oxygen, and Turbidity. Sampling frequencies ranged from daily to bi-monthly.

- *Quarterly Monitoring.* This category consisted of: (1) compounds with Federal and State drinking water MCLs; (2) compounds included on EPA's priority pollutant list; (3) compounds with current CDPH NLs; (4) compounds on the US EPA's current Unregulated Contaminant Monitoring Rule (UCMR3) list; (5) other Radionuclides (Cesium-137, Iodine-29, Iodine-131); 6) other compounds recommended by the IAP (Lithium, benzo(k)fluoranthene, hexavalent chromium). Samples were collected quarterly.

- *Constituents of Emerging Concern (CECs).* During the Q1 and Q2 Testing Periods, an initial characterization study was conducted based on four monthly sampling events for 91 CECs, including pesticides, herbicides, pharmaceuticals, and ingredients in personal care products representing a wide range of chemical and physical properties. Following the initial characterization study, the CEC monitoring program was modified to include the health-based and performance-based indicators recommended by the State Board's expert panel on CEC monitoring for groundwater recharge projects that utilize RO/advanced oxidation. The complete report produced by the expert panel can be found online at the following website: http://www.waterboards.ca.gov/water_issues/programs/water_recycling_policy/recycledwater_cec.shtml. One sample was collected for this suite of CECs. In addition, 37 CECs were selected for monitoring as potential treatment performance indicators based on occurrence in the RO feed water as measured during the initial characterization study or CECs recommended by the IAP. Weekly samples were collected over a period of four weeks.

- *Whole Effluent Toxicity Testing*. This program, conducted during the Q2 Testing Period, consisted of acute and chronic toxicity assays for a blend of purified water and Lake Murray (local reservoir primarily holding imported water) and a control sample. The chronic test organisms were *Ceriodaphnia dubia* (water flea), *Pimephales promelas* (fathead minnow) and *Selenastrum capricornutum* (green algae). The test organisms used for the acute testing were *Ceriodaphnia dubia* and *Pimephales promelas*.

- *Quality Assurance/Quality Control (QA/QC) Testing*. A QA/QC Plan was developed for the project consisting of the collection and analysis of field duplicates, blind duplicates, travel blanks, field blanks, and split samples. In addition, third-party validations were performed by Laboratory Data Consultants, Inc. using EPA Level IV guidelines to assess data quality and review laboratory and sample handling procedures by WECK and MWH Labs.

There was some overlap for parameters in the different categories. For example some of the constituents included in the routine monitoring category were also assessed as part of the quarterly monitoring category.

2.4.3 Water Quality Monitoring Results – Regulated Constituents

Results from water quality monitoring conducted through the Q4 Testing Period showed that the Demonstration Facility produced purified water that reliably met drinking water and the 2008 and 2011 CDPH Groundwater Replenishment Reuse Draft Regulations, while providing multiple barriers to chemicals and pathogens. The purified water met all regulatory requirements and goals defined for the project.

Project Specific Goals

A summary of water quality monitoring results of regulated constituents is presented in Table 2-19, and a comparison of key water quality results and project specific goals is presented in Table 2-20. Table 2-20 shows values for all parameters returning quantifiable laboratory results above the laboratory reporting level. Sample results less than the laboratory reporting level (LRL) or the method detection limit (MDL) were considered to be not quantifiable or not detectable, both shown as "ND" in the table. It should be noted that CDPH has established detection limits for purposes of regulatory reporting (DLRs) for all parameters listed in existing CDPH regulations. In some cases the DLR was higher than the laboratory reporting level, resulting in values shown in Table 2-20 that would be considered non-detectable under standard CDPH reporting. As analytical methods advance in the industry, it has allowed the measurement of compounds at increasingly low concentration. Standard, approved analytical methods were used for all constituents, when available.

For purposes of calculating average values and standard deviations, non-quantifiable values below the laboratory reporting level were assumed to be 50 percent of that value, while values below the method detection limit were assumed to be 50 percent of that value. Calculated average values less than the laboratory reporting level are considered non-quantifiable and shown as "ND" in Table 2-20. Average concentrations for all constituents measured in the purified water were below the project specific goals for the Demonstration Facility.

Federal and State Drinking Water Maximum Contaminant Levels

All constituents currently regulated for drinking water supplies were monitored quarterly in the tertiary effluent prior to chlorination, purified water, and imported raw aqueduct water. Primary drinking water standards are established by the EPA and CDPH, and are based on MCLs, established to provide the maximum feasible protection to public health, based on EPA health guidelines for both acute (short term) and chronic (long term) health risks. In addition, secondary MCLs have been established for non-health concerns, based on aesthetic issues, such as taste, odor, or color in the water. Secondary MCLs are considered guidelines rather than enforceable limits, as they are not related to public health at these concentrations. Currently, the EPA has established primary MCLs for 81 constituents, including 17 inorganic constituents, 51 organic compounds, 6 radionuclides, 4 disinfection byproducts, and three disinfectants. In addition, CDPH has establishing state specific MCLs for 11 additional constituents, including 2 inorganic constituents and 9 organic compounds, resulting in a total of 92 primary MCLs relevant to drinking water supplies in California. CDPH and EPA have established secondary MCL's for 15 contaminants. Federal and CDPH primary and secondary MCL's and results from quarterly monitoring are provided in Quarterly Testing Report No. 3 (Appendix B).

Results from the quarterly monitoring have shown that the purified water consistently met all primary MCLs established by both EPA and CDPH. In addition, the purified water met all numerical secondary drinking water MCLs. CDPH has also established a non-numerical secondary MCL to have

non-corrosive water. This standard can be met either by blending with other water supplies or by adding stabilizing chemicals to address the aggressive nature of highly purified water.

Table 2-19 Water Quality Monitoring Results of Regulated Constituents

Regulation and Guideline Group		Number of Constituents / Parameters	Total Number of Tests[1]	Purified Water Results
Federal and State MCLs	Primary Drinking Water MCL [2]	90	1,781	√ Meets all
	Secondary Drinking Water MCL [3]	18	1,290	√ Meets all
	Microbial [4]	4	1,547	√ Non-Detect
CDPH	CDPH Notification Level [5]	30	716	√ Below all
	CDPH Groundwater Replenishment [6]	142	2,244	√ Meets all
Regional Board	Regional Board Requirements for the Reservoir [7]	143	4,404	√ Meets all
	Total Number of Constituents / Parameters[8]	**231[8]**	**7,523[8]**	----------

Notes:

[1] The total number of tests represents the approximate number of tests conducted at all sample locations shown in Figure 2-1 and the Imported Raw Aqueduct Water.

[2] Maximum Contaminant Levels and Regulatory Dates for Drinking Water U.S. EPA VS. California November 2008.

[3] California Code of Regulation: Title 22, Division 4, Environmental Health Chapter 15. Domestic Water Quality and Monitoring Regulations Article 16. Secondary Water Standards. Purified water met all Federal and State Secondary MCLs with the exception of pH and corrosivity. The potential Full Scale Facility would include post treatment to meet these requirements.

[4] EPA Total Coliform Rule (published 29 June 1989/effective 31 December 1990). Samples from the Demonstration Facility were analyzed for the following microbial contaminants: Total coliform, Fecal Coliform, and Viruses (Somatic and Male Specific Bacteriophage).

[5] Drinking Water Notification Levels and Response Levels: An Overview. California Department of Public Health Drinking Water Program Last Update: December 14, 2010.

[6] CDPH Groundwater Replenishment Reuse DRAFT Regulation 2011. Purified water meets all numerical water quality requirements for indirect potable reuse via groundwater replenishment.

[7] EPA Numeric Criteria for Priority Pollutants Toxic Pollutants for the State of California Rule. San Diego Regional Water Quality Control Board San Diego Basin Plan Numeric objectives; note some objectives have not been defined.

[8] Because some constituents and parameters are in multiple regulations / guidelines the total of unique parameters is less than the sum.

Table 2-20 Comparison of Key Water Quality Results and Demonstration Goals

Constituent		Units	Laboratory Reporting Level	Purified Water			Water Quality Goal[b]
				Number of Samples	Average Concentration[a]	Maximum Concentration	
Removal Challenge	Bromoform	µg/L	0.5	9	ND	ND	0.5
	Methylene Chloride	µg/L	0.50	9	ND	0.59	4.7
	Trihalomethanes, Total	µg/L	2.0	9	ND	ND	80
	Bromodichloromethane	µg/L	0.5	9	ND	0.7	0.56
	Dibromochloromethane	µg/L	0.5	9	ND	ND	0.5
	Haloacetic Acids (HAA5)	µg/L	1	9	ND	ND	60
	N-Nitrosodiethylamine (NDEA)	ng/L	2	12	ND	4.9	10
	N-Nitrosodimethylamine (NDMA)	ng/L	2	12	ND	5.5	2
	1,4-Dioxane	µg/L	0.5	16	ND	ND	1
	1,2-Dichloroethane	µg/L	0.5	16	ND	ND	0.5
	Boron	mg/L	0.01	28	0.23	0.29	1.0
Common Parameters	Total Organic Carbon[d]	mg/L	0.3	97	ND	ND	0.5
	Total Dissolved Solids	mg/L	10	29	14	19	300
	Chloride	mg/L	0.5	29	3.1	4.3	50
	Sulfate	mg/L	0.5	28	ND	1.1	65
	Turbidity	NTU	-	298	0.05	0.10	0.2
Nutrients	Nitrate as N	mg/L	0.11	74	0.65	1.2	1
	Nitrite as N	mg/L	0.09	71	ND	0.1	1
	Ammonia as N (unionized)	mg/L	varies[c]	71	<0.007[c]	0.027[c]	0.025
	Phosphorus, Total	mg/L	0.01	66	0.02	0.42	0.10
	Nitrogen, Total	mg/L	0.1	74	0.8	1.3	1

Notes:

a. Average concentration calculation assumes non-quantifiable results are half of the laboratory reporting level and non-detectable results are half of the method detection limit.

b. See Testing and Monitoring Plan, Table 5-2 (Appendix A).

c. Unionized values of ammonia were estimated based on U.S. Environmental Protection Agency's *Aqueous Ammonia Equilibrium – Tabulation of Percent Un-ionized Ammonia (EPA-600/3-79-091)* using average values of temperature and pH measured on-site.

d. Laboratory results showed a single positive result of 1.4 mg/L on January 12, 2012. However, online monitoring for that same day recorded that the TOC was <0.1 mg/L. See Section 2.5.1 for more information on the online monitoring of TOC.

Acronyms:

ND – Not detectable or not quantifiable, shown for all values below laboratory reporting level
mg/L – milligrams per liter, equivalent to parts per million (ppm)
µg/L – micrograms per liter, equivalent to parts per billion (ppb)
ng/L – nanograms per liter, equivalent to parts per trillion (ppt)
NTU – Nephelometric Turbidity Units

CDPH Notification Levels

Notification levels (NLs) are health-based advisory levels established by CDPH for chemicals in drinking water that do not have MCLs. When chemicals are found at concentrations greater than their NL's, certain reporting requirements apply. In addition, CDPH has established Response Levels at two to three times higher than each NL, where CDPH recommends removal of a drinking water source from service to protect public health. Currently, the CDPH has established NLs and Response Levels for 30 constituents. During the testing period, these constituents were monitored quarterly in the tertiary effluent prior to chlorination, purified water and imported raw aqueduct water. CDPH NL's and results from quarterly monitoring are provided in Quarterly Testing Report No. 4 (Appendix B). Results from the quarterly monitoring have shown that the purified water is consistently below all NLs as established by CDPH.

Groundwater Replenishment Reuse Draft Regulations

The CDPH's Division of Drinking Water and Environmental Management is responsible for establishing standards for wastewater reuse in accordance with the "Water Recycling Criteria" in Title 22 of the California Code of Regulations. In conjunction with the CDPH and the State Board, the Regional Boards have permitting and oversight authority for Groundwater Recharge Reuse Projects. Groundwater Replenishment Reuse Draft Regulations were developed and updated most recently in November 2011. These regulations are currently in the formal regulation adoption process. CDPH is working to adopt uniform water recycling criteria for groundwater recharge by December 31, 2013.

The Groundwater Replenishment Reuse Draft Regulation is provided at the following website: http://www.cdph.ca.gov/HealthInfo/environhealth/water/Pages/Waterrecycling.aspx

Additionally, CDPH is developing draft regulations for the use of recycled water for surface water augmentation, but has not yet released a draft for public review. For the time being, an assumption has been made that CDPH requirements will be similar to those for groundwater replenishment. These treatment requirements include:

- Compliance with primary and secondary drinking water MCLs in the final recycled water.
- Total nitrogen cannot exceed 5 mg/L.
- TOC cannot exceed 0.5 mg/L divided by the CDPH-specified maximum average Recycled Water Contribution.
- The turbidity of the RO product water cannot exceed 0.2 NTU more than 5 percent of the time in any 24-hour period and can never exceed 0.5 NTU.
- The RO permeate UVT must be 90 percent or greater at 254 nanometers (nm).
- The final recycled water must be disinfected such that the 7-day median number of total coliforms cannot exceed 2.2 total coliform bacteria per 100 mL and the number of total coliform organisms cannot exceed 23 total coliform bacteria per 100 mL in more than one sample in any 30-day period.
- Advanced oxidation must achieve 0.5-log reduction in 1,4-dioxane, whether it is present or not in the source water. Additionally, the removal of indicator compounds or surrogates can be substituted for the reduction of 1,4-dioxane.

Purified water from the Demonstration Facility has met the requirements listed above. Detailed data tables can be found in the Quarterly Testing Report No. 3 (Appendix B).

Regional Board Requirements for the Reservoir

In California the regulation, protection and administration of environmental water quality are carried out by the State Board and nine Regional Boards. The San Diego region is designated as Region (9) and is governed by the San Diego Regional Board. Each Regional Board adopts a Water Quality Control Plan or Basin Plan, which recognizes and reflects differences in existing water quality, the beneficial uses of the region's ground and surface water and the local water quality conditions and problems. The Basin Plan is designed to preserve and enhance the water quality and protect the beneficial uses of all regional water bodies.

The Basin Plan includes designated beneficial uses of the San Vicente Reservoir, water quality objectives to protect those uses, the state anti-degradation policy for surface water, and toxicity requirements (including applicable federal and state standards). The Basin Plan establishes beneficial uses for surface waters and groundwater in the region and numeric and narrative water quality objectives to protect those uses. Permit limits are established for those constituents that have the reasonable potential to cause or contribute to an excursion above any water quality objective. The Basin Plan allows for a mixing zone (e.g., dilution factor) to be considered for inland surface waters on a case-by-case basis. If a dilution factor is approved, the permit limit (and reasonable potential evaluation) could be based on modified water quality objectives. The designated beneficial uses of San Vicente Reservoir are:

- Municipal and Domestic Supply
- Agricultural Supply
- Industrial Process Supply
- Industrial Service Supply
- Contact Water Recreation: fishing from shore or boat is permitted, but other water contact recreational (REC-1) uses are prohibited. However, per Section 115840(a) of the Health and Safety Code, CDPH allows the reservoir to be used for body contact recreation, and thus other REC-1 uses apply.
- Non-body Contact Water Recreation
- Warm Freshwater Habitat
- Cold Freshwater Habitat
- Wildlife Habitat

The Basin Plan includes various numerical and narrative water quality standards for numerous constituents. Narrative and numeric nutrient requirements are also included. For waste discharge requirements established for recycled water discharges to surface water such as the San Vicente Reservoir, the Basin Plan allows the Regional Board to use the phosphorus goal for flowing waters (0.1 mg/L) as a guideline or to determine compliance with the narrative objective using four factors, including use of best available technology economically feasible for the removal of nutrients. It should

be noted that the nutrient requirements (including phosphorus and nitrogen) for the potential Full-Scale Facility have not yet been established.

During the testing period, general parameters with Basin Plan numeric objectives were sampled on a weekly, bi-weekly or monthly basis. Sampling locations varied by constituent as presented in the T&M Plan and included tertiary effluent prior to chlorination, RO feed, RO permeate and purified water. The results are presented in Quarterly Testing Report No. 3 (Appendix B).

Overall the results for all samples collected to date in the purified water met the Basin Plan objectives. Important observations and information related to these results follow:

Phenolic Compounds - On four occasions in 2011, the total phenolic compounds were reported above the Basin Plan numeric objective of 1 µg/L. The first monthly sample of the purified water was analyzed using EPA Method 420.4 total phenolics (method detection level =10 µg/L) for which the result was at 22 µg/L. Because this method has a method detection level greater than the Basin Plan numeric objective it was suspected that the method was not sensitive enough to accurately quantify the low concentrations of phenolic compounds expected in the purified water. After the first monthly sample, all subsequent samples for phenolic compounds were analyzed with a more sensitive method EPA 8270 C-SM. This method analyzes 14 individual phenolic compounds with method detection level between 1 to 2 µg/L.

On three additional occasions, one or more of the 14 compounds (phenol) was reported above the numeric objective for total phenolic compounds of 1 µg/L. These compounds were not found in the RO permeate upstream of the advanced oxidation, indicating that the positive results may have been caused by sample mix-up or by inadvertent contamination of the sample. Phenol is a common compound used in plastics and in water bottles. While phenol free bottles were used for all sampling, outside contamination cannot be altogether ruled out as the cause of the two quantifiable results. Following these occurrences, the frequency of sampling for phenolic compounds was therefore increased (from monthly to bi-weekly) to confirm the purified water met the required objective. The results showed both the RO permeate and purified water for 15 additional sample dates were always below quantifiable levels.

pH - The pH measured in the purified water was within the expected range of 5.5 to 6.5. The potential Full-Scale Facility would be designed with post-treatment to adjust pH to a value which would meet the Basin Plan numerical objective. The objective for pH states the change in pH level cannot exceed 0.5 units and that pH shall not be depressed below 6.5 or raised above 8.5.

Nitrogen and Phosphorus – Although the Basin Plan nutrient requirements for the potential Full-Scale Facility were not established at the time this report was prepared, nitrogen and phosphorous were tested in the purified water. The testing results showed that the water purification process achieved a high removal of these nutrients with total nitrogen being removed to an average concentration of 0.8 mg/L and total phosphorus being removed to an average concentration of 0.02 mg/L.

EPA California Toxics Rule (CTR)

The California Toxics Rule (CTR) is a federal regulation established to protect both aquatic life and human health by limiting surface water discharges based on 105 priority toxic pollutants. EPA

promulgated the rule after a State court overturned California's water quality control plans in 1994, which had contained state specific water quality criteria for priority toxic pollutants. Implementation procedures for the CTR were established by the State Board through the SIP. The SIP includes: i) procedures to determine which priority pollutants need effluent limitations (e.g., reasonable potential analysis); ii) methods to calculate water quality-based effluent limitations; and iii) policies regarding mixing zones, metals translators, monitoring, pollution prevention, reporting levels for determining compliance, and whole effluent toxicity control. Permit limits are established for those CTR constituents that have the reasonable potential to cause or contribute to an excursion above any applicable criteria including consideration of dilution (Section 1.3 of the SIP). If a dilution factor is approved, the permit limit would be based on this modification of the water quality criteria in addition to other factors as set forth in Section 1.4 of the SIP. The CTR criteria are presented in the T&M Plan (Appendix A).

The CTR requirements for the potential Full-Scale Facility have not been defined yet by the Regional Board. The City will assess the water quality results and the final permit limits based on CTR criteria when they are established by the Regional Board.

Whole Effluent Toxicity Testing

Whole Effluent Toxicity refers to the aggregate toxic effect to aquatic organisms from all pollutants contained in a facility's wastewater (effluent). It is one way that the EPA implements the Clean Water Act's prohibition of the discharge of toxic pollutants in toxic amounts. Whole Effluent Toxicity tests measure wastewater's effects on specific test organisms' ability to survive, grow and reproduce.

The test methods are specified at 40 CFR 136.3, Table IA, and consist of exposing living aquatic organisms (plants, vertebrates and invertebrates) to various concentrations of a sample of wastewater, usually from a facility's effluent stream. These tests are used by the National Pollutant Discharge Elimination System (NPDES) permitting authority to determine whether a facility's permit will need Whole Effluent Toxicity requirements.

At this time it is unknown if the potential Full-Scale Facility would be permitted under the NPDES however, in order to get some preliminary information on the toxicity of the purified water, WET testing was done one time during the reporting period utilizing both acute and chronic freshwater bioassays. All tests were performed by Nautilus Environmental Laboratories (San Diego, CA). Tests were conducted per EPA protocols: EPA/821/R-02/013 (2002) Chronic Manual and EPA/821/R-02/012 (2002) Acute Manual. The chronic test organisms included: Ceriodaphnia dubia (water flea), Pimephales promelas (fathead minnow) and Selenastrum capricornutum (green algae). The test organisms used for the acute testing included water flea and fathead minnow.

The sample water was comprised of a blend of purified water collected from the Demonstration Facility and imported raw aqueduct water collected from Lake Murray. The final blend was made up of 67 percent purified water and 33 percent imported raw aqueduct water to achieve the target total hardness of 50 mg/L. Prior to testing, the pH of the blended sample was raised to approximately 8.5 using sodium hydroxide. In addition, sodium thiosulfate was added to the sample to remove residual chlorine and hydrogen peroxide. Laboratory control water was EPA moderately hard mineral water (20 percent diluted). A reference control consisting of deionized water (67 percent) mixed with raw aqueduct water (33 percent) was also utilized.

Overall, the results showed there was no toxicity observed in the sample for any of the acute and chronic tests performed. The statistical results of the purified sample follow:

- No Observed Effect Concentration values (percent effluent) for all species and endpoints tested were reported as 100 percent.
- Lowest Observed Effect Concentration values (percent effluent) for all species and endpoints tested were reported as >100 percent.
- Toxic Units were reported as 1.0 for all species and end points tested with the exception of the Water Flea 96-hr Acute survival TU = 0.41 and the Fathead minnow 96- hr acute survival TU=0.

2.4.4 Water Quality for Other Non-Regulated Constituents

Additional non-regulated constituents were monitored at various locations in the purification process and the imported raw aqueduct water. These constituents are grouped into two main categories: those included in the 2012 EPA Unregulated Contaminant Monitoring Rule (UCMR3) and other CECs, such as pharmaceutical compounds and personal care products. In addition, lithium and six nitrosamine compounds beyond the two nitrosamine compounds mentioned previously in Section 2.4.3 (NDMA and N-nitrosodiethylamine) were monitored in the purified water, based on the recommendation of the Demonstration Project Independent Advisory Panel. All together, 127 non-regulated constituents were evaluated (111 when accounting for duplication with regulated constituents) beyond the constituents discussed previously in Section 2.4.3.

Unregulated Contaminant Monitoring Rule (UCMR)

The UCMR3 is the latest of the UCMR series, issued by the EPA. The third Unregulated Contaminant Monitoring Rule (UCMR3) was signed by the EPA Administrator on April 16, 2012. UCMR3 will require monitoring for 30 contaminants using EPA and/or consensus organization analytical methods during 2013-2015. Once every five years, the EPA issues a new list of no more than 30 unregulated contaminants to be monitored by public water systems, in accordance with 1996 amendments to the Safe Drinking Water Act. The UCMR provides scientifically valid data on the occurrence of contaminants in drinking water. These data provide information that the agency uses to develop regulatory decisions. UCMR3 was published in the Federal Register on May 2, 2012 (77 FR 26072).

The UCMR3 is divided into three lists of constituents:

- Assessment Monitoring (List 1) includes 21 constituents listed in six individual EPA methods (200.8, 218.7, 300.1, 522, 524.3, and 537). Any systems serving a retail population greater than 10,000 must monitor for List 1.
- Screening Survey Monitoring (List 2) includes seven natural and synthetic hormones (EPA method 539). All very large systems (greater than 100,000 retail population) must also monitor for List 2. A randomly selected set of 320 large systems (greater than 10,000 retail population) must also monitor for List 2.
- Pre-Screen Testing (List 3) – 2 Constituents. A representative selection of 800 undisinfected groundwater public water systems serving 1,000 or fewer people will participate in monitoring for two constituents.

A complete summary of the methods, reporting limits and required sample locations is shown at: http://water.epa.gov/lawsregs/rulesregs/sdwa/ucmr/ucmr3/methods.cfm.

Sampling and testing of water at the Demonstration Facility included List 1 and List 2 of the UCMR3. Samples were collected quarterly on the feed water (tertiary effluent prior to chlorination) to the Demonstration Facility, the purified water, and the imported raw aqueduct water.

Constituents of Emerging Concern

The term constituents of emerging concern (CEC) refers to new classes of manufactured chemicals, such as pharmaceuticals, personal care products, pesticides, and other industrial chemicals. While many CECs are present in water supplies, the detection of many of these chemicals is so recent that robust methods for their quantification and toxicological data for interpreting potential human or ecosystem health effects are unavailable. The water purification process is designed to provide a multiple barrier approach for removal of CECs. In 2010, under the Recycled Water Policy, the State Board established a Science Advisory Panel to provide guidance for developing potential CEC threats to human and aquatic life.

As part of the robust water quality monitoring program implemented at the Demonstration Facility, CEC monitoring was conducted at multiple locations throughout the water purification process. The monitoring plan also included the collection of samples from imported raw aqueduct water. The target list of CECs consists of 90 compounds commonly found in treated wastewater effluent representing a wide range of chemical and physical properties. The list includes compounds identified by the Science Advisory Panel to have toxicological relevance. These compounds along with their common description includes: NDMA (rocket fuel, disinfection by-product), 17 beta-estradiol (estrogenic hormone), caffeine (stimulant) and triclosan (anti-microbial). The list includes compounds identified by the Science Advisory Panel as indicators of treatment performance. The specific performance indicator compounds along with their common description include: DEET (mosquito repellant), gemfibrozil (lipid regulator), iopromide (X-ray contrasting agent) and sucralose (artificial sweetener) along with certain surrogate parameters (e.g. ammonia, dissolved organic carbon, conductivity). The complete list of CECs monitored during the testing period along with their common use is presented in Appendix B.

The main objectives of the CEC monitoring plan as detailed in the T&M Plan (Appendix A) are as follows:

- Characterize the tertiary effluent prior to chlorination
- Identify appropriate performance indicator compounds to be monitored on an on-going basis
- Identify surrogate parameters, and assess and compare removal efficiency to indicator compounds
- Assess the ability of the water purification process to remove CECs
- Compare the water quality of the purified water to imported raw aqueduct water

The overall CEC monitoring plan consisted of three phases as described below:

- **Initial Characterization** – Samples were collected monthly for four months from the following sample locations: tertiary effluent (prior to chlorination), RO feed, RO permeate, purified water

and imported raw aqueduct water. Samples were analyzed for the 91 compound list described above.

- **On-going Characterization -**Based on assessment of results from the initial characterization phase, five compounds were identified for on-going characterization. Four of these compounds (NDMA, 17 beta-estradiol, caffeine and triclosan) were identified by the Science Advisory Panel based on toxicological relevance. The fifth compound (1,4-dioxane) is currently presented as an option for sizing and evaluating advanced oxidation performance for direct groundwater injection reuse applications as specified in the CDPH November 2011 Groundwater Replenishment Reuse Draft Regulation. Samples were collected on a quarterly basis from the following locations: tertiary effluent prior to chlorination, RO feed, RO permeate, purified water, and imported raw aqueduct water.

- **Identification of Potential Performance Indicator Compounds -**Based on assessment of results from the initial characterization phase, 37 compounds were identified as potential performance indicator compounds. These compounds were selected based on one or more of the following factors: 1) identified by the Science Advisory Panel as potential performance indicators for groundwater injection (via surface spreading or direct injection) reuse applications 2) consistency of occurrence in the RO feed during the initial characterization, 3) recommendations from the IAP. Samples were collected weekly for four weeks from the following locations: RO feed, RO permeate, and purified water. Results of the performance indicator compound testing are discussed in Section 2.5 Integrity and Reliability Monitoring.

Non-Regulated Constituents Results

While 127 non-regulated constituents were measured, only 111 were unique constituents after accounting for overlaps with regulated compounds and among non-regulated lists. Of the non-regulated constituents measured at the Demonstration Facility, only six were found to be quantifiably detected in the purified water. Table 2-21 provides a summary of these six constituents, including average and maximum values measured in both the purified water and imported raw aqueduct water. These six constituents are discussed in more detail below. Since these constituents do not have regulatory limits, the results are discussed in terms of either the Health Reference Level identified by the EPA, or the Drinking Water Equivalent Level (DWEL), where no Health Reference Level has been provided by the EPA. Health Reference Levels and DWELs represent an acceptable concentration in drinking water, assuming an average person consumes two liters of water (about 8.5 cups) per day over 70 years. DWELs are developed from tolerable daily intakes (TDIs), acceptable daily intakes (ADI), or EPA identified Reference Doses (RfDs), which all describe a daily dose below which risks to public health are judged to be minimal, assuming repeated daily exposure over a lifetime through consumption of drinking water.

Table 2-21 Summary of Other Non-regulated Constituents in Purified Water and Imported Raw Aqueduct Water (Detected Constituents of 111 Monitored)

Constituent	Classification/ Common Use	Units	Laboratory Reporting Level	Purified Water			Imported Raw Aqueduct Water		
				Number of Samples	Average Concentration[a]	Maximum Concentration	Number of Samples	Average Concentration[a]	Maximum Concentration
Bromochloromethane	UCMR3 Disinfection byproduct	µg/L	0.06	4	0.23	0.25	4	ND	0.08
Chromium (VI)[b]	UCMR3 Disinfection byproduct, industrial byproduct	µg/L	0.02	4	0.09	0.16	4	0.05	0.05
Strontium	UCMR3 Naturally occurring metal, Dietary Supplement	µg/L	0.3	4	ND	0.37	4	405	610
Acesulfame-K	CEC Sugar Substitute	ng/L	20	9	ND	50	4	343	370
Iohexal	CEC X-ray contrast agent	ng/L	10	9	ND	19	4	43	55
Triclosan	CEC Antibacterial	ng/L	10	9	ND	19	5	ND	ND

Notes:

a. Average concentration calculation assumes non-quantifiable results are half of the laboratory reporting level and non-detectable results are half of the method detection limit.

b. Three Chromium (VI) samples were sent to another lab and all results were below the detection limit of 0.0059 µg/L. The CDPH Detection Limit for purposes of Reporting (DLR) is 1 µg/L.

Acronyms:

ND – Not detectable or not quantifiable, shown for all values below laboratory reporting level
µg/L – micrograms per liter, equivalent to parts per billion (ppb)
ng/L – nanograms per liter, equivalent to parts per trillion (ppt)

TDIs are derived from published information about pharmacology and toxicity for constituents. DWELs are not regulatory limits, but have been established by professional organizations for some constituents typically sampled for in water supplies to assist with the interpretation of water quality results for constituents without regulatory limits. More information on DWELs can be found in the following publications:

- Monitoring Strategies for Chemicals of Emerging Concern in Recycled Water, Recommendations of a Science Advisory Panel (State Board, Final Report, June 25, 2010)
- Development and Application of Tools to Assess and Understand the Relative Risks of Drugs and Other Chemicals in Indirect Potable Reuse Water (WateReuse Research Foundation, 2010)

Unregulated Contaminant Monitoring Rule

Results from the testing show 27 of the 30 compounds included in the UCMR3 were consistently below quantifiably detectable levels in the purified water. The three constituents, which were detected, included bromochloromethane, hexavalent chromium, and strontium. It should be noted that on May 2, 2012, the EPA issued the Final Rule Promulgation, which removed two constituents from the original List 1: n-Propylbenzene and sec-Butylbenzene. While these two constituents were removed from the final UCMR3 list, they had both been monitored as part of the 30 compounds previously referenced, and were never detected at any point in the treatment process. Additional information about the detected UCMR3 constituents, and their occurrence in the purified water, is presented below and in Quarterly Testing Report No. 4 (Appendix B).

Bromochloromethane

Bromochloromethane, also called Halon 1011, is used as a fire-extinguishing fluid and to suppress explosions, as well as a solvent in the manufacturing of pesticides. It may also occur as a disinfection byproduct in drinking water, when chlorine used for disinfection reacts with organic material in the water.

Bromochloromethane was detected four times out of four samples in the purified water, with an average value of 0.22 µg/L and a maximum value of 0.25 µg/L.

The DWEL for bromochloromethane is 40 µg/L (40,000 ng/L) (State Board, June 2010), which is more than 170 times higher than the concentration measured in the purified water, suggesting that the concentrations measured in the purified water do not pose a health risk for human consumption.

Hexavalent Chromium (Chromium-6)

Chromium is an odorless, tasteless metallic element found naturally in rocks, plants, soil and volcanic dust, and animals. Chromium is commonly found in two forms: trivalent chromium (chromium-3) and hexavalent chromium (chromium-6). The trivalent form is a required nutrient and has very low toxicity. The hexavalent form, also commonly known as chromium-6, is more toxic and has been known to cause cancer when inhaled. In recent scientific studies in laboratory animals, chromium-6 has also been linked to cancer when ingested. Chromium-6 is currently regulated in California as part of the total chromium MCL of 50 µg/L, which was originally established assuming all of the chromium present is in the hexavalent form.

In 2008, EPA began a rigorous and comprehensive review of chromium-6 health effects based on new scientific information. When this human health assessment is finalized, the EPA will carefully review the conclusions and consider all relevant information to determine if the current chromium standard

should be revised. The lowest reference dose for chromium-6 currently identified by EPA as not having evidence of adverse health effects is 0.9 µg/kg/day (IRIS, Draft 75 FR 60454 EPA/635/R-10/004C), which is equivalent to a DWEL of 11 µg/L. Chromium-6 concentrations measured in the purified water were approximately 500 times lower than the current MCL and more than 100 times lower than the DWEL associated with the lowest reference dose identified by EPA.

Additional information on hexavalent chromium can be found at: http://www.cdph.ca.gov/certlic/drinkingwater/Pages/Chromium6.aspx .

CDPH is in the process of developing an MCL specific to chromium-6. Currently CDPH is collecting data associated with the risks and prevalence of chromium-6 and has established a detection limit for purposes of reporting (DLR) of 1 µg/L. This detection limit is 33 to 50 times higher than the laboratory reporting level used by the primary laboratory where chromium-6 samples were taken during the Demonstration Facility operation. As a result, data from the Demonstration Facility includes concentrations that are currently considered undetectable based on CDPH guidelines.

During the Demonstration Facility operation, chromium-6 samples were sent for analysis to two separate labs. Information about the sampling of chromium-6 is provided below and in Quarterly Testing Report No. 4 (Appendix B).

- For Lab 1, the method used was EPA 218.6 (laboratory reporting level = 0.02 µg/L) / EPA 218.7 (laboratory reporting level = 0.03 µg/L). Chromium-6 was found at quantifiable concentrations in the purified water four times out of four samples, with an average value of 0.09 µg/L and a maximum value of 0.16 µg/L. The laboratory reporting level, using EPA 218.7, is in accordance with current UCMR3's reporting level.
- Chromium-6 was not detected in the tertiary effluent by Lab 1, suggesting that chromium-3 may have been oxidized by the advanced oxidation process to form the low levels of chromium-6 measured in the purified water. A contaminate created by a disinfection process is known as a disinfection byproduct.
- Lab 2 analyzed chromium-6 using method EPA 218.6 with all results in purified water reported below detectable levels. The Lab 2 laboratory reporting level was 0.3 µg/L, which is higher than Lab 1.
- All results from both labs were below the CDPH detection limit (DLR) of 1 µg/L.

Strontium

Strontium is a naturally-occurring metal that is used as a dietary supplement and in various industrial applications, such as pyrotechnics and automobile manufacturing. Strontium was detected in one of the four quarterly samples analyzed from the purified water, with a concentration measured as 0.37 µg/L and a blind duplicate sample reported as 0.41 µg/L.

While the EPA has not established an MCL for strontium, a health reference level of 4.2 mg/L (4,200 µg/L) was identified as part of the 2009 Contaminant Candidate List 3 (CCL3). This health reference level is more than 10,000 times higher than the single detectable value measured in the purified water, indicating that the concentrations measured in the purified water do not pose a health risk for human consumption.

In addition, USEPA regulates a radioactive isotope of strontium (strontium 90), with an MCL of 8 pCi/L. Sample results for strontium 90 were consistently below the minimum detectable levels in both the tertiary effluent and the purified water.

Constituents of Emerging Concern

Results from the initial characterization phase of CEC monitoring are presented in Appendix B (Section 3). CEC results measured at the various sample locations are presented in the units of nanograms per liter (ng/L), or parts per trillion. Analogies used to describe a 1 ng/L concentration would be the equivalent of 1 penny in 10 billion dollars or 1 drop in 20 Olympic size swimming pools. When assessing low level CEC results such as these, it is important to keep in mind that analytical variability and influence of false positive/negative results becomes a more significant issue at such minute levels. Technologies were not available to measure compounds at these low concentrations a decade ago, and there is still considerable debate about the significance of such low measured concentrations. Therefore, it is important to assess results as a whole data set including quality control sample results before making conclusions on the significance of a single result.

Thirty-nine of the 90 CEC compounds were detected at quantifiable levels in the tertiary effluent prior to chlorination with values generally ranging from 5.5 to 9,500 ng/L. Higher levels were seen for the artificial sweeteners sucralose and acesulfame-k, which were detected at concentrations averaging 40,000 and 30,000 ng/L, respectively.

Results showed the RO process was effective at removing the majority of the CECs present in the tertiary effluent, and advanced oxidation further reduced the remaining constituents. For constituents found in significant concentrations in the tertiary effluent, the purification process achieved greater than 98% removal. This is further discussed in 2.5.3. Only three CECs found at quantifiable concentrations in the purified water. These compounds include iohexal, acesulfame-k, and triclosan. Additional information on all three compounds and the potential significance of the measured concentrations are discussed below.

Acesulfame-K (Ace-K): Acesulfame Potassium (Ace-K) is a widely used artificial sweetener. Ace-K is used in a variety of consumables, including soft drinks, sports drinks, chewable and liquid medications, and other foods. During the testing period, Ace-K was below quantifiable levels in the purified water in seven of nine samples analyzed, with an average concentration below quantifiable levels and maximum concentration of 50 ng/L (laboratory reporting level=20 ng/L). Ace-K was below detectable levels in the RO permeate or RO permeate duplicate in samples collected on the same day that results in the purified water (after advanced oxidation) were reported above the laboratory reporting level, suggesting that even the low levels measured on these days may have resulted from sampling or analytical error.

The Food and Drug Administration has established an acceptable daily intake (ADI) for Ace-K of 50 mg/kg. Based on this, the calculated DWEL for Ace-K is 525 mg/L, which is a concentration 10 million times greater than the maximum value reported in the purified water. This suggests that the concentrations of Ace-K measured in the purified water (and in the tertiary water before purification) do not pose a threat to public health.

Iohexal: This compound is a contrasting agent used in x-ray procedures, such as coronary angiographs. Iohexal is typically injected into the body, allowing organic iodine compounds to block x-rays as they pass through the body. This allows for delineation between body structures containing iodine and structures that do not contain iodine. This compound was below quantifiably detectable

levels in the purified water for eight of nine samples analyzed, with an average value of below quantifiable levels and a maximum value of 19 ng/L (laboratory reporting level=10 ng/L). RO permeate and RO permeate duplicate QC samples collected during the same sampling event as the single positive result were below quantifiable levels, suggesting that the single positive result may have been the result of analytical error.

The DWEL for this compound is 720,000 ng/L (State Board, June 2010), which is nearly 38,000 times higher than the maximum concentration reported in the purified water, suggesting that the concentrations measured do not pose a threat to public health.

Triclosan: 2,4,4' –trichloro-2'-hydroxydiphenyl ether (triclosan) is used as a synthetic broad-spectrum antibacterial agent. Triclosan is used in a variety of consumer products, such as antimicrobial hand soaps, toothpaste, and over-the-counter drugs. It also functions as a material preservative in adhesives, fabrics, vinyl, plastics (toys, toothbrushes), polyethylene, polyurethane, polypropylene, floor wax emulsions, textiles (footwear, clothing), caulking compounds, sealants, rubber, carpeting, and a wide variety of other products. In commercial, institutional, and industrial equipment, triclosan is used to prevent microbial growth in conveyor belts, fire hoses, dye bath vats, HVAC coils, and ice-making equipment. This compound was found to be below quantifiable levels in seven out of nine samples, with an average value below quantifiable levels and a maximum value of 19 ng/L. Duplicate samples collected for a second lab from the RO permeate and purified water at the same time as one of the two positive results were found to be below detectable levels.

A number of factors suggest that the two results reported above the laboratory reporting level in the purified water may have resulted from sample contamination. The first factor is the widespread use of this compound in personal care products. Though careful measures (use of gloves, avoidance of products that contain triclosan, etc.) were taken during all sampling events to minimize the possibility of field contamination, such contamination cannot be ruled out. All sample bottles used were one time use EPA certified bottles; however, the laboratory conducting the analysis reported that because there are no commercially available preserved containers for the CECs, bottles are preserved by lab staff prior to shipping to clients for collection. This introduces the risk of contamination. Another important factor is that duplicate quality control samples taken from both the RO permeate and purified water (collected on the same day as one of the two samples reported above the laboratory reporting level) were analyzed by a second lab and reported non-detectable values (less than 2.5 ng/L).

It should be noted that the CDPH Science Advisory Panel recommended a more practical reporting limit of 50 ng/L for triclosan, which would suggest that all of the samples measured in the purified water should be considered below quantifiably detectable levels.

The DWEL for triclosan ranges between 350 to 2,600,000 ng/L (State Board, June 2010), which is 18 to nearly 137,000 times higher than the maximum concentration reported in the purified water, suggesting that no public health concerns are associated with the low levels of triclosan which may or may not have been present in the purified water.

2.4.5 Data Validation

Third-party validation was performed on the water quality data from WECK Laboratory and MWH Labs for the first quarterly sampling event. The purpose of the validation was to assess data quality and to review laboratory and sample handling procedures in order to identify possible procedural alterations to be implemented for subsequent sampling events. The third party validation process

showed all the data validated to be acceptable. It was also confirmed that the majority of the data met the strict analytical standards of the EPA Contract Laboratory Program.

For two CEC compounds (oxolinic acid and n-diethyl-meta-toluamide (DEET)), false positive results were initially reported by one of the laboratories, suggesting that quantifiable values of oxolinic acid and DEET had been detected in the purified water; however, subsequent testing and further comparison of test results with method blanks indicated that the original laboratory reporting level for these compounds had been set too low. The laboratory therefore revised the testing reports, confirming that quantifiable results for these two compounds had not been detected at any point in the purified water. Such anomalies are common when attempting to quantify organic compounds at such low detection levels using test methods that have not yet been fully standardized. Additional information on these two compounds is discussed below.

DEET: DEET is the most common active ingredient in insect repellents. DEET is used to repel biting flies, biting midges, black flies, chiggers, deer flies, fleas, gnats, horse flies, mosquitoes, no-see-ums, sand flies, small flying insects, stable flies, and ticks. Product types include liquids, pressurized liquids, ready-to-use formulations and impregnated material. Product concentrations range from 4 percent to 100 percent of DEET as an active ingredient.

DEET was originally reported to have been detected at a concentration of 8.7 ng/L in a single sample, based on a laboratory reporting level of 2 ng/L; however, the analytical laboratory conducting the analysis later revised the laboratory reporting level to 10 ng/L, based on continued variability in test blank results. The original test report was therefore revised, confirming that none of the nine samples contained quantifiable levels of DEET in the purified water. In addition, a duplicate sample of the purified water taken at the same time as the original positive value and analyzed by a second laboratory reported the result as not detectable, based on detection limit of 2.5 ng/L. Such variability in test results is common when attempting to quantify organic compounds at such low detection levels.

Oxolinic Acid: This compound is an antibiotic commonly used as veterinary medication for animals such as fish, calves, pigs, and poultry. It is delivered to the animal through an oral route. Oxolinic acid inhibits bacterial DNA-gyrase replication, and is commonly used to treat urinary tract infections in humans outside the U.S., a use which has not yet been approved by the U.S. Food and Drug Administration.

Oxolinic acid was originally reported to have been detected at a concentration of 5.5 ng/L in a single sample, based on a laboratory reporting level of 5 ng/L; however, the analytical laboratory conducting the analysis revised the laboratory reporting level to 10 ng/L, based on variability in test blank results. The original test report was therefore revised, confirming that none of the four samples contained quantifiable levels of oxolinic acid in the purified water.

2.5 Integrity and Reliability Monitoring

The integrity and reliability of the Demonstration Facility water purification processes were evaluated closely during the testing period. Integrity monitoring was conducted using several direct and indirect methods employed at various stages in the testing period. In addition, critical control point monitoring was implemented to identify any changes in the performance of the treatment processes that can adversely impact the final water quality. Overall integrity monitoring results showed the processes

met their intended treatment performance on a continuous basis. The specific methods used to evaluate each water purification process and results are summarized below.

2.5.1 Summary of Integrity Monitoring Results

Membrane Filtration

The integrity monitoring of the membrane filtration systems included the performance of daily pressure decay tests along with online filtrate turbidity monitoring. Results showed both the membrane filtration systems were intact over the testing periods. The filtrate turbidity was consistently below 0.05 NTU, lower than the limit of 0.2 NTU (0.5 NTU maximum). The pressure decay values were consistently below 0.1 psi over 5 minutes, which is below the limit of 0.4 psi over 5 minutes and corresponds to greater than 4-log (99.99 percent) calculated removal of *Cryptosporidium* and *Giardia* for each of the two membrane filtration systems. Over the testing period, estimates of the log removal value of *Cryptosporidium* and *Giardia* achieved by the membrane filtration systems were performed based on the measured values of pressure decay. These estimated log removal values were determined using the equation for air liquid conversion ratio as presented in the EPA Membrane Filtration Guidance Manual, 2005. This equation requires several inputs categorized as operating parameters, direct integrity test parameters, and unit and membrane characteristics. Values for these parameters were obtained from the membrane manufacturers and / or by field verification.

Reverse Osmosis

The integrity monitoring of the RO systems included the performance of vacuum/pressure decay testing of individual elements (pre-installation), conductivity vessel probing (post-element installation) along with online monitoring of conductivity and TOC during normal operation. Results of the vacuum/pressure decay testing indicated the RO elements to be intact with no breaches in glue lines or membrane material prior to installation. Vessel probing results were indicative of intact RO systems with no leaks at interconnectors or end caps. Both RO systems achieved consistent conductivity rejection throughout the testing period with average values of 98.7 percent (Hydranautics) and 98.5 percent (Toray). Eleven months of online TOC monitoring showed the combined RO permeate TOC was consistently below 100 µg/L, indicating TOC removal ranging from 98.8 – 99.8 percent.

It should be noted that TOC values measured online in the RO permeate throughout the testing period (ranging from 0.02 to 0.08 mg/L) were much lower than the laboratory reporting limit of 0.3 mg/L for samples sent offsite for laboratory analysis. Online TOC analyzers are known to be capable of detecting lower concentrations of organic content compared with desktop analyzers used by most laboratories, due to the decreased presence of organic interferences in the measurement system. During the collection of field samples for laboratory analysis, samples can be contaminated with organics from the several sources, including the sample vials themselves and carbon dioxide from the atmosphere. Because of the increased precision that the online analyzers have at low concentrations, they are considered a more appropriate method for measuring TOC in RO permeate, compared with the lower precision laboratory analysis.

UV Disinfection and Advanced Oxidation

The integrity monitoring of the UV disinfection and advanced oxidation system included continuous online power monitoring of the UV reactor and daily drawdown testing of the hydrogen peroxide dosing pump. On several occasions during the Q1 Testing Period, the UV disinfection and advanced oxidation system experienced a ballast failure which caused the control system to automatically increase the reactor power to 100 percent thereby maintaining treatment performance at all times.

During the Q2 Testing Period, no ballast failures occurred. One ballast and one lamp failed during the Q3 Testing Period. One ballast failure occurred during the Q4 Testing Period, which makes a total of six ballast failures during the Q1 through Q4 testing period.

2.5.2 Summary of Critical Control Point Monitoring Results

Table 2-22 provides a summary of the initial critical control point monitoring implemented during the Demonstration Facility testing period. The plan identified critical control points for the membrane filtration, RO, and UV disinfection and advanced oxidation systems, as well as critical limit parameters, critical limits, and corrective actions. The values of limits and corrective actions were refined and further defined throughout the testing period.

Table 2-22 Summary of Demonstration Facility Critical Control Point Monitoring

Critical Control Point	Critical Limit Parameter	Monitoring Frequency	Alert Limit	Critical Limit	Example Corrective Actions
MF/UF	Pressure Decay	1 per day	Value above baseline that approaches critical limit.	0.4 psi / 5 min based on the maximum decay predicted to achieve 4-log removal Cryptosporidium	Confirm Results. Assess fiber breakage. Isolate/ repair/replace damaged membrane.
RO	TOC, Conductivity	Continuous	Percent change of measured concentration in combined RO permeate	Online permeate conductivity = 150 µS/cm. Online permeate TOC = 100 ppb or greater for five consecutive measurements.	Automatic shutdown (conductivity). Monitor individual RO trains. Verify analyzer accuracy. Conduct vessel probing.
UV	Reactor Power Level	Continuous	System ramps up 100% if 2 to 7 lamps fail or 1 to 3 ballasts fail	0% (8 or more lamp failures or 4 ballast failures)	System alarm. Automatic increase of reactor power to 100% or system shutdown. Check/ replace lamps and/or ballasts.
UV	Hydrogen peroxide dose rate/Continuous Flow Confirmation	1 per day by draw down Continuous flow confirmation	Minimum dose (~22 mL/min) to provide 3 mg/L peroxide	0 mL/min indicating pump failure or loss of flow confirmation	Check dosing system. Recalibrate pump. Auto switch to standby pump.

Acronyms:

TOC – total organic carbon
mL/min – milliliters per minute
mg/L – milligrams per liter
psi – pounds per square inch
min – minute
µS/cm – microsiemens/centimeter
ppb – parts per billion, equivalent to micrograms per liter (µg/L)

Table 2-23 provides a summary of the critical control point monitoring results obtained during the testing period. During the Q1 Testing Period, one exceedance of the established critical alert limit for pressure decay occurred on the UF system. After further investigation, it was determined the high pressure decay rate resulted from a leak in the air piping not the actual membrane(s). Upon repair of the leak, the measured pressure decay test results were well below the critical alert limit for the remainder of the reporting period. During the Q1 Testing Period, the critical alert limit for the UV

reactor power level was not met on four separate occasions, each due to ballast failures. In response, the reactor power automatically increased to 100 percent. Based on the reactor performance to date it has been determined that a reactor power level of approximately 70 percent is required to achieve the target log removal of NDMA. As a result, the occurrences of ballast failures are highly unlikely to have jeopardized the treatment performance and UV disinfection and advanced oxidation because the reactor was sized to meet the water quality goals when operating at 70 percent power. The programming of the UV reactor called for the reactor to adjust to 100 percent power when two lamps or a single ballast failed. No exceedances of critical alert limits were identified for any of the critical limit parameters during the Q2 Testing Period. However two critical alert limits were exceeded in the Q3 Testing Period.

During the Q3 Testing Period, two critical alert limit exceedances occurred. The first incident was due to the loss of flow confirmation on the hydrogen peroxide dosing pump of the UV disinfection and advanced oxidation system. Once this occurred, the system automatically switched to the stand-by pump. However, the stand-by pump also shut off due to low flow resulting from air lock, thereby causing the system to automatically shut down. The Demonstration Facility operations staff was present when the event occurred and quickly restarted the system with no issues for the remainder of the testing period. The second incident was due to a single ballast failure on the UV disinfection and advanced system. The system automatically increased power to 100 percent to accommodate power loss thereby maintaining treatment performance. An alarm notified the operations team of this occurrence, and shortly after the system was taken offline and the ballast was replaced.

During the Q4 Testing Period, six critical alert limit exceedances occurred. Five of these were due to the loss of flow confirmation on the hydrogen peroxide dosing pump of the UV/AOP system. Once this occurred, the system auto switched to the stand-by pump. On two occasions the switch to duty pump was successful and the system operated without interruption. However, on the other three occasions, the stand-by pump also shut off due to low flow resulting from air lock, thereby causing the UV/AOP system to automatically shut down. The operations staff were notified by alarms when the unit was shut down, shortly after the system was restarted after operating both pumps in manual to remove entrained air. The issue was resolved by making adjustments to the degassing interval and pulse length on the peroxide dosing skid and opening a valve on the pump skid to allow off gas to return to the peroxide storage tank.

The sixth critical alert limit exceedance occurred due to a single ballast failure on the UV/AOP system. The system automatically increased power to 100 percent to accommodate power loss thereby maintaining treatment performance. An alarm notified the operations team of this occurrence, shortly after the system was taken offline and the ballast was replaced.

Table 2-23 Summary of Demonstration Facility Critical Control Point Monitoring Results

Critical Control Point	Critical Limit Parameter	Monitoring Frequency	Number of Exceedances Above Limits				Notes
			Q1	Q2	Q3	Q4	
MF/UF	Pressure Decay	1 per day	1 (UF)	0	0	0	Pressure decay above limit due to leak in air piping not membrane integrity. Repair made, pressure decay test repeated and passed.
RO	TOC, Conductivity	Continuous	0	0	0	0	None.
UV Disinfection and Advanced Oxidation	Reactor Power Level	Continuous	4	0	1	1	Exceedances due to occurrences of single failed ballasts. System automatically increased power to 100% to accommodate power loss.
UV Disinfection and Advanced Oxidation	Hydrogen Peroxide Dose/ Continuous Flow Confirmation	1 per day (draw down) Continuous (flow confirmation)	0	0	1	5	Q3 -Duty pump auto switched to standby pump and standby pump shutoff, due to low flow (air lock). System automatic shutdown. Restarted shortly after issue self-resolved. Q4 - Pump failures due to air locking. Adjustments made to degas interval and return off gas piping.

2.5.3 CEC Performance Indicator Monitoring

During the reporting period four performance indicators identified by the State Board Science Advisory Panel were monitored quarterly (Caffeine, 17 β-estradiol, NDMA, triclosan) along with 1,4-dioxane to serve as potential performance indicators for the Demonstration Facility and potentially the Full-Scale Facility. In addition, 37 CECs were considered as potential performance indicators, with 16 selected for additional monitoring, based on consistently quantifiable concentrations in the tertiary effluent used as the source water. Differential removal was calculated based on the average (n=4) concentrations measured in the feed and product of each water purification process as follows:

- RO Removal = [RO Feed – RO Permeate] / [RO Feed]
- Advanced Oxidation Removal = [Advanced Oxidation Process Influent –Advanced Oxidation Process Product] / [Advanced Oxidation Process Influent]

The removal results for the 16 selected constituents are included in Table 2-24, demonstrating nearly complete removal of all compounds with the combined processes of RO and UV/AOP.

Table 2-24 CEC Potential Indicator Characterization Results

Compound	Units	MDL	LRL	Average RO Feed (n = 5)	Average RO Perm. (n = 5)	Average UV/AOP (n = 5)	RO Removal	UV/AOP Removal
Acesulfame-K	ng/L	20	20	33,000	<27	<22	>99.9%	>16.5%
Amoxicillin	ng/L	6.4	20	220	<6.4	<6.4	>97%	-
Carbamazepine	ng/L	1.2	5	190	<5	<1.2	>99%	-
Dilantin	ng/L	13	20	120	<13	<13	>88.8%	-
Diuron	ng/L	1.8	5	77	<1.8	<5	>97.7%	-
Fluoxetine	ng/L	10	10	84	<10	<10	>88%	-
Lidocaine	ng/L	1.1	5	170	<1.1	<1.1	>99.3%	-
Lopressor	ng/L	5.1	20	340	<20	<5.1	>97.6%	-
NDMA	ng/L	0.96	2	3	<2	<0.96	>65.5%	-
Primidone	ng/L	4.8	5	100	<4.8	<4.8	>95.4%	-
Sucralose	ng/L	42	100	55,000	<100	<42	>99.9%	-
Sulfamethoxazole	ng/L	2.8	5	950	<2.8	<2.8	>99.7%	-
TCEP	ng/L	3.2	10	300	<10	<10	>98.3%	-
TCPP	ng/L	20	100	2,000	<100	<100	>97.6%	-
Triclosan	ng/L	6.3	10	48	<10	<10	>84.1%	-
Trimethoprim	ng/L	1.8	5	330	<5	<5	>99.1%	-

Notes:

a. For calculating average concentrations, results reported below the LRL were considered the value of the LRL and for values reported below the MDL, the value of the MDL was used.

b. Dashes shown for the UV/AOP Removal indicate the average concentrations in the RO permeate and UV/AOP were both below the LRL or MDL and removal could not be quantified.

Acronyms:

ng/L – nanograms per liter, equivalent to parts per trillion (ppt)
LRL – laboratory reporting level
MDL – method detection limit

Because many of these constituents were removed by the RO to levels at or below quantifiable limits, removal within the UV could not be accurately measured, creating challenges with identifying usable performance indicators. Of the four constituents recommended by the Science Advisory Panel, only triclosan was found at any time in the RO product, but even here it was at concentrations too low to use as a reliable performance monitor for advanced oxidation. Similarly, 1,4-dioxane was removed to levels below quantifiable limits by the RO process, making it too low to monitor performance of the advanced oxidation using this compound.

For the 16 constituents monitored as performance indicators (Table 2-24), removal generally exceeded 95 percent within the RO when sufficient quantities were present in the source water to calculate such removals. In some cases, greater than 99.9 percent removal was observed (sucralose and Ace-K). For the advanced oxidation process, however, no reliable performance indicator was found, due to the low levels present in the RO product. The most promising constituents measured were tris (2-chloroethyl) phosphate, tris (1-chlor-2-propyl) phosphate (two flame retardant compounds), and Ace-K, which sometimes had low levels measurable in the RO product (ranging from

non-quantifiable to 160 ng/L). These low concentrations in the RO product allowed a measured reduction by the advanced oxidation of up to 40 percent, however, higher removals may have been observed had higher concentrations been present.

During the initial two weeks of the performance CEC sampling period, surrogate compounds (TOC, conductivity, monochloramine, and UV254) were monitored daily. Results from this monitoring are shown in Table 2-25. For the RO process, the average removal results were: TOC = 99.6 percent; conductivity = 99.0 percent; and UV254 = 88.8 percent. For the advanced oxidation process, the average removal results were: UV254 = 68.7 percent; and monochloramine = 72.8 percent. Figure 2-11 presents the observed reduction in monochloramine across the UV disinfection and advanced oxidation process during operation of the Demonstration Facility.

Table 2-25 Removal of Online Monitoring Surrogates by Unit Processes

Compound	Units	Avg RO Feed (n = 14)	Avg RO Perm. (n = 14)	Avg UV/AOP (n = 14)	RO Removal	UV/AOP Removal
TOC	mg/L	7.2	0.031	--[a]	99.6%	--
Conductivity	µS/cm	1,348	14	--	99.0%	--
UV254	cm^{-1}	0.158	0.018	0.006	88.8%	68.7%
Monochloramine	mg/L	--	3.14	0.85	--	72.8%

Notes:

a. Dashes shown for values that were not measured.

Acronyms:

mg/L – milligrams per liter, equivalent to parts per million (ppm)
µS/cm – microSiemens per centimeter
cm^{-1} – centimeters to the negative first power

Results from field testing demonstrated that the removal of UV254 and monochloramine within the UV Disinfection and advanced oxidation process was due primarily to UV photolysis rather than advanced oxidation, however, the reliable presence of these constituents in the water downstream of both RO and advanced oxidation, and their ease of sampling and consistent removal suggests that they could serve as reliable surrogates for Full-Scale Facility performance monitoring.

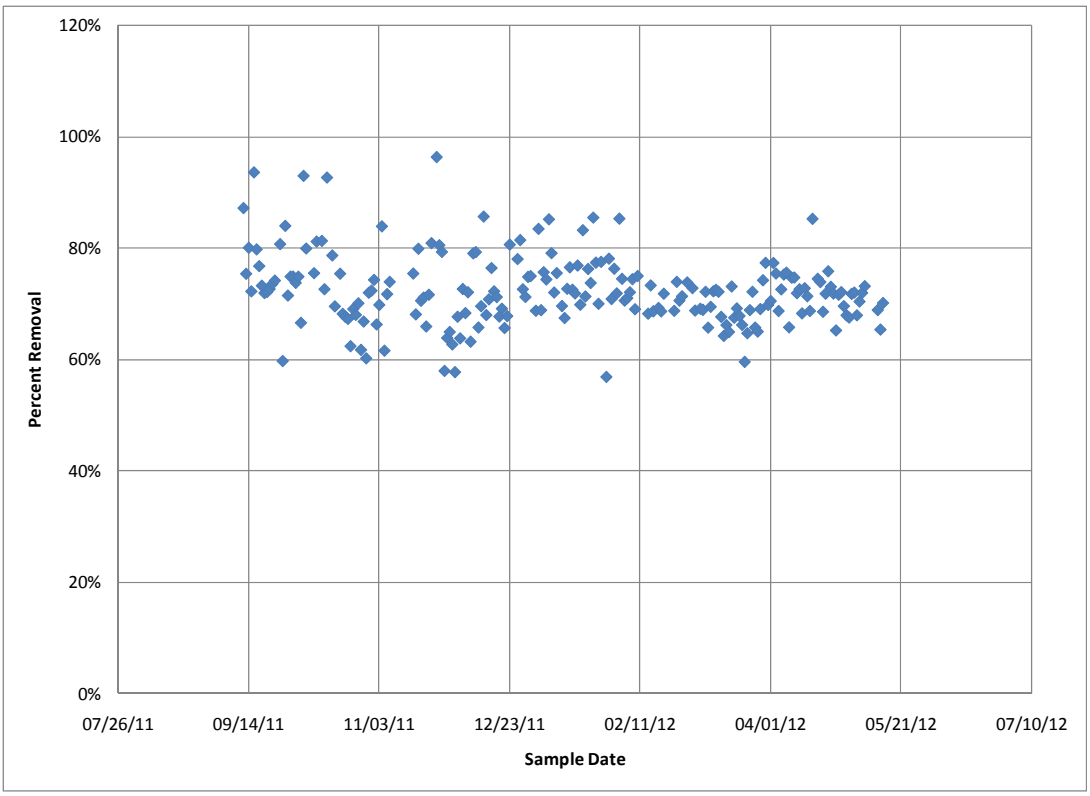


Figure 2-12
Monochloramine Removal by UV and Advanced Oxidation

Although not part of the initial surrogate monitoring, ammonia was also evaluated as a potential surrogate compound for advanced oxidation performance, due to its consistent removal within the AOP and an associated increase seen in the nitrate residual. Since ammonia is not expected to be oxidized to nitrate without the presence of an oxidizing agent, it was considered that ammonia could potentially serve as a surrogate parameter for the overall advanced oxidation process rather than just the UV component. Figure 2-12 presents the percent reduction of ammonia by the UV/AOP, based on biweekly grab samples sent off-site for laboratory analysis. The results show an ammonia reduction between 30 to 70 percent; however, results varied considerably from day to day, and may have been influenced by variability in the sampling procedure associated with offsite analysis. It is not known if the use of an online ammonia analyzer could provide a more consistent measure of AOP performance, providing a more reliable tool for surrogate monitoring. Further research should consider the use of ammonia as a potential surrogate, as it was consistently present both upstream and downstream of advanced oxidation.

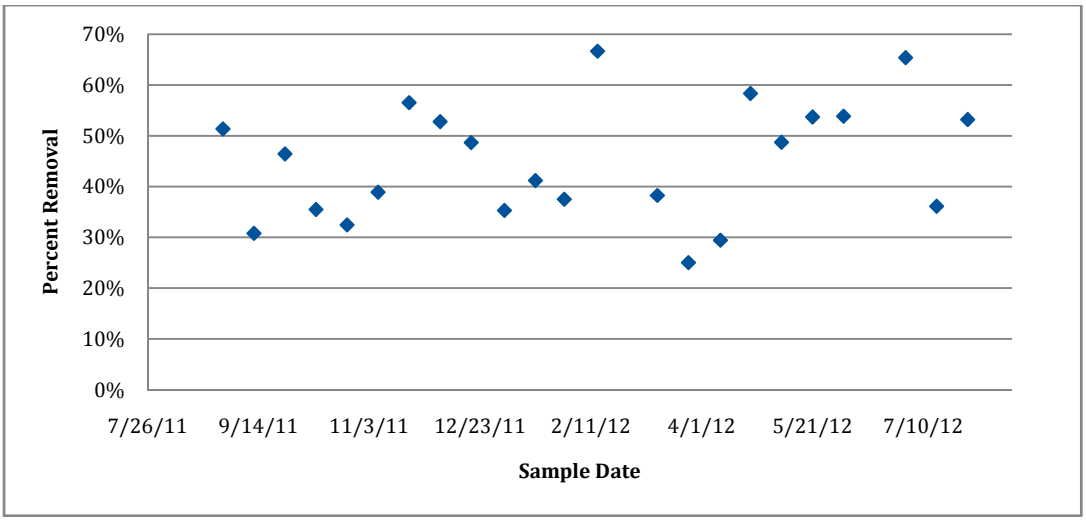


Figure 2-13
Ammonia Removal by Advanced Oxidation

2.6 Independent Advisory Panel

The Independent Advisory Panel (IAP) was convened in May 2009 to provide expert peer review of technical, scientific, regulatory, and policy aspects for the Demonstration Project. At their first meeting in May 2009, the IAP provided input on the Demonstration Facility project components, including the treatment train. During the course of the Demonstration Project the IAP reviewed work products and provided feedback on various aspects of the project including the Demonstration Facility and potential Full-Scale Facility. The IAP activities associated with the AWP Facility Study are summarized below.

- Review of Demonstration Facility T&M Plan (October 2010)
- Review of Demonstration Facility preliminary testing results (December 2011)
- Review of the AWP Facility Study Report (November 2012)

2.6.1 Testing & Monitoring Plan

The Final T&M Plan (Appendix A) established the testing program and water quality goals for the Demonstration Facility. The T&M Plan was reviewed and commented on by the IAP in October 2010. As a result of the comments received, the T&M Plan was expanded to include sampling for additional water quality parameters and increased frequency and number of samples for constituents that were identified in the draft plan. These comments and a description of how the comments were addressed are included as an appendix to the T&M Plan.

2.6.2 Preliminary Testing Results

The first quarter testing and monitoring results were presented to the IAP in December 2011. As a result of the comments received, the third and fourth quarter sampling was focused on improving the correlation of indicator compounds for performance and integrity monitoring.

2.6.3 AWP Facility Study Report

The AWP Facility Study Report was reviewed and commented on by the IAP in November 2012. Based on the results presented in this report, the IAP concluded that the purified water produced at the Demonstration Facility "met or exceeded all of the drinking water requirements and also provided multiple barriers for regulated and unregulated chemical and microbial constituents. The water produced is of a higher quality than any source available to the City of San Diego."

Additional information on the IAP and its advisory activities can be found in the Demonstration Project Report.

2.7 Conclusions

The primary purpose of the City's Demonstration Facility was to demonstrate the feasibility of water purification technologies to produce purified water for the City to determine the feasibility of a full-scale IPR/RA project. A full-scale project would assist with the City's effort to provide a local and sustainable water supply. To achieve this primary purpose, operation of the Demonstration Facility supported the project goals by the following means:

- Water quality monitoring throughout the testing period demonstrated that membrane filtration, followed by RO, and UV disinfection and advanced oxidation can reliably produce purified water that consistently meets all drinking water quality standards.
- Energy consumption was monitored at the Demonstration Facility, providing background data for energy requirements of a potential full-scale facility, including the evaluation of opportunities for energy saving measures.
- Operational data and observations collected from the Demonstration Facility testing period can be used to estimate construction costs and annual operation and maintenance costs for a Full-Scale Facility.
- Further research should also consider the use of ammonia as a potential surrogate for advanced oxidation performance, as it is not impacted by photolysis and was found to be consistently present upstream and downstream of advanced oxidation.

Section 3

Full-Scale Facility Considerations

This section presents energy conservation opportunities and other design considerations for the Full-Scale Facility based on observations made during operation of the Demonstration Facility.

3.1 Energy Conservation

The energy conservation considerations for the Full-Scale Facility provided herein are based on operational experience of the Demonstration Facility from start-up in mid-June 2011 through the end of the Q4 Testing Period (ending July 31, 2012). Energy conservation considerations are presented for the water purification processes: membrane filtration, reverse osmosis, and UV disinfection and advanced oxidation.

3.1.1 Membrane Filtration

At the Demonstration Facility, the power consumption of the UF system was consistently higher than the MF system; however, this is attributed to differences in the size and type of compressors used to control automatic valves. The UF system air compressor design may have been oversized and could be optimized in full-scale design. Both MF and UF similarly achieved the membrane filtration water quality goals throughout the testing period. A full-scale MF system is not anticipated to have significantly lower power consumption than a full-scale UF system and, therefore, both MF and UF should be equally considered for the Full-Scale Facility.

Variable Speed Feed Pumps

The AWP Facility influent pumps will pump tertiary effluent prior to chlorination from North City to the Full-Scale Facility. The pumps will need to ramp up and down through a wide range of speed settings to accommodate backwashing (approximately twice an hour for each membrane filtration skid) and daily integrity testing. The flow can be modulated using either throttling valves or variable speed drives; the throttling valves will be less expensive on a capital cost basis, but variable speed drives will use power more efficiently and are expected to be less expensive on a lifecycle cost basis. Variable speed feed pumps should therefore be considered for the Full-Scale Facility to conserve energy and reduce overall project costs.

Lifecycle Selection for Membrane Filtration System

Before detailed design, it is recommended that the City conduct additional side-by-side pilot testing of multiple membrane filtration system vendors. The purpose of the testing would be to prequalify vendors and establish design criteria for the vendor's most-recent equipment designs to gather actual operational data to be used for the lifecycle bid evaluation. The data for each vendor could be used to allow the City to procure the membrane filtration system on a lifecycle-cost basis to select the most cost-effective system in terms of both capital and O&M costs (including power usage) and be confident that the selected equipment can meet the design criteria.

3.1.2 Reverse Osmosis

Two energy saving measures recommended for the RO system are the use of a two-stage design rather than a three-stage and the incorporation of energy recovery devices.

Two-Stage Reverse Osmosis System

During the testing period, it was observed that the three-stage system required an average eight percent higher feed pressure than the two-stage system under similar operating conditions (i.e., flux, recovery, antiscalant dose, temperature). The higher pressure requirement is attributed to the vessel configuration rather than differences in the membranes, because the specific flux for the membranes used in both trains were identical. Similar water quality results (as measured by TOC, UV254, nitrate, etc.) were observed by both RO systems throughout the testing period. A two-stage RO system should, therefore, be considered for the Full-Scale Facility to reduce the power usage.

Energy Recovery Devices

The design of the Demonstration Facility included energy recovery devices to reduce the overall power usage of the RO systems and evaluate their potential benefits for the Full-Scale Facility. While numerous types of energy recovery devices are available and in use at desalination facilities, recovering as much as 98 percent of the waste energy from concentrate streams, the lower efficiency centrifugal-type devices are generally the only devices applicable for low salinity applications, such as this. Figure 3-1 illustrates the configuration of the centrifugal style TurboCharger energy recovery devices employed at the Demonstration Facility. These devices make use of residual energy from the concentrate stream of the second RO stage to drive a turbine coupled with a pump (the turbine/pump combination represents the energy recovery device). The pump then provides a pressure boost to the interstage water feeding the second RO stage. Using an energy recovery device in this manner has two intrinsic benefits: first, the pressure boost to the second stage reduces the required feed pressure for the overall system; and second, by providing an interstage boost, the production of the first and second stage can be more evenly balanced, reducing the risk of fouling from poor hydraulic conditions within the RO membranes. While the immediate economic benefits of reduced feed pressure can be easily calculated, the longer term benefits from reduced rates of fouling are more difficult to quantify, and are therefore not included in the evaluation presented below.

The actual energy savings achieved by the energy recovery devices at the Demonstration Facility was compared against values predicted during design using RO design software and efficiency projections from the energy recovery device manufacturer (Energy Recovery Inc). IMSDesign software (v.2012) was used to model the two-stage side of the Demonstration Facility, and an interstage boost of 24 psi (boost pressure to the second stage) was projected for one-year-old membrane elements, based on the average water quality conditions seen during the first twelve months of operation. Actual interstage boost for this side of the system averaged 23 psi after initial repairs on the device had been completed, indicating that the projected efficiency was within five percent of the values measured. This same software model was then used to estimate the potential energy savings for the Full-Scale Facility, assuming an average feed water TDS of 1,100 mg/L, based on historic concentrations observed at North City. A two-stage RO system was assumed, using Hydranautics ESPA2 membranes and a hydraulic recovery of 85 percent. Projections were run for three different membrane ages, with older membranes characterized by higher feed pressures and higher available energy for the recovery devices.

Table 3-1 presents results of the energy recovery projections for initial operation (year zero), three years, and five years. The table includes the anticipated boost pressure to the second stage, the expected impact this boost will have in reducing the overall feed pressure to the RO system, and the overall efficiency at which energy is expected to be recovered from the concentrate under these operating conditions. The table also includes assumed design criteria for the energy recovery device and the anticipated cost and economic benefit of employing the devices for the Full-Scale Facility.

The potential annual power cost savings were estimated based on reduced feed pumping pressure, assuming that the RO system will be designed with five trains (four duty and one standby), each with 4.5 mgd capacity. The energy savings are based on normal operation of four energy recovery devices for the four duty trains, but the capital cost is based on five energy recovery devices, one for each train. It should be noted that the assumption of a redundant RO train was used for conservative planning purposes. Redundant RO trains are not common, even in drinking water treatment facilities, due to increased risks of fouling under low flow conditions and to the operational challenges of moving RO units in and out of stand-by mode. In the event that the future facility does not include a redundant RO unit, the capital cost of the devices would be expected to be 20 percent lower than the number shown in Table 3-1.

Projected energy savings from the energy recovery devices are approximately $113,800 annually for a two-stage RO configuration, assuming a power cost of $0.12/kWh, and that conditions at year three are generally representative of the average conditions over the life of the membranes (five to seven years). Estimated capital cost for incorporating the devices into the facility is $607,500, including equipment, installation, and other implementation costs discussed further in Section 5. Based on these numbers, the anticipated payback period for the energy recovery devices is less than six years. The expected life of the Turbocharger devices is 20 years, indicating that the economic benefit of utilizing the devices is expected to significantly exceed the cost of their incorporation. The benefits and costs of incorporating energy recovery into the future Full-Scale Facility should therefore be further evaluated at a future date.

Table 3-1 Impact of Energy Recovery Devices on RO Operation

Parameter	Year 0	Year 3	Year 5.5
Average Boost to Second Stage [1,2]	23 psi	37 psi	53 psi
Reduction in First-Stage Feed Pressure [1,2]	6 psi	11 psi	17 psi
Concentrate Energy Recovered [1,2]	55%	59%	61%
Total Energy Reduction	4%	6%	7%
Equipment Model Number	ERI Turbocharger LPT-2000		
Number of Units	4 Duty, 1 Standby		
Total Capital Cost for Energy Recovery Devices [3]	$607,500		
Total Power Usage Savings [4,5]	$113,800		
Payback Period [5]	6 Years		

Notes:

1) RO Projections assumed 85% recovery, 1,100 mg/L of TDS in feed water, and Hydranautics ESPA2 membranes.
2) As membranes age, the RO feed pressures and concentrate pressures increase, requiring more energy to produce the water, but also allowing for more energy to be recovered.
3) Capital cost includes five energy recovery devices (one for each RO train).
4) Power usage savings assumes four operating units and 12¢/kWh average power cost.
5) Three-year old membranes were assumed to be average conditions for total power savings and payback period calculations.

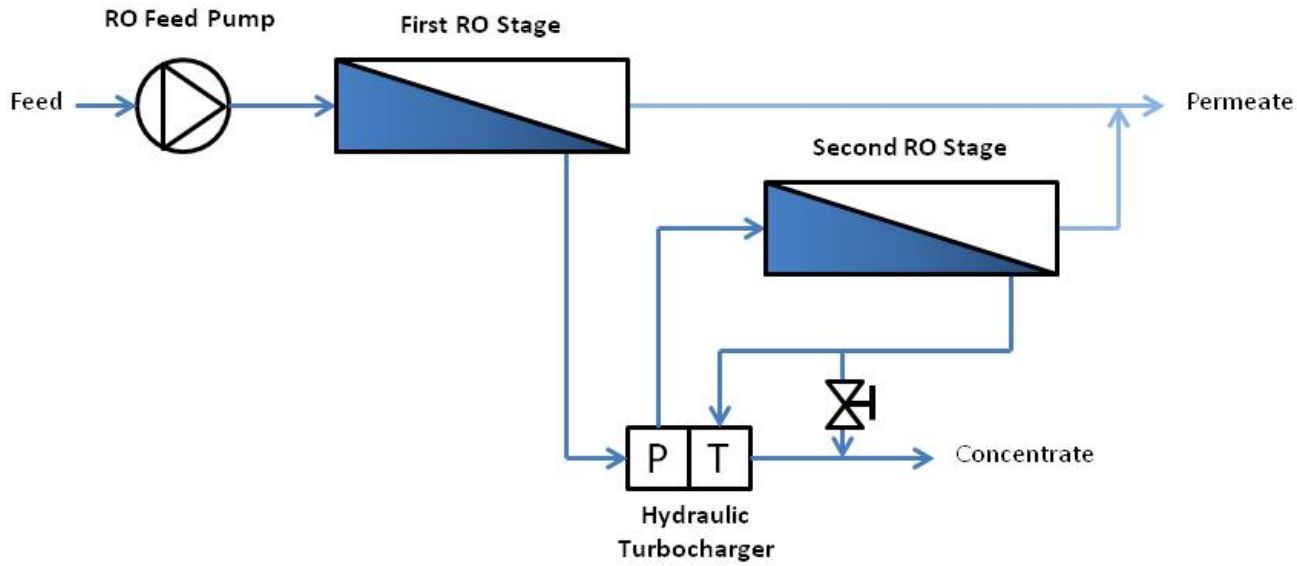


Figure 3-1
Two-Stage RO Design with Energy Recovery Device (Hydraulic Turbocharger)

3.1.3 UV Disinfection and Advanced Oxidation

The following are UV disinfection and advanced oxidation energy conservation considerations for the Full-Scale Facility.

More Efficient UV System Design

The average reactor power level required to achieve the target NDMA removal as predicted by the Trojan control system was approximately 67 percent, which corresponds to an average power of 12.6 kW. The power required to achieve the target removal was observed to increase as runtime increased. The increased power was attributed to the decrease in temperature during winter months, as well as lamp aging, both of which increased the applied power to achieve a target contaminant removal. The average EEO value predicted over the testing period was 0.26 kWh/1000 gallons/ log removal. However, when measured during the testing period, the EEO was better than projected at 0.19 kWh/1000 gallons/log removal. For the Full-Scale Facility, multiple UV vessels in series will likely be used, similar to existing full-scale facilities, achieving further increases in efficiency and lower EEO values.

Improved Reactor Controls

The reactor power of the UV disinfection and advanced oxidation system at the Demonstration Facility increased to 100 percent when a minimum of two lamps or one ballast failed on the system or when there was no flow to the UVT analyzer. The Full-Scale Facility design should be coordinated with the manufacturer to determine how the system can be optimized so that the default is not to ramp up power to 100 percent power while still providing adequate treatment. Ramping up to 100 percent power while the UV system is providing adequate treatment would cause the Full-Scale Facility to use unnecessary power.

The UV reactors for the Full-Scale Facility could be designed to adjust to 100 percent power only when more of the allowable number of ballasts and lamps are out of service. In addition, the UV disinfection

and advanced oxidation system could be specified to have a lag time before adjusting to 100 percent power if the UVT analyzer experiences no flow. The flow to the UVT analyzer can be corrected by operations staff based on a system alarm.

3.2 Other Design Considerations

This section summarizes other design considerations for the Full-Scale Facility based on observations made during operation of the Demonstration Facility. These considerations are summarized in Table 3-2 and discussed in this section.

Table 3-2 Other Full-Scale Facility Considerations

Design Consideration	Effect
Membrane Filtration System	
Evaluate multiple manufacturers	• Promote competitive bidding • Determine best available equipment
Increase flux rate	• Smaller facility footprint • Reduce capital cost • Increase fouling, operational pressure, and O&M costs
Use of chemically enhanced backwashes	• Decreased clean in place frequency • Allows higher fluxes and lower capital cost • Higher chemical usage
Reverse Osmosis	
Evaluate multiple manufacturers	• Promote competitive bidding
Increase recovery (85 percent or higher)	• Maximize water production • Increase cleaning frequency
Increase flux rate	• Smaller facility footprint • Reduce capital cost • May improve hydraulics and reduce fouling/scaling potential
Add pH suppression capability	• Reduce potential fouling if water quality changes
UV Disinfection and Advanced Oxidation	
Evaluate multiple manufacturers	• Promote competitive bidding • Determine best available equipment
Reduce hydrogen peroxide dose	• Reduce chemical usage

3.2.1 Membrane Filtration

The following are other membrane filtration design considerations for the Full-Scale Facility.

Membrane Filtration Technology Selection

Two types of membrane filtration systems were tested at the Demonstration Facility: a Pall MF system and a Toray UF system. As mentioned above, both the MF and UF achieved the membrane filtration water quality goals of the Demonstration Facility; therefore, either system could be considered for the Full-Scale Facility. In addition to the two membranes tested during the Demonstration Facility, there are other membrane systems that may be considered for the Full-Scale Facility. It is recommended that other systems be considered to obtain competitive equipment pricing for the Full-Scale Facility. These include pressure systems, similar to those used at the Demonstration Facility, and submerged systems, such as the system used at the Orange County Water District Groundwater Replenishment

System. While there are basic conceptual differences between these two systems, the more significant differences are between manufacturers and systems in operating pressures, recovery, and efficiency between the systems and operating configurations. Therefore, lifecycle evaluations of multiple membrane filtration system vendors are recommended (refer to Section 3.1.1). Any manufacturer/equipment considered should meet the minimum qualifications discussed in Section 4.2.10.

Optimize Membrane Filtration Operating Conditions

Based on the relatively low membrane fouling rates observed for the MF and UF systems during the reporting period, it may be possible to optimize the operating conditions for the potential Full-Scale Facility by increasing the operating flux and feed water recovery. Such changes would result in a smaller footprint (i.e., fewer number of skids) to achieve the target production capacity thereby reducing the initial capital cost. Increasing the feed water recovery would also reduce the volume of backwash waste that would be required to be discharged to North City. This would also increase the Full-Scale Facility capacity based on the fixed available capacity of tertiary effluent.

Increasing these parameters could also increase the membrane fouling rates and operating pressure, which would result in higher O&M costs by increasing the frequency of chemical cleanings and feed pump pressure requirements. Optimization of these parameters would be specifically beneficial for the MF system as the system was operated at a lower feed water recovery than the UF system and exhibited a lower fouling rate.

Another operating condition that could be investigated is the use of chemically enhanced backwashes or frequent (daily or weekly) maintenance cleans to lessen membrane fouling thereby decreasing the number of full chemical cleanings required over a given time period. Both of these actions would increase the chemical usage (and O&M cost) of the Full-Scale Facility.

Flow Equalization of Membrane Filtrate

During operation of the Demonstration Facility, excess filtrate water produced from the MF and UF systems overflowed the filtrate tank to the drain. The filtrate storage tank was sized to accommodate downtime of the MF and UF system during the daily PDTs conducted on each system. It was also observed that the overflow of filtrate water from the storage tank increased when the feed water recovery of the RO systems was increased from 80 percent to 85 percent recovery as the RO feed water flow to meet the design permeate flow decreased. The design and operating strategy of the MF or UF system and filtrate storage tank for the Full-Scale Facility should be optimized to avoid wasting filtrate water and meet the demand of the RO system.

3.2.2 Reverse Osmosis

The following are other RO design considerations for the Full-Scale Facility.

Reverse Osmosis Technology Selection

Comparison of the two-stage and three-stage RO system performance during this reporting period showed similar membrane fouling rates and permeate water quality despite the fact that the Hydranautics ESPA2 LD membranes are advertised as low fouling membranes and the Toray TML membranes were projected to achieve higher rejection of nitrate. In addition to the two membranes tested during the Demonstration Facility, there are other RO membranes that should be considered for the Full-Scale Facility and new membranes will be developed before the Full-Scale Facility is designed. It is recommended that other membranes be tested to assess their operating performance

(i.e., scaling and fouling rates) and permeate water quality in order to obtain competitive equipment pricing for the Full-Scale Facility. Any manufacturer/equipment considered should meet the minimum qualifications discussed in Section 4.2.10.

85 Percent RO Recovery to Maximize Water Production

Based on the low fouling rates observed on the RO systems during nearly six months of operation at 80 percent recovery, the RO systems were successfully increased to 85 percent recovery to maximize water production. In previous pilot testing conducted by the City, stable operations were not achievable at 85 percent recovery due to excessive fouling and scaling. The same effects have not been observed at the Demonstration Facility, possibly due to improved system hydraulics from higher fluxes (the piloting was done at fluxes between 10 and 12 gfd), or due to changes in water quality since the piloting was completed. Further consideration of recoveries as high as 87 to 88 percent could also be considered if additional water production is required, however, these higher recoveries should be successfully tested at the Demonstration Facility before considering them for full-scale design.

While increasing the recovery would increase the overall capacity of the Full-Scale Facility, long term operation at the higher recovery rates may warrant more O&M requirements. Such requirements may include an increase in the number of chemical cleanings due to increased membrane fouling and scaling and increased membrane replacement frequency. Although the antiscalant type and dose was sufficient without acid to prevent fouling during operation of the Demonstration Facility, water quality will change over time and could require changes in antiscalant or potentially the use of acid to maintain operation at 85 percent recovery for the Full-Scale Facility. If further increases above 85 percent recovery are considered, additional changes may be required, such as increases in RO flux or the addition of a third RO stage.

Higher RO Design Flux

While RO systems at the Demonstration Facility were tested at design flux of 12 gfd and feed water recoveries of 80 and 85 percent, the Full-Scale Facility design may consider a higher flux rate of 14 gfd. A pilot study performed at the Los Angeles Donald C. Tillman Water Reclamation Plant (Wetterau et al, 2011) observed that poor hydraulic conditions—high beta values or low crossflow velocities—can contribute to fouling in a two-stage RO configuration when an overall average flux below 12 gfd is maintained with a recovery of 85 percent. These findings are supported by challenges with scaling that have been experienced at the Leo J. Vander Lans Water Treatment Facility and the Terminal Island AWP Facility, both designed with two-stage RO and 85 percent recovery. Both facilities are in the process of expanding, and both will be operated at fluxes above 12 gfd when the expansions are complete.

It is recommended that an RO flux of 14 gfd be considered for the Full-Scale Facility in a two-stage configuration to take advantage of improved hydraulics and reduced scaling potential, and to allow some degree of turn-down for the RO skids during low supply flow conditions. To confirm the reliability of plant operation under such conditions, a higher flux should be tested with North City's tertiary effluent before the design of the Full-Scale Facility.

3.2.3 UV Disinfection and Advanced Oxidation

The following are other UV disinfection and advanced oxidation design considerations for the Full-Scale Facility.

Power Monitoring for Ballast Failure

The UV system at the Demonstration Facility had several ballast failures. While it is suspected that the ballast failures were caused by faulty ballasts, there is a chance that they could have been caused by power surges. The design of the Full-Scale Facility should include power monitoring of the Full-Scale Facility power sources to determine if a transient voltage surge suppressor should be included in the UV system design.

Optimize UVT Analyzer Inlet Connection

For the Full-Scale Facility, the UVT analyzer inlet connection should be located in a pipe run that is always running full with RO permeate and away from areas where air entrainment could be introduced. Air entrainment in the UVT analyzer inlet connection caused the UVT analyzer to malfunction several times at the Demonstration Facility, due primarily to the need for overhead piping at the Demonstration Facility. Such flow configurations should be avoided, to the extent possible, in the Full-Scale Facility design.

Optimize Hydrogen Peroxide Dose

The UV disinfection and advanced oxidation system at the Demonstration Facility was designed to achieve 1.2-log removal of NDMA based on the draft 2008 CDPH Groundwater Recharge Reuse Regulations. During the testing period, however, the CDPH revised the draft regulations (November 21, 2011) to specify that advanced oxidation be sized to achieve only 0.5-log removal of 1,4-dioxane or on demonstrated log removals of select indicator compounds from different functional groups. This change may make it possible to design the UV disinfection and advanced oxidation system at the Full-Scale Facility a lower UV dose. Based on initial studies completed by the Orange County Water District, it may also be possible to reduce the hydrogen peroxide dose below 3 mg/L and still achieve the 0.5-log removal requirement for 1,4-dioxane.

3.2.4 Chemical Systems

The following are other chemical systems design considerations for the Full-Scale Facility.

Prevent Air Locking

The chemical in the full scale design should be designed to prevent air locking, locating metering pumps sufficiently below the low level in the feed tanks to maintain pressures and prevent off-gassing.

Chemical Cleanings

The membrane filtration and reverse osmosis systems will require chemical cleanings. Based on the chemical cleanings that were conducted at the Demonstration Facility, the following elements for the clean-in-place system should be considered for the Full-Scale Facility design:

- Minimizing the volume of piping between the clean in place tank and equipment skids would reduce the cleaning solution volume requirement.
- Optimizing the clean in place tank configuration to limit the volume required to submerge the pump used to recirculate cleaning solution would reduce the cleaning solution volume requirement.
- The addition of flow meters on chemical cleaning solution dosing pumps would prevent over dosing and overuse of cleaning chemicals.

- The inclusion of an inline pH meter on the clean in place skid would be useful to help ensure target pH is met through the recirculation process and minimize over usage of chemicals needed to make pH adjustments.
- The inclusion of a designated neutralization tank (s) should be considered to allow more aggressive cleanings (e.g., pH below City's current discharge requirements).
- The use of acid followed by caustic was observed to be more effective than caustic followed by acid during clean in place procedures conducted on the RO systems.
- Use of North City cogeneration facility waste heat to heat chemical tanks during cleaning should be investigated prior to final design.

Increasing soak and recirculation times of standard chemical solutions on the RO systems improved cleaning efficiency and avoided the need for proprietary costly cleaning solutions.

3.2.5 Online Water Quality Instrumentation

This section describes lessons learned and observations made during operation of the Demonstration Facility regarding the online water quality instrumentation utilized throughout the testing program. Table 3-3 provides a list of online water quality analyzers installed at the Demonstration Facility. The table provides the location, purpose, and manufacturer and model for each analyzer. A brief description of the purpose and operational experience with each instrument is provided below.

Table 3-3 Water Quality Instruments Utilized at the Demonstration Facility

Analyzer Location	Parameter Measured	Instrument Manufacturer and Model	Purpose
MF filtrate	Turbidity	HACH 1720 E	MF integrity monitoring
UF filtrate	Turbidity	HACH 660 SC	UF integrity monitoring
Pre MF/UF filtrate storage tank	Total chlorine	HACH CL-17	Chlorine dosing control
Post MF/UF filtrate storage tank	Total chlorine	HACH CL-17	RO membrane protection
RO feed	Oxidation reduction potential	HACH pHD sc Digital Differential Sensor	RO membrane protection
RO feed	Conductivity	HACH probe	RO integrity monitoring
Train A RO permeate	Conductivity	HACH probe	RO integrity monitoring
Train B RO permeate	Conductivity	HACH probe	RO integrity monitoring
Combined RO permeate/RO feed	Total organic carbon	GE / Sievers 5310C	RO integrity monitoring
UV influent	UV transmittance	TrojanOptiView	UV dose adjustment
UV influent/product	Monochloramine	HACH Pocket Colorimeter II	Advanced oxidation integrity monitoring

- **Oxidation Reduction Potential (ORP) Analyzer –** The Demonstration Facility included an ORP analyzer at the feed of the RO systems. The purpose of this meter was to detect changes in ORP, which may be indicative of the presence of free chlorine that can damage the RO membranes. Throughout the testing the ORP of the feed water stayed fairly consistent around 400 millivolt (mV). The control system was set to give a warning if the ORP reached 500 mV and shut down if the value reached 550 mV. As a redundant measure, a flow confirmation switch was installed on the ammonia hydroxide pump to directly monitor that ammonia was being added at all times to form combined chlorine.

- **Chlorine Analyzers –** The Demonstration Facility included two online chlorine analyzers and one portable monochloramine analyzer. One online analyzer was located upstream and the other downstream of the MF/UF filtrate storage tank. The intention of the upstream meter was for chemical dosing, to ensure the target chloramine concentration was present in the membrane filtration filtrate to prevent biological fouling of the MF, UF, and RO systems. The downstream analyzer was tied to a control loop, which was set to alarm if total chlorine in the feed exceeded 4.0 mg/L, the maximum concentration allowed by the RO membrane manufacturers. The portable monochloramine analyzer was used in conjunction with the UV system to evaluate the use of monochloramine as a surrogate for CEC destruction. Based on successful correlation of monochloramine destruction at the Demonstration Facility, it is recommended that online analyzers be considered at the Full-Scale Facility to monitor the integrity of the UV process.

- **Turbidimeters –** Online turbidimeters were equipped on both the MF and UF systems to monitor filtrate turbidity on a continuous basis. Average filtrate turbidities based on readings taken twice per day from the online analyzer displays were 0.05 NTU for the MF system and 0.016 NTU for the UF system. The lower turbidity values measured on the UF system were attributed to the fact that this system uses a laser turbidimeter (HACH Model Filter Trak 660 SC), which uses advanced incident light, whereas the MF system uses a conventional incandescent light turbidimeter (HACH 1720 E). The specifications on the laser turbidimeter states the unit can detect changes in turbidity as low as 0.0003 NTU. Based on experience at the Demonstration Facility, both turbidimeters worked as intended and are suitable for the Full-Scale Facility.

- **UVT Analyzer** – The UV disinfection and advanced oxidation system was equipped with an online UVT analyzer located at the UV reactor influent. The purpose of the UVT analyzer was to provide feedback to the UV control system to adjust reactor power based on the measured UVT in the influent water. During the course of operation the analyzer operated as intended with the exception of the low flow alarms causing the reactor to alarm. Discussion on the possible use of online UVT for integrity monitoring and the Full-Scale Facility is discussed in Section 4.3.3.

- **Portable TOC Analyzer –** The RO system was equipped with one online TOC analyzer (GE Model 5310 C). The main purpose of the analyzer was to provide continuous monitoring of TOC in the RO permeate. However, the unit was also used each quarter to characterize the RO feed water TOC over a one to two-week period. The unit was also used to measure the TOC in grab samples from various locations in the Demonstration Facility process including MF filtrate, UF filtrate, and in the permeate from each RO Train. In general the analyzer operated as expected during the testing period. However, in order to achieve accurate measurements of the low concentrations of TOC (e.g., less than 100 ppb) in the RO permeate it was necessary to install an

inorganic carbon removal unit on the analyzer. It was also observed during December 2011 that the accuracy of the analyzer was impacted by large swings in the internal cell and ambient temperature. Lastly, it is was necessary to frequently replace consumables on the unit including oxidizer and acid reagents, UV lamp, tubing, and resin per the manufacturer's recommended maintenance schedule. Additional recommendation on the use of online TOC monitoring for the full-scale integrity monitoring is provided in Section 4.3.3.

- **Conductivity Analyzers –** The RO system was equipped with online conductivity analyzers on the feed water and permeate. During the course of operation the analyzer operated as intended and correlated well with daily measurements taken with a hand held meter. Discussion of the use of online conductivity monitoring and the Full-Scale Facility is presented in Section 4.3.3.

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Section 4

Full-Scale Facility Conceptual Design

This section presents the recommendations for design of a Full-Scale Facility consistent with the water purification processes that are being operated at the Demonstration Facility. As discussed in Section 2, these water purification processes produced purified water that meets the required regulatory limits.

4.1 Full-Scale Facility Overview

The Full-Scale Facility consists of the following treatment components, as shown in the process flow diagram presented in Figure 4-1.

- AWP Facility influent pump station
- Pretreatment chemical addition (chloramination for biofouling control)
- Membrane filtration system (MF or UF)
- Membrane filtration break tank
- RO transfer pumps
- RO pre-treatment chemical addition (antiscalant and sulfuric acid for scale control)
- Cartridge filters
- RO feed pumps
- RO system
- UV disinfection and advanced oxidation system using ultraviolet light with hydrogen peroxide (UV/H_2O_2)
- Post treatment/stabilization chemical addition (pH and LSI adjustment for corrosion control)
- Purified water pump station and pipeline to San Vicente Reservoir (see the Purified Water Conveyance System Final Conceptual Design Report for more information)

Figure 4-2 shows the preliminary hydraulic profile of the Full-Scale Facility.

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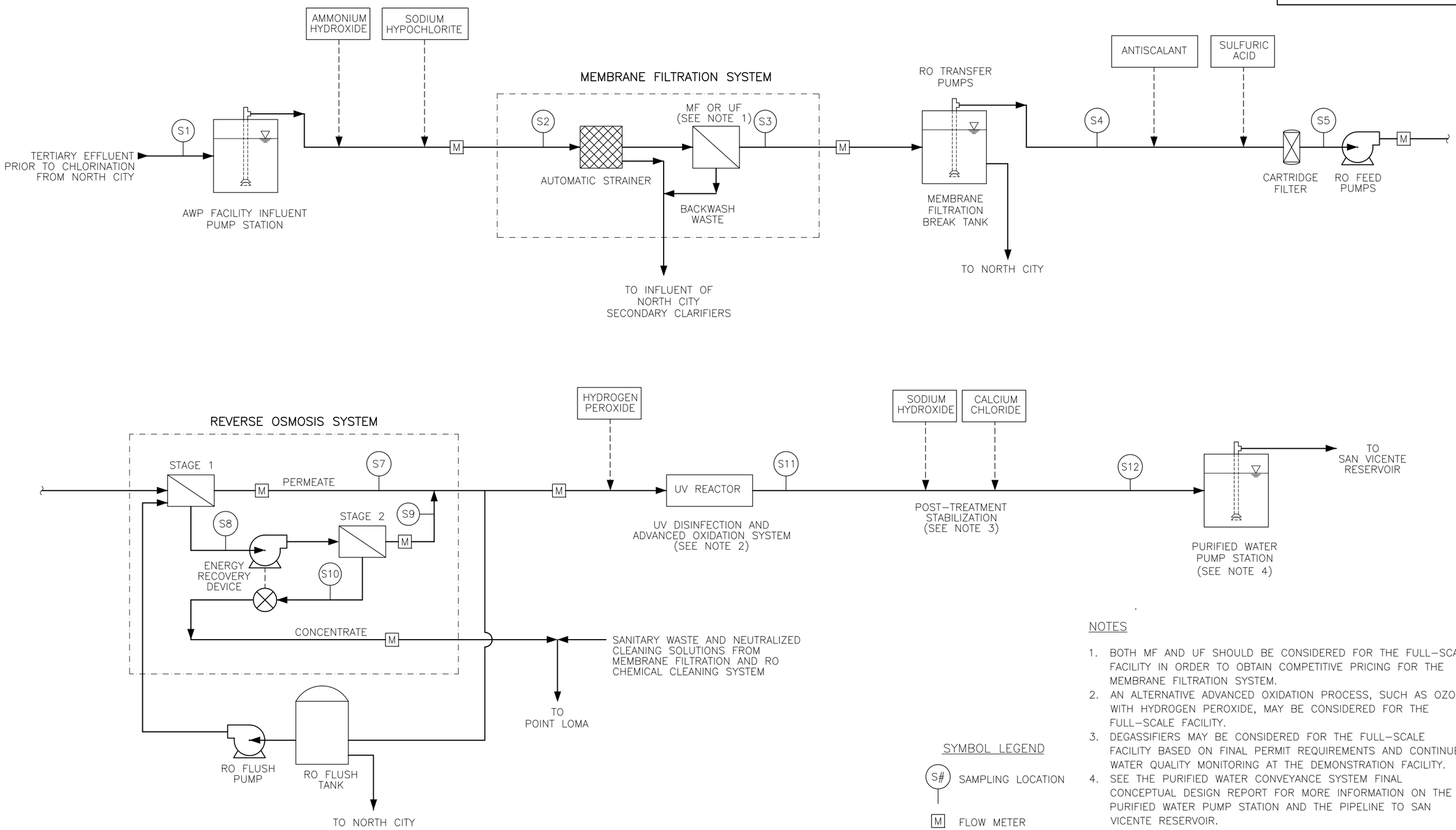

SYMBOL LEGEND

S# SAMPLING LOCATION

M FLOW METER

NOTES

1. BOTH MF AND UF SHOULD BE CONSIDERED FOR THE FULL-SCALE FACILITY IN ORDER TO OBTAIN COMPETITIVE PRICING FOR THE MEMBRANE FILTRATION SYSTEM.
2. AN ALTERNATIVE ADVANCED OXIDATION PROCESS, SUCH AS OZONE WITH HYDROGEN PEROXIDE, MAY BE CONSIDERED FOR THE FULL-SCALE FACILITY.
3. DEGASSIFIERS MAY BE CONSIDERED FOR THE FULL-SCALE FACILITY BASED ON FINAL PERMIT REQUIREMENTS AND CONTINUED WATER QUALITY MONITORING AT THE DEMONSTRATION FACILITY.
4. SEE THE PURIFIED WATER CONVEYANCE SYSTEM FINAL CONCEPTUAL DESIGN REPORT FOR MORE INFORMATION ON THE PURIFIED WATER PUMP STATION AND THE PIPELINE TO SAN VICENTE RESERVOIR.

CITY OF SAN DIEGO INDIRECT POTABLE REUSE/RESERVOIR AUGMENTATION DEMONSTRATION PROJECT

FULL-SCALE FACILITY PROCESS FLOW DIAGRAM (JANUARY 2013)

FIGURE 4-1

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FILENAME: 78220-SF-RPT-Fig4-1 2-22-13 12:25pm uchimurark XREFS: 78220-G-SHBD |<<--
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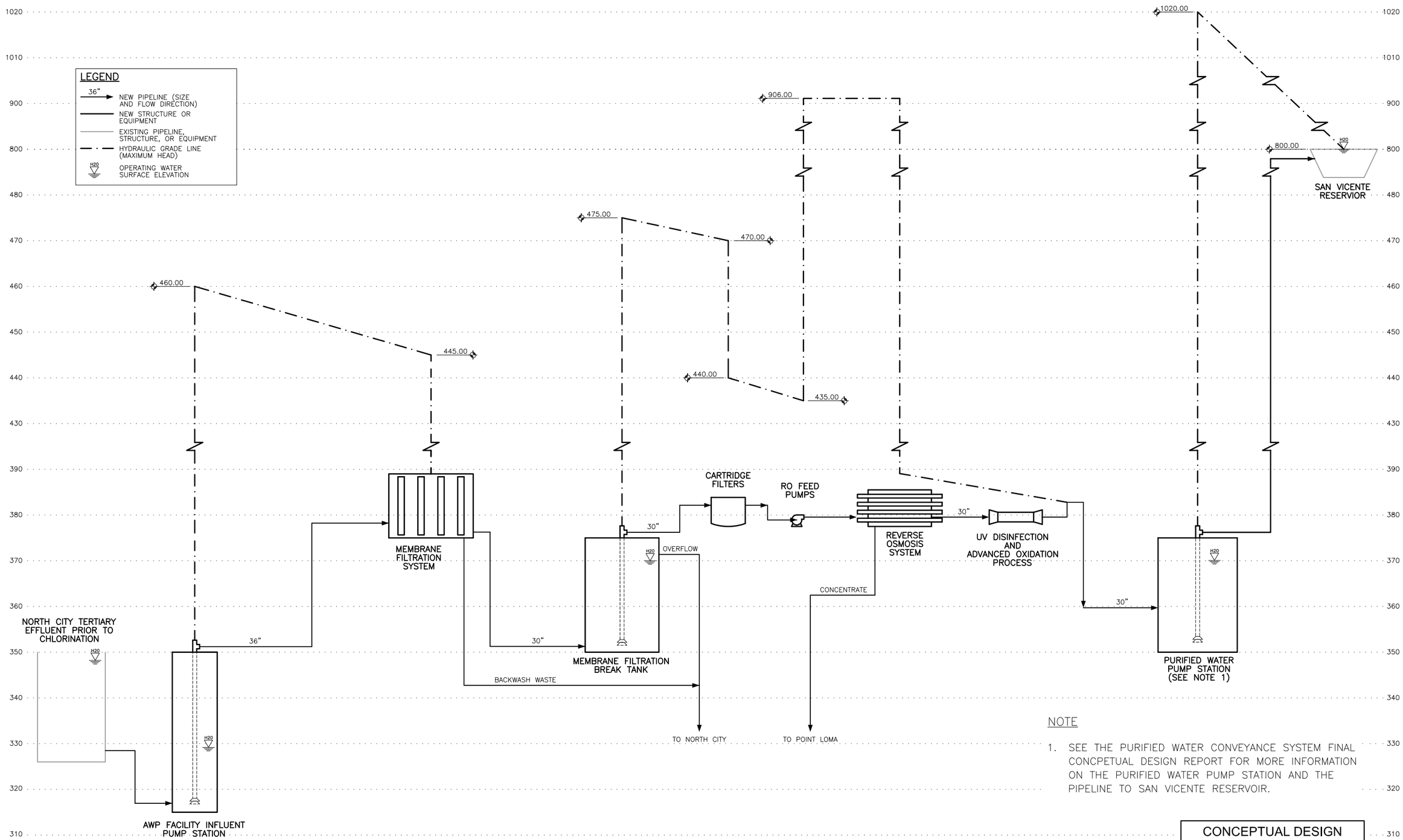

NOTE

1. SEE THE PURIFIED WATER CONVEYANCE SYSTEM FINAL CONCPETUAL DESIGN REPORT FOR MORE INFORMATION ON THE PURIFIED WATER PUMP STATION AND THE PIPELINE TO SAN VICENTE RESERVOIR.

CONCEPTUAL DESIGN
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CITY OF SAN DIEGO INDIRECT POTABLE REUSE/RESERVOIR AUGMENTATION DEMONSTRATION PROJECT

FULL-SCALE FACILITY HYDRAULIC PROFILE (JANUARY 2013)

FIGURE 4-2

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FILENAME: 78220-SF-RPT-Fig4-2 2-22-13 12:24pm uchimurark XREFS:\ 78220-G-SHBD
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4.1.1 Capacity

The City's Full-Scale Reservoir Augmentation Capacity Analysis Technical Memorandum has defined a capacity for the Full-Scale Facility of 18 mgd, which would produce an annual average of 15 mgd of purified water. This sizing is based on the capacity of the North City, maintaining recycled water available for existing recycled water users, and a 95 percent online factor.

Maintaining recycled water available for existing recycled water users requires that the Full-Scale Facility sizing account for the seasonal demands of recycled water. The Full-Scale Facility will operate at the design capacity (18 mgd) in winter when recycled water demands are lowest, and will operate at a reduced production in summer when recycled water demands are highest. This seasonal variation, in combination with the online factor, will result in an average annual production of 15 mgd of purified water from the Full-Scale Facility. Therefore, the estimated capital costs presented in Section 4 are based on a capacity of 18 mgd, while the estimated O&M costs are based on annual average production of 15 mgd.

The City's Full-Scale Reservoir Augmentation Capacity Analysis Technical Memorandum is included in Appendix C.

4.1.2 Location

The proposed project site will be located on approximately 8.7 acres of available City-owned property immediately north of North City. A pipe gallery /access tunnel will be provided under Eastgate Mall Road connecting North City just west of the guard shack to the Full-Scale Facility. The tunnel will be sized to accommodate the following:

- Tertiary effluent/Full-Scale Facility feed pipeline (pressure)
- Membrane filtration backwash pipeline (gravity)
- RO concentrate pipeline (pressure)
- Electrical conduit
- Instrumentation and control conduit
- Maintenance cart travel

The footprint of the proposed Full-Scale Facility is approximately 6.0 acres. The site layout is based on locating the Operations, Maintenance, and Administration Building on the south for visitor access. Process areas not enclosed in a building will be installed under canopies.

Figure 4-3 shows the existing North City site; the location of the Full-Scale Facility site north of North City; the location of the AWP Facility influent pump station at North City; the preliminary routing of the tertiary effluent, membrane filtration backwash, RO concentrate, and instrumentation and control conduit at North City; and the tunnel between North City and the Full-Scale Facility site. Figure 4-4 shows the preliminary site layout for the Full-Scale Facility.

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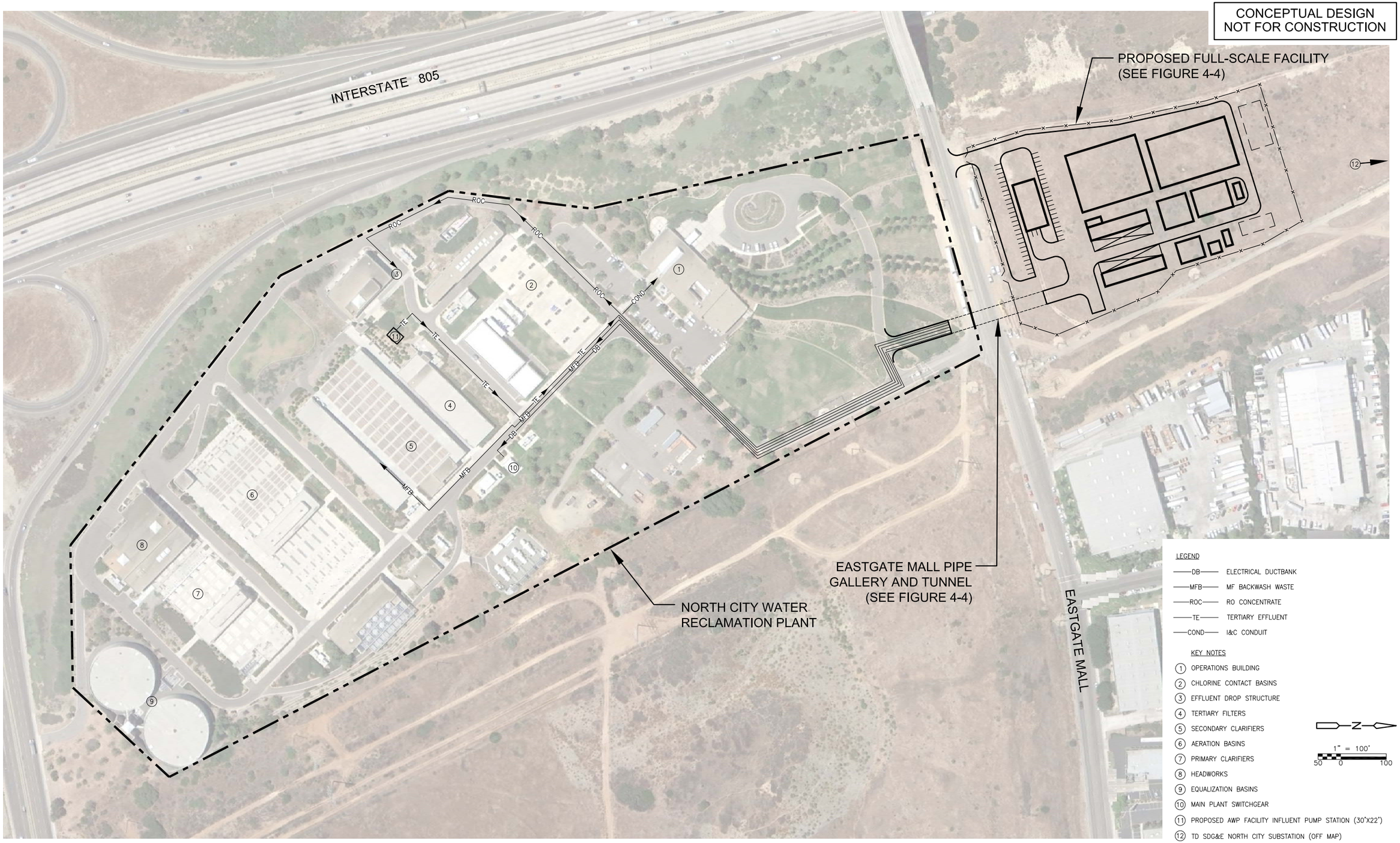

CITY OF SAN DIEGO INDIRECT POTABLE REUSE/RESERVOIR
AUGMENTATION DEMONSTRATION PROJECT

FULL-SCALE FACILITY PROPOSED IMPROVEMENTS (JANUARY 2013)

FIGURE 4-3

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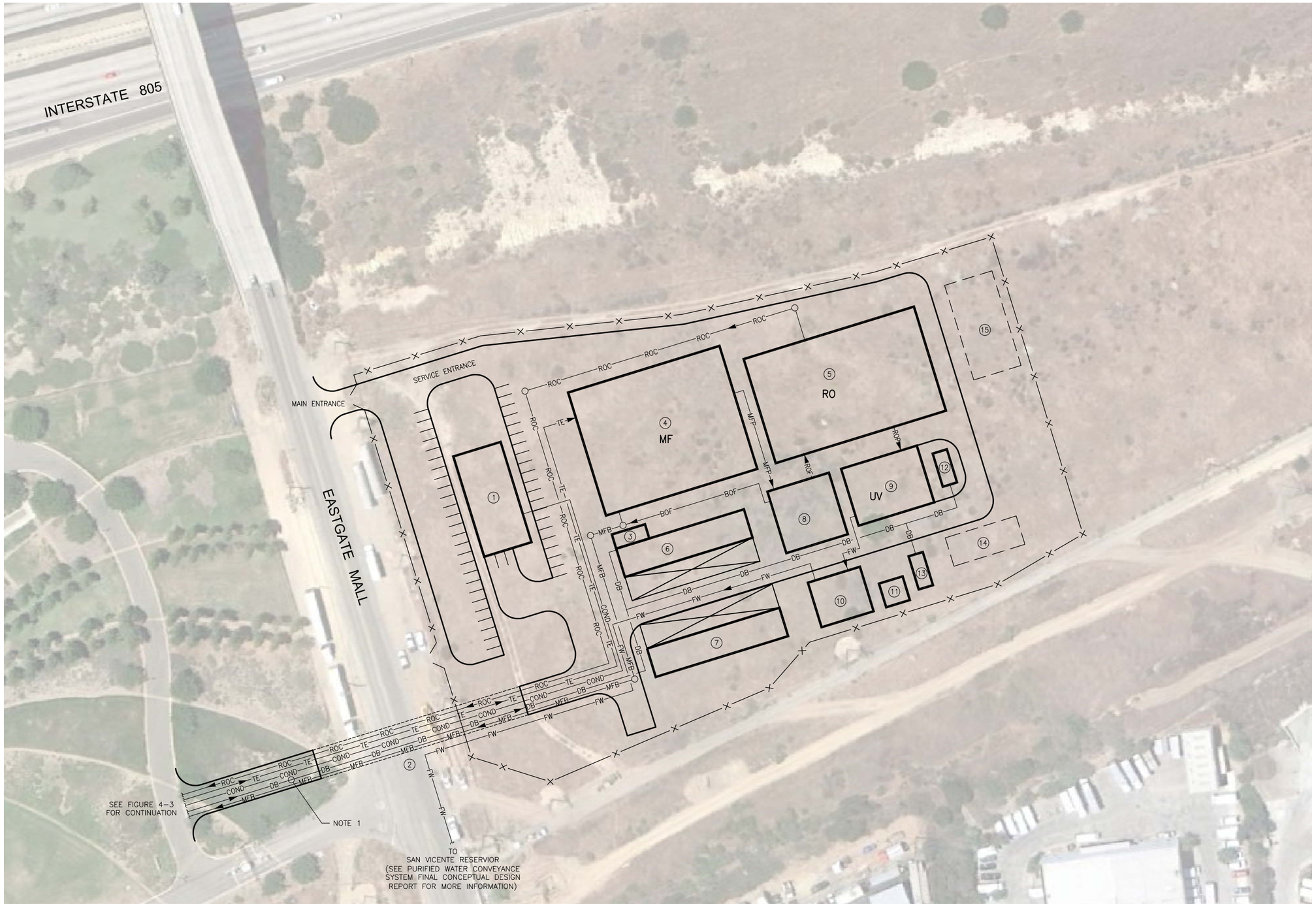

LEGEND

- CHAIN LINK FENCE
- LOADING PADS (25' WIDE)
- BOF — BREAK TANK OVERFLOW
- COND — I&C CONDUIT
- DB — ELECTRICAL DUCTBANK
- FW — FINISHED WATER
- MFB — MF BACKWASH WASTE
- MFP — MF PERMEATE
- ROF — RO FEED
- ROC — RO CONCENTRATE
- ROP — RO PERMEATE
- TE — TERTIARY EFFLUENT

KEY NOTES

1. OPERATIONS, MAINTENANCE, AND ADMINISTRATION BUILDING (106' X 50')
2. EASTGATE MALL PIPE GALLERY AND TUNNEL
3. ELECTRICAL SUBSTATION 700USS (15' X 35')
4. MF BUILDING (160' X 130')
5. RO BUILDING (180' X 110')
6. CHEMICAL STORAGE AREA (135' X 30')
7. POST-TREATMENT CHEMICAL STORAGE AREA (140' X 30')
8. MF BREAK TANK, CARTRIDGE FILTERS, AND BOOSTER PUMPS (65' X 65')
9. UV FACILITY (80' X 60')
10. PURIFIED WATER PUMP STATION (55' X 47')
11. SURGE TANK (25' X 25')
12. ELECTRICAL SUBSTATION 680USS (15' X 35')
13. ELECTRICAL SUBSTATION 690USS (15' X 35')
14. FUTURE DEGASSIFIER (75' X 30')
15. FUTURE TESTING AREA (50' X 100')

NOTE

1. DUCTBANK FROM NCWRP TO AWPF TO SUPPLY COGENERATION POWER TO THE FULL-SCALE AWPF. COGENERATION POWER WILL PROVIDE BACKUP POWER FOR RO FLUSH PUMPS AND CONTROL SYSTEM IN THE EVENT OF AN SDG&E POWER OUTTAGE.

N

1" = 50'

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CITY OF SAN DIEGO INDIRECT POTABLE REUSE/RESERVOIR AUGMENTATION DEMONSTRATION PROJECT

FULL-SCALE FACILITY SITE PLAN (JANUARY 2013)

FIGURE 4-4

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4.2 Process Descriptions and Preliminary Design Criteria

Preliminary design criteria for each process area are described herein and are summarized in Figures 4-5 and 4-6.

4.2.1 AWP Facility Influent Pump Station

The influent pump station to pump tertiary effluent prior to chlorination to the membrane filtration facility will be located on the North City site west of the tertiary filters. Figure 4-7 shows a preliminary layout for the influent pump station. A total of four multi-stage vertical turbine pumps (three duty and one standby) will be used to supply influent water to the Full-Scale Facility. The wet well will receive tertiary effluent from the existing tertiary filtered water line. A slide gate and/or valves will be installed in the existing tertiary filtered water line to allow flow to be directed to the pump station. The water surface elevation within the wet well will "float" with the water surface elevation in the tertiary filtered water line maintaining the same water surface elevations. As recommended in Section 3.1.1, the pumps will be equipped with variable frequency drives to supply tertiary influent at varying flow conditions. The tertiary effluent will be pumped through a pipeline that will be installed in the tunnel under Eastgate Mall Road to the Full-Scale Facility.

4.2.2 Membrane Filtration

The membrane filtration system provides pretreatment for the RO system to reduce the particulate and biological fouling of the RO membranes. The membrane filtration system will effectively remove inert particulates, organic particulates, colloidal particulates, pathogenic organisms, bacteria and other particles by the size-exclusion sieve action of the membranes. As described in the Demonstration Project Report, membrane filtration could provide 4-log reduction of *Cryptosporidium* and *Giarda* towards the overall reduction goals (see the Demonstration Project Report for more information on the overall log reduction goals for the potential full-scale IPR/RA project; note that the concentrations of *Cryptosporidium* and *Giarda* were not high enough in the tertiary effluent prior to chlorination and membrane filtration filtrate to demonstrate these log reductions at the Demonstration Facility). These log removal credits will be approved by CDPH provided that approved membranes and required integrity monitoring are used (e.g., daily pressure decay tests and online turbidimeters). Table 4-1 presents the membrane filtration water quality goals.

Table 4-1 Membrane Filtration Water Quality Goals

Constituent	Design Criteria
Cryptosporidium	Undetectable[1]
Giardia	Undetectable[2]
Suspended Solids	Undetectable[3]
95th Percentile Filtrate Turbidity	<0.1 NTU
Filtrate Silt Density Index (SDI)	<3

Notes:

1) EPA Method 1623. Method detection limit for Cryptosporidium is 1 Oocysts/100L, so the membrane filtration water quality goal is zero Oocysts/100L.
2) EPA Method 1623. Method detection limit for Giardia is 1 Cysts/100L, so the membrane filtration water quality goal is zero Cysts/100L.
3) EPA Method 160.2. Method detection limit is 1.0 mg/L, so the goal is to be <1.0 mg/L.

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Advanced Water Purification Facility Design Criteria

Design Product Water	18.0	mgd
AWP Facility Influent Flows		
Design Flow	22.8	mgd
Minimum Flow	14.8	mgd
1-RO Train	5.7	mgd

AWP Facility Influent Pump Station		
Design Flow	22.8	mgd
Minimum Flow	14.8	mgd
1-RO Train	5.7	mgd
Pump Type	Vertical Turbine/Submersible	
No. of Duty Pumps	3	units
No. of Standby Pumps	1	units
Design Flow per Pump	5,857	gpm
Minimum Pressure	50	psi
Variable Frequency Drive (VFD)	Yes	

MF System		
Minimum Recovery	93%	
MF Permeate Flow, Design	21.2	mgd
MF Permeate Flow, Minimum	13.8	mgd
MF Permeate Flow, 1-RO Train	5.3	mgd
MF Strainer		
Type	Auto-Backwash Strainer	
No. of Duty Units	4	units
No. of Standby Units	1	units
Screen Pore Size, Minimum	300	microns
Strainer Recovery, Minimum	100%	
Clean Strainer Headloss, Maximum	1.0	psi
Dirty Strainer Headloss, Maximum	10	psi
Strainer Size	18	inch
Flow per Strainer	5,000	gpm/unit
Configuration		
No. of Duty Skids	12	skids
No. of Standby Skids	2	
Redundancy	N + 2	
Capacity per Skid	1.90	mgd/skid
MF Recovery, Minimum	93%	
Instantaneous Flux, Maximum	35	gfd
Average Flux, Maximum	33	gfd
Total Membrane Area Required	699,551	sf
Total No. of Membrane Modules Required	1,300	modules
No. of Membrane Modules per Skid	116	modules/skid
Membrane Area per Skid	62,408	sf/skid
No. of Backwashes per skid	48	per day
Backwash time	90	seconds
Backwash Interval	25 to 30	minutes
MF Backwash Waste Flow, Design	1.6	mgd
MF Backwash Waste Flow, Design [1]	2,000	gpm
MF Backwash Waste Flow, Minimum	1.0	mgd
MF Backwash Waste Flow, Minimum	1,250	gpm
MF Backwash Waste Flow, 1-RO Train	0.4	mgd
MF Backwash Waste Flow, 1-RO Train	307	gpm
Maintenance Wash Interval, Minimum	1	week
CIP Interval, Minimum	30	days
Typical CIP Duration, Each Skid, Each Clean	4-6 hours	
Air Compressor	Provided by Vendor	

[1] Flow is based on actual flow per minute for a backwash. Differs from daily flow.

Design Product Water	18.0	mgd
MF CIP Pumps	Provided by vendor	
No. of Duty Pumps	1	units
No. of Standby Pumps	1	units
Citric Acid Day Tank		
No. of Duty Tanks	1	units
Days of Storage	14	days
Total Storage Volume Required	580	gal
CIP Citric Acid Transfer Pumps		
No. of Duty Pumps	1	units
No. of Standby Pumps	1	units
Pump Type	Diaphragm Metering	
CIP Sodium Hydroxide Transfer Pumps		
No. of Duty Pumps	1	units
No. of Standby Pumps	1	units
Pump Type	Diaphragm Metering	
CIP Sodium Hypochlorite Transfer Pumps		
No. of Duty Pumps	1	units
No. of Standby Pumps	1	units
Pump Type	Diaphragm Metering	

Membrane Filtration Break Tank		
No. of Duty Tanks	2	units
No. of Standby Tanks	-	units
Residence Time, Minimum	25	min
Volume Required, Total	368,000	gal

RO Transfer Pump Station		
Design Flow	21.2	mgd
Minimum Flow	13.8	mgd
1-RO Train	5.3	mgd
Pump Type	Vertical Turbine	
No. of Duty Pumps	4	units
No. of Standby Pumps	1	units
Design Flow per Pump	4,085	gpm
Minimum Pressure	50	psi

Cartridge Filters		
Design Flow	21.2	mgd
Minimum Flow	13.8	mgd
No. of Units	7	units
No. of Standby Units	1	units
Pore Size, Minimum	5	microns
Filter Material	Polypropylene	
Filtration Rate	3	gpm/10 inch
Filtration Rate	12	gpm/40 inch
Filters per Vessel	176	
Capacity per Filter	2,112	gpm
Capacity per Filter	3.04	mgd

RO Feed Pump Station		
Design Flow	21.2	mgd
Minimum Flow	13.8	mgd
1-RO Train	5.3	mgd
Pump Type	Vertical Turbine	

Design Product Water	18.0	mgd
RO Feed Pump Station (con't)		
No. of Duty Pumps	4	units
No. of Standby Pumps	1	units
Design Flow per Pump	4,085	gpm
Target Pressure	290	psi
Variable Frequency Drive (VFD)	Yes	

RO System		
Recovery	85%	
Feed Design Flow	21.2	mgd
Feed Minimum Flow	13.8	mgd
Feed 1-RO Train	5.3	mgd
Permeate Flow, Design	18.0	mgd
Permeate Flow, Minimum	11.7	mgd
Permeate Flow, 1-RO Train	4.5	mgd
Concentrate Flow, Design	3.2	mgd
Concentrate Flow, Minimum	2.1	mgd
Concentrate Flow, 1-RO Train	0.8	mgd
Material	Composite Polyamide	
Configuration	Spiral Wound	
Type	High Rejection, Low Fouling	
Element Size	8	inch diameter
Membrane Area per Element	400	sf
No. of Duty RO Trains	4	
No. of Standby RO Trains	1	
Capacity per Train	4.5	mgd
No. of Elements per Vessel	7	
No. of Stages	2	

Energy Recovery		
No. Energy Recovery Devices	5	units
Energy Recovery Boost	20	psi

RO Flush Tank		
No. of Duty Tanks	2	units
No. of Standby Tanks	-	units
Total Storage Volume Required	19,790	gal

RO Flush Pumps		
Pump Type	Horizontal Centrifugal	
No. of Duty Pumps	2	units
No. of Standby Pumps	1	units
Flush Time per Train	3	min
Total Flush Time	8	min
Design Flow per Pump	1,097	gpm

CIP System		
CIP Tanks		
No. of Duty Tanks	1	units
No. of Standby Tanks	1	units
No. of Tank Immersion Heaters	2	units
Heating Frequency/Duration	30 hours/6-months	
Heater Power Requirements	200	kW
Flush Volume per Train	3,290	gal
Tank Volume, Each (+25%)	4,100	gal

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Design Product Water	18.0	mgd
RO CIP Pumps		
Pump Type	Horizontal Centrifugal ANSI	
No. of Duty Pumps	2	units
No. of Standby Pumps	1	units
Recirculation Time	5	min
Design Flow per Pump	658	gpm
Minimum Pressure	60	psi
Citric Acid Day Tank		
No. of Duty Tanks	1	units
No. of Standby Tanks	0	units
Total Storage Volume Required	500	gal
CIP Citric Acid Pumps		
No. of Duty Pumps	1	units
No. of Standby Pumps	1	units
Pump Type	Diaphragm Metering	
Sodium Hydroxide Day Tank		
No. of Duty Tanks	1	units
No. of Standby Tanks	0	units
Total Storage Volume Required	500	gal
CIP Sodium Hydroxide Transfer Pump		
No. of Duty Pumps	1	units
No. of Standby Pumps	1	units
Design Flow per Pump	10	gpm
Minimum Target Pressure	20	psi
Variable Frequency Drive (VFD)	No	
Sodium Hydroxide Feed Pump		
No. of Duty Pumps	1	units
No. of Standby Pumps	1	units
Pump Type	Diaphragm Metering	

UV Disinfection and Advanced Oxidation		
Criteria (see Note 2)	0.5 log 1,4 dioxane removal	
Type of UV System	Low-Pressure High-Output (LPHO)	
Flow Capacity	6	mgd/train
Power Draw	18.5	kW/single reactor
Maximum Power Draw	333	kW
No. of Duty Trains	3	units
No. of Standby Trains	0	units
No. of Chambers per Train	3	units
No. of Reactors per Chamber	2	units
No. of Lamps per Reactor	72	units
Total No. of Lamps	1,296	units
Hydrogen Peroxide		
Concentration	50%	
Dose, Design	5.0	mg/L
Dose, Minimum	2.0	mg/L
No. of Duty Tanks	2	units
No. of Standby Tanks	0	units
Days of Storage	30	days
Total Storage Volume Required	4500	gal
No. of Duty Pumps	4	units
No. of Standby Pumps	1	units
Pump Capacity, Each	1.94	gph
Pump Type	Diaphragm Metering	

Design Product Water	18.0	mgd
Ammonium Hydroxide		
Concentration	19%	
Dose, Design	1.5	mg/L
Dose, Minimum	0.8	mg/L
No. of Duty Tanks	2	units
Days of Storage	30	days
Total Storage Volume Required	5,900	gal
No. of Duty Pumps	3	units
No. of Standby Pumps	1	units
Pump Capacity, Each	3.3	gph
Pump Type	Diaphragm Metering	

Sodium Hypochlorite		
Concentration	12.5%	
Dose, Design	5.0	mg/L
Dose, Minimum	3.0	mg/L
No. of Duty Tanks	2	units
Days of Storage	14	days
Total Storage Volume Required	10,720	gal
No. of Duty Pumps	3	units
No. of Standby Pumps	1	units
Pump Capacity, Each	13.0	gph
Pump Type	Diaphragm Metering	

Antiscalant		
Concentration	100%	
Dose, Design	4.0	mg/L
Dose, Minimum	2.0	mg/L
No. of Duty Tanks	2	units
Days of Storage	30	days
Total Storage Volume Required	2,100	gal
No. of Duty Pumps	3	units
No. of Standby Pumps	1	units
Pump Capacity, Each	1.2	gph
Pump Type	Diaphragm Metering	

Sulfuric Acid		
Concentration	93%	
Dose, Design	60.0	mg/L
Dose, Minimum	20.0	mg/L
No. of Duty Tanks	3	units
Days of Storage	30	days
Total Storage Volume Required	22,300	gal
No. of Duty Pumps	3	units
No. of Standby Pumps	1	units
Pump Capacity, Each	12.7	gph
Pump Type	Diaphragm Metering	

Sodium Bisulfite		
Concentration	38%	
No. of Duty Tanks	Drum	units
Days of Storage	N/A	days
Total Storage Volume Required	55	gal
No. of Duty Pumps	1	units
No. of Standby Pumps	1	units
Pump Capacity, Each	6.5	gph
Pump Type	Diaphragm Metering	

Design Product Water	18.0	mgd
Post Treatment		
LSI	-1.0 to 1.0	
pH	6.5 - 9.0	
Calcium Chloride		
Concentration	34.7%	
Dose, Design	20.0	mg/L
Dose, Minimum	10.0	mg/L
No. of Duty Tanks	3.3	units
Days of Storage	30	days
Total Storage Volume Required	23,100	gal
No. of Duty Pumps	2	units
No. of Standby Pumps	1	units
Pump Capacity, Each	13.2	gph
Pump Type	Diaphragm Metering	
Sodium Hydroxide		
Concentration	50.0%	
Dose, Design	15.0	mg/L
Dose, Minimum	5.0	mg/L
No. of Duty Tanks	3	units
Days of Storage	30	days
Total Storage Volume Required	10,840	gal
No. of Duty Pumps	2	units
No. of Standby Pumps	1	units
Pump Capacity, Each	6.1	gph
Pump Type	Diaphragm Metering	

Design Product Water	18	mgd
Purified Water Pump Station (See Note 1)		
Design Flow	18	mgd
Minimum Flow	3.5	mgd
Pump Type	Vertical Turbine	
No. of Duty Pumps	3	units
No. of Standby Pumps	1	units
Design Flow per Pump	4,200	gpm
Head At Design Flow (C=120)	651	feet
Pump Speed	1770	RPM
Motor HP	900	HP
Drive Type	Variable Speed	

NOTE:

1. SEE THE PURIFIED WATER CONVEYANCE SYSTEM FINAL CONCPETUAL DESIGN REPORT FOR MORE INFORMATION ON THE PURIFIED WATER PUMP STATION AND THE PIPELINE TO SAN VICENTE RESERVOIR.
2. THE UV DISINFECTION AND ADVANCED OXIDATION SYSTEM SIZING WILL ALSO BE BASED ON FINAL CTR REQUIREMENTS (ONCE THEY ARE DEFINED). SEE SECTION 4.2.4 FOR MORE INFORMATION.

CITY OF SAN DIEGO INDIRECT POTABLE REUSE/RESERVOIR AUGMENTATION DEMONSTRATION PROJECT

FULL-SCALE FACILITY DESIGN CRITERIA II (JANUARY 2013)

FIGURE 4-6

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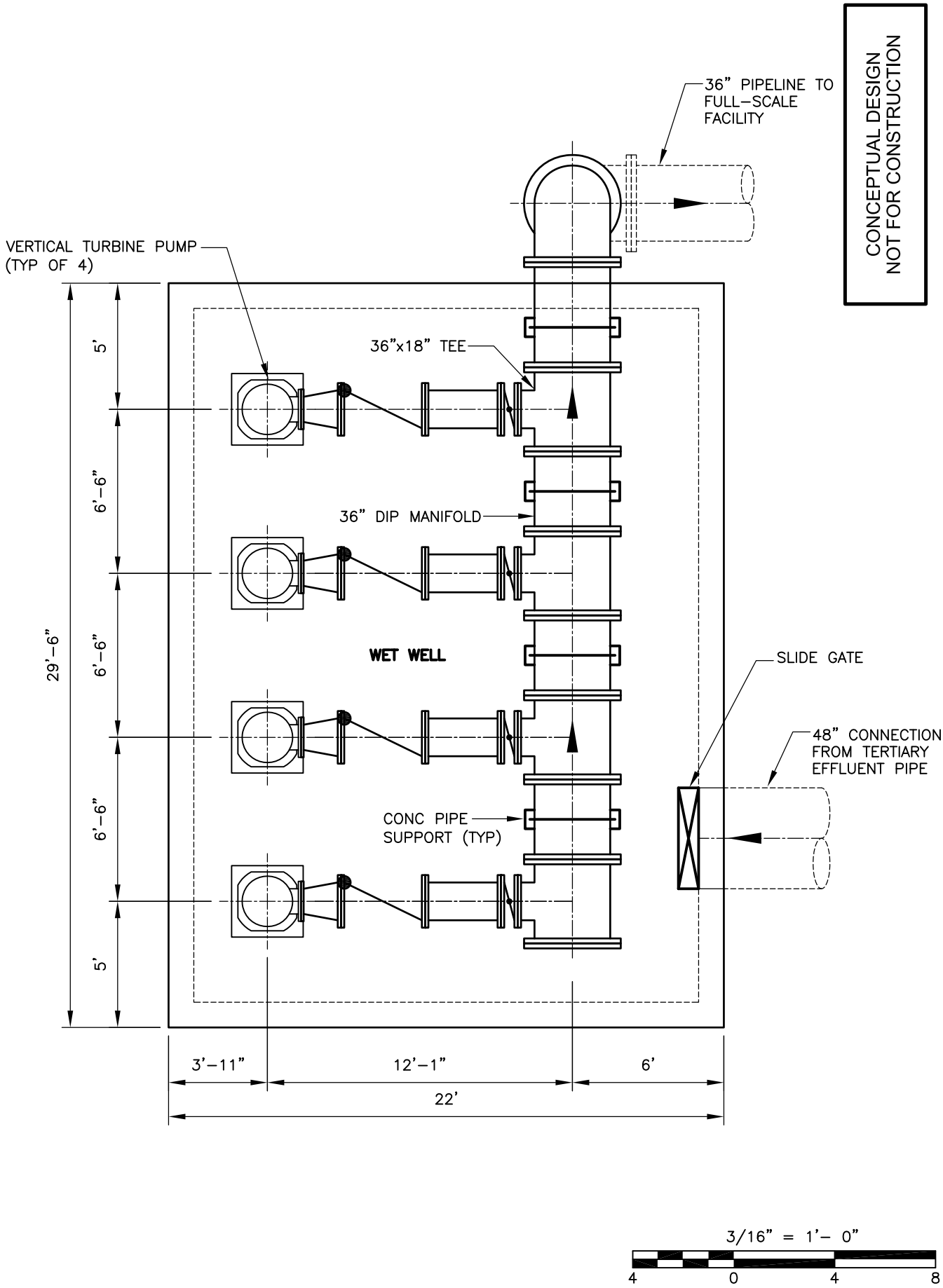

CITY OF SAN DIEGO INDIRECT POTABLE REUSE/RESERVOIR
AUGMENTATION DEMONSTRATION PROJECT
FULL-SCALE FACILITY INFLUENT PUMP STATION LAYOUT (JANUARY 2013)
FIGURE 4-7

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Pre-Treatment Chemical Addition

Ammonium hydroxide and sodium hypochlorite will be added downstream of the membrane feed pumps and upstream of the membrane filtration pre-filters for chloramination to control the biological fouling of the membrane filtration membranes. The target combined chlorine concentration (chloramines) is 3 to 5 mg/L, which is used at the Demonstration Facility. The chemicals will be flow paced based on the membrane filtration feed flow rate and trimmed based on the combined chlorine concentration.

Membrane Filtration Pre-Filters

The membrane filtration pre-filters or strainers will be provided immediately upstream of the membrane filtration membranes to protect the membrane filtration membranes from damage and/or fouling due to larger particles. Pre-filters are typically provided by the membrane manufacturers as part of a complete membrane filtration system package and are required by the membrane filtration system warranty.

Membrane Filtration Systems

Two types of membrane filtration systems were tested at the Demonstration Facility: a Pall MF system and a Toray UF system. As discussed in Section 2, both the MF and UF achieved the membrane filtration water quality goals described above in Table 4-1; therefore, either system could be considered for the Full-Scale Facility. The preliminary design criteria, layouts, and cost estimates are presented herein are based on the Pall MF system since Pall meets the minimum recommended qualifications, is more conservative from a space requirement, and has lower capital and O&M costs.

Figure 4-8 shows the membrane filtration system layout based on the Pall MF system. The layout is based on the 35 gfd instantaneous flux rate (33 gfd average flux rate at 93 percent MF recovery) that has been demonstrated. However, the good membrane performance and long cleaning cycles imply that a higher flux rate may be achievable. The membrane filtration footprint could be reduced if a higher flux rate is utilized. After the vendor prequalification and equipment pre-selection, the size of the membrane filtration building will need to be adjusted to accommodate the pre-selected membrane filtration system vendor.

See Sections 3.1.1 and 3.2.1 for energy conservation and other design considerations, respectively, for the membrane filtration systems.

Membrane Filtration Break Tank

The membrane filtration break tank will serve as a flow equalization reservoir for the membrane filtration filtrate prior to being pumped to the RO system. The membrane filtration filtrate will be conveyed to the membrane filtration break tank with residual pressure from the membrane filtration system. The membrane filtration break tank will mitigate the impact of the variations in the membrane filtration filtrate flow (resulting from backwashes, cleanings, and integrity tests) by providing equalization volume equivalent to approximately 25 minutes of the maximum RO feed flow between the membrane filtration and RO processes. The membrane filtration filtrate flow varies due to the membrane filtration backwashes (occur every 25 to 30 minutes for each unit), daily maintenance cleans, and daily membrane integrity tests.

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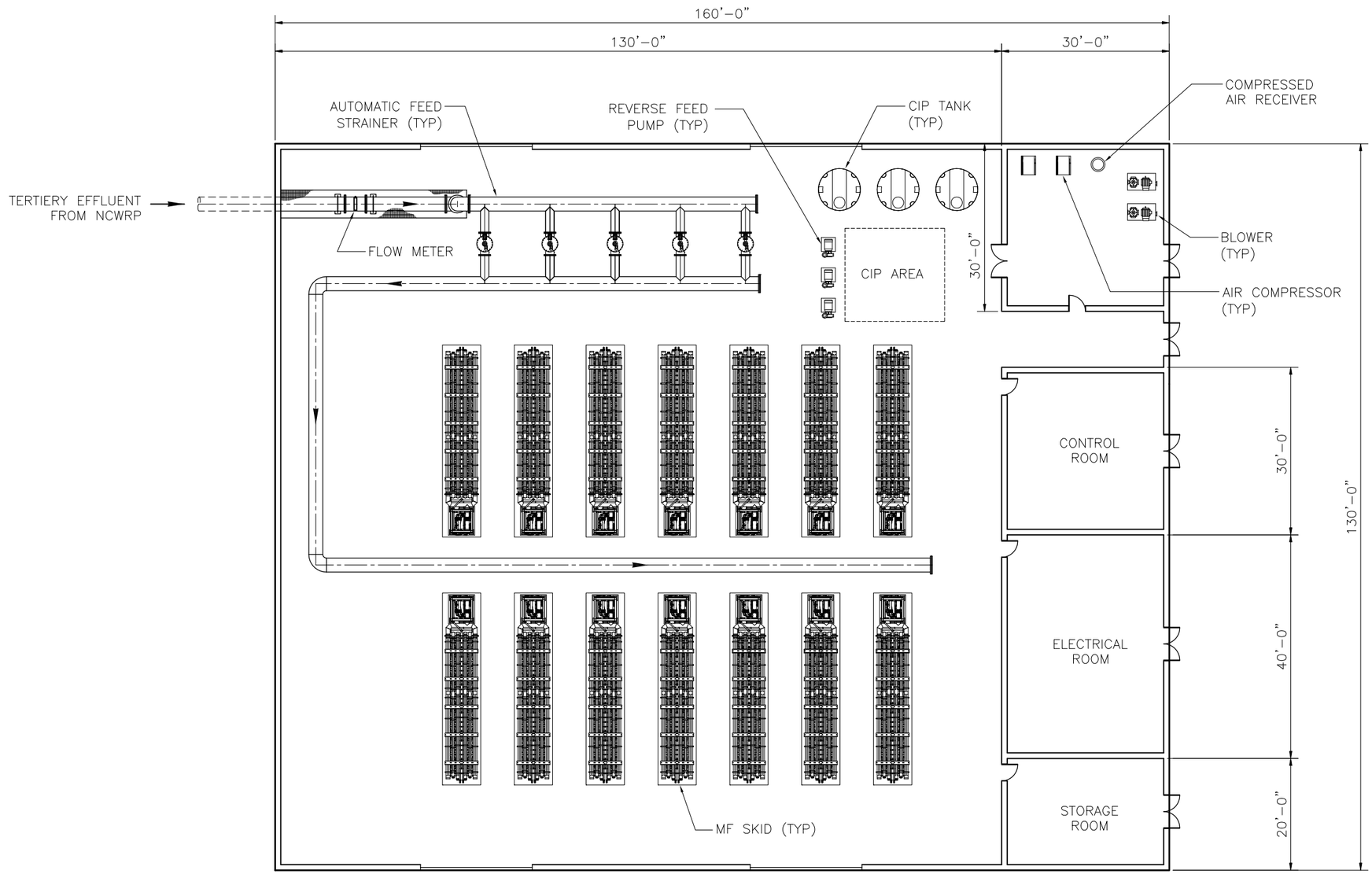

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CITY OF SAN DIEGO INDIRECT POTABLE REUSE/RESERVOIR AUGMENTATION DEMONSTRATION PROJECT

FULL-SCALE FACILITY MF SYSTEM LAYOUT (JANUARY 2013)

FIGURE 4-8

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4.2.3 Reverse Osmosis

While RO is traditionally used for purification and desalination in water treatment, it also has a long history of being effectively utilized in wastewater treatment processes for removal of a wide array of dissolved constituents. RO has also proven to be effective at removing dissolved organic material, including regulated synthetic organic compounds, volatile organic compounds (VOCs), and unregulated CECs, such as pharmaceutical compounds, personal care products, pesticides, herbicides, and other industrial products. RO is recognized as the best available technology for reducing TDS and most trace organic constituents in wastewater effluent intended for groundwater replenishment and as tested here for reservoir augmentation.

RO is expected to receive 2-log (99 percent) removal credit from CDPH for viruses, *Giardia*, and *Cryptosporidium* towards the overall log reduction goals for the potential full-scale IPR/RA project (see the Demonstration Project Report for more information on the overall log reduction goals for the potential full-scale IPR/RA project). These log removal credits will be approved by CDPH provided online monitoring can verify a minimum 2-log reduction in some type of surrogate monitoring parameter, such as conductivity, UV254, or TOC. To date, CDPH has permitted one facility granting such credits to an RO system, a seawater desalination facility using conductivity as the surrogate (Sand City, California). Monitoring results from the Demonstration Facility did not show a consistent 2-log reduction in conductivity, but did show greater than 2-log reduction in TOC, providing an opportunity to use TOC monitoring as the surrogate parameter.

It should be noted that somatic and male specific coliphage (viruses) measured during the Demonstration Facility operation were generally below detectable levels in the RO feed water, making it impossible to measure a removal across the RO membranes without spiking the water with additional viruses (which was not done as part of the AWP Facility Study). Removal of numerous organic and inorganic compounds (including CECs) were observed, as discussed in Section 2.

The RO facility includes the following processes:

- RO transfer pumps
- RO pre-treatment chemical addition (antiscalant and sulfuric acid for scale control)
- Cartridge filters
- RO feed pumps
- RO system

The RO transfer pumps will pump membrane filtration filtrate from the membrane filtration break tank through the RO cartridge filters to the RO feed pumps.

The cartridge filters, located upstream of the RO, help protect the RO membranes from particulates that may be introduced in the membrane filtration break tank or through chemical addition. Note that cartridge filters were not used at the Demonstration Facility because of the controlled environment upstream of the RO system (closed plastic membrane filtration break tank and no acid feed), which eliminated the introduction of particulates upstream of RO. At the Demonstration Facility, the membrane filtration break tank was also painted black and located under the Demonstration Facility canopy to control algae growth.

Antiscalant will be added to control scaling of the RO membranes. Antiscalant will be fed upstream of the RO cartridge filters.

Although the Demonstration Facility has operated successfully without the addition of sulfuric acid or any other type of acid, many full-scale AWP Facilities use sulfuric acid to lower the pH of the RO feed water to control scale from the sparingly soluble salts, such as calcium carbonate, calcium phosphate, and magnesium hydroxide. While concentrations of these constituents were not high enough to require acid during operation of the Demonstration Facility, the historic water quality data suggest that acid could be required at some point in the future. The preliminary layouts and cost estimates are based on adding sulfuric acid upstream of the RO cartridge filters.

Each RO train will be paired with a dedicated feed pump. Note that these pumps are required in addition to the RO transfer pumps as the pressure needed to feed RO is greater than the rated pressure of most cartridge filter vessels. Design alternatives are available for avoiding these transfer pumps, such as using high pressure cartridge filters or directly coupling the membrane filtration process with the RO; however, use of these measures are not common and a conservative, more traditional approach has been assumed for planning purposes.

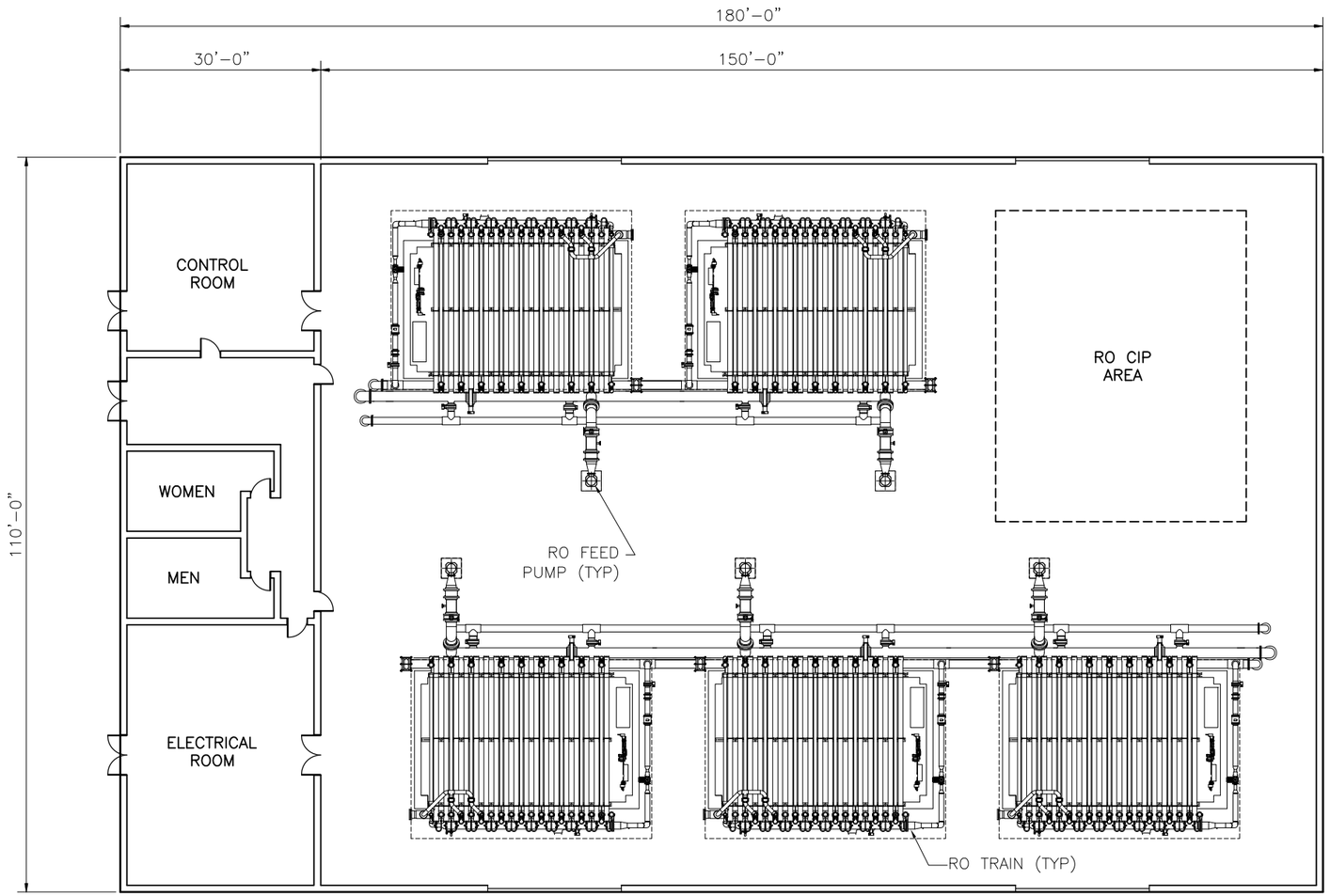
The required RO feed pump pressure is a function of the incoming pressure from the RO transfer pumps, the headloss in the cartridge filters upstream and the associated piping, and the required feed pressure into the RO system. The required discharge pressure for the RO feed pumps will vary as the RO operating pressure changes due to water quality changes and RO membrane fouling. Therefore, variable frequency drives will be used for the RO feed pumps to adjust to varying pressure requirements. The rated design point for the pumps will be selected from within this range such that the pumps will operate near best efficiency for the most common operating conditions.

As discussed in Section 3.1.2, the RO System is recommended to have a two-stage membrane configuration with energy recovery devices, which is the basis for the preliminary layout, design criteria, and cost estimate. Additional design considerations for the RO system are discussed in Section 3.2.2.

The RO trains are assumed to have 8-inch elements (see Figure 4-5), which are the most common size in the IPR and desalination industries to date. Sixteen-inch elements are available as an alternative and are being used at one facility in Scottsdale, Arizona; however, a more traditional and conservative design using 8-inch elements was assumed for planning purposes. The final RO skid requirements, including vessel size, should be determined during detailed design.

The preliminary layout, design criteria, and cost estimate are also based on a flux rate of 12 gfd, consistent with how the Demonstration Facility was operated for the first two quarters. The preliminary layout for the RO system is shown on Figure 4-9.

CONCEPTUAL DESIGN
NOT FOR CONSTRUCTION



PLAN
3/32"1-=0"

3/32" = 1'- 0"
8 0 8 16

CITY OF SAN DIEGO INDIRECT POTABLE REUSE/RESERVOIR AUGMENTATION DEMONSTRATION PROJECT

FULL-SCALE FACILITY RO SYSTEM LAYOUT (JANUARY 2013)

FIGURE 4-9

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4.2.4 UV Disinfection and Advanced Oxidation

The final water purification process is disinfection and advanced oxidation, which is required per the November 2011 CDPH Groundwater Recharge Reuse Draft Regulations for full advanced treatment. A disinfection process is needed so the Full-Scale Facility and IPR/RA process meet the pathogenic microorganism control requirements included in the regulations. Based on the Demonstration Project Report, UV must provide a 6-log reduction of viruses, *Cryptosporidium,* and *Giarda* towards the overall reduction goals (see the Demonstration Project Report for more information on the overall log reduction goals for the potential full-scale IPR/RA project). Note that no viruses, bacteria, or protozoa were found at any time in the RO permeate/UV system feed at the Demonstration Facility, making it impossible to directly measure pathogen removal without spiking them into the water. Removal credits must be based on challenge testing and the associated credits granted by CDPH.

Advanced oxidation is considered the best available technology to destroy CECs that pass through RO membranes due to their low molecular weight and low ionic charge, notably NDMA and flame retardants. To date, the only advanced oxidation process that has been permitted at full-scale AWP facilities in California is UV/H_2O_2. UV/H_2O_2 destroys microconstituents through two simultaneous mechanisms:

- The first mechanism is through UV photolysis (exposure to UV light) where UV photons are able to break the bonds of certain chemicals if the bond's energy is less than the photon energy.
- The second mechanism is through UV light reacting with H_2O_2 to generate hydroxyl radicals. The H_2O_2 is added to the RO permeate upstream of the UV process at a dose ranging between 1.0 to 5.0 mg/L.

As with the Demonstration Facility, the conceptual design for the Full-Scale Facility includes UV reactors for the dual purpose of disinfection and advanced oxidation. Table 4-2 provides a summary of the driving factors for UV system design for disinfection.

Table 4-2 UV Disinfection Design Considerations

Function/Constituent	Log Reduction	UV Dose
Enteric virus	6-log [1]	286 mJ/cm^2 [2]
Cryptosporidium oocyst	6-log [1]	27.8 mJ/cm^2 [4]
Giardia cyst	6-log [1]	27.2 mJ/cm^2 [3]

Notes:

1) See Demonstration Project Report. Note that the concentrations of MS2 coliphage (a surrogate for enteric viruses), Giardia, and Cryptosporidium were not high enough in the RO permeate and purified water to demonstrate these log reductions at the Demonstration Facility.
2) Per EPA UV Guidance Manual (November 2006), a 4-log virus removal requires 186 mJ/cm^2. An additional 2-log removal requires another 100 mJ/cm^2. Therefore, a minimum UV dose for 6-log virus removal is estimated to be 286 mJ/cm^2.
3) Per EPA UV Guidance Manual (November 2006), a 4-log Cryptosporidium removal requires 22 mJ/cm^2. An additional 2-log removal requires another 5.8 mJ/cm^2. Therefore, a minimum UV dose for 6-log Cryptosporidium removal is estimated to be 27.8 mJ/cm^2.
4) Per EPA UV Guidance Manual (November 2006), a 4-log Giardia removal requires 22 mJ/cm^2. An additional 2-log removal requires another 5.2 mJ/cm^2. Therefore, a minimum UV dose for 6-log Giardia removal is estimated to be 27.2 mJ/cm^2.

Acronym:

mJ/cm^2 – millijoules per square centimeter

The UV/H_2O_2 system will also be designed to meet the draft groundwater recharge regulations requirements for advanced oxidation, i.e., the advanced oxidation system shall provide at least a level of treatment equivalent to a 0.5-log 1,4-dioxane reduction or a 0.3 to 0.5-log removal of an approved indicator compound. It is generally accepted that an equivalent UV dose for NDMA and 1,4-dioxane removal is higher than the UV dose needed for disinfection, e.g., the required UV dose for 1-log reduction of NDMA could be in the range of 500 to 1,000 millijoules per square centimeter (mJ/cm^2), Hence, the sizing of the UV system will be governed by the UV dose required for advanced oxidation.

Testing at the Demonstration Facility indicated that NDMA concentrations in the purified water were below the CDPH notification limit of 10 ng/L. The Full-Scale Facility will also need to meet an NDMA requirement per the CTR, which was not fully defined at the time this report was written. Therefore, the UV sizing requirements need to take into account both the CDPH notification level and the final NDMA requirements per the CTR once those requirements have been fully established for adding the water to the San Vicente Reservoir.

The preliminary layout for the UV system is shown on Figure 4-10.

4.2.5 Post-Treatment/Stabilization

The product water from the Full-Scale Facility will be pumped to the San Vicente Reservoir approximately 23 miles east of the Full-Scale Facility. Product water quality must minimize corrosion of the purified water pipeline and the pumping equipment (Langelier Saturation Index [LSI]). Table 4-3 summarizes the stabilization goals for the purified water.

Table 4-3 Purified Water Post-Treatment/Stabilization Goals

Constituent	Design Criteria
pH	6.5 – 9.0
Hardness	>20 mg/L as $CaCO_3$
LSI	-1.0 to 1.0

The post-treatment strategy assumed for the preliminary layouts and cost estimate for the Full-Scale Facility includes the addition of calcium chloride to increase hardness and the addition of caustic soda to increase pH. This strategy allows operators to control hardness and pH independently, producing stable purified water that can be matched to any desired combination of pH, hardness, and alkalinity.

While not shown on Figure 4-4, degassifiers may be considered for the Full-Scale Facility. This issue needs to be evaluated when the CTR requirements are defined and as the City moves towards preliminary design and permitting for the Full-Scale Facility. As part of the CTR there will be a limit for bromodichloromethane (BCDM) for the Full-Scale Facility, which has not been established yet. Depending on the BDCM limits, degassifiers may be needed to decrease the BDCM concentration.

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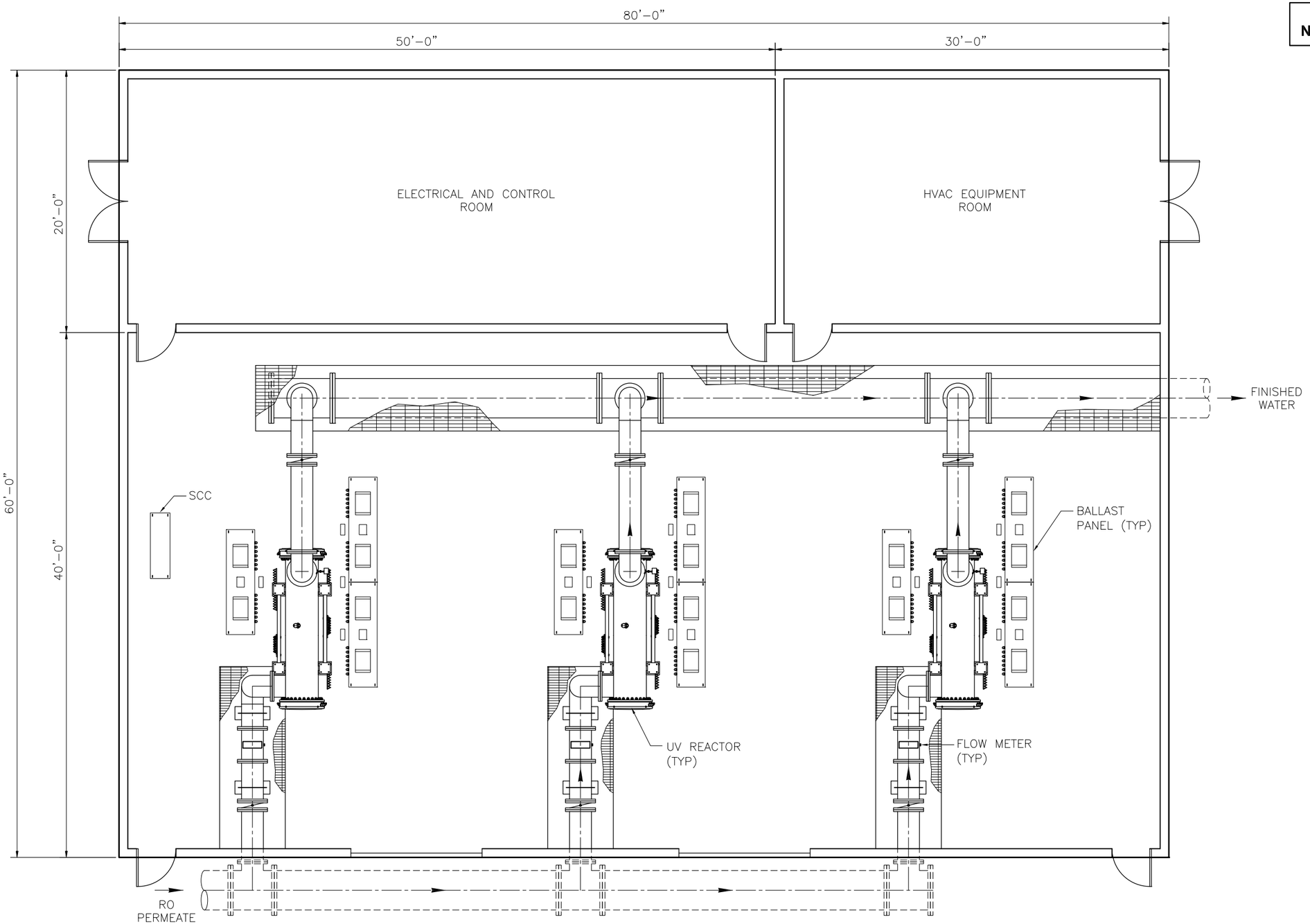

PLAN

1/4"=1'-0"

1/4" = 1'- 0"

2 1 0 2 4

CITY OF SAN DIEGO INDIRECT POTABLE REUSE/RESERVOIR AUGMENTATION DEMONSTRATION PROJECT

FULL-SCALE FACILITY UV DISINFECTION AND ADVANCED OXIDATION SYSTEM LAYOUT (JANUARY 2013)

FIGURE 4-10

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4.2.6 Chemical Cleaning Systems

Citric acid will be used to clean the membrane filtration and RO membranes. The cleaning requirements are specific to each membrane system vendor, so the citric acid system design would be completed after the membrane filtration equipment pre-selection. Caustic soda will be used intermittently for the neutralization of the membrane filtration chemical cleaning waste, the RO chemical cleaning and waste neutralization. A preliminary list of chemical cleaning system equipment requirements is included in Figure 4-6. It was assumed that electrical power will be used to heat the chemical cleaning solutions. Use of waste heat from the North City cogeneration facility to heat chemical tanks during cleanings should be investigated prior to final design.

4.2.7 Waste Streams

The waste streams of the Full-Scale Facility include membrane filtration prefilters backwash flows, membrane filtration backwash waste, RO concentrate, spent chemical cleaning solutions, and sanitary waste (i.e., restrooms). It is assumed that the membrane filtration backwash will be routed to the influent of the North City secondary clarifiers for treatment and the RO concentrate, neutralized CIP solutions, and sanitary waste streams will be discharged to North City's effluent drop structure for ultimate treatment at the Point Loma Wastewater Treatment Plant (Point Loma). Alternatively, sanitary waste streams could be discharged into the existing 10-inch sewer in Eastgate Mall for treatment at North City. The waste streams are summarized in Table 4-4.

Table 4-4 Full-Scale Facility Waste Stream Flows

Flows	Frequency	Percent of Feed Flows	TDS (mg/L)
Membrane Filtration Pre-filters Backwash Flows	Intermittent	2% of Full-Scale Facility Influent Flow	Average 1,000 Maximum 1,100
Membrane Filtration Backwash Waste Flows	Intermittent	5% of Full-Scale Facility Influent Flow	Average 1,000 Maximum 1,100
RO Concentrate Flows	Continuous	15% of RO Feed Flow	Average 6,500 Maximum 7,200

Note: Chemical cleaning waste is intermittent. Volumes will be confirmed during the preliminary design phase.

4.2.8 Operations, Maintenance, and Administration Building

The Operations, Maintenance, and Administration Building will be located on the southern part of the site and is assumed to have a total building square footage of 5,300 square feet, based on 12 full-time employees. It is also assumed that all laboratory functions will be conducted at North City; thus, laboratory space will not be provided at the Full-Scale Facility. Table 4-5 summarizes the spatial planning assumed for this building.

Table 4-5 Operations, Maintenance, and Administration Building Spatial Planning

Space Designation	Area, square feet
Lobby/Reception	450
Offices/Cubicles	1,500
Break Room/Kitchenette	240
Conference Room	340
Control Room	600
Restrooms/Lockers/Showers	440
Mechanical/Electrical	240
Maintenance Shop/Storage	1,000
Circulation	490
Total	**5,300**

4.2.9 Preliminary Electrical Design Criteria

Full-Scale Facility (Except for the AWP Facility Influent Pump Station)

Power will be supplied to the Full-Scale Facility from San Diego Gas & Electric's (SDG&E) Eastgate Mall Substation, which is located north of the proposed Full-Scale Facility site location. The Eastgate Mall Substation will feed an assumed power supply of 12 kilovolts (KV) to the Full-Scale Facility Main Switchgear, which would then feed six transformers. The expected power requirement for the Full-Scale Facility is around 6,500 kilovolt-amperes (KVA) demand load as summarized in the Full-Scale Facility preliminary load list presented in Table 4-6.

Table 4-6 Full-Scale Facility Preliminary Load List

Substation	Switchgear	Bus A (Amps)	Bus B (Amps)	Voltage (KV)	Bus A (KVA)	Bus B (KVA)
68USS	68SWGR1A/68SWGR1B	1,412	1,412	0.48	1,173	1,173
69USS	69SWGR1A/69SWGR2B	114	228	4.16	821	1,642
70USS	70SWGR1A/70SWGR2B	1,111	879	0.48	923	730
Subtotal KVA					2,916	3,544
Total KVA						6,460

The six pad mounted transformers will be fed from the Full-Scale Facility Main Switchgear and will feed 480 Volt 3-phase power to double- ended switchgears 68SWGR1A and 68SWGR1B, 4160 Volt 3-phase power to double-ended switchgears 69SWGR1A and 69SWGR1B, and 480 Volt 3-phase power to double-ended switchgears 70SWGR1A and 70SWGR1B.

68SWGR1A and 68SWGR1B will feed the five RO Feed Pumps (see Figure 4-11). 69SWGR1A and 69SWGR1B will feed the four Finished Water Pumps (see Figure 4-12). 70SWGR1A and 70SWGR1B (see Figure 4-13) will feed the two double-ended motor control centers (MCC-1A/1B, 2A/2B) (see Figures 4-14 and 4-15, respectively) and Distribution Panel (DP-1). MCCs will in turn feed power to the integral horsepower motors and other large loads. A dry type distribution transformer will feed

the lighting panel board. The lighting panel board will feed 120 Volt single phase power to the fractional horsepower motors, lighting, receptacles and other small loads.

The six main transformers shall be less-flammable liquid filled three-phase pad mounted type, dead front with externally clamped high voltage bushing wells for 200A fused loadbreak elbow connectors and surge arresters. The use of less flammable insulating liquid in transformers allow them to be located close to building structures without undue risk of fire; and in addition, the liquid is bio-degradable and non-toxic.

There will be two switchgears rated at 3,200 Amps, 480Volts and one switchgear rated at 600 Amp 4,160 Volt. The 3,200-Amp switchgear consists of 3,200A main breakers at bus "A" and bus "B" and a 3,200A tie breaker between bus "A" and bus "B." The 600-Amp switchgear consists of 600A main breakers at bus "A" and bus "B" and a 600A tie breaker between bus "A" and bus "B." The Kirtkey interlocks will be incorporated in the main and tie circuit breakers of the switchgears. The switchgears shall be provided with a circuit monitor.

The new transformers and the switchgears will be fully rated double-ended systems, so in the event that one end is not available, the other end can carry the whole loads on bus A and bus B without going into load shedding mode. Similar to North City, Bus B can be supplied from the Genesee substation to provide additional redundancy to the system.

The electrical system will not be solidly grounded system, but instead will have the system neutral grounded through a high resistance. A high resistance pulsing neutral grounding unit will be provided to improve process reliability by avoiding downtime due to line to ground faults and assist in trouble shooting such faults.

The motor control centers shall be in NEMA 1A gasketed structures with NEMA Class II type B factory wiring and tinned copper main horizontal and vertical buses. The Kirtkey interlocks will be incorporated in the main and tie circuit breakers of the MCCs. The motor control centers shall be provided with circuit monitors, transient voltage surge suppression and active harmonic correction units.

The AWP Facility influent pumps, RO feed pumps, and finished water pumps shall be provided with circuit monitors.

AWP Facility Influent Pump Station

Since the AWP Facility influent pump station would be located at North City west of the existing tertiary filters (see Figure 4-3), the four new influent pumps would be powered from the existing North City switchgear 61SWBD1/2. The existing switchgear 61SWBD1/2 has an approximate existing demand load of 1,395/1,045A. The four new influent pumps will add approximately 906 amps, totaling approximately 3,346 amps (approximately 2,777 KVA). The existing transformers on bus A and bus B are 2000/2300/2576 KVA OA/FA 55/65 degree C.

A coordination study needs to be completed during preliminary design to determine the actual electrical demand on the 61USS substation, where the 61SWBD1/2 switchgear is located. The overall loading to the 68 Main Plant Switchgear (68 MPS) will also need to be evaluated. If there is not enough capacity on the 61SWBD1/2 with the four new influent pumps, then the following options could be considered:

- Eliminate the future North City influent pump no. 2 from the 61SWBD1/2 load since the existing four influent pumps should be able to satisfy the flow to North City.
- Install forced air cooling fans on the transformer radiators to accommodate the added loads.
- Keep the tie breaker open. If one bus source is down, the tie breaker could be closed, but only after following a load shedding schedule.
- Upsize the existing transformer such that any one transformer could carry loads on both bus A and bus B.

Table 4-7 presents the approximate existing North City loads on 61USS, as well as the approximate future demands on 61USS substation with the four new AWP Facility influent pumps, and Figure 4-16 shows the single line diagram. The existing and future loads connected to 61SWBD1/2 need to be confirmed during preliminary design.

Table 4-7 Approximate Existing and Proposed Loads on 61USS Substation Powered from the North City Main Plant Switchgear (68MPS)

61USS Substation	Switchgear/ Switchboard	Bus A (Amps)	Bus B (Amps)	Voltage (KV)	Bus A (KVA)	Bus B (KVA)
Existing	61SWBD1/61SWBD2	1,395	1,045	0.48	1,158	868
Future	61SWBD1/61SWBD2	2,000	1,347 [1]	0.48	1,660	1,119

Notes:

1) The standby AWP Facility influent pump is assumed to be connected to bus B.

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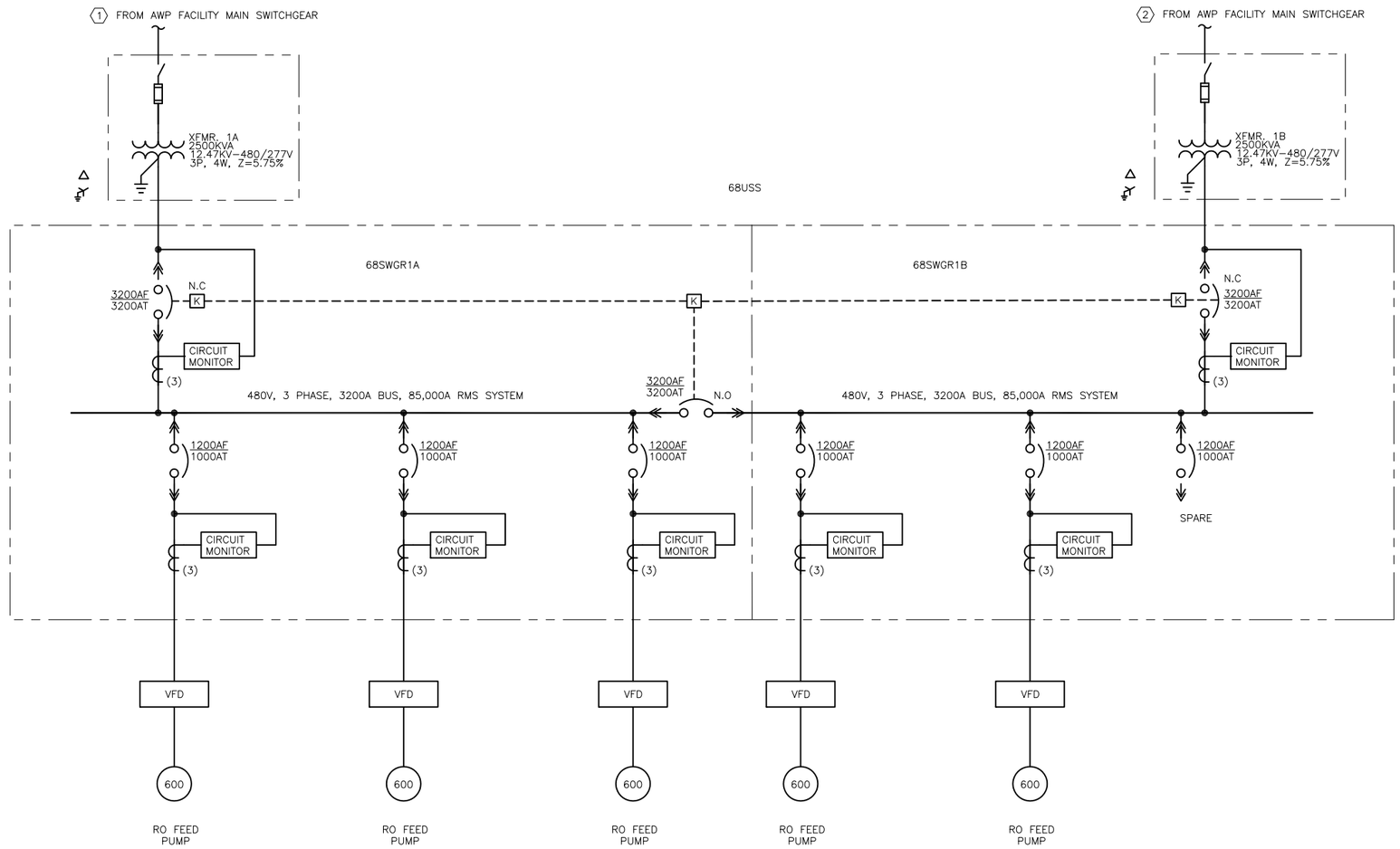

68SWGR1A AND 68SWGR1B

ONE LINE DIAGRAM

N.T.S.

CITY OF SAN DIEGO INDIRECT POTABLE REUSE/RESERVOIR AUGMENTATION DEMONSTRATION PROJECT

FULL-SCALE FACILITY ONE LINE DIAGRAM 1 (JANUARY 2013)

FIGURE 4-11

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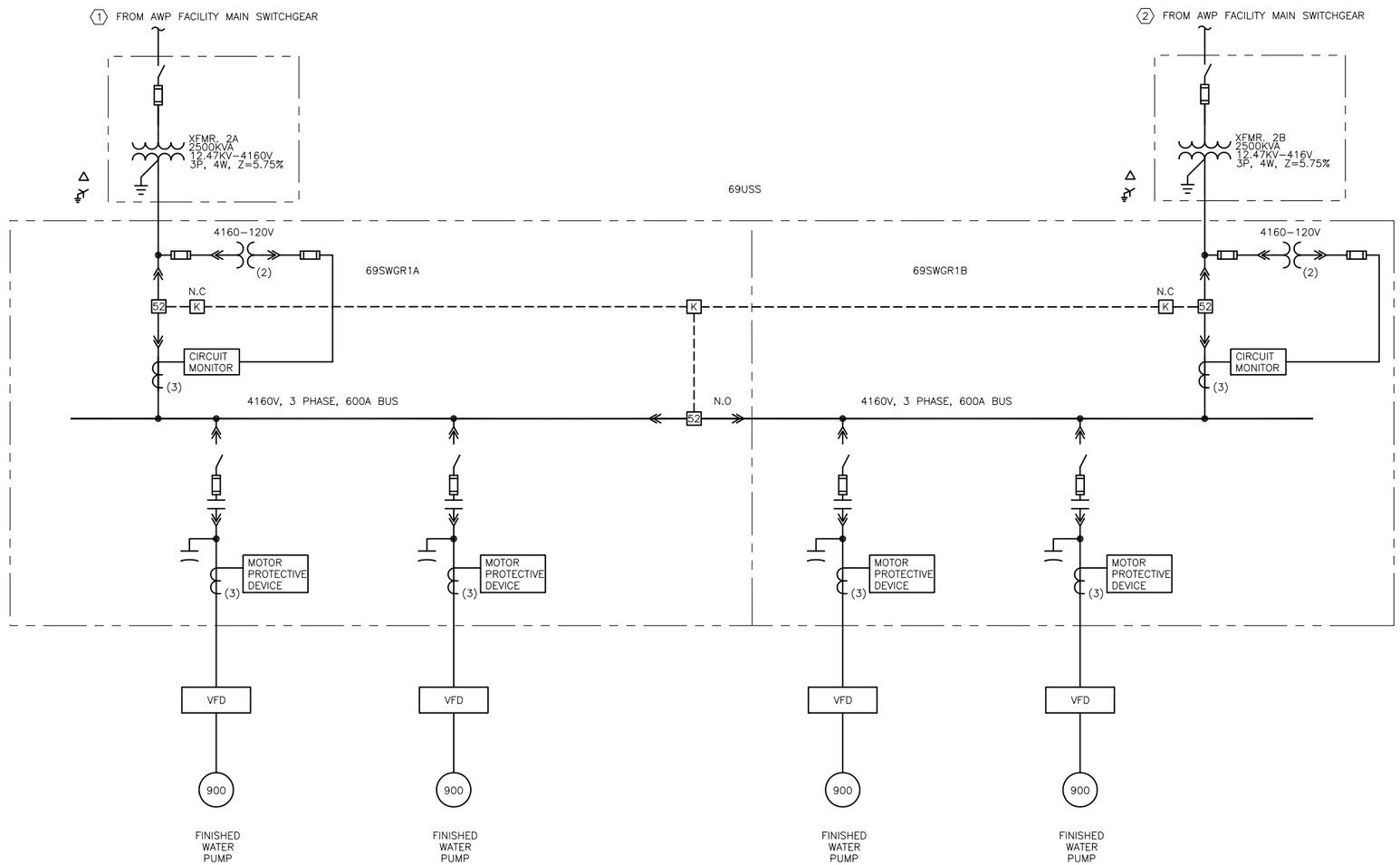

69SWGR1A AND 69SWGR1B

ONE LINE DIAGRAM

N.T.S.

CITY OF SAN DIEGO INDIRECT POTABLE REUSE/RESERVOIR AUGMENTATION DEMONSTRATION PROJECT

FULL-SCALE FACILITY ONE LINE DIAGRAM 2 (JANUARY 2013)

FIGURE 4-12

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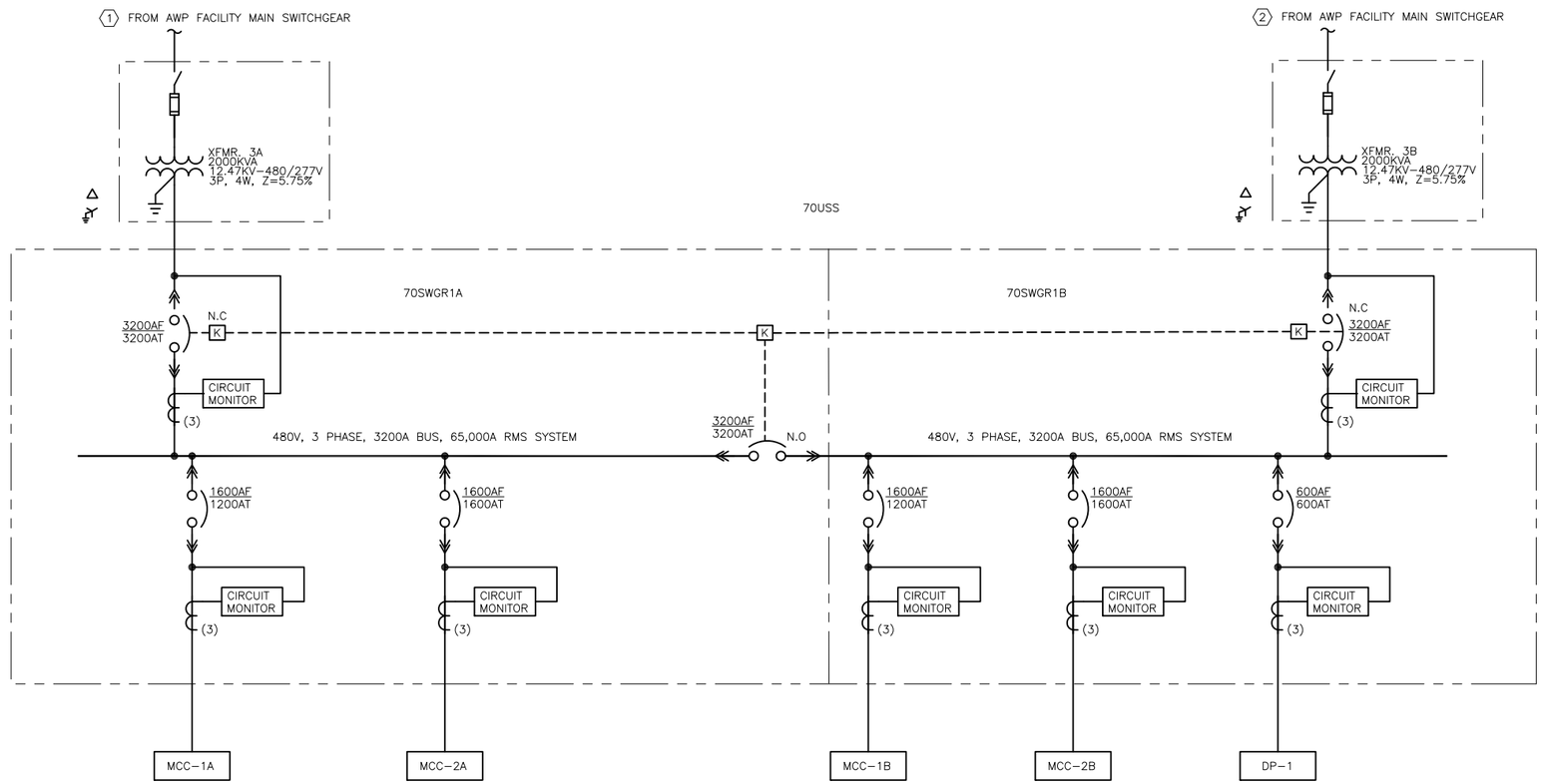

70SWGR1A AND 70SWGR1B

ONE LINE DIAGRAM

N.T.S.

CITY OF SAN DIEGO INDIRECT POTABLE REUSE/RESERVOIR AUGMENTATION DEMONSTRATION PROJECT

FULL-SCALE FACILITY ONE LINE DIAGRAM 3 (JANUARY 2013)

FIGURE 4-13

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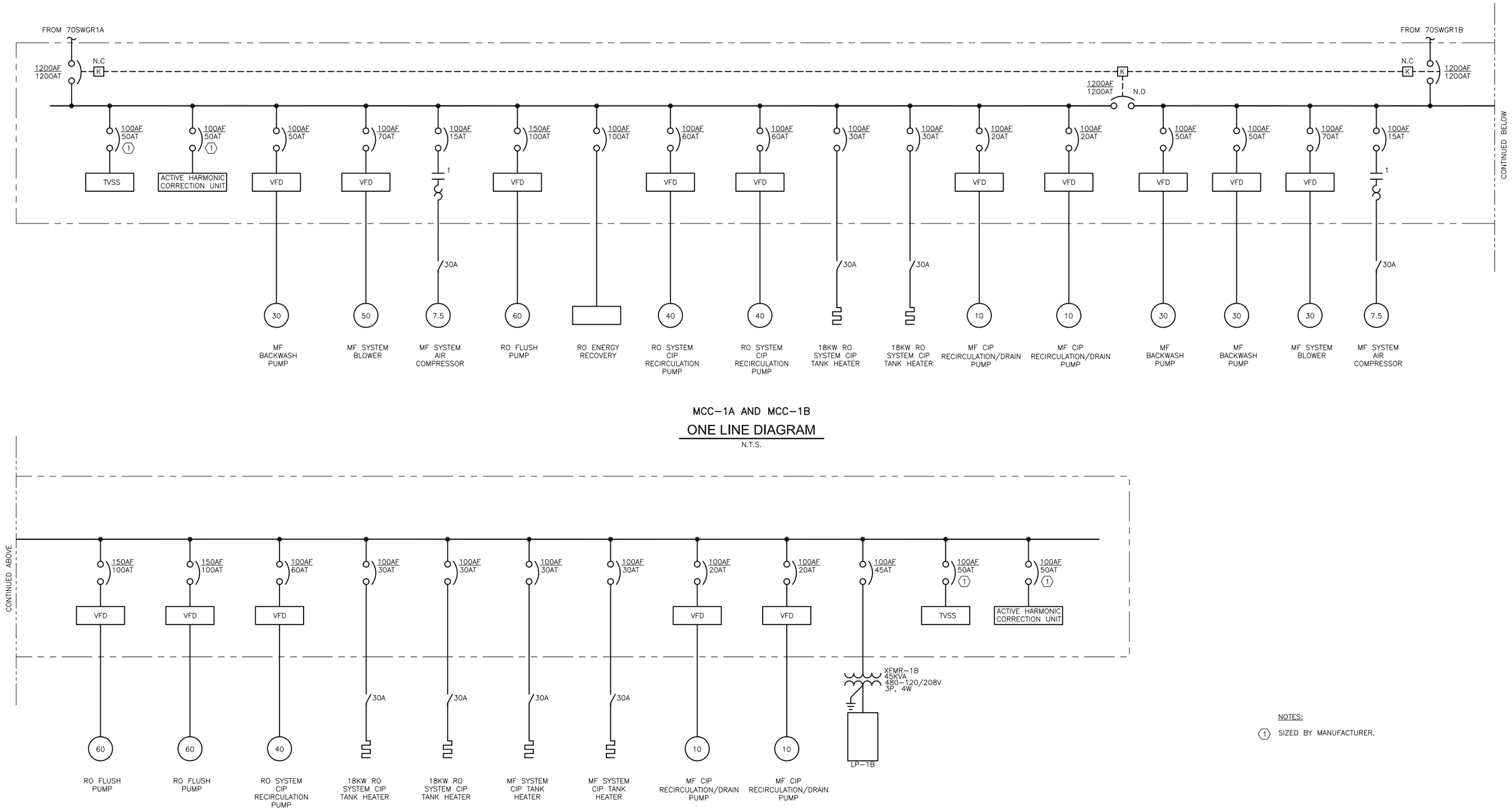

MCC-1A AND MCC-1B

ONE LINE DIAGRAM

N.T.S.

NOTES:

(1) SIZED BY MANUFACTURER.

CONCEPTUAL DESIGN
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CITY OF SAN DIEGO INDIRECT POTABLE REUSE/RESERVOIR AUGMENTATION DEMONSTRATION PROJECT

FULL-SCALE FACILITY ONE LINE DIAGRAM 4 (JANUARY 2013)

FIGURE 4-14

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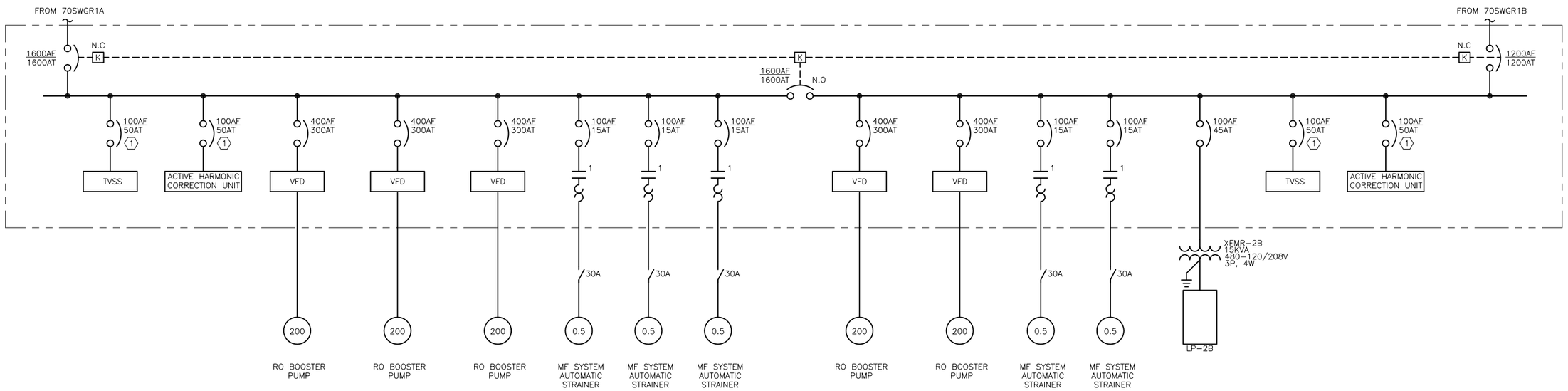
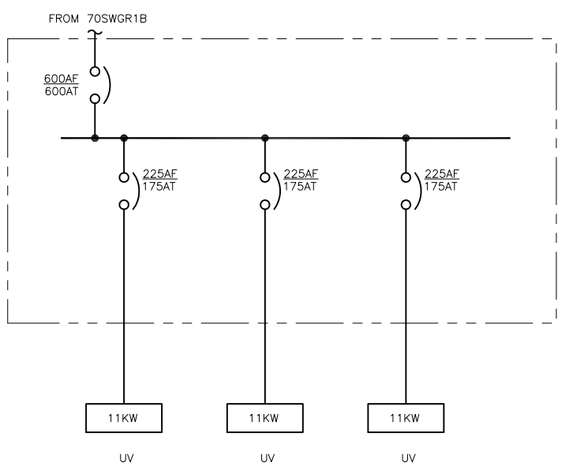


MCC-2A AND MCC-2B

ONE LINE DIAGRAM

N.T.S.



DP-1

ONE LINE DIAGRAM

N.T.S.

NOTES:

1. SIZED BY MANUFACTURER.

CONCEPTUAL DESIGN
NOT FOR CONSTRUCTION

CITY OF SAN DIEGO INDIRECT POTABLE REUSE/RESERVOIR AUGMENTATION DEMONSTRATION PROJECT

FULL-SCALE FACILITY ONE LINE DIAGRAM 5 (JANUARY 2013)

FIGURE 4-15

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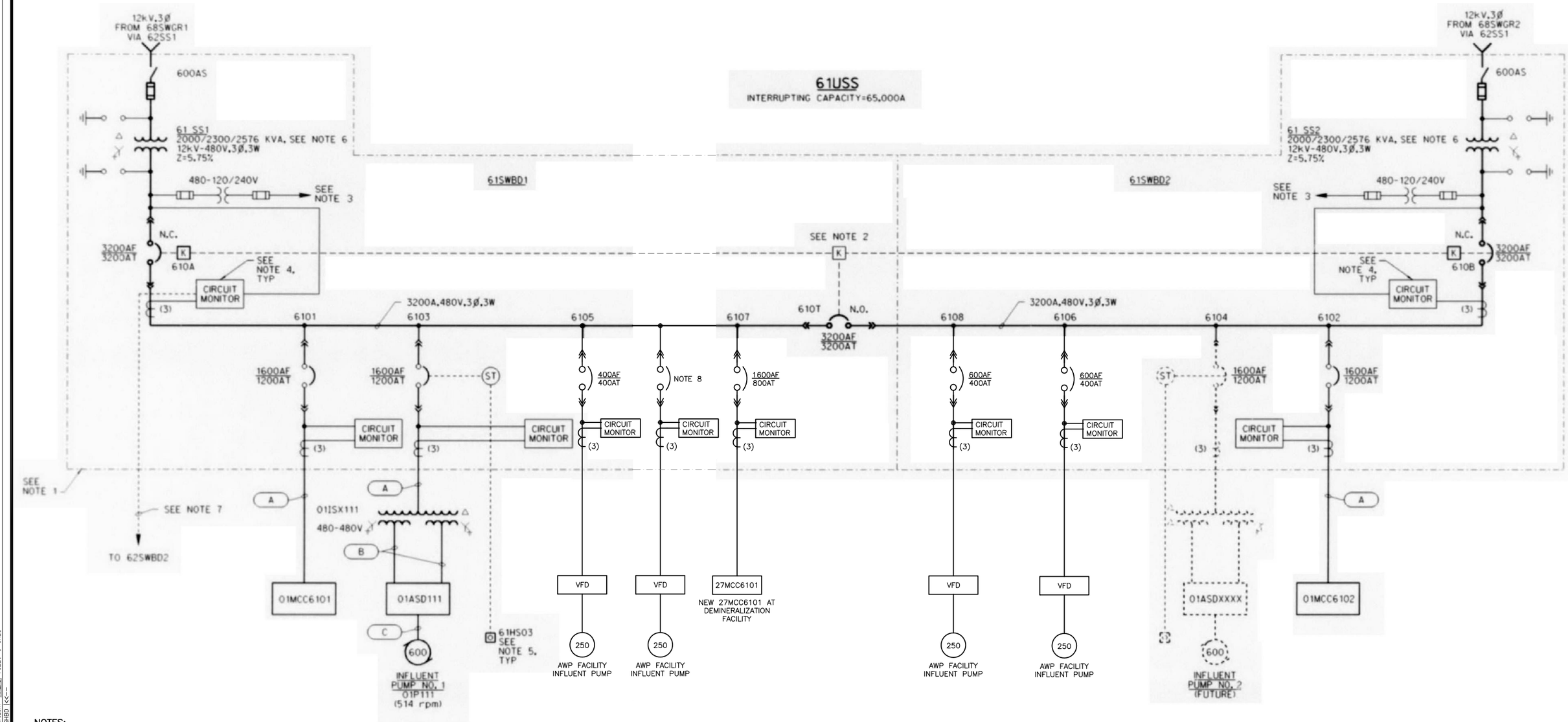

NOTES:

1. ALL CONDUCTORS SHALL ENTER THE BOTTOM OF THE EQUIPMENT.
2. KEY INTERLOCKED SO THAT ONE BREAKER MUST BE OPEN.
3. SUBSTATION TRANSFORMER FANS. FAN CONTROLS, ETC.
4. SOLID STATE MONITOR SYSTEM,. SEE SPECIFICATIONS FOR DETAILED REQUIREMENTS.
5. SHUNT TRIP PUSHBUTTON LOCATED AT INFLUENT PUMP STATION.
6. TRANSFORMER KVA RATINGS AS INDICATED ARE OA 55°C/FA 55°C/FA 65°C.
7. TWISTED SHIELD PAIR (TYPE 3) DATA HIGHWAY.
8. FIELD VERIFY SPARE SPACE.

480V FEEDER SCHEDULE: *(THIS DWG ONLY)

TYPE	CONDUIT		CONDUCTORS PER CONDUIT		
	QTY	SIZE	PHASE	NEUT	GRD
A	4	4"	3-350KCM	—	*3/0
B	2	3"	3-350KCM	—	*1
C	3	3"	3-500KCM	—	*2/0

* FOR REFERENCE ONLY. FEEDER DESCRIPTION IN CIRCUIT AND RACEWAY SCHEDULE SHALL TAKE PRECEDENCE.

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CITY OF SAN DIEGO INDIRECT POTABLE REUSE/RESERVOIR AUGMENTATION DEMONSTRATION PROJECT

FULL-SCALE FACILITY INFLUENT PUMPS ONE LINE DIAGRAM (JANUARY 2013)

FIGURE 4-16

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4.2.10 Proven Water Purification Processes and Equipment Manufacturers

The information in this report is based on the water purification processes and equipment manufacturers that were used for the Demonstration Facility. These are proven technologies and most of the equipment manufacturers that provided the equipment for the Demonstration Facility have provided process equipment for other AWP Facilities of similar size and complexity. During the detailed design phase of this project, additional equipment manufacturers should be considered based on the specifications summarized herein. The minimum qualifications for consideration include:

- Technology and equipment shall have been used for water reuse applications for IPR in the United States, at recycled water treatment facilities of 5.0 mgd capacity or greater;
- Technology shall have operating experience and equipment that has been approved by the CDPH; and,
- Automated pressure decay or equivalent integrity test (for membrane filtration systems only).

4.3 System Controls, Redundancy, and Reliability

4.3.1 Automated Control Systems

The Full-Scale Facility will be operated on a fully-automated control system. The membrane filtration, RO, and UV systems will each have a vendor-provided control system with programmable logic controller (PLC) that monitors and operates the respective treatment process based on flows, pressures, levels, and water quality parameters, such as pH, ORP, chlorine residual, turbidity, and conductivity. All equipment will be provided with instruments (such as flow transmitters, pressure transmitters and switches, level transmitters and switches, water quality analyzers, high temperature switches, vibration switches, lamp intensity) that allow the control system to monitor and alert the operators of abnormal conditions with alarms and notifications. The overall control system for the Full-Scale Facility will communicate with each of the membrane filtration, RO, and UV control systems, as well as provide controls for the miscellaneous process equipment including chemical storage and feed systems and finished water reservoirs.

Since the Full-Scale Facility will treat tertiary effluent prior to chlorination from North City, the overall control system for the Full-Scale Facility will also communicate with the North City control system. The tertiary effluent flow available to the Full-Scale Facility will vary depending on North City's recycled water demands; these demands are typically highest in the summer and significantly lower in the winter. Therefore, the tertiary effluent flow and water levels in the effluent channel will likely be included in the information communicated from North City to the Full-Scale Facility.

4.3.2 Equipment Redundancy

Redundancy is based on the required reliability of the facility or process, and different levels of redundancy are required based on available back up services (e.g., redundant primary electrical feeds) and emergency maintenance capabilities (e.g., available uninstalled back-up equipment).

The Full-Scale Facility has the ability to shut-down at any time because it has the option to go offline by ceasing to receive tertiary effluent from North City. North City, which treats wastewater flows that would otherwise be treated at Point Loma, also has the capability and option to divert flow to Point Loma and go offline any time either by ceasing diversion from the sewer or diverting off-specification water back to the sewer for treatment at Point Loma. Therefore, the Full-Scale Facility is considered a non-essential facility and will have limited redundancy. The redundancy provided will allow the Full-

Scale Facility to continue to operate at capacity when a single process unit is offline for maintenance or cleaning. Equipment redundancy is identified in the design criteria for the unit processes shown in Figures 4-5 and 4-6.

As discussed in Section 4.1.1, the capacity of the Full-Scale Facility (18 mgd) takes into account a 95 percent online factor and the seasonal demands of the recycled water to be able to produce an annual average of 15 mgd of purified water. The assumed online factor allows for the facility to be offline for 5 percent of the year for maintenance and repairs and still meet annual production goals.

The components that require redundant capacity at a non-essential facility such as the Full-Scale Facility are as follows:

- Process mechanical (membrane filtration, RO, UV, chemicals)
- Instrumentation and controls (networks, computers)
- Monitoring/alarm/notification system
- Electrical (power)
- Civil/site facilities (raw and purified water tankage, warehouse, yard piping)
- Other portions of the facility, including occupied structures; heating, ventilating, and air conditioning (HVAC); electrical; plumbing; and conveyance systems are often critical for the plant operation, but not always provided with redundancy

The following parameters were used to assess the required reliability/redundancy of the Full-Scale Facility and its components:

- Operating standards
- Maintainability
- Critical operating and maintenance concerns
- Spare parts availability
- Regulatory requirements
- Life safety requirements

The following addresses general requirements for the major process systems (membrane filtration, RO and UV).

Membrane Filtration

The membrane filtration system consists of modular operating units called “skids.” Due to the frequent cleaning cycles (backwashes every 20-30 minutes, daily maintenance cleans, and monthly recovery cleans) and integrity testing, the membrane filtration system will be designed with a minimum of N+2 configuration (where N is equal to the number of units for design condition) to allow the system to operate at the design flux during cleanings and maintenance events. A minimum of two “spare” skids will be provided. The “spare” skid will operate in conjunction with other units that are producing water, and the system as a whole will operate at a flux rate lower than the design flux rate

under normal operating conditions. When one skid is taken out of service for major cleaning or maintenance, the whole system will be capable of operating at design flux rate even during backwash cycles.

Reverse Osmosis

The RO system consists of modular operating units called "trains," each with an operating flow that is not as flexible as the membrane filtration units, due to the sensitive chemical balance of the concentrated salts on the feed side of the membrane. Operating other trains at a higher flow to accommodate a train down for service could result in excess fouling if unacceptable RO fluxes, feed pressures, or flow velocities result from such a change; however, careful design considerations and strict limits on flow conditions can avoid such challenges. While the RO membranes are not cleaned as often as the membrane filtration units, the cleaning process can typically require a day or two to conduct. In addition, the RO feed pumps can have long lead times for repairs or replacement if they are taken out of service. For these reasons, it is assumed that an N+1 configuration (where N is equal to the number of units for design condition) could be implemented as shown in the design criteria. It should be noted, however, that redundant RO trains are not common, even in the drinking water industry, and that operational challenges can be experienced under lower than optimal flow conditions or when RO trains are taken out and put back into service frequently. A minimum average flux for the RO system of 12 gfd should be maintained if operating at 85 percent recovery, regardless of whether or not a redundant unit is used.

The RO flush system is a critical component to prevent irreversible fouling of the RO membranes, which would require membrane replacement. RO membrane elements represent a significant investment and need to be protected. Replacement also requires considerable time so assuring that the membranes are operated and flushed properly cannot be overstated. The flush system pumps, and associated valves and instruments must be provided with backup power to assure that the membranes are protected in the event of plant shutdown due to power failure (see Section 4.4.1).

UV Disinfection and Advanced Oxidation

The UV reactors are designed with three duty and zero standby trains. However, each train is designed with three dual reactors. Since the lamps could be replaced without draining the reactor vessels and because each reactor could be shut down independently, the shutdown of an entire train is not required to replace lamps and/or ballasts. In addition, the failure of lamps or ballasts does not require immediate replacement since the intensity of the UV lamps can be automatically increased to compensate for the failed lamps. When the numbers of lamps and/or ballasts that have failed reaches the maximum amount allowed before replacement, the operator could replace the lamps and/or ballasts by shutting down the affected reactors or corresponding ballast panels one at a time.

For replacement of lamps, only the affected reactor needs to be shut down, which would reduce the treatment capacity of the respective train by one-sixth. The flow through the train would remain the same, and the UV light intensity could be increased to compensate for the reduced number of UV lamps for the duration of the reactor shutdown, which can typically be accomplished in less than one hour. Similarly, for the replacement of ballasts, only the affected ballast enclosure needs to be shut down, the treatment capacity of the UV train would be reduced by one-sixth, and the reduced treatment capacity could be compensated by increasing the intensity of the UV lamps in service.

4.3.3 Integrity Monitoring

Monitoring and controls at the Full-Scale Facility will be critical to monitor the system performance and confirm the integrity of the treatment processes. Integrity monitoring was included in the design and operations of the Demonstration Facility, which is summarized in Section 2.5. A key component of the integrity monitoring plan is the critical control point monitoring to identify any changes in the performance of the treatment processes that can adversely impact the final water quality. Critical control points (e.g. membrane filtration, RO, and disinfection and advanced oxidation systems) were identified as well as critical limit parameters, alert limits, critical limits, and corrective actions.

During the design phase for the Full-Scale Facility, the City would develop a similar on-line monitoring and response plan that provides sufficient features and assurances that any foreseeable malfunction could be promptly identified and appropriate responses applied.

Based on the integrity and critical control point monitoring experience with the Demonstration Facility, the following points should be taken into consideration when designing the control system for the Full-Scale Facility.

- If a pressure decay test yields a result higher than the critical limit, then the affected membrane filtration skid should be taken offline and a standby skid brought online.
- If the critical limit for conductivity or TOC is exceeded on the RO system, then the affected RO skid should be taken offline and the standby skid brought online.
- Based on consistent conversion of ammonia to nitrate by the advanced oxidation process, online monitoring of ammonia should be evaluated as a potential integrity monitoring method for advanced oxidation.
- Consider alternatives for response to lamp and ballast failures on the UV system. See Section 3.1.3.
- Consider using an online instrument to measure peroxide concentration which would be tied into the pump speed control logic and make automatic adjustments to maintain the desired dose rate. Also consider adding a flow meter to provide constant feedback on the chemical flow rate.

4.4 Operation During Abnormal Conditions

As discussed in Section 4.3.2, since North City has the ability to divert influent flow or off-specification tertiary effluent to the Point Loma. Likewise the Full-Scale Facility will have the ability to shut down during abnormal operating conditions. This eliminates the need for typical equipment redundancy and backup power that would be required to ensure a 100 percent online factor, which reduces the overall capital and O&M costs for the Full-Scale Facility.

4.4.1 Operation During Power Outages

The Full-Scale Facility will not have backup power (dual power feed or emergency generators). The Full-Scale Facility is planned to have a ductbank connection between North City and the Full-Scale Facility (see Figure 4-3), which would allow North City to provide power to the Full-Scale Facility. North City power is mainly generated from the cogeneration system, supplemented by SDG&E power.

The cogeneration or SDG&E power from North City would be used to power critical equipment at the Full-Scale Facility, including the distributed control system and the RO flush pumps.

For momentary outages, the Full-Scale Facility can be restarted when power is restored.

For extended outages (i.e., outages lasting longer than 5 to 10 minutes), the RO system should be flushed after 5 minutes of outage using RO flush system. The RO flush pumps will be on North City cogeneration or SDG&E power to allow continued operation during a power outage. The Full-Scale Facility can be restarted when power is restored.

The distributed control system should also be provided with an uninterruptable power supply.

4.4.2 Operation During Equipment Failure, Maintenance, or Cleaning

The conceptual design for the Full-Scale Facility includes sufficient equipment redundancies to prevent the loss of purified water production if a single process unit is out of service due to malfunction, maintenance, or cleaning. The Full-Scale Facility can continue to operate normally under these conditions. If more units than accounted for by redundancy need to be taken out of service, then the production of the Full-Scale Facility would need to be reduced until the equipment is repaired. During these conditions, North City would need to divert flow to Point Loma.

The Full-Scale Facility will not operate at the maximum production capacity year-round; rather, the facility will operate at the maximum production capacity in winter when North City's recycled water demands are lowest and will operate at less than the maximum production capacity in summer when the recycled water demands are the highest (see the Purified Water Conveyance System Final Conceptual Design Report in Appendix C for more information). During summer when the influent flows to the Full-Scale Facility are lower, the facility will have more equipment redundancy and could accommodate a higher number of units out of service for maintenance, cleaning, or equipment failure than during winter when the facility will be operating at the maximum production capacity.

In the unlikely case of pipe failures, the Full-Scale Facility (or a portion) would need to be shut down until the pipe is repaired.

4.4.3 Operation During Process Upsets

The operations of the Full-Scale Facility will need to be modified when there are process upsets at North City and the recycled water does not meet permit requirements (off-specification water), or if the purified water quality does not meet permit requirements.

In the event that there is a process upset at North City (e.g., addition of extra coagulant, bypassing of tertiary filters) and the tertiary effluent does not meet permit requirements, then the North City operations staff should notify the Full-Scale Facility operations staff. The tertiary effluent prior to chlorination fed to the Full-Scale Facility will have online monitoring that alarms through the control system if the influent turbidity exceeds the Title 22 requirements for turbidity (i.e., exceeds 2 NTU). If North City operations staff thinks that the turbidity excursion will be short-term, then the Full-Scale Facility may remain in operation until it is resolved. If the excursion is anticipated to be longer-term, then the City may want to shut down the Full-Scale Facility until the issue is resolved to avoid the need to perform more frequent cleanings of the membrane filtration system, which will increase the Full-Scale Facility operating costs. If the Full-Scale Facility is shut down, then North City would divert water to Point Loma. The permit to operate will specify specific influent water quality requirements to assure safe purified water and protect water purification equipment.

The permits for the Groundwater Replenishment System and Alamitos Barrier Recycled Water Project both include requirements that the turbidity at inlet to RO cannot exceed 0.2 NTU more than 5 percent of the time within a 24-hour period (1.2 hours) and 0.5 NTU at any time. Based on the operational data from the Demonstration Facility, the Full-Scale Facility will be able to meet these requirements based on the current water quality produced by North City. As presented in Section 2, the feed turbidity was always less than 2 NTU and the MF and UF filtrate turbidity (RO influent) was always less than 0.2 NTU. Based on the Demonstration Facility data, it may be possible to continue running the Full-Scale Facility even if North City is having a process upset, as long as North City is still providing primary, secondary, and tertiary treatment (i.e., not bypassing a unit process because of the upset) and the MF and UF filtrate meets the permit requirements.

Based on the Alamitos Barrier Recycled Water Project permit, there also may be biological oxygen demand, total suspended solids, and total organic carbon influent requirements for the Full-Scale Facility feed water. If similar requirements are included for the Full-Scale Facility, then excursions of these constituents should prompt discussion between the North City and Full-Scale Facility operations staff and determine whether or not the Full-Scale Facility needs to be shut down until the process upset is resolved.

The other type of process upset is if there is a malfunction at the Full-Scale Facility. This hypothetical event is characterized as a malfunction of a water purification process or processes at the Full-Scale Facility. As discussed in Section 4.3.3, the Full-Scale Facility would incorporate integrity monitoring to confirm the unit processes are operating as designed and according to the permit. As a worst case, a malfunction could allow filtered North City effluent to flow into the purified water conveyance pipeline. As described in the Demonstration Project Report, the purified water conveyance pipeline would provide up to 10 hours to identify a malfunction, validate the malfunction, and stop flows in the conveyance pipeline before the off-specification water would be released into San Vicente Reservoir. If necessary, water in the conveyance pipeline could be diverted into the sanitary sewer system and treated at Point Loma.

Section 5

Full-Scale Facility Estimated Costs

This section provides the estimated capital costs and O&M costs the Full-Scale Facility, as well as costs for the overall project.

The capital costs were estimated based on the proposed Full-Scale Facility capacity of 18 mgd, while the O&M costs were estimated for the annual average purified water production of 15 mgd. The difference in the capacity for the capital and O&M costs is based on the seasonal variation of recycled water demands, which impacts how much tertiary effluent that can be treated at the Full-Scale Facility. The Full-Scale Facility will operate at the design capacity (18 mgd) in winter months when recycled water demands are lowest and will operate at a reduced production in summer months when recycled water demands are highest. This will result in an annual average purified water production of 15 mgd.

5.1 Estimated Capital Costs for the Full-Scale Facility

This section provides the estimated capital costs for the conceptual Full-Scale Facility. The conceptual design for the Full-Scale Facility is described in Section 4. The estimated construction cost for the Full-Scale Facility is presented in Table 5-1 below.

Appendix D includes additional breakdown of estimated construction cost for each of the process areas and buildings. The breakdown includes Total Amount and Grand Total columns. The Total Amount column represents the direct costs to the contractor, which include labor, materials, subcontractors, and equipment. The Grand Total includes the contractor direct costs plus construction allowances, permits and sales tax, which are estimated as summarized below based on previous construction project experience:

- Maintenance of traffic allowance – 5 percent
- Miscellaneous metals allowance – 2 percent
- Painting allowance – 2 percent
- Instrumentation and controls allowance – 8 percent
- Electrical allowance – 18 percent
- City of San Diego permits – 1 percent
- Sales tax (materials, equipment, and other) – 7.75 percent

Table 5-1 Estimated Construction Cost for the Full-Scale Facility[1]

Parameter	Capital Cost[2,3]
Construction Costs[4]	
AWP Facility Influent Pump Station	$2,800,000
Site Civil/Yard Piping[5,6]	$5,800,000
Operations, Maintenance, and Administration Building	$1,600,000
Membrane Filtration Break Tank and Pump Station	$4,000,000
Chemical Storage Area #1 (Pre-Treatment Chemical Facility)[7]	$2,400,000
Membrane Filtration Facility[8]	$25,300,000
Reverse Osmosis Facility[9]	$21,300,000
UV Disinfection and Advanced Oxidation System[10]	$9,900,000
Chemical Storage Area #2 (Post-Treatment Chemical Facility)[11]	$2,100,000
Construction Subtotal	**$75,200,000**
Contingency (30% of Construction Total)	$22,600,000
Overhead & Profit	$9,800,000
Insurance & Bond	$2,900,000
Construction Total	***$110,500,000***
Implementation Costs	
Engineering & Pre-Construction (20% of Total Construction Cost)	$22,100,000
Environmental Documentation	$1,000,000
Construction Management (10% of Total Construction Cost)	$11,100,000
Implementation Total	***$34,200,000***
Total Capital Cost (Construction Total + Implementation Total)[12]	**$144,700,000**

Notes:

1) This table presents costs for the Full-Scale AWP Facility only. For costs related to the Purified Water Pump Station and Purified Water Pipeline, refer to Table 5-4 and the Demonstration Project Report.
2) Includes installation costs and indirect costs (project management, field management and support, training, quality assurance and control, project safety, construction allowances, permits, and sales tax).
3) All costs are in February 2012 dollars. The Engineering News Record (ENR) Construction Cost Index is 9267.57 and the ENR Building Cost Index is 5144.49 for February 2012.
4) Construction duration is assumed to be 30 months. Based on a 40 hour work week with no overtime.
5) No rock excavation is assumed to be required. Only nominal dewatering is assumed to be needed. No consideration for contaminated soils or hazardous materials (e.g. asbestos, lead) is included. Site grading, drainage and containment are included with assumptions made based on the aerial photograph.
6) Includes pressure membrane filtration feed pipeline, gravity membrane filtration backwash, pressure RO concentrate pipelines, and chemical feed pipelines.
7) Includes sodium hypochlorite, ammonium hydroxide, sulfuric acid, and antiscalant.
8) Includes citric acid and sodium hydroxide system for membrane filtration chemical cleaning systems.
9) Includes cartridge filters and RO feed pumps.
10) Hydrogen peroxide system is included with the UV disinfection and advanced oxidation system.
11) Includes calcium chloride and sodium hydroxide.

5.2 Estimated O&M Costs for the Full-Scale Facility

The O&M cost estimate for the Full-Scale Facility considers power costs, chemical costs, equipment replacement costs, maintenance costs, laboratory costs, and labor costs. Table 5-2 presents the estimates for annual O&M costs for the Full-Scale Facility. Additional detail is provided in Appendix B. The largest annual O&M costs are anticipated to be power (33 percent), maintenance and equipment replacement (13 + 17 = 30 percent), labor (17 percent), and chemical consumption (16 percent).

Table 5-2 Estimated Annual O&M Costs for the Full-Scale Facility

Parameter	Annual O&M Cost[1]	Approximate Percentage of Annual O&M Costs
Power Costs[2]		
AWP Facility Influent Pump Station	$306,000	
Membrane Filtration System	$43,000	
Reverse Osmosis System	$1,614,000	
UV Disinfection and Advanced Oxidation System	$185,000	
Miscellaneous Equipment	$7,000	
Buildings	$481,000	
Power Costs – Subtotal	***$2,636,000***	***33%***
Chemical Costs		
Membrane Filtration Pretreatment	$223,000	
Reverse Osmosis Pretreatment	$431,000	
Hydrogen Peroxide for Advanced Oxidation	$216,000	
Post Treatment	$358,000	
Membrane Cleaning	$103,000	
Chemical Costs – Subtotal	***$1,331,000***	***16%***
Replacement of Consumables (Equipment Replacement)		
Membrane Filtration Membranes	$441,000	
Reverse Osmosis Cartridge Filters and Reverse Osmosis Membranes	$319,000	
UV Lamps and Ballasts	$281,000	
Replacement of Consumables – Subtotal	***$1,041,000***	***13%***
Maintenance Costs[3]	***$1,409,000***	***17%***
Other Costs (Compliance Testing and Security)[4]	***$310,000***	***4%***
Labor Costs[5]	***$1,418,000***	***17%***
Total Annual O&M Cost[6]	**$8,145,000**	**100%**

Notes:

1) All costs are in February 2012 dollars.
2) Power cost is assumed to be $0.12/kWh.
3) Assumed to be 1.7% of the equipment construction cost based on a review of actual maintenance costs for the Orange County Water District's Groundwater Replenishment System.
4) The annual compliance testing cost is assumed to be $150,000/year. This is based on half of the Demonstration Facility compliance testing cost of $300,000/year.
5) Estimated staffing = 12 personnel plus outside lab allowance, based on information provided by the City. The estimated staffing of 12 personnel was based on assessment of the department wide resources and additional needs to support and integrate this new facility as part of the City's existing treatment facilities. However, it is anticipated that this labor estimate will be updated in the future when the full-scale facility is constructed and the evaluation of new treatment technology provided at that time.
6) This table presents costs for the Full-Scale Facility only. For costs related to the Purified Water Pump Station and Purified Water Pipeline, refer to Table 5-5 and the Demonstration Project Report.

The O&M cost estimate is based on the preliminary design criteria developed for the Full-Scale Facility (see Section 4). The assumptions used for the O&M cost estimate are summarized below:

- The power consumption for each major water purification process was estimated taking into consideration efficiency of equipment and motors, and variation in equipment performance over time (e.g., membrane fouling over time will increase membrane feed pumping pressure and, therefore, increase power consumption). The average power demand for the Full-Scale Facility (annual average purified water production of 15 mgd) is approximately 2.1 to 3.1 megawatts, and the estimated total annual power consumption is 18,200,000 to 27,400,000 kilowatt-hours per year.
- The chemical consumption was estimated based on a range of dose rates defined in the design criteria.
- The replacement costs for microfiltration membrane modules assume a seven-year membrane life. The replacement costs for RO cartridge filters and RO membrane modules are based on other AWP facilities of similar size. The replacements costs for UV lamps and ballasts are based on 12,000 hours of life per lamp and seven years of life for ballasts based on information provided by Trojan.
- The annual maintenance cost for equipment is assumed to be 1.7 percent of the equipment construction cost based on a review of actual maintenance costs for GWRS.
- The annual compliance testing cost is assumed to be $150,000 per year. This is based on half of the Demonstration Facility compliance testing cost of $300,000 per year.
- The labor cost assumes 12 personnel based on information provided by the City of San Diego.

5.2.1 Comparison with Data from the Demonstration Facility

The estimated annual O&M costs for the Full-Scale Facility were compared to the O&M cost of the Demonstration Facility based on the first three quarters of operations. The estimated unit O&M costs for the Full-Scale Facility for most of the process areas are within 5 percent to 30 percent of the O&M costs for the Demonstration Facility (see Table 5-3). The differences are within an appropriate level of contingency since the Demonstration Facility has been operating within the first year of the equipment and membrane life, and many variables are anticipated to change over the course of the facility operation as the membranes age and water quality changes.

The largest difference between the estimated O&M costs for the Full-Scale Facility and the actual costs for the Demonstration Facility was for the RO system in which the estimated O&M costs for the Full-Scale Facility were estimated to be 60 percent higher than the Demonstration Facility. The differences between the two costs are discussed in more detail below. Additional information about energy conservation opportunities for the Full-Scale Facility RO system, including a discussion of using a two-stage RO system and energy recovery devices, are presented in Section 3.

Table 5-3 Full-Scale Facility Estimated O&M Costs Compared with the Demonstration Facility Operations Data

Process Area	Comparison	Notes
Membrane Filtration System	Full-Scale Facility unit power consumption estimate is approximately 10% lower than the unit power consumption of the Demonstration Facility.	Power consumption for Demonstration Facility included power consumption from chemical cleaning of RO system (chemical cleaning system was shared with RO, but measured as part of MF system).
RO System	Full-Scale Facility unit power consumption estimate is approximately 60% higher than the Demonstration Facility data.	RO feed pressure during first year of Demonstration Facility was operated at 126 psi (pump was sized for 175 psi). For the Full-Scale Facility the RO feed pumps are sized to operate at average feed pressure of 180 psi at year 2.5 (pump is sized for 230 psi at year 5). The increase in average pressure takes into consideration membrane age and potential increase in influent water TDS. Also, the Demonstration Facility did not have cartridge filters, which require additional booster pumping. These are included in the estimated O&M costs for the Full-Scale Facility.
UV System	Full-Scale Facility unit power consumption estimate is the same as the Demonstration Facility data.	Used 70% of maximum power draw value to estimate power consumption for the Full-Scale Facility.
Sodium Hypochlorite	Full-Scale Facility chemical usage estimate is 25% higher than the Demonstration Facility data.	Assumed 5 mg/L dose for the estimated O&M costs for the Full-Scale Facility. Dosed 3.8 mg/L at the Demonstration Facility. Higher dose is based on expected changes in water quality from both variations in the supply and higher salt passage as the RO membranes age.
Ammonium Hydroxide	Same	Assumed 1.5 mg/L dose for the estimated O&M costs for the Full-Scale Facility. Same dose was used at the Demonstration Facility.
Antiscalant	Full-Scale Facility chemical usage estimate is 29% higher than Demonstration Facility data.	Assumed 4.0 mg/L dose for the estimated O&M costs for the Full-Scale Facility. Dosed 3.0 mg/L at the Demonstration Facility.
Hydrogen Peroxide	Full-Scale Facility chemical usage estimate is 25% higher than Demonstration Facility data.	Assumed 5.0 mg/L dose for the estimated O&M costs for the Full-Scale Facility. Dosed 3.0 mg/L at the Demonstration Facility.
Sulfuric Acid	Not used at Demonstration Facility.	Assumed 60 mg/L dose for the estimated O&M costs for the Full-Scale Facility in the event that water quality changes. Did not use at the Demonstration Facility.

RO Booster Pumps

The Demonstration Facility does not include booster pumps or cartridge filters, which are included in the Full-Scale Facility conceptual design. Cartridge filters were not needed at the Demonstration Facility since concrete or concrete-lined tanks and piping, which could introduce debris into RO feed water, were not used between the membrane filtration and RO membranes. Cartridge filters are typically used upstream of the RO membranes to remove any particulate material inadvertently introduced after the membrane filtration system (spalled concrete, impurities in chemicals such as sulfuric acid, etc.). RO booster pumps are required to pump water through the cartridge filters ahead of the main RO feed pumps. In a larger facility, avoiding the use of concrete and concrete lined materials will be more challenging. While it has been done successfully in a handful of membrane

filtration/RO facility, planning for the Full-Scale Facility should allow for a more conventional design approach with RO booster pumps and cartridge filters, as presented in Section 4.2.3. Based on these assumptions, it was estimated that four duty RO booster pumps rated at 200 horsepower each will be required for the Full-Scale Facility.

RO Recovery

The RO system Trains A and B were operated at both 80 and 85 percent recovery during the testing period and has operated well at both recoveries. The pumping requirements for the Full-scale Facility are based on a recovery of 85 percent to maximize water production.

Influent Water Quality

The water quality of the tertiary filter effluent, which feeds the Demonstration Facility, has been lower in TDS when compared with historic TDS levels prior to 2011. The TDS concentrations influence the feed pressures required for the RO system, as higher TDS results in higher osmotic forces that must be overcome in the RO process. The TDS observed at the Demonstration Facility since August 2011 has averaged 860 mg/L. There has been a downward trend in the TDS levels in the NCWRP effluent since 2006, when TDS concentrations were as high as 1,260 mg/L. TDS levels can change depending on San Diego's source of drinking water (low salinity State Project Water vs. higher salinity Colorado River Water) and conservation efforts, which tend to drive TDS higher. It is expected that the TDS levels could again approach 1,100 to 1,150 mg/L if the drought, which started in 2011, continues or the contribution of water from the Colorado River increases. The estimated RO feed pressure for the Full-Scale Facility is based on 1,100 mg/L, instead of the 860 mg/L that is currently being measured at the Demonstration Facility, to represent the average of the range of TDS that the Full-scale Facility could potentially treat. This higher TDS results in a higher RO feed pressure and higher power consumption when compared to the Demonstration Facility.

Membrane Age

The other factor that influences the RO feed pressure is the membrane age. As the membranes age, higher pressures are required to force the flow through the membranes. RO membrane projection software (Hydranautics IMSDesign v2009) was used to compare the feed pressures required at year one and year five of an RO membrane. At year one with 85 percent recovery and 1,100 mg/L TDS, the feed pressure required is estimated to be 132 psi for a two-stage system including energy recovery. At year five the feed pressure is estimated to be 206 psi for the same operating conditions and system configuration. The average over the life of the membrane must be considered; therefore, 180 psi was used for the estimated O&M costs. This is compared to current pressure of 126 psi at the Demonstration Facility after twelve months of operation (June 2011 to May 2012) under lower influent TDS conditions and operating at both 80 to 85 percent recovery.

5.3 Estimated Costs for the Full-Scale Project

The estimated costs for the Full-Scale Project incorporate the Full-Scale Facility, Purified Water Pump Station, and the Purified Water Pipeline. Table 5-4 presents the estimated construction costs for the Full-Scale Project, Table 5-5 presents the estimated O&M costs for the Full-Scale Project, and Table 5-6 presents the estimated additional auxiliary program costs to support the Full-Scale Project. The Full-Scale Project and the associated costs are discussed in more detail in the Demonstration Project Report.

Table 5-4 Estimated Construction Costs for the Full-Scale Project

Parameter	Capital Cost
Total Full-Scale Facility Capital Cost (Construction Total + Implementation Total)[1]	**$144,700,000**
Purified Water Pipeline System Construction Costs[2]	
Purified Water Pump Station	$8,000,000
Purified Water Pipeline	$114,200,000
Pipeline System Construction Total	***$122,200,000***
Pipeline System Implementation Costs	
Contingency (30% of Construction Total)	$36,700,000
Engineering & Construction Management (30% of Construction Total)[3]	$36,700,000
Environmental Documentation and Mitigation	$24,400,000
Land Acquisition	$4,500,000
Pipeline System Implementation Total	***$102,300,000***
Total Pipeline System Capital Cost (Construction & Implementation)[2]	**$224,500,000**
Total Capital Cost (Full-Scale Facility and Pipeline System)	**$369,200,000**

Notes:

1) Refer to Table 5-1 for a breakdown of the Full-Scale Facility construction cost.
2) From the Demonstration Project Report.
3) Includes costs associated with regulatory compliance and permitting.

Table 5-5 Estimated Annual O&M Costs for the Full-Scale Project

Parameter	Annual O&M Cost[1]
Full-Scale Facility[1]	$8,145,000
Treatment at North City to Support Full-Scale Facility[2]	$3,965,000
Purified Water Pump Station[2,3]	$1,885,000
Purified Water Pipeline[2,4]	$1,500,000
Total Annual O&M Cost	**$15,495,000**

Notes:

1) Refer to Table 5-2 for a breakdown of the Full-Scale Facility O&M costs.
2) From the Demonstration Project Report.
3) Includes power and maintenance.
4) Includes maintenance.

Table 5-6 Estimated Auxiliary Program Costs for the Full-Scale Project[1]

Parameter	Auxiliary Cost
Auxiliary Upfront Cost	
Source Control Program Upfront Cost[2]	$500,000
Auxiliary Annual Cost	
Source Control Program Annual Costs[3]	$50,000
Public Outreach Annual Program Costs[4]	$700,000

Notes:

1) From the Demonstration Project Report.
2) Source control upfront costs include a chemical inventory program and GIS tracking database (approximately $50,000), a pollutant prioritization program to be completed by existing City staff (approximately $50,000 for initial set-up work), and a local limits evaluation for North City (approximately $400,000). For additional information on source control program costs, refer to the Enhanced Source Control Plan for the Full-Scale Advanced Water Purification Facility Technical Memorandum (RMC, 2013).
3) Source control annual costs include $25,000/yr for annual updates to the chemical inventory program and GIS tracking database, an average of $10,000/yr for periodic updates to the pollutant prioritization program, and $15,000/yr, on average, for updates to the local limits analysis. For additional information on source control program costs, refer to the Enhanced Source Control Plan for the Full-Scale Advanced Water Purification Facility Technical Memorandum (RMC, 2013).
4) Public outreach annual costs include initial start-up of outreach efforts. Annual public outreach costs will be scaled back following full-scale reservoir augmentation project operations.

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Advanced Water Purification Facility Study Report

Appendix A

Testing and Monitoring Plan

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Final Testing and Monitoring Plan

August 31, 2011

CITY OF SAN DIEGO

Indirect Potable Reuse/Reservoir Augmentation Demonstration Project
Advanced Water Purification Facility

The City of San Diego

City of San Diego PUBLIC UTILITIES Water & Wastewater

CDM

in association with: MWH

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List of Acronyms & Abbreviations

°C	Degrees Celsius
°F	Degrees Fahrenheit
AQWATEC	Advanced Water Technology Center, Colorado School of Mines
AOP	Advanced Oxidation Process
ASTM	American Standard Technical Method
AWP	Advanced Water Purification
Basin Plan	San Diego Basin Plan
BAT	Best Available Technology
BOD	Biological oxygen demand
CCP	Critical control point
CDPH	California Department of Public Health
CDWR	California Department of Water Resources
CEC	Chemicals of Emerging Concern
CFD	Computational fluid dynamics
CFU/mL	Colony forming units per milliliter
CIP	Clean-in-place
City	City of San Diego
City Council	San Diego City Council
CLP	Contract Lab Program
CWA	Clean Water Act
/day	Per day
DBP	Disinfection By-product
DO	Dissolved oxygen
DMA	Dimethylamine
DP	Differential pressure
EBEP	Enclosed Bay and Estuaries Plan
EEO	Electrical Energy per Order
ELAP	Environmental Laboratory Accredited Program
gpm	Gallons per minute
g/mol	Grams per mol
gfd	gallons per square-foot day
gpm	gallons per minute
GWRS	Ground Water Replenishment System
H_2O_2	Hydrogen peroxide
HACCP	Hazard Analysis and Critical Control Point
HRT	Hydraulic residence time
IAF	Integrated averaging factor
IAP	Independent Advisory Panel
in	Inch
IMP	Integrity Monitoring Plan
IPR	Indirect Potable Reuse
ISWP	Inland Surface Waters Plan
kW	Kilowatt
L/m^2	Liters per square meter

lb	Pound
LDC	Laboratory Data Consultants, Inc.
LPHO	Low pressure high output
LT2ESWTR	Long Term 2 Enhanced Surface Water Treatment Rule
MCL	Maximum contaminant limit
MF	Microfiltration
MGD	Million gallons per day
mg/L	Milligrams per Liter
MPN/100 mL	Most probable number per 100 milliliters
MRL	Method reporting level
MTBE	Methyl tert-butyl ether
MTL	Monitoring Trigger Level
MW	Molecular weight
µg/L	Micrograms per Liter
N	Nitrogen
NA	Not applicable
NaOCl	Sodium hypochlorite
NC	North City
NCWRP	North City Water Reclamation Plant
ND	Non Detect
NDMA	N-nitrosodimethylamine
NDBA	N-nitrosodi-n-butylamine
NDEA	N-nitrosodiethylamine
NDPA	N-nitrosodi-n-propylamine
NH2Cl	Monochloramine
NMEA	N-nitrosomethylethylamine
NPIP	N-nitrosopiperidine
NTR	National Toxics Rule
NYPR	N-nitrosopyrrolidine
ng/L	nanograms per liter
NTU	Nephelometric Turbidity Units
O&M	Operations and maintenance
OCWD	Orange County Water District
OH	Hydroxyl radical
P	Phosphorus
PAT	Project Advisory Team
PCPP	Pharmaceutical and Personnel Care Products
POM	Point of monitoring
ppm	parts per million
ppb	parts per billion
ppt	parts per trillion
psi	Pounds per square inch
PVC	Polyvinyl chloride
QA	Quality assurance
QC	Quality control
QCP	Quality control point

RA	Reservoir Augmentation
RO	Reverse osmosis
RWC	Recycled Water Contribution
RWQCB	Regional Water Quality Control Board
SAP	Science Advisory Panel
SCADA	Supervisory control and data acquisition
SVI	Sludge volume index
SWRCB	State Water Resources Control Board
T&M	Testing and Monitoring
TDS	Total dissolved solids
TLD	Trace leak detection
TMP	Transmembrane pressure
TN	Total nitrogen
TOC	Total organic carbon
UF	Ultrafiltration
USEPA	United States Environmental Protection Agency
UV	Ultraviolet
UVT	Ultraviolet transmittance

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Section 1
Background

1.1 City of San Diego Indirect Potable Reuse / Reservoir Augmentation Demonstration Project

In January 2004, the San Diego City Council (City Council) directed the City Manager to conduct a study to evaluate options to increase the use of recycled water produced at the City of San Diego's (City) two water reclamation plants. The City Council mandated the study to also include research on the health effects of reuse options and to facilitate active involvement of the public.

The Water Reuse Study (City of San Diego, Draft Final Report, March 2006) resulted in the identification of six potential options to maximize the use of the City's existing recycled water. The various project stakeholders identified the North City-3 (NC-3) strategy to be the most beneficial reuse strategy. The NC-3 option includes reservoir augmentation of the City's San Vicente Reservoir using highly purified tertiary water from the City's North City Water Reclamation Plant (NCWRP).

The Water Reuse Study represented Phase I of a three phase program that may lead to the implementation of full scale indirect potable reuse reservoir augmentation (IPR/RA) project. Phase II is the current demonstration project and Phase III will be the full scale IPR/RA project. In October 2007, the City Council voted to proceed with the demonstration project consisting of the following components:

- Design, construct, operate and test a demonstration scale Advanced Water Purification Facility (AWP Facility) at the NCWRP.
- Conduct a Limnology and Reservoir Detention study for the San Vicente Reservoir to establish residence time and short circuiting conditions of advanced treated water in the reservoir.
- Conduct a public outreach and education program.
- Convene an Independent Advisory Panel (IAP) to provide expert review of the technical, scientific, and regulatory aspects of the project.
- Define regulatory requirements for a full scale IPR/RA project (Phase III of the program).

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Section 2
Objectives, Development and Organization

A key component to the operation and testing of the AWP Facility is the development and implementation of a comprehensive Testing and Monitoring (T&M) Plan. This section provides specific objectives of the testing and monitoring component of the AWP Facility, information on how the T&M Plan was developed, and a roadmap as to where key components of the plan are located in the document.

2.1 Testing and Monitoring Objectives

The ultimate goal of testing and monitoring the AWP Facility is to generate the necessary data to support the regulatory approval and permitting of the proposed full-scale IPR/RA project. Specific objectives of the testing and monitoring component are provided in the following paragraphs.

- **Demonstrate that the proposed AWP technology, operation and performance meets the criteria outlined by the California Department of Public Health (CDPH) and California Department of Water Resources (CDWR) 1996 proposed framework for Regulating IPR by Surface Water Augmentation.** The selection of the treatment technologies, operational strategy and water quality sampling plan associated with the AWP Facility will target meeting the following criteria:

  - Enable CDPH to find that the proposed technology will ensure that the recycled water meets or exceeds all applicable primary and secondary drinking water standards and poses no significant threat to public health

  - Compliance with the draft 2008 CDPH groundwater recharge criteria for injection.

  - Maintenance of reservoir quality.

  Other criteria established by the proposed IPR/RA project framework, which are also being evaluated as part of the overall demonstration project, and supported by the operation of the AWP Facility, include:

  - Maintenance of appropriate San Vicente Reservoir residence time based on reservoir dynamics.

  - Provision of an effective source control program for discharges into the wastewater collection system.

- **Evaluate nutrient removal performance of the baseline AWP Facility treatment train.** A key objective of the demonstration testing will be to collect nutrient removal data and associated product water quality of the AWP Facility. The performance goals for product water nutrient levels of the proposed full-scale

facility are driven by the Regional Water Quality Control Board (RWQCB) as outlined in the San Diego Basin Plan (Basin Plan). The Basin Plan sets a threshold limit for total phosphorus concentration for any streams at the point of entering inland standing body surface waters, such as San Vicente Reservoir, of 0.05 milligrams phosphorus per liter (mg-P/L). Though the RWQCB has not established nitrogen thresholds, the Plan references the use of natural nitrogen to phosphorus (N:P) ratios of 10:1, which would establish a total nitrogen threshold at 0.5 milligrams of nitrogen per liter (mg-N/L). However, the Basin Plan notes certain exceptions to these levels can be made on a case-by-case basis for discharges of reclaimed water to surface waters. A goal of the overall demonstration project is to work with the RWQCB to establish specific nutrient goals for the full scale IPR/RA project. The established regulatory requirements and nutrient removal performance of the baseline AWP Facility treatment train will dictate if any additional treatment would be needed beyond the baseline treatment train.

- **Implement a monitoring plan for Chemicals of Emerging Concern (CECs) tailored to the NCWRP tertiary water characteristics and current recommendations of the State Water Resources Control Board (SWRCB).** The proposed T&M Plan includes a specific CEC monitoring program to be implemented over the demonstration period. The basis of the plan is the prioritization framework and recommendations presented in the Final Report "Monitoring Strategies for Chemicals of Emerging Concern in Recycled Water," published by the SWRCB on June 25, 2010. The compounds selected for monitoring can be classified into two general categories including compounds that have toxicological relevance and compounds that serve as suitable performance indicators. The specific compounds incorporated into the T&M Plan are based on previous CEC data captured during the City's Advanced Water Treatment Research Studies (2005) and the on-going NCWRP sewer shed investigation, as well as occurrence data for secondary/tertiary treated effluents summarized in the SWRCB report. The proposed plan is multi-tiered with the intention of being carried over to the monitoring requirements of the full-scale IPR/RA project.

- **Demonstrate integrity monitoring techniques and performance reliability measures for the AWP Facility treatment train, which can be implemented at the full-scale facility.** The overall T&M Plan includes a comprehensive plan to monitor the integrity and reliability of each unit process throughout the demonstration period to achieve water quality objectives. The foundation of this T&M Plan is the use of a surrogate/indicator approach for continuous performance monitoring of each unit process. A correlation is made between removals of indicator compounds (i.e., an individual compound that is present in the source water with characteristics of a larger family of compounds) and surrogate compounds (i.e., quantifiable change of bulk parameter corresponding to performance of individual unit process). The T&M Plan also includes direct and indirect measures of the microfiltration/ultrafiltration (MF/UF) and reverse osmosis (RO) membrane integrity, as well as the ultraviolet (UV) system of the advanced oxidation process

(AOP). With regards to RO integrity monitoring, a tiered approach is proposed with the use of different direct and indirect monitoring methods corresponding to different stages of RO commissioning and operation.

- **Validate the performance of AWP Facility unit processes using full-scale treatment equipment.** The AWP Facility baseline treatment train will use a multiple barrier approach consisting of MF/UF, RO, and UV/AOP with a total production capacity of approximately 1 million gallons per day (MGD). The design of the system incorporates the use of MF, UF, and RO membranes which are the same size, specification, and configuration as those that could be utilized for the full-scale IPR/RA facility. UV/AOP system selection was based on review of the system used at the Orange County Water District's (OCWD's) Groundwater Replenishment (GWR) System and consultation with representatives of Trojan, Inc., the UV System manufacturer. The proposed UV/AOP demonstration system is the UV Phox Model 72AL75, which is a single chamber version of the reactors used at OCWD. During the initial phase of testing, the ability of the unit to achieve 1.2-log (93.7%) removal of N-Nitrosodimethylamine (NDMA) at a flow of 1 MGD will be verified. Results obtained during initial testing will establish the power setting at which to operate the system for the remainder of the operations period.

- **Define vendor pre-qualification criteria for the full-scale AWP Facility.** As part of the testing program, vendor pre-qualification criteria will be developed for the full-scale AWP Facility. Testing will include two different low pressure (MF/UF) membranes and two different RO membranes. The performance of the Trojan UV Phox system will be monitored to access and gain further insight on AOP performance. Both water quality and operational performance observed during the demonstration plant study will be utilized to develop pre-qualification criteria for consideration during procurement of equipment for the full-scale facility. Though operation and testing of the AWP Facility will provide useful information to develop vendor pre-qualification criteria it is not intended to pre- qualify vendors for the potential full-scale AWP. Pre-qualification of vendors for the full scale AWP would require further evaluation outside the current scope of work.

- **Monitor and collect operational performance and maintenance requirements of the AWP Facility equipment -** During the testing period, key operational parameters and maintenance requirements of each unit process (MF/UF, RO and UV/AOP) will be monitored on a routine basis. This information will be evaluated to assess ways to improve operational efficiencies and provide a basis for estimating operations and maintenance (O&M) costs for the full-scale AWP Facility.

- **Evaluate the degradation and by-product formation of nitrosamines and 1, 4-dioxane by UV/AOP and compare alternative chloramines application conditions to mitigate NDMA formation.** Nitrosamines and 1,4-dioxane will be monitored in the AWP Facility product water by performing an initial spiking experiment and

performing quarterly sampling to demonstrate log removal requirements established by the CDPH and assess the ability of the treatment train to meet current notification limits, respectfully. In addition, possible by–products, that may form as a result of the oxidation of nitrosamines (*e.g. NDMA, NDBA, NDEA, NDPA, NMEA, NPIP, NYPR*) and 1, 4-dioxane will be evaluated during the testing period. Based on monitoring data from the AWP Facility and an initial literature review performed by the project team, bench-scale testing may be performed to simulate worse conditions to identify potential UV/AOP by-products and at what level and conditions they occur. Should bench testing be conducted, results may be used to adjust operating conditions for the UV/AOP component of the AWP Facility and tailor the monitoring program for the product water. As part of the overall T&M Plan, the use of pre-formed chloramines and sequential chloramines formed in-situ will be evaluated to reduce the formation potential of nitrosamine compounds due to chloramination upstream of the RO system, which is required to prevent biological fouling.

2.2 T&M Plan Development

Several sources of information serve as the basis of this T&M Plan, which include:

- Final Report of the *May 11-12, 2009 Meeting of the Independent Advisory Panel (IAP) for the City of San Diego IPR/RA Demonstration Project* (IAP Final Report), NWRI, September 2009.
- CDPH comments to the IAP Final Report, December 2009, and the City's response to comments, May 2010.
- City of San Diego, *Advanced Water Treatment Research Studies* conducted at the NCWRP, 2005.
- Final Report *Monitoring Strategies for CECs in Recycled Water, Recommendations of Science Advisory Panel*, SWRCB, June 25, 2010.
- CDPH Groundwater Recharge Reuse Draft Regulations, August 2008.
- IAP Subcommittee Findings and Recommendations of the Advanced Water Purification Facility Subcommittee Meeting, November 15, 2010, NWRI.
- Input received from the project team's Project Advisory Committee (PAC):
    - Professor Dr. Jörg Drewes, Advanced Water Technology Center (AQWATEC), Colorado School of Mines.
    - Professor Dr. Shane Snyder, University of Arizona, Arizona Laboratory for Emerging Contaminates.

- Professor Dr. Bill Cooper, University of California, Irvine, Urban Water Research Center.
- Professor Dr. Greg Leslie, UNSW Global, University of New South Wales.
- Ms. Margie Nellor, Nellor Environmental.

- Comments received from the IAP/CDPH/RWQCB on the *City of San Diego IPR/RA Demonstration Project Advanced Water Purification November 30, 2010 Final Draft Testing and Monitoring Plan.*

2.3 T&M Plan Organization

This T&M Plan conforms to the recommendations outlined in the IAP Final Report (September 2009), CDPH comments to the IAP Final Report (December 2009), and the City's response to CDPH comments (May 2010). The T&M Plan is organized as follows:

Section 1 - Background

Section 2 – Objectives, Development and Organization

Section 3 – Materials and Methods

Section 4 – Process Operation, Activities, and Schedule

Section 5 – Demonstration Facility Process Evaluation

Section 6 – Specialty Testing

Section 7 – Quality Assurance / Quality Control

Section 8 – Additional Scope of Services

Section 9 – References

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Section 3
Materials and Methods

3.1 Demonstration Testing Site

3.1.1 North City Water Reclamation Plant

The AWP Facility is located at the City of San Diego's North City Water Reclamation Plant (NCWRP) located at 4949 Eastgate Mall, San Diego, California 92121.

The NCWRP currently produces 22.5 MGD of recycled water of which approximately 7.3 MGD is used for the non-potable beneficial use in the surrounding area. NCWRP has a total design capacity of 30 MGD. The recycled water distribution system consists of approximately 83 miles of recycled water pipeline, two reservoirs and three pump stations.

A general schematic of the NCWRP treatment process is provided in **Figure 3-1.** As shown the AWP Facility will receive feed water from the tertiary filters, product water will be returned to the NCWRP recycled water upstream of the chlorine contact chamber.

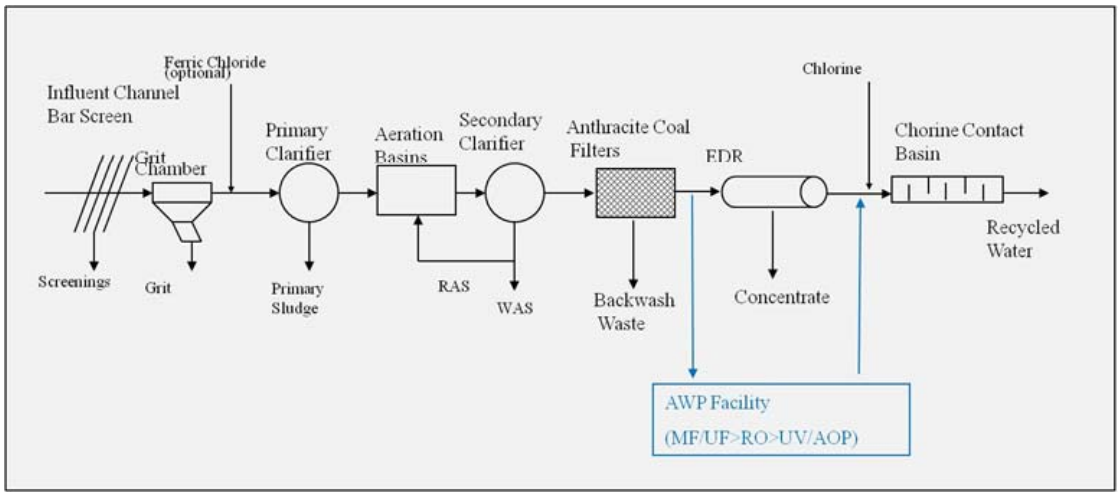

Figure 3-1
NCWRP Treatment Process

The NCWRP is a tertiary treatment plant and consists of the following major treatment processes:

- Influent headworks – consists of bar screen and grit chamber to remove large debris and coarse sediments.
- Primary Treatment – consists of primary sedimentation basins to remove settable solids not removed in the grit chamber.

- Secondary Treatment – consists of aeration basins (anoxic and aerobic) that promote biological treatment of wastewater through microbial decomposition and secondary clarifiers, which remove the settled activated sludge.
- Tertiary Treatment – consists of anthracite coal filters to remove particulate matter.
- Demineralization - utilizes electrodialysis reversal (EDR) for partial demineralization.
- Disinfection - consists of chlorine contact chambers where chlorine is applied to the water to kill bacteria and other microbes prior to distribution to recycled water customers through the recycled water distribution system.

The AWP Facility is located on a concrete pad adjacent to the existing EDRs #4 and #5. The new pad area is 3,800 square feet (50 feet x 76 feet). The western edge of the new pad houses the EDR unit #6 and is not part of this project. The operations trailer is located on the existing Research Pad, which has an area of 2,000 square feet (40 feet x 50 feet). An aerial photograph of the NCWRP showing the demonstration facility site in proximity to NCWRP unit processes is provided in **Figure 3-2**.

3.1.2 AWP Facility Layout

A layout of the AWP Facility showing the location of main components including equipment skids, chemical storage tanks, and the trench drain is provided in **Figure A-1 (Appendix A)**. The AWP Facility is laid out to facilitate public tours through the facility in order of treatment process: MF/UF, RO, and UV/AOP.

Both pads have steel frame roofs with 18 feet of vertical clearance. The Research Pad is equipped with lights, outlets, raceways, and electrical panels.

The AWP Facility is connected to the NCWRP product water by an 8-inch Schedule 80 polyvinyl chloride (PVC) pipe anticipated to deliver water to the demonstration plant at 980 gallons per minute (gpm) and a pressure between 50 to 70 pounds per square inch (psi). The water is delivered by the same pumps that feed EDRs #4, 5 and 6. Two drains are provided for liquid process and cleaning waste. The drains are routed overhead in the AWP Facility and EDR #6 areas and then routed below grade to discharge to an existing manhole. Water produced by the AWP Facility is discharged into the tertiary effluent piping upstream of the chlorine contact tanks. As with the drain piping, the product water piping is routed overhead in the AWP Facility and EDR #6 areas and then routed below grade to discharge into the existing product water pipeline.

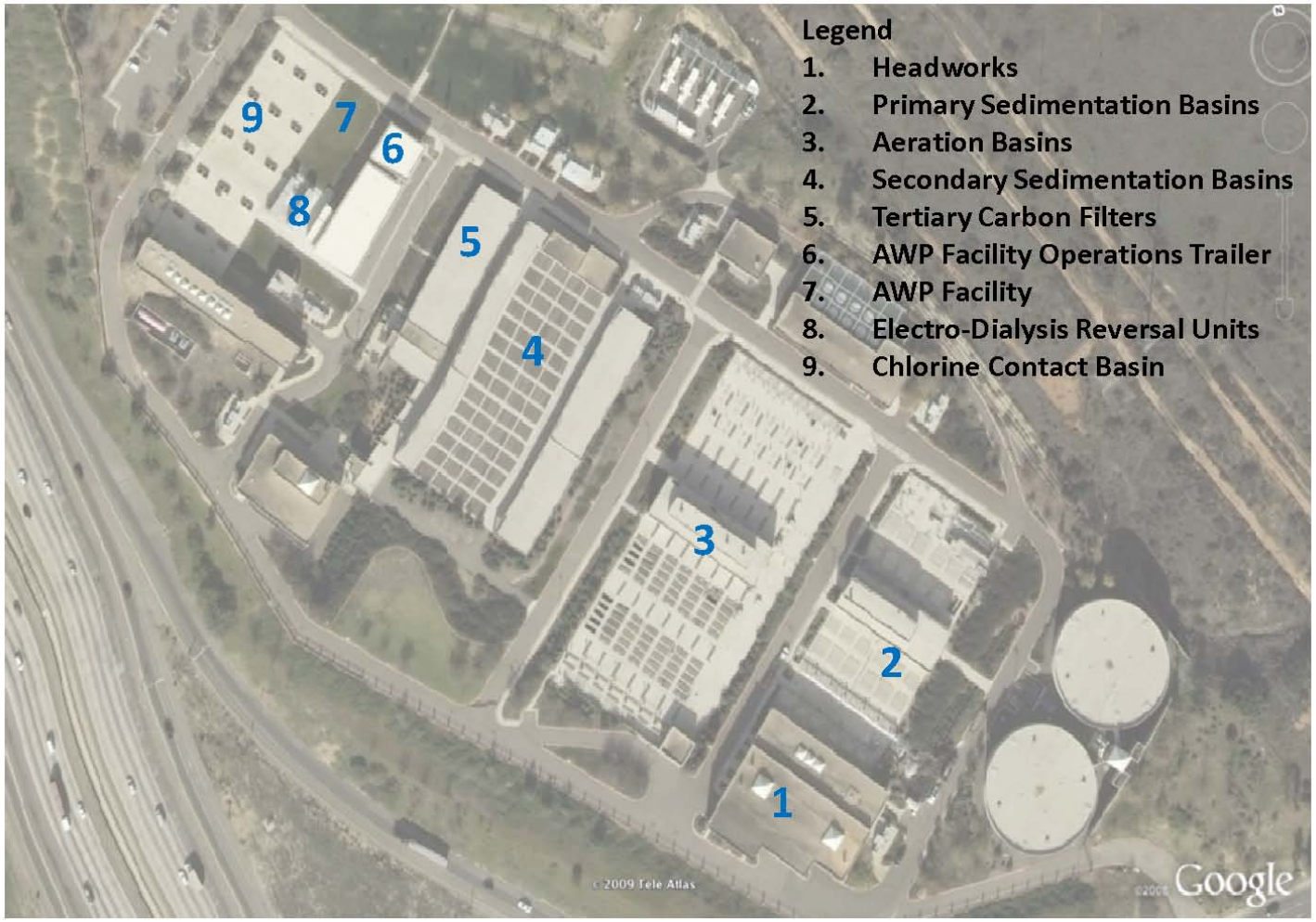

Figure 3-2
Aerial Photograph of the NCWRP

3.1.3 Feed Water Characteristics

The AWP Facility testing will be conducted using tertiary treated water (prior to chlorination and demineralization) from the NCWRP. **Table 3-1** presents water quality of disinfected tertiary filtered effluent based on data collected at NCWRP during the 2009 annual monitoring report. While the water quality shown in **Table 3-1** is based on measurements made post chlorination it should be representative (with the exception of microbial parameters: heterotrophic plate count, total coliform and total coliphage) of the filtered effluent which will be used during the testing.

Table 3-1
NCWRP Disinfected Effluent Water Quality Data

Parameter	Unit	Value
pH	--	7.13 [1]
TSS	mg/L	ND [1]
VSS	mg/L	ND [1]
Turbidity	NTU	0.63 [1]
Ammonia-N	mg/L	ND [2]
TKN	mg/L	ND [2]
Aluminum	µg/L	86 [1]
Arsenic	µg/L	0.58 [1]
Boron	µg/L	325 [1]
Chloride	mg/L	240 [1]
Sulfate	mg/L	217 [1]
Silica	mg/L	14 [4]
Iron (total)	µg/L	113 [1]
Calcium	mg/L	62.3 [1]
Magnesium	mg/L	26.7 [1]
Conductivity	micromhos/cm	1,530 [2]
TDS	mg/L	893 [1]
Hardness	mg/L	265 [1]
Alkalinity (bicarbonate)	mg/L	103 [1]
BOD	mg/L	ND [1]
HPC	cfu/mL	ND [3]
Total Coliphage	MPN/ 100mL	ND [3]
Total Coliforms	MPN/ 100mL	ND [1]

[1] Average value measured in December 2009, NCWRP Annual Monitoring Report
[2] Based on measurement October 6, 2009
[3] Based on data presented in Long Term Testing Experimental Plan (MWH, 2005)
[4] Based on average values collected July 14 - 19, 2005 (MWH, 2007)

3.1.3.1 NCWRP Operational Changes to Reduce Effluent Total Nitrogen

In January 2008 the City began a 12-month study to assess improving the NCWRP recycled water quality by enhancing the plant's denitrification process (Trussell et al., 2010). The purpose of this project was to document the plant's nitrogen removal performance over that time period and to provide recommendations to improve water quality and nitrogen removal. Results of the study produced five possible immediate action recommendations and two potential future capital improvements to further reduce total nitrogen. The five possible immediate actions include:

- Increase aeration solids retention time from 5.8 days to 10 days to ensure complete nitrification (< 1 mg/L of ammonia) and to encourage the filamentous bacteria growth which will increase sludge volume index (SVI).
- Take a primary sedimentation tank offline and cease the addition of coagulant to the primary treatment process, in order to increase primary effluent Biochemical Oxygen Demand (BOD).
- Bring down the dissolved oxygen (DO) set point to 1 mg/L to improve denitrification efficiency at the anoxic zones by carrying less oxygen in the internal recycling streams. Before changing the DO set point, preventive maintenance for the air control system should be performed to ensure accurate airflow control and avoid DO deficits at the aerobic zones. It is also recommended to first set the DO set point to 2 mg/L to make sure the DO controller is reliable before bringing the DO set point down to 1 mg/L.
- Lab use the Environmental Laboratory Accredited Program (ELAP) approved methods for nitrate analyses and elimination of weekly ammonia effluent sampling.
- Take two additional secondary sedimentation tanks offline, one tank at a time, to reduce energy and reduce maintenance costs.

The two potential future capital improvements to further reduce total nitrogen include:

- Increase anoxic volume from 20% to 40% of the total aeration volume to allow additional anoxic contact time for denitrification. With anoxic volume at 40%, a DO set point of 2 mg/L will be required to avoid air deficits at the aerobic zones.

Increase internal recycle rate from 1.6 times the average primary effluent flow to 3 times the average primary effluent flow to introduce more nitrates to the anoxic zone for oxidation of influent biodegradable organic matter. With the optimization of the NCWRP's operations per Trussell Technologies' recommendations, the nitrification process will be more stable and the total nitrogen should be reduced by approximately 10 to 15%. If all of Trussell Technologies recommendations, including

some capital improvement projects (CIP), were to be implemented then the total nitrogen in the NCWRP tertiary water could be reduced by more than 50%.

Figure 3-3 provides average monthly values of nitrate measured in the NCWRP between January 2010 and September 2010. As shown, the values have shown an overall decreasing trend with an average nitrate value of 11.5 mg-N/L based on samples measured between May 1 2010 to August 31 2010. This improvement is credited to on-going changes to the plant process per findings of the study described above. The changes are being made gradually with final adjustments to be completed in December 2010 prior to start up of the AWP Facility scheduled for February 2011. The ongoing enhancements may result in ultimate lower nitrogen values in the AWP Facility product water which is an important aspect over the overall IPR/RA project with respect to reservoir quality.

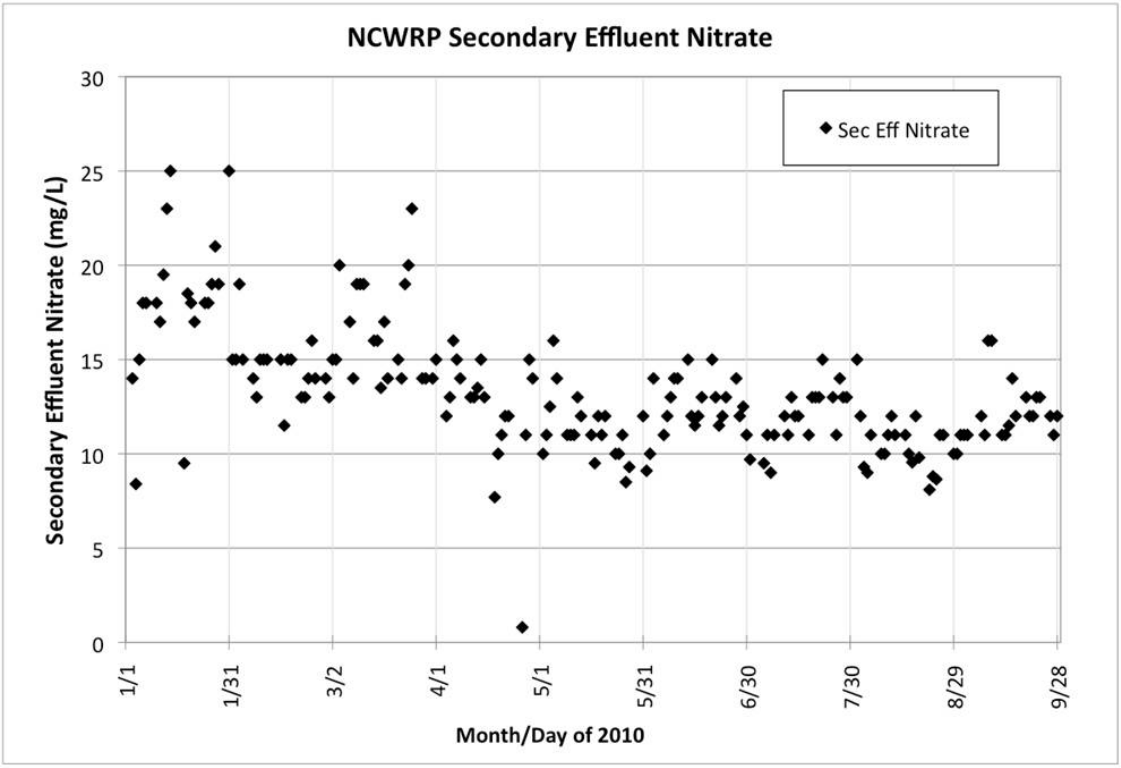

Figure 3-3
NCWRP Effluent Nitrate Data

3.1.3.2 CECs

A key component in characterizing the NCWRP tertiary water for the AWP Facility is analyzing the water for new classes of chemicals potentially impacting recycled water quality, or CECs. CECs include currently used pesticides, industrial chemicals, endocrine disrupting compounds (EDCs), and pharmaceuticals and personal care products (PPCPs). The majority of CECs are not part of the Citys NCWRP annual water quality monitoring; however, analysis for CECs in NCWRP tertiary water was

conducted as part of the City's AWT Research Studies conducted in 2005. **Table 3-2** presents concentration for 29 CEC compounds measured in the NCWRP tertiary water. As described later in **Section 5**, this data was considered during the development of the specific CEC monitoring plan for the AWP Facility.

Table 3-2
[1]NCWRP Tertiary Effluent Water CEC Data

Parameter	Unit	Value (3/23/05)	Value (4/13/05)
Hydrocodone	ng/L[2]	80	87
Trimethoprim	ng/L	383	346
Acetaminophen	ng/L	1	ND
Caffeine	ng/L	ND	ND
Erythromycin-H_2O	ng/L	335	311
Sulfamethoxazole	ng/L	758	817
Fluoxetine	ng/L	46	36
Pentoxifylline	ng/L	ND	ND
Meprobamate	ng/L	252	271
Dilantin	ng/L	133	117
TCEP	ng/L	353	225
Carbamazepine	ng/L	223	327
DEET	ng/L	146	393
Atrazine	ng/L	1	1
Diazepam	ng/L	4.5	1.2
Oxybenzone	ng/L	ND	1.4
Estriol	ng/L	ND	ND
Ethynylestradiol	ng/L	ND	ND
Estrone	ng/L	18	6.3
Estradiol	ng/L	ND	ND
Testosterone	ng/L	ND	ND
Progesterone	ng/L	ND	ND
Androstenedione	ng/L	4.4	4.9
Iopromide	ng/L	633	453
Naproxen	ng/L	48	23
Ibuprofen	ng/L	24	28
Diclofenac	ng/L	52	71
Triclosan	ng/L	94	171
Gemfibrozil	ng/L	146	222
NDMA	ng/L	14	23
1,4-Dioxane	µg/L[3]	43	ND

[1] Data Collected for the 2005 AWP Pilot Study (MWH, 2007)
[2] ng/L – nanograms per liter
[3] µg/L – micrograms per liter

3.1.3.3 NCWRP Collection System Catchment Area Investigation

Under a separate contract, the City recently completed a desktop study to identify specific contaminants of concern in the NCWRP collection system based on a survey of industrial dischargers. The final technical memorandum prepared by RMC (**provided in Appendix B**) provides results of data review conducted on 30 industries within the NCWRP collection system area categorized in the TM as follows:

- Two Class 1, federally regulated, pharmaceutical manufacturers;
- Twenty Class 2 industries with the greatest industrial wastewater flow; and
- Nine industries (mainly R&D) geographically clustered on Nancy Ridge Drive, including one Class 2 industry.

The major findings of the study include a comprehensive listing of chemicals used or stored by each facility. This list was reviewed by the project team in the development the T&M Plan for the AWP Facility provide in Section 5. Based on this review, it is recommend that the City follow up with two discharges (02-0730 and 02-0972) for further screening based on the number of reported compounds present. A first step would be to assemble flow data for each discharger, which could be either concentration or mass load estimates. Based on this information it may be possible for the City to identify specific contaminants to add to the monitoring program.

Under a separate contract, the City recently completed a desktop study to identify specific contaminants of concern in the NCWRP collection system based on a survey of industrial dischargers. The final technical memorandum prepared by RMC (provided in Appendix B) provides results of data review conducted on 30 industries within the NCWRP collection system area categorized in the TM as follows:

- All (total of 2) Class 1, federally regulated, pharmaceutical manufacturers;
- Twenty Class 2 industries with the greatest industrial wastewater flow; and
- Nine industries (mainly research and development) geographically clustered on Nancy Ridge Drive, including one Class 2 industry.

3.2 AWP Facility Configuration

This section includes information about the AWP Facility equipment and configuration, including the process flow diagram, information about the selected equipment, discussion of the dual-train configuration, and scale-up rationale and suitability for the equipment.

3.2.1 Process Flow Diagram

The AWP Facility with sample locations is shown on the process flow diagram provided in **Figure A-2** located in **Appendix A**.

3.2.1.1 Selected Equipment and Dual-Train Configuration

The AWP Facility is configured to test MF and UF side-by-side to allow comparison of their effectiveness for RO pretreatment. Operational performance parameters, such as flux, fouling, cleaning intervals, and chemical consumption, as well as filtrate water quality will be directly compared for the MF and UF.

Pall MF membranes were selected because Pall MF system has a strong record of reliability and membrane integrity at numerous reuse and drinking water facilities.

Toray UF membranes were selected for the UF system because these membranes are CDPH-certified, use PVDF material, similar to the Pall MF membranes, but have approximately a 5 times smaller pore size. Toray membranes can be used in a standardized skid configuration, which could accommodate UF membranes from Norit, Dow, or Toray. This provides flexibility with the AWP Facility if the City decides to test another UF manufacturer, and could also provide advantages for membrane replacement in the full-scale plant.

Chlorine and ammonia are injected in the common header pipe upstream of the MF and UF trains, for chloramination or break-point chlorination, to ensure that the feed water for MF and UF have the same water quality.

In addition, the AWP Facility is configured to test two 0.5 mgd capacity RO trains side-by-side to allow the following evaluation:

- Comparison of two different RO membranes to quantify the trade-offs between greater rejection and lower feedwater pressure; and
- Comparison of 2-stage and 3-stage configuration to quantify the impacts on energy recovery and fouling rate.

The two types of RO membranes selected for testing include the lower pressure, Hydranautics ESPA 2 membranes, and the higher pressure and higher rejection, Toray TML20-400 membranes. The Hydranautics ESPA 2 membranes are used in other advanced treatment facilities, such as OCWD's GWR System. The Toray membranes were selected as they are anticipated to have higher nitrate rejection than the Hydranautics membranes.

The MF and UF filtrate are combined in the MF/UF Filtrate Tanks, upstream of the RO, and antiscalant is injected in the common RO feed water pipe upstream of the RO feed pumps, to provide the same feed water quality to both RO trains. Providing each RO train the same quality feed water is critical to the above-listed evaluation to confirm that the differences in RO performance in the two trains are not attributable to the differences in feed water quality.

The RO permeate from the two RO trains are combined and treated through an AOP, comprised of ultraviolet light (UV) coupled with hydrogen peroxide (H_2O_2). Trojan

UVPhox™, a low pressure and high output (LPHO) UV system is used to demonstrate UV/H_2O_2 AOP. The advantages of LPHO UV include electrical efficiency, longer lamp life, narrower UV wavelength targeted for microbial destruction. Trojan LPHO UV systems have a proven history with advanced water treatment in California with systems installed at the OCWD GWR System, the West Basin Edward C. Little Water Recycling Facility, and the Water Replenishment District Leo J. Vander Lans Advanced Water Treatment Facility.

The sampling locations are also shown on **Figure A-2**. In addition to the 12 sampling points shown on **Figure A-2**, the sampling ports for the permeate from each RO membrane vessel of each train and the concentrate from each RO stage of each train will be provided on the RO skid.

3.2.2 Scale-Up Rationale and Suitability

The MF, UF, and RO systems are directly scalable to the full-scale plant. The systems can be scaled up or down based on the flux (i.e., by using the same flux tested in the AWP Facility for the full-scale plant). For a given flow, the desired flux could be achieved by adjusting the number of membrane elements provided (total membrane area).

Because of reactor hydraulics, the UV system is the most difficult process to scale-up from the AWP Facility to the full-scale plant. The larger the UV system, the more electrically efficient the system will be. If the AWP Facility UV system were scaled-up for the full-scale plant, then the full-scale system would be much more electrically inefficient than a system designed specifically for the full-scale plant. It is typical for the UV vendors to use bench scale testing, UV transmittance (UVT), contaminant removal goals, and computational fluid dynamics (CFD) modeling to size the UV systems. Therefore, the UV system for the AWP Facility is sized for the 1 MGD plant capacity and to achieve the NDMA and 1,4-dioxane reduction requirements in the 2008 draft CDPH regulations. The primary goal of the AWP Facility AOP system is to focus on demonstrating AOP effectiveness at the 1 MGD capacity to prove the required removal efficiencies to gain public acceptance.

It should be noted, it is not the goal of the UV/AOP demonstration testing to validate reactor performance for the potential the future full-scale AWP Facility. Validation testing of the exact reactor configuration designed for the full-scale AWP Facility would be required during plant commissioning. This would include verification the UV/AOP system can achieve log removal requirements for NDMA and 1, 4 dioxane as specified in the August 4, 2008 CDPH Draft Groundwater Recharge Regulations. **Appendix C** contains a TM provided by the project team to the City on May 21, 2010 which describes the selection process of the specific UV / AOP system unit to be tested as part of the demonstration testing. The City provided this memorandum to CDPH in June 2010 for review and comment.

3.3 Description of Certified Laboratories

For thorough water quality analysis, several different laboratories were selected to conduct analysis of samples collected during the demonstration period, which include MWH Laboratories, Weck Laboratories, Biovir Laboratories, and the AQWATEC Laboratory at the Colorado School of Mines. In addition, Laboratory Data Consultants, Inc. (LDC) was selected to perform data validation of the laboratory analyses. Selecting multiple laboratories allows for specific analysis to be performed by labs that specialize in that area, increasing accuracy and lowering detection levels. Additionally, multiple laboratories allows for labs with overlapping capabilities to perform redundant analysis for increased quality assurance (QA)/quality control (QC), via split sampling.

The commercial and specialty laboratories that will be used over the course of the testing period to perform water quality analysis per the T&M Plan are presented in **Section 5**. **Table 3-3** identifies the laboratories to be used, and provides specific information on their credentials and types of analysis they will perform as part of the test plan. The laboratories performing analysis of regulated compounds will utilize EPA-approved methods. Laboratories performing analysis on non-regulated compounds (e.g., CECs) were carefully selected based on use of peer-reviewed methods utilizing state of the art analytical equipment. Laboratory analysis data validation will be performed by LDC, Inc. as described in **Section 7.5**.

Table 3-3
Water Quality Analysis Laboratories and Data Validation

Laboratory Name and Address	Certifications / Credentials	Area of Specialty	Analysis to be Performed
MWH Laboratories 750 Royal Oaks Dr, Ste 100 Monrovia, CA 91016	CDPH NELAP USEPA UCMR2 WaterRF project 4176 – Principal Investigator	Potable and recycled water analysis, CECs	CECs UCMR3 QC Weck Lab Analysis
Weck Laboratories, Inc. 1489 E. Clark Ave City of Industry, CA 91745	CDPH NELAP USEPA UCMR2 California MBE	Water, soil, and hazardous waste analysis	General Parameters Federal and CA MCLs Priority Pollutants CDPH Notification Limits AOP Byproducts
Biovir Laboratories, Inc. 685 Stone Rd, Unit 6 Benicia, CA 94510	NELAC CDPH NELAP	Water microbiology	Coliphage
Colorado School of the Mines, Environmental Science and Engineering Dept / AQWATEC 1500 Illinois St Golden, CO 80401		Water quality issues and engineering solutions in indirect potable reuse	QC MWH CEC analysis
LDC, Inc. 7750 El Camino Real, Ste 2L Carlsbad, CA 92009	State of CA Certified Small Business	Data quality, data validation, and environmental chemistry	Laboratory sampling data validation
On-Site Laboratory Components	NA	Continuous process performance monitoring	Routine analysis of general water quality and process performance parameters

3.4 On-site Lab Description

The AWP Facility will include an operations trailer which will be used to house desks, lap top computers, filing cabinets and phones for on-site operations staff as well as an on-site laboratory. The on–site lab will be used to perform routine water quality analysis as identified in **Section 5**.

3.5 Description of AWP Facility Process Equipment

The following section describes the major AWP Facility process equipment including the MF/UF systems, RO systems and the UV/AOP system. Information is also

provided for ancillary equipment including strainers, chemical dosing systems, and on-line water quality monitoring instrumentation.

3.5.1 Pre-Filtration System

A pre-filter system will be used upstream of the MF/UF systems to remove particles present in the NCWRP tertiary water. Specifications for the filtration system are provided in **Table 3-4.**

Table 3-4
Technical Specification Pre-filtration System

Parameter	Unit	Toray	Pall
Manufacturer		Amiad	Amiad
Model	---	SAF 3000	Filtomat 014C
Maximum Flow Rate	USgpm	660	350
Minimum working pressure	psi	30	30
Maximum working pressure	psi	150	150
Filter Area	in2	465	232.5
Screen size	micron	150	300
Inlet / Outlet diameter	in	(3”, 4”, 6”)	(3”, 4”)
Maximum Temperature	°C	50	55
Weight (empty)	lb	232 (3”)	66 (3”)

3.5.2 MF/UF Systems

The MF system utilizes the Aria Water Treatment System manufactured by Pall Corporation (Port Washington, NY). The UF system is designed around a standardized skid(s) configuration which can accommodate several manufacturers’ membranes. Initially, UF membranes manufactured by Toray will be used and tested. The skid system has been designed and supplied by H2O Innovation (Poway, CA).

The major components of the MF/UF system are:

- MF/UF Skids;
- Reverse Flow system comprised of a reverse flow pump, reverse flow storage tank, pressure sensors and pressure switches;
- Compressed Air system comprised of rotary screw compressor, air receiver tanks, coalescing filters, pressure gauges, flow meters;
- Chemical, Hot Water and Neutralization System comprised of recirculation tank, heater, hot water transfer pumps, chemical transfer pump, flow switches, temperature gauges and transmitters and control panel;
- Chlorine injection system comprised of chlorine dosing pump, dilution tank, containment tank and calibration column;

- Sodium Metabisulfate feed system comprised of dosing pump, dilution tank, containment tank and calibration column; and
- Coagulant feed system comprised of dosing pump, dilution tank and containment tank.

The skids will be painted steel frames. **Table 3-5** provides general specifications for the MF/UF membranes.

Table 3-5
MF and UF Membrane Specifications

Manufacturer	Pall	Toray
Mode of Operation	Pressured/ Outside-in	Pressured/ Outside-in
Type	Aria packaged model AP-6	Toray membranes in standard skid
No. of Fibers per Module	6,350	
Membrane area per module	538 sq ft	775 sq ft
No. of modules per unit	48	32
Dimensions of modules	6” diameter x 80” long	
Removal Rating/Nominal pore size	0.1 um	0.02 um
Membrane material	PVDF	PVDF
Min/Max inlet Pressure	15/45 psi	15/45 psi
Maximum Operating Temperature	40 ° C	40 ° C

3.5.3 RO System

The major components of the RO system are:

- RO Skid;
- High Pressure Feed Pumps;
- Chemical pre-treatment anti-scalant system comprised of anti-scalant chemical pumps, chemical tank;
- Cleaning system comprised of RO cleaning storage tank, cleaning pump, immersion heater, bag filter unit, flow meters, pressure gauges and indicators, temperature gauges and indicators;
- Permeate flushing system comprised of a storage tank, flow meter and flushing pump;
- Sampling Panel; and
- Control Panel.

Skid Configuration

The RO system will consist of two independent trains housed on one skid designed and supplied by Enaqua (Poway, CA). The skids are composed of structural steel with baked epoxy and powdered coated for corrosion resistance. **Table 3-6** provides specifications of the RO skid.

Table 3-6
Technical Specification RO Membrane Skid

Parameter	Unit	Value
Approximate Dimension (LXWXH)	Feet	25X9X9
Number of Passes	----	1
Number of Trains	----	2
Train 1 array	----	11x6
Train 2 array	----	11x6x3
Train 1 Membranes per vessel	----	7
Train 2 Membranes per vessel	----	6

RO Membranes

Specifications for the RO membranes to be tested during the demonstration period are provided in **Table 3-7.**

Table 3-7
Technical Specification RO Membranes

Parameter	Unit	Hydranautics	Toray
Commercial designation	'------	ESPA2	TML
Membrane Material		Polyamide (thin film composite)	Polyamide (thin film composite)
Nominal membrane area per element	ft2	400	400
Operating pH Range		2-10.6	2-11
Cleaning pH Range		1-12	1-12
Maximum feedwater turbidity	Nephelometric Turbidity Units (NTU)	1	
Maximum feedwater SDI (15 min.with 0.45 micron)		5	5
Maximum Feed Water Chlorine Concentration		<0.1 parts per million (ppm)	ND
Maximum Operating Temperature	°F	113	113
Maximum Operating Pressure	psig	600	600
Spiral Wound Configuration			
Element length	Inches	40	40
Element diameter	Inches	7.89	7.9
Permeate channel diameter (O.D.)	Inches	1.125	1.125

3.5.4 UV-AOP System

The demonstration facility will utilize a UVPhox UV-oxidation treatment system by Trojan Technologies for UV treatment. The UV unit is a LPHO amalgam lamp system. The lamp power can be adjusted between 100% and 60% in 2% increments. General design criteria for the UV/AOP system are provided in **Table 3-8.**

Table 3-8
UV-AOP Design Criteria

Flow Rate	1 MGD
UVT @ 254 nm	95%
Target Contaminant	NDMA
Target Contaminant Reduction	1.2 Log NDMA Reduction
Target Contaminant	1,4 Dioxane
Target Contaminant Reduction	0.5 Log 1,4 Dioxane Reduction
Radical Parent Compound	Hydrogen Peroxide
Parent Compound Dose	3 mg/l

The UV system consists of the following major components:

- Trojan UVPhox Model 72AL75 stainless steel pressure reactor vessel; and
- H_2O_2 dosing and storage skid system – Includes metering pumps, H_2O_2 holding tank with double containment, and remote monitoring equipment.

Specifications for the UV /AOP system are provided in **Table 3-9**.

Table 3-9
Trojan UV System Specification

Parameter	**Unit**	**Value**
Manufacturer		Trojan Technologies, Inc
Model and ID Number		UVPhox Model 72AL75
Inside Diameter of Reactor	Inches	75
Lamp Type		LPHO
Enclosure Dimensions (HxWxD)	Inches	84x48x24
Overall Length	Inches	86
End Cap Diameter	Inches	41
Required end space for service	Inches	72

Table 3-9 Trojan UV System Specification		
Parameter	**Unit**	**Value**
Flange Size	Inches	(20,16,12,8)
Maximum Operation Pressure	Psi	65
Number of Lamps		72
Electrical Supply		480V, 3 phase
Approximate Panel Draw	kW	18.5
Weight: Dry/Wet	Lb	2100/3700

3.5.5 Auxiliary Systems

The demonstration facility will include several auxiliary systems including:

- Membrane CIP System (MF/UF and RO)
- Chemical Dosing systems
  1. Anti-Scalant
  2. Sulfuric Acid (if required)
  3. Coagulant (if required)
  4. Pre-formed Chloramines
- On-line Water Quality Monitoring Equipment
  1. Turbidimeters
  2. Conductivity/pH meters
  3. ORP Analyzer
  4. Chlorine Analyzers
  5. Total Organic Carbon (TOC) Analyzer
  6. Ultraviolet Transmittance (UVT) Analyzer

3.6 Integrity Monitoring Experimental Methods

Several integrity monitoring techniques will be employed during the demonstration testing period to assess the integrity of the MF/UF and RO membrane systems. Experimental methods for these techniques to be followed during the test period are

provided below. The integrity monitoring plan to be implemented during the testing and monitoring period is provided in **Section 5**. **Additional services related to integrity monitoring included November 30, 2010 Final Draft Testing and Monitoring Plan not in the current scope are provided in Section 8.**

3.6.1 Testing of RO Membranes Prior to Installation

As part of this demonstration testing program, RO membrane suppliers will be requested to provide the project team with vacuum decay or pressure hold test results on all membranes supplied for testing. In accordance to American Society for Testing and Materials (ASTM 2003) D3923-94 the acceptable pressure decay rate for RO membranes is 0.2 bar /minute. The manufacturers will be required to provide documentation that all membrane products meet or exceed these criteria. In addition, manufacturers will be requested to provide wet testing data for each membrane which includes measured salt rejection under set flow and recovery conditions. Lastly, the RO suppliers will also be requested to provide a statement that all membranes supplied for testing were selected randomly from a standard production lot.

3.6.2 Vessel Probing

Following complete installation of the membranes into each of the pressure vessels, conductivity probing will be conducted on each vessel to develop product water conductivity profiles.

The probing method to be employed was adapted from specific testing protocols developed by the project team and individual RO membrane manufacturers. (Adham et al., 1998c; Hydranautics 1998; Film Tec 2003). In general, conductivity measurements are made by taking grab samples at various locations along an individual pressure vessel during operation at set flow conditions. A general schematic of the conductivity probing set up which will be used during the test period is provided in **Figure 3-4.**

Each pressure vessel will be equipped with a ½ inch valve and tube connector located at one end to allow permeate samples to be taken from various locations. The location of each sampling point identified along a vessel (typical) is described in **Table 3-10**. Samples will be collected from each sampling point by letting product water flow for several minutes until values stabilize. Conductivity will be measured using a hand held conductivity meter.

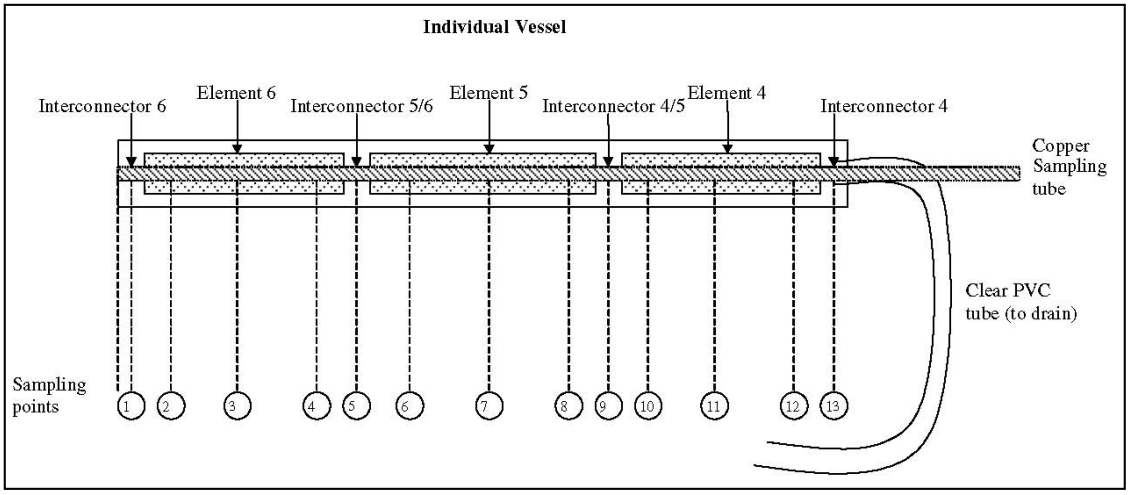

Figure 3-4
Example of RO Vessel Probing Set-up

Table 3-10 Vessel Conductivity Probing Sampling Locations		
Location Number	**Description**	**Approx. Distance from edge (Inches)**
1	Interconnector 1	3.75
2	Element 1 –12 inch off center	10.75
3	Element 1-center	22.75
4	Element 1-12 inch off center	34.75
5	Interconnector 1/2	42.75
6	Element 2-12 inch off center	50.75
7	Element 2 center	62.75
8	Element 2-12 inch off center	74.75
9	Interconnector 2/3	82.75
10	Element 3-12 inch off center	90.75
11	Element 3-center	102.75
12	Element 3-12 inch off center	114.75
13	Interconnector 3/4	122.75
14	Element 4-12 inch off center	130.75
15	Element 4-center	142.75
16	Element 4-12 inch off center	154.75
17	Interconnector 4/5	162.75
18	Element 5-12 inch off center	170.75
19	Element 5-center	182.75
20	Element 5-12 inch off center	194.75
21	Interconnector 5/6	202.75
22	Element 6-12 inch off center	210.75
23	Element 6-center	222.75
24	Element 6-12 inch off center	234.75
25	Interconnector 6/7	242.75
26	Element 7-12 inch off center	250.75
27	Element 7-center	262.75
28	Element 7-12 inch off center	274.75
29	Interconnector 7	282.75

Section 4
Process Operation, Activities and Schedule

4.1 Operational Test Plan

During the test period, the performance of the various unit processes of the AWP Facility treatment train will be evaluated at different conditions. **Table 4-1** provides values for various operational conditions associated with each unit process to be used over the test period.

Table 4-1
Operational Monitoring Parameters of the AWP Facility Treatment Train

Unit Process	Operational Criteria
Microfiltration / Ultrafiltration	*Pre-treatment*
	Pre-screen (300 micron)
	Free or combined chlorine dose = 3 mg/l
	Sulfuric Acid Dose = 0 to 50 mg/L
	Coagulant dose = 0 to 10 mg/L
	Membrane System
	Flow Mode = direct (dead end filtration)
	Maximum Instantaneous Flux = 30 gfd
	Minimum Feedwater Recovery = 95%
	Backwash Frequency = 15 to 30 min.
	Backwash Flow Rate = 520 to 680 gpm for 1 minute
Reverse Osmosis	*Pre-treatment*
	Anti-scalant dosing = 1 to 3 mg/L
RO System 1: Hydranautics ESPA 2	*Membrane System*
	Number of Stages: 2
	Flux (average)= 11.9 gfd
	Feedwater Recovery = 80%
RO System 2: Toray TML20-400	*Membrane System*
	Number of Stages: 3
	Flux (average)= 11.6 gfd
	Feedwater Recovery = 80%

Table 4-1 Operational Monitoring Parameters of the AWP Facility Treatment Train (Cont.)	
Ultraviolet / Advanced Oxidation	Influent Flow = 694 gpm
	Type of UV System= LPHO
	Number of Lamps= 72
	Watts per Lamp= 260 W
	Lamp power setting: 60 to 100%
	Hydrogen peroxide dose = 3 mg/L
	Total Power Draw= 18.5 kW

Testing of the AWP Facility is divided into several components including: Testing, Commissioning, and Start-up; Initial Testing Activities; Phase I Testing; Phase II Testing; and Phase III Testing. A description of each testing period is described below.

4.1.1 Testing, Commissioning, and Start-Up

A 30-day period has been designated to testing, commissioning, and start-up of the AWP Facility. A separate Start-Up Procedures and Operational Plan was developed as part of the project. This document includes details on field functional equipment testing, loop checks, system integration, and acceptance testing, equipment QA/QC, and calibration of instruments, gauges and meters.

4.1.2 Initial Testing Activities

A 10 week period has been designated to conducting initial test activities for the AWP Facility.

Tasks to be completed over this period for each unit process are summarized in **Table 4-2**. As shown, the integrity of the membrane systems will be checked by performing Online turbidity monitoring (MF/UF), Pressure Decay Tests (MF/UF), Online conductivity and TOC monitoring (RO) and vessel probing (RO). In addition, the productivity of the new membranes will be established by measuring the flux and pressure of the membranes. Lastly, the UV system will undergo check of the intensity sensor (if required) along with performance of NDMA spiking experiments to establish flow and power settings required for 1.2-log removal of NDMA. These settings will be used for remainder of the testing period.

Table 4-2 Initial Testing Activities	
Unit Process	**Testing Activity**
Microfiltration / Ultrafiltration	Pressure Decay Testing
	Flux Testing
	Calibrate Online Turbidimeters
Reverse Osmosis System (s)	Online Conductivity Monitoring
	Vessel Probing
	Set up chloramines dosing system
	Verify Pressure gage accuracy
	Set up online TOC Analyzer
Ultraviolet / Advanced Oxidation	Calibration of online UVT Analyzer
	NDMA Spiking experiment

Phase I Establishment of Baseline Operating Conditions

Phase I testing will include the operation of the Pall MF and Toray UF systems for a runtime of 60 to 90 days to establish baseline operating parameters including coagulant dose, flux, maintenance cleaning requirements and the feedwater recovery of each system. During this time, filtrate from the two low pressure (MF/UF) membrane systems will be combined to provide feed water to two RO systems, which will utilize Toray Model TML20-400 (Train B) and Hydranautics Model ESPA2 (Train A) membranes, respectfully. Product water from the two RO systems will be combined to supply feed water to the UV/AOP system. Upon completion of the Phase I testing period, all membrane systems will be cleaned, regardless of the degree of fouling that has occurred, to allow fouling trends during Phase II to be established using clean membranes.

During the initial period the MF and UF systems will be operated at a nominal flux and water recovery of 30 gallons per square foot per day (gfd) and 95%, respectively. The actual operating conditions will be based on recommendations provided by the manufacturers, based on the NCWRP tertiary water characteristics, historical performance of the membranes on similar waters and technical judgment of parameters that most likely will result in successful long term operation with minimal membrane cleanings. The performance under these conditions will be judged based on the success criteria and action plan shown in **Table 4-3**. During Phase I testing the MF and UF systems will be operated without the use of coagulant addition pretreatment. Should fouling exceed success criteria, coagulant dosing will be required per the manufacturer's recommendations.

During the initial operating period the Train A and Train B RO systems will be operated with a two and three-stage configuration , respectfully under the flux

conditions provided above and an equivalent recovery of 80%. During this time the pH of the feedwater will not be suppressed. Success criteria for the RO systems during Phase I is provided in **Table 4-3**. As shown, if the temperature corrected specific flux either membrane decreases by more that stated limit (after an initial cleaning) and/or the membranes do not produce filtrate total nitrogen (TN) requirement, the recovery for that system may be reduced to 75% for Phase II testing. In addition depending on the type of fouling observed it may be required to suppress the pH of the feed water using sulfuric acid. Note information gained during this time will also be used to adjust operational set points during Phase III of the AWP Facility testing.

During the initial test period the UV/AOP system will be operated under the manufacturers recommend lamp power and peroxide dose settings to achieve 1.2-log removal of NDMA and 0.5-log removal of 1,4-dioxane based on a flow rate of 1 MGD. The performance of the UV/AOP system at various power settings will be verified by conducting spiking experiments. During the initial test period lamp fouling and aging will be assessed per criteria list in **Table 4-3**.

Table 4-3
Phase I Success Criteria / Alternative Action Plan

Measured Parameter	Success Criteria (30 day runtime)	Options if Success Criteria not met
MF/UF Systems		
Increase in Temperature Corrected TMP	Max. Increase 20% (to be confirmed with mfg) from clean membrane TMP in 720 hours.	Perform CIP. Restart system. Lower flux. Add coagulant pre-treatment Phase II. Add chlorine to backwash (BW). Increase BW frequency
Pressure Decay (daily)	<1 psi /min	Repeat PDT test. Repair broken fibers. Check / repair leaks on air lines / fittings.
Turbidity	Filtrate not to exceed 0.15 NTU. Avg 24 hour <0.10 NTU for 95% of the time.	Perform maintenance / calibration of on-line turbidimeter. Perform PD test. Repair fibers.
SDI (207 kPa, 15 mins., 0.45 micron)	Filtrate < 3	Check / flush filtrate storage tank. Perform PD test. Repair fibers.
RO Systems (Toray TML/Hydranautics ESPA2)		
Decrease in Temperature Corrected Specific Flux	Max. 20% from clean membrane value	Clean membranes. Restart. Increase feed chloramines Reduce recovery Acidify feed

Table 4-3 **Phase I Success Criteria / Alternative Action Plan**		
RO Systems (Toray TML/Hydranautics ESPA2)		
Measured Parameter	**Success Criteria (30 day runtime)**	**Options if Success Criteria not met**
Decrease in conductivity rejection	Max. 0.5%	Profiling and probing of pressure vessels. Clean membranes. Restart if decrease occurs again reduce recovery to 75% for Phase II testing
Increase in Feed to Concentrate Differential Pressure (DP)	Max. 7% from initial conditions	Flush feed lines and feed tank. Clean membranes.
Total Nitrogen	Permeate NTE 0.5 mg/L TN	Reduce recovery. Change RO feedwater pH. Assess need for IX. Check for change in feed water concentration.
UV /AOP System		
Lamp fouling /aging	% drop intensity / delivered dose over 720 hours	Clean lamps; flush feed line, replace lamps if needed
Intensity Sensor	Within set % of reference sensor after 720 hours	Replace sensor.
NDMA	1.2 log removal	Adjust lamp power and / or flow settings. Check feedwater concentration: has it changed?
1,4 Dioxane	0.5 log removal	Adjust lamp power and / or flow settings; increase peroxide dose. Check feedwater concentration: has it changed?
Power Draw	~11 kw	Check power setting. Replace bad ballast(s) or lamp(s)
Hydrogen Peroxide Feed Concentration	3 mg/L	Check dosing pump / measure draw down/ adjust pump speed.

Phase II Steady State Operation

Phase II testing will be conducted over a target runtime of 208 days (~5,000 hours) to collect long term operational and water quality performance data of the MF/UF, and RO systems.

The 5,000 hours is based on target runtime of the MF/RO and UF/RO treatment trains at the design flow rate. The 5,000 hours does not include downtime due to routine shutdowns (e.g. maintenance, testing, cleanings, process modifications, etc. which may take from 2 hours to 36 hours). For example, if after operating for 500 hours of continuous operation any component of a train requires to be taken offline for a routine shutdown requiring 24 hours, upon start up the runtime clock for said train would begin at 500 hours. For non-routine events that result in downtimes exceeding 36 hours, the project team will meet with the City and their Project

Management consultant to discuss the most appropriate option to meeting the target 5,000 hours of runtime. Examples of non-routine event may an upset in the NCWRP that may impact the availability of tertiary water in terms of quantity and/or quality, damage to membranes due to chlorine, or irreversible fouling.

During Phase II a key focus of the RO monitoring will be to compare the nitrogen rejection, operating pressure and overall energy consumption of the two RO systems. The Toray TML membrane is designed for higher nitrate rejection but operates and higher pressure. The Phase II will also allow performance data to be collected on a two-stage versus three-stage system.

Phase III Collect Information on Improving Operational Efficiency

Time allowing, the final phase of the overall 12 month testing will be designated to gaining preliminary information on options for increasing efficiency the of the various unit processes based on information obtained during Phase II. Phase III will occur over an approximately 45 day period. Parameters to be considered include:

- Chemical usage
- Membrane flux, recovery
- Backwashing frequency
- Reduction of UV dose
- Others

Upon completion of Phase III testing, the project team will develop pre-qualification criteria to be considered during procurement of equipment for the full scale facility.

4.2 Chemical Addition

4.2.1 Chlorine Dosing/ Ammonium Hydroxide & Preformed Chloramines

During part of the testing phase, it is planned to dose free chlorine upstream of the MF and UF systems followed by ammonium hydroxide immediately downstream to form combined chloramines to inhibit microbial growth through the RO membranes. However, as part of the NDMA and Chloramines Investigation Plan provided in **Section 6**, trials with pre-formed chloramines dosed upstream of the MF/UF systems will also be tested to assess inhibition of NDMA formation. The dose rates will be set to 2 to 3 mg/L combined chlorine in the MF/ UF product.

4.2.2 Acid and Anti-scalant

RO performance projections indicate that fouling from calcium carbonate and calcium phosphate can be controlled for the NCWRP water at an 80% recovery without the

use of acid. An acid system will be provided should it be required at any point to maintain stable operation. Acid will be fed upstream of the MR/UF systems to prevent plugging of RO membranes from impurities in the acid solution.

Anti-scalant containing a dispersant will be added to the RO influent to minimize precipitation of soluble salts as well as disperse colloidal fouling. A nominal dose of 1 to 3 mg/L, per the manufacturer's recommendations, will be the starting point for anti-scalant design criteria. At least two different anti-scalants provided by different manufacturers will be tested over the demonstration period, including products from King Lee Technologies (San Diego, CA) and Avista Technologies, Inc. (San Marcos, CA).

4.2.3 Coagulant Dosing

Coagulant dosing will be tested as pretreatment to the UF system to enhance membrane productivity by increasing particle floc size, which can lead to decreased pore plugging, reduce cake layer resistance and increase backwashing efficiency. Typical coagulants and doses provided by the manufactures include Poly Aluminum Chloride at 0.5 – 1 mg/L as Al.

4.2.4 Hydrogen Peroxide Dosing

Hydrogen peroxide will be dosed upstream of the UV system to form free-hydroxyl radicals. These strong oxidizing agents will oxidize trace organics including UV photolysis products which can result in the re-formation of NDMA. The nominal dose of peroxide to be employed during normal operation based on experience at currently operating full scale AWP Facilities is 3 mg/L. However spiking experiments will be conducted to assess the impact of operating with lower peroxide dose on 1,4 dioxane removal. Reduction of peroxide dose may reduce the degree of by-product formation and result in overall O&M savings.

4.2.5 Chemical Cleaning of Membranes

The chemical cleaning of the MF/UF systems typically employs a chlorine soak (250 - 500 mg/L) followed by an acid (pH 2-3) cleaning soak. Each cleaning step includes a rinse and drain cycle before the membrane system is returned to operation. Past studies by the project team have shown the free chlorine residual of the filtrate returned to 0 mg/L after the filtration of 2.0 liters per square meter (L/m^2) per unit membrane area following the chlorine cleaning step and the pH returned to background levels after approximately 18 L/m^2 per unit membrane area following the acid cleaning step. This information will be used as a guideline to determine the need to waste filtrate after start up following a cleaning. Specific cleaning protocols to be followed during the testing period have been provided by the MF and UF system by Pall and Toray, respectfully, and are included in **Appendix E**.

The RO membranes will be cleaned using the manufacturers recommended chemical cleaning procedures. In general, the type and concentration of chemicals used for

cleaning RO membranes are specific to the type of fouling. For example, for organic fouling which can occur after long term operation of RO membranes on wastewater, cleaning solutions with a high pH (10 - 11) such as sodium hydroxide, in combination with sodium dodecysulfate, are required. A caustic (high pH) cleaning solution is also effective for removing silicates from RO membranes should silica scaling or fouling occur. However, for inorganic fouling, such as metal oxides, a low pH (4) cleaning using a weak acid such as citric acid is required. Specific cleaning protocols to be followed during the testing period have been provided by the RO membrane suppliers, Toray and Hydranautics, respectfully, are included in **Appendix E.**

4.2.6 Calculated Parameters

Membrane Systems

A number of calculated parameters will be needed to establish the performance of the MF, UF, and RO membrane systems. These calculated parameters are defined as follows:

Transmembrane Pressure (TMP)

The average net driving force for the MF/UF and RO membrane systems will be calculated according to the following equation:

$$P_{net} = \frac{(P_i + P_o)}{2} - P_p - \Delta\pi \qquad (1)$$

where,

P_{net}	=	net driving force
P_i	=	pressure at the inlet of the membrane module
P_o	=	pressure at the outlet of the membrane module
P_p	=	permeate pressure
$\Delta\pi$	=	net osmotic pressure of the feed and permeate

It should be noted that osmotic pressure for the MF and UF membranes is negligible since the membranes do not remove dissolved salts. Hence, the net driving force (Pnet) is referred to as the transmembrane pressure by neglecting the net osmotic pressure term from equation 1. Thus, equation 1 reduces to the following:

$$P_{tm} = \frac{(P_i + P_o)}{2} - P_p \qquad (2)$$

where,

Ptm = transmembrane pressure

For the RO membranes equation 1 will be used to determine net operating pressure. An integrated averaging factor (IAF) assuming 100% salt rejection can be used to estimate the average osmotic pressure as follows:

$$\Delta\pi = IAF\,\pi_f$$

where,

πf = osmotic pressure of the feed stream

IAF = Ln [1/(1-R)] / R, (R = recovery expressed as decimal) = 2.2 (for 85% recovery)

The following approximation can be used to determine osmotic pressure of the feed stream:

- 1,000 mg/L NaCl solution ~ 11.6 psi of osmotic pressure, π

A correlation between NaCl concentration and conductivity can be assumed (1.6 micromhos of conductivity = 1mg/l NaCl)

Temperature Adjustment for Flux Calculation

Temperature correction to 20°C for flux of the MF/UF membranes will be made according to Equation 3, which is based on the variation of water viscosity with temperature:

$$J_{tm}(\text{at}20°\text{C}) \equiv \frac{Qp \times e^{-0.0239\times(T-20)}}{S} \qquad (3)$$

Where,

J_{tm} = instantaneous flux, (L/h-m^2)

Q_p = permeate flow, (L/h)

T = temperature, (°C)

S = membrane surface area, (m^2)

Temperature corrections to 25°C for transmembrane flux of the RO membranes will be made according to the manufacturer's temperature correction factors.

Determination of Specific Flux

The specific flux or permeability is the relationship between flux and the net driving pressure. The relationship is defined by the formula:

$$J_{SP} = \frac{J_{tm}}{P_{Net}} \tag{4}$$

where,

J_{SP} = specific flux (lmh/bar)

Likewise, the temperature-corrected specific flux can be calculated using the temperature corrected flux.

Determination of Differential Pressure

Differential pressure of the RO membranes is the difference between the feed pressure and concentrate pressure, calculated as follows:

$$\Delta P = Pf - Pc \tag{5}$$

where,

ΔP = differential pressure

P_p = pressure measured in RO feed

P_c = pressure measured in RO concentrate

Because the differential pressure varies with flow rate and temperature in the spiral wound membrane, values should be normalized to compare measured values with initial values.

Normalized Differential Pressure

Differential pressure of the RO membranes can be normalized with respect to concentrate and permeate as follows:

Where,

$$\Delta Pn = \Delta P \frac{(2 * Q_{c0} + Q_{p0})^{1..5}}{(2 * Q_c + Q_p)^{1.5}} \quad (6)$$

ΔPn = normalized differential pressure (bar)

ΔP = differential pressure (bar)

Q_{c0} = initial concentrate flow (lpm)

Q_{p0} = initial permeate flow (lpm)

Determination of Feed Water Recovery (FWR)

The parameter "feed water recovery" (FWR) represents the net water production of the MF/UF and RO systems. The FWR will be calculated according to the following equation:

$$\text{FWR} = [1 - \frac{\text{Vol. of water was ted}}{\text{Vol. of raw water used}}] \text{ x } 100\% \quad (7)$$

FWR represents the percent recovery of feed water and accounts for: (1) the permeate water used for backwashing and maintenance cleaning of the membranes (MF/UF system only), and (2) the concentrate water bleed (RO system only).

Rejection

The rejection of constituents by MF/UF process will be calculated as follows:

$$R = (1 - \frac{C_p}{C_F}) * 100\ \% \quad (8)$$

Where:

R = Rejection,

C_p = Product water concentration, (mg/L)

C_F = Feed water concentration, (mg/L)

Normalized RO Salt Passage (Rejection)

Because temperature and flow impact salt passage through RO, salt rejection is normalized as follows:

$$SP_n = \left(\frac{Q_p}{Q_{pn}}\right) * \left(\frac{STCF_n}{STCF}\right) * SP \quad (9)$$

where,

SP_n = normalized salt passage (%)

SP_a = actual salt passage (%)

Qp = permeate flow rate measured at given temperature

Qp_n = permeate flow rate normalized to 25 deg C

$STCF_n$ = salt transport temperature correction factor at 25 deg C

STCF = salt transport temperature correction factor at given temperature

Actual salt passage through RO is impacted by the feedwater recovery and is calculated as follows:

$$SP_a = \left(\frac{C_p}{C_{fb}}\right) \quad (10)$$

Where,

SP_a = actual salt passage (%)

C_p = permeate concentration (mg/L)

C_{fb} = feed – concentrate concentration (mg/L) = C_f * IAF

R = Salt Rejection = (1 – SP) * 100

4.3 Testing & Activities Schedule

The schedule for the AWP Facility testing program is provided in **Figure 4-1**. The schedule covers a 24-month period and consists of Tasks 1-5, as described below.

Task 1 will include approximately 12-week period dedicated to the installation and start up of the demonstration equipment to be conducted by the project team's construction group. Starts up activities to be conducted for the 15-day period following equipment installation include: field functional equipment testing, loop checks, and system integration.

Task 2 includes a 12-month testing period of the AWPF which includes four phases. During the initial testing phase (10-weeks) specific testing, as provided in **Figure 4-1,** will be conducted to ensure the membrane processes are intact, determine flow and power settings for the UV/AOP system, optimize chloramines dosing, and assess performance of the systems under "new" conditions. Phase I Testing (12-weeks) is designed to establish baseline operating conditions and performance for each unit process. Specific acceptance criteria and "alterative action" plans for each unit process have been established for this time period as presented in **Table 4-3.** The focus of Phase II testing is to operate the membrane systems for 5,000 hour of operation under steady state conditions to monitor operational and water quality performance. Phase III (time allowing) is planned for 6 weeks to gain additional information on each unit processes based on information obtained during previous testing phase.

Task 3 allocates 6-months to continued operation of the AWP Facility primarily for public tours and education as well as optional additional testing to be conducted at the City's discretion.

Task 4 will span the entire demonstration testing period to assess the operational and water quality performance of the MF, UF, RO and UV/AOP systems. Quarterly progress reports will be produced throughout the 12 month test period. These reports will include valuable information including current performance data on all systems, changes to testing protocols, and overall progress. The PAC members will review the reports to ensure the quality of data and to make any suggestions regarding any necessary changes to the demonstration testing protocols. Should a drastic change occur in performance at any time during the test period the PAC would be notified and provided data immediately via email or telephone to ensure quick feedback on potential cause/solution of the problem. The City will also distribute these reports to the IAP members and Regulatory Agencies for review.

Task 5 allocates 12 months to allow for preparation of the final AWPF. This report shall contain experimental procedures and analytical methods used over the test

period, statistical and graphical representation of the results, interpretation of results, regulatory relevance of the results, and optimization of operating conditions.

Other Testing Activities - The schedule also identifies when the various components of the water quality monitoring program and integrity monitoring plan will be implemented. The water quality monitoring plan includes several components including: 1) routine sampling, 2) quarterly sampling, 3) initial CEC monitoring and 4) microbial monitoring As shown in **Figure 4-1**, the routine water quality sampling plan is scheduled to begin 6-weeks after the start of the 12 month test period to allow the treatment systems to stabilize and ensure they are operating at steady state to obtain representative data as recommended by the IAP in comments received on the November 30, 2010 Final Draft Testing and Monitoring Plan. Details on the water quality monitoring program and integrity testing plan are provided in **Section 5**.

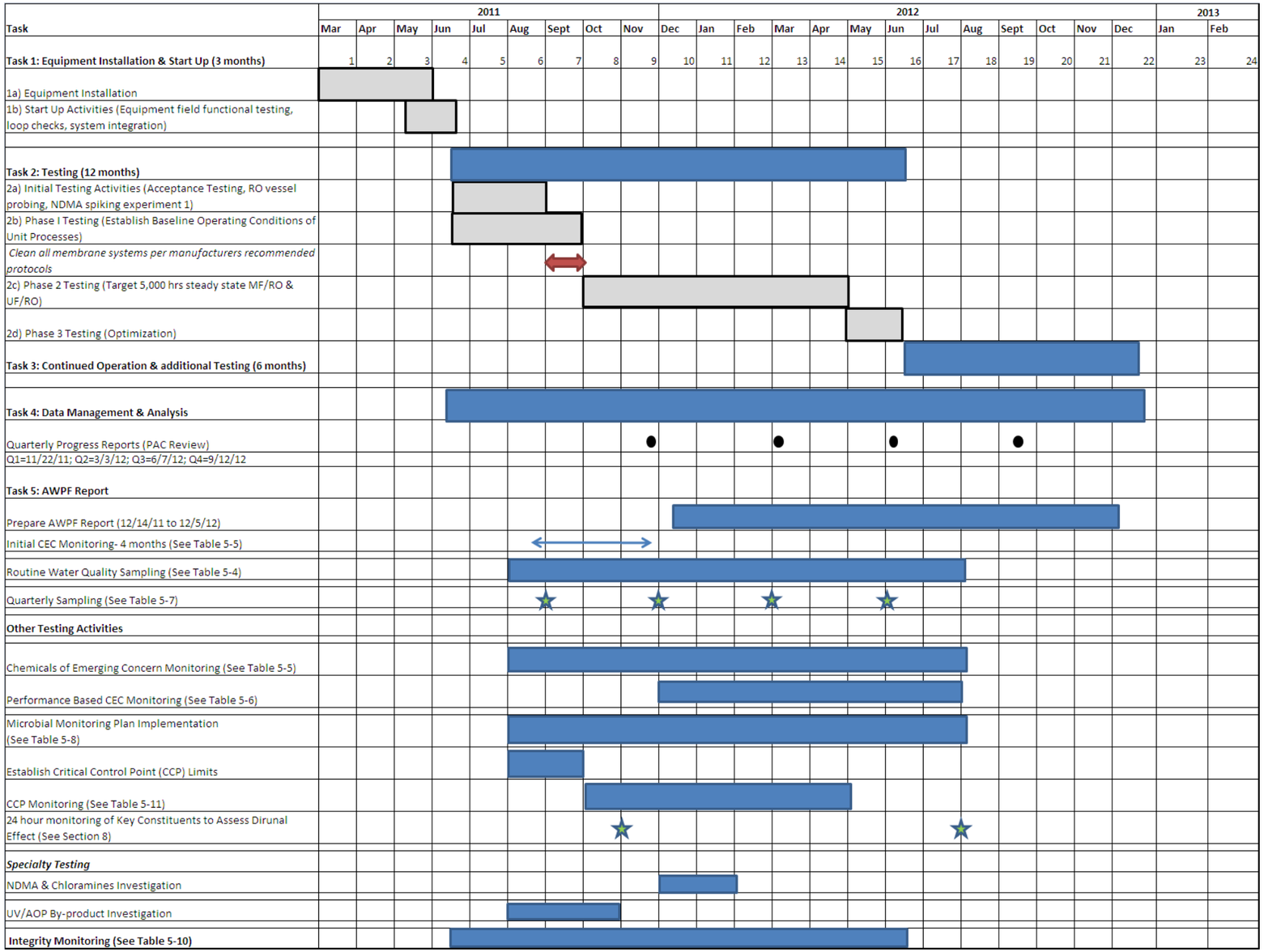

Figure 4-1
Testing Schedule City of San Diego AWP Facility

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4.4 Maintenance Requirements for Test Equipment

The maintenance requirements for the AWP Facility test equipment will be included in the vendor-supplied O&M manuals, which will be included in the Start-Up Procedures and Operational Plan. In general, the O&M manuals for the AWP Facility equipment will include the following information. This outline will be tailored for the specific equipment or skid.

1. System description
2. Installation instruction
3. Operations
    a. Start-up
    b. Shut down
    c. Normal operating conditions
    d. Membrane cleaning
4. Maintenance
    a. Spare Parts
    b. Lubricants
    c. Maintenance Records
5. Troubleshooting
6. Warranty

Table 4-4 summarizes the Demonstration Plant major equipment that will require maintenance during the 18-month operational period. The maintenance procedures for this equipment will be included in the Start-Up Procedures and Operational Plan.

Table 4-4
Demonstration Plant Major Equipment Requiring Maintenance

Skid or Equipment	Equipment Requiring Maintenance
MF Skid	Strainer Valves (automatic and manual) Backwash pump and motor Air compressor system and motor Turbidimeter
UF Skid	Strainer Valves (automatic and manual) Backwash pump and motor Air compressor system Turbidimeter
RO Skid	RO feed pumps and motor RO flush pumps and motor Energy recovery system Flow meters Valves (automatic and manual)
UV Skid	UV lamps, Peroxide dosing system, Intensity Sensor
CIP System	CIP pump and motor CIP tank heater Valves (automatic and manual)
Chemical Systems (sulfuric acid, sodium hypochlorite, ammonium hydroxide, antiscalant, and hydrogen peroxide)	Chemical pumps Anti-Siphon valves Pressure Relief valves
Tanks	Valves Level indicators
Sump Pump	Sump pump and motors
Other	Pressure reducing valves (PRVs) on MF and UF influent piping Flow meters Valves (automatic and manual) Pressure Relief valve
Online Instruments	pH/temperature meter Chlorine analyzer ORP analyzer Conductivity analyzer
Field Instruments and Analytical Equipment	See Table 5-3.

4.5 Residuals Management Plan for Process and Cleaning Wastes

This section identifies the residuals that will be generated from the AWP Facility and how the residuals will be managed. **Table 4-5** identifies the process and cleaning wastes that will be generated from the AWP Facility, the frequency of flow (i.e., continuous or intermittent), and the discharge point.

Table 4-5
Residuals Management Plan for Process and Cleaning Wastes

Process and Cleaning Wastes	Continuous (C) or Intermittent (I)	Discharge Point
MF & UF Skids		
Automatic strainer backwash	I	Hard piped to trench drain, pumped to existing 8" AWT SDR with sump pump
MF/UF backwash	I	Hard piped to existing 8" AWT SDR from the MF and UF skids through overhead piping (not pumped with sump pump), drains by gravity (no back pressure on this line)
Chemically enhanced backwash (CEB)	I	Hard piped to existing 8" AWT SDR from the MF and UF skids (not pumped with sump pump)
RO Skid		
Concentrate	C	Hard piped to existing 8" AWT SDR from the RO skid (not pumped with sump pump)
Permeate flush	I	Hard piped to existing 8" AWT SDR from the RO skid (not pumped with sump pump)
MF/UF filtrate tank and RO permeate tank, drains and overflows	I	Temporary piping to trench drain from tank drain when needed, modulate drain flow with tank drain valve so do not overflow sump, pumped to existing 8" AWT SDR with sump pump
Clean-in-place (CIP) tank, drains and overflows[1]	I	Pumped to the existing 8" AWT SDR from the CIP tank by the CIP pumps
Washdown water	I	Drain by gravity across pad to trench drain, pumped to existing 8" AWT SDR with sump pump
Chemical wastes (residual chemicals remaining at end of plant operational period)	I	If there are residual chemicals at the end of the Demonstration Plant operational period, determine if the City can use them in their process or return to chemical vendors

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Section 5
AWP Facility Process Evaluation

5.1 Operational Performance Monitoring

The operational performance of each unit process will be monitored by taking frequent manual readings and downloading data from the Supervisory Control and Data Acquisition (SCADA) system. **Table 5-1** provides specific parameters to be monitored from each system along with the manual monitoring frequency of each parameter. Parameters collected by SCADA will be recorded every 2 to 5 minutes and downloaded routinely and as needed. The manual data collection sheets to be used for each unit process are provided in **Appendix F**.

Table 5-1
Operational Monitoring Parameters of the AWP Facility Treatment Train

Monitoring Parameter	Location	Frequency
MF/UF Systems		
Temperature	Feed	1/day
Flow Rate	Permeate, backwash, chemical dosing pumps	1/day
Chlorine Concentration	Permeate (Filtrate)	1/day
Pressure (before and after backwash)	Feed, permeate (Filtrate)	1/day
Power	Main supply	1/day
Reverse Osmosis Systems		
Temperature	Feed	2/day
Flow Rate	Permeate (stage 1/ stage 2 / stage 3), combined, acid dosing pump, anti-scalant dosing pump	1/week
Pressure	Feed, permeate, concentrate (Stage 1 / Stage 2 / Stage 3)	2/day
Conductivity	Feed, permeate (stage 1,2 3 and combined)	2/day
Power	Main supply	2/day
UV/AOP System		
[1] Power	Lamp input	2/day
[2]UV Intensity	UV Chamber/Intensity Sensor	2/day
UV Transmittance	Feed	2/day
Flow rate	Feed, peroxide dosing pump	1/day

[1] A power factor adjustment will be requested from Trojan to estimate full scale power usage of the UV/AOP system based on actual power usage of the demonstration system. [2] Once per quarter the accuracy of the online UV intensity sensor will checked using a reference sensor

Operational data collected from the various unit processes will be used to calculate key performance parameters. Membrane fouling associated with the MF, UF and RO systems will be assessed by monitoring temperature corrected specific flux and TMP throughout the test period. A decrease in the temperature corrected specific flux under constant flux operation will indicate membrane fouling is occurring. When the acceptable drop in temperature corrected flux or maximum TMP level has been reached over the specified time period provided in Table 4-3, membrane cleaning will be performed. RO performance will also be assessed by monitoring the feed to concentrate DP normalized to initial DP values. An increase in normalized DP values with operation time will indicate the feed channels of the membranes have become plugged making it necessary to perform membrane cleaning. In addition, the conductivity rejection of the RO membranes will be continuously monitored. A significant decrease in conductivity rejection will necessitate membrane cleaning or repair of damaged o-rings, as appropriate.

Operational data collected from the UV system will be used to assess fouling and aging associated with UV lamps and intensity sensors along with lamp wiper efficiency. On a quarterly basis the UV intensity sensor will be verified using a reference sensor to assess its accuracy.

5.2 Water Quality Performance Monitoring

The following section outlines the specific treated water quality goals of the AWP Facility based on existing recycled water regulations, as well as anticipated future regulatory requirements specific to the City's proposed full-scale AWP Facility, which would be used to augment the current raw drinking water source at San Vicente Reservoir. The overall approach for water quality performance demonstration monitoring is to collect water quality data at different locations throughout the AWP Facility treatment process to analyze process performance, and to compare treated water quality to objectives, screening levels, and existing water supplies. This water quality monitoring program has four main objectives:

- Assess the overall AWP Facility treatment trains ability to meet the established and anticipated treated water quality goals relevant to the full scale AWP Facility surface water augmentation of San Vicente Reservoir.
- Monitor water quality throughout the treatment train to assess performance and efficiency of each unit process.
- Identify CECs in NCWRP tertiary effluent and evaluate removal efficiency of those CECs by the AWP Facility system.
- Compare AWP Facility system end-of-pipe water quality to the water quality of the City's existing raw water supply.

The water quality monitoring will be conducted through sampling and analysis of AWP Facility system water, at various points through the treatment process, by both

on-site and off-site laboratory facilities. Water quality parameters that need to bedetermined frequently to control the operation of the treatment process will be analyzed on-site using batch, on-line, and/or portable water quality test units. On-site monitoring will typically be conducted on a daily basis. Water quality parameters that do not require daily monitoring will be analyzed through sampling sent to one of four off-site laboratories. Off-site facilities utilized in this monitoring program will be MWH Labs, Weck Labs, Biovir Labs, and the Colorado School of Mines Laboratory. For a discussion of qualifications and certifications of each of these facilities, refer to **Section 3**.

Individual analytical parameters are chosen for several different reasons as listed:

- Indicators that assist in monitoring AWP Facility performance;
- Federal and/or state regulated constituents;
- Constituents that are monitored at the request of federal and/or state regulators, but not regulated; and
- CECs as identified by the Recycled Water Science Advisory Panel convened by the SWRCB.

The water quality monitoring plan contains four individual components, which are identified below and described in detailed referenced Sections.

- Routine Water Quality Sampling Plan (Section 5.2.2)
- Chemicals of Emerging Concern Monitoring Plan (Section 5.2.3)
- Quarterly Monitoring Plan (Section 5.2.4)
- Microbial Monitoring Plan (Section 5.2.5)

Note: the specific sampling regimes associated with the various components of the overall water quality sampling plan listed above are subject to modification throughout the testing period based on the project team's assessment of analytical results, comments received from the reviewers of the Quarterly Progress reports and development of regulatory requirements for the potential full scale project. Such changes will be documented in the Quarterly Progress reports and adjustments will be made to the existing sampling regime to ensure the overall analytical budget is not exceeded. Changes which require an increase in the analytical budget would be presented to the City for approval prior to implementation.

5.2.1 Treated Water Quality Goals

The City's IPR/RA AWP Facility includes three separately contracted tasks by others that are underway, but not yet completed. These tasks will provide key information that will shape the final regulatory-based water quality goals for the AWP Facility at NCWRP. The three tasks are:

- Defining state and federal regulatory requirements for a full-scale project;
- Performing a limnology and reservoir study for the San Vicente Reservoir, which will provide recommendations related to controls for nutrients; and
- Providing an independent expert review of the technical, scientific, and regulatory aspects of the project by the IAP.

Since this work is still underway, it is not feasible at this time to define the ultimate regulatory-based water quality goals for the demonstration plant. However, proposed interim goals are presented here for review by CDPH, RWQCB and the IAP as described below.

Regulatory Requirements

The overall purpose of the demonstration project is to prove that the AWP Facility meets all federal and state regulatory requirements that would be applied to a full-scale project as permit limits. These requirements would be primarily based on:

- The CDPH requirements for use of recycled water for nonrestricted recreational impoundments. These regulations require that recycled water meet the requirements for disinfected tertiary effluent, which will be met by the AWP Facility based on design.
- Recommendations from CDPH regarding the use of recycled water for surface water augmentation. CDPH is currently developing draft regulations for this use, but has not yet released a draft for public review. For the time being, a reasonable assumption is that the CDPH treatment conditions for the OCWD's GWR System for 100% reuse of advanced treated recycled water for groundwater recharge can be used as interim requirements in evaluating the AWP Facility. These treatment requirements are:
    - Compliance with primary and secondary drinking water maximum contaminant levels (MCLs) in the final recycled water.
    - TN cannot exceed 5 mg/L.

- TOC cannot exceed 0.5 mg/L divided by the CDPH-specified maximum average Recycled Water Contribution (RWC)[1]. Based on the OCWD's RWC of 100 percent, the TOC cannot exceed 0.5 mg/L.
- The turbidity of the RO product water cannot exceed 0.2 NTU more than 5 percent of the time in any 24-hour period and can never exceed 0.5 NTU at any time.
- The RO permeate UV transmittance must be 90 percent or greater at 254 nanometers (nm).
- The final recycled water must be disinfected such that the 7-day median number of total coliforms cannot exceed 2.2 total coliform bacteria per 100 mL and the number of total coliform organisms cannot exceed 23 total coliform bacteria per 100 mL in more than one sample in any 30-day period.
- AOP must achieve at a minimum a 1.2 log NDMA reduction and 0.5 log 1,4-dioxane reduction, whether NDMA and 1,4-dixoane are present or not.

- The Basin Plan, including designated beneficial uses of the San Vicente Reservoir, water quality objectives to protect those uses, the state anti-degradation policy for surface water, and toxicity requirements (including applicable federal and state standards). The Basin Plan establishes beneficial uses for surface waters and groundwater in the region and numeric and narrative water quality objectives to protect those uses. Permit limits are established for those constituents that have the reasonable potential to cause or contribute to an excursion above any water quality objective. The Basin Plan allows for a mixing zone (e.g., dilution factor) to be considered for inland surface waters on a case-by-case basis. If a dilution factor is approved, the permit limit (and reasonable potential evaluation) could be based on this simplified modification of the water quality objectives in the Basin Plan[2]:

  Ce = Co + Dm (Co)
  where
  Ce = the effluent limitation
  Co = the water quality objective to be met at the completion of initial dilution
  Dm = minimum probable initial dilution expressed as parts water per part wastewater (the Dm is not the same as the CDPH RWC)

The designated beneficial uses of San Vicente Reservoir are:

- Municipal and Domestic Supply (MUN).

[1] The maximum RWC has not yet been established for the project and is dependent on the outcome of the limnology studies.
[2] This calculation does not consider ambient concentrations of constituents. It will be necessary to work out how a mixing zone would be specifically (if at all) with the RWQCB. For example: Ce = Co + Dm (Co – Cs), where Cs is the background surface water concentration (which must be less than the Co).

- Agricultural Supply (AGR).
- Industrial Process Supply (PROC).
- Industrial Service Supply (IND).
- Contact Water Recreation: fishing from shore or boat is permitted, but other water contact recreational (REC-1) uses are prohibited. However, per Section 115840(a) of the Health and Safety Code, CDPH allows the reservoir to be used for body contract recreation, and thus other REC-1 uses apply.
- Non-body Contact Water Recreation (REC-2).
- Warm Freshwater Habitat (WARM).
- Cold Freshwater Habitat (COLD).
- Wildlife Habitat (WILD)
- Applicable numeric water quality objectives in the Basin Plan include: Total dissolved solids (TDS), chloride, sulfate, percent sodium, iron, manganese, boron, turbidity, color, fluoride, nutrients (nitrogen and phosphorus), unionized ammonia, fecal coliform, dissolved oxygen, pH, primary and secondary MCLs, and phenolic compounds. These requirements are presented in **Appendix G**.

Narrative water quality objectives have been established for oil and grease, pesticides, radionuclides, sediment, suspended and settleable solids, taste and odor, temperature, and toxicity.

Narrative and numeric nutrient requirements are included in the Basin Plan. For waste discharge requirements established for reclaimed water discharges to surface water such as the San Vicente Reservoir, the Basin Plan allows the RWQCB to use the phosphorus goal for flowing waters (0.1 mg/L) as a guideline or to determine compliance with the narrative objective using four factors, including use of best available technology (BAT) economically feasible for the removal of nutrients. Additional input on potential nutrient requirements (including phosphorus and nitrogen) will be available in approximately 6 months after completion and review of the limnology study results.

- Water quality criteria established for priority pollutants by the U.S. Environmental Protection Agency (USEPA). The Clean Water Act (CWA) requires states to adopt numeric water quality criteria for those toxic pollutants which the USEPA has issued advisory CWA 304(a) criteria and which may reasonably be expected to interfere with the maintenance of designated beneficial uses. In 1991, California adopted water quality "objectives" (equivalent to the federal "criteria" component

of federal water quality standards) for a number (but not all) of the priority pollutants designated by USEPA in the Inland Surface Waters Plan (ISWP) and Enclosed Bays and Estuaries Plan (EBEP). After adoption, USEPA disapproved portions of the plans because California had not had not issued objectives for all of the priority pollutants. In 1992, USEPA promulgated the National Toxics Rule (NTR) to bring non-complying states into compliance with the CWA. The 1992 NTR established federal standards in California for roughly 40 priority pollutants not covered in the ISWP and EBEP. In 1994, the ISWP and EBEP were overturned in state court in due to failure of the SWRCB to comply with state law in adopting the objectives contained in the plans. In 1995, USEPA elected to proceed with adopting the CWA 304(a) water quality criteria for California.

In 2000, USEPA promulgated the California Toxics Rule, that that included aquatic life criteria for 23 priority pollutants and human health criteria for 57 priority pollutants. In adopting criteria in the CTR, the USEPA updated some of the CWA 304(a) criteria based on new or revised reference doses and cancer potency factors and updated aquatic life toxicity data sets. The human health criteria are comprised of two categories. First are the "water and organism" criteria, which are based on a cancer risk of 10^{-6} and an assumed exposure through consumption of drinking water and eating fish. The "water and organism" criteria are applied to protection of MUN beneficial uses. Second are the "organism only" criteria, which are based on a cancer risk of 10^{-6} and an assumed exposure through eating fish. The "organism only" criteria are applied to protection of REC-1 and REC-2 beneficial uses. The aquatic life criteria are based on toxicity and are applied to pertinent wildlife beneficial uses. For any "discharge" to a water of the United States, the most stringent criteria for all beneficial uses must be met. The CTR criteria are presented in **Appendix G**.

- Implementation procedures for the CTR established by the SWRCB through the Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California (SIP). The SIP includes i) procedures to determine which priority pollutants need effluent limitations (e.g., reasonable potential analysis), ii) methods to calculate water quality-based effluent limitations, and iii) policies regarding mixing zones, metals translators, monitoring, pollution prevention, reporting levels for determining compliance, and whole effluent toxicity control. Permit limits are established for those CTR constituents that have the reasonable potential to cause or contribute to an excursion above any applicable criteria including consideration of dilution (Section 1.3 of the SIP). If a dilution factor is approved, the permit limit would be based on this modification of the water quality criteria in addition to other factors as set forth in Section 1.4 of the SIP.

Water Quality Goals for Regulated Constituents

As part of the AWP Facility demonstration study, two types of monitoring activities will be undertaken for regulated parameters:

- Collection of data for all regulated parameters in the final product water and/or designated points in the treatment process. These data will be compared to anticipated limits. It is expected that for the most part, these constituents will be below reporting levels.

- Targeted collection of data for key regulated compounds (target constituents) to optimize treatment as discussed below.

A review of pilot plant data collected for the City of San Diego Advanced Water Treatment Research Studies (MWH, 2007), provides insight on those regulated compounds that should be more closely evaluated for the demonstration testing (e.g., those compounds that potentially provide a challenge to the treatment process). The goals established for the proposed target constituents will differ from the regulated limits. These goals have been established to ensure optimization of the various treatment processes rather than to establish specific goals for a future full scale AWP Facility. It is expected that additional input will be provided on target constituents based on review by CDPH and the IAP.

Table 5-2 presents a preliminary set of target constituents, anticipated regulatory requirements and proposed demonstration goals.

Table 5-2 Anticipated Water Quality Goals for Regulated Constituents: San Diego AWP Facility

Constituent	Units	Proposed Demonstration Goal (average)	Anticipated Regulatory Limit (maximum)	Basis	Critical Beneficial Use/Issue
Total organic carbon (TOC)	mg/L	0.5	[1]0.5	CDPH	MUN
Ammonia (unionized as N)	ug/L	25	25 or Ce=25+Dm(25)	Basin Plan	Habitat
Nitrate (as N)	mg/L	[2]1	10 or Ce=10+Dm(10)	CDPH & Basin Plan	MUN
Total nitrogen	ug/L	[2]1000	[1]5000	CDPH	MUN
			[1,2]1000	Basin Plan	Biostimulation
Total phosphorus	ug/L	[2]100	[1,2]100	Basin Plan	Biostimulation
N-nitrodisodimethylamine (NDMA)	Log reduction	> 1.2-log	[1]1.2- log	CDPH	MUN
	ng/L	Not detected	[3]0.69 or Ce=0.69+Dm(0.69)	CTR/SIP	
1,4-Dioxane	Log reduction	> 0.5-log	[1]0.5- log	CDPH	MUN
1,2-Dichloroethane	ug/L	< 0.38	[3]0.38 or Ce=0.38+Dm(0.38)	California Toxics Rule	MUN
Total trihalomethanes	ug/L	< 80	[1]80	CDPH	MUN
Bromoform	ug/L	Not detected	[3]4.3 or Ce=4.3+Dm(4.3)	California Toxics Rule	MUN
Chlorodibromomethane	ug/L	Not detected	[3]0.401 or Ce=0.401+Dm(0.401)	California Toxics Rule	MUN
Dichlorobromomethane	ug/L	Not detected	[3]0.56 or Ce=0.56+Dm(0.56)	California Toxics Rule	MUN
Halo acetic acid (HAA)	ug/L	< 60	[1]60	CDPH	MUN
Methylene chloride	ug/L	< 4.7	[3]4.7 or Ce=4.7+Dm(4.7)	California Toxics Rule	MUN
Turbidity	NTU	< 0.2	[1]0.2	CDPH	MUN
Chloride	mg/L	50	[3]50 or Ce=50+Dm(50)	Basin Plan	MUN
Total dissolved solids (TDS)	mg/L	300	[3]300 or Ce=300+Dm(300)	Basin Plan	MUN

1. Potential limit based on best available information developed to date. Value subject to change.
2. Tentative goals based on providing best available treatment economically achievable and achieving Basin Plan total nitrogen and total phosphorus objectives for flowing waters.
3. Based on simplified version for determining California Toxics Rule (CTR) permit limits for priority pollutants. Section 1.4 of the State Implementation Plan contains specific steps and procedures that take into consideration ambient background concentration, the coefficient of variation of measured concentration data, and dilution credit. In some cases, the calculated effluent limitation can be lower than the CTR criterion. Ce - effluent concentration; Dm – dilution factor.

5.2.2 Routine Water Quality Sampling Plan

Table 5-3 and **Table 5-4** present a routine sampling plan which includes parameters that will be measured on-site using handheld and on-site lab equipment along with parameters that will measured by outside certified laboratories, respectfully. Routine sampling is intended to assess performance and control of individual unit processes as well as collect characterization data on NCWRP tertiary water. The routine sampling regime proposed in **Table 5-4** has been developed to assess the ability of the AWP Facility to meet the initial water quality objectives provided in **Table 5-2**. The proposed specific parameters, target demonstration goals, sampling frequency and sample collection methods are based on the following:

1. Input received to date on the anticipated regulatory requirements for the potential full scale AWP facility;
2. Information required to assess treatment performance;
3. Information required to support future permit applications for the potential full scale AWP Facility;
4. Compare the water quality performance of the two RO Systems;
5. Data typically required by CDPH and RWQCB as part of compliance for similar discharges.

Sample locations are defined in the process flow diagram provided in **Figure 5-1** below.

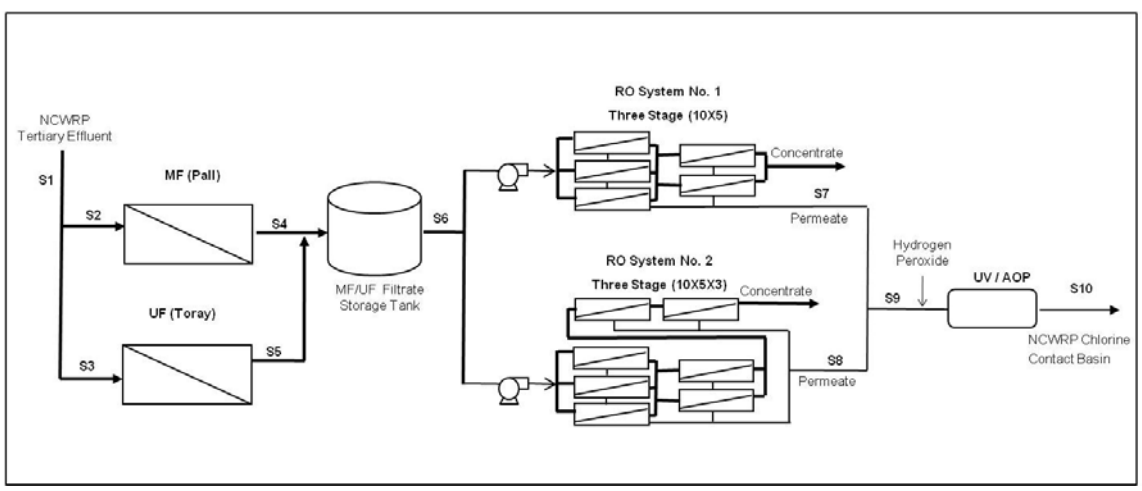

Figure 5-1
AWPF Process Schematic

As indicated in Table 5-3, a portable low range TOC analyzer (dynamic operating range of 0.03 parts per billion [ppb] to 50 ppm) will be used to monitor TOC concentrations at various points in the AWP treatment train to identify any large variations in measured concentrations which would indicate a change in the NCWRP tertiary water quality and / or possible integrity breach of the AWP Facility unit processes(s). The portable unit will be set up for on-line measurement (similar to OCWD Groundwater Replenishment System) of TOC in the RO combined product water. The portable unit will also be used to measure grab samples taken daily from various locations of the AWP train. It should be noted the location of the on-line TOC analyzer may be moved to other locations in the train i.e. RO feed for a short time during the testing period to capture continuous TOC data.

Table 5-3
On-site Routine Water Quality Monitoring Plan for the San Diego AWP Facility

Analyte / Contaminant Group	[1]Sampling Location(s)	[2] Initial Sampling Frequency	Sampling Equipment/ Method	Sample Type
On-site				
Temperature	S1, S6, S9, S10	daily	Portable meter HACH SensION156	Grab
pH	S1, S6, S9, S10	daily	Portable meter HACH SensION156	Grab
Turbidity	S1,S4,S5,S6, S9, S10	daily	HACH 2100 Q Portable Turbidimeter)	Grab
Turbidity	S1, S4,S5	continuous	Turbidimeter (HACH 1720D / FilterTrack 660)	On-line
UV 254	S1, S4, S5, S6, S7, S8	1/week	Spectrophotometer (HACH)	Grab
UV 254	S9, S10	daily	Spectrophotometer (HACH)	Grab
[3]TOC	S7, S8, S10	weekly	[2] GE Sievers 900 Portable TOC Analyzer	Grab
[3]TOC	S6,S9	daily	GE Sievers 900 Portable TOC Analyzer	[4]Grab/Online
Dissolved Oxygen (DO)	S10	weekly	Portable meter HACH SensION156	Grab
Conductivity	S6, S7, S8	daily	Conductivity probe	Online
Conductivity	S6, S7, S8	weekly	Portable meter HACH SensION156	Grab
Silt Density Index	S6	1/week	ASTM D4189	Grab
Total Chorine Residual	S4/S5 combined	daily	HACH CL-17	On-line
Total Chorine Residual	S1, S3, S6, S9, S10	daily	Chlorine Pocket Colorimeter HACH	Grab
Free Chorine Residual	S6	daily	Chlorine Pocket Colorimeter HACH	Grab

1. Sampling locations are shown in Figure 5-1.
2. Sampling frequencies / locations will be reassessed periodically.
3. Dynamic operating range is 0.03 ppb to 50 ppm.
4. S9 to be monitored on-line all other sampling locations via grab sampling.

Table 5-4
Certified Laboratory Routine Water Quality Monitoring Plan for the San Diego AWP Facility

Constituent	[1] Sample Location	[2,3] Type of Sample	[4] Analytical Method	Monitoring Frequency	[5] Total Number of Samples per location
Total organic carbon (TOC)	S6, S7, S8	Grab	SM5310C	Monthly	3
TOC	S9	24-Hour Composite	SM5310C	Monthly	12
TOC	S10	24-Hour Composite	SM5310C	2 per week	104
Ammonia Nitrogen	S6, S7, S8	Grab	EPA 350.1	Bi-weekly (once per 2 weeks	6
Ammonia Nitrogen	S9	24-Hour Composite	EPA 350.1	Bi-weekly (once per 2 weeks	26
Ammonia Nitrogen	S10	24-Hour Composite	EPA 350.1	2 per week	104
Nitrate / Nitrite	S6, S7, S8	Grab	EPA 353.2	[5] Bi-weekly (once per 2 weeks	6
Nitrate / Nitrite	S9	24-Hour Composite	EPA 353.2	[5] Bi-weekly (once per 2 weeks	26
Nitrate / Nitrite	S10	24-Hour Composite	EPA 353.2	2 per week	104
Total Nitrogen	S6, S7, S8	Grab	Various (Determined by Calculation)	[5] Bi-weekly (once per 2 weeks)	6
Total Nitrogen	S9	24-Hour Composite	Various (Determined by Calculation)	[5] Bi-weekly (once per 2 weeks)	26
Total Nitrogen	S10	24-Hour Composite	Various (Determined by Calculation)	2 per week	104
Total phosphorus	S6, S7, S8	Grab	EPA 365.1	[5] Bi-weekly (once per 2 weeks)	104
Total phosphorus	S9	24-Hour Composite	EPA 365.1	[5] Bi-weekly (once per 2 weeks)	6
Total phosphorus	S10	24-Hour Composite	EPA 365.1	2 per week	26
Nitrosamines	S1, S6	Grab	EPA 521	Monthly	12

1. Sampling locations are shown in Figure 5-1.
2. All samples to be taken as grab samples for the initial 2 months due to delays in the receipt and installation of auto-samplers.
3. Composite samples to be collected on a time weighted basis.
4. MDLs, RLs, TATs, sample hold times for each method are provided in Appendix I.
5. Total samples based on a sampling period of 3 months (S6, S7, S8) and 12 months (S1, S9 and S10).

Table 5-4
Certified Laboratory Routine Water Quality Monitoring Plan for the San Diego AWP Facility (Cont.)

Constituent	[1] Sample Location	[2,3] Type of Sample	[4] Analytical Method	Monitoring Frequency	[5] Total Number of Samples per location
Nitrosamines	S7, S8	Grab	EPA 521	Monthly	3
Nitrosamines	S9, S10	24-Hour Composite	EPA 521	Monthly	12
1,4-Dioxane	S6, S7, S8	Grab	EPA 3520C	Monthly	3
1,4-Dioxane	S9, S10	24-Hour Composite	EPA 3520C	Monthly	12
[6]VOCs	S1, S9, S10	Grab	EPA 524.2	Monthly	12
Halo acetic acids (HAA5)	S1, S6	Grab	EPA 552.2	Monthly	12
Halo acetic acids (HAA5)	S7, S8	Grab	EPA 552.2	Monthly	3
Halo acetic acids (HAA5)	S9, S10	24-Hour Composite	EPA 552.2	Monthly	12
Phenols	S10	24-Hour Composite	EPA 8270-SM	Monthly	12
Chloride, Fluoride, Sulfate	S6, S7, S8	Grab	EPA 300.0	Bi-weekly (once per 2 weeks	6
Chloride, Fluoride, Sulfate	S10	24-Hour Composite	EPA 300.0	Bi-weekly (once per 2 weeks	26
Total dissolved solids (TDS)	S6, S7, S8	Grab	SM 2540C	Bi-weekly (once per 2 weeks	3
Total dissolved solids (TDS)	S10	24-Hour Composite	SM 2540C	Bi-weekly (once per 2 weeks	26
Metals (Fe, Na, Mn, B)	S10	24-Hour Composite	SM 2540C	Bi-weekly (once per 2 weeks	26
Color	S10	24-Hour Composite	SM 2540C	Bi-weekly (once per 2 weeks	26

1. Sampling locations are shown in Figure 5-1.
2. All samples to be taken as grab samples for the initial 2 months due to delays in the receipt and installation of auto-samplers.
3. Composite samples to be collected on a time weighted basis.
4. MDLs, RLs, TATs, sample hold times for each method are provided in Appendix I.
5. Total samples based on a sampling period of 3 months (S6, S7, S8) and 12 months (S1, S9 and S10).
6. Include: 1,2 dichloroethane, methylene chloride, tri-halomethanes (THM).

5.2.3 Chemicals of Emerging Concern Monitoring Plan

5.2.3.1 Background

The SWRCB adopted a Recycled Water Policy in February 2009 with the purpose of providing permitting clarity to California projects that use recycled water for non-potable landscape irrigation and for groundwater recharge (surface spreading and injection). The Policy did not address projects that use recycled water for surface water augmentation. A key component of the Policy was how to address new classes of chemicals referred to as CECs. CECs include pharmaceuticals, current use pesticides, and industrial chemicals. Many CECs are potentially present in recycled water however the detection of many is so recent that robust methods for their quantification and toxicological data for interpreting potential human or ecosystem health effects are unavailable.

Under the Recycled Water Policy, the SWRCB established a Science Advisory Panel (SAP) to provide guidance for developing monitoring programs that assess potential CEC threats to human and aquatic.

The SAP included six panel members versed in a mix of disciplines: chemistry, biochemistry, toxicology, epidemiology, risk assessment, and engineering. During September of 2009 and May 2010, four in person meetings and several conference calls occurred. These meetings were designed to allow for stakeholder input to clarify the SAP's charge, exchange information, dialog with the SAP, and allow considerations of public comments in the report. Overall four products were developed by the SAP to assist the SWRCB to refine the direction of the Recycled Water Policy regarding CEC monitoring (SWRCB, 2010):

Product 1 - Conceptual Framework to determine which CEC's to monitor

1) Measured Environmental Concentration (MEC) of CECS in source water (secondary or tertiary effluent) for reuse projects

2) Monitoring Trigger Level (MTL) for each compound or group of compounds based on toxicological relevance

3) Compare MEC to MTL. CECs with MEC/MTL > 1 should be prioritized for monitoring. CECs with a ratio of less than "1" should only be considered if they represent viable treatment process performance indicators; and,

4) Screen the list from step 3 to ensure that a commercially-available robust analytical method is available for that compound.

Product 2 - Application of the framework to identify a list of chemicals that should presently be monitored

1) Through a survey that was shared with Californian stakeholders, the SAP compiled available California MEC data. In this effort, the SAP made conservative assumptions on MEC's: 1) that reported concentrations were representative of the

entire state and 2) that analytical methods used to quantify data are accurate – these two assumptions maximized the number of candidate chemicals that are toxicologically relevant.

2) For groundwater recharge projects (e.g., surface spreading, direct injection), four compounds were identified as possible indicator compound based on their toxicological relevance. In addition, four additional CECs were identified for surface spreading and direct injection operations as viable performance indicator compounds along with certain surrogate parameters (e.g., ammonia, dissolved organic carbon, conductivity). The SAP also recommended method reporting levels (MRLs) that were compound specific and that ranged from 1 to 100 ng/L for the following CECs.

   Indicator compounds based on toxicological relevance:

   a. NDMA,

   b. 17beta-estradiol

   c. Caffeine

   d. Triclosan

   Performance Indicators:

   a. DEET (N,N-Diethyl-meta-toluamide)

   b. Gemfibrozil

   c. Iopromide

   d. Sucralose

The SAP believed it was critical to emphasize that if a compound exceeds its respective MTL at the point of monitoring (POM), the finding does not necessarily indicate a public health risk. The MEC/MTL framework was only developed for the purpose of prioritizing CECs for monitoring. The SAP's proposed MEC/MTL ratios should not be used to make predictions about risk.

Lastly, the SAP strongly recommended to the SWRCB to reapply the prioritization process on at least a triennial basis. The regular review process would fill data gaps for compounds with little or no occurrence and toxicological information in California. In order to fill data gaps for CECs with limited or no information on MECs in California, the SAP suggested that the State initially conduct a more thorough review of CECs likely to occur in recycled water using MEC and predicted environmental concentration (PEC) data from the peer-reviewed literature and

occurrence studies outside California. Those CECs that exhibit MEC/MTL ratios above "1" could be placed on a secondary monitoring list that is measured less frequently to confirm absence or presence of these CEC in California. In addition, this secondary monitoring list could be populated by CECs that exhibit a relatively low MTL (less than 500 ng/L) but could have the potential to trigger a MEC/MTL ratio of larger than "1". The Panel suggested monitoring select CECs for which currently no California MECs are available in secondary/tertiary treated effluent but analytical methods exist:

- 1,2,3-Trichloropropane
- Hydrazine
- Quinoline

Product 3 A Sampling design and approach for interpreting results from CEC monitoring programs

The SAP provided recommendations for a phased, performance-based approach for implementing landscape irrigation and groundwater recharge recycled water monitoring programs and multi-tiered framework for interpreting the data. The first phase involves screening that would be initiated at project start-up and continue through the early years of project operation. If a specific CEC consistently exhibits low occurrence, the SAP recommended deleting the CEC from further monitoring provided that production data do not suggest a significant increase in use. If CECs exceed thresholds identified in the report, the SAP recommended moving to a second phase of enhanced monitoring to confirm the presence and frequency of such CEC(s). The third phase, should concentrations continue to be high, would require initiation of source identification and/or toxicology studies. The final phase would involve engineering removal studies and/or modification of plant operation if found to be warranted by the results of the third phase.

Product 4 Priorities for future improvements in monitoring and interpretation of CEC Data

The science of CEC investigation is still in its early stages and the recommended that the State could undertake several activities that would greatly improve both monitoring and data interpretation for recycled water management, including:

- Develop and validate more and better analytical methods to measure CECs in recycled water;
- Encourage development of bioanalytical screening techniques that allow better identification of the "unknown unknown" chemicals; and,

- Develop a process to predict likely environmental concentrations of CECs based on production, use and environmental fate, as a means for prioritizing chemicals on which to focus method development and toxicological investigation.

In addition to these research recommendations, the SAP recommended that the State develop a process to rapidly compile, summarize, and evaluate monitoring data as they become available.

The SWRCB intends to adopt specific recommendations on CEC monitoring for recycled water landscape irrigation and groundwater recharge projects taking into consideration the suggestions from the SAP.[3]

5.2.3.2 Proposed CEC Monitoring Plan for City of San Diego AWP Facility

The project team worked with several SAP members to tailor the overall recommendations of SAP report to produce a monitoring program specific for the City's AWP Facility. The project team acknowledged that the SAP framework was originally not developed for surface water augmentation projects. However, since surface water augmentation requires treatment standards that are similar or potentially more stringent than direct injection projects, applying the SAP framework in concept was deemed appropriate.

In deriving such a monitoring program for the City's AWP Facility, the following aspects were addressed:

- Application of the conceptual framework developed by the SAP to the City's AWP Facility demonstration-scale project
- Comparison of CECs recommended for monitoring identified during the SAP's initial CEC occurrence survey for secondary/tertiary treated effluent in California to CECs quantified in the NCWRP tertiary effluent in the past
- Phased / Performance Based Approach to Monitoring CECs
- Sampling Protocols

Application of SAP Framework to San Diego's AWP Facility

Concentrations of CECs measured in NCWRP tertiary treated effluent based on pilot testing conducted in 2005 are summarized in **Table H-1** (**Appendix H**). The list of CECs has been augmented by chemicals that where identified by the SAP as toxicological relevant. MEC/MTL ratios for each compound based on the SAP report and MEC/MTL values based on average concentrations measured in NCWRP tertiary effluent are also provided in the table. Only two compounds exceed a MEC/MTL

[3] The SWRCB may adopt recommendation in November 2010.

ratio of 1 and confirm the recommended list of CECs to be included in recycled water monitoring programs as proposed by the SAP.

Table 5-5 provides the proposed CEC monitoring plan for the AWP Demonstration Facility. The overall CEC monitoring plan includes an initial feed water characterization period which includes sampling of the NCWRP tertiary water monthly for the first four months. During this time, samples will be analyzed for a list of ninety-one (91) EDC/PPCP compounds representing a wide range of chemical and physical properties. The sampling locations for this period also include RO feed, combined RO product, UV/AOP product and imported aqueduct water. Information used from the initial characterization period will used to 1) characterize NCWRP tertiary effluent, 2) identify appropriate AWP performance indicator compounds to be monitored on an on-going basis, 3) assess AWP unit process CEC removal performance and 4) compare AWP product water quality to the City's imported raw drinking water. The proposed CEC monitoring plan also includes an initial list of CEC compounds to be monitored on an on-going basis (i.e. sampled quarterly). Currently, the proposed list contains compounds prioritized based on toxicological evidence by the SAP (SWRCB, 2010). These compounds have maximum environmental concentrations (MEC) values that exceeded monitoring trigger limits (MTLs). In addition, the on-going characterization includes specific compounds recommended by the IAP (NWRI, 2010), CDPH and the State Board. As noted in Table 5-4, information obtained from the initial feed water characterization period will be used to make modifications to the list of compounds to be monitored on an on-going basis.

Table 5-5
Proposed CEC Water Quality Monitoring Plan for the San Diego AWP Facility

CEC Contaminant Group	[1] Sampling Locations	Rationale for Monitoring
Initial Feed Water Characterization (sample monthly for the first four months)		
[2] List of 91 CECs analyzed by MWH Laboratories	S1, S6, S9, S10 Imported Aqueduct Water	• Characterize NCWRP tertiary water. • Identify appropriate indicator constituents. • Assess AWP unit process CEC removal performance. • Compare water quality of AWP to imported water.
1, 4-Dioxane	S1, S6, S9, S10 Imported Aqueduct Water	
NDMA	S1, S6, S9, S10 Imported Aqueduct Water	
[3] ***Preliminary List for On-going Characterization (Quarters 3 and 4)***		
Caffeine	S6, S9, S10	Compounds prioritized based on toxicological evidence. Measured environmental concentration (MEC) greater than monitoring trigger level (MTL), as developed in SWRCB, 2010.
E2 (17β-Estradiol)	S6, S9, S10	
NDMA	S6, S9, S10	
Triclosan	S6, S9, S10	
DEET	S6, S9, S10	[4] IAP Sub-committee Recommendation
Carbamazepine	S6, S9, S10	[4] IAP Sub-committee Recommendation / [5] CDPH
Primidone	S6, S9, S10	[4] IAP Sub-committee Recommendation
PFAA's	S6, S9, S10,	[4] IAP Sub-committee Recommendation
1,4 dioxane	S6, S9, S10	[4] IAP Sub-committee Recommendation / [5] CDPH
UCMR3 (selective)	S6, S9, S10	[4] IAP Sub-committee Recommendation
Hydrazine	S6, S9, S10	[4] IAP Sub-committee Recommendation
Quinoline	S6, S9, S10	[4] IAP Sub-committee Recommendation
Nicotine	S6, S9, S10	[4] IAP Sub-committee Recommendation
Bisphenyl A	S6, S9, S10	[5] CDPH/State Board
Chlorate	S6, S9, S10	
Boron	S6, S9, S10	
Chromium, hexavalent (CrVI)	S6, S9, S10	
Diazinon	S6, S9, S10	
Naphthalene	S6, S9, S10	
Nitrosamines (NDPA, NDEA, NPYR, NMEA)	S6, S9, S10	
1,2,3 Trichloropropane	S6, S9, S10	
TCEP	S6, S9, S10	
Vanadium	S6, S9, S10	

[1] Sample locations shown in Figure 5-1.
[2] List contains pesticides, herbicides, PPCPs see **Appendix I** for complete list. :
[3] Compounds selected for On-going characterization may change based on results of initial feed water characterization.
[4] CECs recommended for monitoring memorandum: Findings and Recommendations of the AWPFr Purification Facility Sub-committee Meeting, November 15, 2010, NWRI (Appendix K).
[5] CDPH letter to State Board September 13, 2010 in response to SWRCB 2010 Report.

Performance-Based Approach to Monitoring CECs

Tables 5-6 provides the proposed initial list of surrogate parameters and indicator CECs to be measured for the performance-based monitoring program for the AWP Facility. This program will be initiated after the first quarter of operation is complete and operating at steady state conditions. During the first four weeks, differentials between RO feed and permeate and UV-AOP feed and final product water will be determined for performance surrogate parameters and performance CEC indicators. The operational set-points for RO (i.e., flux and recovery) and the UV/AOP process (i.e., EEO or dose and H_2O_2 dose) shall be maintained constant. After start-up, monitoring for CEC indicators is reduced to quarterly while surrogate parameters are measured more frequently to demonstrate that the pre-determined differential values can be achieved. After start-up, those operational set-points should be selected that were set during the initial performance evaluations. If set-points are modified, the differentials for surrogate and indicator CECs will need to be determined again. Based on recommendations from the IAP sub-committee (NWRI 2010), the initial list of proposed performance indicators will be re-evaluated based on information obtained from the initial feed water CEC monitoring program provided in Table 5-5.

Additional services related to performance based CEC monitoring based on comments received on the November 30, 2010 Final Draft Testing and Monitoring Plan from the CDPH not in the current Testing and Monitoring scope are described in Section 8.

Table 5-6
Proposed performance-based CEC Monitoring Plan for the San Diego AWP Facility

Parameter	Sampling Locations	Purpose
[1] Initial RO Performance Characterization		
Δ Conductivity (online)	S6, S7, S8	Determine initial differential removal of surrogate parameter for process performance validation.
ΔTOC (daily for 2 weeks)	S6, S7, S8	
ΔDEET (once a week for first four weeks)	S6, S7, S8	Identified for surface spreading and direct injection operations as viable performance indicator compounds along with certain surrogate parameters (SWRCB, 2010).
ΔSucralose (once a week for first four weeks)	S6, S7, S8	
ΔNDMA (once a week for first four weeks)	S6, S7, S8	
ΔCaffeine (once a week for first four weeks)	S6, S7, S8	
[1] Initial UV/AOP Performance Characterization		
[2]ΔUVA-254 nm (daily)	S9, S10	Determine initial differential removal of surrogate parameter for process performance validation.
Δ NDMA (once a week for first four weeks)	S9, S10	Identified for surface spreading and direct injection operations as viable performance indicator compounds along with certain surrogate parameters (SWRCB, 2010).
Δ Total Chloramines (daily)	S9, S10	Determine initial differential removal to assess viability of use as a surrogate parameter for process performance validation.).
On-going Monitoring to Assure RO Performance **(Quarters 2,3,4)**		
ΔConductivity (online)	S6, S7, S8	Determine differential removal of surrogate parameter for process performance validation
ΔTOC (once a week)	S6, S7, S8	
ΔDEET (every quarter)	S6, S7, S8	
ΔSucralose (every quarter)	S6, S7, S8	
ΔNDMA (every quarter)	S6, S7, S8	
ΔCaffeine (every quarter)	S6, S7, S8	
On-going Monitoring to Assure UV/AOP Performance		
ΔUVA-254 nm (daily)	S9, S10	
Δ NDMA (every quarter)	S9, S10	

[1] Note initial performance characterization is to begin after the first quarter of testing is complete.
[2] UV 254 will be measured by grab samples using a HACH DR 4000 Spectrophotometer with 10 cm sample cell to increase accuracy. Values will be compared to UV 254 values calculated from UVT values measured by the on-line analyzer equipped on the feed of the Trojan UV/AOP system. The location of the on-line analyzer will be changed from the feed to product once per day for 1 hour to assess the sensitivity of the on-line analyzer to measure UV 254 removal.

Sampling Protocols

Methods used to quantify indicator CECs need to meet stringent QA/QC measures, including blanks, replication, and matrix spikes. The SAP recommended the use of isotope-dilution and tandem mass spectrometry whenever possible, for details see

SWRCB (2010). Additional details on specific measure to be taken during sampling of CEC is provided in **Section 7**.

5.2.4 Quarterly Monitoring Plan

Table 5-7 identifies various contaminant groups that will be monitored on a quarterly basis by collecting grab samples from various locations throughout the AWP Facility treatment train. The purpose of the quarterly sampling for various groups are categorized as public health regulatory, reservoir regulatory, and AWP Facility unit process performance.

Quarterly sampling locations will include imported aqueduct water collected by the City staff at the Miramar Water Treatment Plant. This will allow comparison of water quality from the AWP Facility to source waters which supply the City's drinking water facilities. As indicated in Figure 4-1, quarterly sampling will not begin until the AWP Facility unit processes have been stabilized and are operating at steady-state conditions, which is anticipated to be 8 weeks after Phase 1 Testing begins.

Table 5-7
Quarterly Water Quality Monitoring Plan for the San Diego AWP Facility

[1] Contaminant Group	[2,3] Sampling Location(s)	Purpose
Compounds regulated under Federal and State Primary and Secondary Drinking Water Standards.	S1, S10, Imported Aqueduct Water	Public Health Regulatory
Disinfection by-products (trihalomethanes, haloacetic acids, bromated chlorite, NDMA, chlorate).	S1, S6, S9, S10, Imported Aqueduct Water	Public Health / Reservoir Regulatory
Compounds included on USEPA's Priority Pollutant List.	S1, S10, Imported Aqueduct Water	Public Health Regulatory
Compounds with current CDPH Notification Limits.	S1, S10, Imported Aqueduct Water	Public Health Regulatory
Unregulated Contaminant Monitoring Rule (UCMR 3) Proposed Contaminants Assessment Monitoring (List 1).	S1, S10, Imported Aqueduct Water	Public Health Regulatory
TOC, Total Nitrogen, Total Phosphorus.	S1, S10, Imported Aqueduct Water	Public Health / Reservoir Regulatory
Unregulated Radionuclides (cesium -137, iodine 129 & 131).	S1, S10, Imported Aqueduct Water	Public Health
Others: Lithium, Benzo(k)fluroanthene, hexavalent chromium.	S1, S10, Imported Aqueduct Water	Public Health Regulatory
CECs.	See Table 5-5	Public Health Regulatory & AWP performance
Surrogates for Performance Assessments.	See Table 5-6	AWP Unit process performance

[1] Individual compounds comprising each contaminant group and information on analytical methods to be employed for each parameter are provided in Appendix G.
[2] Sampling locations designated S# represent various locations in the AWP Facility treatment train-See Figure 5-1.
[3] All Quarterly samples to be collected as grab samples.

5.2.5 Microbial Monitoring Plan

As stated in the Final IAP report, the ability to demonstrate the selected AWP Facility treatment train provides control of microorganisms is a key component of the testing. Based on specific monitoring recommendations provided in the IAP report and input from the project team's water quality experts, a specific microbial monitoring plan has been developed as described below.

5.2.5.1 Routine Bacteria and Virus Surrogate Sampling

The microbial testing program includes routine sampling of fecal indicator bacteria and virus surrogates for a 12 month monitoring period, as provided in **Table 5-8**. The

purpose of the routine microbial sampling regime is to enumerate bacterial and viral surrogates after each step of the AWP Facility train. This will capture seasonal variability of the AWPF performance (if any). The routine bacteria and virus surrogate sampling plan includes the measurement of total and fecal coliform, F-coliphage and Somatic coliphage before and after each treatment stage of the AWPF. After 1-month of data collection, the sampling frequency for parameters being measured daily (e.g., total & fecal coliform) will be reduced to weekly. Likewise, the sampling frequency for parameters being measured weekly (F-coliphage and Somatic coliphage) will be reduced to monthly after 3 months of data collection.

Additional services related to microbial monitoring based on comments received on the November 30, 2010 Final Draft Testing and Monitoring Plan from the IAP not in the current Testing and Monitoring scope are described in Section 8.

Table 5-8
Routine Bacteria and Virus Surrogate Monitoring Plan for the San Diego AWP Facility

Monitoring Parameter	Units	[1]Analytical Methods	MDL	[2]Sampling Location							[3] Initial Sampling Frequency	Monitoring Period (months)
				S1	S4	S5	S6	S7	S8	S10		
Total & Fecal Coliform	MPN	SM 9221B	2/100 ml	√	√	√	√	√	√	√	Daily (Mon-Fri)	12
F-& Somatic coliphage	pfu/ml	EPA 1602	1 /100 ml	√	'---	'---	'---	'---	'---	'---	Weekly	12
F-& Somatic coliphage	pfu/ml	EPA 1601	Presence/Absence in 1000 ml		√	√	√	√	√	√	Weekly	12

[1] TATs, sample hold times for each method are provided in Appendix I.
[2] Sampling locations are shown in Figure 5-1.
[3] Initial sampling frequencies will be reduced to weekly and monthly after the first month and third month of the test period for parameters being measured daily and weekly, respectfully.

5.2.6 Integrity Monitoring Plan

The integrity of the various AWP Facility processes is a crucial aspect of ensuring the overall system meets the water quality objectives, and achieves the multiple barrier concept required by the Department of Public Health. The following section provides a specific Integrity Monitoring Plan (IMP) to be implemented during the demonstration test period. The main purpose of the IMP is to provide a systematic approach to apply existing tools, techniques, and practices that have been developed to monitor and maintain the integrity of the various AWP Facility unit processes. Key components of the plan which have been adopted from published Guidance Manuals (USEPA 2005) and studies (USBR 2000, MWH 2006) follow:

- Confirm and establish baseline performance of each unit process under "intact" conditions prior to start–up;
- Maintain continuous verification of integrity throughout the operational period;
- Implement on-going maintenance and operational practices to mitigate integrity breaches on all unit processes;
- Record and analyze collected integrity data; and
- Develop measurable performance criteria and action plans if changes in performance occur due to breaches in integrity.

A key objective of the AWP Facility demonstration program is to demonstrate the reliability of the membrane processes (MF/UF and RO) to consistently produce, high-quality product water. As a result, an integrity-monitoring plan will be implemented throughout the test period to verify the membrane systems are intact at the onset of testing and assess any degradation of integrity which may occur during long term operation. This will be accomplished by performing different types of direct and indirect monitoring techniques.

5.2.6.1 Integrity Monitoring Methods & Implementation Schedule

A summary of the various integrity methods and techniques to be used for each unit process is provided in **Table 5-9**. Information for each method includes the purpose, frequency of implementation and at what stage(s) in the AWP Facility construction and operation the methods will be employed. Specific information and testing protocols to be used for each method are provided in **Section 3**.

The integrity of the MF and UF systems will be assessed directly by conducting periodic air pressure hold tests. This test can be conducted on several membrane elements (modules) simultaneously; thus, it can test the integrity of a full rack of membrane elements used for full-scale systems. The test is conducted by pressurizing the filtrate side of the membrane lumen after which the pressure will be held and the decay rate will be monitored over time. Minimal loss of the held pressure at the feed

side indicates a passed test, while a significant decrease of the held pressure indicates a failed test. The MF and UF systems will include an automated air pressure-hold test function, which can be initiated from the system's control panel. This function will also allow the user to adjust the time interval between tests. In addition to pressure decay, the integrity of the MF/UF will be assessed by continuously monitoring the filtrate turbidity of the system by a highly sensitive turbidity meter. An intact MF/UF membrane is expected to produce product water with turbidity ≤0.2 NTU.

Several methods will be employed at various times during the test period to assess the integrity of the RO membrane systems, which serve as the heart of the overall AWP Facility treatment train. As part of this demonstration testing program, RO membrane suppliers have been be requested to provide the project team with vacuum decay or pressure hold test results on all membranes supplied for testing. In accordance to ASTM D3923-94 the acceptable pressure decay rate for RO membranes is 0.2 bar/minute. After installing the membranes, the integrity of the membrane systems will be assessed by conducting probing of each pressure vessel. This method involves measuring conductivity at various locations along the inside of the RO membrane element's permeate tubes of an individual vessel as the system is operating. Because salts are being rejected in the direction of the feedwater flow a gradual increase in permeate conductivity is expected in intact vessels. A sudden spike or jump in conductivity at a given location inside the permeate tube often indicates a breach in system integrity. Such breaches could be due to membrane defects and/or faulty or misaligned o-rings, interconnectors or end caps.

During the operations phase, RO membrane integrity will be monitored continuously by on-line measurement of electrical conductivity in the feed and permeate. Loss of integrity in the RO membrane elements, o-rings, interconnectors and/or end caps may be detected by detecting an increase in the RO permeate conductivity by this indirect method. In addition, TOC will be monitored in the feed and permeate of the RO systems by taking daily grab samples. Measurement of TOC will be made on-site using a highly sensitive analyzer to allow a higher log removal than the conductivity monitoring method. As an overall integrity check of the RO systems and to detect changes in the NCWRP tertiary water quality, the TOC analyzer will also be used to provide on-line measurement of the combined RO product water.

In addition to the implementation of the methods described above periodic monitoring of select water quality parameters for each unit process will be employed through the test period. This will allow verification of integrity throughout the operational period. The specific parameters selected are based on treatment removal mechanism of each unit process and past performance data, as described in **Section 5**.

Table 5-9
Summary of Integrity Monitoring Methods proposed for the San Diego AWP Facility

Unit Process	Method	Purpose	Plant Stage	Frequency
MF/UF	Pressure Decay Testing	Direct check of membrane integrity	Start up and Operation	1 per 24 hours
MF/UF	On-line turbidity monitoring	Indirect check of membrane integrity	Start Up and Operation	Continuous
RO	Vacuum decay / pressure hold testing	Direct check of membrane integrity (glue lines, tears / holes in membrane material)	Prior to delivery of RO products from suppliers	One time unless used as diagnostic tool for individual elements
RO	Vessel Probing (conductivity)	Indirect check of RO membrane system integrity (o-rings, inter-connectors, end caps, etc.)	Post RO membrane installation and during operation if needed	One time all vessels with periodic checks of individual vessels as needed
RO	Continuous on-line RO permeate conductivity monitoring	Indirect method of checking RO membranes, o-rings, interconnectors and end caps.	Post RO membrane installation and continuously during operation	Continuous
RO	RO permeate TOC monitoring	Indirect method of checking RO membranes, o-rings, interconnectors and end caps.	Post membrane installation and daily during operation	On-line RO product combined. Grab RO feed Daily
MF, UF, RO, UV	[2] Indicator / Surrogate Monitoring	Indirect check of integrity / system performance	Start Up and during Operation	Periodic

[1] Based on guidelines integrity methods used for membrane systems to comply with the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR).[2] See Table 5-5 for specific performance indicators / surrogates to be measured for each unit process throughout the test period.

5.2.7 Critical Control Point Monitoring

A key component of the integrity monitoring plan will be to develop a procedure to identify any change in the performance of the treatment process that can adversely impact the final water quality before the out of specification water leaves the plant. One approach that can be used to assess the performance of the treatment process without the need for end point monitoring is the use of Hazard Analysis and Critical Control Point (HACCP) techniques. HACCP techniques were developed for the food industry and codified in the Guidelines for the Application of the Hazard Analysis Critical Control Point (HACCP) System (Codex Alimentarius, ALINORM 95/13, Annex to Appendix III).

The HACCP process is used to identify specific potential hazard(s) that can be present in the feed to a recycled water treatment process and establish preventative measures for their control. The HACCP process results in the development of a management system that monitors, evaluates and controls the potential hazards, rather than relying on analysis of the final product water quality inspection.

An important part of the HACCP process is the identification of key monitoring points at different stages of the treatment process. Analysis at these monitoring sites can provide information that can be used as a critical control point (CCP) or a quality control point (QCP). The purpose of the critical control point is to monitor a process parameter, such as turbidity, conductivity, power consumption, chlorine residual and total organic carbon that relates to the reduction in concentration of specific hazards at that part of the treatment process. Operational limits are established for these critical control points so that continuous monitoring of the CCP parameters will provide information on how the treatment process is performing on the removal of these parameters.

An important part of this study will be to use the HACCP process to establish CCP's for the dual membrane and AOP process and set performance limits and a set of procedures for corrective actions that would be taken in the event that the limit values are exceeded. **Table 5-10** provides a summary of the CCP monitoring to be conducted as part of Phase II testing. The specific baseline values, alert limits, critical limits and corrective action plans corresponding to each CCP will be established during the Phase I testing period.

Table 5-10
Summary of Critical Control Point Monitoring for the San Diego AWPF

Critical Control Point	Critical Limit Parameter	Monitoring Frequency	[1]Alert Limit	[1]Critical Limit	[1]Corrective Action
MF/UF	Pressure Decay	1 per day	Value above baseline that approaches Critical limit.	1 per 24 hours	Confirm Results. Assess fiber breakage.
RO	TOC UVT	Continuous	% change of measured concentration in combined RO permeate.	Above value which changes LRV.	Monitor individual RO trains. Verify analyzer accuracy. Conduct vessel probing..
UV/AOP	Reactor Power Draw	Continuous	Value above baseline that approach critical limit.	One time unless used as diagnostic tool for individual elements	System alarm and shutdown. Check / replace lamps and/or ballasts.
UV/AOP	Hydrogen peroxide dose rate	1 per day by draw down	Value above baseline that approach critical limit.	Below minimum dose to provide 3 mg/L peroxide.	Check dosing system. Recalibrate pump.

[1] specific limit values and corrective actions to be established during Phase I Testing.

Section 6
Specialty Testing

6.1 Introduction

Several specialty testing evaluations will be conducted during the course of the demonstration testing period. Specific evaluations include:

- Spiking experiments on the UV/AOP system to determine reactor power and hydrogen peroxide set points to achieve 1.2 log removal of NDMA and 0.5 log removal using product water from the RO systems.
- Chloramines and nitrosamines investigations to evaluate and compare sequential versus preformed chloramines application to inhibit organic and biological fouling of the RO systems and assess nitrosamines formation.
- Evaluation of UV/AOP by-products.

The above testing activities were identified based on recommendations and technical issues identified in the IAP report and CDPH comment responses along with input from the project team's PAC. Details on the specific objectives and test methods to be employed for each evaluation are provided below.

6.2 NDMA and 1,4-Dioxane Spiking Experiment

6.2.1 Background/Objective

The testing outlined in this section will demonstrate the specific NDMA and 1,4-Dioxane reduction ability of the AWP Facility UV/AOP process. The design criterion stipulates that the UV System will achieve 1.2 $\log_{10}$ reduction of NDMA and 0.5 log reduction of 1,4-Dioxane at a system peak flow rate of 1 MGD.

The City conducted a pilot test of the proposed AWP Facility train (MWH 2007)) and demonstrated that the effluent water downstream of the NCWRP contained background concentrations of NDMA ranging between 10 to 80 ng/L (10 to 80 parts per trillion [ppt]) that were too low to obtain the necessary resolution to demonstrate the required resolution; therefore, NDMA will be spiked to concentrations between 700 to 1000 ng/L.

Similar to NDMA, concentrations of 1,4-Dioxane are not present in the effluent water at levels to obtain the necessary resolution to demonstrate the required removal rate and therefore 1,4-Dioxane will be spiked. A concentrated NDMA and 1,4-Dioxane solution will be injected upstream of the inline static mixer designed for mixing of hydrogen peroxide.

The specific objectives of the NDMA and 1,4-Dioxane investigation are as follows:

- Establish and confirm manufacturers' reactor power set point to achieve 1.2 log removal of NDMA for the TrojanUVPhox Model 72AL75 UV-AOP system under the design flow and UVT conditions.
- Determine the maximum NDMA log removal rate of the TrojanUVPhox Model 72AL75 UV-AOP system under design flow rate and UVT conditions.
- Collect data on the impact of H2O2 dose on the removal of 1,4-Dioxane by UV/AOP.

6.2.2 Mixing Study

A mixing test to be performed with H2O2 to measure the residence time distribution within the system and determine the equilibration time required for the subsequent tests. The test will determine the relevant hydraulic residence times (HRT) that the experiment should be allowed to run before obtaining samples after a process change. The test involves the following steps:

- H_2O_2will be turned off for a period of 15 minutes prior to the test to ensure that it is flushed from the system. Samples will be collected at the AOP effluent to verify that there is no H_2O_2 residual using a Hydrogen Peroxide Test Kit (HACH Model HYP-1). Once it is verified no $H_2O_2$is present, the test can begin.
- The mixing test will be completed by starting the hydrogen peroxide injection at t=0. H_2O_2will be continuously injected at 3 mg/L into the influent stream with the UV lamps off. Samples will be collected at the UV system influent (after static mixer) and the effluent to capture the start of H_2O_2 injection and will continue until the H_2O_2concentration is at steady state concentrations, typically 2-3 HRT's. The results of the mixing study will be used to optimize the spiking experiments.

6.2.3 NDMA and 1,4-Dioxane Spiking Test Plan

The test plan consists of two separate spiking experiments. During experiment one NDMA only will be spiked upstream of the UV/AOP and the reactor power will be varied between the minimum and maximum settings. During this experiment the reactor will be operated at the design flow rate of 1 MGD and UV transmittance (UVT) of approximately 97%. In addition, the expected chloramines residual present in the UV/AOP is 3 mg/L. The log removal of NDMA will be determined for each set point. In addition 1,4 dioxane will be measured in the UV/AOP feed and effluent to assess removal of inherent concentrations present. The results will be plotted to establish the relationship between NDMA LRV and reactor power under design conditions. In addition, values of electrical energy per order (EEO) for the reactor will be calculated based on results of the spiking experiment.

During experiment two NDMA and 1,4 dioxane will be spiked upstream of the UV/AOP and the peroxide dose will be varied between 1 and 5 mg/L. It should be noted during normal operation and sampling events the UV/AOP peroxide dose will be set at 3 mg/L based on the dose currently approved by CDPH for the OCWD Groundwater Replacement System. However, the purpose of the spiking experiment is to gain information on the impact of peroxide dose on 1,4 dioxane removal by the UV/AOP. During this experiment the reactor will be operated under the reactor power conditions determined in Experiment 1 to achieve 1.2 log removal of NDMA. The log removal of 1,4 dioxane & NDMA will be determined for each set point.

The testing apparatus/equipment required to conduct the spiking experiments shall be per **Figure 6-1** and is comprised of the following equipment:

- Chemical Storage tank and cover– 30 gallon black polyethylene
- Chemical Storage tank mixing rod
- Chemical dosing pump
- Hydrogen Peroxide monitoring kit
- Piping and valving to make the connections between the components
- Stock spiking solution 1 L prepared by certified laboratory experienced with preparing spiking solutions.

Table 6-1 provides details on the experimental test runs that will be conducted as part of spiking experiment 1. The log removal of NDMA and 1,4-Dioxane will be calculated.

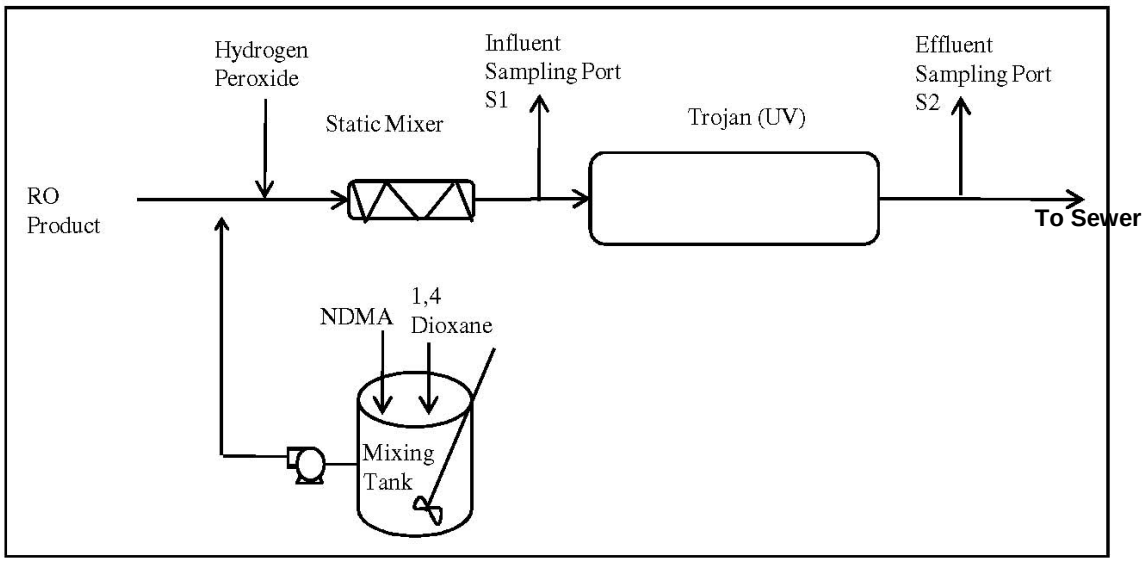

Figure 6-1
Spiking Set-up

Table 6-1
Spiking Experiment 1

Sample ID	Target LRV	Target Flowrate (gpm)	Target UVT (%)	Target NDMA Feed Concentration (ng/l)	[1] Target Reactor Power (%)	Target Peroxide Dose (mg/L)
Batch	NA	NA	NA	NA	NA	NA
Control IN	0	695	97	1000	0	0
Control OUT	0	695	97	1000	0	0
Control IN	0	695	97	1000	0	3
Control OUT	0	695	97	1000	0	3
RUN 1	1.2	695	97	1000	66	3
RUN 2	1.6	695	97	1000	80	3
RUN 3	1.0	695	97	1000	60	3
RUN 4	2.5	695	97	1000	100	3

[1]. Target reactor power settings were recorded from the TrojanUVPhox Model 72AL75 human interface (HMI) screen at different Target LRV's (user set point) during operation at the target flow and UVT.

For each sample run, three individual 1.0 L influent samples will be taken from the influent sample port and three effluent samples will be grabbed from the effluent sample port. Samples will be collected in UV proof (dark glass bottles) bottles with preservative. Samples will be sent to a certified lab and tests shall be performed per EPA analytical methods. All samples will be analyzed for NDMA and 1 influent and 1 effluent will be analyzed from each run will be analyzed for 1,4 dioxane.

Concurrent sampling and recording of feed UVT, effluent H_2O_2concentration, feed flow, temperature, target reactor power, actual reactor power, target LRV, actual LRV EEO, and lamp hours will be performed. Documentation of the number of lamps in service will also be recorded.

- Control – The test plan includes two runs in which the UV unit is in the off position. This will act as the control experiment. Samples will be collected from the influent and effluent with and without peroxide.

- Run 1 will consist of operating the UV unit at the manufacturers recommended power setting to achieve 1.2 log removal of NDMA at 695 gpm. The H_2O_2 will be dosed at 3 mg/L. Three influent and three effluent samples will be collected at approximately 5 minutes apart.

- Run 2 will increase the UV power setting to 80% of the maximum output of the UV unit and the H_2O_2 will be dosed at 3 mg/L. Three influent and three effluent samples will be collected at approximately 5 minutes apart.

- Run 3 will reduce the UV power settings approximately 60% (minimum power setting). Three influent and three effluent samples will be collected at approximately 5 minutes apart.

- Run 4 will reduce the UV power settings approximately 60% (minimum power setting). Three influent and three effluent samples will be collected at approximately 5 minutes apart.

A total of (29) NDMA and (8) 1,4 dioxane samples will be collected analyzed as part of this spiking experiment. The spiking experiment will last approximately 2 to 2-1/2 hours. The first 15-30 minutes will be to set-up and verify that the testing and dosing apparatus are operating correctly and to give the system time to reach equilibrium as determined in the mixing study per **Section 6.2.2**.. During the spiking experiment the UV/AOP effluent will be directed to sewer. Any remaining volume in the mixing tank at the conclusion of the experiment will be run through the UV unit to completely destroy any remaining chemical. A minimum of two mixing tank volumes of clean water will be run through the testing apparatus to flush the system of chemicals prior to putting UV/AOP product back into the NCWRP recycled water system.

Table 6-2 provides details on the experimental test runs that will be conducted as part of Spiking Experiment 2. The purpose of this experiment is to assess the impact of hydrogen peroxide concentration on 1,4 dioxane removal by UV/AOP.

Table 6-2
Spiking Experiment 2

Sample ID	Target NDMA / 1,4 dioxane LRV	Target Flowrate (gpm)	Target UVT (%)	Target NDMA & 1, 4 Dioxane Feed Concentration (ng/l)	[1] Target Reactor Power (%)	Peroxide Dose (mg/L)
Batch	NA	NA	NA	NA	NA	NA
Control IN	0	695	97	1000	0	0
Control OUT	0	695	97	1000	0	0
Control IN	0	695	97	1000	0	3
Control OUT	0	695	97	1000	0	3
RUN 1	1.2 / 0.5	695	97	1000	66	1
RUN 2	1.2 / 0.5	695	97	1000	66	3
RUN 3	1.2 / 0.5	695	97	1000	66	5

1. Final flow and power set points to be based on spiking experiment 1 result.

For each sample run, three individual 1.0 L influent samples will be taken from the influent sample port and three effluent samples will be grabbed from the effluent

sample port. Samples will be collected in UV proof (dark glass bottles) bottles with preservative. Samples will be sent to a certified lab and tests shall be performed per EPA analytical methods. All samples will be analyzed for 1,4 dioxane and 1 influent and 1 effluent will be analyzed for NDMA.

Concurrent sampling and recording of feed UVT, effluent H_2O_2concentration, feed flow, temperature, target reactor power, actual reactor power, target LRV, actual LRV EEO, and lamp hours will be performed. Documentation of the number of lamps in service will also be recorded.

- Control – The test plan includes two runs in which the UV unit is in the off position. This will act as the control experiment. Samples will be collected from the influent and effluent with and without peroxide.

- Run 1 will consist of operating the UV unit at the manufacturers recommended power setting to achieve 1.2 log removal of NDMA at 695 gpm. The H_2O_2 will be dosed at 1 mg/L. Three influent and three effluent samples will be collected at approximately 5 minutes apart.

- Run 2 will consist of operating the UV unit at the manufacturers recommended power setting to achieve 1.2 log removal of NDMA at 695 gpm. The H_2O_2 will be dosed at 3 mg/L. Three influent and three effluent samples will be collected at approximately 5 minutes apart.

- Run 3 will consist of operating the UV unit at the manufacturers recommended power setting to achieve 1.2 log removal of NDMA at 695 gpm. The H_2O_2 will be dosed at 5 mg/L. Three influent and three effluent samples will be collected at approximately 5 minutes apart.

A total of (23) 1,4 dioxane and (11) NDMA samples will be collected analyzed as part of this spiking experiment. The spiking experiment will last approximately 2 to 2-1/2 hours. The first 15-30 minutes will be to set-up and verify that the testing and dosing apparatus are operating correctly and to give the system time to reach equilibrium as determined in the mixing study per **Section 6.2.2**. During the spiking experiment the UV/AOP effluent will be directed to sewer. Any remaining volume in the mixing tank at the conclusion of the experiment will be run through the UV unit to completely destroy any remaining chemical. A minimum of two mixing tank volumes of clean water will be run through the testing apparatus to flush the system of chemicals prior to putting UV/AOP product back into the NCWRP recycled water system.

6.3 Chloramines and Nitrosamines Investigation

6.3.1 Background/Objective

The City's AWP Facility will utilize chloramines to control organic and biological fouling of the MF, UF, and RO membranes. It is well documented that the combination of chloramines and nitrogenous precursors present in wastewater, such as dimethylamine (DMA), are common pathways for disinfection by-product (DBP) formation (Mitch et al., 2003). Previous research shows that NDMA formation is dependent on such factors as the individual water matrix, the level of chlorine/chloramines addition and pH (Mitch et al., 2004). In addition, the formation is linked directly to the chloramines dose, pH and hence chloramines species. Formation control and treatment processes are used to limit NDMA in treated water. Chloramines can be created either by sequential addition of ammonia (aqueous ammonia) and chlorine (sodium hypochlorite) directly to the wastewater or by a side stream process that pre-forms chloramines prior to application to the wastewater. The latter has been shown to be an effective method to reduce by-product formation as it results largely in mono-chloramines formation (MWH, 2010).

The specific objectives of the chloramines and nitrosamine investigation follows:

- Gain operational performance data on the RO systems at different chloramines feed concentrations to optimize and develop criteria for the full-scale AWP Facility.
- Evaluate nitrosamines formation under different chloramines application conditions including pre-formed, sequential with and without acid addition (will acid make a difference?).

6.3.2 Description of Chloramines Dosing Alternatives

Figure 6-2 provides a general flow schematic of the chloramine dosing alternatives to be evaluated during the testing period. Option 1 will include sequential addition of sodium hypochlorite (NaOCl) the tertiary water upstream of MF and UF followed by ammonium hydroxide (NaOH) to the MF/UF product water. Option 2 will include the addition of ammonium hydroxide into a carrier water (RO permeate) followed by subsequent dosing with sodium hypochlorite. The solution will then be stored in a large pressure vessel to allow for approximately 10 minutes of detention time to form monochloramine (NH_2Cl), which will be dosed into tertiary water upstream of the MF and UF systems.

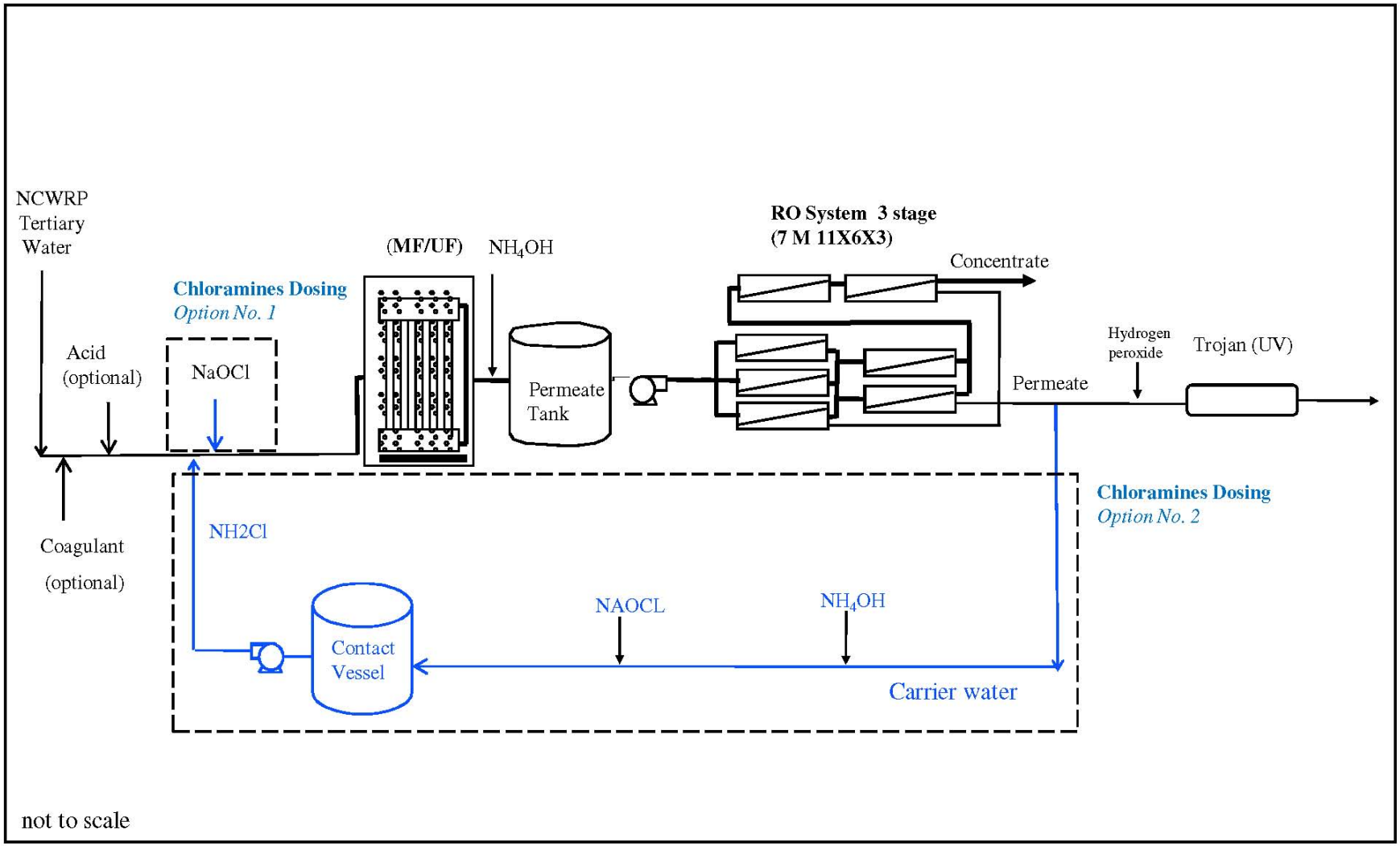

Figure 6-2
General schematic of chloramines dosing alternatives

6.3.3 Performance Monitoring

A sampling regime will be put in place during phase II of the demonstration test period to compare the two chloramines dosing alternatives described above. **Table 6-3** provides the specific parameters, locations, and frequency of the proposed sampling regime. Samples will be collected weekly from the tertiary water and RO feed to assess NDMA formation associated with chloramination. Other nitrosamines, less likely to be formed, along with precursors (DMA) will be measured once over the test period. The various forms of chloramines, along with free chlorine, total chlorine, free ammonia, temperature and pH will be monitored daily for process control. Nitrosamines samples will be sent to off-site certified laboratories for analysis, all other parameters will be analyzed in the on-site lab. The sampling regime will be conducted over a 2 month period with 30 days designated to using sequential chloramines application, followed by a 30 day period during which pre-formed chloramines will be utilized. Two alternatives will be compared in terms of NDMA formation, mono-chloramines production, stability, etc. Based on results, one of the two alternatives will be selected for use during remainder of the 12 month test period. Optimization of the selected chloramines dosing strategy including the identification of the minimal dose necessary to prevent RO fouling will be completed during the testing period. The starting dose of chloramines will be based on the RO manufacturer's permissible limits. The impact of adding acid to the feed water for RO scaling control on chloramines specification and NDMA formation will also be evaluated during this time.

Table 6-3
[1]NDMA and Chloramines Sampling Regime

Parameter	Sampling Location	Frequency
NDMA	S1, S6, S10	1/week
DMA	S1, S6, S10	1/month
NDEA	S1, S6, S10	1/month
NMEA	S1, S6, S10	1/month
NPIP	S1, S6, S10	1/month
NYPR	S1, S6, S10	1/month
NDBA	S1, S6, S10	1/month
Total Chloramine	S6, S9, S10	1/day
Mono Chloramine	S6, S9, S10	1/day
Di Chloramine	S6, S9, S10	1/day
Nitrogen trichloride	S6, S9, S10	1/day
Free Chlorine	S6, S10	1/day
Free ammonia	S6, S10	1/day
pH	S6, S10	1/day
temperature	S6	1/day

[1] Note the sampling regime provided will be conducted over two 30 day periods. During the first 30 days, option 1 - sequential chloramines conditions will be in place. For the next 30 day period, option 2 -pre-formed chloramines conditions will be in place. Sampling locations shown in Figure 5-1.

6.4 UV/AOP By-product Evaluation

Comments made by the CDPH on the IAP report indicate that by-products of NDMA and 1,4-Dioxane from the UV/AOP process may be a concern. There has been limited research into by-product formation and as part of development of this Testing and Monitoring Plan, a review of past research was performed by Dr. William J. Cooper at the University of California, Irvine. A summary of key findings and recommendations are provided below.

6.4.1 N-Nitrosodimethylamine (NDMA)

The UV/H_2O_2 process when applied to NDMA is a two step process, 1) photolysis of the NDMA by 254 nm UV light, and 2) oxidation of the products primarily thorough the hydroxyl radical (•OH) mediated reactions. The photolysis of NDMA has been studied at pH 3 and 7 with the major difference being the rate of destruction, i.e. at pH 3 NDMA is destroyed approximately six times faster than at pH 7. In both cases the major organic reaction by-product was DMA. Formaldehyde was observed at both pH 3 and 7 and was shown to be tenfold less that the DMA at pH 3 and fivefold less than DMA at pH 7. Therefore, the lower the pH during the photolysis, the more effective the photolysis of NDMA.

The advanced oxidation of DMA has not been studied in any detail; however, it is possible that decomposition would likely form formaldehyde and thus is the source of that observed in the studies reported.

6.4.2 1,4-Dioxane

The oxidation of 1,4-dioxane is considerably more complicated than that of NDMA. Focusing only on hydroxyl radical (•OH) oxidation there was a comprehensive study conducted by Stefan and Bolton (2002) and documented the loss of the parent compound (1,4-dioxane) and the formation of a number of reaction by-products. These by-products were 1,2-ethanediol diformate; 1,2-ethanediol monoformate; methoxyacetic acid, acetic acid, formic acid, oxalic acid, glyoxal, acetaldehyde and formaldehyde.

For the most part, these by-products will be easily biodegraded and likely cause no alarm. The one exception may be formaldehyde. As both NDMA and 1,4-dioxane result in the formation of formaldehyde this may be the compound to analyze to determine the efficiency of the processes.

Table 6-4 presents the predicted formaldehyde concentrations (by-product formation from UV/AOP process) expected from 100 ng/L NDMA and 1,4-dioxane concentration doses.

Table 6-4
Predicted Formaldehyde Formation from UV/AOP Process

Compound	Parent Concentration		pH	Formaldehyde Concentration	
	Weight concentration	Molar concentration		Weight concentration	Molar concentration
NDMA[1]	100 ng/l	1.4 nM	3	10.4 ng/l	0.14 nM
NDMA	100 ng/l	1.4 nM	7	21 ng/l	0.28 nM[2]
1,4-dioxane[3]	100 ng/l	1.14 nM	Not specified	17 ng/l	0.19 nM

[1] Stefan, Mihaela I.; Bolton, James R. UV direct photolysis of N-nitrosodimethlyamine (NDMA): kinetic and product study. *Helvetica Chimica Acta*, **2002**, *85(5)*, 1416-1426.
[2] The maximum concentration of formaldehyde was observed after 60 minutes irradiation, pH = 7, which was the time it took in lab experiments to approach 1.2 log removal of the NDMA. The concentration was 10 % of the influent NDMA concentration. Therefore it appears that at lower the lower pH the reaction will be faster and less formaldehyde will be formed.
[3] Stefan, Mihaela I.; Bolton, James R. Mechanism of the Degradation of 1,4-Dioxane in Dilute Aqueous Solution Using the UV/Hydrogen Peroxide Process. *Environmental Science and Technology*, **1998**, *32(11)*, 1588-1595.

During the 2005 AWT studies conducted at NCWRP NDMA was measured in the NCWRP tertiary effluent at concentrations ranging from 14-80 ng/l. Based on the data presented in **Table 6-4** the expected formaldehyde concentration that would result from UV/AOP would be significantly less than the current CDPH Drinking Water Notification Level of 0.1 mg/L. Also the concentration of 1,4-dioxane measured in the RO feed ranged from 43 to 71 ug/L (43,000 to 71,000 ng/L) and in the RO permeate ranged from 4.7 to 6.9 ug/L (4,700 to 6,900 ng/L). Based on the predicted rate of formation, it is expected that formaldehyde concentrations of 0.007 to 0.012 mg/L may be formed which is significantly below the Notification Levels for formaldehyde.

Recommended AOP Byproduct Monitoring Plan

Based on information found in peer reviewed literature and past pilot testing conducted at NCWRP it does not appear UV/AOP byproduct formation will be an issue. <u>These findings will be confirmed by taking grab samples from (S9) and (S10) and measuring formaldehyde on a weekly basis during the 8 weeks of the routine sampling period</u>. Based on results bench scale experiments may be developed and employed to gain further insight on UV/AOP byproducts. The bench scale experiments will be conducted at concentrations higher than found in natural waters so as to enable the identification of reaction by-products. From these, a kinetic model that describes the destruction of the parent compounds and the reaction by-products will be developed. A UV 254 irradiation system will be used and methods that they have been used for determining reaction mechanisms for other DBPs, and for evaluating AOP destruction of methyl tert-butyl ether (MTBE), emerging CECs, harmful algal bloom toxins and pharmaceuticals. LC/MS and LC/MS-MS and LC/MS-MS-MS and high resolution NMR for reaction by-product identification will be employed.

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Section 7
Quality Assurance/Quality Control (QA/QC)

The following section provides a general description of QA/QC procedures to be employed during the demonstration testing period, including data analysis, lab testing, field sampling procedures, sample handling and storage, data validation and equipment.

7.1 Data Analysis and Laboratory Testing

Some of the analysis required for routine sampling will occur at the on-site laboratory, while more specialized analyses will be sent to a certified laboratory. All laboratory testing procedures conducted on-site and at the external laboratory will comply with EPA testing procedures. Laboratories will follow protocols of California ELAP, TNI2011 standards, and the 5th Edition EPA Manual for the Certification of Laboratories for Drinking Water, as applicable.

Data collected and analyzed on-site will be regularly verified with data from the certified laboratory analyses. This will result in a comprehensive database, which can be used for data analysis, retrieval, reporting and graphics. All data will be checked and verified by the operations manager / project engineer before and after entry into the database. The collection of data files will be sent to selected PAC members on a regular basis for review and analyses. **Table 7-1** shows QA/QC measures to be taken for onsite and laboratory analysis. **Table 7-2** displays specific laboratory QC procedures that will be utilized during CEC analysis, as provided by MWH Laboratories.

Table 7-1 **On-Site & Certified Laboratory QA/QC Measures**	
pH (report to nearest 0.1 pH unit)	Weekly 3 point calibration with certified pH buffers in the range of measurements (4.0, 7.0 and 10.0)
Temperature (report to nearest 0.1 ° C)	Initial and quarterly verification against NIST thermometer
Turbidity, online (report to nearest 0.05 NTU for filtrate)	Weekly comparison to bench top turbidimeter; recalibrate if difference is > 20%
Turbidity, bench top (report to nearest 0.05 NTU for filtrate)	Initial and weekly calibration with primary standards of 20 ,100 and 800 NTU. Daily verification with 10 NTU standard.
Conductivity, online	Weekly comparison to portable meter, recalibrate if difference is > 20%
Conductivity, portable meter	Initial and weekly calibration with primary standards of 23 uS/cm and 2,764 uS/cm.
Water Quality Analysis Outside Laboratories	Follow California ELAP procedures, TNI2011 standards, and the 5th Edition EPA Manual for the Certification of Laboratories for Drinking Water, as applicable
Microbial Analysis Outside Laboratory	Follow federal NELAP and California ELAP procedures, and USEPA Standards and Protocols for Testing Microbial Water

Table 7-2 **Laboratory QC Measures for CEC Analysis**	
Quality Control	**Criteria**
Method Blank	< MRL
MRL Level Check Sample	50 - 150%
LCS and LCSD	70 - 130% or 60 - 140%, depending on compound
MS / MSD	60 – 140%

7.2 Sampling Procedures

The following sections describe the equipment and procedures that will be utilized to collect demonstration water quality samples. A summary of the proposed water quality monitoring and sampling plan is provided in **Section 5** of this report.

Water sample collection activities will be conducted by two project team operations personnel with the exception of sample processing, which will be conducted by the contracted laboratory. Sampling procedures will be provided by the contracted laboratories to follow USEPA guidelines.

7.2.1 General Sampling Procedures

Sampling personnel will utilize clean handling techniques when processing the samples such that only new powder- and phthalate-free vinyl gloves (nitrile) will be worn when handling the sample bottles. In general, personnel will wear clean vinyl gloves during all sample retrieval operations and change gloves frequently, usually with each change in task.

After opening stainless steel sample location valves and allowing treated water to flow for two to three minutes, personnel will collect water samples from appropriate locations along the AWP Facility treatment train, label sample collection bottles appropriately, and place them into coolers packed with ice packs/blue ice at the conclusion of the sampling event. Personnel will then ship the sealed coolers under chain-of-custody to the contracted laboratory. The laboratory will process and analyze the samples in accordance with their standard operating procedures.

Strict adherence with the sample volume quantities, preservation methods and hold times provided by the certified laboratories for each analytical method will be followed in order to meet reporting limits.

7.2.2 CEC Sampling Procedures

In addition to the above general sampling procedures, certain steps will be taken to ensure the integrity of samples that will be analyzed for trace CECs. These steps include avoiding smoking and handling or ingesting pharmaceuticals or caffeinated beverages shortly before and during sampling events. Contracted laboratories will follow additional protocols and recommendations set forth in the Science Advisory Panel's *Monitoring Strategies of Chemicals of Emerging Concern in Recycled Water* Final Report.

7.2.3 Microbial/Biological Parameters Sampling Procedures

Collecting water samples for analysis for biological parameters requires additional procedures to ensure sample integrity. A general description of sampling procedures to be followed for various microbial parameters is provided below with more detailed information provided in **Appendix J**.

Bacterial parameters

- Requires sterilization of the sample valve prior to collecting the grab sample. Sterilization will be conducted with a hand-held propane torch.
- Samples will be stored with blue ice and at a target temperature of 3-8 °C.
- Follow sample collection and handling procedures as specified in USEPA Methods 1602 (F- and somatic coliphage), 1682 (salmonella), and SAP 2009 Draft (E. coli O157), and method SM 9221 (coliform).

Virus analysis

- Follow sampling procedures detailed in the USEPA *Information Collection Requirements Rule – Protozoa and Enteric Virus Sample Collection Procedures*.
  - Note: This method (1995) specifies a 1MDS electropositive filter, the filter type now being used is a NanoCeram electropositive filter.
- Requires the use of a virus sampling apparatus (chlorine sterilized filter concentrator).
  - The sampling apparatus, and training on the use of the device, will be provided by Biovir Laboratories.
  - Prior to sampling the apparatus must be flushed with 20 gallons (76 liters) of water.
- Samples for virus analysis will be stored with blue ice and at a target temperature of 4 ° C.

Cryptosporidium (not in current sampling plan)

- Follow sample collection procedures detailed in Biovir's Example Procedure for Collecting Filtered Water Samples (Using HV Envirochek Capsule Filters) for Method 1622/23 Analysis.
- Samples will be cooled as quickly as possible by immersion in an ice bath, and kept at a target temperature of 4 ° C. Care will be taken to avoid shipping samples with unnecessary ice/cold packs to keep from freezing the filter element.
- Sample will be dechlorinated using sodium thiosulfate.

7.2.4 Sampling Equipment and Supplies

Sampling equipment and supplies include the equipment required for the collection of demonstration water quality samples, associated sample collection and handling supplies, decontamination equipment, sample collection bottles and coolers, etc. Equipment to be utilized during sampling events includes the following:

- Gloves
- Rinse Bottles
- Ice packs
- Coolers
- Propane Torches (microbial)

- Timers
- Virus Sampling Apparatus (Chlorine Sterilized Filter Concentrator)

7.3 Sample Designation and Handling

Sample handling and designation procedures are included to provide sufficient project-specific QA/QC measures. Project-specific QA/QC requirements and procedures described in the following sections include:

- QC sample collection requirements.
- Sample container requirements and preservation.
- Sample documentation and handling.
- Chain-of-custody documentation.

7.3.1 QC Sample Collection Requirements

Field and laboratory QC samples will be collected and analyzed as a quality check of sampling and analytical procedures, as described below. Quality Control sample collection frequencies for this project are presented below in **Table 7-3**. The following field and laboratory QC samples will be collected during the demonstration period:

- Field Duplicate. A portion of the collected sample volume will be analyzed identically to evaluate laboratory precision, reproducibility of sample handling and analytical procedures, sample heterogeneity, and analytical procedures.
- Split Sample. A portion of the collected sample volume will be analyzed by a separate laboratory with overlapping capabilities utilizing identical analytical methods to evaluate laboratory accuracy, reproducibility of sample handling and analytical procedures, sample heterogeneity, and analytical procedures.

Table 7-3
QC Sampling

QC Sample Type	Frequency	Sample Location
Duplicate Sample	Collect one blind duplicate per quarterly sampling event	Rotated quarterly
Split Sample	**First Quarter**: Collect split sampling for all quarterly monitoring parameters listed in Table 7-4. **Quarterly**: Collect split sampling for CECs	UV/AOP product water

Laboratories split analysis responsibilities for samples collected during quarterly monitoring are presented below in **Table 7-4**.

Table 7-4
Quarterly Sampling Event Split Sampling

Contracted Laboratory	Split Analysis Responsibilities
MWH Labs	• Primary State/Federal Drinking Water Standards • Secondary State/Federal Drinking Water Standards • USEPA Priority Pollutants • Potential AOP Byproducts • CDPH Drinking Water Notification Compounds
Colorado School of the Mines	• Constituents of Emerging Concern

7.3.2 Sample Containers

The contract laboratories will provide certified clean sample collection containers as appropriate for the required analyses. Sample container quality protocols will be strictly enforced and assured by the laboratory. The laboratory will retain certificates of analyses from each lot of containers for a period of at least 5 years. Sample containers will be kept closed until used. The sample containers, preservation, and holding time requirements for this project are presented in **Appendix J**.

7.3.3 Sample Preservation and Holding Time

The use of proper chemical and thermal preservation is critical to maintain the validity of project samples. Sample bottles will be placed into a cooler packed with wet ice. The target temperature for the cooler is 6° C, with the exception of coolers containing samples for biological parameters which will be cooled as is described in the above microbial/biological parameters sampling procedures. If samples are received by the lab the same day as sampling occurred target temperatures need not be reached; however, samples must show evidence of chilling. Samples will be shipped under chain-of-custody to the contract laboratory as soon as possible after sample collection activities. The laboratory will document the sample temperature upon receipt.

7.3.4 Sample Storage, Packaging, and Transport

Proper sample handling procedures will be followed so sample quality is not compromised after the collection of the sample and prior to submitting the sample to the laboratory. Each sample will be handled according to the protocol specific to the environmental media.

Sample Storage
Collected samples will remain in the possession of a designated project team representative at all times until custody is relinquished to the laboratory (in person or through shipment), or until the samples are placed in a secure storage location.

Sample Packaging
Samples will be transported in the same coolers used for temporary sample storage. Samples will be accompanied by a completed chain-of-custody form, sealed in a Ziploc® or equivalent bag to prevent damage to the document, and taped inside the lid of the cooler. Individual glass sample containers will be wrapped in bubble wrap bags or placed in foam packaging, and placed in polyethylene bags to prevent any potential compromising of sample integrity.

Sample Transport
Samples destined for out-of-area laboratories will be repackaged (as necessary) for shipping. Bubble wrap and foam will be used to help prevent sample bottle breakage during shipping. Samples will be placed into coolers packed with wet ice and labeled appropriately for shipping. Express delivery from common carriers will be used for shipping. A chain-of-custody form will accompany each cooler during shipment.

7.4 Documentation

Verifiable sample custody is of primary importance during field and laboratory procedures. Such practices ensure samples have been properly acquired, preserved, and identified. This information will be collected in a variety of formats, specific to the function they perform in the sampling procedure (e.g., field logbooks, sampling field forms, sample labels, chain-of-custody forms, etc.). Sampling records create a complete record of field procedures, including circumstances of collection and integrity of the samples. This will also allow for detailed tracking of each sample from collection through transport and laboratory analysis. The following information outlines specific procedures that will be implemented during sampling events.

7.4.1 Logbook

Sampling activities will be documented in a logbook. The first entry at the beginning of each sampling event will include the date and time, project number, names of personnel on-site, and the purpose of the sampling event (e.g., routine monitoring, quarterly monitoring). Each subsequent page will be started with the project number and the date.

Information included in the field logbook will include the following items:

- Observations relevant to the sampling event, equipment conditions, and events that may have occurred prior to sampling that may influence the integrity or the representativeness of the sample.

- Observations of site activities not covered under regular activities, including presence of persons on-site not related to the sampling activities, and actions by those people affecting work performance.
- Sketches of relevant information.
- Information relevant to a change in scope or change in Work Plan procedure, with documentation of subsequent approval.
- Type and/or level of health and safety equipment used.

Information compiled in the field logbook will be written legibly in language that is clear, concise, and without interpretation.

7.4.2 Chain-of-Custody Procedures

The chain-of-custody is an integral component of the sampling process as it stands as a permanent record of sample holding and shipment. Sample custody is documented from collection through transport, analysis, and reporting.

Samples will remain in the custody of authorized personnel or appropriate staff until receipt by the laboratory or relinquished to the shipper. The corresponding chain-of-custody form will be in plain view at all times, in physical possession, or in a locked location where no tampering will occur. The chain-of-custody form will be crosschecked for errors and signed by the sampler.

Coolers with their respective chain-of-custody form(s) will be checked into the laboratory by a laboratory representative, and the chain-of-custody form will be relinquished to the laboratory by signing and dating the custody form appropriately. The project team operations staff will retain one copy of the signed chain-of-custody form for the project files. The laboratory representative will verify cooler temperature, sample designation, and other relevant sample conditions. The original chain-of-custody form or a photocopy will be returned to the project manager with the analytical results and kept in the project files.

7.5 Data Analysis

The data collected for this project will be reviewed prior to reporting. The following sections describe data validation and preliminary statistical analysis that will be performed on collected laboratory analytical data.

7.5.1 Data Validation Review

A complete third-party data validation of the AWP Facility product water (S10) will be performed on laboratory results obtained for the first quarterly sampling event. Results of this validation will be used to determine data quality and review laboratory procedures. Labs will make procedural alterations based on this data validation as necessary.

Third party validation is beneficial whenever analytical data may be subject to intense scrutiny that could result in the accuracy of the reported data being challenged in a court of law. The USEPA issued guidance documents detailing analytical data evaluation and review processes for inorganic and organic data produced under the USEPA Contract Lab Program (CLP). The CLP supports a major portion of the sample analysis needs of the USEPA Superfund Program. Due to the potential for legal challenges, samples submitted under this program must be analyzed in conformance with specified analytical protocols and the assembled data package must go through a technical quality assurance review (validation) prepared by an independent third party. In 1986, the Director of the Office of Emergency and Remedial Response proposed several levels of data validation.

Commercial third party specialists performing water quality data validation utilize the guidance issued under the USEPA CLP program. Level IV review is the most rigorous and is characterized by QA/QC protocols and documentation resulting in a complete qualitative and quantitative analysis of the analytical data (USEPA 1987). Data that fulfills the requirements of this level of third party validation fulfills the minimum data quality standards needed to allow the data to be used for its intended objective.

The data validation will consist of an evaluation of sample and measurement collection, custody, analysis, and reporting to identify any quality control deficiencies. Data collected will either be used as reported, qualified as estimated, or rejected for its intended use.

Analytical data validation will comprise the bulk of the data validation effort, and will be performed in accordance with applicable USEPA data validation guidelines for organic and inorganic parameters. LDC, Inc., an independent, third-party, will evaluate the quality of the work based on this document and an established set of laboratory guidelines to ensure the following:

- Sample preparation information is correct and complete.
- Analysis information is correct and complete.
- Appropriate procedures have been followed, specifically with adherence to holding times.
- Analytical results are correct and complete.
- Laboratory QC check results for absence of blank contamination, initial and continuing calibrations, surrogate compound recoveries within limits, allowable matrix spike/duplicate recoveries, accurate internal control standard recoveries, and adequate instrumental performance, are within appropriate QC limits (**Table 7-2**).

- Documentation is complete (observed anomalies in the preparation and analysis have been documented and holding times are documented).
- Laboratory qualifiers have been assigned to each sample with data usability limitations.

7.5.2 Data and Statistical Analysis

Following each quarterly sampling event, validated results for all CEC data will be provided to PAC members. Those PAC members will produce a letter providing scientific interpretation of the data, identifying any anomalies, and providing recommendations for re-sampling or increases in sampling frequency.

Final review of the reported data performed by project team personnel will include an examination of the data in terms of the qualitative data quality objectives and the logbook will be reviewed for completeness and correctness. The data may be qualified based on significant concerns related to representativeness, comparability, and completeness. Each will be discussed, as appropriate, in terms of the deficiencies and associated project impacts. A basic statistical analysis of the data will be performed for collected quarterly monitoring data including determination of the mean, variance and standard deviation for all monitored constituents. The results of this statistical analysis will be provided to select PAC members for final QA/QC and recommendations.

7.5.2.1 Determination of the Number of Samples to Obtain Statistically Significant Data

A key component of the design of the water quality monitoring plan for the AWP Facility is the determination of the number of samples to be collected for the various parameters of interest. A proposed strategy was presented in **Section 5** based on the overall objective of the demonstration program and to provide an acceptable level of effectiveness based on the budget for the demonstration project. The design also took into consideration variability in the NCWRP tertiary water, data from the prior AWT pilot testing, and performance results from full-scale AWT facilities, such as those operated by OCWD for the GWR System and West Basin Municipal Water District for the West Basin Barrier Project. For most parameters the historical AWT data are at or below levels of detection; for detected constituents, the concentrations are typically below regulatory levels. Thus, the sampling frequency for the AWP Facility will generate sufficient numbers of samples to further substantiate this historical data set. The purpose of this section is to review that design in light of the 2009 IAP recommendations and subsequent input from CDPH.

In its 2009 report, the IAP recommended that:

> *"The frequency of monitoring should be adequate to enable statistical analysis of the data and provide the public with confidence on the*

> *performance of the treatment technologies and the extent to which wastewater-derived contaminants are controlled."*

For chemicals, the IAP did not provide a specified sampling frequency. For pathogens, the IAP provided recommendations on initial sampling frequencies for different methods in **Table 6.3.**.. In its comments on the IAP report, CDPH indicated that 1) a UV system designed to achieve a 1.2-log NDMA reduction would provide higher doses than what is required for adenovirus; and 2) requested more information on the specifics of the epifluorescence microscopy program.

The project team proposes a framework for discussion with the IAP and CDPH to define what criteria will drive the data collection needs for statistical certainty. The proposed approach would allow various analytes to be sorted into higher or lower monitoring levels.

Criteria requiring higher statistical certainty which will mean more frequent initial monitoring (at least initially):

- Variations in influent concentration and low effluent requirements (i.e. nitrogen);
- Need to consistently demonstrate non-detects through direct measure and/or indirect surrogate measure (e.g. emerging contaminants); and
- Process operations outside of previously demonstrated envelope.

Based on comments received by the IAP Subcommittee on the initial Draft Testing and Monitoring Plan (NWRI, 2010), factors to consider for the routine sampling plan:

- Appropriate sample volumes required to meet target detection limits;
- Sampling frequency and timing;
- Parameters to be collected using grab samples versus composite sampling;
- The need to collect composite samples on a time weighted or flow paced basis;
- Statistical analysis to be performed on water quality data sets to determine statistical certainty.

7.6 AWP Facility Equipment

All equipment associated with the AWP Facility unit process equipment such as pressure gages, flow meters, and safety switches will be calibrated on-site or checked for factory calibration during start up. In addition the accuracy of key components will be check on a periodic basis as summarized in **Table 7-5**.

Table 7-5
Equipment QC Criteria

Parameter	Equipment	Frequency	Acceptance Criteria
Flow Rates	On-line turbidity meters	Daily	+/- 20%
	Chemical dosing pumps	Daily	+/- 15%
	System rotameters and digital flow meters	Quarterly	+/- 10%
Pressure Gages	System pressure and vacuum gauges	Quarterly	+/- 5%

Calibration or verification records will be kept for flow meters, pressure gages, and on-line water quality analyzers.

Section 8
Additional Scope of Services

The following section provides details of additional scope of services outside of the Final Testing and Monitoring Plan. Theses scope items were either included in the November 30, 2010 Draft Testing and Monitoring Plan (Draft T&M Plan) or developed by the project team based on comments received from the IAP/CDPH/RWQCB on the Draft T&M Plan (**See Appendix K**). The project team will implement all or select scope items upon authorization from the City.

8.1 Integrity Monitoring Methods

Two additional integrity RO monitoring methods identified in the Draft T&M Plan include challenge testing with MS2 virus and TRASAR fluorescent dye. The City will reassess the possibility of MS2 virus challenge testing in the 3rd quarter once the regulatory requirements for the full scale project become more defined. Detail of each method is provided in the following sections.

8.1.1 MS2 Virus Challenge Testing

Though it is not an objective of the testing plan to demonstrate the ability of the RO membranes to remove viruses, conducting virus challenge experiments is a powerful means of monitoring RO system integrity. Accordingly, an optional service for consideration, challenge experiments can be performed on each RO system during start up and upon completion of the target 5,000 hour test period.

If required, challenge experiments would be conducted using MS2 virus. MS2 virus is not a human pathogen; however, this organism is similar in size (0.025 microns), shape (icosahedron) and nucleic acid (RNA) to polio virus and hepatitis virus. Because MS2 is not a human pathogen, live MS2 virus will be used in the seeding experiments. Organism stocks can be obtained from Biovir laboratories and upon receipt would be stored refrigerated at 4 C in the dark for less than 2 days prior to being used in the seeding experiments. The ATCC strain number of the virus to be used is 15597 and the bacterial host will be E.Coli (ATCC#700891).

A schematic of the proposed virus seeding set up is provided in **Figure 8-1.** The figure is based on a three stage system operating at 75% recovery. Samples will be taken from the following seven locations for the 3-stage system:

- S1 - RO feed (common)
- S2 - RO stage 1 permeate
- S3 - RO stage 2 permeate

- S4 - RO inter-stage 1/2
- S5 - RO stage 3 permeate
- S6 – RO inter-stage 2/3
- S7 – RO system 1 permeate (combined)

All samples will be analyzed by Biovir Laboratories, which is State-certified to perform MS2 analysis.

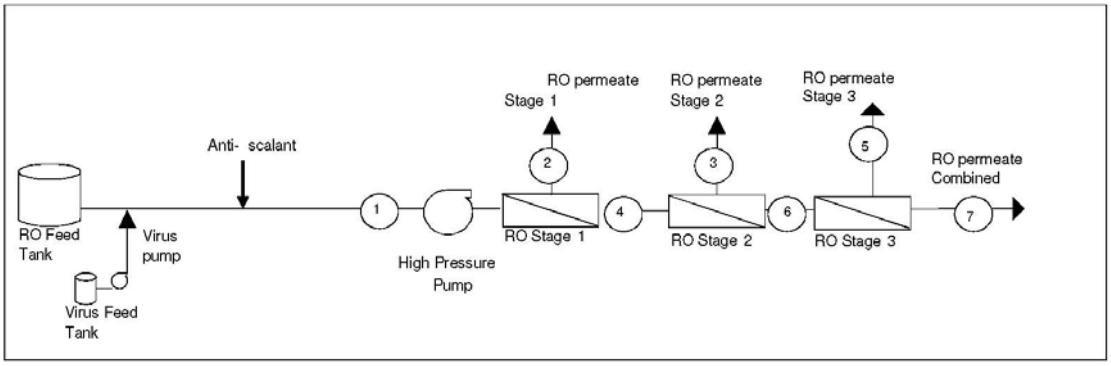

Figure 8-1
Virus Seeding Set-up 3-Stage RO System

Table 8-1 provides details on the sampling locations, QA/QC samples and total number of samples required per challenge experiment. Challenge experiments will be scheduled to be conducted one per system during start up to establish baseline performance and one following 5,000 hours of operation to demonstrate performance reliability over the test period.

Table 8-1 Sampling Details for MS2 Virus Challenge Experiments (Optional)				
RO System	**RO System Sample Frequency**	**QA/QC Sample quantity and description**	**Total number of samples per experiment**	**Scheduled experiments**
3-stage Toray	Samples to be collected: S1, and S7 every 5 min. for 30 min.	2 samples @ virus feed tank (begin and end of experiment) 1 negative control samples experiment @ RO permeate prior to MS2 injection	17	(1) during start up; (1) @ completion of testing
2-stage Hydranautics	Samples to be collected: S1 and S7 every 5 min. for 30 min.	2 samples virus feed tank (begin and end of experiment) 1 negative control samples experiment @ RO permeate prior to MS2 injection	17	(1) during start up; (1) @ completion of testing

Table 8-2 provides details associated with virus seed stock and RO feed concentrations, based on 1.20 MGD RO feed flow.

Table 8-2 MS2 Phase Challenge Experiment Details Required for 1.20 MGD Feed Flow	
Stock Volume Required (mL)	1000
Stock Virus Concentration (pfu/mL)	1.00E+11
Total MS2 virus in Send Tank (pfu)	1.00E+14
Seed Tank Volume (gallons)	50
Virus Injection Concentration (pfu/mL)	5.29E+08
Injection flow rate (mL/min)	4000
Feed Flow (gpm)	868
Feed Virus Concentration (pfu/100mL)	6.44E+07
Time Stock will last (minutes)	47.3

8.1.2 TRASAR Challenge Testing

Should the City choose to add it, challenge experiments can also be conducted during the testing period using a chemical product named TRASAR® offered by Nalco, Inc (Naperville, IL). TRASAR® is composed of fluorescent molecules (molecular weight

[MW] = 614 grams per mol [g/mol]) and has been historically used for chemical dosing control in drinking water and industrial applications (Zeiher et al, 2003). Dosing control can be achieved by adding a known quantity of TRASAR® to a given chemical (such as antiscalant) and measuring its concentration using Nalco's trace leak detection (TLD) system. The TLD system detects TRASAR® by measuring fluorescence. A feedback control system can then be used to adjust the chemical dose based on the measured TRASAR® concentration.

Recently, Nalco has further modified the TLD system to detect TRASAR® at low concentrations (ng/L) which enables it to act as an RO integrity monitoring system (Zeiher et al., 2002). In principle for RO membrane system integrity monitoring, the TRASAR® is injected into the RO feedwater and if the membrane system is intact, then the TRASAR® is rejected by the RO membranes and is not detected in the RO permeate. If there is a breech in the integrity of the RO membrane system which allows the TRASAR to leak into the RO permeate the TLD system should detect its presence and thus signal a loss of membrane integrity. Details of the TRASAR system provided by Nalco are provided in **Appendix D**. For challenge testing TRASAR® will be dosed continuously over a 10-minute period to the feed of the RO system to achieve a target concentration between 10-15 mg/L and upto 5-6 LRV sensitivity.

8.2 CEC Spiking Experiment to Assess UV/AOP Efficacy

The CDPH comments (CDPH, 2011) on the Draft T&M Plan suggested a Surrogate / Indicator Framework including challenge or spiking studies be applied during the AWPF testing to assess the effectiveness of the AOP process. Based on this comment, the project team recommends one spiking experiment be conducted after the first quarter of testing is complete to demonstrate the removal of several indicator compounds with the removal of surrogate parameters (UVA, chloramines), which can be easily measured on a frequent basis. The indicator compounds to be included in the spiking experiment will be based on occurrence data collected in the feed and product water of the AOP process with the overall goal of selecting compounds that will serve as good indicator compounds representative of wide range of characteristics for ongoing monitoring. The project team will work closely with the project advisory committee including Dr. Jorg Drewes and Dr. Shane Snyder to develop the list of compounds to be included in the CEC spiking experiment. The CEC spiking experiment will be conducted under UV/AOP conditions determined from the results of the NDMA, 1,4 dioxane spiking experiment presented in Section 6.2 using a similar experimental set up.

This added scope item would require the following:

- Certified lab preparation of the spiking solution containing (10) selected indicator compounds.

- Certified lab analysis of approximately 12 samples taken from the influent and effluent of the UV/AOP system including control samples.
- Labor required for set up and administration of the spiking experiment.
- Supplies and equipment.
- Data analysis.

8.3 Assessment of AWPF Product Water Stabilization Requirements

Upon review of the Draft T&M Plan, the IAP Subcommittee provided the project team with a series of comments including a recommendation to consider evaluating options to stabilize the AWPF product water (NWRI, 2010). The primary objective of the assessment would be to determine the extent to which secondary disinfection and / or corrosion control in addition to lime treatment may be required for the potential full-scale AWPF. The IAP Subcommittee presented the option of conducting pilot testing using a pipe-loops or annular reactors to achieve the aforementioned objectives. After consideration of this information, the project team recommends the City consider conducting an initial bench scale study during the AWPF Demonstration phase to gain insight on corrosion and biogrowth potential of AWP product water and to identity possible post treatment strategies that could be considered from the full scale AWPF. Based on the information gained from the bench testing, the City may decide to conduct pipe-loop studies at a later stage in the approval and decision process to move forward with a full- scale AWPF.

The specific objectives of the proposed product water stabilization bench scale testing follow:

- Assess the microbial re-growth and corrositivity potential of the AWPF product water.
- Identify possible post treatment strategies to inhibit corrosion of the conveyance system of the full scale AWPF.
- Identify possible secondary disinfection strategies to inhibit bio-growth in the conveyance system of the full scale AWPF.
- Assess nitrogenous disinfection byproduct (DBP) formation potential of the AWP product water under various secondary disinfection strategies
- Provide recommendation on further testing required prior to the selection and design of the post treatment system for the potential full-scale AWPF

8.3.1 Bench Scale Testing Approach

The following provides a proposed outline of the bench scale testing approach to meet the above objectives:

The specific objectives of the proposed product water stabilization bench scale testing follow:

- Characterize the assimilable organic carbon (AOC) and biodegradable organic carbon (BDOC) content of the AWPF Demonstration product water.
- Collect, treat and analyze batch samples of the AWPF product water to evaluate options for achieving a neutral or slightly positive Langelier Saturation Index (LSI). Strategies to be considered include: 1) increasing the hardness and alkalinity using lime or calcite contractor along with carbon dioxide addition for pH adjustment, 2) adding polyphosphate or silicate inhibitor 3) simply raising the pH with lime addition only.
- Perform chlorine demand decay tests of the AWPF product water to determine the chlorine demand and Nitrogenous DBP formation potential.
- Assess biofilm growth and corrosion of pipe coupons configured in an annular reactor (with and without secondary disinfection & corrosion control) using pipe material and hydraulic detention times under similar conditions being considered with regards to the conveyance system for the full-scale AWPF.

8.4 Microbial Monitoring

Upon review of the Draft T&M Plan, the IAP suggested that it may be possible to reduce the monitoring frequency for Cryptosporidium (before MF/UF) by sampling for aerobic spores like B. subtilis as potential surrogates for Cryptosporidium. B subtilis are much smaller than Cryptosporidium and thus would be a conservative indicator that can be analyzed quickly and inexpensively. B. subtilis analyses could be performed in conjunction with Cryptosporidium studies and more frequently as potential MF/UF process performance indicators. The use of aerobic spores would be appropriate if the spores service the prior disinfection process. This would need to be evaluated.

The project team agrees B. subtilis may serve a good surrogate for Cryptosporidium as it is smaller and should be removed by sieving. However, it is unknown if the spores will survive the addition of chloramines upstream of the MF/UF systems to have substantial levels. Also, it may be difficult to differentiate whether observations of reduced concentrations in the MF/UF filtrate is due to disinfectant contact time during filtration, or actual removal. In order to answer these questions, the project team would recommend conducting conventional microbial inactivation bench scale

experiments using B. subtilis under various conditions including chloramines concentration, pH and contact time.

8.5 Provisions to Address the State Water Board's draft Policy for Toxicity Assessment and Control

The RWQCB's comments (California Regional Water Quality Control Board – San Diego Region, 2011) on the Draft T&M Plan specified that the Plan should include provisions for addressing the State Board's draft Policy for Toxicity Assessment and Control.

Based on this comment, the project team recommends discussing with the State Board the option of conducting quarterly Whole Effluent Toxicity testing on the AWPF effluent using current Standard EPA test methods. Each test would include 3 freshwater species (algae, fish and invertebrate) per the EPA protocol. The initial sample volume per test would be 5 gallons with 3 discreet samples required per test over a 7 day period. Based on their local experience conducting similar testing for Padre Dam Municipal Water District it is recommended that Nautilus Environmental Laboratories (NEL) perform the testing. Based on initial discussion with NEL it is suggested AWPF effluent samples be remineralized to specific pH, alkalinity and hardness prior to conducting the testing. Turnaround time on the analytical results in approximately 2weeks.

8.6 Assessment of Diurnal Effect on Key Constituents

Per comments received by the CDPH on the November 30, 2010 Final Draft Testing and Monitoring Plan, it is recommended that two 24 hour sampling events during the 12 month operating period be conducted to assess diurnal variations of key constituents by collecting grab samples of the RO feed (S6) every 4 hours for the following compounds:

- Caffeine (14 samples total)
- Sucralose (14 samples total)
- Total nitrogen(14 samples total)
- Nitrate / Nitrite(14 samples total)
- Total phosphorus (14 samples total)
- 1,4 dioxane (14 samples total)
- NDMA(14 samples total)

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Section 9
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APPENDIX A – AWP FACILITY DRAFT PFD & SITE LAYOUT

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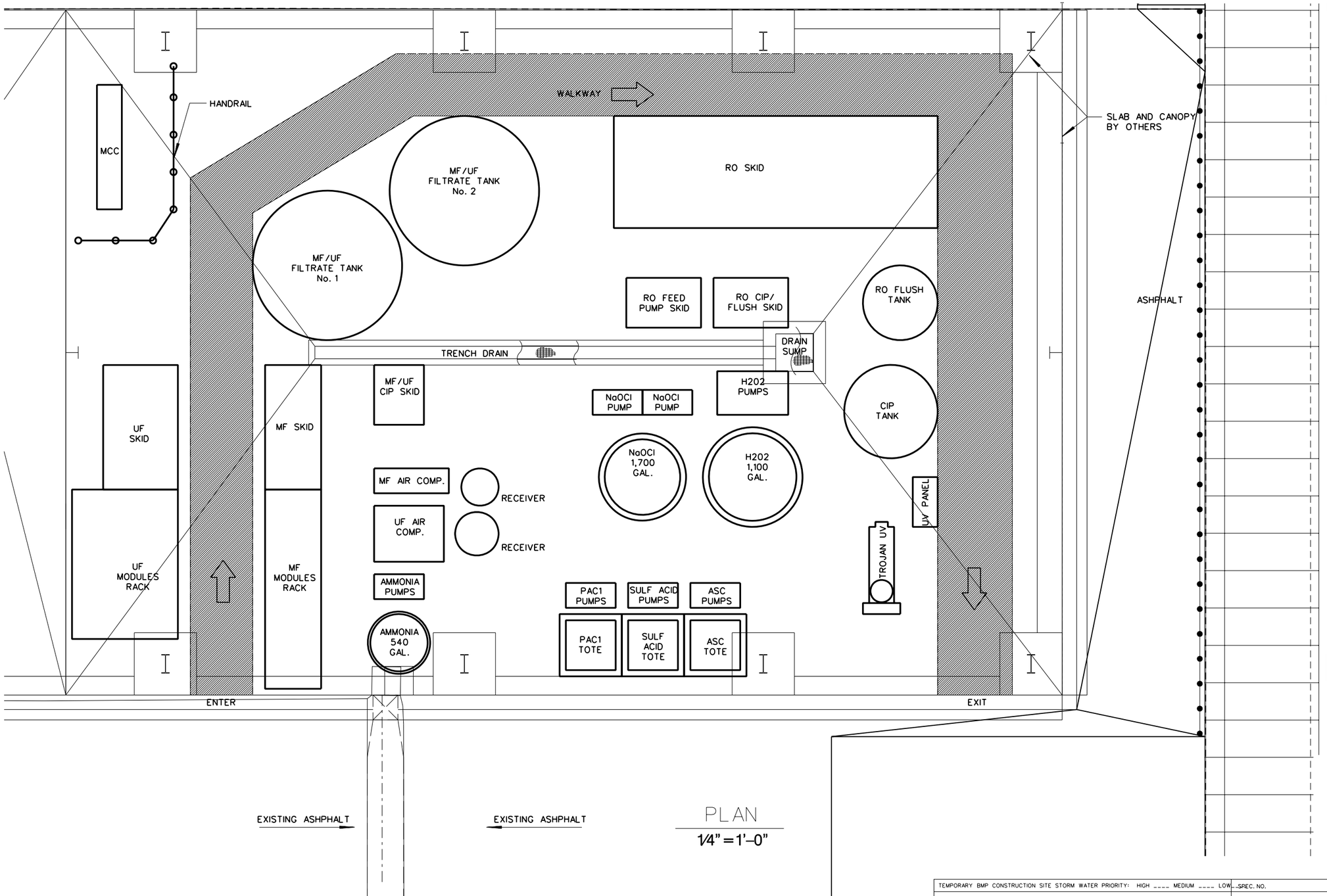

PLAN

1/4" = 1'-0"

A-1

INDIRECT POTABLE REUSE/RESERVIOR AUGMENTATION DEMONSTRATION PROJECT ADVANCED WATER PURIFICATION FACILITY

MECHANICAL PLAN

TEMPORARY BMP CONSTRUCTION SITE STORM WATER PRIORITY: HIGH ____ MEDIUM ____ LOW ____ SPEC. NO.

CONSULTANT

CONSULTANT STAMP

CITY OF SAN DIEGO, CALIFORNIA
ENGINEERING AND CAPITAL PROJECTS DEPARTMENT
SHEET OF SHEETS

WBS 0-00000
WBS 0-00000

APPROVED:
FOR CITY ENGINEER
DATE

SUBMITTED BY:
ASSOCIATE ENGINEER
PROJECT ENGINEER

DESCRIPTION	BY	APPROVED	DATE	FILMED
ORIGINAL	XX/XX			

SEE SHEETS
CCS27 COORDINATE
SEE SHEETS
CCS83 COORDINATE

CONTRACTOR _____ DATE STARTED _____
INSPECTOR _____ DATE COMPLETED _____

19905-XX-D

CONSTRUCTION CHANGE / ADDENDUM			
CHANGE	DATE	AFFECTED OR ADDED SHEET NUMBERS	APPROVAL NO.

WARNING
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IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

CITY OF SAN DIEGO
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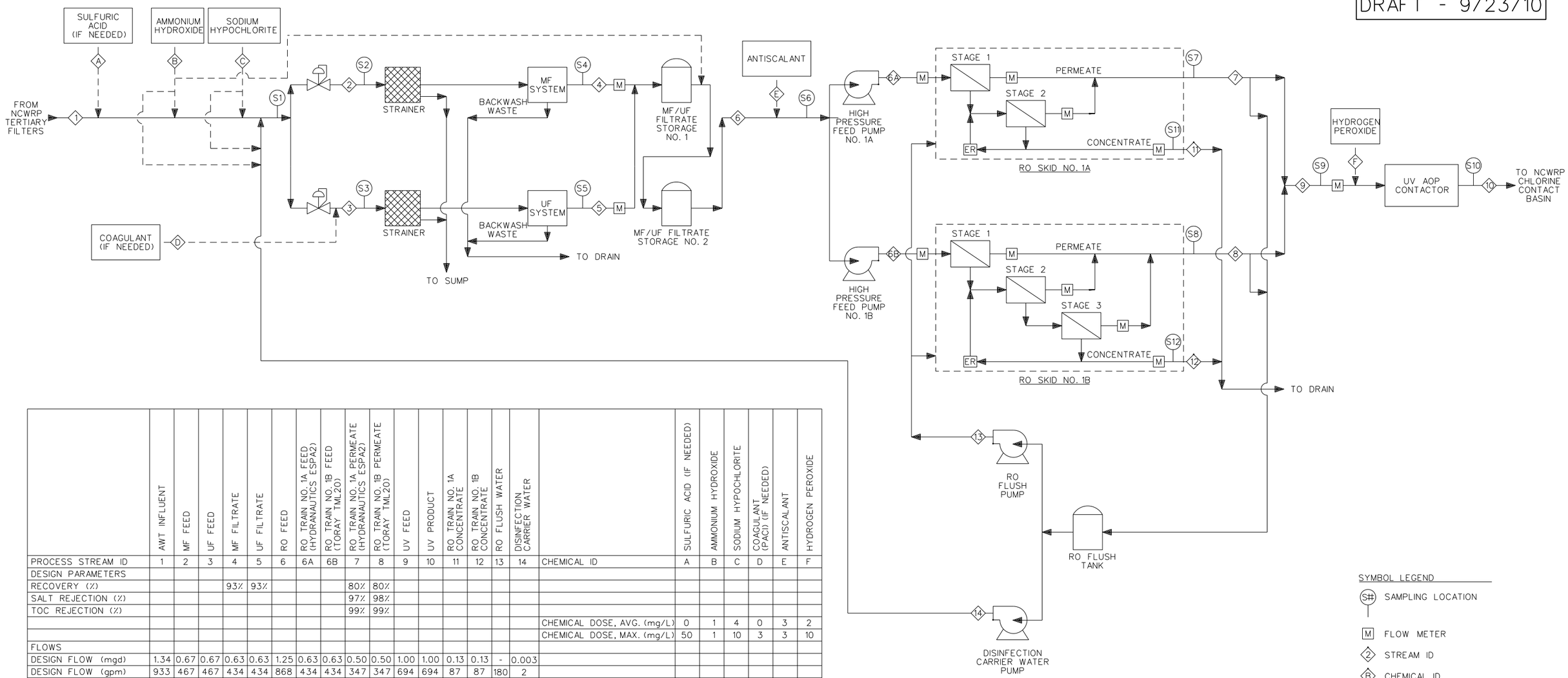

	AWT INFLUENT	MF FEED	UF FEED	MF FILTRATE	UF FILTRATE	RO FEED	RO TRAIN NO. 1A FEED (HYDRANAUTICS ESPA2)	RO TRAIN NO. 1B FEED (TORAY TML20)	RO TRAIN NO. 1A PERMEATE (HYDRANAUTICS ESPA2)	RO TRAIN NO. 1B PERMEATE (TORAY TML20)	UV FEED	UV PRODUCT	RO TRAIN NO. 1A CONCENTRATE	RO TRAIN NO. 1B CONCENTRATE	RO FLUSH WATER	DISINFECTION CARRIER WATER
PROCESS STREAM ID	1	2	3	4	5	6	6A	6B	7	8	9	10	11	12	13	14
DESIGN PARAMETERS																
RECOVERY (%)				93%	93%				80%	80%						
SALT REJECTION (%)									97%	98%						
TOC REJECTION (%)									99%	99%						
FLOWS																
DESIGN FLOW (mgd)	1.34	0.67	0.67	0.63	0.63	1.25	0.63	0.63	0.50	0.50	1.00	1.00	0.13	0.13	-	0.003
DESIGN FLOW (gpm)	933	467	467	434	434	868	434	434	347	347	694	694	87	87	180	2
PRESSURES																
PRESSURE, AVG. (psi)	60	30	50	0.4	0.4	0.4	217	217	4.3	4.3	4.3	4.3	0	0	60	65
PRESSURE, MAX. (psi)	60	30	50	5.6	5.6	5.6	228	228	4.3	4.3	4.3	4.3	0	0	60	75
CONSTITUENTS																
pH, AVG.	7.1	7.2	7.2	7.2	7.2	7.2	7.2	7.2	5.9	5.2	5.6	5.6	7.8	7.8	5.6	5.6
pH, MIN.	7.0	6.4	6.4	6.4	6.4	6.4	6.4	6.4	5.1	4.6	4.9	4.9	7.0	7.0	4.9	4.9
pH, MAX.	7.3	7.7	7.7	7.7	7.7	7.7	7.7	7.7	6.4	6.2	6.3	6.3	8.3	8.0	6.3	6.3
TDS, AVG. (mg/L)	920	925	925	925	925	925	925	925	28	19	23	23	4510	4550	23	23
TDS, MAX. (mg/L)	980	991	991	991	991	991	991	991	30	20	25	25	4840	4880	25	25
TOC, AVG. (mg/L)	8.5	8.5	8.5	8.5	8.5	9.4	9.4	9.4	0.1	0.1	0.1	0.1	47	47	0.1	0.1
TOC, MAX. (mg/L)	10	10	10	10	10	11	11	11	0.1	0.1	0.1	0.1	55	55	0.1	0.1
TOTAL CL2, AVG. (mg/L)	0.0	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
TOTAL CL2, MAX. (mg/L)	0.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0

	SULFURIC ACID (IF NEEDED)	AMMONIUM HYDROXIDE	SODIUM HYPOCHLORITE	COAGULANT (PACI) (IF NEEDED)	ANTISCALANT	HYDROGEN PEROXIDE
CHEMICAL ID	A	B	C	D	E	F
CHEMICAL DOSE, AVG. (mg/L)	0	1	4	0	3	2
CHEMICAL DOSE, MAX. (mg/L)	50	1	10	3	3	10
FEED FLOW, AVG., EA. (gph)	0	0.4	1.4	0	0.14	0.25
FEED FLOW, MAX., EA. (gph)	1.6	0.4	3.6	0.64	0.14	1.3
pH, AVG.	0.03	11.6	12	1.5-2	2-4	3.3

SYMBOL LEGEND

- S# SAMPLING LOCATION
- M FLOW METER
- 2 STREAM ID
- B CHEMICAL ID
- ER ENERGY RECOVERY DEVICE

NOTES

BACKWASH SYSTEMS FOR MF AND UF AND CIP SYSTEMS FOR MF, UF AND RO ARE NOT SHOWN FOR CLARITY.

A-2

INDIRECT POTABLE REUSE/RESERVIOR AUGMENTATION DEMONSTRATION PROJECT ADVANCED WATER PURIFICATION FACILITY

PROCESS FLOW DIAGRAM

TEMPORARY BMP CONSTRUCTION SITE STORM WATER PRIORITY: HIGH ____ MEDIUM ____ LOW ____ SPEC. NO.

CONSULTANT

CDM
Camp Dresser & McKee Inc
1925 Palomar Oaks Way, Suite 300
Carlsbad, California 92008
Tel: (760) 438-7755
consulting • engineering • construction • operations

IN ASSOCIATION WITH MWH

CONSULTANT STAMP

CITY OF SAN DIEGO, CALIFORNIA
ENGINEERING AND CAPITAL PROJECTS DEPARTMENT
SHEET __ OF __ SHEETS

WBS 0-00000
WBS 0-00000

APPROVED: FOR CITY ENGINEER ____ DATE ____
SUBMITTED BY: ASSOCIATE ENGINEER

DESCRIPTION	BY	APPROVED	DATE	FILMED
ORIGINAL	XX/XX			

PROJECT ENGINEER
SEE SHEETS
CCS27 COORDINATE
SEE SHEETS
CCS83 COORDINATE

CONTRACTOR ____ DATE STARTED ____
INSPECTOR ____ DATE COMPLETED ____

19905–XX–D

CONSTRUCTION CHANGE / ADDENDUM

CHANGE	DATE	AFFECTED OR ADDED SHEET NUMBERS	APPROVAL NO.

WARNING
0 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

CITY OF SAN DIEGO
PUBLIC WORKS PROJECT

$plot$date$time$$ $user$

APPENDIX B – TECHNICAL MEMORANDUM: SURVEY OF NCWRP INDUSTRIAL DISCHARGERS PREPARED BY RMC

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Technical Memorandum

City of San Diego Water Purification Demonstration Project

Subject: **Survey of North City Water Reclamation Plant Industrial Dischargers**

Prepared For: City of San Diego Public Utilities Department

Prepared by: Tish Berge

Reviewed by: Tom Richardson

Date: June 21, 2010

Reference: 0104-004

The purpose of this technical memorandum is to outline the process used to identify specific contaminates of concern in the North City Water Reclamation Plant (NCWRP) sewershed based on industrial discharger information and to report the results of this process. This TM is organized as follows:

- Background
- Approach
- Findings

1 Background

The scope of services for the City of San Diego Water Purification Demonstration Project Advanced Water Purification (AWP) Demonstration Plant includes a Local Contaminates Investigation. The RMC team was tasked with identifying specific contaminates of concern in the NCWRP sewershed based on industrial discharger information. This information will be provided to the AWP consultant for use in identifying analytes and indicators included in a Testing and Monitoring Plan.

1.1 NCWRP Sewershed Industrial Base

The NCWRP sewershed has a large concentration of pharmaceutical/research and development (R&D) facilities. Generally only R&D biomedical industry activity is conducted in the area and the discharge may differ daily due to the intermittent nature of the business and frequent turnover of tenants. The team worked with the City of San Diego Public Utilities Industrial Wastewater Control Program to identify the information available for these dischargers via the industrial permitting process.

1.2 City of San Diego Pretreatment Program Permits

The City of San Diego Industrial Wastewater Control Program issues permits to industrial dischargers in San Diego and the 16 Participating Agencies that constitute the Metro sewer system tributary area. Permits issued are based upon industrial type and flow as follows:

- Class 1 – Federally regulated industry - pharmaceutical manufacturer.
- Class 2 – Potential for toxics – laboratories are required to follow Best Management Practices and Toxic and Prohibited Organic Chemical Management Plan (TOMP). For reference, these documents are provided at the end of this technical memorandum as Attachments 1 and 2.
- Class 3 – Potential for conventional pollutants (i.e. biochemical oxygen demand [BOD] and total suspended solids [TSS]) in quantities that could interfere with the collection system or upset the wastewater treatment plant's biological processes. Class 3 permits are not discussed further here

as typical Class 3 pollutants are not discharged in large quantities from R&D biomedical industries.

- Class 4 – Flow is less than 25 gallons per day and permit is not necessary. Class 4 permits are not discussed further as R&D biomedical industries generally done fall within this category.

1.2.1 Class 1 Permits

The US Environmental Protection Agency (EPA) regulates certain classes of industrial waste dischargers as significant industrial users. Significant Industrial User is defined by the US EPA as an industrial user that discharges process wastewater into a publicly owned treatment works (POTW) and meets at least one of the following:

1. All industrial users subject to Categorical Pretreatment Standards under the Code of Federal Regulations - Title 40 (40 CFR) Part 403.6, and CFR Title 40 Chapter I, Subchapter N- Effluent Guidelines and Standards; and
2. Any other industrial user that:
    a. Discharges an average of 25,000 gallons per day or more of process wastewater to the POTW (excluding sanitary, non-contact cooling and boiler blowdown wastewater); or
    b. Contributes a process wastestream which makes up 5 percent or more of any design capacity of the POTW treatment plant; or
    c. Has a reasonable potential for adversely affecting the POTW's operation or for violating any pretreatment standard or requirement.

1.2.2 Class 2 Permits

Each industry is required to submit a list of chemicals stored or used onsite with the initial permit application and every four years thereafter. Most of the chemicals are not expected to be found in the sewer as the discharge of concentrated toxic organics to the sewer is prohibited.

The TOMP requires the following:

- No disposal of chemicals to the sewer
    - There may be a small amount of chemical disposed due to laboratory glassware washing
    - Materials are concentrated and disposed of as a liquid/solid waste
- Provide an inventory of chemicals, which is included in the permit application
- Certify twice a year that the facility is following the TOMP

1.2.3 Permit Information Available

Each permit file includes the permit application, the TOMP, and lists other chemicals maintained on site. The TOMP identifies the CWA priority pollutant toxic organics used (using a checklist and separating into halogenated and non-halogenated) and flammable chemicals used or stored. For the other chemicals maintained and used on site, the type and quantity of data varied greatly with some users reporting in excess of 10,000 chemicals. Data were available in either electronic of hardcopy format. Larger hardcopy files were scanned for text recognition using optical character recognition.

2 Approach

Given the number of permits for industries in the NCWRP sewershed, and the extensive lists of chemicals associated with those industries, the team decided to use a representative subset of industries in developing the inventory. Within the NCWRP sewershed, there are 198 industries with City of San Diego permits. Of these 198 industries, 102 are either biotech R&D or some other type of R&D with the remaining 96 industries covering 49 different industry types from car washes and gas stations to electronic equipment manufacturers and veterinary services. Due to the large prevalence of biotech and

R&D industries within the sewershed, the team selected a subset of these 102 industries. The subset totaled 30 industries and included the following:

- All (two total) Class 1, federally regulated, pharmaceutical manufacturers;
- Twenty Class 2 industries with the greatest industrial wastewater flow; and
- Nine industries (mainly R&D) geographically clustered on Nancy Ridge Drive, including one Class 2 industry.

2.1 Data Review

With the assistance of the City of San Diego Public Utilities Industrial Wastewater Control Program, the team reviewed the permit files for each of the selected industries. Based on information provided in the TOMP, the team compiled a list of the toxic organics used by each industry. Each industry also included a comprehensive list of other chemicals stored or used on site. These varied from one list of just a dozen chemicals/products to lists of more than 10,000 chemicals / products. Therefore, the team decided to use the US EPA's Contaminant Candidate List 3 (CCL3) to prioritize the chemicals and aid in review.

As a result, the final data list provides a listing of toxic organics used (as identified in the TOMP), flammable chemicals used/stored (as identified in the TOMP), and CCL3 chemicals used/stored.

2.1.1 Chemicals of Emerging Concern (CEC)

Constituents/chemicals of emerging concern (CECs) represent a challenging problem for regulators to address, owing to the lack of approved analytical methods to identify and quantify the presence of CECs and limited scientific knowledge about their sources, fates, and effects. The California State Water Resources Control Board (SWRCB) recently issued a Recycled Water Policy that, among other efforts, attempts to incorporate the most current science on CECs into regulatory policies for use by various state agencies. As a part of this policy, Southern California Coastal Water Research Project (SCCWRP) was asked to convene a panel of six experts to provide recommendations to the SWRCB. This "blue ribbon" panel addressed several questions, including:

1. What are the appropriate constituents to be monitored in recycled water, and what are the applicable monitoring methods and detection limits?
2. What are the possible indicators (i.e. surrogates) that represent a suite of CECs?

Based on the information compiled by the SCCWRP panel, the team used the List of Contaminants on US EPA's Contaminant Candidate List 3 (CCL3) [Table D-1, Final Report (Draft for Public Comments) Monitoring Strategies for Chemicals of Emerging Concern (CECs) in Recycled Water Recommendations of a Science Advisory Panel, April 15, 2010]. The U.S. Government has a long history of developing regulations for contaminants in drinking water to protect public health; the process has evolved over several decades and includes the placement of currently non-regulated contaminants to be further evaluated on the USEPA's Candidate Contaminant List (or CCL). The most recent CCL is CCL3, which utilized the expert opinions provided by the National Research Council as well as the National Drinking Water Advisory Council. This multi-step process includes three key elements:

- Identification of a broad universe of potential biological chemical and chemical contaminants (CCL Universe);
- Application of screening criteria based on potential occurrence and human health relevance (preliminary CCL or PCCL); and,
- Selection of priority contaminants based on more detailed occurrence and health effect data as well as expert judgment, public comment, and external advisory committees (draft and final CCL).

A draft of the CCL3 was released in February of 2008 and the final CCL3 was published in October of 2009; the list was then referenced in the recent report by the "blue ribbon" panel.

3 Findings

Based on the available data set and the criteria for review, the team assembled a comprehensive listing of chemicals used or stored by facility. This table appears on the following page.

Facility No.	02-0033	02-0043	02-0059	02-0332	02-0518	02-0641	02-0715	02-0721	02-0730	02-0744	02-0751	02-0752	02-0756	02-0880	02-0761	02-0762	02-0795	02-0803	02-0806	02-0808	02-0843	02-0861	02-0913	02-0939	02-0961	02-0972	02-0978	02-1047	03-1041	03-1081
TOXIC ORGANIC, HALONGENATED																														
aldrin																										x				x
benzofluoranthene																										x				
carbon tetrachloride	x		x	x			x	x	x	x		x								x			x			x				X
chlordane																										x				
chlorinated benzenes	x		x			x	x	x	x			x								x						x				X
chloroalky ethers																				x						x				
chlorinated naphthalene								x	x																	x				X
chlorinated phenols						x	x	x	x			x								x			x			x				
chloroform	x	x				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	X
chlorinated cresols																										x				
DDT and metabolites							x			x																x				
dichlorobenziden																							x			x				
dichloroethylenes			x						x																	x				
dichloropropane									x										x							x				
dichloropropene																										x				
dieldrin																										x				x
endrin and metabolites																										x				
fluoranthene																										x				
freons							x		x	x		x														x				
haloethers						x						x			x					x			x			x				
halomethanes (inc. methylene chloride)	x					x	x	x	x	x		x			x	x		x	x	x		x	x	x		x				x
heptachlor and metabolites																										x				
hexachlorobutadiene																										x				
hexachlorocyclohexane									x																	x				
hexachlorocyclopentadiene	x								x																	x				
pentachlorophenol							x		x			x														x				

Facility No.	02-0033	02-0043	02-0059	02-0332	02-0518	02-0641	02-0715	02-0721	02-0730	02-0744	02-0751	02-0752	02-0756	02-0880	02-0761	02-0762	02-0795	02-0803	02-0806	02-0808	02-0843	02-0861	02-0913	02-0939	02-0961	02-0972	02-0978	02-1047	03-1041	03-1081
polychlorinated byphenyls (PCBs)																										x				
2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)																														
tetrachloroethylene	x		x			x			x			x														x				
toxaphene																										x				
1,1,1-trichloroethane									x	x																x				
trichloroethylene				x				x	x			x		x									x			x				
vinyl chloride																										x				
chlorinated ethanes								x																						
TOXIC ORGANIC, NON-HALOGENATED																														
acenapthene																										x				x
acrolein	x					x		x	x			x							x	x			x			x				
acrylonitrile	x					x			x			x	x							x			x			x				x
benzene	x		x			x	x	x	x	x		x							x	x		x	x			x				x
benzidine	x						x		x														x			x				
chrysene									x			x														x				
2,4-dimethylphenol									x			x														x				
dinitrotoluene						x			x			x														x				
diphenylhydrazine									x			x														x				
endosulfan and metabolites												x														x				
ethylbenzene			x				x		x			x														x				x
isophorone									x																	x				
napthalene	x		x			x	x		x				x									x	x			x				x
nitrobenzene	x					x		x	x			x									x		x			x				
nitrophenols	x					x	x	x	x	x		x						x					x			x				
nitrosamines												x														x				
phenol	x	x				x	x	x	x	x		x						x	x		x	x	x		x	x	x		x	
phthalate esters						x			x																	x				x

Facility No.	02-0033	02-0043	02-0059	02-0332	02-0518	02-0641	02-0715	02-0721	02-0730	02-0744	02-0751	02-0752	02-0756	02-0880	02-0761	02-0762	02-0795	02-0803	02-0806	02-0808	02-0843	02-0861	02-0913	02-0939	02-0961	02-0972	02-0978	02-1047	03-1041	03-1081
polynuclear aromatic hydrocarbons						x			x			x														x				
toluene	x	x	x			x	x	x	x	x		x		x	x	x		x	x	x	x	x	x	x		x				x
CHEMICAL OF EMERGING CONCERN (CCL3)																														
1,1,2,2-tetrachloroethane									x														x							
1,1-dichloroethane									x																					
1,1-dichloropropene																														
1,2,4-trimethylbenzene									x																					x
1,2-diphenylhydrazine									x			x														x				
1,3-dichloropropane																														
1,3-dichloropropene									x																					
2,2-dichloropropane									x																					
2,4,6-trichlorophenol									x														x							
2,4-dichlorophenol									x														x							
2,4-dinitrophenol	x						x		x	x			x																	x
2,4-dinitrotoluene									x																					
2,6-dinitrotoluene									x																					
2-methyl-Phenol (AKA o-cresol)								x	x																					
Acetochlor																														
Alachlor ESA & other acetanilide pesticide degradation products																							X							
Aldrin																										x				x
Aluminum									x														x							
atrazine-desethyl																														
Boron																														
Bromobenzene								x	x														x							x
DCPA de-acid																														

Facility No.	02-0033	02-0043	02-0059	02-0332	02-0518	02-0641	02-0715	02-0721	02-0730	02-0744	02-0751	02-0752	02-0756	02-0880	02-0761	02-0762	02-0795	02-0803	02-0806	02-0808	02-0843	02-0861	02-0913	02-0939	02-0961	02-0972	02-0978	02-1047	03-1041	03-1081
degradate																														
DCPA mono-acid degradate																														
DDE									x																					
Diazinon	x																													x
Dieldrin																										x				x
Disulfoton																														
Diuron									x																					
EPTC (s-ethyl-dipropylthiocarbamate)																														
Fonofos																														
Hexachlorobutadiene																										x				
Linuron																														
Manganese									x				x																	
Methyl bromide (AKA Bromomethane)								x	x																					
Methyl-t-butyl ether (MTBE)							x		x	x			x			x		x					x							
Metolachlor																														
Metribuzin																														
Molinate																														
Naphthalene	x		x			x	x		x				x									x	x			x				x
Nitrobenzene	x					x		x	x			x									x		x			x				
Organotins																														
Perchlorate																														
p-Isopropyltoluene (p-cymene)									x																					
Prometon																														
RDX																														
Sodium	x						x		x	x			x										x							
Sulfate																														

Facility No.	02-0033	02-0043	02-0059	02-0332	02-0518	02-0641	02-0715	02-0721	02-0730	02-0744	02-0751	02-0752	02-0756	02-0880	02-0761	02-0762	02-0795	02-0803	02-0806	02-0808	02-0843	02-0861	02-0913	02-0939	02-0961	02-0972	02-0978	02-1047	03-1041	03-1081
Terbacil																														
Terbufos																														
Triazines & degradation products of triazines including but not limited to Cyanazine																														
Vanadium																														

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ATTACHMENT 1

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Best Management Practice Requirements for Laboratories within NCWRP Sewershed

Waste Handling Best Management Practices for Laboratories

The Industrial Wastewater Control Program has compiled the following list of required and recommended practices to help your business comply with Industrial Waste Discharge Requirements and to promote pollution prevention and waste minimization in laboratories.

Requirements

- Do not dispose of hazardous waste to the sewer or storm drain; such disposal is strictly prohibited. For assistance in determining whether a waste is hazardous, contact the San Diego County Hazardous Materials Management Division at (619) 338-2231.

- Prevent leaks or spills from accidentally entering the sewer.

  Drain protection can be accomplished through one of the following four options:
  1) Move the fluids to an area from which they could not flow to the drains. 2) Plug the drains or cap the drain pipes, as applicable. 3) Install a raised lip or curb around the drains or extend the drain pipes, a minimum of four inches above any area features which could contain fluids. 4) Construct spill containment for the fluids, of capacity equal to the largest fluid vessel plus any fire water volume required by fire codes, and exclude the drains from the containment area. Drain plugs, raised lips, drain curbs, or containment walls must be of a permanent nature and materials resistant to corrosion by the fluids, e.g. epoxy grout or epoxy coated concrete. Drain pipe caps or extensions must be welded or glued.

- Never use sinks as secondary containment or for chemical storage.

- Eliminate or reduce single-pass water to less than 500 gpd.

- Implement the approved Management Plan for Toxic and Prohibited Organic Chemicals on file with this office.

- All biohazardous medical wastes must be managed and discharged in compliance with the July 2005 California Medical Waste Management Act and revisions and amendments thereto, as set forth in the California Health and Safety Code, Sections 117600 - 118360.

Recommendations

Waste Minimization

- Substitute less toxic materials in production and cleanup operations when feasible.

- Order chemicals in the minimum quantities necessary for a process/protocol; this eliminates waste resulting from process changes and expiration dates passing.

- Work with the minimum amount of chemicals required by a process/protocol; this reduces waste in the event of a spill and encourages prudent chemical handling.

- Reuse/Recycle spent solvents when possible.

revised Feb 2010

- Practice water conservation by installing flow restrictors and recycling water when possible.

Drain Protection

- Utilize secondary containment to prevent leaks or spills from accidentally entering the sewer. Trays or plastic holders can be used for small volumes; larger volumes should be stored in bermed or diked storage areas. Secondary containment should be kept dry. Never store incompatible chemicals together in the same containment area. Other spill prevention measures include:

  - Using coated containers to reduce spills caused by breakage.
  - Storing chemicals in latched cabinets and using shelf barriers.
  - Checking storage container integrity on a regular basis.
  - Storing chemicals in approved cabinets or on low shelves.

- Maintain a written spill response plan and be sure that all employees are familiar with it. Be sure that spill clean up supplies are adequately stocked and easily accessible.

- Keep a mercury spill clean up kit in labs where mercury is used. Consider substituting electronic sensing devices for mercury containing equipment to prevent spills associated with breakage. Mercury in thermometers is the most likely source of this contaminant in labs.

Other

- Post signs next to lab sinks and drains to remind employees that disposal of hazardous waste to the sewer is prohibited.

- Practice good housekeeping by cleaning up spills immediately, clearly labeling all containers, utilizing proper chemical storage practices, and keeping clutter to a minimum.

- Be sure that all employees have been informed of your company's chemical handling and disposal protocols as well as the spill response plan. Periodic refresher training will keep employees informed of changes and updates.

- Film Processing: Refer to the City's Best Management Practice Requirements for Silver-Rich Solutions.

For more information, contact:

The City of San Diego
Industrial Wastewater Control Program
9192 Topaz Way, MS 901D
San Diego, CA 92123-1119
(858) 654-4100

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ATTACHMENT 2

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TOMP for Industries within NCWRP Sewershed

SAN DIEGO METROPOLITAN SEWERAGE SYSTEM
Toxic and Prohibited Organic Chemical Management Plan

FOR METRO USE ONLY
IND:. _____
EPA:_____Y_____N TTO:__Y__N
REVIEWED BY:_____
ACCEPTED:_____ Y _____N
DATE: _____

Please complete and return this form within 15 days to:
Industrial Wastewater Control Program
City of San Diego
9192 Topaz Way
San Diego, CA 92123-1119
PH: 858/654-4100

BUSINESS NAME OF APPLICANT: _____

FACILITY ADDRESS: STREET _____

CITY _____ ZIP CODE _____

MAILING ADDRESS: STREET _____
(If different than facility address) CITY _____ ZIP CODE _____

If your industrial facility has a Hazardous Materials Business Plan (Business Plan) it may be submitted in lieu of this form, provided the information requested herein has been adequately covered in the Business Plan.

1. Indicate all toxic organics used:

HALOGENATED
- ☐aldrin
- ☐benzofluoranthene
- ☐carbon tetrachloride
- ☐chlordane
- ☐chlorinated benzenes
- ☐chloroalky ethers
- ☐chlorinated naphthalene
- ☐chlorinated phenols
- ☐chloroform
- ☐chlorinated cresols
- ☐DDT and metabolites
- ☐dichlorobenziden
- ☐dichloroethylenes
- ☐dichloropropane
- ☐dichloropropene
- ☐dieldrin
- ☐endrin and metabolites
- ☐fluoranthene
- ☐freons

HALOGENATED (cont.)
- ☐haloethers
- ☐halomethanes (inc. methylene chloride)
- ☐heptachlor and metabolites
- ☐hexachlorobutadiene
- ☐hexachlorocyclohexane (all isomers)
- ☐hexachlorocyclopentadiene
- ☐pentachlorophenol
- ☐polychlorinated biphenyls (PCBs)
- ☐2,3,7,8 - tetrachlorodibenzo-p-dioxin (TCDD)
- ☐tetrachloroethylene
- ☐toxaphene
- ☐1,1,1-trichloroethane
- ☐trichloroethylene
- ☐vinyl chloride

NON-HALOGENATED
- ☐acenapthene
- ☐acrolein
- ☐acrylonitrile
- ☐benzene
- ☐benzidine
- ☐chrysene
- ☐2,4 - dimethylphenol
- ☐dinitrotoluene
- ☐diphenylhydrazine
- ☐endosulfan and metabolites
- ☐ethylbenzene
- ☐isophorone
- ☐napthalene
- ☐nitrobenzene
- ☐nitrophenols
- ☐nitrosamines
- ☐phenol
- ☐phthalate esters
- ☐polynuclear aromatic hydrocarbons
- ☐toluene

2. List all flammable chemicals used/stored:

- ☐ acetonitrile
- ☐ acetone
- ☐ ethanol
- ☐ ethyl acetate
- ☐ fuels
- ☐ methanol
- ☐ mineral spirits/paint thinner
- ☐ pyridine
- ☐ toluene
- ☐ xylene
- ☐ other _____
  _____
  _____

3. Total volume of waste organics generated monthly _____
4. Do you routinely dispose of any of the chemicals listed in 1) or 2) above to the sewer? __ Y __ N
5. Do you segregate organic wastes for disposal? __ Y __ N. List the segregation criteria/categories.

_____
_____
_____

6. How do you manage/dispose of organic wastes?
   - ☐ On-site recovery/reuse
   - **Contract hauling for:**
     - ☐ Off-site recovery/reuse
     - ☐ Energy recovery
     - ☐ Incineration
     - ☐ Landfill

7. What is the largest volume of chemicals
   a) Stored in a single container? _____
   b) Moved as one load? _____

8. Are there any drains leading to the sewer in areas of chemical storage or use? ___ Y ___ N

9. What spill **prevention** measures does your company have in place?
   ☐ Training ☐ Equipment

Describe: _____
_____
_____

10. What spill **containment** provisions does your company have?
    ☐ Training ☐ Equipment

Describe: _____
_____
_____

Attach any sketches, plans, procedures, or extra sheets required to describe your facility=s organic chemical management plan.

CERTIFICATION: (This plan must be signed by an authorized representative.)

I hereby certify that the information provided in this questionnaire is familiar to me, is complete, and represents an accurate statement of fact to the best of my knowledge.

PRINT NAME: _____ TITLE: _____

SIGNATURE: _____ DATE: _____ PH: ( ) _____

APPENDIX C – TECHNICAL MEMORANDUM: INITIAL PLANNING FOR THE UV/AOP COMPONENT OF THE AWP FACILITY PREPARED BY CDM/MWH

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Attachment A

1925 Palomar Oaks Way, Suite 300
Carlsbad, CA 92008
Ph: (760) 438-7755
Fax: (760) 438-7411

Memorandum

To: *Anthony Van, Bill Pearce - City of San Diego*

From: *Randy Hill, Greg Wetterau (CDM), Jay DeCarolis (MWH)*

Date: *May 21, 2010*

Subject: Initial planning for the UV/AOP component of the City of San Diego AWT Demonstration Plant, in response to CDPH comments to the UV System section of the IAP Report

Background

The purpose of this technical memorandum is to document the CDM/MWH's initial recommendation with regards to the selection of the UV system to be procured and operated as part of the City of San Diego's AWT Demonstration Project. The memorandum is written to address comments presented by the California Department of Public Health (CDPH) in regards to the IAP report as provided below:

CDPH Comment: "The Trojan Phox ultraviolet (UV) system at Orange County Water District (OCWD) consists of three reactors per treatment train (8.75 millions of gallons per day [mgd] capacity). Each reactor has two chambers. Each chamber has 72 lamps. Conceivably, if the exact same reactor is used, the capacity of one chamber is 1.46 mgd. OCWD's demonstration project was 5 mgd. The specifics of the UV demonstration unit should be addressed in the engineering report that is submitted for our review and approval.

UV Reactor Selection

As part of developing recommendations on the specific UV unit(s) to be tested during the City of San Diego's AWT demonstration project, the CDM/MWH team 1) reviewed the design and operation of the OCWD's UV/AOP system used at the GWRS and 2) spoke with representatives from Trojan.

Review of design and operation of OCWD AOP system used for the GWRS.

A basic flow diagram of the OCWD GWRS UV system is provided in Figure 1 (attached). As shown, the configuration of each train is consistent with the CDPH comment (see above). Each train passes a total flow of 8.75 mgd, contains three (3) reactors, and each reactor contains 2 chambers each with 72 lamps. Other pertinent information considered when reviewing the OCWD system follows:

- The system contains 8 primary trains configured in parallel; however, the (3) three reactors of each individual train are stacked vertically and configured in series, with two chambers in series within each reactor.

- Based on the series configuration, 8.75 mgd flows through each train, reactor, and chamber, resulting in significantly different hydraulic conditions than a single chamber reactor operated at 1.46 mgd. The GWRS UV system is configured to provide sufficient contact time and optimal hydraulics in the six chambers to achieve the required log removal established by CDPH.

Discussions with Trojan

The project team contacted Trojan to assess the feasibility of using a single reactor of the exact same model used in the OCWD train (dual chamber UVPhox Model D72AL75) operated at a flow rate needed to achieve an identical residence time as the OCWD reactors. Trojan confirmed that a flow rate of 2.92 mgd would be required to achieve an identical residence time with this dual chamber reactor; however, the hydraulics would remain considerably different due to the reduced flow rate when using a single reactor rather than the three in series used at OCWD. Because the demonstration plant is being sized for 1 MGD product capacity, operating the UV at 2.92 mgd in batch mode would require a large volume storage tank, VFD driven pumps, and additional controls, and would prevent the ability to continuously operate the AOP system at the demonstration plant.

As an alternative, Trojan recommended using a UVPhox Model 72AL75, which is a single chamber version of the reactors used at OCWD (In the name designation, "D" represents a dual chamber reactor, "72" the number of lamps per chamber, and "75" the diameter of the reactor in centimeters). Trojan has projected that this reactor will achieve 1.3-log NDMA removal at 1 mgd, with a hydraulic residence time roughly 33 percent longer than the OCWD reactors. It should be noted that a flow of 1.46 mgd would be required to achieve an identical residence time as the OCWD reactors, however, Trojan has projected that only 1.1-log destruction of NDMA would be achieved at this higher flow rate due to the poorer hydraulic conditions at the demonstration plant compared with the multiple reactors in series used at OCWD. At the 1-mgd flow, lamp intensity would need to be reduced to achieve 1.2-log NDMA destruction during operation and water quality monitoring at the demonstration plant.

Testing Recommendations

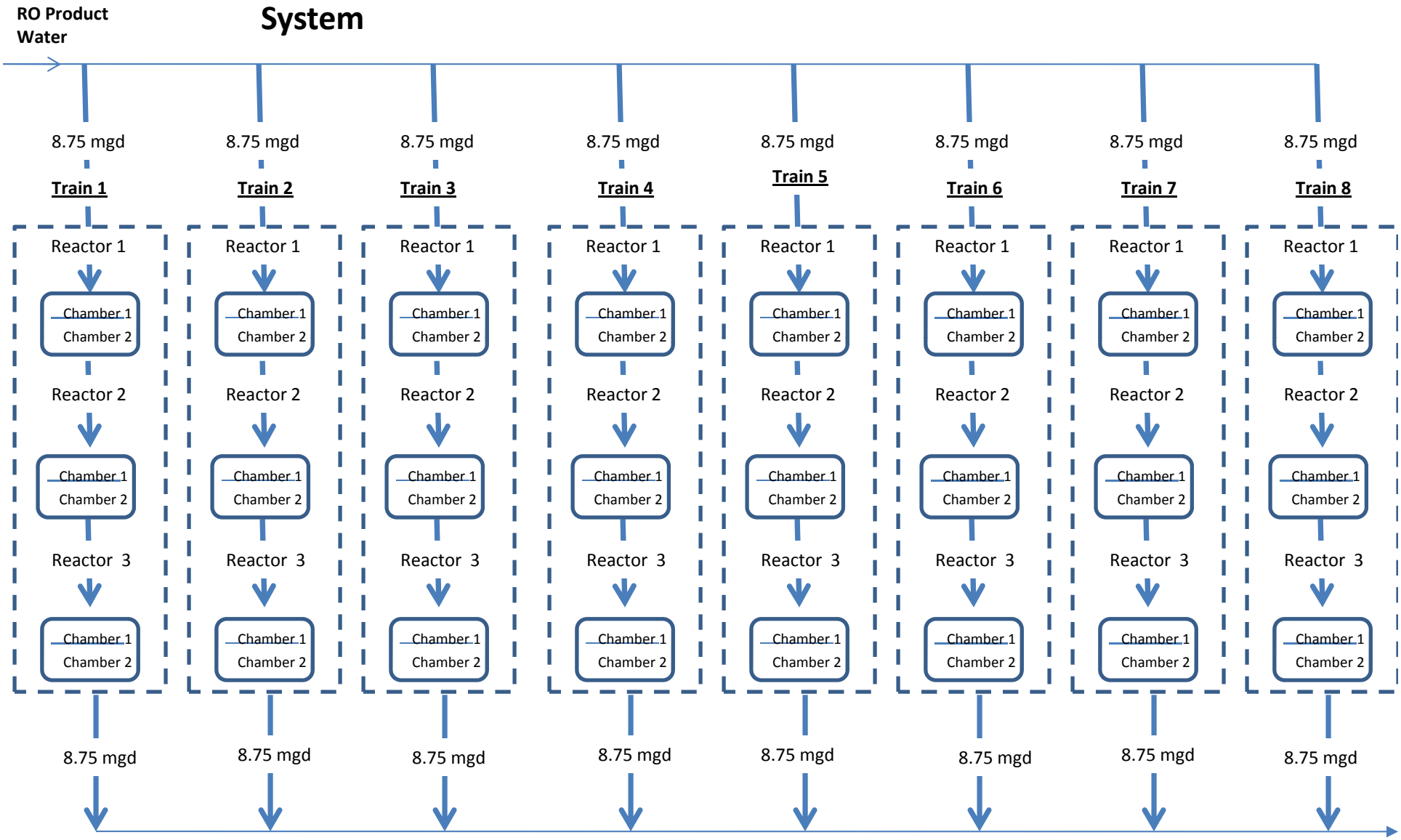
Based on review of OCWD's UV configuration and discussion with Trojan, the project team recommends testing the Trojan UVPhox Model 72AL75 reactor for the San Diego AWT demonstration plant. During the initial phase of the demonstration operation the project team will verify the UV unit can meet 1.2 log removal of NDMA at 1 mgd flow rate by conducting spiking experiments, allowing the team to determine the exact power setting the unit requires for 1.2 log NDMA removal. The unit will then be operated under these settings for the

remainder of the demonstration period during all routine and quarterly water quality sampling events.

Should CDPH require, the project team will perform UV collimated beam studies to assess the delivered dose required to reach the 1.2 log NDMA removal. This will include the development of standard curves for log removal by exposing RO product spiked with NDMA to UV light under different intensity settings and exposure time periods using a bench scale collimated beam unit. CDPH may also request that MS2 phage spiking be done to demonstrate 4-log virus removal; however, testing done at OCWD and West Basin has demonstrated that the dose required to achieve NDMA destruction is more than sufficient for achieving 4-log virus reduction.

Because the UV system proposed for the demonstration plant would not be completely identical to the full scale (slightly different reactors and different train configuration) the energy efficiency obtained from the demonstration plant would not be directly comparable to that of the full scale system. Accordingly, for the full scale plant the City would have the option to either use the exact reactor and train configuration as OCWD or another operational advanced treatment facility or to selected a different system and conduct validation testing of the full-scale unit during plant commissioning, similar to the approach taken by the existing advanced treatment facilities operating in southern California.

Figure 1 -Basic Configuration of OCWD's GWR UV / AOP System



APPENDIX D – TECHNICAL SPECIFICATIONS: 3D TRASAR® AUTOMATION SYSTEM FOR RO SYSTEMS , NALCO INC.

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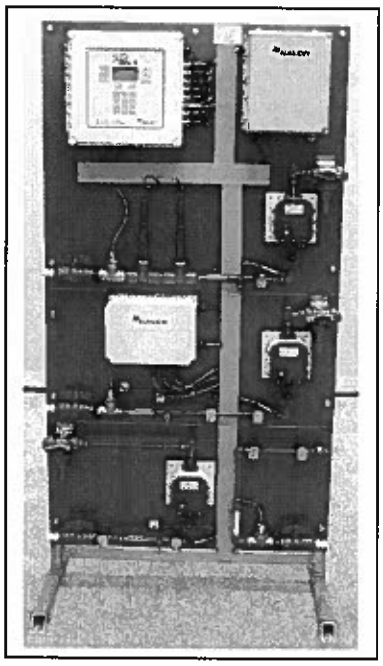
Nalco SPECIFICATION # TBA

3D TRASAR® Automation for Reverse Osmosis Systems

- Optimize performance of Reverse Osmosis systems through data collection, trending and interpretation
- Improve control of antiscalant treatment programs even as operating conditions and water quality change
- Continuously monitors the system and alerts operators to "out of desired range" conditions permitting corrective action before performance is affected
- Availability of treatment program data, operational data and reports via the web simplifies process assurance compliance and troubleshooting.
- Modular design enables the system to be customized to meet customer needs.
- User-friendly interface makes the system easy to install, configure and operate



Description

3D TRASAR Automation for Reverse Osmosis Systems is a modular control platform designed to provide advanced control of antiscalant treatment programs and enable operational data collection for performance analysis. The system uses an updated version of the tried-and-true 3D TRASAR controller coupled with Nalco patented fluorescence technology to optimize control of antiscalant programs and enhance monitoring of pH adjustment and oxidant destruction programs. The expanded capabilities of this new 3D TRASAR controller permit continuous measurement of the key reverse osmosis system parameters.

- Feedwater: Fluorescence (treatment and background), conductivity, temperature, pH, ORP, and flow
- Permeate: Conductivity, temperature, flow and pressure
- Concentrate: Fluorescence, conductivity, temperature, flow and pressure
- Membrane/Interstage: Pressure

The data, along with operating data from the customer's DCS can be wirelessly transmitted back to Nalco for analysis, trending and interpretation. This web capability provides easy access to data, system reporting and enables alerting of key personnel to conditions outside of "best practices".

The 3D TRASAR Automation for Reverse Osmosis Systems is a modular system. It can be customized to handle a variety of reverse osmosis system configurations and upgraded as changes are made to operating conditions or process equipment. Quick-connectors simply installation, sensor calibration/maintenance and in-field upgrades.

3D TRASAR Automation for Reverse Osmosis Systems is just one more example of how Nalco innovation protects your reverse osmosis system, saves water and energy and increases efficiency. 3D TRASAR technology detects, determines and delivers the next dimension in reverse osmosis water management.

Modular Design

The heart of the 3D TRASAR for Reverse Osmosis Systems is the Feedwater System. It provides the sensors, controller and communications interface needed to automate antiscalant treatment programs. They are available as either frame-mount or panel-mount (to mount on the wall) versions.

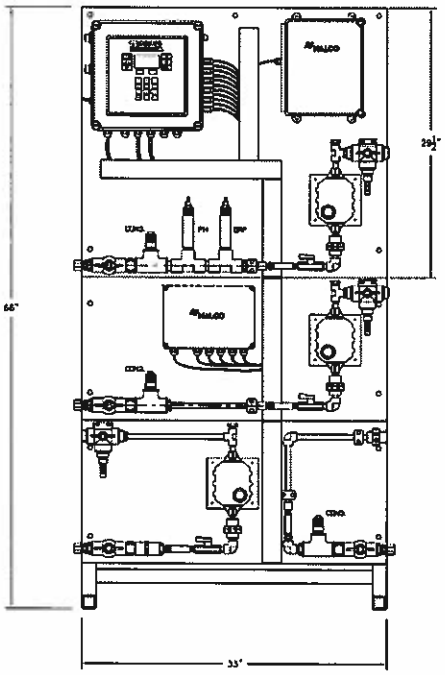
Feedwater System

Standard Features:

- 3D TRASAR Controller
- Fluorometer
- Conductivity & Temperature
- Sample Flow Switch
- Nalco Global Gateway (Regional Standards)

Options:

- pH & ORP Probes
- Analog Input Modules (provides 6 inputs prewired to accept pressure transmitters and 2 user-wireable inputs)



060-RO6011.88 System with 060-RO1000.88 and 060-RO1120.88 Add-On Modules mounted on frame

Mounting

Panels should be mounted on a flat wall so that the controller is at eye level. Add-On Module panels are mounted on the frame below the mains system panel. Wall mounted Add-On Modules must be close enough to the main panel for the probe cables to be connected.

Add-On Modules

There are 4 Add-On Modules for the 3D TRASAR for Reverse Osmosis Systems. They are all supplied as panel that con be mounted on the frame of the Feedwater System or on the wall.

Fluorometer/Conductivity Add-On Module

- Fluorometer
- Fluorometer Splitter Box (permits up to 4 fluorometers to be connected to the 3D TRASAR Controller)
- Conductivity (5-10,000 µS) & Temperature
- Sample Flow Switch

Fluorometer Add-On Module*

- Fluorometer
- Sample Flow Switch

Note: Requires temperature input from another module.

Permeate Conductivity Add-On Module

- Conductivity (1-500 µS) & Temperature
- Sample Flow Switch

Fluorometer & Permeate Conductivity Add-On Module

- Fluorometer
- Conductivity (1-500 µS) & Temperature
- Sample Flow Switch

To Order

Systems & Add-On Modules

Part No.	Description
060-RO4000.88	Fluorometer/Conductivity System, Wall Mount (No pH, ORP, or Analog Input Module)
060-RO4001.88	Fluorometer/Conductivity System, Frame Mount (No pH, ORP or Analog Input Module)
060-RO6000.88	Fluorometer/Conductivity System, Wall Mount (No Analog Input Module)
060-RO6001.88	Fluorometer/Conductivity System, Frame Mount (No Analog Input Module)
060-RO6010.88	Fluorometer/Conductivity System, Wall Mount, Analog Input Module
060-RO6011.88	Fluorometer/Conductivity System, Frame Mount, Analog Input Module
060-RO1000.88	Fluorometer/Conductivity Add-On Module
060-RO1100.88	Fluorometer Add-On Module
060-RO1120.88	Fluorometer + Permeate Conductivity Add-On Module
060-RO1110.88	Permeate Conductivity Add-On Module

Accessories

Part No.	Description
060-ROFSB100.88	Fluorometer Splitter Box
060-ROAIM100.88	Analog Input Module
060-ROSRB100.88	4-20mA Signal Repeater (split/repeat up to 4 signals)
060-ROHP500.88	Pressure Transducer, 500 psi, 1/4" MNPT
060-ROLP145.88	Pressure Transducer, 150 psi, 1/4" MNPT
060-ROEXC005.88	Cable, Extension, 5 m, (for Pressure Transducer)
060-ROEXC010.88	Cable, Extension, 10 m, (for Pressure Transducer)
060-ROEXC030.88	Cable, Extension, 30 m, (for Pressure Transducer)

Spare & Replacement Parts

Part No.	Description
060-TR3220.88	Fluorometer
TBA	Cable, Fluorometer, 4 ft, with quick-connect
6041271	Conductivity Sensor,1.0K (5-10,000 µS), with quick-connect
6041272	Conductivity Sensor,0.1K (1-500 µS)), with quick-connect
6042175	Flow Switch, with quick-connect
060-TR5411.88	pH Replacement probe
060-TR5412.88	Cable, 6 ft, pH
060-TR5421.88	ORP Replacement probe
060-TR5422.88	Cable, 6 ft, ORP
060-TR5222.88 *	Desiccant canister (fluorometer)
060-TR5223.88 *	Desiccant indicator (fluorometer)
991-19432523.88 *	Fuse, 10 A, 250V SLO-BLO (main fuse)
991-05047661.88	Ethernet crossover cable, 6' (2m), orange

Calibration Solutions & Supplies

460-S0940.75 *	TRASAR Calibration solution, 1L bottle
460-S0800.75	10% Sulfuric Acid, 1:1, 1L bottle
500-P2817.88	Flow cell brush, 16"
500-P0116.88	Beaker, 800 ml, plastic (3 each required)
500-P2147.88 *	Syringe, 60cc, plastic (2 each required)
001-H07641.88 **	Conductivity standard solution, 10,000 S/cm, 500 mL
001-H07642.88 **	Conductivity standard solution, 5000 S/cm, 500 mL
460-S0297.75 **	Conductivity standard solution, 3000 S/cm, 1L
460-S0298.75 **	Conductivity standard solution, 600 S/cm, 1L
460-S0743.75 **	Conductivity standard solution, 200 S/cm, 1L
460-S0299.75 **	Conductivity standard solution, 40 S/cm, 1L
460-S0408.75 **	pH standard solution, pH 10 buffer, 1L
460-S0407.75 **	pH standard solution, pH 7 buffer, 1L

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APPENDIX E – MEMBRANE CLEANING PROTOCOLS

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Issued in June 2008

TORAY MEMBRANE MODULE
Instruction Manual

Model: Pressured Type PVDF Hollow Fiber Membrane Module "HFU Series"

issued by Toray Industries, Inc.

Water Treatment & Environment Division

8-1, Mihama 1-chome, Urayasu, Chiba 279-8555 Japan
Tel: +81-47-350-6033
Fax: +81-47-350-6066
URL: http://www.toray.com

BJJHJEBG

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I. Introduction

Toray PVDF Hollow Fiber Membrane Module “HFU series” is the pressured type hollow fiber UF (ultra filtration) membrane module developed with the polymer science and the membrane fabrication technologies accumulated for a long time in Toray Industries, Inc.

The membrane material is Poly-vinylidene Fluoride (PVDF). The nominal molecular weight cut off of the membrane is 150,000 daltons. Testing has confirmed that more than 90% of 150,000 daltons model polymers is consistently removed.

The module, with Polyvinylchloride (PVC) casing, is pressure-driven which products much purified water than siphon-driven. The maximum operating pressure is 300 kPa (43.5 PSI). The flow direction is outside-to-inside which is suitable for high turbidity water treatment because the air-scrubbing can be adopted to remove suspended solid effectively.

1. Characteristics of Toray "HFU series" Membrane Modules

(1) High Filtration Flux

HFU series provides high filtration flux and stable operation for the filtration of various raw water sources. The membrane is made with a special spinning method, which enables high permeability and high fouling resistance.

(2) Excellent Water Quality

HFU series provides very good water quality for the filtrate, extremely low turbidity since the membrane has 150,000 dalton nominal molecular weight cut off. HFU series is recommended to be applied to tertiary treatment of sewage water and RO pretreatment in seawater desalination.

(3) High Mechanical Strength

The membrane of HFU series has very high mechanical strength because it is made of PVDF with the special spinning method developed by Toray. HFU series provides high integrity and durability under recommended operating conditions.

(4) High Chemical Durability

The membrane material of HFU series is PVDF, which allows you to clean the membrane with high concentrations of chlorine and with high concentrations of acid resulting in better cleaning and longer sustainable membrane flux rates.

2. Applications of Toray "HFU series" Membrane Modules

- Tertiary Treatment of Sewage Water
- RO Pretreatment in Seawater Desalination
- Industrial Water Production
- Reuse of Industrial Waste Water

II. For Your Safety

- Please be sure to read and follow the instructions below before using HFU series. This manual should be retained for future reference.

- Follow the safety precautions as they are intended to protect operators and equipment from various risks such as physical harm and/or property damage. The following table shows a level of potential risk for each indicated symbol.

DANGER	This symbol indicates an imminent hazardous situation which will result in serious injury or death when the instruction is not observed.
WARNING	This symbol indicates a potentially hazardous situation which will result in serious injury or death when the instruction is not observed.
CAUTION	This symbol indicates a potentially hazardous situation which might result in injury or property damage when the instruction is not observed.

- The following table explains the information to be noted.

Prohibited	"Prohibited" This symbol indicates a prohibited action or procedure.
Instruction	"Instruction" This symbol indicates an important action or procedure which has to be taken without fail.

1. Safety Instruction for Unpacking and Installation

DANGER

Instruction

Be sure to wear safety gear such as rubber gloves and safety glasses for unpacking. The membrane is packaged in sodium hypochlorite solution (100mg/l). If the solution happens to splash onto the skin, wash the affected part with running water. If the solution happens to get in the eyes or mouth, wash the affected part with sufficient amounts of clean running water for more than 15 minutes and see a doctor immediately.

WARNING

Instruction

Be sure to wear safety gear such as a helmet and safety shoes to avoid injury.

CAUTION

Prohibited

The preservative solution should be drained out before using the modules. After that, keep clean water in the modules to prevent the hollow fiber membrane from drying out. Do not allow the modules to dry out even for a few hours.

Prohibited

The membrane modules should not be frozen.

Prohibited

Be careful not to damage or dent the modules during handling.

Instruction

Victaulic clamps are applied for connecting the modules of HFU-2020 or HFU-1020 to the piping. Follow the instruction of the G-type Victaulic Joint Set-up Guide at the connection point. Wrong connections may damage the modules.

Instruction

IDF/ISO Clamp Union Fittings 1.5 are applied for connecting the modules of HFU-2008 or HFU-1010 to the piping. Do not over-tighten the clamp as damage to the module may occur.

Prohibited

Keep the connection surface free of any dirt or oils.

Instruction

Be sure to install the modules vertically for effective air scrubbing.

2. Safety Instruction for Filtration Operation

DANGER

Instruction

Flush all the piping out with clean water and make sure no debris is remaining in the piping prior to connecting the modules.

Instruction

Confirm that the preservative chemical in the modules is completely drained out before starting the filtration operation. The preservative chemical is harmful to humans.

Flush the modules at low pressure, filling from the bottom, and vent to remove any air from the modules. Air left in the modules may cause water hammer and may result in damage to the membrane. Prior to use, make certain modules are flushed and filtrate water meets the required quality.

WARNING

Instruction

Always monitor filtrate water quality such as turbidity and/or the number of particles during filtration, and stop the operation if abnormal water quality is detected.

Prohibited

Do not exceed the maximum applicable pressure of 300 kPa (43.5 PSI). Higher pressures can damage the modules. Do not exceed the maximum temperature of 40 degree C (104 degree F). The higher temperature damages the modules.

Prohibited

Do not freeze the membrane modules.

Instruction

The operating conditions, including the filtration flux and the periodical physical cleaning, must be properly set-up otherwise the trans-membrane pressure may rise too quickly. The operation range is described in the latter section of this manual.

Instruction

Do not overfeed air to the modules. Excessive scrubbing air damages the membranes and/or shortens the membrane life.
The air flow rate should be within the range below for each module type.

HFU-2020: 4.8 – 9.0 Nm^3/h (2.8 – 5.3 scfm)
HFU-2008: 0.7 – 1.2 Nm^3/h (0.4 – 0.7 scfm)
HFU-1020: 4.8 – 9.0 Nm^3/h (2.8 – 5.3 scfm)
HFU-1010: 1.2 – 2.2 Nm^3/h (0.7 – 1.3 scfm)

Instruction

Integrity tests, such as Pressure Decay Test (PDT) or Diffusive Air Flow (DAF) Test, must not exceed an air pressure of 100kPa (14.5 PSI). Keep the source air pressure lower than 200 kPa (29 PSI), to prevent module damage.

3. Safety Instruction for Chemical Cleaning

DANGER

Instruction

Take special precautions when handling chemicals during chemical cleaning. Wear the safety gear such as safety glasses and protective gloves. If chemicals come in direct contact with your skin or your clothes, treat appropriately based on the MSDS.

Prohibited

Do not mix sodium hypochlorite with acid. Such mixture generates toxic chlorine gas.

Instruction

Stop operation whenever any anomaly occurs with the equipment or any signs of an anomaly are observed.

CAUTION

Instruction

In the chemical cleaning, strictly follow the procedure described in the latter section of this manual. Otherwise you may damage the modules or negatively affect the membrane performance.

4. Safety Instruction for Disposal

WARNING

Instruction

When dispose modules, please apply a service of a qualified waste disposing company. When modules are to incinerate, please dispose by appropriate facilities which can neutralize hydrogen fluoride (HF) gas. HF gas is generaterd at membrane incineration.

III.

Specifications of Toray "HFU series" Membrane Modules

Table 1. Specifications of membrane *1)

Membrane Material		PVDF (Polyvinylidene fluoride)
Nominal Molecular Weight Cut Off		150,000 *2)
Trans-Membrane Pressure	Maximum *3)	300 kPa (43.5 PSI)
	Normal Operation	Lower than 200 kPa (29.0 PSI)
Operating Temperature Range		0 – 40 degree C (32 – 104 degree F)
Operating pH Range		1 – 10

*1): Please note that the specifications are subject to changes from time to time.

*2): The nominal molecular weight cut off is determined with the model test of dextran.

*3): TMP should be below 300 kPa (43.5 PSI) at any time even when the feed pump is not stable.

Table 2. Feed water limits *1)

Turbidity	Intermittent Peak *4)	100 NTU
	Continuous Maximum	30 NTU
TSS	Intermittent Peak *4)	100 mg/L
	Continuous Maximum	30 mg/L
Pretreatment Filter Mesh Size		smaller than 200 micron meter
Temperature Range		0 – 40 degree C (32 – 104 degree F)
pH Range		1 – 10
Maximum Feed Pressure		300 kPa (43.5 PSI)

*1): Please note that the specifications are subject to changes from time to time.

*4): The duration time should be less than 48 hours and the occurrence frequency should not exceed more than once a month.

Table 3. Cleaning limits *1)

Cleaning pH Range	0 – 12
Cleaning Temperature Range	0 – 40 degree C (32 – 104 degree F)
Maximum concentration of NaClO as Cl_2	3,000 mg/L
Maximum NaClO exposure (lifetime contact time) as Cl_2	1,000,000 mg/L hours
Maximum acid contact time	1,000 hours (pH≥0)

*1): Please note that the specifications are subject to changes from time to time.

Table 4. Specifications of modules *1)

Module Type		HFU-2020	HFU-1020	HFU-1010 (small module for pilot test)	HFU-2008 (small module for pilot test)
Membrane Surface Area (Outer Surface)		72 m^2 (775 ft^2)	29 m^2 (312 ft^2)	7.0 m^2 (75 ft^2)	11.5 m^2 (124 ft^2)
Dimensions	Diameter	216 mm (8.50 inches)	216 mm (8.50 inches)	114 mm (4.49 inches)	89 mm (3.50 inches)
	Length	2,160 mm (7.087 ft.)	1,120 mm (3.675 ft.)	1,078 mm (3.537 ft.)	2,000 mm (6.562 ft.)
Weight	Full of water	110 kg (243 lbs)	60 kg (132 lbs)	15 kg (33 lbs)	18 kg (40 lbs)
	Drained	67 kg (148 lbs)	40 kg (88 lbs)	9 kg (20 lbs)	11 kg (24 lbs)
Materials	Housing	Polyvinylchloride			
	Potting	Epoxy Resin			
Connections	Top	Victaulic joints 80A	Victaulic joints 80A	IDF/ISO Clamp Union Fittings 1.5s	IDF/ISO Clamp Union Fittings 1.5s
	Bottom	Victaulic joints 80A	Victaulic joints 80A	IDF/ISO Clamp Union Fittings 1.5s	IDF/ISO Clamp Union Fittings 1.5s
	Side	Victaulic joints 65A	Victaulic joints 65A	IDF/ISO Clamp Union Fittings 1.5s	IDF/ISO Clamp Union Fittings 1.5s
Operating Conditions	Max. Feed Water Flow	12 m^3/h (53 gpm)	4.8 m^3/h (21 gpm)	1.2 m^3/h (5.1 gpm)	2.0 m^3/h (8.4 gpm)
	Max. Backwash Flow	13.5m^3/h (59 gpm)	5.4 m^3/h (23 gpm)	1.3 m^3/h (5.7 gpm)	2.1 m^3/h (9.4 gpm)
	Max. Air Flow	9.0 Nm^3/h (5.3 scfm)	9.0 Nm^3/h (5.3 scfm)	2.2 Nm^3/h (1.3 scfm)	1.2 Nm^3/h (0.7 scfm)
	Filtration Method	Outside-to-inside, Dead End or Cross Flow			
	Max. Inlet Pressure	300 kPa (43.5 psi)			
	Maximum Temperature	40 degree C (104 degree F)			

*1): Please note that the specifications are subject to changes from time to time.

CAUTION

Handle and operate the modules within the ranges and the limits indicated in Table 1 to 4. Operation outside these ranges or limits may damage the modules, may affect filtration performance, and will void the warranty.

IV.

Configuration of Toray "HFU Series" Membrane Modules

(1): Filtrate Outlet / Inlet of Backwash Water

(2): Air Outlet / Backwash Water Outlet

(3): Feed Water Inlet / Air Inlet / Drain Outlet

Connections

	Pipe fitting outer diameter mm (in)	Connectors
(1)	89.1 (3 1/2”)	Victaulic joints 80A
(2)	76.3 (3”)	Victaulic joints 65A
(3)	89.1 (3 1/2”)	Victaulic joints 80A

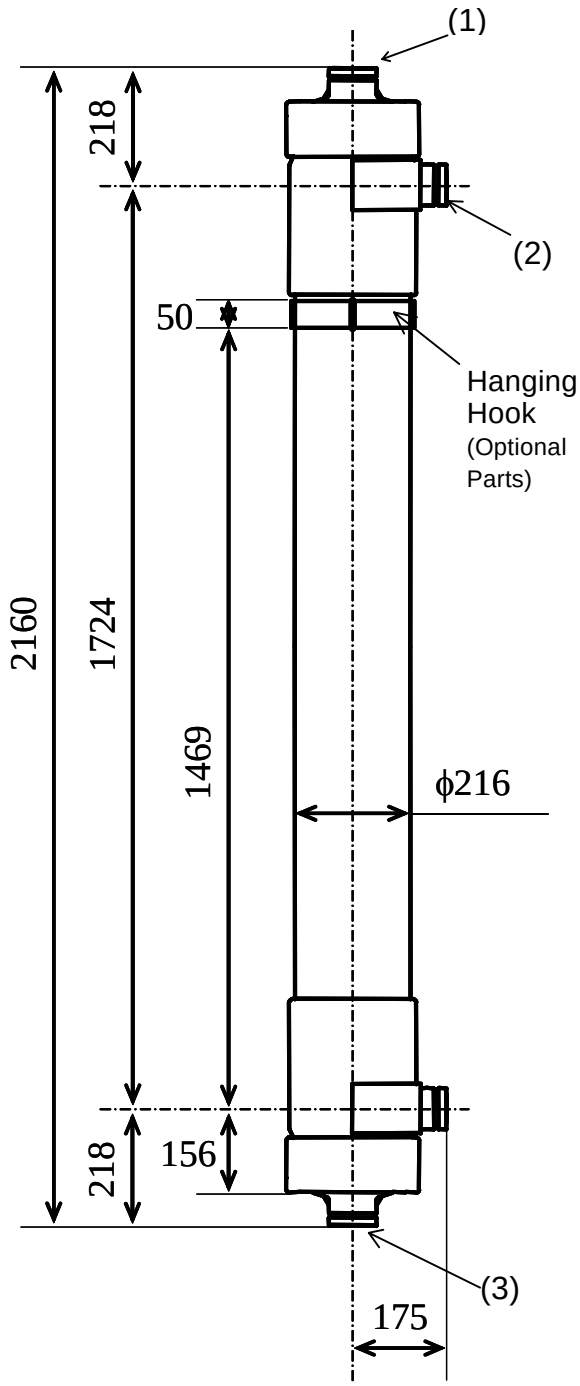


Fig. 1 Type: HFU-2020

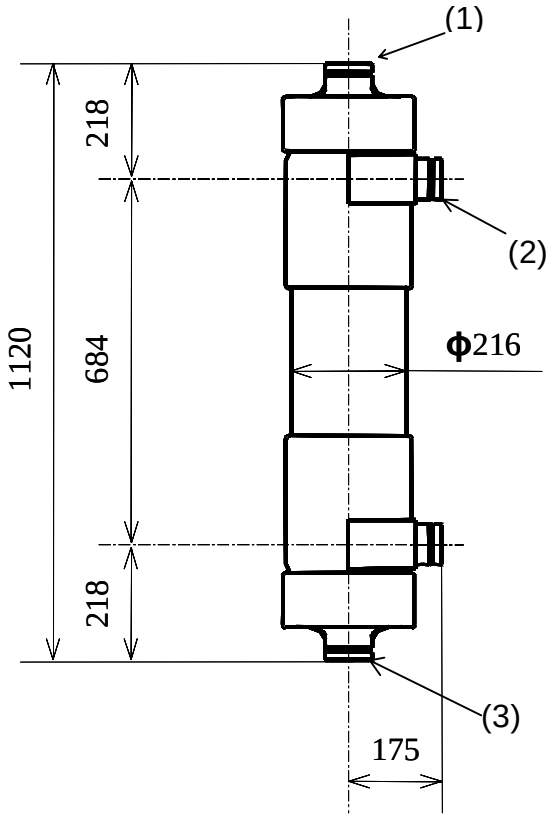


Fig. 2 Type: HFU-1020

(1): Filtrate Outlet / Inlet of Backwash Water

(2): Air Outlet / Backwash Water Outlet

(3): Feed Water Inlet / Air Inlet / Drain Outlet

Connections

	Pipe fitting outer diameter mm (in)	Connectors
(1)	50.5 (2”)	IDF/ISO Clamp Union Fittings 1.5s
(2)	50.5 (2”)	IDF/ISO Clamp Union Fittings 1.5s
(3)	50.5 (2”)	IDF/ISO Clamp Union Fittings 1.5s

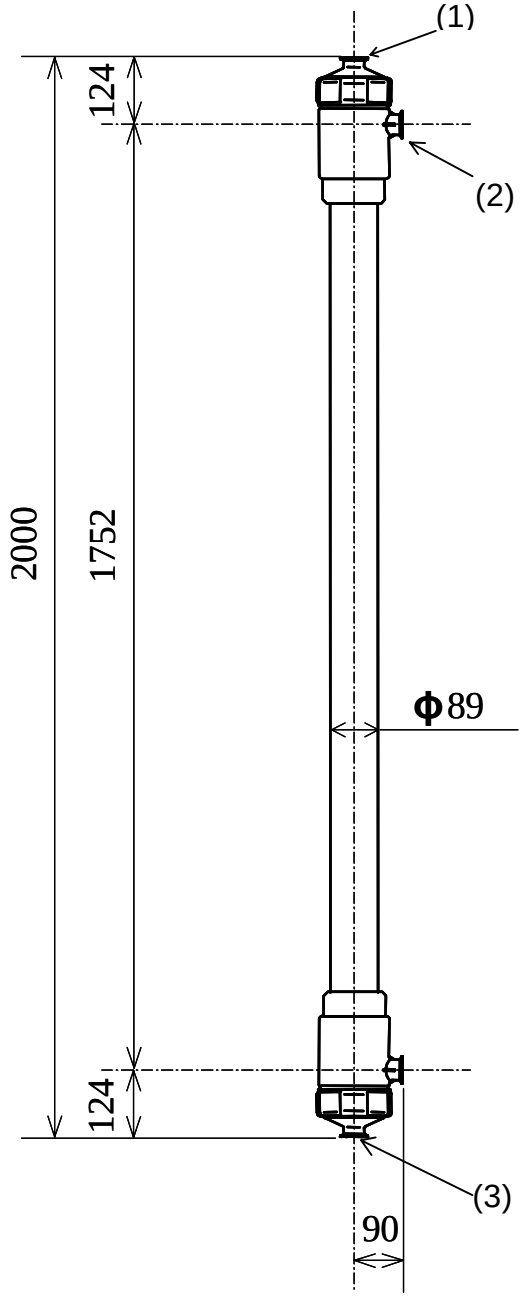


Fig. 3 Type: HFU-2008

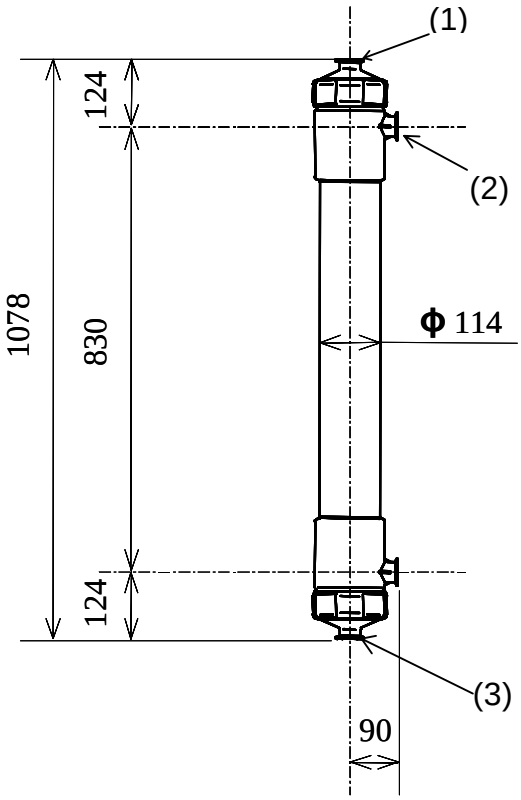


Fig. 4 Type: HFU-1010

Installation

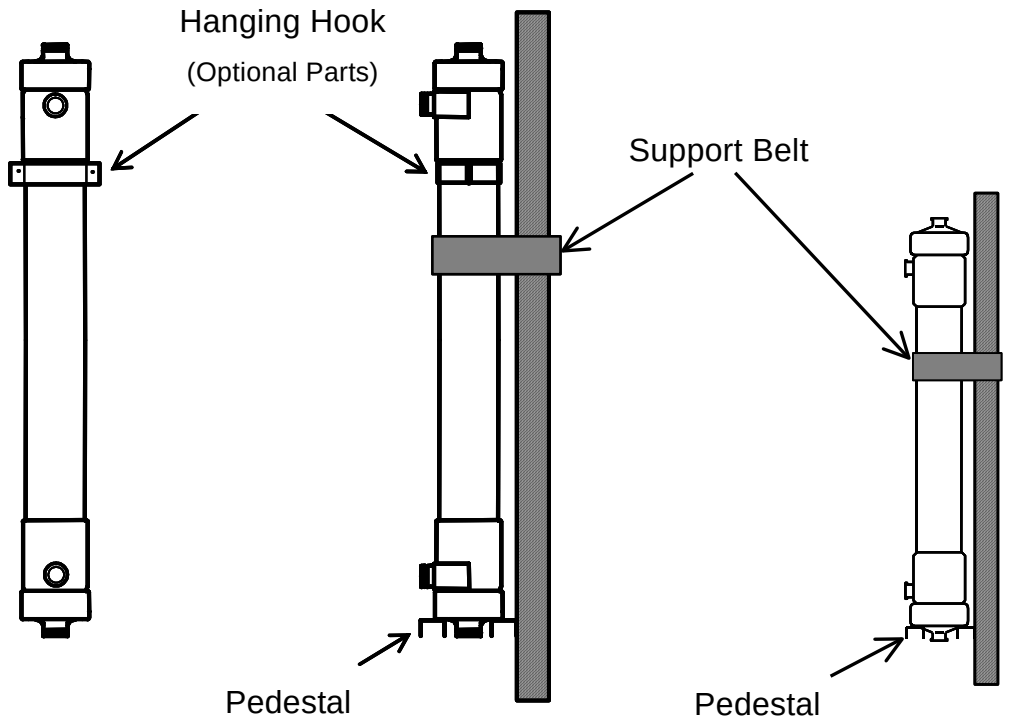
The standard method to install the membrane modules is described below.

1. Unpack the membrane module from wooden box or corrugated box.
2. Remove plugging plate from each nozzle of the module.
3. Drain out the preservative solution from the module.

DANGER	- Wear rubber gloves and safety glasses when you drain the preservative chemical. Note that the preserving chemical is sodium hypochlorite solution (100 mg/l of chlorine). If this solution splashes onto your skin, wash the affected part with running water. If the solution gets in your eyes or mouth, wash the affected part with enough amounts of running water for over 15 minutes and see a doctor immediately.

4. Put the module vertically on the pedestal in the module rack. Fix the module upright with the hanging hook and/or the supporting belt. (see Fig. 5)

WARNING	- Don't drop the module. - Use equipment such as chain blocks, a crane, or a forklift truck when you handle the module. The HFU-2020 module is too heavy to handle by hand.
CAUTION	- Be careful not to install the module upside down. Confirm the module is installed in the right direction. - Don't over-tighten the module with the hanging hook and/or the supporting belt, or you may damage the module. - Don't allow the hollow fiber membrane to dry out even for a few hours, especially in summer. - Don't freeze the module.



(1) HFU-2020, HFU-1020 (2) HFU-2008, HFU-1010

Fig. 5 Installation of the membrane module

5. Connect the piping to each connection point of the module with Victaulic clamps (HFU-2020, HFU-1020) or ferrule joints (HFU-2008, HFU-1010). (see Fig. 6)

CAUTION

- Keep the connection surface free of any dirt or oils.
- Follow the instruction of the G-type Victaulic Joint Set-up Guide when using Victaulic Joint. A wrong use may cause the damage to the module.
- Do not overtighten the clamp when using ferrule joint (IDF/ISO Clamp Union Fittings 1.5s), or you may damage the module.

6. Make sure that the module is installed vertically.

CAUTION	- If the module is not installed vertically, the effect of the air scrubbing would be reduced and effective filtration will be impaired.

VI. Operation

1. Filtration

(1) Check that all piping is connected appropriately and flushed out prior to the operation. Fig. 6 shows a typical example of piping.

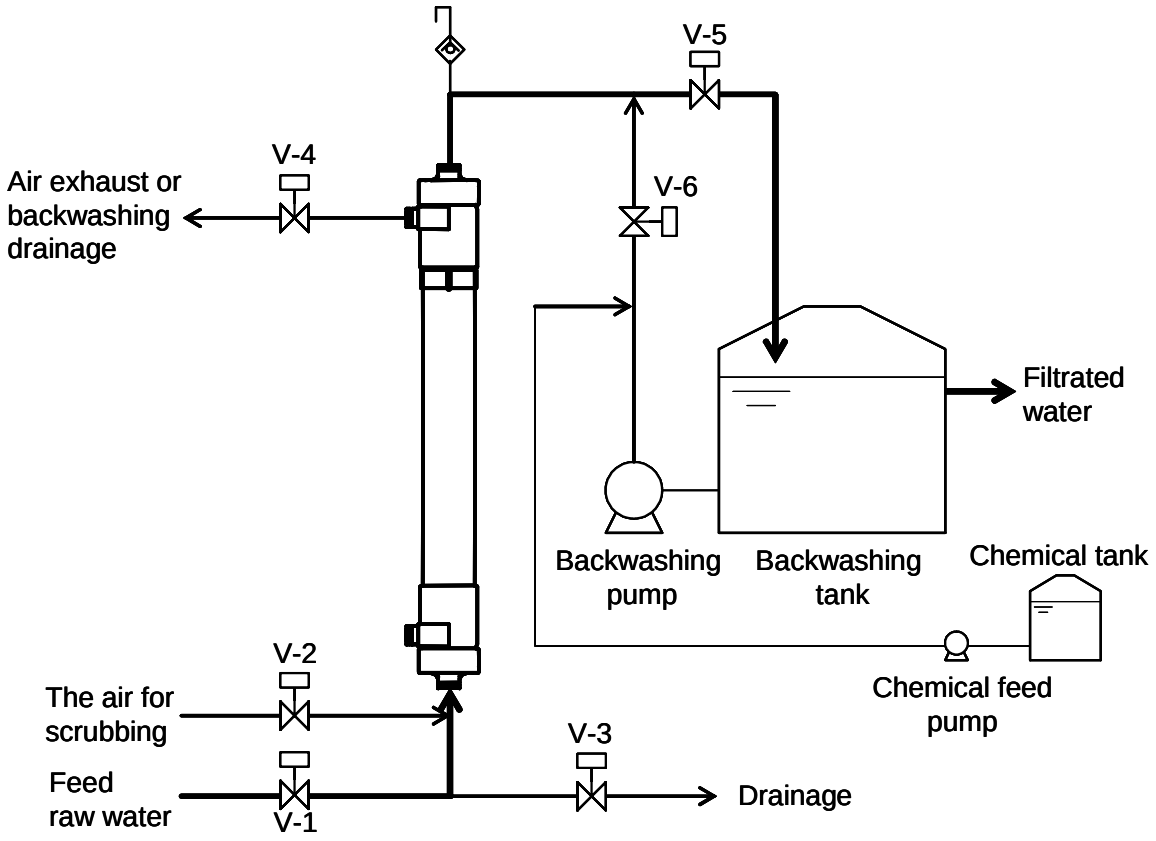


Fig. 6 Typical example of piping

(2) Make sure the feed water valve (V-1), the drainage valve (V-3), and the valve for the scrubbing air (V-2) are “closed”.

(3) Make sure the filtrate water line is open. Open the air exhaust valve (V-4).

(4) Gradually open the feed water valve (V-1) and charge the feed water to the module to purge any air out.

CAUTION

- Don't open the feed water valve (V-1) quickly, or water-hammer may occur and the module could be damaged.

(5) Confirm that the air is out of the module, and then close the air exhaust valve (V-4).

(6) Set appropriate volume of filtrate water flow.

CAUTION

- Don't exceed 300 kPa (43.5 PSI) to avoid damage to the module.
- Operating conditions including the filtration flux and the physical cleaning should be properly set up, observing the rise of trans-membrane pressure. (Details are described in the next session.) Please contact us if you need technical support.

(7) When stopping operation, gradually close the feed water valve (V-1).

2. Backwash and Air-scrubbing

The physical cleaning with backwash followed by air-scrubbing should be carried out periodically and automatically for the continuous filtration. The frequency of the physical cleaning mainly depends on the raw water quality. (Typical frequency is once every 30 minutes normally for surface water filtration. Please contact us if you need technical support.) Fig. 7 shows a typical example of the flow diagram for backwash and air-scrubbing. Don't carry out the backwash and the air-scrubbing simultaneously since it may damage the membrane.

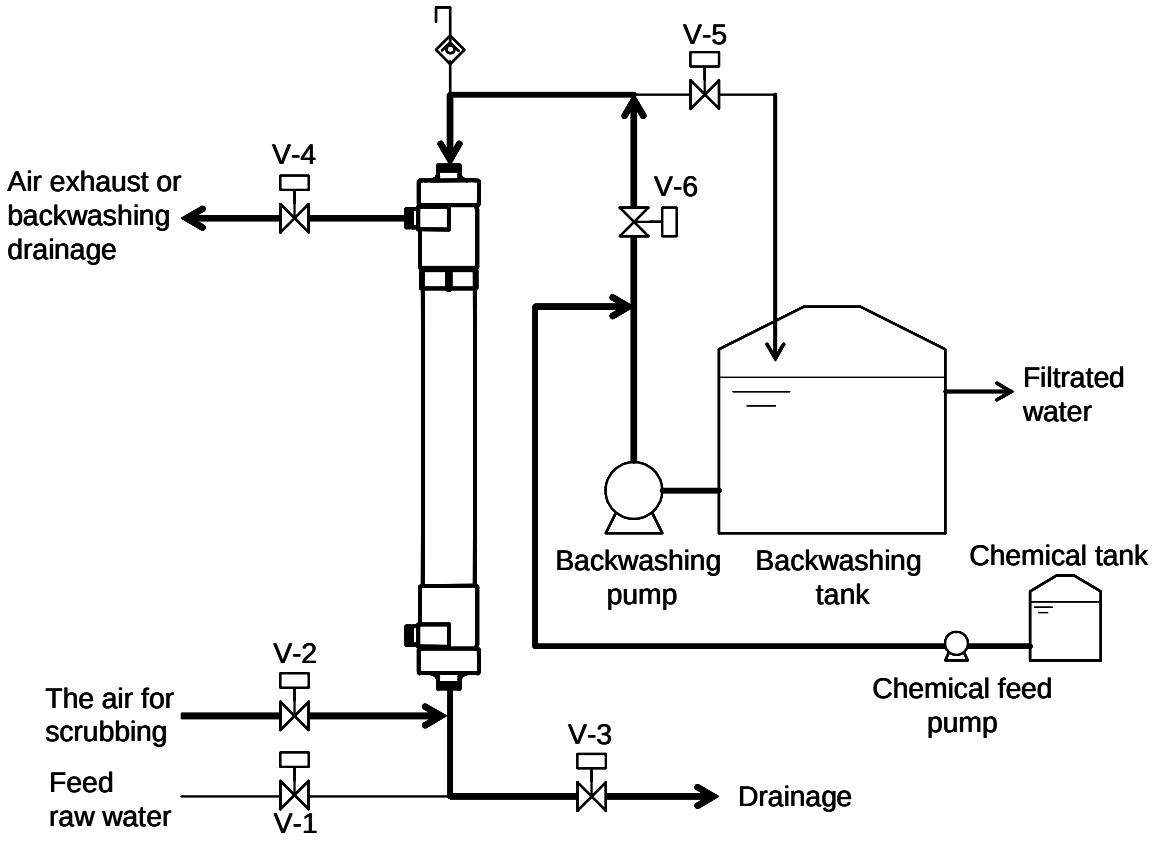


Fig. 7 Flow diagram for backwash and air-scrubbing

(1) Close the feed water valve (V-1) and stop the feed water pump.

(2) Open the air exhaust valve (V-4).

(3) Close the filtrate water valve (V-5) and open the backwashing valve (V-6) to feed back the filtrate water from the backwashing tank to the membrane module. During backwash, chemical feed pump can be operated to dose chemical to the backwash water. The dosing chemical is usually sodium

hypochlorite and the dosing ratio should be up to 50 mg/L as Cl_2.

The flow rate of backwash water is set up in advance for 1.0 to 1.5 times filtrate water flow rate (don't exceed Max. Backwash Flow described in Table 4).

(4) After backwashing for a fixed time (normally 30 seconds, up to 60 seconds), close the backwashing valve (V-6) and stop the backwashing pump.

(5) Open the air exhaust valve (V-4) and the air-scrubbing valve (V-2) for air-scrubbing for a fixed time (normally 30 seconds, up to 60 seconds).

CAUTION

- The air flow rate for air-scrubbing should be within the range below. Excessive air flow rate may damage the hollow fiber membrane.

  HFU-2020: 4.8 – 9.0 Nm^3/h, normally 6.0 Nm^3/h
  (2.8 – 5.3 scfm, normally 3.5 scfm)

  HFU-2008: 0.7 – 1.2 Nm^3/h, normally 0.8 Nm^3/h
  (0.4 – 0.7 scfm, normally 0.5 scfm)

  HFU-1020: 4.8 – 9.0 Nm^3/h, normally 6.0 Nm^3/h
  (2.8 – 5.3 scfm, normally 3.5 scfm)

  HFU-1010: 1.2 – 2.2 Nm^3/h, normally 1.5 Nm^3/h
  (0.7 – 1.3 scfm, normally 0.9 scfm)

(6) Close the air-scrubbing valve (V-2) and open the drainage valve (V-3).

(7) Close the drainage valve (V-3) after the water is all drained out.

(8) Run the feed water pump and open the feed water valve (V-1).

(9) Close the air exhaust valve (V-4) after the air is purged from the module.

CAUTION

- Always monitor filtrate water quality during filtration, and stop the operation if abnormal water quality is detected. If abnormal water quality is detected, check the integrity of the module with PDT (Pressure Decay Test) or DAF (Diffusive Air Flow Test). The recommended test procedure is provided as the technical information by Toray.

3. Toray Maintenance Cleaning

Instead of chemical dosing for every backwash, soaking the membrane to chemical solution several tens of minutes a day is also effective for membrane performance retention. This process is called Toray Maintenance Cleaning (TMC). The TMC is usually held following the backwash and air-scrubbing which does not contain the chemical dosing. The frequency and soaking time of the TMC mainly depends on the raw water quality. (Normally once a day and each soaking time are 20 minutes. Please contact us if you need technical support.) Fig. 8 shows a typical example of flow diagram for the TMC.

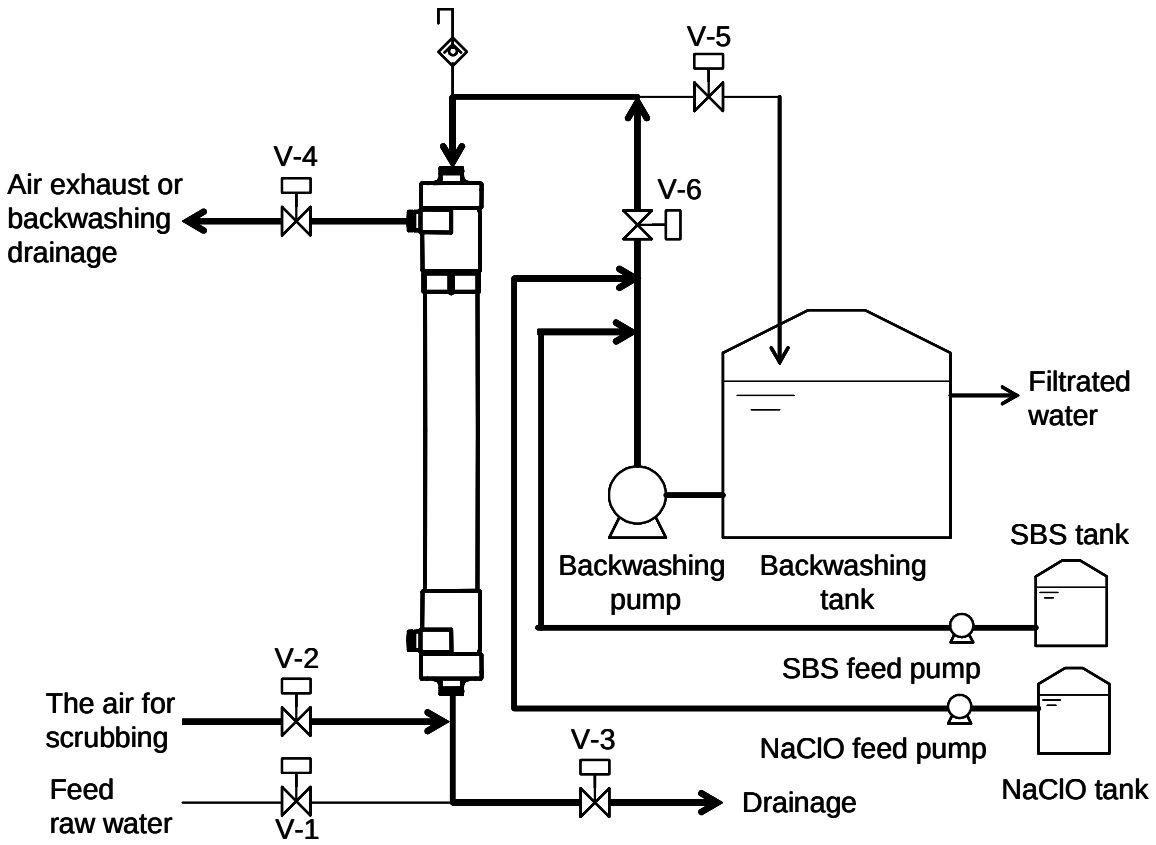


Fig. 8 Flow diagram for the TMC

(1) Open the air exhaust valve (V-4) and the drainage valve (V-3).

(2) Open the backwashing valve (V-6), run the NaClO feed pump and the backwashing pump to feed the chemical enhanced backwash water to the membrane module.

The flow rate of backwash water is set up in advance for 1.0 to 1.5 times filtrate water flow rate (don't exceed Max. Backwash Flow described in Table 4).

(3) As soon as the NaClO is detected in the drainage water, close the drainage valve (V-3).

(4) After making sure water comes out from upper part of the side nozzle of the membrane module, stop the NaClO feed pump, close the backwashing valve (V-6) and stop the backwashing pump.

(5) Soak the membrane in the chemical for a fixed time (normally 20minutes). During the soak, open the air-scrubbing valve (V-2) a few times (normally every 5 minutes and each scrubbing time are 30 seconds).

(6) Open the backwashing valve (V-6), run the sodium bi-sulfite (SBS) feed pump and the backwashing pump to deactivate the chlorine residue for a fixed time (normally 30 seconds).

(7) Stop the SBS feed pump and the backwashing pump and close the backwashing valve (V-6), and then open the air-scrubbing valve for a fixed time (normally 30 seconds).

CAUTION

- The air flow rate for air-scrubbing should be within the range below. Excessive air flow rate may damage the hollow fiber membrane.

  HFU-2020: 4.8 – 9.0 Nm^3/h, normally 6.0 Nm^3/h
  (2.8 – 5.3 scfm, normally 3.5 scfm)

  HFU-2008: 0.7 – 1.2 Nm^3/h, normally 0.8 Nm^3/h
  (0.4 – 0.7 scfm, normally 0.5 scfm)

  HFU-1020: 4.8 – 9.0 Nm^3/h, normally 6.0 Nm^3/h
  (2.8 – 5.3 scfm, normally 3.5 scfm)

  HFU-1010: 1.2 – 2.2 Nm^3/h, normally 1.5 Nm^3/h
  (0.7 – 1.3 scfm, normally 0.9 scfm)

(8) Close the air-scrubbing valve (V-2), open the drainage valve (V-3) to drain the chemical from the membrane module.

(9) Close the drainage valve (V-3), and then open the backwashing valve (V-6) and run the backwashing pump (normally 30 seconds). Stop the backwashing pump and close the backwashing valve (V-6), and then open the air-scrubbing valve (V-2) (normally 30 seconds). Repeat this procedure until the overflow water meets the required water quality.

(10) Make sure the air-scrubbing valve (V-2) and the backwashing valve (V-6) are “closed” and the backwashing pump is “stopped”.

CAUTION

- Always monitor filtrate water quality during filtration, and stop the operation if abnormal water quality is detected. If abnormal water quality is detected, check the integrity of the element with PDT (Pressure Decay Test) or DAF (Diffusive Air Flow) Test. The test procedure is provided as the technical information by Toray.

4. Temperature Correction Factor

The permeability of the membrane is influenced by temperature mainly because the water viscosity changes with temperature. When you evaluate the permeability correctly, you need to eliminate the temperature effect with the temperature correction factor (TCF) shown in Fig. 9.

A Trans-Membrane Pressure (TMP) measured at some real temperature can be converted to 25 degree C corrected TMP with multiplying by TCF at real temperature shown in Fig. 9.

A filtrate flow rate measured at some real temperature can be converted to 25 degree C corrected filtrate flow rate with divided by TCF at real temperature shown in Fig. 9.

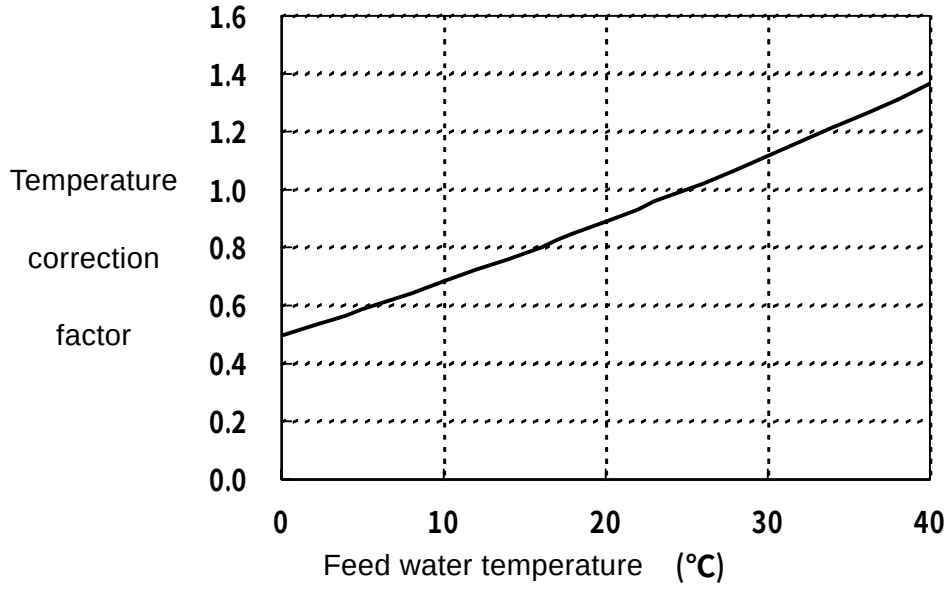


Fig. 9 Temperature correction factor (TCF) for HFU series

The equation for calculating TCF at a temperature (T degree C) is as follows.

TCF
= 0.0008902 / (0.01257187 x EXP((1－0.005806436 x (273.15 + T)) / (0.001130911 x (273.15 + T) - 0.000005723952 x (273.15 + T) x (273.15 + T))) / 1000)

VII. Chemical Cleaning

The chemical cleaning should be carried out to remove foulants accumulated in the membrane pores or sticking to the membrane surface.

CAUTION

- Carry out the chemical cleaning before the trans-membrane pressure rises up to 200 kPa (29.0 PSI), or the module filtration performance could be reduced significantly.
- Follow the instruction described in this manual when you carry out the chemical cleaning. If you use the unacceptable chemicals or perform the cleaning altered from the recommended procedure, the membrane could be seriously damaged.

DANGER

- Pay full attention when handling chemicals and be sure to wear the safety gear such as glasses and gloves. The chemicals used for the chemical cleaning are harmful to people. If chemicals directly contact your skin, your eyes or other body parts, take the appropriate treatment as stated in its MSDS.
- Do not mix sodium hypochlorite with acid. Such mixture generates toxic chlorine gas.
- Stop operations when any instrumental anomalies occur or any sign of anomalies are observed.

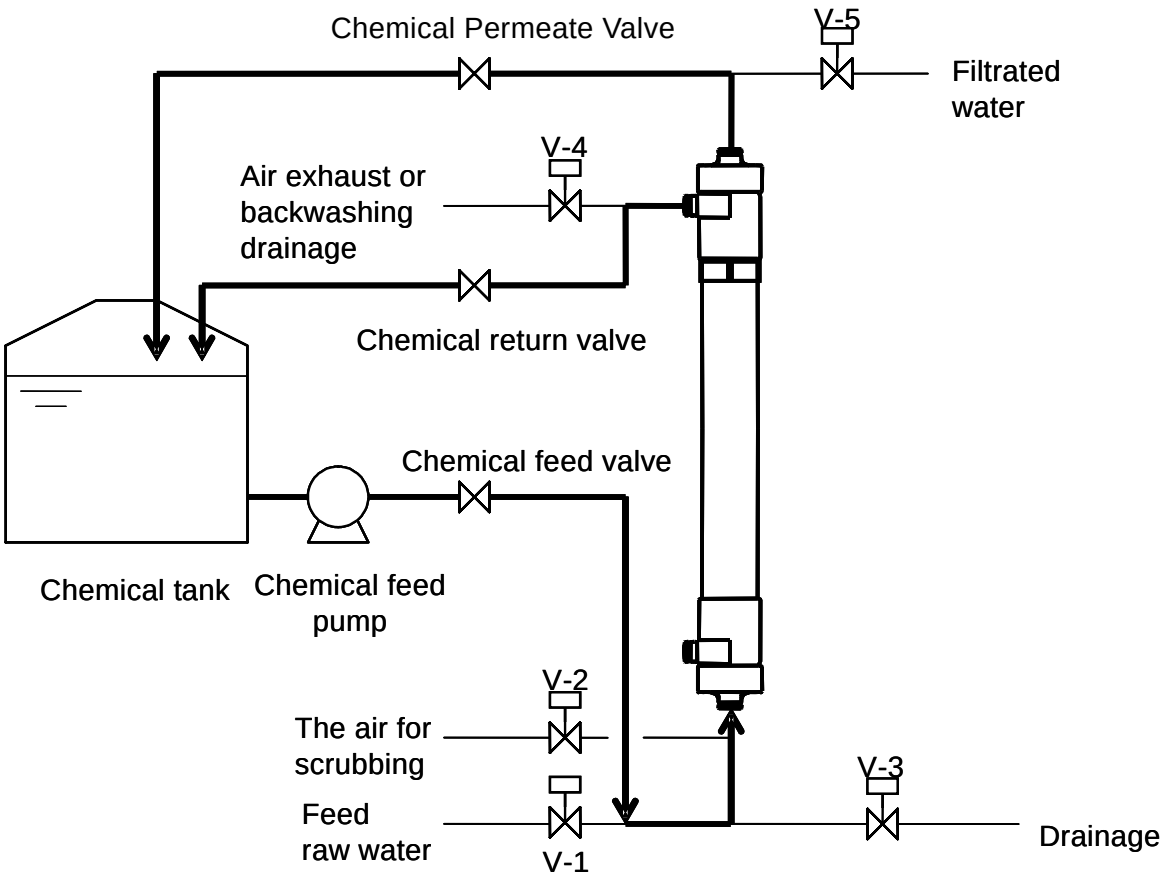


Fig. 10 Flow diagram for chemical cleaning

(1) The flow diagram for cleaning simultaneously both outer surface and inside of hollow fiber membranes is shown in Fig. 10. The flow diagram can be changed case by case. Please contact us if you need the information in detail.

(2) Open the chemical return valve and then open the chemical feed valve.

(3) Run the chemical feed pump to start the circulation of chemical and then open the chemical permeate valve to have the chemical permeate through the membrane.

(4) Circulate the chemical for a fixed time.

(5) Stop the chemical feed pump.

(6) Drain the chemical and rinse the cleaning line and the module thoroughly with product water.

CAUTION

- Take appropriate measures to prevent the mis-operation or accidents that could cause the chemicals to get into the product water. Check the piping and correctly position of each valve before starting the chemical cleaning.

(7) The standard conditions for chemical cleaning are shown in Table 5.

- The concentration and the circulation time shown in Table 5 should be observed. Otherwise the membrane module may get damaged and/or the life of membrane may be shortened.
- To get enough cleaning effect, the cleaning temperature should be higher than 20 degree C.
- The circulation flow rate for each type of the module is as follows.

  HFU-2020: 50 L/min (13 gpm)
  HFU-2008: 8 L/min (2.1 gpm)
  HFU-1020: 20 L/min (5.3 gpm)
  HFU-1010: 5 L/min (1.3 gpm)

Table 5. Standard conditions for chemical cleaning

Pollutants	Chemicals	Maximum Concentration	Circulation Time (hr)
Inorganic substances	Citric acid *1	3.0 wt%	1 - 3
Organic substances	Sodium hypochlorite	3,000 mg/l as chlorine	1 - 3

*1: Besides citric acid, hydrochloric acid (with the maximum concentration of 1.0 mol/l), oxalic acid (with 1.0 wt%), sulfuric acid (with 0.05 mol/l) and nitric acid (with 0.1 mol/l) are acceptable.

CAUTION	- In the case of cleaning with acid and with sodium hypochlorite alternately, rinse the cleaning line and the module with clean water thoroughly after each cleaning. Use product water for rinsing and make sure that pH of the water in the module is in the range between pH 6.5 and 7.5 after rinsing.

DANGER	- Do not use any other chemicals than those indicated above. - Do not mix sodium hypochlorite with acid. Such mixture generates toxic chlorine gas.

VIII. Storage of Membrane Module

Follow the instruction below when you store the modules.

CAUTION - Be careful not to freeze the modules.

1. Storage of New Membrane Modules

Keep the modules in the original packing in a dark and cool place.
Avoid direct sunlight and moisture.

2. Storage of Membrane Modules after use

(1) Short term, or temporary, shutdown or storage

In the case of the suspension of operation for less than four days, stop the feed water and keep modules full of water.

If the suspension lasts for four days to less than eight days, fill the module with the chemical described in Table 6. Use filtrate quality water.

Table 6. Conditions for storing membrane modules for less than eight days

Maximum Storage period	Chemical	Concentration of the chemical
7 days	sodium hypochlorite	20 mg/l as chlorine

(2) Long term storage

First carry out a chemical cleaning with sodium hypochlorite. Fill the module with the chemical described in Table 7. Use filtrate quality water. Follow the instructions shown in the table 7.

Keep the modules sealed with the aqueous chemical solution shown in Table 6 or Table 7. If removing modules from the system, seal them and store out of direct sunlight.

Table 7. Conditions for storing membrane modules for more than seven days

Storage period	Preservative Chemical	Concentration of the chemical
more than 7 days	sodium bisulfite	1,000 mg/l

DANGER

- Rinse the module thoroughly with clean water after the chemical cleaning with sodium hypochlorite, and fill the module with sodium bisulfite solution. Toxic chlorine gas is generated in the case of mixing sodium hypochlorite with sodium bisulfite without first flushing with water.

3. Replace Preservative Chemical

Check the pH value of sodium bisulfite solution as the preservative and replace the chemical if the pH is below three (3.0). Sodium bisulfite solution with a pH of 3 - 6 is active for the preservation. Sodium bisulfite reacts with oxygen and forms sulfuric acid which results in a lower pH.

This Instruction Manual does not intend to guarantee the results of application of the information provided herein or the safety and the compatibility of this product.
Before using this product, the user is asked to check for its safety and compatibility with the intended purpose.
The content of this Instruction Manual is subject to revision from time to time.
Unauthorized use or reproduction of this manual is forbidden.

Toray Membrane USA, Inc.
Cleaning Procedures for Composite Polyamide RO Membrane Elements

This bulletin provides general information about the most typical foulants which may affect the performance of Composite Polyamide Reverse Osmosis (RO) membrane elements, and procedures for the removal of these foulants. The information in this bulletin applies to both 4-inch and 8-inch diameter RO membrane elements.

The surface of the RO membrane is subject to fouling by foreign materials which may be present in the feed water. Examples are:

- Calcium carbonate scale
- Sulfate scale of calcium, barium or strontium
- hydrates of metal oxides (iron, manganese, copper, nickel, aluminum, etc.)
- Polymerized silica scale
- Inorganic colloidal deposits
- Mixed inorganic/organic colloidal deposits
- NOM organic material (Natural Organic Matter)
- Man-made organic compounds (e.g. antiscalant/dispersants, cationic polyelectrolytes)
- Biological (bacterial bioslime, algae, mold, or fungi)

The term fouling used here includes the build up/ deposition of all kinds of layers on the surface of the membrane, including scale formation.

Note: The Composite Polyamide type of RO membrane elements may not be exposed to chlorinated water under any circumstances. Any such exposure may cause irreparable damage to the membrane. Absolute care must be taken following any disinfection of piping or equipment or the preparation of cleaning or storage solutions to ensure that no trace of chlorine is present in the feedwater to the RO membrane elements. If there is any doubt about the presence of chlorine, perform chemical testing. Neutralize any chlorine residual with a sodium bisulfite solution, and ensure adequate mixing and contact time to accomplish complete dechlorination. Dosing rate is 1.8 to 3.0 ppm sodium bisulfite per 1.0 ppm of free chlorine.

Note: It is recommended that all RO membrane cleaning operations should be closely coordinated with Toray Membrane USA during the RO membrane element warranty period. TMUS field service personnel are available to be on site for cleaning assistance, should the need arise. Please contact TMUS for current charges for this service.

Note: The use of cationic surfactant should be avoided in cleaning solutions, since irreversible fouling of the membrane elements may occur.

The nature and rapidity of fouling depends on a number of factors, including:

- quality of the feedwater
- system recovery rate
- element flux

Type of Foulant/ Problem	Probable Location	Pressure Drop	Feed Pressure	Salt Passage
Metal Oxide Fouling (e.g. Fe,Mn,Cu,Ni,Zn)	1st stage lead elements	Rapid increase	Rapid increase	Rapid Increase
Colloidal Fouling (organic and/or inorganic complexes)	1st stage/ lead elements	Gradual increase	Gradual increase	Slight increase
Mineral Scaling (e.g. Ca, Mg, Ba, Sr)	Last stage/ tail elements	Moderate increase	Slight increase	Marked increase
Polymerized Silica	Last stage/ tail elements	Normal to increased	Increased	Normal to increased
Biological Fouling	Any stage, usually lead	Marked increase	Marked increase	Normal to increased
Organic Fouling (dissolved NOM)	All stages	Gradual Increase	Increased	Decreased
Antiscalant Fouling	2nd stage most severe	Normal to increased	Increased	Normal to increased
Oxidant damage (e.g Cl2, Ozone,KmnO4)	1st stage most severe	Normal to decreased	Decreased	Increased
Hydrolysis damage (out of range pH)	All stages	Normal to decreased	Decreased	Increased
Abrasion damage (carbon fines, etc)	1st stage most severe	Normal to decreased	Decreased	Increased
O-ring leaks (at interconnectors or adapters)	Random (typically at feed adapter)	Normal to decreased	Normal to decreased	Increased
Glue line leaks (due to perm pressure > feed pressure in service or standby)	1st stage most severe	Normal to decreased	Normal to decreased	Increassed
Glue line leaks (due to closed permeate valve while cleaning or flushing)	Tail element of a stage	Increased (based on prior fouling and high delta P	Increased (based on prior fouling and high delta P	Increased

Note: Pressure Drop is defined as the Feed pressure minus the Concentrate pressure

Table 1 Types of foulant, and their usual symptoms

Foulant types and effective cleaners

Calcium Carbonate Scale: Calcium carbonate is a mineral scale that may be deposited from almost any feedwater if there is a failure in the antiscalant/dispersant addition system or in the acid injection pH control system. An early detection of calcium carbonate scaling is essential to prevent damage caused by the crystals on the active membrane layers. Calcium carbonate scale detected early can be removed by lowering the feedwater pH to between 3.0 and 5.0 for one or two hours. Longer resident accumulations of calcium carbonate scale can be removed by a low pH cleaning with a citric acid solution.

Calcium, Barium & Strontium Sulfate Scale: Sulfate scale is a much "harder" mineral scale than calcium carbonate and is therefore more difficult to remove. Sulfate scale may be deposited if there is a failure in the antiscalant/dispersant feed system or if there is an over feed of sulfuric acid in pH adjustment. Early detection of the resulting sulfate scaling is essential to prevent damage caused by the crystals on the active membrane layers. Barium and strontium sulfate scales are particularly difficult to remove as they are insoluble in almost all cleaning solutions. Special care should be taken to prevent their formation.

Calcium Phosphate Scale: This scale is particularly common in municipal wastewaters and water supplies which may contain high levels of phosphate. This scale can generally be removed with acidic pH cleaners.

Metal Oxide/Hydroxide Foulants: Typical metal oxide and metal hydroxide foulants are iron, zinc, manganese, copper, aluminum, etc. They can be the result of corrosion products from unlined pipes and tanks; from oxidation of the soluble metal ion with air, chlorine, ozone, potassium permanganate; or from a pretreatment filter system upset that utilizes iron or aluminum based coagulant aids. Can generally be removed with low pH cleaners

Polymerized Silica Coating: A silica gel coating resulting from the super-saturation and polymerization of soluble silica can be very difficult to remove. It should be noted that this type of silica fouling is different from silica-based colloidal foulants, which may be associated with either metal hydroxides or organic matter. Polymerized silica scale can be very difficult to remove by traditional chemical cleaning methods.

Colloidal Foulants: Colloids are inorganic or mixed inorganic/organic based particles that are suspended in water and will not settle out due to gravity. Colloidal matter typically contains one or more of the following major components: iron, aluminum, silica, sulfur, or organic matter. High pH cleaners are generally more effective against this type of foulant

Dissolved NOM/ Organic Foulants: The sources of dissolved NOM (Natural Organic Matter) foulants are typically derived from the decomposition of vegetative material into surface waters or shallow wells. The chemistry of organic foulants is very complex, with the major organic components being either humic acid or fulvic acid. Dissolved NOMs can quickly foul RO membranes by being absorbed onto the membrane surface. Once absorption has occurred, then a slower fouling process of gel or cake formation begins. It should be noted that the mechanism of fouling with dissolved NOM should not be confused with the mechanism of fouling created by NOM organic material that is bound with colloidal particles. High pH cleaners are generally more effective against this type of foulant. Please note that wastewaters may contain a range of naturally occurring and man-made organic compounds. Should any of these compounds chemically bond to the membrane, cleaning regimes may be ineffective in removing the foulant.

Microbiological Deposits: Organic-based deposits resulting from bacterial slimes, fungi, molds, etc. can be difficult to remove, particularly if the feed path is plugged. Plugging of the feed path makes it difficult to introduce and distribute the cleaning solutions. To inhibit additional growth, it is important to clean and sanitize not only the RO system, but also the pretreatment, piping, dead-legs, etc. High pH cleaners in association with biocide treatments are most effective against this type of problem.

Selection and Use of Cleaning Chemicals

There are a number of factors involved in the selection of a suitable cleaning chemical (or chemicals) and proper cleaning protocol. At the time of the first cleaning, it is recommended to contact:

- Manufacturer of the equipment,
- RO element manufacturer,
- RO specialty chemical and service supplier.

Proper identification of the foulant is essential to prescibe the correct cleaners to most effectively remove the foulant.

Once the suspected foulant(s) are identified, one or more cleaning chemicals will be recommended.
These cleaning chemical(s) can be:

- Generic (typically technical grade, available from local chemical supply companies)
- Private-labeled proprietary chemicals.

Independent RO service companies are available who can determine the proper chemicals and cleaning protocol for your situation by testing a fouled element at their facility. For difficult situations, this is a recommended option.

It is not unusual to use a number of different cleaning chemicals in a specific sequence to achieve the optimum cleaning. As foulants may be laid down in discrete “layers”, the sequence of cleaning can be important.

Typically, a low pH cleaning is first used to remove foulants (such as mineral scale), followed by a high pH cleaning to remove organic material. This is not always the case - there are instances where a high pH cleaning may used first to remove foulants like oil or biological matter, followed by a low pH cleaning. The optimum sequence can usually only be determined by conducting tests.

Some cleaning solutions are “combination” agents, and may have detergents added to aid in the removal of heavy biological and organic debris, while others have a chelating agent like EDTA added to aid in the removal of colloidal, organic and biological material, as well as sulfate scale. Advice on the best use of such cleaners is best obtained directly from the manufacturer of the speciality cleaners.

TMUS has no objection to the use of speciality cleaners, providing it has been adequately demonstrated that the cleaner will not damage the Toray membrane.

General Precautions in Cleaning Chemical Selection and Usage

- If using a proprietary chemical, be sure the chemical has been qualified for use with the membrane by the chemical supplier. The chemical supplier’s instructions should not be in conflict with TMUS’s recommended cleaning parameters and limits.
- Use the mildest cleaning regimen. This includes the cleaning parameters of pH, temperature, and contact time. This will optimize the useful life of the membrane.
- Clean at the recommended target temperatures to optimize cleaning efficiency and membrane life.
- Use the minimal amount of chemical contact time to optimize membrane life.

- Be prudent in the adjustment of pH at the low and high pH range to extend the useful life of the membrane. A “gentle” pH range is 4 to 10, while the harshest is 2 to 12.
- Typically, the most effective cleaning sequence is low pH followed by high pH solutions. One known exception is oil-fouled membranes should not use a low pH clean first as the oil will coagulate.
- Cleaning and flushing flows should be in the same direction as the normal feed flow to avoid potential telescoping and element damage.
- When cleaning a multi-stage RO, the most effective cleaning plan is to clean one bank/stage at a time so cleaning flow velocities can be optimized and foulants from upstream stages will not pass through to downstream stages.
- Flushing detergents with higher pH permeate can reduce any foaming problems.
- Verify that proper disposal requirements for the cleaning solution are followed.
- If the system has been fouled biologically, consider the extra step of introducing a sanitizing biocide chemical after a successful cleaning. Biocides can be introduced
    - immediately after cleaning,
    - periodically (e.g. once a week),
    - continuously during service.
- Ensure that the biocide is compatible with the membrane, does not create any health risks, is effective in controlling biological activity, and is not cost prohibitive before going this route.
- Safety Considerations
    - Be sure all hoses and piping can handle the temperatures, pressures and pH which will be encountered during a cleaning.
    - Always add chemicals slowly to an agitated batch of make-up water.
    - Always wear safety glasses and appropriate protective gear when working with chemicals.
    - Don’t mix concentrated acids with caustic solutions.
    - Thoroughly rinse the 1st cleaning solution from the RO system before introducing the next solution.

pH and Temperature Limits for Cleaning Toray

Membrane Type	**45 C (113 F)**	**35 C (95 F)**	**30 C (86 F)**
Brackish (“7 “and “L”)	2-10	2-11.5	2-12
Low Pressure Brackish (“G” And “H”)	2-10	2-11.5	2-12
Seawater	2-10	2-11	2-12

Note: The above cleaning parameters denote the maximum temperature limits for a corresponding range of pH. Cleaning operations performed at the extremes may result in a more effective cleaning, but can shorten the useful life of the membrane due to hydrolysis.effects. To optimize the useful life of a membrane, it is recommended to use the least harsh cleaning solutions necessary and to minimize the contact time whenever possible.

Cleaning and Flushing Flow Rates per RO Pressure Tube
(differential Pressures are not to exceed 60 psi (4 bar) across any tube.)

Element Diameter	**GPM**	**LPM**
4-inches	6 to 10	23 to 38
8-inches	24 to 40	91 to 151

Elements should be cleaned at the highest flow rate possible without exceeding 60 psi differential pressure limit. Exceeding the limit can result in mechanical damage to the elements.

Cleaning Solution Volume Requirement per RO Element
(This volume does not include additional volumes required for piping, filters, etc. or the initial 20% of volume dumped to drain.)

Element Size	**Normal Fouling**	**Heavy Fouling**	**Normal Fouling**	**Heavy Fouling**
	(Gallons)	(Gallons)	(Liters)	(Liters)
4 x 40 inches	2.5	5	9.5	19
8 x 40 inches	9	18	34	68

Cleaning Tank sizing

Required volume of cleaning solution can be estimated as follows:

1. Cleaning solution requirement per element (see above) x number of elements to be cleaned

Plus

2. Swept volume of connecting pipework to and from cleaning skid

Plus

3. Extra 20% of (1+2) above for first part of cleaning solution sent to drain

RO Cleaning Skid

The successful cleaning of an RO on-site requires a well designed RO cleaning skid. See Figure 1 for a typical arrangement. The skid may or may not be hard piped to the RO skid and may use flexible hose for connections to the RO skid.
For a multi-stage RO, it is recommended that each bank/array be cleaned one stage at a time to optimize cross-flow cleaning velocity.
The source water for chemical solution make-up and rinsing should be clean RO permeate or DI water and be free of hardness, transition metals (e.g. iron), and chlorine..

RO Cleaning Tank:
This tank needs to be sized properly to accommodate the displacement of water in the hose, piping, and RO elements. (see above).The tank should be designed to:

- Allow 100 % drainage
- easy access for chemical introduction and mixing
- recirculation line from the RO Cleaning Pump,
- proper venting,
- overflow,
- return line located near the bottom to minimize foam formation when using a surfactant.

RO Cleaning Pump:
This pump needs to be sized to develop the proper cross-flow velocity to scrub the membrane clean. The maximum recommended pressure is 60 psi (4 bar) at the inlet to the pressure vessels to minimize the production of permeate during cleaning and so reduce the convective re-deposition of foulant back on the membrane surface. The table above gives the recommended flow rate ranges for each pressure tube.

RO Cleaning Cartridge Filter:

Normally 5 to 10-micron and is designed to remove foulants that have been displaced from the cleaning process. Filter must be located upstream of the RO elements.

RO Tank Heater or Cooler:
The maximum design temperature for cleaning is 113° F (45° C). It should be noted that heat is generated and imparted by the RO Cleaning Pump during recirculation which can act as a heater,

RO Tank Mixer: This component is recommended for optimal mixing of chemical, though some designers rely solely on the slow introduction of chemical while maintaining a recirculation through the RO Cleaning Pump back to the tank.

Instrumentation: Cleaning system instrumentation should be included to monitor flow, temperature, pressure, and tank level.

Sample Points:
Sample valves should be located to allow pH and TDS measurements off the RO Cleaning Pump discharge and the concentrate side recirculation return line.

Permeate Return Line:
A small amount of the cleaning solution can permeate through the membranes, therefore a permeate-side return line back to the RO Cleaning Tank is required.
Important: The permeate line and any permeate valves must always be open to atmospheric pressure during the cleaning and flushing steps or damage to RO elements can occur. If the permeate line is closed, the permeate pressure can build up and become higher than the feed-side pressure of the tail elements. This can result in excessive permeate back-pressure which can damage the membrane glue lines in the tail elements.

RO Membrane Element Cleaning and Flushing Procedures

The RO membrane elements can be cleaned in place in the pressure tubes by recirculating the cleaning solution across the high-pressure side of the membrane at low pressure and relatively high flow. A cleaning unit is needed to accomplish this task. See fig 1 for general arrangement.

RO cleaning procedures may vary dependent on the situation. The time required to clean a stage is from 4 to 8 hours. A general procedure for cleaning the RO membrane elements is as follows:

1. Perform a low pressure flush at 60 psi (4 bar) or less of the pressure tubes by pumping clean water from the cleaning tank (or equivalent source) through the pressure tubes to drain for several minutes. Flush water should be clean water of RO permeate or DI quality and be free of hardness, transition metals, and chlorine.
2. Mix a fresh batch of the selected cleaning solution in the cleaning tank. The dilution water should be clean water of RO permeate or DI quality and be free of hardness, transition metals, and chlorine. The temperature and pH should be adjusted to their target levels.
3. Start recirculation. Initially send the displaced water from the system to drain so y cleaning chemical is not diluted. Then divert the first 20%of the returned cleaning solution (the most highly fouled cleaning solution) to drain before allowing the remaining cleaning solution to recirculate back into the RO Cleaning Tank. For the first 5 minutes, slowly throttle the flow rate to 1/3 of the maximum design flow rate. This is to minimize the potential plugging of the feed path with a large amount of dislodged foulant. For the second 5 minutes, increase the flow rate to 2/3 of the maximum design flow rate, and then increase the flow rate to the maximum design flow rate. If required, readjust the pH back to the target when it changes more than 0.5 pH units. Circulate the cleaning solution through the pressure tubes for approximately one hour or as required.
4. An optional soak and recirculation sequence can be used, if required. The soak time can be from 1 to 8 hours depending on the manufacturer's recommendations. Caution should be used to maintain the proper temperature and pH.
5. Upon completion of the chemical cleaning step, a low pressure cleaning rinse with clean water (RO permeate or DI quality and free of hardness, transition metals, and chlorine) is required to remove all traces of chemical from the Cleaning Skid and the RO Skid. Drain and flush the cleaning tank; then completely refill the Cleaning Tank with clean water for the Cleaning Rinse. Rinse the pressure tubes by pumping all of the rinse water from the Cleaning Tank through the pressure tubes to drain. A second cleaning can be started at this point, if required.
6. Once the RO system is fully rinsed of cleaning chemical with clean water from the Cleaning Tank, a final low pressure clean-up flush can be performed using pretreated feedwater.The permeate line should remain open to drain. Feed pressure should be less than 60 psi (4bar). This final flush continues until the flush water flows clean and is free of any foam or residues of cleaning agents. This usually takes 15 to 60 minutes. The operator should sample the flush water going to the drain for detergent removal and lack of foaming by using a clear flask and shaking it. A conductivity meter can be used to test for removal of cleaning chemicals. The flush water to drain should be within 10-20% of the feedwater conductivity.A pH meter can also be used to compare the flush water to drain to the feed pH.

7. Once all the stages of a train are cleaned and the chemicals flushed out, the RO can be restarted and placed into a Service Rinse. The RO permeate should be diverted to drain until it meets the quality requirements of the process (e.g. conductivity, pH, etc.). It is not unusual to take a period from a few hours to a few days for the RO permeate quality to fully stabilize, especially after high pH or very low pH cleanings..

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Technical Service Bulletin

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Foulants and Cleaning Procedures for composite polyamide RO Membrane Elements (ESPA, ESNA, CPA, LFC, NANO and SWC)

This bulletin provides general information about the usual foulants affecting the performance of Hydranautics' Composite Polyamide Reverse Osmosis (RO) membrane elements and the removal of these foulants. The information in this bulletin applies to 4-inch, 6-inch, 8-inch, 8.5-inch, and 16-inch diameter RO membrane elements.

Note: The Composite Polyamide type of RO membrane elements may not be exposed to chlorinated water under any circumstances. Any such exposure will cause irreparable damage to the membrane. Absolute care must be taken following any disinfection of piping or equipment or the preparation of cleaning or storage solutions to ensure that no trace of chlorine is present in the feedwater to the RO membrane elements. If there is any doubt about the presence of chlorine, perform chemical testing to make sure. Neutralize any chlorine residual with a sodium bisulfite solution, and ensure adequate mixing and contact time to accomplish complete dechlorination. Dosing rate is 1.8 to 3.0 ppm sodium bisulfite per 1.0 ppm of free chlorine.

Note: It is recommended that all RO membrane cleaning operations should be closely coordinated with Hydranautics during the RO membrane element warranty period. Hydranautics field service personnel are available to be on site for cleaning assistance, should the need arise. Please contact Hydranautics for current charges for this service.

Note: The use of cationic surfactant should be avoided in cleaning solutions, since irreversible fouling of the membrane elements may occur.

If additional information is needed, please contact the Technical Services Department at:

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RO Membrane Fouling and Cleaning

During normal operation over a period of time, RO membrane elements are subject to fouling by suspended or sparingly soluble materials that may be present in the feedwater. Common examples of foulants are:

- Calcium carbonate scale
- Sulfate scale of calcium, barium or strontium
- Metal oxides (iron, manganese, copper, nickel, aluminum, etc.)
- Polymerized silica scale
- Inorganic colloidal deposits
- Mixed inorganic/organic colloidal deposits
- NOM organic material (Natural Organic Matter)
- Man-made organic material (e.g. antiscalant/dispersants, cationic polyelectrolytes)
- Biological (bacterial bioslime, algae, mold, or fungi)

The nature and rapidity of fouling depends on a number of factors, such as the quality of the feedwater and the system recovery rate. Typically, fouling is progressive, and if not controlled early, will impair the RO membrane element performance in a relatively short time. Cleaning is should accur when the RO shows evidence of fouling, just prior to a long-term shutdown, or as a matter of scheduled routine maintenance. The elements shall be maintained in a clean or “nearly clean” condition to prevent excessive fouling by the foulants listed above. Some fouling is allowed as long as:

- normalized permeate flow decrease is less than 10%

- normalized permeate quality decrease is less than 10%

.

- normalized pressure drop, as measured between the feed and concentrate headers, increase is less than 15%.

Cleaning should be carried out before these values are exceeded to maintain the elements in a clean or “nearly clean” condition. Effective cleaning is evidenced by the return of the normalized parameters to their initial, Start-up, value. In the event you do not normalize your operating data, the above values still apply if you do not have major changes in critical operating parameters. The operating parameters that have to stay constant are permeate flow, permeate back-pressure, recovery, temperature, and feed TDS. If these operating parameters fluctuate, then it is highly recommended that you normalize the data to determine if fouling is occurring or if the RO is actually operating normally based on the change in a critical operating parameter. Hydranautics offers a free normalization software program called ROData, which can be downloaded from our web site at www.membranes.com.

Monitoring overall plant performance on a regular basis is an essential step in recognizing when membrane elements are becoming fouled. Performance is affected progressively and in varying degrees, depending on the nature of the foulants. Table 1 “RO Troubleshooting Matrix” provides a summary of the expected effects that common foulants have on performance.

RO cleaning frequency due to fouling will vary by site. A rough rule of thumb as to an acceptable cleaning frequency is once every 3 to 12 months. If you have to clean more than once a month, you should be able to justify further capital expenditures for improved RO pretreatment or a re-design of the RO operation. If the cleaning frequency is every one to three months, you may want to focus on improving the operation of your existing equipment but further capital expenditure may be harder to justify.

It is important to clean the membranes when they are only lightly fouled, not heavily fouled. Heavy fouling can impair the effectiveness of the cleaning chemical by impeding the penetration of the chemical deep into the foulant and in the flushing of the foulant out of the elements. If normalized membrane performance drops 30 to 50%, it may be impossible to fully restore the performance back to baseline conditions.

When inorganic or polyelectrolyte coagulants are used in the pretreatment process, there can often be incomplete reaction of the coagulant and thus insufficient formation of a filterable floc. The user should ensure that excessive amounts of coagulant are not fed to the RO system, as it can lead to fouling. Polyelectrolyte fouling can often be very difficult to remove and result in higher than expected feed pressure. Excessive amounts of inorganic coagulant can be measured by using SDI filter equipment. In the case of iron, the iron on the SDI filter pad should typically be 3 µg/pad and never above 5 µg/pad. In regards to polymer coagulants, the user should discuss the concern with their chemical supplier and have them ensure that the chemical will not adversely affect the membrane.

In addition to the use of turbidity and SDI, particle counters are also very effective to accurately measure the suitability of the feedwater for NF/RO elements. The measure of particles greater than 2 microns in size should be < 100 particles per millilitre.

One RO design feature that is commonly over-looked in reducing RO cleaning frequency is the use of RO permeate water for flushing foulants from the system. Soaking the RO elements during standby with permeate can help dissolve scale and loosen precipitates, reducing the frequency of chemical cleaning.

What you clean for can vary site by site depending on the foulant. Complicating the situation frequently is that more than one foulant can be present, which explains why cleanings frequently require a low pH and high pH cleaning regiment.

Note: The membrane elements shall not be exposed to feed water containing oil, grease, or other foreign matter which proves to chemically or physically damage the integrity of the membrane.

Table 1: RO Troubleshooting Matrix

(Pressure Drop is defined as the Feed pressure minus the Concentrate pressure)

Possible Cause	Possible Location	Pressure Drop	Feed Pressure	Salt Passage
Metal Oxide Fouling (e.g. Fe,Mn,Cu,Ni,Zn)	1st stage lead elements	Rapid increase	Rapid increase	Rapid increase
Colloidal Fouling (organic and/or inorganic complexes)	1st stage lead elements	Gradual increase	Gradual increase	Slight increase
Mineral Scaling (e.g. Ca, Mg, Ba, Sr)	Last stage tail elements	Moderate Increase	Slight increase	Marked increase
Polymerized Silica	Last stage tail elements	Normal to increased	Increased	Normal to increased
Biological Fouling	Any stage, usually lead elements	Marked increase	Marked increase	Normal to increased
Organic Fouling (dissolved NOM)	All stages	Gradual increase	Increased	Decreased
Antiscalant Fouling	2nd stage most severe	Normal to increased	Increased	Normal to increased
Oxidant damage (e.g Cl_2, ozone,$KMnO_4$)	1st stage most severe	Normal to decreased	Decreased	Increased
Hydrolysis damage (out of range pH)	All stages	Normal to decreased	Decreased	Increased
Abrasion damage (carbon fines, etc)	1st stage most severe	Normal to decreased	Decreased	Increased
O-ring leaks (at interconnectors or adapters)	Random (typically at feed adapter)	Normal to decreased	Normal to decreased	Increased
Glue line leaks (due to permeate back-pressure in service or standby)	1st stage most severe	Normal to decreased	Normal to decreased	Increased
Glue line leaks (due to closed permeate valve while cleaning or flushing)	Tail element of a stage	Increased (based on prior fouling & high delta P)	Increased (based on prior fouling & and high delta P)	Increased

Discussion on Foulants

Calcium Carbonate Scale: Calcium carbonate is a mineral scale and may be deposited from almost any feedwater if there is a failure in the antiscalant/dispersant addition system or in the acid injection pH control system that results in a high feedwater pH. An early detection of the resulting calcium carbonate scaling is absolutely essential to prevent the damage that crystals can cause on the active membrane layers. Calcium carbonate scale that has been detected early can be removed by lowering the feedwater pH to between 3.0 and 5.0 for one or two hours. Longer resident accumulations of calcium carbonate scale can be removed by a low pH cleaning with a citric acid solution.

Calcium, Barium & Strontium Sulfate Scale: Sulfate scale is a much "harder" mineral scale than calcium carbonate and is harder to remove. Sulfate scale may be deposited if there is a failure in the antiscalant/dispersant feed system or if there is an over feed of sulfuric acid in pH adjustment. Early detection of the resulting sulfate scaling is absolutely essential to prevent the damage that crystals can cause on the active membrane layers. Barium and strontium sulfate scales are particularly difficult to remove as they are insoluble in almost all cleaning solutions, so special care should be taken to prevent their formation.

Calcium Phosphate Scale: This scale is particularly common in municipal waste waters and polluted water supplies which may contain high levels of phosphate. This scale can generally be removed with acidic pH cleaners. At this time, phosphate scaling calculations are not performed by the Hydranautics RO Design software. As a rule of thumb, contact Hydranautics technical department if phosphate levels in the feed are 5 ppm or higher.

Metal Oxide/Hydroxide Foulants: Typical metal oxide and metal hydroxide foulants are iron, zinc, manganese, copper, aluminum, etc. They can be the result of corrosion products from unlined pipes and tanks, or result from the oxidation of the soluble metal ion with air, chlorine, ozone, potassium permanganate, or they can be the result of a pretreatment filter system upset that utilizes iron or aluminum-based coagulant aids.

Polymerized Silica Coating: A silica gel coating resulting from the super-saturation and polymerization of soluble silica can be very difficult to remove. It should be noted that this type of silica fouling is different from silica-based colloidal foulants, which may be associated with either metal hydroxides or organic matter. Silica scale can be very difficult to remove by traditional chemical cleaning methods. Contact Hydranautics technical department if the traditional methods are unsuccessful. There does exist harsher cleaning chemicals, like ammonium biflouride, that have been used successfully at some sites but are considered rather hazardous to handle and can damage equipment.

Colloidal Foulants: Colloids are inorganic or mixed inorganic/organic based particles that are suspended in water and will not settle out due to gravity. Colloidal matter typically contains one or more of the following major components: iron, aluminum, silica, sulfur, or organic matter.

Dissolved NOM Organic Foulants: The sources of dissolved NOM (Natural Organic Matter) foulants are typically derived from the decomposition of vegetative material into surface waters or shallow wells. The chemistry of organic foulants is very complex, with the major organic components being either humic acid or fulvic acid. Dissolved NOMs can quickly foul RO membranes by being absorbed onto the membrane surface. Once absorption has occurred, then a slower fouling process of gel or cake formation starts. It should be noted that the mechanism of fouling with dissolved NOM should not be confused with the mechanism of fouling created by NOM organic material that is bound up with colloidal particles.

Microbiological Deposits: Organic-based deposits resulting from bacterial slimes, fungi, molds, etc. can be difficult to remove, particularly if the feed path is plugged. Plugging of the feed path makes it difficult to

introduce and distribute the cleaning solutions. To inhibit additional growth, it is important to clean and sanitize not only the RO system, but also the pretreatment, piping, dead-legs, etc. The membranes, once chemically cleaned, will require the use of a Hydranautics approved biocide and an extended exposure requirement to be effective. For further information on biocides, refer to Hydranautics Technical Service Bulletin TSB-110 “Biocides for Disinfection and Storage of Hydranautics Membrane Elements”.

Selection and Use of Cleaning Chemicals

There are a number of factors involved in the selection of a suitable cleaning chemical (or chemicals) and proper cleaning protocol. The first time you have to perform a cleaning, it is recommended to contact the manufacturer of the equipment, the RO element manufacturer, or a RO specialty chemical and service supplier. Once the suspected foulant(s) are identified, one or more cleaning chemicals will be recommended. These cleaning chemical(s) can be generic or can be private-labeled proprietary chemicals. Typically, the generic chemicals can be of technical grades and are available from local chemical supply companies. The proprietary RO cleaning chemicals can be more expensive, but may be easier to use and you cannot rule out the advantage of the intellectual knowledge supplied by these companies. Some independent RO service companies can determine the proper chemicals and cleaning protocol for your situation by testing at their facility a fouled element pulled from your system.

It is not unusual to use a number of different cleaning chemicals in a specific sequence to achieve the optimum cleaning. Typically, a high pH cleaning is used first to remove foulants like oil or biological matter, followed by a low pH cleaning to remove foulants like mineral scale or metal oxides/hydroxides fouling. There are times that order of high and low pH cleaning solutions is reversed or one solution only is required to clean the membranes. Some cleaning solutions have detergents added to aid in the removal of heavy biological and organic debris, while others have a chelating agent like EDTA added to aid in the removal of colloidal material, organic and biological material, and sulfate scale. An important thing to remember is that the improper selection of a cleaning chemical, or the sequence of chemical introduction, can make the foulant worse.

Hydranautics recommends that the membrane system operator thoroughly investigate the signs of fouling before they select a cleaning chemical and a cleaning protocol. Some forms of fouling (iron deposits and scaling commonly associated with well waters) may require only a simple low pH cleaning. However, for most complex fouling phenomena, Hydranautics recommends the following sequence:

1. Flushing with permeate with addition of non oxidizing biocide (DBNPA or similar type) at the end of the flushing.
2. High pH CIP – Temperature versus pH as per recommendations in this TSB
3. Flushing with permeate until pH on the brine side is below pH 8.5
4. Low pH CIP
5. Acid flushing with permeate and non oxidizing biocide (DBNPA or similar type)

General Precautions in Cleaning Chemical Selection and Usage

- If you are using a proprietary chemical, make sure the chemical has been qualified for use with your Hydranautics membrane by the chemical supplier. The chemical supplier’s instructions should not be in conflict with Hydranautics recommended cleaning parameters and limits listed in this Technical Service Bulletin.
- If you are using generic chemicals, make sure the chemical has been qualified for use with your Hydranautics membrane in this Technical Service Bulletin.
- Use the least harshest cleaning regiment to get the job done. This includes the cleaning parameters of pH, temperature, and contact time. This will optimize the useful life of the membrane.
- Clean at the recommended target temperatures to optimize cleaning efficiency and membrane life.
- Use the minimal amount of chemical contact time to optimize membrane life.

- Be prudent in the adjustment of pH at the low and high pH range to extend the useful life of the membrane. A “gentle” pH range is 4 to 10, while the harshest is 2 to 12.
- Oil and biologically -fouled membranes should not use a low pH clean-up first as the oil and biological matter will congeal.
- Cleaning and flushing flows should be in the same direction as the normal feed flow to avoid potential telescoping and element damage.
- When cleaning a multi-stage RO, the most effective cleaning is one stage at a time so cleaning flow velocities can be optimized and foulants from upstream stages don’t have to pass through down-stream stages.
- Flushing out detergents with higher pH permeate can reduce foaming problems.
- Verify that proper disposal requirements for the cleaning solution are followed.
- If your system has been fouled biologically, you may want to consider the extra step of introducing a sanitizing biocide chemical before and after a successful cleaning. Biocides can be introduced before and immediately after cleaning, periodically (e.g. once a week), or continuously during service. You must be sure that the biocide is compatible with the membrane, does not create any health risks, is effective in controlling biological activity, and is not cost prohibitive.
- For safety reasons, make sure all hoses and piping can handle the temperatures, pressures and pH’s encountered during a cleaning.
- For safety reasons, always add chemicals slowly to an agitated batch of make-up water.
- For safety reason, always wear safety glasses and protective gear when working with chemicals.
- For safety reasons, don’t mix acids with caustics. Thoroughly rinse the 1st cleaning solution from the RO system before introducing the next solution.

Selecting a Cleaning Solution

Table 2 lists the recommended generic chemical solutions for cleaning an RO membrane element based on the foulant to be removed.

Important: It is recommended that the MSDS of the cleaning chemicals be procured from the chemical supplier and that all safety precautions be utilized in the handling and storage of all chemicals.

Table 2: Hydranautics Recommended Chemical Cleaning Solutions

Foulant	Gentle Cleaning Solution	Harsher Cleaning Solution
Calcium carbonate scale	1	4
Calcium, barium or strontium sulfate scale	2	4
Metal oxides/hydroxides (Fe, Mn, Zn, Cu, Al)	1	5
Inorganic colloidal foulants	1	4
Mixed Inorganic/organic colloidal foulants	2	6
Polymerized silica coating	None	7
Biological matter	2 or 3	6
NOM organic matter (naturally occurring)	2 or 3	6

Table 3 “Hydranautics Recipes for Cleaning Solutions” offers instructions on the volumes of bulk chemical to be added to 100 U.S. gallons (379 liters) of make-up water. Prepare the solutions by proportioning the amount of chemicals to the amount of make-up water to be used. Make-up water quality should be of RO permeate or deionized (DI) quality, and be free of chlorine and hardness. Before forwarding the cleaning solution to the membranes, it is important to thoroughly mix it, adjust the pH according to the target pH, and stabilize the temperature at the target temperature. Unless otherwise instructed, the cleaning design parameters are based on a chemical recirculation flow period of one hour and an optional chemical soak period of one hour.

Table 4 “Hydranautics Maximum pH and Temperature Limits for Cleaning” highlights the maximum pH and temperature limits for specific membranes, after which irreparable membrane damage can occur. A suggested minimum temperature limit is 70 F (21 C), but cleaning effectiveness and the solubility of the cleaning chemical is significantly improved at higher temperatures.

Description of Cleaning Solutions

Note: The notation (w) denotes that the diluted chemical solution strength is based on the actual weight of the 100% pure chemical or active ingredient.

Solution 1: This is a low pH cleaning solution of 2.0% (w) citric acid ($C_6H_8O_7$). It is useful in removing inorganic scale (e.g. calcium carbonate, calcium sulfate, barium sulfate, strontium sulfate) and metal oxides/hydroxides (e.g. iron, manganese, nickel, copper, zinc), and inorganic-based colloidal material. Note: Citric acid is available as a powder.

Solution 2: This is a high pH cleaning solution (target pH of 10.0) of 2.0% (w) of STPP (sodium tripolyphosphate) ($Na_5P_3O_{10}$) and 0.8% (w) of Na-EDTA (sodium salt of ethylaminediaminetetraacetic acid). It is specifically recommended for removing calcium sulfate scale and light to moderate levels of organic foulants of natural origin. STPP functions as an inorganic-based chelating agent and detergent. Na-EDTA is an organic-based chelating cleaning agent that aids in the sequestering and removal of divalent and trivalent cations and metal ions. STPP and Na-EDTA are available as powders.

Solution 3: This is a high pH cleaning solution (target pH of 10.0) of 2.0% % (w) of STPP (sodium tripolyphosphate) ($Na_5P_3O_{10}$) and 0.025% (w) Na-DDBS ($C_6H_5(CH_2)_{12}$-SO_3Na) (sodium salt of dodecylbenzene sulfonate). It is specifically recommended for removing heavier levels of organic foulants of natural origin. STPP functions as an inorganic-based chelating agent and detergent. Na-DDBS functions as an anionic detergent.

Solution 4: This is a low pH cleaning solution (target pH of 2.5) of 0.5% (w) of HCL (hydrochloric) acid. It is useful in removing inorganic scale (e.g. calcium carbonate, calcium sulfate, barium sulfate, strontium sulfate and metal oxides/hydroxides (e.g. iron, manganese, nickel, copper, zinc) and inorganic-based colloidal material. This cleaning solution is considered to be harsher than Solution 1. HCL acid, a strong mineral acid, is also known as muriatic acid. HCL acid is available in a number of concentrations: (18 ^{0} Baume = 27.9%), (20 ^{0} Baume = 31.4%), (22 ^{0} Baume = 36.0%).

Solution 5: This is a lower pH cleaning solution (natural pH is between pH 4 and 6. No pH adjustment is required) 1.0% (w) of $Na_2S_2O_4$ (sodium hydrosulfite). It is useful in the removal of metal oxides and hydroxides (especially iron fouling), and to a lesser extent calcium sulfate, barium sulfate and strontium sulfate. Sodium hydrosulfite is strong reducing agent and is also known as sodium dithionite. The solution will have a very strong odor so proper ventilation is required. Sodium hydrosulfite is available as a powder.

Solution 6: This is a high pH cleaning solution (target pH of 11.5) of 0.1% (w) of NaOH (sodium hydroxide) and 0.03% (w) of SDS (sodium dodecylsulfate). It is useful in the removal of organic foulants of natural origin, colloidal foulants of mixed organic/inorganic origin, and biological material (fungi, mold, slimes and biofilm). SDS is a detergent that is an anionic surfactant that will cause some foaming. This is considered to be a harsh cleaning regiment. ***Note: Do not exceed maximum pH and temp limits for specific elements. See Table4.***

Solution 7: This is a high pH cleaning solution (target pH of 11.5) of 0.1% (w) of NaOH (sodium hydroxide). It is useful in the removal of polymerized silica. This is considered to be a harsh cleaning regiment. *Note: Do not exceed maximum pH and temp limits for specific elements. See Table4.*

Important: It is recommended that the MSDS of the cleaning chemicals be procured from the chemical supplier and that all safety precautions be utilized in the handling and storage of all chemicals.

Table 3: Hydranautics Recipes for Cleaning Solutions

The quantities listed below are to be added to 100 U.S.gallons (379 liters) of dilution water.

Cleaning Solution	Bulk Ingredients	Quantity	Target [1] pH Adjustment	Target [1] Temp.
1	**Citric acid** (as 100% powder)	17.0 pounds (7.7 kg)	No pH adjustment is Required.	104 F (40 C)
2	**STPP** (sodium tripolyphosphate) (as 100% powder) **Na-EDTA** (Versene 220 or equal) (as 100% powder)	17.0 pounds (7.7 kg) 7.0 pounds (3.18 kg)	Adjust to pH 10.0 with sulfuric or hydrochloric acid.	104 F (40 C)
3	**STPP** (sodium tripolyphosphate) (as 100% powder) **Na-DDBS** Na-dodecylbenzene sulfonate	17 pounds (7.7 kg) 0.21 pounds (0.1 kg)	Adjust down to pH 10.0 with sulfuric or hydrochloric acid.	104 F (40 C)
4	**HCl acid** (hydrochloric acid (as 22^0 Baume or 36% HCL)	0.47 gallons (1.78 liters)	Slowly adjust pH down to 2.5 with HCL acid. Adjust pH up with sodium hydroxide.	95 F (35 C)
5	**Sodium hydrosulfite** (as 100% powder)	8.5 pounds (3.86 kg)	No pH adjustment is required.	95 F (35 C)
6	**NaOH** (sodium hydroxide**)** (as 100% powder) (or as 50% liquid) **SDS** (sodium dodecylsulfate)	0.83 pounds (0.38 kg) 0.13 gallons (0.49 liters) 0.25 pounds (0.11 kg)	Slowly adjust pH up to 11.5 with sodium hydroxide. Adjust pH down to 11.5 by adding HCL acid.	86 F (30 C)
7	**NaOH** (sodium hydroxide) (as 100% powder) (or as 50% liquid)	0.83 pounds (0.38 kg) 0.13 gallons (0.49 liters)	Slowly adjust pH up to 11.5 with sodium hydroxide. Adjust pH down to 11.5 by adding HCL acid.	86 F (30 C)

[1] - Note: These pH and temperature targets are recommendations only. For maximum pH and temperature limits for specific elements. See Table 4.

Table 4: Hydranautics pH and Temperature Limits for Cleaning

(See Table 3 for target pH and temperatures)

Membrane	Continuous Operation		Maximum Cleaning Temp			
	<45 C	≤ 36 C	50 C	≤45 C	≤35 C	≤25 C
NANO-SW, NANO-BW	3 to 8.5	3 to 9	Contact Hydranautics Technical Department	Contact Hyd Tech Dept	1 to 10.5	1 to 11.5
ESNA1-LF, ESNA1-LF2, ESNA1-K1	3 to 9.5	2 to 10	Contact Hydranautics Technical Department	2 to 10.5	1 to 11	1 to 12
ESPA1, ESPA3, ESPA4	3 to 9.5	2 to 10	Contact Hydranautics Technical Department	2 to 10.5	1 to 11	1 to 12
ESPA2	3 to 10	2 to 10.6	Contact Hydranautics Technical Department	2 to 10.5	1 to 11	1 to 12
ESPAB	3 to 10.5	2 to 11	Contact Hydranautics Technical Department	2 to 11	1 to 11.5	1 to 12.5
LFC3, LFC3-LD	3 to 9.5	2 to 10	Contact Hydranautics Technical Department	2 to 10.5	1 to 11	1 to 12
CPA3	3 to 10	2 to 10.8	Contact Hydranautics Technical Department	2 to 11	1 to 11.5	1 to 12.5
CPA5-LD, ESPA2-LD	3 to 10.5	2 to 11	Contact Hydranautics Technical Department	2 to 11.5	1 to 12	1 to 13
SWC4+, SWC5, SWC5-LD, SWC6	3 to 10.5	2 to 11	Contact Hydranautics Technical Department	2 to 11	1 to 12	1 to 13

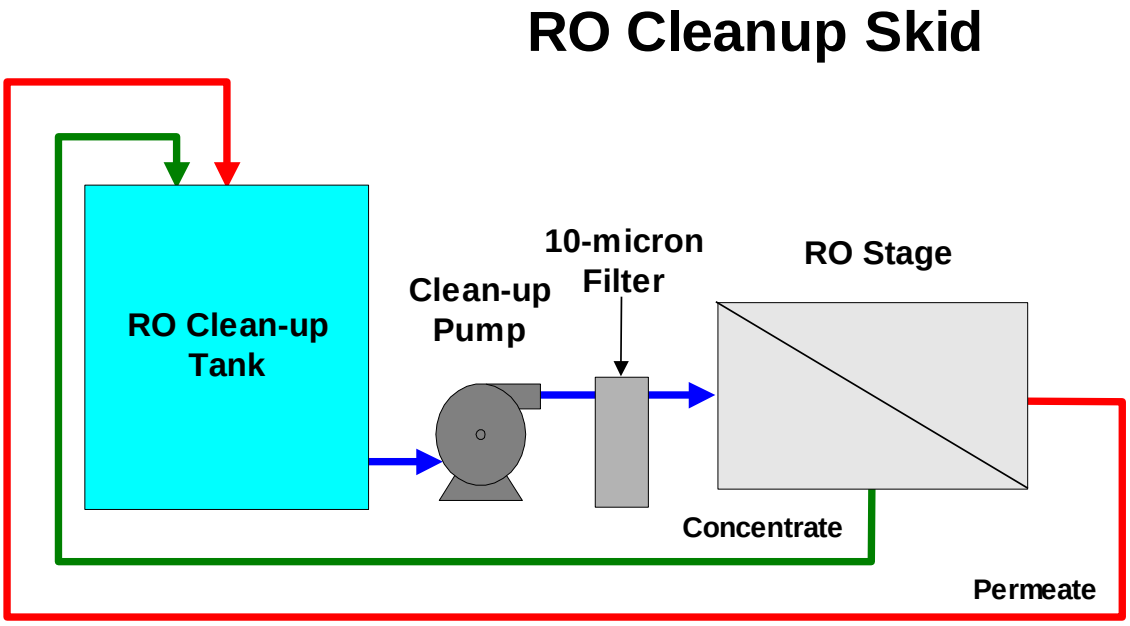
Note: The above cleaning parameters denote the maximum temperature limits for a corresponding range of pH. Cleaning operations performed at the extremes may result in a more effective cleaning, but can shorten the useful life of the membrane due to hydrolysis. To optimize the useful life of a membrane, it is recommended to use the least harsh cleaning solutions and minimize the contact time whenever possible. The pH of the feed stream or cleaning solution should be closely monitored and controlled. The pH meters used to measure and control pH should be regularly calibrated to ensure accuracy. It is typical to re-circulate cleaning chemicals through the RO for 1 hour. At the pH limits shown above, cleaning exposure at temperatures less than 40 C is limited to 60 minutes, at temperatures greater than 40 C exposure is limited to 30 minutes. Extended soaking is possible, but at less aggressive pH levels. See page 14 for more information on cleaning and flushing procedures.

Table 5: Cleaning and Flushing Flow Rates per RO Pressure Tube (Pressures are not to exceed 60 psi (4 bar) at inlet to tubes.)		
Element Diameter	**GPM**	**LPM**
4-inches	6 to 10	23 to 38
6-inches	12 to 20	46 to 76
8-inches	24 to 40	91 to 151
8.5-inches	27 to 45	102 to 170
16-inches	96 to 160	360 to 600

Table 6: Cleaning Solution Volume Requirement per RO Element (these volumes do not include volumes required for piping, filters, etc) (these volumes do not include initial 20% of volume dumped to drain)				
Element Size	**Normal Fouling** (Gallons)	**Heavy Fouling** (Gallons)	**Normal Fouling** (Liters)	**Heavy Fouling** (Liters)
4 x 40 inches	2.5	5	9.5	19
6 x 40 inches	5	10	19	38
8 x 40 inches	9	18	34	68
8.5 x 40 inches	10	20	38	76
16 x 40 inches	36	72	136	272

RO Cleaning Skid

The successful cleaning of an RO on-site requires a well designed RO cleaning skid. Normally this skid is not hard piped to the RO skid and uses temporary hosing for connections. It is recommended to clean a multi-stage RO one stage at a time to optimize cross-flow cleaning velocity. The source water for chemical solution make-up and rinsing should be clean RO permeate or DI water and be free of hardness, transition metals (e.g. iron), and chlorine. Components must be corrosion proof. Major cleaning system components are:



- RO Cleaning Tank: This tank needs to be sized properly to accommodate the displacement of water in the hose, piping, and RO elements. The table below denotes the amount of chemical solution that needs to be made for a single RO element. The tank should be designed to allow 100 % drainage, easy access for chemical introduction and mixing, a recirculation line from the RO Cleaning Pump, proper venting, overflow, and a return line located near the bottom to minimize foam formation when using a surfactant.
- RO Cleaning Pump: This pump needs to be sized to develop the proper cross-flow velocity to scrub the membrane clean. The maximum recommended pressure is 60 psi (4 bar) at the inlet to the pressure vessels to minimize the production of permeate during cleaning and reduce the convective redeposition of foulant back on to the membrane surface. The table below denotes the flow rate ranges for each pressure tube.
- RO Cleaning Cartridge Filter: Normally 5 to 10-micron and is designed to remove foulants that have been displaced from the cleaning process.
- RO Tank Heater or Cooler: The maximum design temperature for cleaning is 113^0 F (45^0 C). It should be noted that heat is generated and imparted by the RO Cleaning Pump during recirculation.
- RO Tank Mixer: This is recommended to get optimal mixing of chemical, though some designers rely solely on the slow introduction of chemical while maintaining a recirculation through the RO Cleaning Pump back to the tank.
- Instrumentation: Cleaning system instrumentation should be included to monitor flow, temperature, pressure, and tank level.
- Sample Points: Sample valves should be located to allow pH and TDS measurements off the RO Cleaning Pump discharge and the concentrate side recirculation return line.

- Permeate Return Line: A small amount of the cleaning solution can permeate through the membranes and so a permeate-side return line back to the RO Cleaning Tank is required.

  Important: The permeate line and any permeate valves must always be open to atmospheric pressure during the cleaning and flushing steps or damage to RO elements can occur. If the permeate line is closed, the permeate pressure can build up and become higher than the feed-side pressure of the tail elements. This can result in excessive permeate back-pressure which can damage the membrane glue lines in the tail elements.

RO Membrane Element Cleaning and Flushing Procedures

The RO membrane elements can be cleaned in place in the pressure tubes by recirculating the cleaning solution across the high-pressure side of the membrane at low pressure and relatively high flow. A cleaning unit is needed to do this. RO cleaning procedures may vary dependent on the situation. The time required to clean a stage can take from 4 to 8 hours.

A general procedure for cleaning the RO membrane elements is as follows:

1. Perform a low pressure flush at 60 psi (4 bar) or less of the pressure tubes by pumping clean water from the cleaning tank (or equivalent source) through the pressure tubes to drain for several minutes. Flush water should be clean water of RO permeate or DI quality and be free of hardness, transition metals, and chlorine.

2. Mix a fresh batch of the selected cleaning solution in the cleaning tank. The dilution water should be clean water of RO permeate or DI quality and be free of hardness, transition metals, and chlorine. The temperature and pH should be adjusted to their target levels.

3. Circulate the cleaning solution through the pressure tubes for approximately one hour or the desired period of time. At the start, send the displaced water to drain so you don't dilute the cleaning chemical and then divert up to 20% of the most highly fouled cleaning solution to drain before returning the cleaning solution back to the RO Cleaning Tank. For the first 5 minutes, slowly throttle the flow rate to 1/3 of the maximum design flow rate. This is to minimize the potential plugging of the feed path with a large amount of dislodged foulant.. For the second 5 minutes, increase the flow rate to 2/3 of the maximum design flow rate, and then increase the flow rate to the maximum design flow rate. If required, readjust the pH back to the target when it changes more than 0.5 pH units.

4. An optional soak and recirculation sequence can be used, if required. The soak time can be from 1 to 8 hours depending on the manufacturer's recommendations. Caution should be used to maintain the proper temperature and pH. *Do not exceed maximum pH and temperature limits for specific elements. See Table 4.* Also note that this does increase the chemical exposure time of the membrane.

5. Upon completion of the chemical cleaning steps, a low pressure Cleaning Rinse with clean water (RO permeate or DI quality and free of hardness, transition metals, and chlorine) is required to remove all traces of chemical from the Cleaning Skid and the RO Skid. Drain and flush the cleaning tank; then completely refill the Cleaning Tank with clean water for the Cleaning Rinse. Rinse the pressure tubes by pumping all of the rinse water from the Cleaning Tank through the pressure tubes to drain. A second cleaning can be started at this point, if required.

5. Once the RO system is fully rinsed of cleaning chemical with clean water from the Cleaning Tank, a Final Low Pressure Clean-up Flush can be performed using pretreated feed water. The permeate line should remain open to drain. Feed pressure should be less than 60 psi (4 bar). This final flush continues until the flush water flows clean and is free of any foam or residues of cleaning agents. This usually takes 15 to 60 minutes. The operator can sample the flush water going to the drain for detergent removal and lack of foaming by using a clear flask and shaking it. A conductivity meter can be used to test for removal of cleaning chemicals, such that the flush water to drain is within 10-20% of the feed water conductivity. A pH meter can also be used to compare the flush water to drain to the feed pH.

7. Once all the stages of a train are cleaned, and the chemicals flushed out, the RO can be restarted and placed into a Service Rinse. The RO permeate should be diverted to drain until it meets the quality requirements of the process (e.g. conductivity, pH, etc.). It is not unusual for it to take from a few hours to a few days for the RO permeate quality to stabilize, especially after high pH cleanings.

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APPENDIX F – EXAMPLE DATA COLLECTION SHEETS

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City of San Diego IPR/RA Demostration Project

MF/UF SYSTEM

DRAFT OPERATIONAL DATA COLLECTION SHEET

Run Number: _____

Date (mm/dd/yy)	Time (hh:mm)	Operator	PLC Temp-erature (degC)	Filtrate Flow		Pressure					Time since Backwash (min)	Backwash Flow (gpm)	Turbidity (NTU)		Notes
				PLC Screen (gpm)	Rota-meter (gpm)	PLC Feed (psi)		PLC Filtrate (psi)		TMP (psi)			Online Feed (NTU)	Online Filtrate (NTU)	
						Left	Right	Left	Right						

Note: Minimum of two readings per day

Comments: _____

City of San Diego IPR/RA Demostration Project

MF/UF SYSTEM

DRAFT EVALUATION OF CLEANING EFFICIENCY

Run Number: _____

Date (mm/dd/yy)	Time (hh:mm)	Operator	Feed Temp-erature (degC)	Filtrate Flow (gpm)		Feed Pressure (psi)	Filtrate Pressure (psi)	TMP (psi)	
BEFORE CLEANING									

Chemical 1: _____ pH _____ Turbidity _____ TDS _____

Visual Color: _____ Flow (gpm): _____ Residual (before): _____ Residual (after): _____

Pressure (psi): _____ Temperature (before): _____ Temperature (after): _____

Describe Chemical Cleaning Procedure (including flows and pressures during cleaning if possible): _____

AFTER CHEMICAL 1									

Chemical 2: _____ pH _____ Turbidity _____ TDS _____

Visual Color: _____ Flow (gpm): _____ Residual (before): _____ Residual (after): _____

Pressure (psi): _____ Temperature (before): _____ Temperature (after): _____

Describe Chemical Cleaning Procedure (including flows and pressures during cleaning if possible): _____

AFTER CHEMICAL 2									

Chemical 3: _____ pH _____ Turbidity _____ TDS _____

Visual Color: _____ Flow (gpm): _____ Residual (before): _____ Residual (after): _____

Pressure (psi): _____ Temperature (before): _____ Temperature (after): _____

Describe Chemical Cleaning Procedure (including flows and pressures during cleaning if possible): _____

AFTER CHEMICAL 3									

Comments: _____

City of San Diego IPR/RA Demonstration Project
On-Site Lab
DRAFT pH Data Log Sheet

Date	Time	Sampler	NC Tert Feed	RO Feed	Combined Permeate

City of San Diego IPR/RA Demonstration Project
On-Site Lab
DRAFT Conductivity/Temperature Data Log Sheet

Date	Time	Sampler	NC Tert Feed		RO Feed		Combined Permeate	
			Temperature (C)	Conductivity (S)	Temperature (C)	Conductivity (S)	Temperature (C)	Conductivity (S)

City of San Diego IPR/RA Demonstration Project
On-Site Lab
DRAFT UV Data Log Sheet

Date	Time	Sampler	NC Tert Feed (S1)	RO Feed (S2)	Combined Permeate

City of San Diego IPR/RA Demonstration Project

DRAFT Long Term RO Performance Testing

DRAFT Operational Data Collection Sheet

Date	***Time***	***Run***	***Operator***	***Feed***	***Feed***	***Feed***	***Pressure***						***Flow***				***Conductivity***				
(mm:dd:yy)	(hh:mm)	***Hours***	***Initials***	***Chlorine*** Free/Total	***pH***	***Temp.*** (deg F)	Feed (psi)	Stage 1 Interstage (psi)	Stage 2 Interstage (psi)	Conc. (psi)	Stage 1 Permeate (psi)	Stage 2 Permeate (psi)	Stage 1 Permeate (gpm)	Stage 2 Permeate (gpm)	[1]Conc. (gpm)	Recycle (gpm)	Feed (µmhos)	Feed (on line) (µmhos)	Combined Permeate (on line) (µmhos)	Stage 1 Permeate (µmhos)	Stage 2 Permeate (µmhos)

Comments: [1] Measured before recycle, actual concentrate flow leaving the system = "Conc." - "Recycle".

City of San Diego IPR/RA Demonstration Project

RO system

Shutdown Log

Operator Initials	***Begin***		***End***		***Shutdown Reason***
	Date (mm:dd:yy)	***Time*** (hh:mm)	***Date*** (mm:dd:yy)	***Time*** (hh:mm)	

Comments:

City of San Diego IPR/RA Demonstration Project

DRAFT UV Performance Testing

DRAFT UV Operational Data Collection Sheet

Date (mm:dd:yy)	Time (hh:mm)	Run Hours	Operator Initials	Flow		H_2O_2 dose (mg/l)	Power Setting (%)	UV Adsorbance cm^{-1}	UVT (%)	Intensity (mW/cm^2)	EEO
				PLC readout (gpm)	Flow meter (gpm)						

Comments: [1] Measured before recycle, actual concentrate flow leaving the system = "Conc." - "Recycle".

APPENDIX G – WATER QUALITY REGULATORY REQUIREMENTS AND GUIDANCE

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Table G-1

Primary Drinking Water Standards for Measured Organic Parameters

Parameter	Units	Primary Drinking Water Standard, MCL	
		Federal	CA
Volatile Organic Compounds			
Benzene	mg/L	0.005	0.001
Carbon tetrachloride	mg/L	0.005	0.0005
1,2 Dichlorobenzene	mg/L	0.6	0.6
1,4 Dichlorobenzene	mg/L	0.075	0.005
1,1 Dichloroethane	mg/L	0	0.005
1,2 Dichloroethane	mg/L	0.005	0.0005
1,1 Dichloroethylene	mg/L	0.007	0.006
cis-1,2 Dichloroethylene	mg/L	0.07	0.006
trans-1,2 Dichloroethylene	mg/L	0.1	0.01
Dichloromethane	mg/L	0.005	0.005
1,3 Dichloropropene	mg/L	NR	0.0005
1,2 Dichloropropane	mg/L	0.005	0.005
Ethylbenzene	mg/L	0.7	0.3
Methyl-tert-butyl ether (MTBE)	mg/L	0	0.013
Monochlorobenzene	mg/L	0.1	0.07
Styrene	mg/L	0.1	0.1
1,1,2,2 Tetrachloroethane	mg/L	0	0.001
Tetrachloroethylene	mg/L	0.005	0.005
Toluene	mg/L	1	0.15
1,2,4 Trichlorobenzene	mg/L	0.07	0.07
1,1,1-Trichloroethane	mg/L	0.2	0.2
1,1,2-Trichloroethane	mg/L	0.005	0.005
Trichloroethylene	mg/L	0.005	0.005
Trichlorofluoromethane	mg/L	0	0.15
1,12Trichloro1,2,2Trifluoroethane	mg/L	0	1.2
Vinyl chloride	mg/L	0.002	0.0005
Xylenes	mg/L	10	1.75
SOCs			
Alachlor	mg/L	0.002	0.002
Atrazine	mg/L	0.003	0.001
Bentazon	mg/L	0	0.018
Benzo(a)pyrene	mg/L	0.0002	0.0002
Carbofuran	mg/L	0.04	0.018
Chlordane	mg/L	0.002	0.0001
Dalapon	mg/L	0.2	0.2
Dibromochloropropane	mg/L	0.0002	0.0002
Di(2ethylhexyl)adipate	mg/L	0.4	0.4
Di(2ethylhexyl)phthalate	mg/L	0.006	0.004
2,4-D	mg/L	0.07	0.07
Dinoseb	mg/L	0.007	0.007
Diquat	mg/L	0.02	0.02
Endothall	mg/L	0.1	0.1
Endrin	mg/L	0.002	0.002
Ethylene dibromide	mg/L	0.00005	0.00005
Glyphosate	mg/L	0.7	0.7
Heptachlor	mg/L	0.0004	0.00001
Heptachlor epoxide	mg/L	0.0002	0.00001
Hexachlorobenzene	mg/L	0.001	0.001
Hexachlorocyclopentadiene	mg/L	0.05	0.05
Lindane	mg/L	0.0002	0.0002
Methoxychlor	mg/L	0.04	0.03
Molinate	mg/L	0	0.02
Oxamyl (Vydate)	mg/L	0.2	0.05
Pentachlorophenol	mg/L	0.001	0.001
Picloram	mg/L	0.5	0.5
Polychlorinated Biphenyls	mg/L	0.0005	0.0005
Simazine	mg/L	0.004	0.004
Thiobencarb	mg/L	0	0.07
Toxaphene	mg/L	0.003	0.003
2,3,7,8_TCDD (Dioxin)	mg/L	3.00E-08	3exp-8
2,4,5-TP (Silvex)	mg/L	0.05	0.05
DBPs			
Total Trihalomethanes	mg/L	0.08	0.1
Total haloacetic acids	mg/L	0.06	0.06
Bromate	mg/L	0.01	0.01
Chlorite	mg/L	1	1

Notes:

-Subsequent to the establishment of the above table maximum residual disinfectant levels (MRDLs) for chloramines, chlorine, and chlorine dioxide have been established at 4.0, 4.0, and 0.8 mg/L, respectively.

Table G-2

Primary Drinking Water Standards for Measured Inorganic Parameters

Parameter	Units	Primary Drinking Water Standard, MCL	
		Federal	CA
Inorganics			
Antimony	mg/L	0.006	0.006
Arsenic	mg/L	0.01	0.01
Asbestos	MFL/L	7	7
Barium	mg/L	2	1
Beryllium	mg/L	0.004	0.004
Cadmium	mg/L	0.005	0.005
Chromium	mg/L	0.1	0.05
Copper	mg/L	1.3	1.3
Cyanide	mg/L	0.2	0.2
Fluoride	mg/L	4	2
Lead	mg/L	0.015	0.015
Mercury	mg/L	0.002	0.002
Nickel	mg/L	0	0.1
Nitrate	mg/L	10 (as N)	45 (as NO_3)
Nitrite as N	mg/L	1	1
Selenium	mg/L	0.05	0.05
Thallium	mg/L	0.002	0.002
Microbial			
Total Coliforms	P/A	Absent	Absent
Radionuclides			
Uranium	ug/L	30	0
Uranium	pCi/L	0	20
Radium 226+228	pCi/L	5	5
Gross Alpha Part.	pCi/L	15	15
Gross Beta Part.	mrem/yr	4	0
Gross Beta Part.	pCi/L	0	50
Strontium 90	pCi/L	8	8
Tritium	pCi/L	20000	20000

Notes:

-As of 6/11/2006 the California gross beta MCL is 4 millirem/year annual dose equivalent to the total body or any internal organ.

-Strontium-90 and tritium are now covered under the gross beta MCL; Stronium-90 MCL = 4 millirem/year to bone marrow; tritium MCL = 4 millirem/year to total body.

-As of 10/18/2007, California has established a MCL for perchlorate at 0.006 mg/L.

-The State and Federal established MCL for nitrate-N + nitrite-N is 10 mg/L.

Table G-3

Secondary Drinking Water Standards for Measured Parameters

Parameter	Units	Secondary, MCL	
		Federal	CA
Aluminum	mg/L	0.2	0.2
Color	Units	15	15
Copper	mg/L	1	1
Corrosivity		Non Corr.	Non Corr.
Foaming Agents (MBAS)	mg/L	0.5	0.5
Iron	mg/L	0.3	0.3
Manganese	mg/L	0.05	0.05
MTBE	mg/L	NR	0.005
Odor Threshold	TON	3	3
Silver	mg/L	0.1	0.1
Thiobencarb	mg/L	NR	0.001
Turbidity	NTU	5	5
Zinc	mg/L	5	5
pH		6.5-8.5	NR
Specific Conductance	micromhos	NR	900
Sulfate	mg/L	250	250
Fluoride	mg/L	2	NR
Chloride	mg/L	250	250
TDS	mg/L	500	500

Table G-4
CDPH Drinking Water Notification Levels

Chemical	Notification Level(mg/L)
Boron	1
n-Butylbenzene	0.26
sec-Butylbenzene	0.26
tert-Butylbenzene	0.26
Carbon Disulfide	0.16
Chlorate	0.8
2-Chlorotoluene	0.14
4-Chlorotoluene	0.14
Dichlorodifluoromethane (Freon 12)	1
1,4-Dioxane	0.003
Ethylene Glycol	14
Formaldehyde	0.1
HMX	0.35
Isopropylbenzene	0.77
Manganese	0.5
Methyl isobutyl ketone (MIBK)	0.12
Naphthalene	0.017
N-Nitrosodiethylamine (NDEA)	0.00001
N-Nitrosodimethylamine (NDMA)	0.00001
N-Nitrosodi-n-propylamine (NDPA)	0.00001
Propachlor	0.09
n-Propylbenzene	0.26
RDX	0.0003
Tertiary butyl alcohol (TBA)	0.012
1,2,3-Trichloropropane (1,2,3-TCP)	0.000005
1,2,4-Trimethylbenzene	0.33
1,3,5-Trimethylbenzene	0.33
2, 4, 6-Trinitrotoluene (TNT)	0.001
Vanadium	0.05

Information obtained from http://www.cdph.ca.gov/certlic/drinkingwater/Pages/NotificationLevels.aspx
Last Updated Dec 14, 2007, for complete list of current notifications levels visit the CDPH website listed above.

UCMR3 ANALYTES

Entry Point	CAS Registry	MRL
17-b-estradiol	50–28–2	0.0004 µg/L
17-a-ethynylestradiol	57–63–6	0.0009 µg/L
estriol	50–27–1	0.0008 µg/L
equilin	474–86–2	0.004 µg/L
estrone	53–16–7	0.002 µg/L
testosterone	58–22–0	0.0001 µg/L
4-androstene-3,17-dione	63–05–8	0.0003 µg/L
1,2,3-trichloropropane	96–18–4	0.03 µg/L
1,3-butadiene	106–99–0	0.1 µg/L
chloromethane	74–87–3	0.2 µg/L
1,1-dichloroethane	75–34–3	0.03 µg/L
n-propylbenzene	103–65–1	0.03 µg/L
bromomethane	74–83–9	0.2 µg/L
sec-butylbenzene	135–98–8	0.04 µg/L
chlorodifluoromethane (HCFC–22)	75–45–6	0.08 µg/L
bromochloromethane (halon 1011)	74–97–5	0.06 µg/L
1,4-Dioxane	123–91–1	0.07 µg/L
Perfluorooctane sulfonic acid (PFOS)	1763–23–1	0.04 µg/L
Perfluorooctanoic acid (PFOA)	335–67–1	0.02 µg/L
Perfluorononanoic acid (PFNA)	375–95–1	0.02 µg/L
Perfluorohexane sulfonic acid (PFHxS)	355–46–4	0.03 µg/L
Perfluoroheptanoic acid (PFHpA)	375–85–9	0.01 µg/L
Perfluorobutanesulfonic acid (PFBS)	375–73–5	0.09 µg/L

Entry Point and Distribution System Maximum Residence Time		
Vanadium	7440–62–2	0.2 µg/L
Molybdenum	7439–98–7	1.0 µg/L
Cobalt	7440–48–4	1.0 µg/L
Strontium	7440–24–6	0.3 µg/L
Chlorate	14866–68–3	20 µg/L

Analyte	MWH Method	MWH Analytical Mode	MRL ng/L
1,7-Dimethylxanthine	LC-MS-MS	Positive	5
2,4-D	LC-MS-MS	Negative	5
4-nonylphenol - semi quantitative	LC-MS-MS	Negative	100
4-tert-octylphenol	LC-MS-MS	Negative	50
Acesulfame-K	LC-MS-MS	Negative	20
Acetaminophen	LC-MS-MS	Positive	5
Albuterol	LC-MS-MS	Positive	5
Amoxicillin (semi-quantitative)	LC-MS-MS	Positive	20
Andorostenedione	LC-MS-MS	Positive	5
Atenolol	LC-MS-MS	Positive	5
Atrazine	LC-MS-MS	Positive	5
Bendroflumethiazide	LC-MS-MS	Negative	5
Bezafibrate	LC-MS-MS	Positive	5
BPA	LC-MS-MS	Negative	10
Bromacil	LC-MS-MS	Positive	5
Butalbital	LC-MS-MS	Negative	5
Butylparben	LC-MS-MS	Negative	5
Caffeine	LC-MS-MS	Positive	5
Carbadox	LC-MS-MS	Positive	5
Carbamazepine	LC-MS-MS	Positive	5
Carisoprodol	LC-MS-MS	Positive	5
Chloramphenicol	LC-MS-MS	Negative	10
Chloridazon	LC-MS-MS	Positive	5
Chlorotoluron	LC-MS-MS	Positive	5
Cimetidine	LC-MS-MS	Positive	5
Clofibric Acid	LC-MS-MS	Negative	5
Cotinine	LC-MS-MS	Positive	10
Cyanazine	LC-MS-MS	Positive	5
DACT	LC-MS-MS	Positive	5
DEA	LC-MS-MS	Positive	5
DEET	LC-MS-MS	Positive	2
Dehydronifedipine	LC-MS-MS	Positive	5
DIA	LC-MS-MS	Positive	5
Diazepam	LC-MS-MS	Positive	5
Diclofenac	LC-MS-MS	Negative	5
Dilantin	LC-MS-MS	Positive	20
Diuron	LC-MS-MS	Positive	5
Erythromycin	LC-MS-MS	Positive	10
Estradiol	LC-MS-MS	Negative	5
Estrone	LC-MS-MS	Negative	5
Ethinyl Estradiol - 17 alpha	LC-MS-MS	Negative	5
Ethylparaben	LC-MS-MS	Negative	20
Flumeqine	LC-MS-MS	Positive	10
Fluoxetine	LC-MS-MS	Positive	10
Gemfibrozil	LC-MS-MS	Negative	5

Analyte	MWH Method	MWH Analytical Mode	MRL ng/L
Ibuprofen	LC-MS-MS	Negative	10
Iohexal	LC-MS-MS	Negative	10
Iopromide	LC-MS-MS	Negative	5
Isobutylparaben	LC-MS-MS	Negative	5
Isoproturon	LC-MS-MS	Positive	100
Ketoprofen	LC-MS-MS	Positive	5
Ketorolac	LC-MS-MS	Positive	5
Lidocaine	LC-MS-MS	Positive	5
Lincomycin	LC-MS-MS	Positive	10
Linuron	LC-MS-MS	Positive	5
Lopressor	LC-MS-MS	Positive	20
Meclofenamic Acid	LC-MS-MS	Positive	5
Meprobamate	LC-MS-MS	Positive	5
Metazachlor	LC-MS-MS	Positive	5
Methylparaben	LC-MS-MS	Negative	20
Naproxen	LC-MS-MS	Negative	10
Nifedipine	LC-MS-MS	Positive	20
Norethisterone	LC-MS-MS	Positive	5
Oxolinic acid	LC-MS-MS	Positive	5
Pentoxifylline	LC-MS-MS	Positive	5
Phenazone	LC-MS-MS	Positive	5
Primidone	LC-MS-MS	Positive	5
Progesterone	LC-MS-MS	Positive	5
Propazine	LC-MS-MS	Positive	5
Propylparaben	LC-MS-MS	Negative	5
Quinoline	LC-MS-MS	Positive	5
Simazine	LC-MS-MS	Positive	5
Sucralose	LC-MS-MS	Negative	100
Sulfachloropyridazine	LC-MS-MS	Positive	5
Sulfadiazine	LC-MS-MS	Positive	5
Sulfadimethoxine	LC-MS-MS	Positive	5
Sulfamerazine	LC-MS-MS	Positive	5
Sulfamethazine	LC-MS-MS	Positive	5
Sulfamethizole	LC-MS-MS	Positive	5
Sulfamethoxazole	LC-MS-MS	Positive	5
Sulfathiazole	LC-MS-MS	Positive	5
TCEP	LC-MS-MS	Positive	5
TCPP	LC-MS-MS	Positive	5
TDCPP	LC-MS-MS	Positive	5
Testosterone	LC-MS-MS	Positive	10
Theobromine	LC-MS-MS	Positive	5
Theophylline	LC-MS-MS	Positive	10
Triclosan	LC-MS-MS	Negative	10
Trimethoprim	LC-MS-MS	Positive	5
Warfarin	LC-MS-MS	Negative	5

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TABLE G-5

PRIORITY POLLUTANT NUMERIC CRITERIA AND GUIDANCE

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A		B Freshwater		C Saltwater		D Human Health (10^{-6} risk for carcinogens) For consumption of:	
# Compound	CAS Number	Criterion Maximum Conc. [d] B1	Criterion Continuous Conc. [d] B2	Criterion Maximum Conc. [d] C1	Criterion Continuous Conc. [d] C2	Water & Organisms (μg/L) D1	Organisms Only (μg/L) D2
1. Antimony	7440360					14 a,s	4300 a,t
2. Arsenic [b]	7440382	340 i,m,w	150 i,m,w	69 i,m	36 i,m		
3. Beryllium	7440417					n	n
4. Cadmium [b]	7440439	4.3 e,i,m,w,x	2.2 e,i,m,w	42 i,m	9.3 i,m	n	n
5a. Chromium (III)	16065831	550 e,i,m,o	180 e,i,m,o			n	n
5b. Chromium (VI) [b]	18540299	16 i,m,w	11 i,m,w	1100 i,m	50 i,m	n	n
6. Copper [b]	7440508	13 e,i,m,w,x	9.0 e,i,m,w	4.8 i,m	3.1 i,m	1300	
7. Lead [b]	7439921	65 e,i,m	2.5 e,i,m	210 i,m	8.1 i,m	n	n
8. Mercury [b]	7439976	[Reserved]	[Reserved]	[Reserved]	[Reserved]	0.050 a	0.051 a
9. Nickel [b]	7440020	470 e,i,m,w	52 e,i,m,w	74 i,m	8.2 i,m	610 a	4600 a
10. Selenium [b]	7782492	[Reserved] p	5.0 q	290 i,m	71 i,m	n	n
11. Silver [b]	7440224	3.4 e,i,m		1.9 i,m			
12. Thallium	7440280					1.7 a,s	6.3 a,t
13. Zinc [b]	7440666	120 e,i,m,w,x	120 e,i,m,w	90 i,m	81 i,m		
14. Cyanide [b]	57125	22 o	5.2 o	1 r	1 r	700 a	220,000 a,j
15. Asbestos	1332214					7,000,000 fibers/L k,s	
16. 2,3,7,8-TCDD (Dioxin)	1746016					0.000000013 c	0.000000014 c
17. Acrolein	107028					320 s	780 t
18. Acrylonitrile	107131					0.059 a,c,s	0.66 a,c,t
19. Benzene	71432					1.2 a,c	71 a,c
20. Bromoform	75252					4.3 a,c	360 a,c
21. Carbon Tetrachloride	56235					0.25 a,c,s	4.4 a,c,t
22. Chlorobenzene	108907					680 a,s	21,000 a,j,t
23. Chlorodibromomethane	124481					0.401 a,c	34 a,c
24. Chloroethane	75003						
25. 2-Chloroethylvinyl Ether	110758						

26. Chloroform	67663					[Reserved]	[Reserved]
27. Dichlorobromomethane	75274					0.56 a,c	46 a,c
28. 1,1-Dichloroethane	75343						
29. 1,2-Dichloroethane	107062					0.38 a,c,s	99 a,c,t
30. 1,1-Dichloroethylene	75354					0.057 a,c,s	3.2 a,c,t
31. 1,2-Dichloropropane	78875					0.52 a	39 a
32. 1,3-Dichloropropylene	542756					10 a,s	1,700 a,t
33. Ethylbenzene	100414					3,100 a,s	29,000 a,t
34. Methyl Bromide	74839					48 a	4,000 a
35. Methyl Chloride	74873					n	n
36. Methylene Chloride	75092					4.7 a,c	1,600 a,c
37. 1,1,2,2-Tetrachloroethane	79345					0.17 a,c,s	11 a,c,t
38. Tetrachloroethylene	127184					0.8 c,s	8.85 c,t
39. Toluene	108883					6,800 a	200,000 a
40. 1,2-Trans-Dichloroethylene	156605					700 a	140,000 a
41. 1,1,1-Trichloroethane	71556					n	n
42. 1,1,2-Trichloroethane	79005					0.60 a,c,s	42 a,c,t
43. Trichloroethylene	79016					2.7 c,s	81 c,t
44. Vinyl Chloride	75014					2 c,s	525 c,t
45. 2-Chlorophenol	95578					120 a	400 a
46. 2,4-Dichlorophenol	120832					93 a,s	790 a,t
47. 2,4-Dimethylphenol	105679					540 a	2,300 a
48. 2-Methyl-4,6-Dinitrophenol	534521					13.4 s	765 t
49. 2,4-Dinitrophenol	51285					70 a,s	14,000 a,t
50. 2-Nitrophenol	88755						
51. 4-Nitrophenol	100027						
52. 3-Methyl-4-Chlorophenol	59507						
53. Pentachlorophenol	87865	19 f,w	15 f,w	13	7.9	0.28 a,c	8.2 a,c,j
54. Phenol	108952					21,000 a	4,600,000 a,j,t
55. 2,4,6-Trichlorophenol	88062					2.1 a,c	6.5 a,c
56. Acenaphthene	83329					1,200 a	2,700 a
57. Acenaphthylene	208968						
58. Anthracene	120127					9,600 a	110,000 a

59. Benzidine	92875					0.00012 a,c,s	0.00054 a,c,t
60. Benzo(a)Anthracene	56553					0.0044 a,c	0.049 a,c
61. Benzo(a)Pyrene	50328					0.0044 a,c	0.049 a,c
62. Benzo(b)Fluoranthene	205992					0.0044 a,c	0.049 a,c
63. Benzo(ghi)Perylene	191242						
64. Benzo(k)Fluoranthene	207089					0.0044 a,c	0.049 a,c
65. Bis(2-Chloroethoxy)Methane	111911						
66. Bis(2-Chloroethyl)Ether	111444					0.031 a,c,s	1.4 a,c,t
67. Bis(2-Chloroisopropyl)Ether	39638329					1,400 a	170,000 a,t
68. Bis(2-Ethylhexyl)Phthalate	117817					1.8 a,c,s	5.9 a,c,t
69. 4-Bromophenyl Phenyl Ether	101553						
70. Butylbenzyl Phthalate	85687					3,000 a	5,200 a
71. 2-Chloronaphthalene	91587					1,700 a	4,300 a
72. 4-Chlorophenyl Phenyl Ether	7005723						
73. Chrysene	218019					0.0044 a,c	0.049 a,c
74. Dibenzo(a,h)Anthracene	53703					0.0044 a,c	0.049 a,c
75. 1,2 Dichlorobenzene	95501					2,700 a	17,000 a
76. 1,3 Dichlorobenzene	541731					400	2,600
77. 1,4 Dichlorobenzene	106467					400	2,600
78. 3,3'-Dichlorobenzidine	91941					0.04 a,c,s	0.077 a,c,t
79. Diethyl Phthalate	84662					23,000 a,s	120,000 a,t
80. Dimethyl Phthalate	131113					313,000 s	2,900,000 t
81. Di-n-Butyl Phthalate	84742					2,700 a,s	12,000 a,t
82. 2,4-Dinitrotoluene	121142					0.11 c,s	9.1 c,t
83. 2,6-Dinitrotoluene	606202						
84 Di-n-Octyl Phthalate	117840						
85. 1,2-Diphenylhydrazine	122667					0.040 a,c,s	0.54 a,c,t
86. Fluoranthene	206440					300 a	370 a
87. Fluorene	86737					1,300 a	14,000 a
88. Hexachlorobenzene	118741					0.00075 a,c	0.00077 a,c
89. Hexachlorobutadiene	87683					0.44 a,c,s	50 a,c,t
90. Hexachlorocyclopentadiene	77474					240 a,s	17,000 a,j,t
91. Hexachloroethane	67721					1.9 a,c,s	8.9 a,c,t

92. Indeno(1,2,3-cd) Pyrene	193395					0.0044 a,c	0.049 a,c
93. Isophorone	78591					8.4 c,s	600 c,t
94. Naphthalene	91203						
95. Nitrobenzene	98953					17 a,s	1,900 a,j,t
96. N-Nitrosodimethylamine	62759					0.00069 a,c,s	8.1 a,c,t
97. N-Nitrosodi-n-Propylamine	621647					0.005 a	1.4 a
98. N-Nitrosodiphenylamine	86306					5.0 a,c,s	16 a,c,t
99. Phenanthrene	85018						
100. Pyrene	129000					960 a	11,000 a
101. 1,2,4-Trichlorobenzene	120821						
102. Aldrin	309002	3 g		1.3 g		0.00013 a,c	0.00014 a,c
103. alpha-BHC	319846					0.0039 a,c	0.013 a,c
104. beta-BHC	319857					0.014 a,c	0.046 a,c
105. gamma-BHC	58899	0.95 w		0.16 g		0.019 c	0.063 c
106. delta-BHC	319868						
107. Chlordane	57749	2.4 g	0.0043 g	0.09 g	0.004 g	0.00057 a,c	0.00059 a,c
108. 4,4'-DDT	50293	1.1 g	0.001 g	0.13 g	0.001 g	0.00059 a,c	0.00059 a,c
109. 4,4'-DDE	72559					0.00059 a,c	0.00059 a,c
110. 4,4'-DDD	72548					0.00083 a,c	0.00084 a,c
111. Dieldrin	60571	0.24 w	0.056 w	0.71 g	0.0019 g	0.00014 a,c	0.00014 a,c
112. alpha-Endosulfan	959988	0.22 g	0.056 g	0.034 g	0.0087 g	110 a	240 a
113. beta-Endosulfan	33213659	0.22 g	0.056 g	0.034 g	0.0087 g	110 a	240 a
114. Endosulfan Sulfate	1031078					110 a	240 a
115. Endrin	72208	0.086 w	0.036 w	0.037 g	0.0023 g	0.76 a	0.81 a,j
116. Endrin Aldehyde	7421934					0.76 a	0.81 a,j
117. Heptachlor	76448	0.52 g	0.0038 g	0.053 g	0.0036 g	0.00021 a,c	0.00021 a,c
118. Heptachlor Epoxide	1024573	0.52 g	0.0038 g	0.053 g	0.0036 g	0.00010 a,c	0.00011 a,c
119-125. Polychlorinated biphenyls (PCBs)			0.014 u		0.03 u	0.00017 c,v	0.00017 c,v
126. Toxaphene	8001352	0.73	0.0002	0.21	0.0002	0.00073 a,c	0.00075 a,c
Total Number of Criteria [h]		22	21	22	20	92	90

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Footnotes to Table in Parargraph (b)(1):

a. Criteria revised to reflect the Agency q1* or RfD, as contained in the Integrated Risk Information System (IRIS) as of October 1, 1996. The fish tissue bioconcentration factor (BCF) from the 1980 documents was retained in each case.

b. Criteria apply to California waters except for those waters subject to objectives in Tables III–2A and III–2B of the San Francisco Regional Water Quality Control Board's (SFRWQCB) 1986 Basin Plan, that were adopted by the SFRWQCB and the State Water Resources Control Board, approved by EPA, and which continue to apply.

c. Criteria are based on carcinogenicity of 10 (-6) risk.

d. Criteria Maximum Concentration (CMC) equals the highest concentration of a pollutant to which aquatic life can be exposed for a short period of time without deleterious effects. Criteria Continuous Concentration (CCC) equals the highest concentration of a pollutant to which aquatic life can be exposed for an extended period of time (4 days) without deleterious effects. ug/L equals micrograms per liter.

e. Freshwater aquatic life criteria for metals are expressed as a function of total hardness (mg/L) in the water body. The equations are provided in matrix at paragraph (b)(2) of this section. Values displayed above in the matrix correspond to a total hardness of 100 mg/l.

f. Freshwater aquatic life criteria for pentachlorophenol are expressed as a function of pH, and are calculated as follows: Values displayed above in the matrix correspond to a pH of 7.8. CMC = exp(1.005(pH) − 4.869). CCC = exp(1.005(pH) − 5.134).

g. This criterion is based on 304(a) aquatic life criterion issued in 1980, and was issued in one of the following documents: Aldrin/Dieldrin (EPA 440/5–80–019), Chlordane (EPA 440/5–80–027), DDT (EPA 440/5–80–038), Endosulfan (EPA 440/5–80–046), Endrin (EPA 440/5–80–047), Heptachlor (440/5–80–052), Hexachlorocyclohexane (EPA 440/5–80–054), Silver (EPA 440/5–80–071). The Minimum Data Requirements and derivation procedures were different in the 1980 Guidelines than in the 1985 Guidelines. For example, a ''CMC'' derived using the 1980 Guidelines was derived to be used as an instantaneous maximum. If assessment is to be done using an averaging period, the values given should be divided by 2 to obtain a value that is more comparable to a CMC derived using the 1985 Guidelines.

h. These totals simply sum the criteria in each column. For aquatic life, there are 23 priority toxic pollutants with some type of freshwater or saltwater, acute or chronic criteria. For human health, there are 92 priority toxic pollutants with either ''water + organism'' or ''organism only'' criteria. Note that these totals count chromium as one pollutant even though EPA has developed criteria based on two valence states. In the matrix, EPA has assigned numbers 5a and 5b to the criteria for chromium to reflect the fact that the list of 126 priority pollutants includes only a single listing for chromium.

i. Criteria for these metals are expressed as a function of the water-effect ratio, WER, as defined in paragraph (c) of this section. CMC = column B1 or C1 value x WER; CCC = column B2 or C2 value x WER.

j. No criterion for protection of human health from consumption of aquatic organisms (excluding water) was presented in the 1980 criteria document or in the 1986 Quality Criteria for Water. Nevertheless, sufficient information was presented in the 1980 document to allow a calculation of a criterion, even though the results of such a calculation were not shown in the document.

k. The CWA 304(a) criterion for asbestos is the MCL.

l. [Reserved]

m. These freshwater and saltwater criteria for metals are expressed in terms of the dissolved fraction of the metal in the water column. Criterion values were calculated by using EPA's Clean Water Act 304(a) guidance values (described in the total recoverable fraction) and then applying the conversion factors in § 131.36(b)(1) and (2).

n. EPA is not promulgating human health criteria for these contaminants. However, permit authorities should address these contaminants in NPDES permit actions using the State's existing narrative criteria for toxics.

o. These criteria were promulgated for specific waters in California in the National Toxics Rule (''NTR''), at § 131.36. The specific waters to which the NTR criteria apply include: Waters of the State defined as bays or estuaries and waters of the State defined as inland, i.e., all surface waters of the State not ocean waters. These waters specifically include the San Francisco Bay upstream to and including Suisun Bay and the Sacramento-San Joaquin Delta. This section does not apply instead of the NTR for this criterion.

p. A criterion of 20 ug/l was promulgated for specific waters in California in the NTR and was promulgated in the total recoverable form. The specific waters to which the NTR criterion applies include: Waters of the San Francisco Bay upstream to and including Suisun Bay and the Sacramento-San Joaquin Delta; and waters of Salt Slough, Mud Slough (north) and the San Joaquin River, Sack Dam to the mouth of the Merced River. This section does not apply instead of the NTR for this criterion. The State of California adopted and EPA approved a site specific criterion for the San Joaquin River, mouth of Merced to Vernalis; therefore, this section does not apply to these waters.

q. This criterion is expressed in the total recoverable form. This criterion was promulgated for specific waters in California in the NTR and was promulgated in the total recoverable form. The specific waters to which the NTR criterion applies include: Waters of the San Francisco Bay upstream to and including Suisun Bay and the Sacramento-San Joaquin Delta; and waters of Salt Slough, Mud Slough (north) and the San Joaquin River, Sack Dam to Vernalis. This criterion does not apply instead of the NTR for these waters. This criterion applies to additional waters of the United States in the State of California pursuant to 40 CFR 131.38(c). The State of California adopted and EPA approved a site-specific criterion for the Grassland Water District, San Luis National Wildlife Refuge, and the Los Banos State Wildlife Refuge; therefore, this criterion does not apply to these waters.

r. These criteria were promulgated for specific waters in California in the NTR. The specific waters to which the NTR criteria apply include: Waters of the State defined as bays or estuaries including the San Francisco Bay upstream to and including Suisun Bay and the Sacramento-San Joaquin Delta. This section does not apply instead of the NTR for these criteria.

s. These criteria were promulgated for specific waters in California in the NTR. The specific waters to which the NTR criteria apply include: Waters of the Sacramento-San Joaquin Delta and waters of the State defined as inland (*i.e.,* all surface waters of the State not bays or estuaries or ocean) that include a MUN use designation. This section does not apply instead of the NTR for these criteria.

t. These criteria were promulgated for specific waters in California in the NTR. The specific waters to which the NTR criteria apply include: Waters of the State defined as bays and estuaries including San Francisco Bay upstream to and including Suisun Bay and the Sacramento-San Joaquin Delta; and waters of the State defined as inland (i.e., all surface waters of the State not bays or estuaries or ocean) without a MUN use designation. This section does not apply instead of the NTR for these criteria.

u. PCBs are a class of chemicals which include aroclors 1242, 1254, 1221, 1232, 1248, 1260, and 1016, CAS numbers 53469219, 11097691, 11104282, 11141165, 12672296, 11096825, and 12674112, respectively. The aquatic life criteria apply to the sum of this set of seven aroclors.

v. This criterion applies to total PCBs, e.g., the sum of all congener or isomer or homolog or aroclor analyses.

w. This criterion has been recalculated pursuant to the 1995 Updates: Water Quality Criteria Documents for the Protection of Aquatic Life in Ambient Water, Office of Water, EPA–820-B–96–001, September 1996. See also Great Lakes Water Quality Initiative Criteria Documents for the Protection of Aquatic Life in Ambient Water, Office of Water, EPA–80–B–95–004, March 1995.

x. The State of California has adopted and EPA has approved site specific criteria for the Sacramento River (and tributaries) above Hamilton City; therefore, these criteria do not apply to these waters.

General Notes to Table in Paragraph (b)(1)

1. The table in this paragraph (b)(1) lists all of EPA's priority toxic pollutants whether or not criteria guidance are available. Blank spaces indicate the absence of national section 304(a) criteria guidance. Because of variations in chemical nomenclature systems, this listing of toxic pollutants does not duplicate the listing in Appendix A to 40 CFR Part 423–126 Priority Pollutants. EPA has added the Chemical Abstracts Service (CAS) registry numbers, which provide a unique identification for each chemical.

2. The following chemicals have organoleptic-based criteria recommendations that are not included on this chart: zinc, 3-methyl-4-chlorophenol.

3. Freshwater and saltwater aquatic life criteria apply as specified in paragraph (c)(3) of this section.

(2) Factors for Calculating Metals Criteria. Final CMC and CCC values should be rounded to two significant figures.

(i) $CMC = WER \times (Acute\ Conversion\ Factor) \times (\exp\{m_A[\ln(hardness)]+b_A\})$

(ii) $CCC = WER \times (Acute\ Conversion\ Factor) \times (\exp\{m_C[\ln(hardness)]+b_C\})$

(iii) Table 1 to paragraph (b)(2) of this section:

Metal	m_A	b_A	m_C	b_C
Cadmium	1.128	−3.6867	0.7852	−2.715
Copper	0.9422	−1.700	0.8545	−1.702
Chromium (III)	0.8190	3.688	0.8190	1.561
Lead	1.273	−1.460	1.273	−4.705
Nickel	0.8460	2.255	0.8460	0.0584
Silver	1.72	−6.52		
Zinc	0.8473	0.884	0.8473	0.884

Note to Table 1: The term ''exp'' represents the base e exponential function.

(iv) Table 2 to paragraph (b)(2) of this section:

Metal	Conversion factor (CF) for freshwater acute criteria	CF for freshwater chronic criteria	CF for saltwater acute criteria	CF [a] for saltwater chronic criteria
Antimony	([d])	([d])	([d])	([d])
Arsenic	1.000	1.000	1.000	1.000
Beryllium	([d])	([d])	([d])	([d])
Cadmium	[b] 0.944	[b] 0.909	0.994	0.994
Chromium (III)	0.316	0.860	([d])	([d])
Chromium (VI)	0.982	0.962	0.993	0.993
Copper	0.960	0.960	0.83	0.83
Lead	[b] 0.791	[b] 0.791	0.951	0.951
Mercury	.....	.....	.....	.....
Nickel	0.998	0.997	0.990	0.990
Selenium	.....	([c])	0.998	0.998
Silver	0.85	([d])	0.85	([d])
Thallium	([d])	([d])	([d])	([d])
Zinc	0.978	0.986	0.946	0.946

Footnotes to Table 2 of Paragraph (b)(2):

[a] Conversion Factors for chronic marine criteria are not currently available. Conversion Factors for acute marine criteria have been used for both acute and chronic marine criteria.

[b] Conversion Factors for these pollutants in freshwater are hardness dependent. CFs are based on a hardness of 100 mg/l as calcium carbonate ($CaCO_3$). Other hardness can be used; CFs should be recalculated using the equations in table 3 to paragraph (b)(2) of this section.

[c] Bioaccumulative compound and inappropriate to adjust to percent dissolved.

[d] EPA has not published an aquatic life criterion value.

Note to Table 2 of Paragraph (b)(2): The term ''Conversion Factor'' represents the recommended conversion factor for converting a metal criterion expressed as the total recoverable fraction in the water column to a criterion expressed as the dissolved fraction in the water column. See ''Office of Water Policy and Technical Guidance on Interpretation and Implementation of Aquatic Life Metals Criteria'', October 1, 1993, by Martha G. Prothro, Acting Assistant Administrator for Water available from Water Resource Center, USEPA, Mailcode RC4100, M Street SW, Washington, DC, 20460 and the note to § 131.36(b)(1).

(v) Table 3 to paragraph (b)(2) of this section:

	Acute	Chronic
Cadmium	CF=1.136672—[(ln {hardness}) (0.041838)]	CF = 1.101672—[(ln {hardness})(0.041838)]
Lead	CF=1.46203—[(ln {hardness})(0.145712)]	CF = 1.46203—[(ln {hardness})(0.145712)]

(c) *Applicability.* (1) The criteria in paragraph (b) of this section apply to the State's designated uses cited in paragraph (d) of this section and apply concurrently with any criteria adopted by the State, except when State regulations contain criteria which are more stringent for a particular parameter and use, or except as provided in footnotes p, q, and x to the table in paragraph (b)(1) of this section.

(2) The criteria established in this section are subject to the State's general rules of applicability in the same way and to the same extent as are other Federally-adopted and State-adopted numeric toxics criteria when applied to the same use classifications including mixing zones, and low flow values below which numeric standards can be exceeded in flowing fresh waters.

(i) For all waters with mixing zone regulations or implementation procedures, the criteria apply at the appropriate locations within or at the boundary of the mixing zones; otherwise the criteria apply throughout the water body including at the point of discharge into the water body.

(ii) The State shall not use a low flow value below which numeric standards can be exceeded that is less stringent than the flows in Table 4 to paragraph (c)(2) of this section for streams and rivers.

(iii) Table 4 to paragraph (c)(2) of this section:

Criteria	Design flow
Aquatic Life Acute Criteria (CMC).	1 Q 10 or 1 B 3
Aquatic Life Chronic Criteria (CCC).	7 Q 10 or 4 B 3
Human Health Criteria.	Harmonic Mean Flow

Note to Table 4 of Paragraph (c)(2): 1. CMC (Criteria Maximum Concentration) is the water quality criteria to protect against acute effects in aquatic life and is the highest instream concentration of a priority toxic pollutant consisting of a short-term average not to be exceeded more than once every three years on the average.

2. CCC (Continuous Criteria Concentration) is the water quality criteria to protect against chronic effects in aquatic life and is the highest in stream concentration of a priority toxic pollutant consisting of a 4-day average not to be exceeded more than once every three years on the average.

3. 1 Q 10 is the lowest one day flow with an average recurrence frequency of once in 10 years determined hydrologically.

4. 1 B 3 is biologically based and indicates an allowable exceedence of once every 3 years. It is determined by EPA's computerized method (DFLOW model).

5. 7 Q 10 is the lowest average 7 consecutive day low flow with an average recurrence frequency of once in 10 years determined hydrologically.

6. 4 B 3 is biologically based and indicates an allowable exceedence for 4 consecutive days once every 3 years. It is determined by EPA's computerized method (DFLOW model).

(iv) If the State does not have such a low flow value below which numeric standards do not apply, then the criteria included in paragraph (d) of this section apply at all flows.

(v) If the CMC short-term averaging period, the CCC four-day averaging period, or once in three-year frequency is inappropriate for a criterion or the site to which a criterion applies, the State may apply to EPA for approval of an alternative averaging period, frequency, and related design flow. The State must submit to EPA the bases for any alternative averaging period, frequency, and related design flow. Before approving any change, EPA will publish for public comment, a document proposing the change.

(3) The freshwater and saltwater aquatic life criteria in the matrix in paragraph (b)(1) of this section apply as follows:

(i) For waters in which the salinity is equal to or less than 1 part per thousand 95% or more of the time, the applicable criteria are the freshwater criteria in Column B;

(ii) For waters in which the salinity is equal to or greater than 10 parts per thousand 95% or more of the time, the applicable criteria are the saltwater criteria in Column C except for selenium in the San Francisco Bay estuary where the applicable criteria are the freshwater criteria in Column B (refer to footnotes p and q to the table in paragraph (b)(1) of this section); and

(iii) For waters in which the salinity is between 1 and 10 parts per thousand as defined in paragraphs (c)(3)(i) and (ii) of this section, the applicable criteria are the more stringent of the freshwater or saltwater criteria. However, the Regional Administrator may approve the use of the alternative freshwater or saltwater criteria if scientifically defensible information and data demonstrate that on a site-specific basis the biology of the water body is dominated by freshwater aquatic life and that freshwater criteria are more appropriate; or conversely, the biology of the water body is dominated by saltwater aquatic life and that saltwater criteria are more appropriate. Before approving any change, EPA will publish for public comment a document proposing the change.

(4) *Application of metals criteria.* (i) For purposes of calculating freshwater aquatic life criteria for metals from the equations in paragraph (b)(2) of this section, for waters with a hardness of 400 mg/l or less as calcium carbonate, the actual ambient hardness of the surface water shall be used in those equations. For waters with a hardness of over 400 mg/l as calcium carbonate, a hardness of 400 mg/l as calcium carbonate shall be used with a default Water-Effect Ratio (WER) of 1, or the actual hardness of the ambient surface water shall be used with a WER. The same provisions apply for calculating the metals criteria for the comparisons provided for in paragraph (c)(3)(iii) of this section.

(ii) The hardness values used shall be consistent with the design discharge conditions established in paragraph (c)(2) of this section for design flows and mixing zones.

(iii) The criteria for metals (compounds #1—#13 in the table in paragraph (b)(1) of this section) are expressed as dissolved except where otherwise noted. For purposes of calculating aquatic life criteria for metals from the equations in footnote i to the table in paragraph (b)(1) of this section and the equations in paragraph (b)(2) of this section, the water effect ratio is generally computed as a specific pollutant's acute or chronic toxicity value measured in water from the site covered by the standard, divided by the respective acute or chronic toxicity value in laboratory dilution water. To use a water effect ratio other than the default of 1, the WER must be determined as set forth in Interim Guidance on Determination and Use of Water Effect Ratios, U.S. EPA Office of Water, EPA–823–B–94–001, February 1994, or alternatively, other scientifically defensible methods adopted by the State as part of its water quality standards program and approved by EPA. For calculation of criteria using site-specific values for both the hardness and the water effect ratio, the hardness used in the equations in paragraph (b)(2) of this section must be determined as required in paragraph (c)(4)(ii) of this section. Water hardness must be calculated from the measured calcium and magnesium ions present, and the ratio of calcium to magnesium should be approximately the same in standard laboratory toxicity testing water as in the site water.

(d)(1) Except as specified in paragraph (d)(3) of this section, all waters assigned any aquatic life or human health use classifications in the Water Quality Control Plans for the various Basins of the State (''Basin Plans'') adopted by the California State Water Resources Control Board (''SWRCB''), except for ocean waters covered by the Water Quality Control Plan for Ocean Waters of California (''Ocean Plan'') adopted by the SWRCB with resolution Number 90–27 on March 22, 1990, are subject to the criteria in paragraph (d)(2) of this section, without exception. These criteria apply to waters identified in the Basin Plans. More particularly, these criteria apply to waters identified in the Basin Plan chapters designating beneficial uses for waters within the region. Although the State has adopted several use designations for each of these waters, for purposes of this action, the specific standards to be applied in paragraph (d)(2) of this section are based on the presence in all waters of some aquatic life designation and the presence or absence of the MUN use designation (municipal and domestic supply). (See Basin Plans for more detailed use definitions.)

(2) The criteria from the table in paragraph (b)(1) of this section apply to the water and use classifications defined in paragraph (d)(1) of this section as follows:

Water and use classification	Applicable criteria
(i) All inland waters of the United States or enclosed bays and estuaries that are waters of the United States that include a MUN use designation.	(A) Columns B1 and B2—all pollutants (B) Columns C1 and C2—all pollutants (C) Column D1—all pollutants
(ii) All inland waters of the United States or enclosed bays and estuaries that are waters of the United States that do not include a MUN use designation.	(A) Columns B1 and B2—all pollutants (B) Columns C1 and C2—all pollutants (C) Column D2—all pollutants

(3) Nothing in this section is intended to apply instead of specific criteria, including specific criteria for the San Francisco Bay estuary, promulgated for California in the National Toxics Rule at § 131.36.

(4) The human health criteria shall be applied at the State-adopted 10 (−6) risk level.

(5) Nothing in this section applies to waters located in Indian Country.

(e)*Schedules of compliance.* (1) It is presumed that new and existing point source dischargers will promptly comply with any new or more restrictive water quality-based effluent limitations (''WQBELs'') based on the water quality criteria set forth in this section.

(2) When a permit issued on or after May 18, 2000 to a new discharger contains a WQBEL based on water quality criteria set forth in paragraph (b) of this section, the permittee shall comply with such WQBEL upon the commencement of the discharge. A new discharger is defined as any building, structure, facility, or installation from which there is or may be a ''discharge of pollutants'' (as defined in 40 CFR 122.2) to the State of California's inland surface waters or enclosed bays and estuaries, the construction of which commences after May 18, 2000.

(3) Where an existing discharger reasonably believes that it will be infeasible to promptly comply with a new or more restrictive WQBEL based on the water quality criteria set forth in this section, the discharger may request approval from the permit issuing authority for a schedule of compliance.

(4) A compliance schedule shall require compliance with WQBELs based on water quality criteria set forth in paragraph (b) of this section as soon as possible, taking into account the dischargers' technical ability to achieve compliance with such WQBEL.

(5) If the schedule of compliance exceeds one year from the date of permit issuance, reissuance or modification, the schedule shall set forth interim requirements and dates for their achievement. The dates of completion between each requirement may not exceed one year. If the time necessary for completion of any requirement is more than one year and is not readily divisible into stages for completion, the permit shall require, at a minimum, specified dates for annual submission of progress reports on the status of interim requirements.

(6) In no event shall the permit issuing authority approve a schedule of compliance for a point source discharge which exceeds five years from the date of permit issuance, reissuance, or modification, whichever is sooner. Where shorter schedules of compliance are prescribed or schedules of compliance are prohibited by law, those provisions shall govern.

(7) If a schedule of compliance exceeds the term of a permit, interim permit limits effective during the permit shall be included in the permit and addressed in the permit's fact sheet or statement of basis. The administrative record for the permit shall reflect final permit limits and final compliance dates. Final compliance dates for final permit limits, which do not occur during the term of the permit, must occur within five years from the date of issuance, reissuance or modification of the permit which initiates the compliance schedule. Where shorter schedules of compliance are prescribed or schedules of compliance are prohibited by law, those provisions shall govern.

(8) The provisions in this paragraph (e), Schedules of compliance, shall expire on May 18, 2005.

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Table G-6

Basin Plan Numeric Water Quality Objectives

Constituent	Water Quality Objective
Total Dissolved Solids	300 mg/L
Chloride	50 mg/L
Sulfate	65 mg/L
Percent Sodium	60%
Iron	0.3 mg/L
Manganese	0.05 mg/L
Boron	1.0 mg/L
Turbidity	20 NTU
Color	20 color units
Fluoride	1.0 mg/L
Nutrients	-Total Phosphorus less than 0.025 mg/L -Natural ratios of total nitrogen to total phosphorus are to be upheld, if no data is available a ratio (N:P) of 10:1 is to be used.
Ammonia (as N)	0.025 mg/L
Fecal Coliform	-Not less than 5 samples every 30 days -Sampling shall not exceed a log mean of 200/100mL -No more than 10% of samples during any 30 day period shall exceed 400/100mL
Dissolved Oxygen	- not less than 6.0 mg/L -annual mean DO shall not be less than 7.0 mg/L more than 10% of the time
pH	-change in pH level shall not exceed 0.5 units -pH shall not be depressed below 6.5 nor raised above 8.5
Phenolic Compounds	1.0 µg/L

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APPENDIX H – COMPARISON OF CEC DATA MEASURED IN NCWRP TERTIARY WATER TO MEC/MTL DATA PRESENTED IN THE SWRCB 2010 FINAL REPORT

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Table H-1 Comparison of CEC Concentrations measured in the NCWRP Tertiary Effluent to MEC/MTL Ratio's Established in the SWRCB Final Report

CEC	Units	MDL	MTL [4]	MEC [4]	Average Detected Concentration[1] [2]	MEC/MTL	Average/MTL	Comments	Use
Hydrocodone	ng/L	1	NA	NA	83.0				Pain killer
Trimethoprim	ng/L	1	61,000	112	387.0	0.00	0.01		Anti-biotic
Acetaminophen	ng/L	1	350,000	550	2.2	0.00	0.00		Analgesic
Caffeine	ng/L	10	350	900	20.0	2.57	0.06		Stimulant
Erythromycin-H_2O	ng/L	1	4,900	113	318.3	0.02	0.06		Anti-biotic
Sulfamethoxazole	ng/L	1	35,000	1,400	857.3	0.04	0.02		Anti-biotic
Fluoxetine	ng/L	1	10,000	31	36.7	0.00	0.00		Anti-depressant
Pentoxifylline	ng/L	1	NA	NA	4.3				Blood thinner
Meprobamate	ng/L	1	260,000	430	283.3	0.00	0.00		Anti-anxiety
Dilantin	ng/L	1	NA	217	141.3				Anti-convulsant
TCEP	ng/L	10	2,500	688	300.3	0.28	0.12		Fire retardent
Carbamazepine	ng/L	1	1,000	400	266.3	0.40	0.27		Anti-seizure/analgesic
DEET [5]	ng/L	1	2,500	1,520	250.0	0.61	0.10		Insect repellant
Atrazine	ng/L	1	NA	NA	2.3				Herbicide
Diazepam	ng/L	1	NA	NA	3.6				Anti-anxiety/muscle relaxant
Oxybenzone	ng/L	1	NA	NA	14.3				Sunscreen
Estriol	ng/L	5	350	NA	6.3		0.02		Steroid
Ethynylestradiol	ng/L	1	350	1	0.5	0.00	0.00		Synthetic birth control
Estrone	ng/L	1	350	73	68.8	0.21	0.20		Steroid
Estradiol	ng/L	1	0.9	8.4	6.3	9.33	7.04		Steroid
Testosterone	ng/L	1			0.5				Steroid
Progesterone	ng/L	1	110,000	18	0.5	0.00	0.00		Steroid
Androstenedione	ng/L	1	NA	NA	5.2				Steroid
Iopromide [5]	ng/L	1	750,000	2,174	556.3	0.00	0.00		X-ray contrast reagent
Naproxen	ng/L	1	220,000	851	183.3	0.00	0.00		Analgesic
Ibuprofen	ng/L	1	34,000	500	57.3	0.01	0.00		Pain killer
Diclofenac	ng/L	1	1,800	230	65.7	0.13	0.04		Arthritis treatment
Triclosan	ng/L	1	350	485	199.7	1.39	0.57		Anti-biotic
Gemfibrozil [5]	ng/L	1	45,000	3,550	689.3	0.08	0.02		Anti-cholesterol
NDMA	ng/L	2	10	68	42.3 [3]	6.80	4.23		Industrial (e.g. rocket fuel production)
1,2,3-Trichloropropane	ng/L	5	5	NA	250 [6]			Never detected. 500 ng/L MDL	
Hydrazine	ng/L	1	10						
Quinoline	ng/L	1	10						
3-Hydroxycarbofuran	ng/L	400	420	NA	250 [6]		0.60	Never detected. 500 ng/L MDL	
Sucralose [5]	ng/L	--	NA	26,390	NA				food sweetener

Notes:

[1]Average and high detected concentrations from tertiary treatment effluent samples collected on 3/23/2005, 4/13/2005, and 12/30/2005.

[2]Non-detections calculated in at half the MDL.

[3]Average and high detected concentrations from tertiary treatment effluent samples collected on 3/23/2005, 4/13/2005, and 12/12/2005.

[4]MTL and MEC as developed in SWRCB, 2010. MTL=Monitor triggering limit; MEC=Measured Environmental Concentration. Compounds with MEC/MTL > 1 recommended for monitoring.

[5]Identified for surface spreading and direct injection operations as a viable performance indicator compound along with certain surrogate parameters (SWRCB, 2010).

[6]Average and high detected concentrations from tertiary treatment effluent samples collected on 3/23/2005, 4/13/2005, and 12/12/2005.

Acronyms:

CEC - Chemical of Emerging Concern
DEET - N, N-Diethyl-meta-Toluamide
MDL - method detection limit
MEC - Measured Environmental Concentration
MTL - Monitoring Trigger Level
NA - not available
ND - not detected
NDMA - N-nitrosodimethylamine
SWRCB - State Water Resources Control Board
TCEP - Tris (2-chloroethyl) phosphate

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APPENDIX I – ANALYTICAL TESTING METHODS, MDLS, TATS

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Table I-1
Compounds to be Monitored Quarterly (non-CEC)

Analyte/Contaminant Group	Method	Turn Around Time	MDL	Units	Rationale
Volatile Organic Compounds (VOCs)					
Benzene	EPA 524.2		0.5	µg/L	Federal and state primary drinking water standards, priority pollutant
Bromoform	EPA 524.2		0.5	µg/L	Priority pollutant
Bromomethane	EPA 524.2		0.5	µg/L	Priority pollutant
tert-Butyl alcohol	EPA 524.2		2	µg/L	CDPH drinking water notification level
n-Butylbenzene	EPA 524.2		0.5	µg/L	CDPH drinking water notification level
sec-Butylbenzen	EPA 524.2		0.5	µg/L	CDPH drinking water notification level
tert-Butylbenzene	EPA 524.2		0.5	µg/L	CDPH drinking water notification level
Carbon Tetrachloride	EPA 524.2		0.5	µg/L	Federal and state primary drinking water standards, priority pollutant
Chlorobenzene	EPA 524.2		0.5	µg/L	Federal and state primary drinking water standards, priority pollutant
Chlorodibromomethane	EPA 524.2		0.5	µg/L	Priority pollutant
Chloroethane	EPA 524.2		0.5	µg/L	Priority pollutant
Chloromethane	EPA 524.2		0.5	µg/L	Priority pollutant
Chloroform	EPA 524.2		0.5	µg/L	Priority pollutant
2-Chlorotoluene	EPA 524.2		0.5	µg/L	CDPH drinking water notification level
4-Chlorotoluene	EPA 524.2		0.5	µg/L	CDPH drinking water notification level
1, 2-Dichlorobenzene	EPA 524.2		0.5	µg/L	Federal and state primary drinking water standards, priority pollutant
1, 3-Dichlorobenzene	EPA 524.2		0.5	µg/L	Priority pollutant
1, 4-Dichlorobenzene	EPA 524.2		0.5	µg/L	Federal and state primary drinking water standards, priority pollutant
Dichlorobromomethane	EPA 524.2		0.5	µg/L	Priority pollutant
Dichlorodifluoromethane (Freon-12)	EPA 524.2		0.5	µg/L	CDPH drinking water notification level
1, 1-Dichloroethane	EPA 524.2		0.5	µg/L	State primary drinking water standards, priority pollutant
1, 2-Dichloroethane	EPA 524.2		0.5	µg/L	Federal and state primary drinking water standards, priority pollutant
1, 1-Dichloroethylene	EPA 524.2		0.5	µg/L	Federal and state primary drinking water standards, priority pollutant
cis-1, 2-Dichloroethylene	EPA 524.2		0.5	µg/L	Federal and state primary drinking water standards
trans-1, 2-Dichloroethylene	EPA 524.2		0.5	µg/L	Federal and state primary drinking water standards, priority pollutant
1, 2-Dichloropropane	EPA 524.2		0.5	µg/L	Federal and state primary drinking water standards, priority pollutant
1, 2-Dichloropropene	EPA 524.2		0.5-5	µg/L	Priority pollutant
1, 3-Dichloropropene	EPA 524.2		0.5	µg/L	State primary drinking water standards
Ethylbenzene	EPA 524.2		0.5	µg/L	Federal and state primary drinking water standards, priority pollutant
Hexachlorobutadiene	EPA 524.2		0.5	µg/L	Priority pollutant
Hexachloroethane	EPA 524.2		0.5-5	µg/L	Priority pollutant
Isopropylbenzene	EPA 524.2		0.5	µg/L	CDPH drinking water notification level
Methyl-tert-butyl ether (MTBE)	EPA 524.2		0.5	µg/L	Federal and state primary and secondary drinking water standards
Methylene Chloride (Dichloromethane)	EPA 524.2		0.5	µg/L	Federal and state primary drinking water standards, priority pollutant
Methyl isobutyl ketone (MIKB)	EPA 524.2		5	µg/L	CDPH drinking water notification level
n-Propylbenzene	EPA 524.2		0.5	µg/L	CDPH drinking water notification level
Styrene	EPA 524.2		0.5	µg/L	Federal and state primary drinking water standards
1, 1, 2, 2-Tetrachloroethane	EPA 524.2		0.5	µg/L	State primary drinking water standards, priority pollutant
Tetrachloroethylene (PCE)	EPA 524.2		0.5	µg/L	Federal and state primary drinking water standards, priority pollutant
Toluene	EPA 524.2		0.5	µg/L	Federal and state primary drinking water standards, priority pollutant
1, 2, 4-Trichlorobenzene	EPA 524.2		0.5	µg/L	Federal and state primary drinking water standards, priority pollutant
1, 1, 1-Trichloroethane	EPA 524.2		0.5	µg/L	Federal and state primary drinking water standards, priority pollutant
1, 1, 2-Trichloroethane	EPA 524.2		0.5	µg/L	Federal and state primary drinking water standards, priority pollutant
Trichloroehtylene (TCE)	EPA 524.2		0.5	µg/L	Federal and state primary drinking water standards, priority pollutant
Trichlorofluoromethane (Freon-11)	EPA 524.2		0.5	µg/L	State primary drinking water standards
1, 2, 3-Trichloropropane	EPA 524.2 MOD		0.005	µg/L	CDPH drinking water notification level
1, 1, 2-Trichloro-1, 2, 2-Trifluoroethane (Freon-113)	EPA 524.2		0.5	µg/L	State primary drinking water standards
1, 2, 4-Trimethylbenzene	EPA 524.2		0.5	µg/L	CDPH drinking water notification level
1, 3, 5-Trimethylbenzene	EPA 524.2		0.5	µg/L	CDPH drinking water notification level
Vinyl Chloride	EPA 524.2		0.5	µg/L	Federal and state primary drinking water standards, priority pollutant
Xylenes, total	EPA 524.2		0.5	µg/L	Federal and state primary drinking water standards
Synthetic Organic Compounds (SOCs)					
Acenapthene	EPA 525.2		0.5	µg/L	Priority pollutant
Acenapthylene	EPA 525.2		0.5	µg/L	Priority pollutant
Acetochlor	EPA 525.2		0.02-5	µg/L	Unregulated comtaminant monitoring program
Acrolein	EPA 556		1-5	µg/L	Priority pollutant
Acrylonitrile					Priority pollutant
Alachlor	EPA 525.2		0.5	µg/L	Federal and state primary drinking water standards, Unregulated comtaminant monitoring program
Aldrin	EPA 505		0.075	µg/L	Priority pollutant
Anthracene	EPA 525.2		0.5	µg/L	Priority pollutant
Atrazine	EPA 525.2		0.4	µg/L	Federal and state primary drinking water standards, IAP recommended
Bentazon	EPA 555		2	µg/L	State primary drinking water standards
Benzidine	EPA 605			µg/L	Priority pollutant
Benzo(a)anthracene	EPA 525.2		0.5	µg/L	Priority pollutant
Benzo(a)pyrene	EPA 525.2		0.1	µg/L	Federal and state primary drinking water standards, priority pollutant
Benzo(g, h, i)perylene	EPA 525.2		0.5	µg/L	Priority pollutant
Benzo(b)fluoranthene	EPA 525.2		0.5	µg/L	Priority pollutant
Benzo(k)fluoranthene	EPA 525.2		0.5	µg/L	Priority pollutant
alpha-BHC	EPA 505		0.01-0.5	µg/L	Priority pollutant
beta-BHC	EPA 505		0.01-0.5	µg/L	Priority pollutant
delta-BHC	EPA 505		0.01-0.5	µg/L	Priority pollutant
Bis(2-chloroethoxy) methane					Priority pollutant
Bis(2-chloroethyl) ether					Priority pollutant
Bis(2-chloroisopropyl) ether					Priority pollutant
Bis(2-ethylhexyl) adipate	EPA 525.2		2	µg/L	Federal and state primary drinking water standards
Bis(2-ethylhexyl) phthalate (DEHP)	EPA 525.2		3	µg/L	Federal and state primary drinking water standards, priority pollutant
4-Bromophenyl phenyl ether					Priority pollutant
Butyl benzyl phthalate	EPA 525.2		0.02-5	µg/L	Priority pollutant
Carbofuran	EPA 531.2		0.4	µg/L	Federal and state primary drinking water standards
Chlordane	EPA 505		0.1	µg/L	Federal and state primary drinking water standards, priority pollutant
2-Chloroethyl vinyl ethers					Priority pollutant
2-Chloronapthalene					Priority pollutant
4-Chlorophenyl phenyl ether					Priority pollutant
Chrysene	EPA 525.2		0.5	µg/L	Priority pollutant
Dalapon	EPA 549		2	µg/L	Federal and state primary drinking water standards
Di-n-butyl phthalate	EPA 525.2		2	µg/L	Priority pollutant
Di-n-octyl phthalate	EPA 525.2		0.02-5	µg/L	Priority pollutant
Dibenzo(g, h)anthracene	EPA 525.2		0.02-5	µg/L	Priority pollutant
Dibromochloropropane	EPA 524.2		0.5	µg/L	Federal and state primary drinking water standards
3, 3-Dichlorobenzidine	EPA 605			µg/L	Priority pollutant
2, 4-Dichlorophenol	EPA 528		0.1-1	µg/L	Priority pollutant
2, 4-Dichlorophenoxy acetic acid (2, 4-D)	EPA 555		3	µg/L	Federal and state primary drinking water standards
4, 4-DDT	EPA 680			µg/L	Priority pollutant
4, 4-DDE	EPA 680			µg/L	Priority pollutant
4, 4-DDD	EPA 680			µg/L	Priority pollutant
Dieldrin	EPA 505		0.02	µg/L	Priority pollutant
Diethyl phthalate	EPA 525.2		0.5	µg/L	Priority pollutant
Dimethyl phthalate	EPA 525.2		0.5	µg/L	Priority pollutant
Dimethoate	EPA 527		0.025	µg/L	Unregulated comtaminant monitoring program
2, 4-Dimethylphenol	EPA 528		0.1-1	µg/L	Priority pollutant
4, 6-Dinitro-o-cresol	EPA 528		0.1-1	µg/L	Priority pollutant
2, 4-Dinitrophenol	EPA 528		0.1-1	µg/L	Priority pollutant
Dinoseb	EPA 555		2	µg/L	Federal and state primary drinking water standards
Diquat	EPA 549.2		0.4	µg/L	Federal and state primary drinking water standards
alpha-Endosulfan	EPA 608			µg/L	Priority pollutant
beta-Endosulfan	EPA 608			µg/L	Priority pollutant

Table I-1
Compounds to be Monitored Quarterly (non-CEC)

Analyte/Contaminant Group	Method	Turn Around Time	MDL	Units	Rationale
Endosulfan sulfate	EPA 608			µg/L	Priority pollutant
Endothall	EPA 548.1		8	µg/L	Federal and state primary drinking water standards
Endrin	EPA 505		0.1	µg/L	Federal and state primary drinking water standards, priority pollutant
Endrin aldehyde	EPA 505		0.01-0.5	µg/L	Priority pollutant
Ethylene Dibromide	EPA 504.1		0.01	µg/L	Federal and state primary drinking water standards
Fluoranthene	EPA 525.2		0.02-5	µg/L	Priority pollutant
Fluorene	EPA 525.2		0.5	µg/L	Priority pollutant
Glyphosate	EPA 547		6	µg/L	Federal and state primary drinking water standards
Heptachlor	EPA 505		0.01	µg/L	Federal and state primary drinking water standards, priority pollutant
Heptachlor epoxide	EPA 505		0.01	µg/L	Federal and state primary drinking water standards, priority pollutant
Hexachlorobenzene	EPA 525.2		0.4	µg/L	Federal and state primary drinking water standards, priority pollutant
Hexachlorocyclopentadiene	EPA 525.2		0.5	µg/L	Federal and state primary drinking water standards, priority pollutant
Indeno(1, 2, 3-cd)pyrene	EPA 525.2		0.5	µg/L	Priority pollutant
Isophorone	EPA 525.2		0.02-5	µg/L	Priority pollutant
Lindane (gamma-BHC)	EPA 505		0.2	µg/L	Federal and state primary drinking water standards, priority pollutant
Methoxychlor	EPA 505		0.5	µg/L	Federal and state primary drinking water standards
Metolachlor	EPA 525.2		0.02-5	µg/L	Unregulated comtaminant monitoring program
Molinate	EPA 525.2		0.5	µg/L	State primary drinking water standards
Napthalene	EPA 524.2		0.5	µg/L	CDPH drinking water notification level, priority pollutant
2-Nitrophenol	EPA 528		0.1-1	µg/L	Priority pollutant
4-Nitrophenol	EPA 528		0.1-1	µg/L	Priority pollutant
n-Nitrosodiethylamine (NDEA)	EPA 521		2	ng/L	Unregulated comtaminant monitoring program
n-Nitrosodimethylamine (NDMA)	EPA 521		2	ng/L	CDPH drinking water notification level, Unregulated comtaminant monitoring program, priority pollutant, process performance, IAP recommended, SWRCB CEC advisory panel
n-Nitrosodiphenylamine	EPA 521		2	ng/L	Other nitrosamine compound (non-UCMR/Notification Limit), priority pollutant
n-Nitroso-di-n-butylamine (NDBA)	EPA 521		2	ng/L	Unregulated comtaminant monitoring program
n-Nitroso-di-n-propylamine (NDPA)	EPA 521		2	ng/L	Unregulated comtaminant monitoring program, priority pollutant
n-Nitrosomethylethylamine (NMEA)	EPA 521		2	ng/L	Unregulated comtaminant monitoring program
n-Nitrosomorpholine	EPA 521		2	ng/L	Other nitrosamine compound (non-UCMR/Notification Limit)
N-nitrosopiperidine (NPIP)	EPA 521		2	ng/L	Other nitrosamine compound (non-UCMR/Notification Limit)
n-Nitrosopyrrolidine (NYPR)	EPA 521		2	ng/L	Unregulated comtaminant monitoring program
Oxamyl (Vydate)	EPA 531.2		0.4	µg/L	Federal and state primary drinking water standards
Parachlorometa Cresol	EPA 528		0.1-1	µg/L	Priority pollutant
Pentachlorophenol (PCP)	EPA 528		0.1-1	µg/L	Federal and state primary drinking water standards, priority pollutant
Phenanthrene	EPA 525.2		0.5	µg/L	Priority pollutant
Phenol	EPA 528		0.1-1	µg/L	Priority pollutant
Picloram	EPA 555		1	µg/L	Federal and state primary drinking water standards
Polychlorinated Biphenyls (PCBs)	EPA 505		0.5	µg/L	Federal and state primary drinking water standards
PCB-1016 (Aroclor 1016)	EPA 505		0.5	µg/L	Priority pollutant
PCB-1221 (Aroclor 1221)	EPA 505		0.5	µg/L	Priority pollutant
PCB-1232 (Aroclor 1232)	EPA 505		0.5	µg/L	Priority pollutant
PCB-1242 (Aroclor 1242)	EPA 505		0.5	µg/L	Priority pollutant
PCB-1248 (Aroclor 1248)	EPA 505		0.5	µg/L	Priority pollutant
PCB-1254 (Aroclor 1254)	EPA 505		0.5	µg/L	Priority pollutant
PCB-1260 (Aroclor 1260)	EPA 505		0.5	µg/L	Priority pollutant
Propachlor	EPA 505		0.5	µg/L	CDPH drinking water notification level
Pyrene	EPA 525.2		0.5	µg/L	Priority pollutant
Simazine	EPA 525.2		0.5	µg/L	Federal and state primary drinking water standards
Surfactants (MBAS)	SM5540C/E425.1		0.05	mg/L	Federal and state secondary drinking water standards
Terbufos Sulfone	EPA 527		0.04	µg/L	Unregulated comtaminant monitoring program
Thiobencarb	EPA 555		1	µg/L	Federal and state primary and secondary drinking water standards
Toxaphene	EPA 505		1	µg/L	Federal and state primary drinking water standards
2, 3, 7, 8-Tetrachlorodibenzo-p-dioxin (2, 3, 7, 8-TCDD)	EPA 1613B		5	pg/L	Federal and state primary drinking water standards, priority pollutant
2, 4, 5-TP (Silvex)	EPA 555		1	µg/L	Federal and state primary drinking water standards
2, 4, 6-Trichlorophenol	EPA 528		0.1-1	µg/L	Priority pollutant
Disinfection by Products (DBPs)					
Total Trihalomethanes	EPA 551.1		0.5	µg/L	Federal and state primary drinking water standards
Total Haloacetic acids	SM6251B		4	µg/L	Federal and state primary drinking water standards
Bromate	EPA 317		1	µg/L	Federal and state primary drinking water standards
Chlorite	EPA 300.1B		10	µg/L	Federal and state primary drinking water standards
Chlorate	EPA 300.1B		20	µg/L	Water treatment disinfection byproduct
Inorganics					
Aluminum	EPA 200.7		25	µg/L	Federal and state secondary drinking water standards
Antimony	EPA 200.7		1	µg/L	Federal and state primary drinking water standards, priority pollutant
Arsenic	EPA 200.7		1	µg/L	Federal and state primary drinking water standards, priority pollutant
Asbestos	EPA 100.2		0.2	MFL	Federal and state primary drinking water standards, priority pollutant
Barium	EPA 200.7		2	µg/L	Federal and state primary drinking water standards
Beryllium	EPA 200.7		1	µg/L	Federal and state primary drinking water standards, priority pollutant
Boron	EPA 200.7		25	µg/L	CDPH drinking water notification level, IAP recommended
Cadmium	EPA 200.7		0.5	µg/L	Federal and state primary drinking water standards, priority pollutant
Calcium	EPA 200.7		1	mg/L	San Diego Basin Plan inland surface water monitoring
Chloride	EPA 300.0		10	mg/L	Federal and state secondary drinking water standards
Chromium	EPA 200.7		1	µg/L	Federal and state primary drinking water standards, priority pollutant
Copper	EPA 200.7		2	µg/L	Federal and state primary and secondary drinking water standards, priority pollutant
Cyanide	SM4500CN-F		0.005	mg/L	Federal and state primary drinking water standards, priority pollutant
Fluoride	EPA 300.0		0.05	mg/L	Federal and state primary drinking water standards
Iron	EPA 200.7		0.02	mg/L	Federal and state secondary drinking water standards
Lead	EPA 200.7		0.5	µg/L	Federal and state primary drinking water standards, priority pollutant
Magnesium	EPA 200.7		0.1	mg/L	San Diego Basin Plan inland surface water monitoring
Manganese	EPA 200.7		2	µg/L	Federal and state secondary drinking water standards, CDPH drinking water notification level
Mercury	EPA 245.1		0.2	µg/L	Federal and state primary drinking water standards, priority pollutant
Nickel	EPA 200.7		5	µg/L	State primary drinking water standards, priority pollutant
Perchlorate	EPA 314		2	µg/L	CDPH drinking water notification level
Potassium	EPA 200.7		1	mg/L	San Diego Basin Plan inland surface water monitoring
Selenium	EPA 200.7		5	µg/L	Federal and state primary drinking water standards, priority pollutant
Silver	EPA 200.7		0.5	µg/L	Federal and state secondary drinking water standards, priority pollutant
Sodium	EPA 200.7		1	mg/L	San Diego Basin Plan inland surface water monitoring
Sulfate	EPA 300.0		2	mg/L	Federal and state secondary drinking water standards
Thallium	EPA 200.7		1	µg/L	Federal and state primary drinking water standards, priority pollutant
Vanadium	EPA 200.7		0.5	µg/L	CDPH drinking water notification level
Zinc	EPA 200.7		5	µg/L	Federal and state secondary drinking water standards, priority pollutant
Nutrients					
Ammonia	EPA 350.1		0.05	mg/L	San Diego Basin Plan inland surface water monitoring, process performance
Nitrate-NO3	EPA 300.0		1.8	mg/L	State primary drinking water standards
Nitrate-N	EPA 300.0		0.4	mg/L	Federal primary drinking water standards
Nitrite-N	EPA 300.0		0.4	mg/L	Federal and state primary drinking water standards, process performance
Nitrogen, total	EPA 300.0/351.2		0.5	mg/L	Process performance monitoring
Orthophosphate	SM4500P-E		0.05	mg/L	Process performance monitoring
Phosphorus, total	E365.1/365.2		0.05	mg/L	Process performance monitoring
Microbial					
Total Coliform	SM9223		2	MPL/100mL	Federal and state primary drinking water standards, process performance
Hetertrophic plate count	SM9215		1	CFU/mL	Process performance monitoring

Table I-1
Compounds to be Monitored Quarterly (non-CEC)

Analyte/Contaminant Group	Method	Turn Around Time	MDL	Units	Rationale
Coliphage	EPA 1601/1602		varies	PFU/mL	Process performance monitoring
Radionuclides					
Uranium	EPA 200.8		1	µg/L	Federal and state primary drinking water standards
Radium-226+228	EPA 903.1 / 904.0		1	pCi/L	Federal and state primary drinking water standards
Gross Alpha particualtes	EPA 900.0		3	pCi/L	Federal and state primary drinking water standards
Gross Beta particulates	EPA 900.0		3	pCi/L	Federal and state primary drinking water standards
Strontium-90	EPA 905.0		1	pCi/L	Federal and state primary drinking water standards
Tritium	EPA 906.0		1,000	pCi/L	Federal and state primary drinking water standards
Explosives					
1, 3-Dinitrobenzene	EPA 529		UCMR	µg/L	Unregulated comtaminant monitoring program
2, 4-Dinitrotoluene	EPA 529		UCMR	µg/L	Priority pollutant
2, 6-Dinitrotoluene	EPA 529		UCMR	µg/L	Priority pollutant
Hexahydro-1, 3, 5-trinitro-1, 3, 5-triazine (RDX)	EPA 529		UCMR	µg/L	Unregulated comtaminant monitoring program
Nitrobenzene	EPA 529		UCMR	µg/L	Priority pollutant
2, 4, 6-Trinitrotoluene	EPA 529		UCMR	µg/L	Unregulated comtaminant monitoring program
Acetanilide Degredates					
Acetochlor ethane sulfonic acid (ESA)	EPA 535		UCMR	µg/L	Unregulated comtaminant monitoring program
Acetochlor oxanilic acid (OA)	EPA 535		UCMR	µg/L	Unregulated comtaminant monitoring program
Alachlor ethane sulfonic acid (ESA)	EPA 535		UCMR	µg/L	Unregulated comtaminant monitoring program
Alachlor oxanilic acid (OA)	EPA 535		UCMR	µg/L	Unregulated comtaminant monitoring program
Metolachlor ethane sulfonic acid(ESA)	EPA 535		UCMR	µg/L	Unregulated comtaminant monitoring program
Metolachlor oxanilic acid (OA)	EPA 535		UCMR	µg/L	Unregulated comtaminant monitoring program
General Water Qualtiy Monitoring Parameters					
Biochemical oxygen demand (BOD)	SM5210B		3	mg/L	Process performance monitoring
Color	S2120B		3	ACU	Federal and state secondary drinking water standards
Corrosivity					Federal and state secondary drinking water standards
Odor threshold	S2150B		1	TON	Federal and state secondary drinking water standards
pH	4500HB/E150		0.001	pH units	Process performance monitoring
Specific conductance	ML/S2510B		2	umho/cm	Federal and state secondary drinking water standards
Temperature					Process performance monitoring
Total anion / cation	SM1030E		0.001	meg/L	Process performance monitoring
Total dissolved solids (TDS)	SM2540C		10	mg/L	Federal and state secondary drinking water standards, Process performance
Total organic carbon (TOC)	SM5310C		0.25	mg/L	Process performance monitoring
Turbidity	EPA 180.1		0.05	NTU	Federal and state secondary drinking water standards, Process performance
Other Compounds					
Acetaminiphen	LC-MS-MS		1	ng/L	Other potential AOP byproduct
n-Acetyl-p-benzoquione					Other potential AOP byproduct
1, 4-Dioxane	EPA 522 MOD		0.5	µg/L	CDPH drinking water notification level, process performance monitoring, IAP recommended
1, 2-dipheylhydrazine					Priority pollutant
Formaldehyde					Other potential AOP byproduct
2, 2', 4, 4', 5, 5'-Hexabromobiphenyl (HBB)	EPA 527		UCMR	µg/L	Unregulated comtaminant monitoring program
2, 2', 4, 4', 5, 5'-Hexabromobiphenyl ether (BDE-153)	EPA 527		UCMR	µg/L	Unregulated comtaminant monitoring program
2, 2', 4, 4', 5-Pentabromodiphenyl ether (BDE-99)	EPA 527		UCMR	µg/L	Unregulated comtaminant monitoring program
2, 2', 4, 4', 6-Pentabromodiphenyl ether (BDE-100)	EPA 527		UCMR	µg/L	Unregulated comtaminant monitoring program
2, 2', 4, 4'-Tetrabromodiphenyl ether (BDE-47)	EPA 527		UCMR	µg/L	Unregulated comtaminant monitoring program

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Table I-2
CECs to be Monitored Quarterly

Analyte/Contaminant Group	Method [1]	Turn Around Time	MDL	Units	Rationale
Hormones					
EE2 (17 Alpha-ethynylestradiol)	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
E2 (17 Beta-Estradiol)	API SCIEX 5000 LC-MS-MS		1	ng/L	Identified CEC, SWRCB CEC advisory panel
Andorostenedione	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Estrone	API SCIEX 5000 LC-MS-MS		1	ng/L	Identified CEC, IAP recommended
Norethisterone	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Progesterone	API SCIEX 5000 LC-MS-MS		1	ng/L	Identified CEC
Testosterone	API SCIEX 5000 LC-MS-MS		1	ng/L	Identified CEC
Pesticides / Herbicides					
2,4-D	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Atrazine	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Bromacil	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Chlorotoluron	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Cyanazine	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
DACT (Diaminochlorotriazine)	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
DEA (Deethylatrazine)	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
DIA (Deisopropylatrazine)	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Diuron	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Isoproturon	API SCIEX 5000 LC-MS-MS		20	ng/L	Identified CEC
Linuron	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Metazachlor	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Propazine	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Simazine	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Pharmaceuticals					
Acetaminophen	API SCIEX 5000 LC-MS-MS		1	ng/L	Identified CEC
Albuterol	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Amoxicillin (semi quantitative)	API SCIEX 5000 LC-MS-MS		20	ng/L	Identified CEC
Atenolol	API SCIEX 5000 LC-MS-MS		1	ng/L	Identified CEC
Bendroflumethiazide	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Bezafibrate	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Butalbital	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Carbadox	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Carbamazepine	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC, IAP recommended
Carisoprodol	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Chloramphenicol	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Chloridazon	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Cimetidine	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Dehydronifedipine	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Diazepam	API SCIEX 5000 LC-MS-MS		1	ng/L	Identified CEC
Diclofenac	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Dilantin (Phenytoin)	API SCIEX 5000 LC-MS-MS		20	ng/L	Identified CEC, IAP recommended
Erythromycin (semiquantitative)	API SCIEX 5000 LC-MS-MS		10	ng/L	Identified CEC
Flumeqine	API SCIEX 5000 LC-MS-MS		10	ng/L	Identified CEC
Fluoxetine (semiquantitative)	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Furosemide	API SCIEX 5000 LC-MS-MS		10	ng/L	Identified CEC
Gemfibrozil	API SCIEX 5000 LC-MS-MS		1	ng/L	Identified CEC, IAP recommended, SWRCB CEC advisory panel
Ibuprofen	API SCIEX 5000 LC-MS-MS		1	ng/L	Identified CEC
Ketoprofen	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Ketorolac	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Lidocaine (Semiquantitative)	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Lincomycin	API SCIEX 5000 LC-MS-MS		10	ng/L	Identified CEC
Lopressor	API SCIEX 5000 LC-MS-MS		20	ng/L	Identified CEC
Meclofenamic	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Meprobamate	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC, IAP recommended
Naproxen	API SCIEX 5000 LC-MS-MS		10	ng/L	Identified CEC
Nifedipine	API SCIEX 5000 LC-MS-MS		20	ng/L	Identified CEC
Oxolinic acid	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Pentoxifylline	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Primidone	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Sulfachloropyridazine	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Sulfadiazine	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Sulfadimethoxine	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Sulfamerazine	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Sulfamethazine	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Sulfamethizole	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Sulfamethoxazole	API SCIEX 5000 LC-MS-MS		1	ng/L	Identified CEC, IAP recommended
Sulfathiazole	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Theophylline	API SCIEX 5000 LC-MS-MS		10	ng/L	Identified CEC
Trimethoprim	API SCIEX 5000 LC-MS-MS		1	ng/L	Identified CEC
Warfarin	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Preservative					
Butylparben	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Ethylparaben	API SCIEX 5000 LC-MS-MS		20	ng/L	Identified CEC
Isobuylparaben	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Methylparaben	API SCIEX 5000 LC-MS-MS		20	ng/L	Identified CEC
Propylparaben	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Stimulants					
1,7-dimethylxanthine	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Caffeine	API SCIEX 5000 LC-MS-MS		3	ng/L	Identified CEC, SWRCB CEC advisory panel
Cotinine	API SCIEX 5000 LC-MS-MS		1	ng/L	Identified CEC
Theobromine	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC
Wastewater Indicators					
4-nonylphenol (qualitative)	API SCIEX 5000 LC-MS-MS		100	ng/L	Identified CEC
4-tert-octylphenol	API SCIEX 5000 LC-MS-MS		10	ng/L	Identified CEC
BPA (Bis Phenol A)	API SCIEX 5000 LC-MS-MS		10	ng/L	Identified CEC
Iohexol	API SCIEX 5000 LC-MS-MS		10	ng/L	Identified CEC
Iopromide	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC, IAP recommended, SWRCB CEC advisory panel
PFOS (Perfluoro octanesulfonate)	API SCIEX 5000 LC-MS-MS		0.2	ng/L	Identified CEC
Sucralose	API SCIEX 5000 LC-MS-MS		100	ng/L	Identified CEC, SWRCB CEC advisory panel
TCEP (Tris(2-chloroethyl) phosphate)	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC, IAP recommended
Other Identified CECs					
DEET (N,N-Diethyl-meta-toluamide)	API SCIEX 5000 LC-MS-MS		2	ng/L	Identified CEC, IAP recommended, SWRCB CEC advisory panel
1, 4-Dioxane	EPA 522 MOD		0.5	µg/L	Identified CEC, IAP recommended, process performance
n-Nitrosodimethylamine (NDMA)	EPA 521		2	ng/L	Identified CEC, IAP recommended, process performance, SWRCB CEC advisory panel
Triclosan	API SCIEX 5000 LC-MS-MS		5	ng/L	Identified CEC, SWRCB CEC advisory panel
1, 2, 3-Trichloropropane	EPA 524.2 MOD		0.005	µg/L	IAP recommended
Hydrazine					IAP recommended
Quinoline					IAP recommended

Notes:
1. API SCIEX 5000 LC-MS-MS analytical method represents the most current, peer-reviewed methodology available.

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APPENDIX J – SAMPLING PROCEDURES FOR MICROBIAL PARAMETERS

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BIOVIR LABORATORIES, INC.

EXAMPLE PROCEDURE FOR COLLECTING FILTERED WATER SAMPLES (Using HV Envirochek Capsule Filters) FOR METHOD 1622/23 ANALYSIS

NOTE! The EPA method 1623: Cryptosporidium and Giardia in Water by Filtration/IMS/FA December 2005
Sample arrival temperature requirement is 0° C to < 20°C *
EPA target arrival temperature <10°C

* Adapted from EPA Document. See http;/www.epa.gov/microbes

Example Procedure for Collecting Filtered Water Samples for Method 1622/1623 Analysis

1.0 Required Materials

Have the following materials available prior to sampling:

- Several pair of new latex gloves*
- Sample Data sheet*
- HV Envirochek capsule Filter and Filer Sampling Equipment w/ 10L cubitainer*
- Small Return cooler w/ 250 mL Temperature blank
- Waterproof Sample label*
- Waterproof Pen
- Cooler / vessel for chilling of sample prior to shipment
- Ice for chilling of sample prior to shipping
- 2 plastic liners (bags)*
- 4-5 Gel Pacs (Frozen)* or
- Ice (cubes or crushed) for shipping
- 5 large ziplocks bags*
- Strapping or duct tape to seal cooler prior to shipping
- Shipping air bill (completed by utilities)

2.0 Collecting the Sample from a Pressurized Source

- Put on a pair of latex gloves.
- Flush the system for 2 to 3 minutes until any accumulated stagnant water or debris has cleared, or temperature and turbidity has become visibly uniform before connecting the sampling unit to the tap.
- While system is flushing record following information on the sample data sheet:
  - Public Water System (PWS)Name and Address
  - Sampler Name
  - PWS ID Number
  - Facility Name and PWS facility ID number
  - Sample collection point name and ID number
  - Sample collection date
  - Source water type (required for E. Coli sample forms)
  - Assay Requested (indicate if Regular or Matrix sample)
- After system has flushed, measure and enter water quality parameters such as temperature, turbidity, pH.
- Connect assembled sampling unit to the sample tap **(without capsule filter)** to sample tap, flush sampling unit for 2-3 minutes and test for leaks, and slowly adjust up an adequate flow. **(maximum** values 100 psi w/ flow restrictor).
- Turn off sample tap, install filter capsule **(retain blue vinyl caps)**, insert three (3) foot length tubing into effluent 10L cubitainer .
- Record start time on sample data sheet. Slowly turn on sample tap. When 10L cubitainer has reached fill mark, turn off sample tap. Record stop time
- **If taking a Matrix spike sample with this sample the two volumes must be the same (within 10%)**
- Hold Capsule filter (inlet pointing up), remove tubing allowing water to drain through the “out port” of the filter. Open bleed valve to speed draining process, and disconnect tubing from capsule filter.
- Seal capsule filter ends with blue caps, close bleed valve, and place into gallon ziplock bag. Seal and place into a second ziplock bag (ie. Double bag)

3.0 Pre-Chilling of Filter

*Supplied if Requested

- Place bagged filter and temperature blank into an ice bath. The filter will float semi- submerged in the ice water.
- A 25˚C filter and temperature blank will chill to approximately 6˚C in 1.5 hours
- Filter and temperature blank should be stored between 0 - 8˚C from time of filtration.
- Sample testing must be completed within 96 hours of sample collection.

4.0 Packing and Shipping the Sample Using Ice Cubes/Crushed Ice

- Create a double liner by inserting one plastic liner into the other. Line the cooler with the liners
- Divide 8-lbs of ice(cubes or crushed) into the ziplock bags, expel as much air as possible then seal. Secure the ends with tape.˚
- Place the chilled filter and temperature blank into the sample cooler, cover with a layer of bubble wrap or similar material. Place an ice pack on top of the insulating material.
- Seal each liner by twisting the top of each bag, and secure with tape.
- Place the completed sample data sheet (chain of custody) into a ziplock bag, seal and tape to the inside cooler lid.
- Close and seal the cooler lid.
- Attach your completed air bill to the cooler, retain sender copy. Send to processing lab
- Alert BioVir at least 24 hours prior to sample shipment date. Indicate courier used and request BioVir contact client if sample not received.
- If problems are encountered with the shipment, communicate with the shipping company and BioVir to resolve.

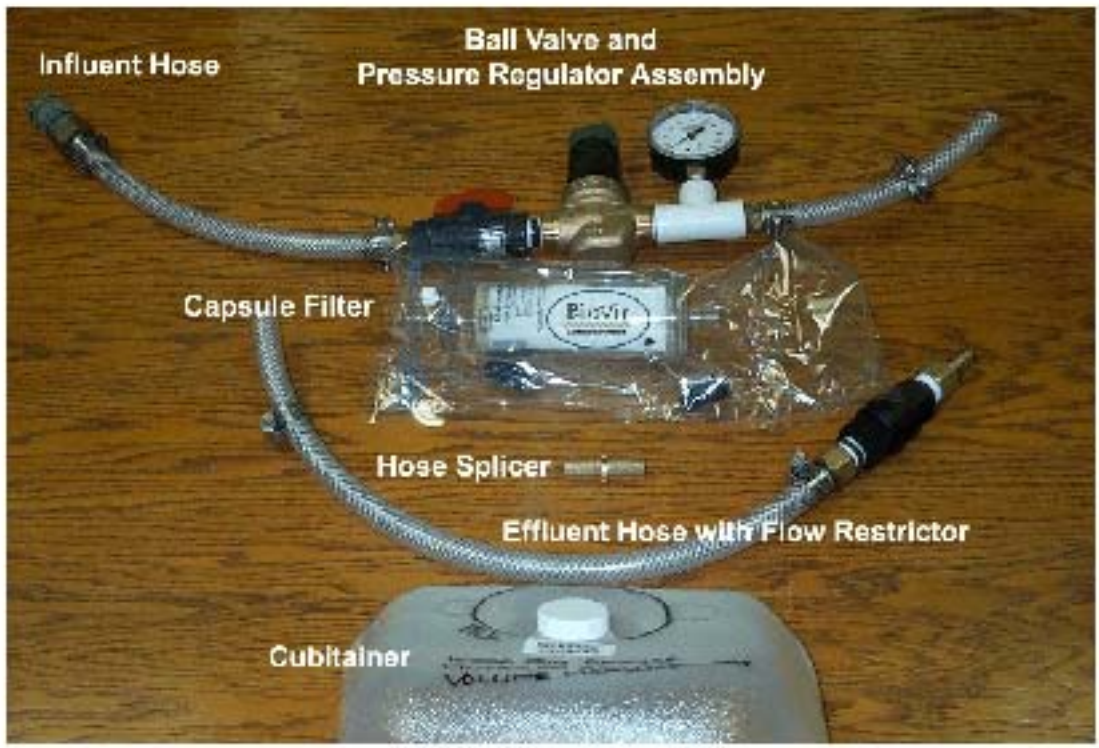
5.0 Packing and Shipping Sample Using Frozen Gel Pacs

- Create a double liner by inserting one bag liner into the other. Line cooler with the liners.
- Place each **FROZEN** gel pac into a ziplock.
- Place the pre-chilled filter and temperature blank into cooler, cover with a layer of bubble wrap or similar material. Place a frozen gel pac on each side and on top of the filter and temperature blank.
- Seal each liner by twisting the top of each bag, and securing with tape.
- Place the completed sample data sheet (chain of custody) into a ziplock, seal and tape to the inside cooler lid.
- Close and seal the cooler lid.
- Attach your completed air bill to the cooler, retain sender copy. Send to processing lab
- Alert BioVir at least 24 hours prior to sample shipment date. Indicate courier used and request BioVir contact client if sample not received.
- If problems are encountered with the shipment, communicate with the shipping company and BioVir to resolve.

NOTE ! It is very important to use the double liners and ziplocks to prevent leakage from the sample cooler. Shipping companies may delay shipment if leakage occurs.

*Supplied if Requested

EPA Method 1623 Field Concentrating Apparatus

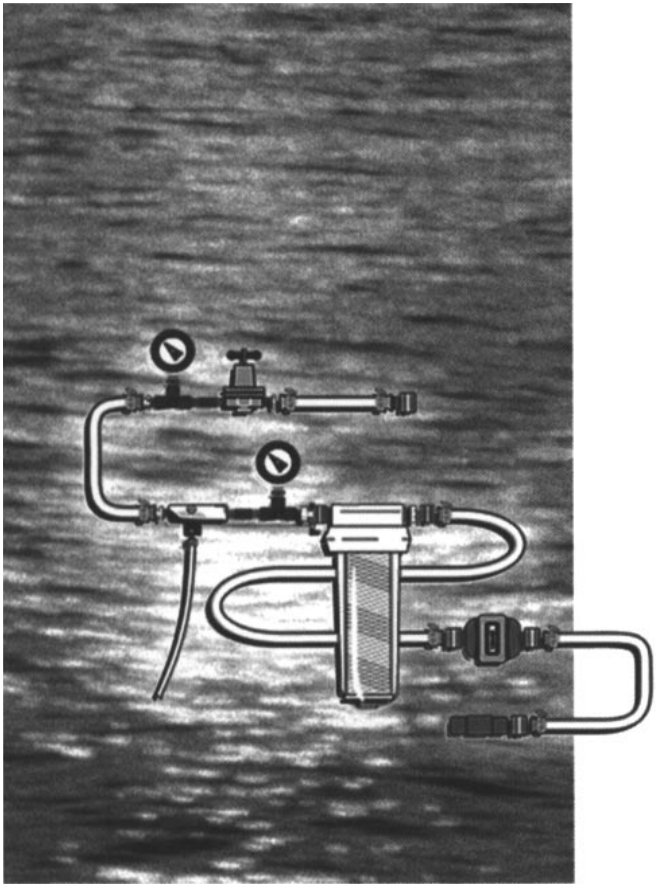


United States
Environmental
Protection Agency

Office of Ground Water
and Drinking Water
Washington, DC 20460

EPA/814-B-95-001
June 1995

Information Collection Requirements Rule— Protozoa and Enteric Virus Sample Collection Procedures



About This Manual

This manual is designed to be brought into the field by drinking water utility personnel when collecting source and finished water samples for protozoa and viruses. The sample collection steps in this manual are consistent with those demonstrated in the accompanying video. To further associate the steps in this manual with the sampling demonstration on the video, the photos for each step are taken directly from the video.

Several graphic conventions are used throughout the manual to differentiate steps or denote special actions:

A step icon is used at the beginning of each step. These steps are parallel to those in the accompanying video.

Actions denoted by this icon are critical to ensuring that the sample will be valid and uncontaminated, such as putting on fresh latex gloves before handling the filter.

Text denoted by this icon provides additional information to the samplers, but may not be part of the actual collection procedure.

Collecting protozoan and virus samples correctly under the Information Collection Requirements Rule can be challenging. Please watch the demonstration video before collecting the samples, and be sure to follow each step in this manual when in the field.

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Protozoan and Enteric Virus Sample Collection Procedures as Defined by the Information Collection Requirements Rule

This manual describes the procedures for collecting source water and finished water samples for protozoan and enteric virus monitoring under the Information Collection Requirements (ICR) rule. This manual and the accompanying video comprise a two-part set of instructional materials that provide public water supply systems with the information needed to properly collect samples for protozoan and virus monitoring. All water utility personnel involved with ICR monitoring should watch the video and review this manual before collecting any samples.

The protozoan collection procedures described in this manual and in the video are based on the procedures in the ICR Protozoan Method for Detecting *Giardia* cysts and *Cryptosporidium* Oocysts in Water by a Fluorescent Antibody Procedure. The total culturable virus collection procedures described in this manual and in the video are based on the procedures in the Virus Monitoring Protocol for the Information Collection Rule. Both of these methods can be requested by calling the Safe Drinking Water Hotline, at (800) 426-4791.

Questions Commonly Asked by Drinking Water Utilities

What is the purpose of the ICR rule?

The ICR rule was developed by EPA to collect occurrence, exposure, and treatment data on drinking water pathogens and disinfectant by-products. The pathogen data are needed to determine whether current Surface Water Treatment Regulations should be revised to include new or more stringent treatment levels for some microbes. The disinfectant by-product data are needed to determine whether to regulate the chemical by-products that form when disinfectants react with organic chemicals in source water.

Although drinking water utilities will be involved in collecting both disinfectant by-product and waterborne pathogen data under the ICR rule, this manual describes the utility's role in collecting data on drinking water pathogen occurrence.

What pathogens are monitored under the ICR rule?

The ICR rule requires public water supply systems to monitor source water (and finished water in some cases) for the following pathogens:

- *Giardia* cysts
- *Cryptosporidium* oocysts
- Total culturable viruses
- Fecal coliform or *Escherichia coli* bacteria
- Total coliform bacteria

EPA is considering revising the current Surface Water Treatment Regulations because existing treatment levels for *Giardia* and viruses

may not be adequate to protect public health for systems supplied by poor-quality source water and because of the new threat posed by *Cryptosporidium*.

Giardia cysts in drinking water cause more reported waterborne disease outbreaks than any other single known pathogen. They also are more resistant to environmental stresses and disinfection than almost all other known waterborne pathogens.

Cryptosporidium oocysts in drinking water have caused major waterborne disease outbreaks in the U.S. and other countries and are even more resistant to disinfection than *Giardia*.

Several enteric viruses have caused waterborne disease and may be responsible for many, if not most, of the outbreaks where a causative agent was not identified (about half of all reported outbreaks). Adequate analytical methodology is not yet available for routine analysis for many enteric viruses, so EPA has required monitoring of total culturable viruses. Total culturable viruses are a group of enteric viruses commonly found in poor-quality waters and which EPA believes are at least somewhat representative of other pathogenic viruses. Monitoring for total culturable viruses is useful because this group contains pathogens and is a potential indicator of other viral pathogens.

Fecal coliforms, *E. coli*, and total coliforms have been used for decades to assess source water quality. Coliform bacteria are much more sus-

ceptible to environmental stress and disinfection than protozoa and viruses, and would be eliminated by any system that eliminated more resistant pathogens. However, the ICR rule requires drinking water utilities to submit coliform monitoring data as general indicators of water quality. Monitoring procedures for fecal coliform, *E. coli*, and total coliform densities have been established and are not addressed by this manual.

Which drinking water utilities have to collect protozoan and virus samples?

Public water supply systems that serve between 10,000 and 100,000 people and use surface water (or groundwater under the influence of surface water) are required to monitor their source water for *Giardia* cysts and *Cryptosporidium* oocysts.

Public water supply systems that serve more than 100,000 people and use surface water (or groundwater under the influence of surface water) are required to monitor their source water for *Giardia* cysts, *Cryptosporidium* oocysts, and total culturable viruses. If pathogen densities in the source water exceed 1 pathogen per liter during the first 12 months of monitoring, then public water supply systems also must sample finished water for the remaining months.

How often must samples be taken?

Public water supply systems that serve between 10,000 and 100,000 people must collect samples every two months for 12 months.

Systems that serve more than 100,000 people must take samples every month for 18 months.

However, these systems may discontinue monitoring if:

- Viruses are not detected in the source water during the first 12 months of monitoring, or
- Source water has been tested for either total coliforms or fecal coliforms at least five times per week for four months before and two months after the effective date of the ICR and the total coliform density is less than 100 colonies/100 mL or the fecal coliform density in 90 percent of all samples is less than 20 colonies/100 mL.

Where should samples be collected?

Samples must be taken at the intake of each treatment plant. If a plant has several sources of water, the system must sample the blended water from all sources. If this is not possible, the source with the highest expected pathogen concentration should be sampled.

Who will analyze the samples?

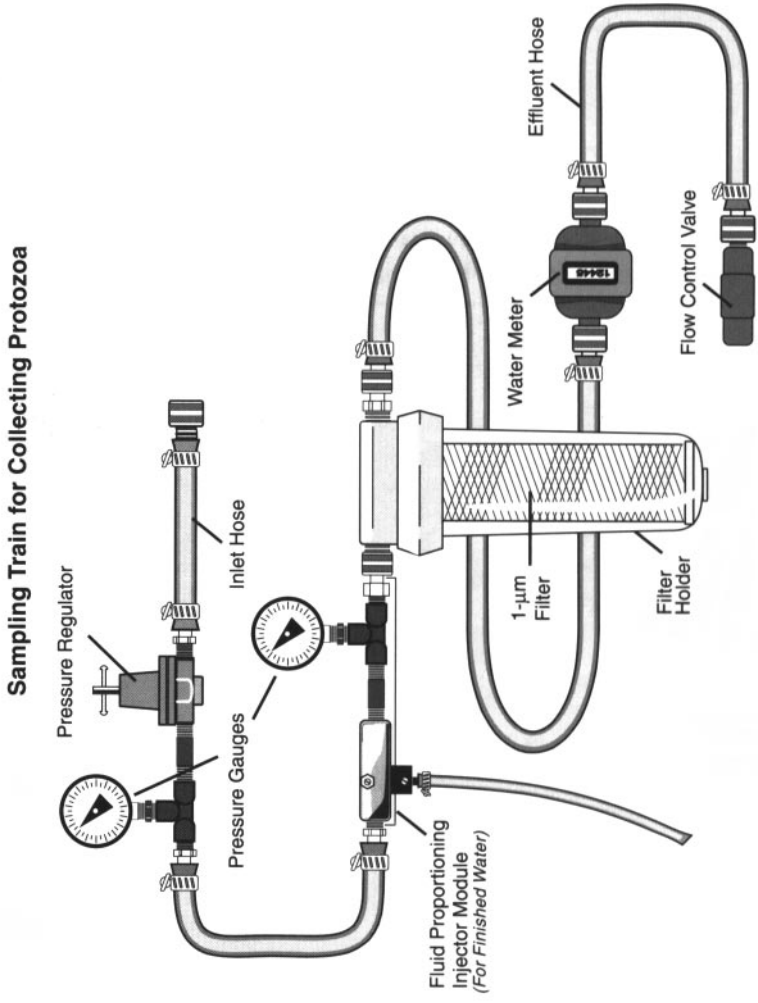
EPA has approved several laboratories to analyze the protozoan and virus samples. Before collecting samples, you must arrange to have them analyzed by an EPA-approved laboratory.

If you have not already located an approved laboratory, notify:

ICR Laboratory Coordinator
EPA Office of Ground Water & Drinking Water
26 West Martin Luther King Drive
Cincinnati, Ohio 45268.

EPA will provide you with a list of approved laboratories or other appropriate guidance.

Sample Collection Procedures for Detecting Protozoa in Water


Sampling Train for Collecting Protozoa
Pressure Regulator
Inlet Hose
Pressure Gauges
Fluid Proportioning Injector Module
(For Finished Water)
1-µm Filter
Water Meter
Filter Holder
Effluent Hose
Flow Control Valve

STEP 1 Each month, your laboratory will send you all of the equipment needed to collect samples for *Giardia* cyst and *Cryptosporidium* oocyst analyses. When you receive the sampling kit, check the contents of the carton. The sampling kit should contain the following items:

- ❑ Sampling train for collecting protozoa (left):
  - Inlet hose
  - Pressure regulator with pressure gauge
  - Fluid proportioning injector module, including an injector and pressure gauge*
  - 1-µm nominal porosity filter and holder made by Parker Hannifan or Filterite
  - Water meter
  - Effluent hose and flow control valve

*Needed for finished water sample collection only

- ❑ Plastic sample bags
- ❑ Ice packs for shipping the collected samples
- ❑ Sample labels

If you are missing any items, contact your laboratory immediately. Do not attempt to collect the samples without a complete sampling kit.

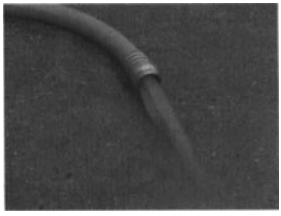
STEP 2 Once you have verified the contents of the sampling kit, place the ice packs in the freezer and repack the box for later use.

COLLECTING SOURCE WATER SAMPLES

When you are ready to collect your protozoa sample, bring the following items with you to the sampling location:

- ❑ Shipping container sent by the laboratory
- ❑ Sampling apparatus
- ❑ Plastic sample bags
- ❑ Sample labels
- ❑ Frozen ice packs
- ❑ Several pairs of new latex gloves
- ❑ pH meter
- ❑ Thermometer
- ❑ Turbidimeter

! If you will be collecting samples from both source water and finished water on the same day, perform the finished water sampling first. Using the sampling apparatus on source water first may cause false positives for finished water sample analyses.

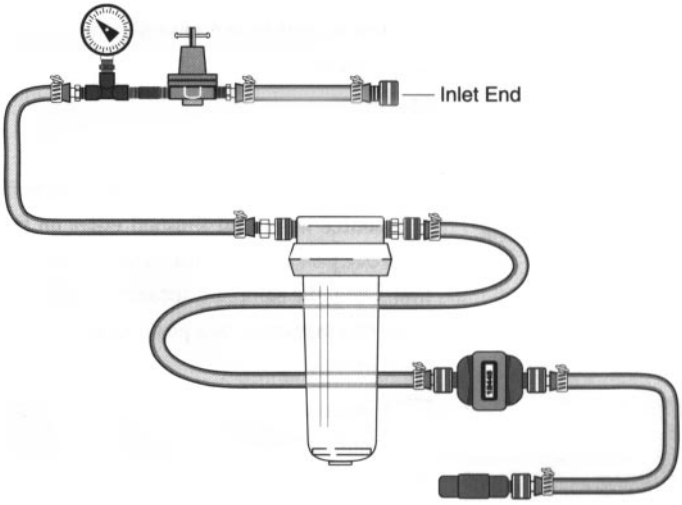


3 Turn on the water at the tap and allow the water to flow for 2 to 3 minutes or until any debris that has accumulated in the sampling line has cleared or the turbidity in the water becomes uniform.

Turn off the water at the tap.

4 Put on new latex gloves to prevent contamination from outside sources. Sterile technique must be used when sampling for *Giardia* and *Cryptosporidium*. Any contamination of the sampling apparatus may bias the final results.

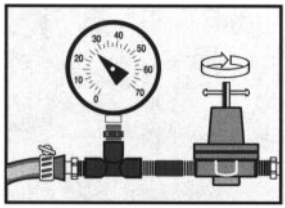
Assemble the sampling apparatus as shown below and connect the inlet end of the sampling apparatus to the sampling tap or to an extension hose connected to the tap.



! Be sure that the filter housing does *not* contain the filter.

Note the water meter reading, then slowly turn on the water.

5 Using the pressure regulator, adjust the water pressure to no more than 30 psi. Flush the sampling apparatus with 20 gallons/ 76 liters of water by allowing the water to flow through the system and out the effluent hose.



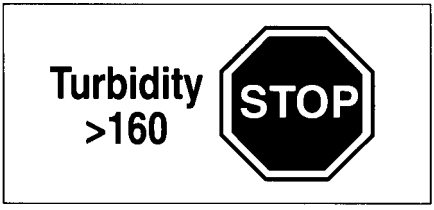
Sampling Step	Volume In GALLONS	Volume In LITERS	Volume In FT^3
System Flush	20	76	2.7

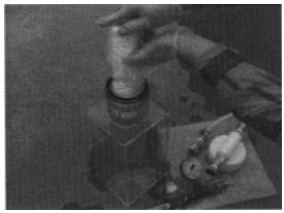
While the water is flushing the sampling apparatus, begin completing your sample label. Record the following information:

- Sampler's name
- Date
- Sample location

Stop Time:_____ Meter Reading:_____ Turbidity:_____
Start Time:_____ Meter Reading:_____ Turbidity:_____
Operator Name:_____ Total Volume Filtered:_____
Date:_____ Sampling Location:_____

6 Measure the turbidity of the source water flowing from the effluent hose. Record the readings on the sample label. If the turbidity is greater than 160 Nephelometric Turbidity Units (NTU), sampling should be rescheduled for a day when the turbidity is lower.





STEP 7 After the system has been flushed with 20 gallons / 76 liters of water, turn off the tap and disconnect the inlet and outlet hoses from the filter housing.

Using the filter wrench, open and drain the filter housing.

Open the filter packaging as aseptically as possible and carefully drop the filter into the filter housing.

! Be sure to hold the loose gasket in place using aseptic technique.

Reassemble the filter housing, and reconnect the inlet and outlet hoses. Place the filter housing in an upright position.

Slowly, turn on the tap and start the water flowing through the sampling apparatus.

Using the pressure regulator, adjust the pressure to no more than 30 psi.

Record the following information on the sample label:

- Time sampling started
- Initial water meter reading (including units)
- Turbidity

Stop Time: _____	Meter Reading: _____	Turbidity: _____
Start Time: _____	Meter Reading: _____	Turbidity: _____
Operator Name: _____	Total Volume Filtered: _____	
Date: _____	Sampling Location: _____	

Monitor the water meter to ensure that the flow rate does not exceed 1 gallon/min (approximately 4 liters/min).

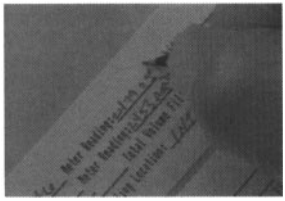
8 Allow at least 26 gallons/100 liters of water to pass through the filter. At a flow rate of approximately 1 gallon/minute, this will require about 30 minutes.

Sampling Step	Volume In GALLONS	Volume In LITERS	Volume In FT^3
Protozoa Flow Rate	1 per minute	4 per minute	.13 per minute
Protozoa Source Water Sample	26	100	3.5

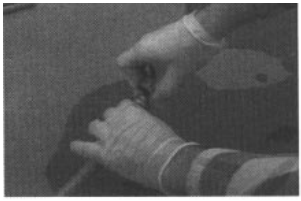
9 When the water meter indicates that 26 gallons/100 liters of water have passed through the filter, turn off the water at the tap.

Record the following information on the sample label:

- Time sampling stopped
- Final water meter reading (including units)
- Final turbidity
- Total volume filtered



Stop Time: _____ Meter Reading: _____ Turbidity: _____
Start Time: _____ Meter Reading: _____ Turbidity: _____
Operator Name: _____ Total Volume Filtered: _____
Date: _____ Sampling Location: _____

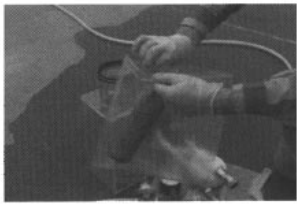


STEP 10 Disconnect the sampling apparatus from the water tap.

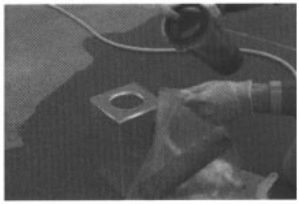
! Be sure to hold the inlet hose *above the level of the outlet hose opening* while the water drains from the housing. This will prevent backwash and loss of particulate matter from the filter.

Disconnect the inlet and outlet hoses from the filter housing.

! Put on fresh latex gloves.



STEP 11 As aseptically as possible, remove the filter from the housing and put it into a plastic sample bag.



STEP 12 Pour all of the water remaining in the filter housing into the same plastic bag.

STEP 13 Seal the plastic sample bag and place it inside the second plastic sample bag. Transfer the label or label information to the outside of the outer bag.

14 Put the bags containing the filter into the shipping container. Place the ice packs around, but not on, the sample bag to prevent freezing the sample. You may want to insert several inflated, empty sample bags between the sample and the ice packs.

15 Seal the container and follow the laboratory's instructions related to the cleaning, storage, and return of sampling equipment.

16 Ship the container by overnight courier to the laboratory. Call the laboratory and notify them of the sample shipment.

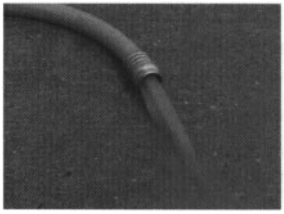
COLLECTING FINISHED WATER SAMPLES

If *Giardia* or *Cryptosporidium* concentrations in your source water samples exceed 1 per liter during the first 12 months of sampling, then you must monitor finished water as well as source water. If you are required to collect samples from both, collect the finished water sample first, then the source water sample.

Receiving and verifying the contents of your sampling kit are addressed in **STEPS 1** and **2** of the source water sampling section.

When you are ready to collect your finished water protozoa sample, bring the following items with you to the sampling location:

- ❑ Shipping container sent by the laboratory
- ❑ Sampling apparatus
- ❑ Fluid proportioning injector (for adding 2% thiosulfate solution to neutralize effects of chlorination or other disinfectant treatments)
- ❑ Plastic sample bags
- ❑ Sample labels
- ❑ Frozen ice packs
- ❑ Several pairs of new latex gloves
- ❑ Approximately 2 gal (4 L) of 2% sodium thiosulfate solution
- ❑ Sterile, 250- or 500-mL graduated cylinder
- ❑ Thermometer

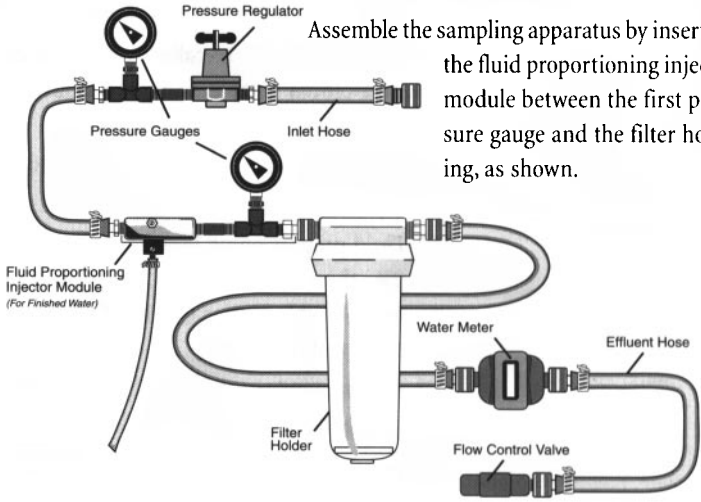


STEP 3 Turn on the water at the tap and allow the water to flow for 2 to 3 minutes or until any debris that has accumulated in the sampling line has cleared or the turbidity in the water becomes uniform.

Turn the water off at the tap

STEP 4 Put on new latex gloves to prevent contamination from outside sources. Sterile technique must be used when sampling for *Giardia* and *Cryptosporidium*. Any contamination of the sampling apparatus may bias the final results.

Assemble the sampling apparatus by inserting the fluid proportioning injector module between the first pressure gauge and the filter housing, as shown.

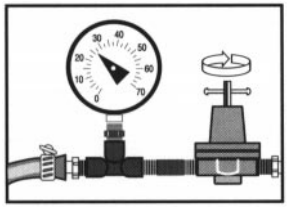


Connect the inlet end of the sampling apparatus to the sampling tap or to an extension hose connected to the tap.

Be sure that the filter housing does NOT contain the filter.

Note the water meter reading, then slowly turn on the water.

5 Using the pressure regulator, adjust the water pressure on the first pressure gauge to no more than 30 psi.



Flush the sampling apparatus with 20 gallons/ 76 liters of water by allowing the water to flow through the system and out the effluent hose.

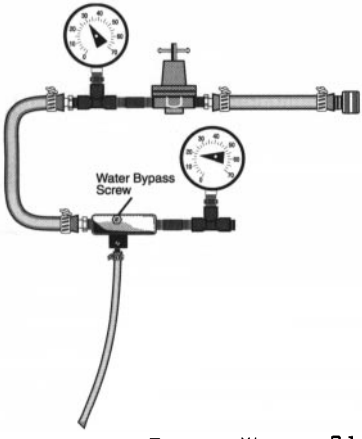
While the water is flushing the sampling apparatus, begin completing your sample label. Record the following information:

- Sampler's name
- Date
- Sample location

Stop Time: _____	Meter Reading: _____	Turbidity: _____
Start Time: _____	Meter Reading: _____	Turbidity: _____
Operator Name: _____	Total Volume Filtered: _____	
Date: _____	Sampling Location: _____	

6 Now, you must adjust the thiosulf injector.

First, using the water bypass screw, the larger top screw in the injector, adjust the pressure on the downstream pressure gauge to be at least 35% less than the pressure shown on the upstream gauge. For ample, if the upstream gauge reads 30 then the second gauge should read no m than 19psi.



Pour the 2% sodium thiosulfate solution into a graduated cylinder. Place the injector tube in the thiosulfate solution, and adjust the smaller injector screw, located on the bottom of the injector, so that the flow rate of the 2% thiosulfate solution is approximately 10 milliliters per minute.

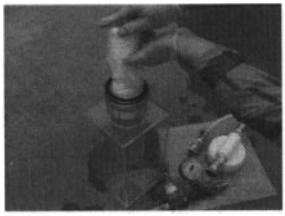
! If there is no suction visibly drawing down the thiosulfate solution, or if too much is flowing, adjust the water bypass screw further to increase or decrease the pressure differential between the two gauges. A greater differential between the upstream and downstream gauges increases the flow rate; a smaller differential decreases the flow rate.

After the thiosulfate flow rate is adjusted properly, transfer the injector tube to a carboy of thiosulfate. You will need to monitor this rate visually throughout sampling to ensure that an adequate amount of thiosulfate is being added to neutralize all of the disinfectants.

Turn off the water at the tap and empty the water in the filter housing.

7 Open the filter packaging as aseptically as possible and carefully drop the filter into the filter housing.

! Hold the loose gasket in place.



Reassemble the filter housing, and reconnect the inlet and outlet hoses.

Slowly, start the water flowing through the sampling apparatus.

Using the pressure regulator, adjust the pressure on the upstream pressure gauge to no more than 30 psi. Using the water bypass screw, readjust the downstream pressure gauge to read 35% less than the upstream gauge, if necessary.

Record the following information on the sample label:

- Time sampling started
- Initial water meter reading (including units)
- Turbidity

Stop Time: _____	Meter Reading: _____	Turbidity: _____
Start Time: _____	Meter Reading: _____	Turbidity: _____
Operator Name: _____	Total Volume Filtered: _____	
Date: _____	Sampling Location: _____	

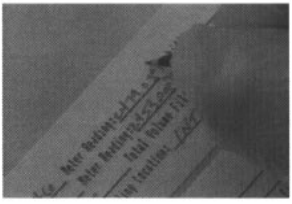
Place the filter housing in an upright position.

Monitor the water meter to ensure that the flow rate does not exceed 1 gallon/min (approximately 4 liters/min).

STEP 8 Allow at least 264 gallons/1000 liters of water to pass through the filter. At a flow rate of approximately 1 gallon/minute, this will require about 4 hours and 45 minutes.

Sampling Step	Volume In GALLONS	Volume In LITERS	Volume In FT^3
Protozoa Flow Rate	1 per minute	4 per minute	.13 per minute
Protozoa Finished Water Sample	264	1000	36

STEP 9 When the water meter indicates that 264 gallons/1000 liters of water have passed through the filter, turn off the water at the tap.



Record the following information on the sample label:

- Time sampling stopped
- Final water meter reading (including units)
- Final turbidity
- Total volume filtered

Stop Time:_____ Meter Reading:_____ Turbidity:_____
Start Time:_____ Meter Reading:_____ Turbidity:_____
Operator Name:_____ Total Volume Filtered:_____
Date:_____ Sampling Location:_____

STEP 10 Disconnect the sampling apparatus from the water tap.

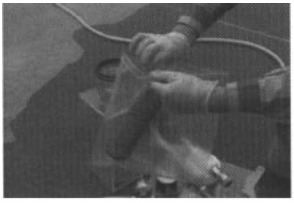
! Be sure to hold the inlet hose *above the level of the outlet hose opening* while the water drains from the housing. This will pre-

vent backwash and loss of particulate matter from the filter.

Disconnect the inlet and outlet hoses from the filter housing.

Put on fresh latex gloves.

11 As aseptically as possible, remove the filter from the housing and put it into a plastic sample bag.



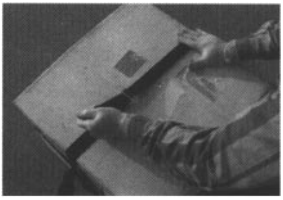
12 Pour all of the water remaining in the filter housing into the same plastic bag.

13 Seal the plastic sample bag and place it inside the second plastic sample bag.

Transfer the label or label information to the outside of the outer bag.

14 Put the bags containing the filter into the shipping container.

Place the ice packs around, but not on, the sample bag to prevent freezing the sample. You may want to insert several inflated, empty sample bags between the sample and the ice packs.



15 Seal the container and follow the laboratory's instructions related to the cleaning, storage, and return of sampling equipment.

16 Ship the container by overnight courier to the laboratory.

Call the laboratory and notify them of the sample shipment.

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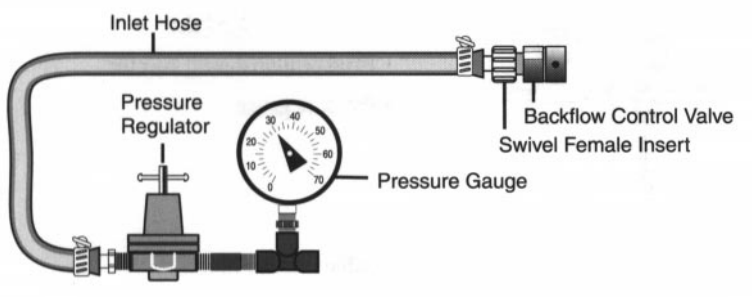
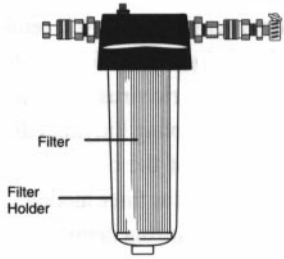
Sample Collection Procedures for Detecting Enteric Viruses in Water

STEP 1 Each month, your laboratory will send you all of the equipment needed to collect samples for enteric virus analyses. When you receive the sampling kit, immediately check the contents of the carton. The sampling kit will be shipped as three modules, and should contain the following items:

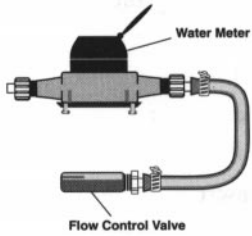
- ❑ Plastic sample bags
- ❑ Ice packs for shipping the collected samples
- ❑ Sample data sheet
- ❑ Regulator Module (below):
  - Backflow control valve
  - Swivel female insert
  - Inlet hose
  - Pressure regulator with pressure gauge





❑ Cartridge Housing Module:

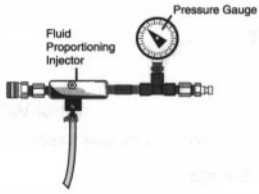
- 1-MDS Zetapor Virosorb filter inside a filter holder



❑ Discharge Module:

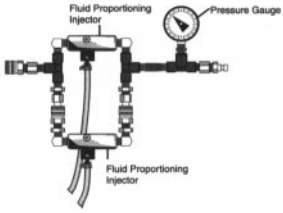
- Water meter
- Flow control valve

The laboratory will also ship three additional modular sections, as required by your facility. These may include:



❑ Single Injector Module:

- Fluid proportioning injector
- Pressure gauge

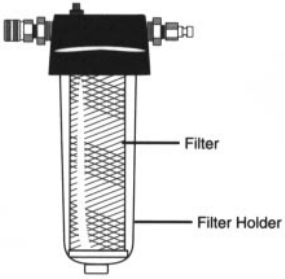


❑ Double Injector Module:

- Two fluid proportioning injectors, in parallel
- Pressure gauge

❑ Prefilter Module:

- 10 µm polypropylene filter inside a filter holder



! The ends of each module should be wrapped in foil to ensure that the equipment remains free of contamination. If your modules are unprotected or compromised, please contact your laboratory immediately for further instructions.

If you are missing any items, contact your laboratory immediately. Do not attempt to collect the samples without a complete sampling kit.

Once you have verified the contents of the sampling kit, place the ice packs in the freezer and repack the box.

COLLECTING SOURCE WATER SAMPLES

When you are ready to collect your virus sample, bring the following items with you to the sampling location:

- ❑ Shipping container sent by the laboratory
- ❑ Regulator Module
- ❑ Cartridge Housing Module
- ❑ Discharge Module
- ❑ Single Injector Module (for adding 0.1-molar hydrochloric acid to adjust pH, if necessary)
- ❑ Prefilter Module (for filtering sediment from highly turbid water, if necessary)
- ❑ Approximately 2 gal (4 L) of 0.1-molar hydrochloric acid solution (for adjusting pH, if necessary)
- ❑ Sterile, 250- or 500-mL graduated cylinder
- ❑ Plastic sample bags
- ❑ Sample data sheet
- ❑ Frozen ice packs
- ❑ Several pairs of new latex gloves
- ❑ pH meter
- ❑ Thermometer
- ❑ Turbidimeter

2 Turn on the water at the tap and allow the water to flow for 2 to 3 minutes or until any debris that has accumulated in the sampling line has cleared or the turbidity in the water becomes uniform.

3 Put on new latex gloves to prevent contamination from outside sources. Sterile technique must be used when sampling for enteric viruses. Any contamination of the sampling apparatus may bias the final results.

Turn off the water at the tap.

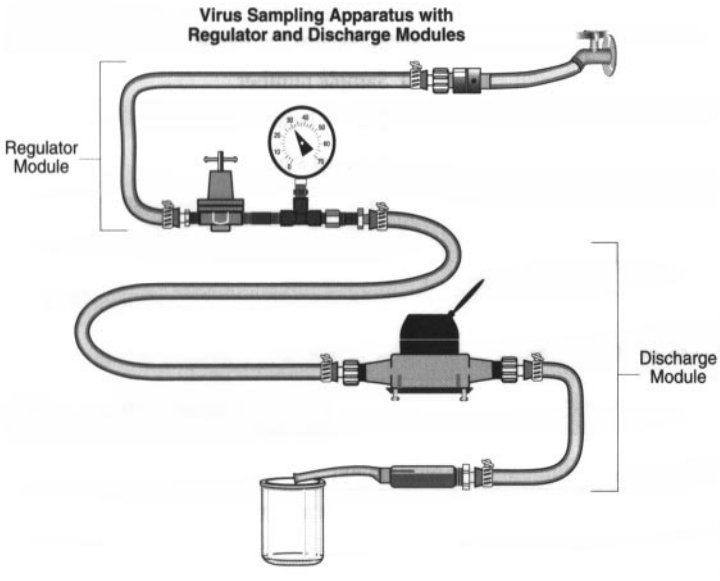
Remove the foil from the backflow regulator on the Regulator Module and connect it to the water tap or to an extension hose connected to the tap.

Remove the foil from the other end of the Regulator Module and from the Discharge Module. Connect the Discharge Module to the Regulator Module.

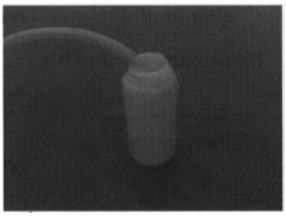
Place the end of the Discharge Module, or an extension hose connected to the Discharge Module, into a 1-liter plastic bottle.

Note the water meter reading, then slowly turn on the water.

Using the pressure regulator, adjust the water pressure to no more than 30 psi.



4 Flush the sampling apparatus with 20 gallons / 76 liters of water by allowing the water to flow through the system, out the effluent hose into the 1-liter plastic bottle.



Sampling Step	Volume In GALLONS	Volume In LITERS	Volume In FT^3
System Flush	20	76	2.7

While the water is flushing the sampling apparatus, begin completing your sample data sheet. Record the following information:

- ❑ Sample number
- ❑ System location
- ❑ Sampler's name

SAMPLE DATA SHEET			
SAMPLE NUMBER:			
SYSTEM LOCATION:			
SAMPLER'S NAME:			
WATER pH:	**WATER TEMPERATURE:**	**°C**	**TURBIDITY:** **NTU**
INIT. METER READING:	**(CHECK UNITS)**	**__ft³**	**__gallons**
date:	**time:**		
FINAL METER READING:	**(CHECK UNITS)**	**__ft³**	**__gallons**
date:	**time:**		
TOTAL SAMPLE VOLUME:		**liters**	
(Final-Initial meter readings x 28.316 (for readings in ft³) or x 3.7854 (for readings in gallons))			
CONDITION ON ARRIVAL:			
COMMENTS:			

5 Measure the pH, temperature, and turbidity of the source water flowing from the effluent hose. Record the readings on the sample data sheet.

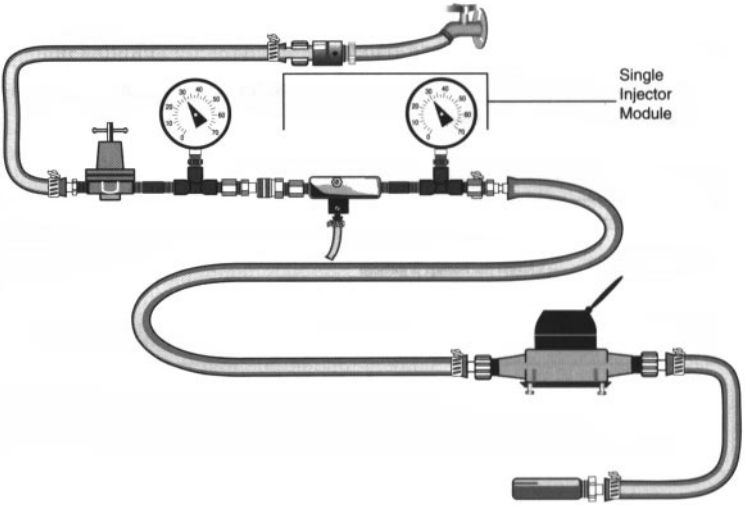
SAMPLE DATA SHEET			
SAMPLE NUMBER:			
SYSTEM LOCATION:			
SAMPLER'S NAME:			
WATER pH:	**WATER TEMPERATURE:**	**°C**	**TURBIDITY:** **NTU**
INIT. METER READING:	**(CHECK UNITS)**	**__ft³**	**__gallons**
date:	**time:**		
FINAL METER READING:	**(CHECK UNITS)**	**__ft³**	**__gallons**
date:	**time:**		
TOTAL SAMPLE VOLUME:		**liters**	
(Final-Initial meter readings x 28.316 (for readings in ft³) or x 3.7854 (for readings in gallons))			
CONDITION ON ARRIVAL:			
COMMENTS:			

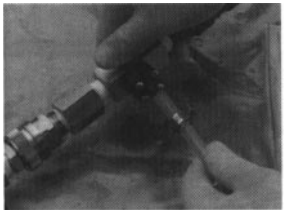
6 Turn off the water at the tap and decide whether you need to insert additional modules into the sampling train.

For source water sampling, you may need to use the Single Injector Module and/or the Pre-filter Module.

First, determine if you need to use the Single Injector Module.

If your pH value is greater than 8.0, you need to insert the Single Injector Module between the Regulator and Discharge Modules before proceeding.

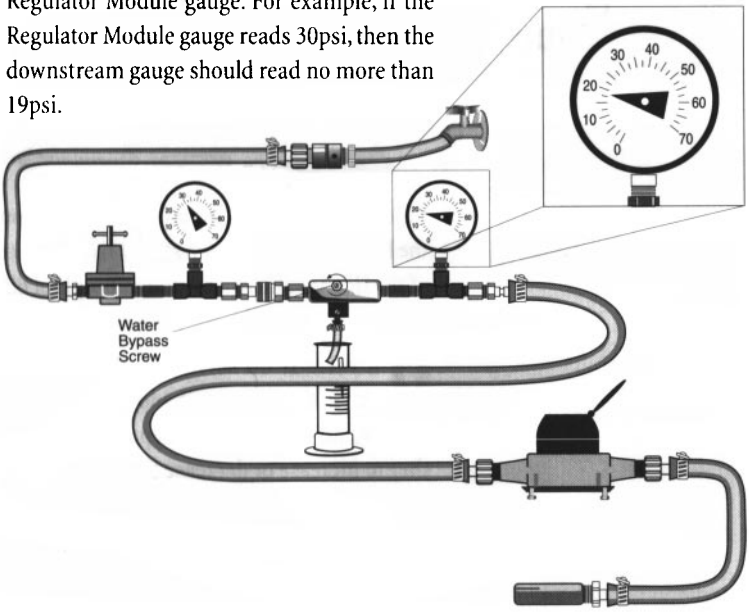


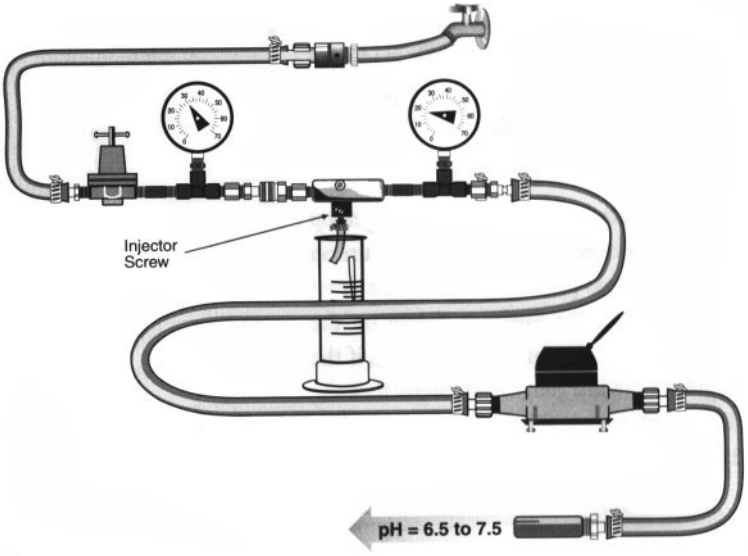


Using aseptic technique, connect the sterile tubing to the injector. Fill the sterile graduated cylinder with 0.1-molar HCl and place the tube in the graduated cylinder.

Turn on the water at the tap.

Using the water bypass screw—the larger top screw in the injector—adjust the pressure on the downstream pressure gauge to be at least 35% less than the pressure shown on the Regulator Module gauge. For example, if the Regulator Module gauge reads 30psi, then the downstream gauge should read no more than 19psi.





Adjust the smaller injector screw, located on the bottom of the injector, so that the flow rate of the HCl is sufficient to maintain a pH of 6.5 to 7.5.

! If there is no suction visibly drawing down the HCl, or if too much HCl is flowing, adjust the water bypass screw further to increase or decrease the pressure differential between the two gauges. A greater differential between the upstream gauges increases the flow rate; a smaller differential decreases the flow rate.

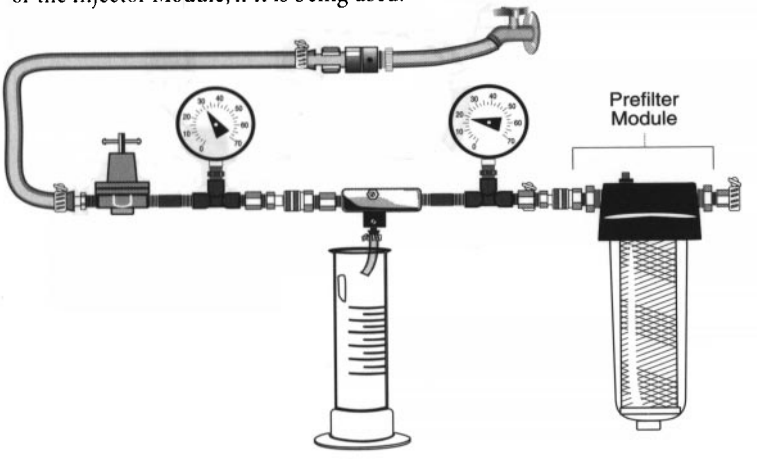
After the HCl flow rate is adjusted properly, transfer the injector tube to a carboy of HCl. Periodically check the pH to ensure that sufficient HCl is being added to maintain a pH of 6.5 to 7.5.

Record the adjusted pH on the Sample Data Sheet.

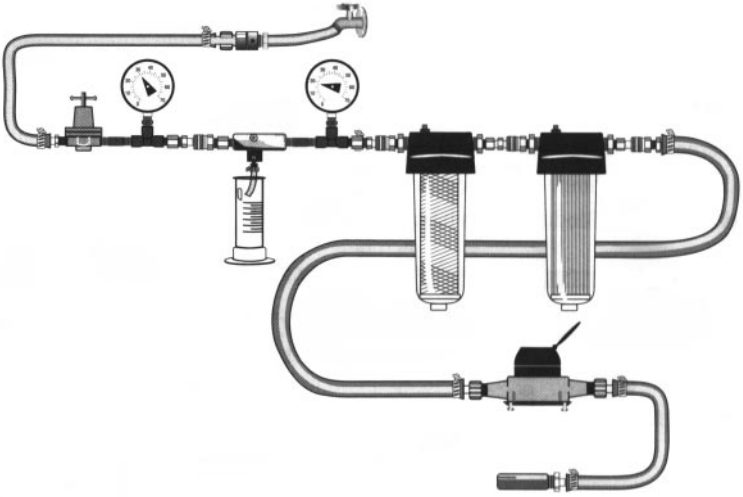
Next, determine if you need to use the Prefilter Module.

Turn off the water at the tap, and note the turbidity. If the turbidity is greater than 75 NTU, or for conditions where the 1-MDS filter is expected to clog before sampling is completed, you will need to use the Prefilter Module.

Disconnect the Discharge Module and connect the Prefilter Module to the Regulator Module or the Injector Module, if it is being used.



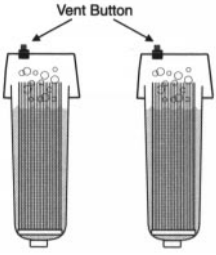
7 Connect the Cartridge Housing Module containing the 1-MDS filter to the Prefilter Module. Then, reconnect the Discharge Module to the outlet end of the Cartridge Housing Module.



Record the following information on the Sample Data Sheet:

- ❑ Date sampling started
- ❑ Time sampling started
- ❑ Initial water meter reading (including units)

SAMPLE DATA SHEET			
SAMPLE NUMBER:			
SYSTEM LOCATION:			
SAMPLER'S NAME:			
WATER pH:	**WATER TEMPERATURE:** °C	**TURBIDITY:**	NTU
INIT. METER READING:	**(CHECK UNITS)**	__ft^3	__gallons
date:	**time:**		
FINAL METER READING:	**(CHECK UNITS)**	__ft^3	__gallons
date:	**time:**		
TOTAL SAMPLE VOLUME:		**liters**	
(Final-Initial meter readings x 28.316 (for readings in ft^3) or x 3.7854 (for readings in gallons))			
CONDITION ON ARRIVAL:			
COMMENTS:			



STEP 8 Slowly, start the water flowing through the sampling apparatus.

Push the red vent buttons on top of the filter housings to expel air in the filters. When the air is totally expelled from the filters, release the button and open the water tap completely.

Using the pressure regulator on the Regulator Module, adjust the pressure regulator to no more than 30 psi.

Using the water bypass screw on the injector, adjust the pressure regulator on the Single Injector Module to be at least 35% less than the pressure shown on the Regulator Module gauge.

Allow 53 - 80 gallons / 200 - 300 liters of water to pass through the filter.

Sampling Step	Volume In GALLONS	Volume In LITERS	Volume In FT^3
Sampling Source Water	53 - 80	200 - 300	7 - 11

! If the virus filter clogs before 53 gallons/ 100 liters are collected, contact the approved analyst at your laboratory for further instructions.

STEP 9 When the water meter indicates that 53 - 80 gallons / 200 - 300 liters of water have passed through the filter, turn off the water at the tap.

Record the following information on the Sample Data Sheet:

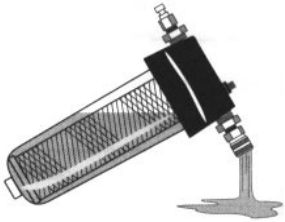
- ❑ Date sampling ended
- ❑ Time sampling ended
- ❑ Final water meter reading (including units)

SAMPLE DATA SHEET			
SAMPLE NUMBER:			
SYSTEM LOCATION:			
SAMPLER'S NAME:			
WATER pH:	**WATER TEMPERATURE:** °C	**TURBIDITY:**	NTU
INIT. METER READING:	**(CHECK UNITS)**	__ft^3	__gallons
date:	**time:**		
FINAL METER READING:	**(CHECK UNITS)**	__ft^3	__gallons
date:	**time:**		
TOTAL SAMPLE VOLUME:		**liters**	
(Final-Initial meter readings x 28.316 (for readings in ft^3) or x 3.7854 (for readings in gallons))			
CONDITION ON ARRIVAL:			
COMMENTS:			

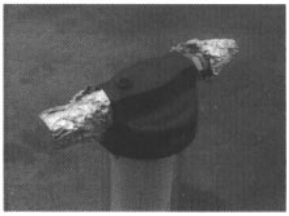
Put on fresh latex gloves.

Carefully, disconnect the sampling apparatus from the water tap.

10 Disconnect the Cartridge Housing Module from the sampling train.



Turn the filter housing upside down and allow excess water to flow out as waste water.



Turn the housing upright, and cover the module ends with sterile foil.

Do not attempt to open the filter housing.

If you are using the Prefilter Module, disconnect it from the sampling train, repeat the draining procedure, and cover the module ends with sterile foil.

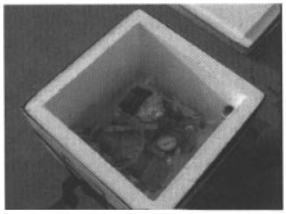
The filters and filter housings are shipped to the laboratory intact. The Discharge Module may be retained at the utility and reused.

Place the filter housings into an insulated shipping box.

Set the ice packs around the housings.

Return the Regulator Module and the Injector Module to the laboratory for cleaning and sterilization.

Place the Sample Data Sheet in a plastic bag and pack it on top of the sampling apparatus.



You may need to use additional packing material to ensure that the contents of the box will not shift during transport.

11 Seal the container and ship it by overnight courier to the laboratory. Call the laboratory and notify them of the sample shipment.

COLLECTING FINISHED WATER SAMPLES

1 If the concentration of any pathogen in your source water samples exceeds 1 per liter during the first 12 months of sampling, then you must monitor finished water as well as source water.

Sampling of finished water begins in the same manner as sampling of source water described previously, as follows:

When you are ready to collect your finished water virus sample, bring the following items with you to the sampling location:

- ❑ Shipping container sent by the laboratory
- ❑ Regulator Module
- ❑ Cartridge Housing Module
- ❑ Discharge Module
- ❑ Single Injector Module (for adding 2% thiosulfate solution to neutralize effects of chlorination or other disinfectant treatments)
- ❑ Double Injector Module (for adding 2% thiosulfate solution to neutralize effects of chlorination or other disinfectant treatments while adding 0.1-molar hydrochloric acid to adjust pH, if necessary)

- ❑ Approximately 2 gal (4 L) of 2% sodium thiosulfate solution
- ❑ Approximately 2 gal (4 L) of 0.1-molar hydrochloric acid solution (for adjusting pH, if necessary)
- ❑ 2 sterile, 250- or 500-mL graduated cylinders
- ❑ Plastic sample bags
- ❑ Sample data sheet
- ❑ Frozen ice packs
- ❑ Several pairs of new latex gloves
- ❑ pH meter
- ❑ Thermometer

2 Turn on the water at the tap and allow the water to flow for 2 to 3 minutes or until any debris that has accumulated in the sampling line has cleared or the turbidity in the water becomes uniform.

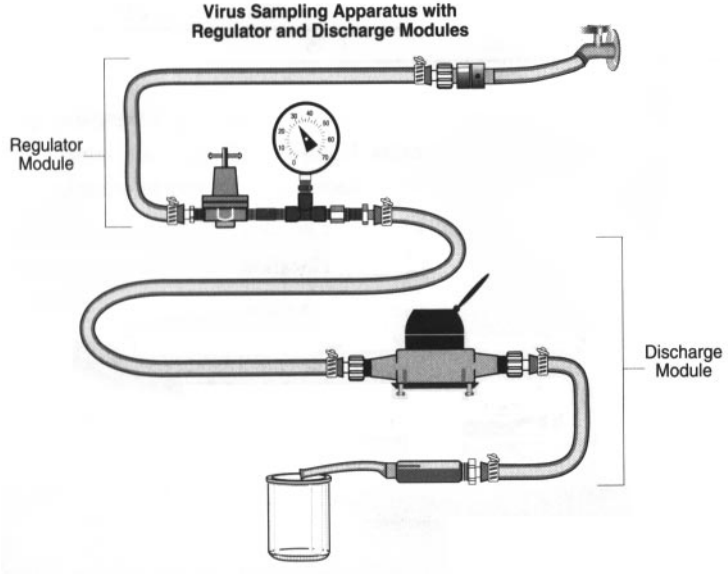
Turn off the water at the tap.

3 Put on new latex gloves to prevent contamination from outside sources. Sterile technique must be used when sampling for enteric viruses. Any contamination of the sampling apparatus may bias the final results.

Remove the foil from the backflow regulator on the Regulator Module and connect the module to the water tap or to an extension hose connected to the tap.

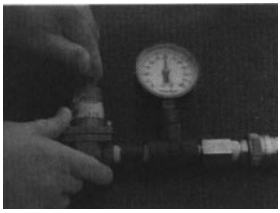
Remove the foil from the other end of the Regulator Module and from the Discharge Module and connect the Discharge Module to the Regulator Module.

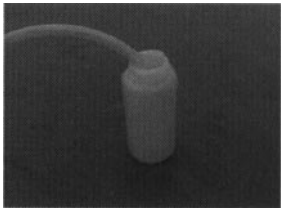
Place the end of the Discharge Module, or an extension hose connected to the Discharge Module, into a 1-liter plastic bottle.



Note the water meter reading, then slowly turn on the water.

Using the pressure regulator, adjust the water pressure to no more than 30 psi.





STEP 4 Flush the sampling apparatus with 20 gallons / 76 liters of water by allowing the water to flow through the system, out the effluent hose into the 1-liter plastic bottle.

Sampling Step	Volume In GALLONS	Volume In LITERS	Volume In FT^3
System Flush	20	76	2.7

While the water is flushing the sampling apparatus, begin completing your sample data sheet. Record the following information:

- ❑ Sample number
- ❑ System location
- ❑ Sampler's name

SAMPLE DATA SHEET

SAMPLE NUMBER:

SYSTEM LOCATION:

SAMPLER'S NAME:

WATER pH: **WATER TEMPERATURE:** °C **TURBIDITY:** NTU

INIT. METER READING: **(CHECK UNITS)** __ft^3 __gallons

date: **time:**

FINAL METER READING: **(CHECK UNITS)** __ft^3 __gallons

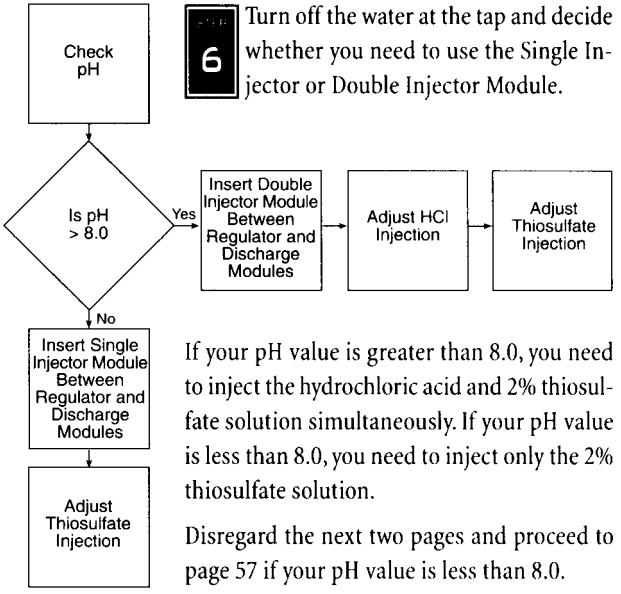
date: **time:**

TOTAL SAMPLE VOLUME: **liters**

(Final-Initial meter readings x 28.316 (for readings in ft^3) or x 3.7854 (for readings in gallons))

5 Measure the pH, temperature, and turbidity of the source water flowing from the effluent hose. Record the readings on the sample data sheet.

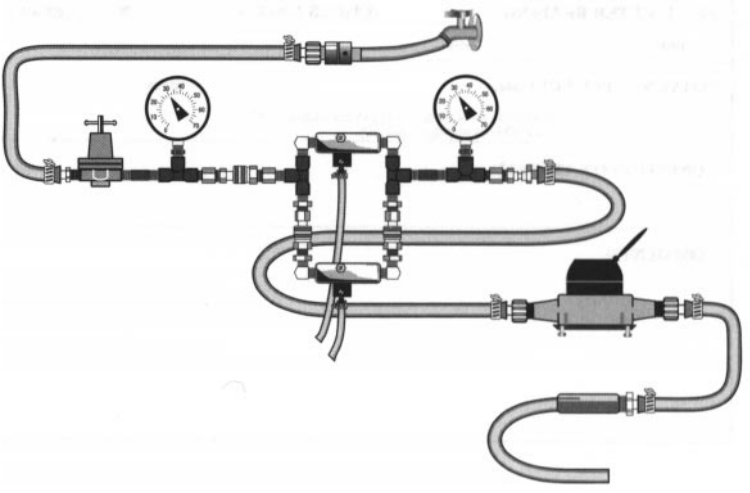
SAMPLE DATA SHEET			
SAMPLE NUMBER:			
SYSTEM LOCATION:			
SAMPLER'S NAME:			
WATER pH:	**WATER TEMPERATURE:**	**°C**	**TURBIDITY:** **NTU**
INIT. METER READING:	**(CHECK UNITS)**	**__ft³**	**__gallons**
date:	**time:**		
FINAL METER READING:	**(CHECK UNITS)**	**__ft³**	**__gallons**
date:	**time:**		
TOTAL SAMPLE VOLUME:		**liters**	
(Final-Initial meter readings x 28.316 (for readings in ft³) or x 3.7854 (for readings in gallons))			
CONDITION ON ARRIVAL:			
COMMENTS:			



6 Turn off the water at the tap and decide whether you need to use the Single Injector or Double Injector Module.

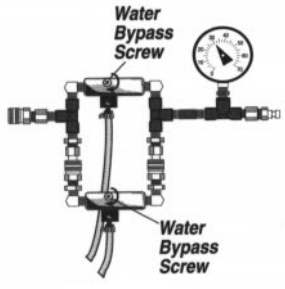
If your pH value is greater than 8.0, you need to inject the hydrochloric acid and 2% thiosulfate solution simultaneously. If your pH value is less than 8.0, you need to inject only the 2% thiosulfate solution.

Disregard the next two pages and proceed to page 57 if your pH value is less than 8.0.



pH > 8.0 Insert the Double Injector Module between the Regulator and Discharge Modules before proceeding.

! Ensure that both injectors are completely closed before proceeding.

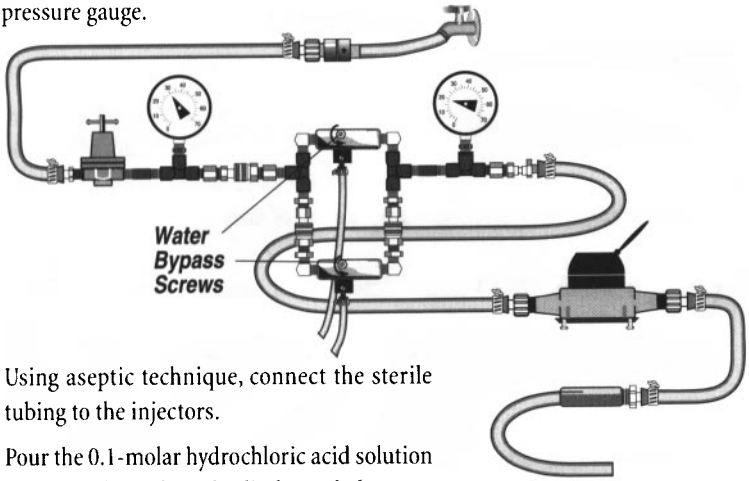


Adjust the water bypass screws on each injector clockwise as far as possible.

Turn on the water.

Next, turn each of the screws one half turn counterclockwise.

Continue opening the water bypass screws in half-turn increments until the reading on the second pressure gauge is approximately 35% less than that shown on the Regulator Module pressure gauge.



Using aseptic technique, connect the sterile tubing to the injectors.

Pour the 0.1-molar hydrochloric acid solution into a sterile graduated cylinder and place one of the injector tubes into it.

Pour the 2% thiosulfate solution into a second, sterile graduated container. Place the tube

from the second injector into the thiosulfate solution.

If there is no suction visibly drawing down the 2% thiosulfate or the HCl, or if too much is flowing, adjust the water bypass screws further to increase or decrease the pressure differential between the two gauges, until the flow is regulated properly.

Adjust the smaller injector screw on the hydrochloric acid injector to add sufficient hydrochloric acid to maintain a pH of 6.5 to 7.5.

After adjusting the injector, transfer the injector tube to the carboy of 0.1-molar hydrochloric acid. As sampling proceeds, periodically check the pH to ensure that it remains between 6.5 and 7.5.

Record the adjusted pH on the Sample Data Sheet.

Next, using the formula below, calculate the rate of thiosulfate injection and adjust the thiosulfate injector to deliver 10 mL of thiosulfate per gallon of flow.

$$\left(\begin{array}{c}\text{Water}\\ \text{Flow}\\ \text{Rate}\end{array}\right) \frac{\text{gallons}}{\text{minute}} \times \frac{\text{10 ml Thiosulfate}}{\text{1 gallon water}} = \left(\begin{array}{c}\text{Thiosulfate}\\ \text{Injection Rate}\end{array}\right) \frac{\text{ml}}{\text{minute}}$$

After the thiosulfate flow rate is adjusted, transfer the injector tube to the carboy of thiosulfate.

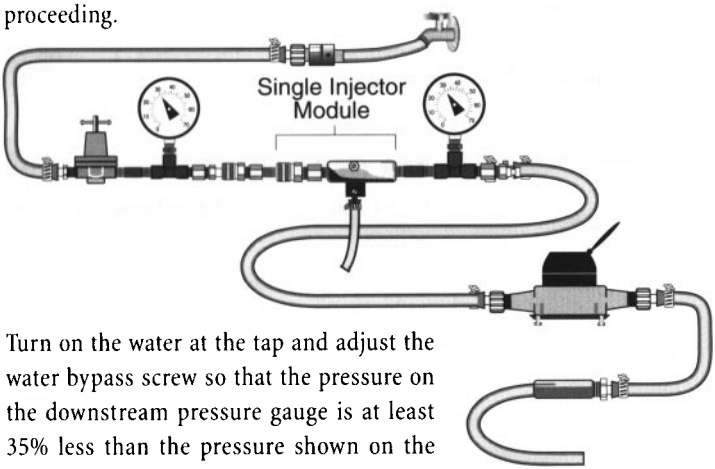
Monitor the thiosulfate flow rate visually throughout sampling.

Disregard the next section and proceed to step 7 (page 58).

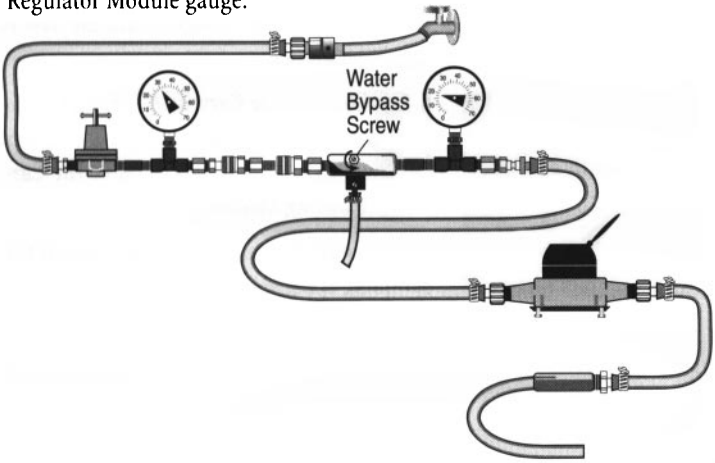
pH < 8.0

If your pH value is less than 8.0, it does not need to be adjusted, and you can use the Single Injector Module to inject the 2% sodium thiosulfate solution.

Insert the Single Injector Module between the Regulator and Discharge Modules before proceeding.



Turn on the water at the tap and adjust the water bypass screw so that the pressure on the downstream pressure gauge is at least 35% less than the pressure shown on the Regulator Module gauge.



Pour the 2% thiosulfate into a graduated cylinder.

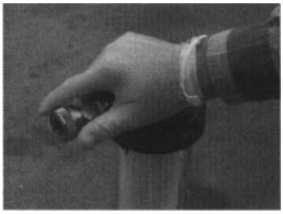
Next, using the formula below, calculate the rate of thiosulfate injection and adjust the thiosulfate injector to deliver 10 mL of thiosulfate per gallon of flow.

$$\left(\begin{array}{c}\text{Water}\\ \text{Flow}\\ \text{Rate}\end{array}\right) \frac{\text{gallons}}{\text{minute}} \times \frac{\text{10 ml Thiosulfate}}{\text{1 gallon water}} = \left(\begin{array}{c}\text{Thiosulfate}\\ \text{Injection Rate}\end{array}\right) \frac{\text{ml}}{\text{minute}}$$

After the thiosulfate flow rate is adjusted, transfer the injector tube to the carboy of thiosulfate.

Monitor the thiosulfate flow rate visually throughout sampling.

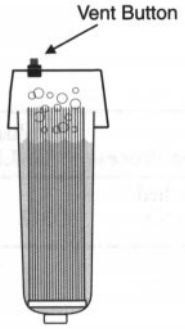
! If there is no suction visibly drawing down the thiosulfate, or if too much is flowing, adjust the water bypass screw further to increase or decrease the pressure differential between the two gauges, until the flow is regulated properly.



STEP 7 Connect the Cartridge Housing Module. Then reconnect the Discharge Module to the outlet end of the Cartridge Housing Module.

Slowly, start the water flowing through the sampling apparatus.

Push the red vent button on top of the filter housing to expel air in the filter. When the air is totally expelled from the filter, release the button and open the water tap completely.



Using the pressure regulator on the Regulator Module, adjust the pressure to no more than 30 psi.

Using the water bypass screw on the injector, adjust the pressure gauge on the Single Injector Module to be at least 35% less than the pressure shown on the Regulator Module gauge .

Record the following information on the Sample Data Sheet:

- ❑ Date sampling started
- ❑ Time sampling started
- ❑ Initial water meter reading (including units)

SAMPLE DATA SHEET			
SAMPLE NUMBER:			
SYSTEM LOCATION:			
SAMPLER'S NAME:			
WATER pH:	WATER TEMPERATURE: °C	TURBIDITY:	NTU
INIT. METER READING: (CHECK UNITS)		__ft³	__gallons
date:	time:		
FINAL METER READING: (CHECK UNITS)		__ft³	__gallons
date:	time:		
TOTAL SAMPLE VOLUME:		liters	
(Final-Initial meter readings x 28.316 (for readings in ft³) or x 3.7854 (for readings in gallons))			
CONDITION ON ARRIVAL:			

STEP 8 Collect 317 - 396 gallons or 1200 to 1500 liters of finished water.

Sampling Process	Volume In GALLONS	Volume In LITERS	Volume In FT^3
Virus Finished Water Sample	317 - 396	1200 - 1500	43 - 53

STEP 9 When the water meter indicates that 317 - 396 gallons / 1200 - 1500 liters of water have passed through the filter, turn off the water at the tap.

Record the following information on the Sample Data Sheet:

- ❑ Date sampling ended
- ❑ Time sampling ended
- ❑ Final water meter reading (including units)

SAMPLE DATA SHEET

SAMPLE NUMBER:

SYSTEM LOCATION:

SAMPLER'S NAME:

WATER pH: **WATER TEMPERATURE:** ˚C **TURBIDITY:** NTU

INIT. METER READING: **(CHECK UNITS)** __ft^3 __gallons

date: **time:**

FINAL METER READING: **(CHECK UNITS)** __ft^3 __gallons

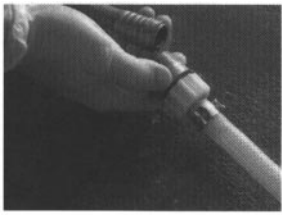
date: **time:**

TOTAL SAMPLE VOLUME: **liters**

(Final-Initial meter readings x 28.316 (for readings in ft^3) or x 3.7854 (for readings in gallons))

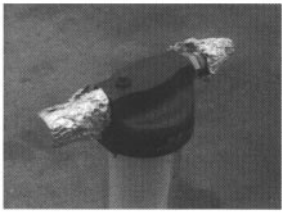
Put on fresh latex gloves.

Carefully, disconnect the sampling apparatus from the water tap.



Disconnect the Cartridge Housing Module from the sampling train. Turn the filter housing upside down and allow excess water to flow out as waste water.

Turn the housing upright, and cover the module ends with sterile foil.



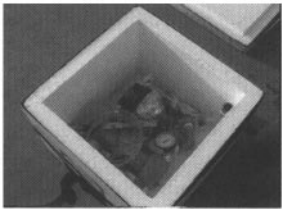
Do not attempt to open the filter housing.

The filter and filter housing are shipped to the laboratory intact. The Discharge Module may be retained at the utility and reused.

STEP 10

Place the filter housing into an insulated shipping box.

Set the ice packs around the housing.



Return the Regulator Module and the Injector Module to the laboratory for cleaning and sterilization.

Place the Sample Data Sheet in a plastic bag and pack it on top of the sampling apparatus. Seal the container.

You may need to use additional packing material to ensure that the contents of the box will not shift during transport.

STEP 11 Ship the container by overnight courier to the laboratory. Call the laboratory and notify them of the sample shipment.

Credits and Acknowledgments

The use of Manufacturer Trade Names in the production does not constitute endorsement by the U.S. Environmental Protection Agency.

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Special thanks to the management and staff of the Fairfax County Water Authority.

APPENDIX K – Memorandum: *Findings and Recommendations of the Advanced Water Purification Facility Subcommittee Meeting,* November 15, 2010, NWRI

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NWRI National Water Research Institute

Joint Powers Agreement Members

Inland Empire Utilities Agency

Irvine Ranch Water District

Los Angeles Department of Water and Power

Orange County Sanitation District

Orange County Water District

West Basin Municipal Water District

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To: Ms. Marsi Steirer
Deputy Water Department Director
Public Utilities Department
City of San Diego
600 B Street, Suite 600
San Diego, CA 92101

From: James Crook, Ph.D., P.E.
Vice Chair, NWRI Independent Advisory Panel for the City of San Diego's Indirect Potable Reuse/Reservoir Augmentation Demonstration Project

Jeff Mosher
Executive Director
National Water Research Institute

Subject: Findings and Recommendations of the Advanced Water Purification Facility Subcommittee Meeting

Date: November 15, 2010

The NWRI Independent Advisory Panel (IAP) for the City of San Diego's Indirect Potable Reuse/Reservoir Augmentation Demonstration Project held an Advanced Water Purification Facility (AWPF) Subcommittee meeting on October 21, 2010, at the City of San Diego's Ocean Monitoring Laboratory in San Diego, California.

Specifically, the Subcommittee of the IAP was charged with the following:

- Review the Draft Testing and Monitoring (T&M) Plan for the Advanced Water Purification Demonstration Facility.
- Resolve key comments on the IAP Report (dated September 17, 2009) as related to the T&M Plan.
- Review key items requiring input from the IAP and California Department of Public Health (CDPH) on the Draft T&M Plan.
- Review the schedule for the approval of the T&M Plan.

Members of the Advanced Water Purification Facility Subcommittee include:

- *Subcommittee Chair:* James Crook, Ph.D., P.E., Water Reuse Consultant (Boston, MA)
- Joseph A. Cotruvo, Ph.D., Joseph Cotruvo Associates (Washington, D.C.)
- Richard Gersberg, Ph.D., San Diego State University (San Diego, CA)
- Audrey D. Levine, Ph.D., P.E., DEE, U.S. Environmental Protection Agency (Washington, D.C.)
- David R. Schubert, Ph.D., The Salk Institute for Biological Studies (La Jolla, CA)

Attendees of the subcommittee meeting are listed in Appendix A. The subcommittee meeting agenda is provided in Appendix B.

The subcommittee findings and recommendations, provided below, will be presented to the full IAP for approval and/or revisions at the next IAP meeting and may be modified prior to inclusion in the next IAP report.

FINDINGS AND RECOMMENDATIONS

The IAP Subcommittee would like to commend the City of San Diego for its efforts in developing a comprehensive T&M Plan for the AWPF and for organizing the Subcommittee to review this effort.

Treatment Process

- To ensure that the pilot testing provides robust data, it is important to integrate potential upstream changes into the overall testing program. It would be worthwhile to identify possible process upgrades that might impact water quality, such as changes in nutrient removal, disinfection, or filtration. Changes to the tertiary wastewater treatment process should be integrated into the testing program now to evaluate the complete range of water quality conditions that might impact the performance and operation of the AWPF. For example:
    - Changes in the type and dose of coagulant should be tested to evaluate water quality impacts, such as pH, conductivity, and mineral composition. As a minimum, the effects of ferric chloride coagulation, currently shown as optional, should be assessed along with other potential treatment modifications.
    - The technical and economic feasibility of conducting partial demineralization by electrodialysis reversal (EDR) should be assessed to optimize the use of reverse osmosis (RO) or identify opportunities to use it as a back-up or supplementary system. Since RO has the capacity to handle some increased total dissolved solids (TDS) loading, it is not clear whether upstream EDR provides enough additional benefits to plant operations to justify the additional expense.
    - The status of the existing filtration process should be evaluated in the context of projected upgrades or modifications. Since filtration will now be functioning as pretreatment for the microfiltration/ultrafiltration (MF/UF) process, its performance should be optimized in conjunction with the pilot testing.

- In recognition of the fact that the UV reactor in the pilot plant is not representative of the UV system to be used in the full-scale AWFP, the IAP recommends that verification of the log removal requirements for NDMA and 1,4-dioxane by the advanced oxidation process (AOP), as specified in the August 4, 2008 California Department of Public Health draft groundwater recharge

regulations, be performed on the full-scale facility prior to implementation of the project.

- The IAP Subcommittee was presented with some pilot plant data relating to NDMA removal. This data set was very limited and should not be considered definitive at this time. The IAP would appreciate the opportunity to review additional data related to NDMA removal as it becomes available.

Water Stabilization

The stability of the product water is important to ensure the integrity of the pipeline from a microbial and corrosion perspective. It would be worthwhile to consider evaluating the options for controlling biofilm growth and corrosion. Using a pipe-loop study or annular reactor to evaluate microbial growth and the effectiveness of alternative control strategies could be a valuable complement to the pilot study once the system is operating at steady-state. These tests could be used to determine the extent to which a secondary disinfectant and/or corrosion control in addition to lime treatment is needed.

Water Quality

The IAP suggests that, except for water quality monitoring needed at startup of the AWPF to optimize the unit processes, water quality monitoring of the full-scale AWPF not begin until the system has been stabilized and is operating at steady-state conditions to obtain representative data.

Microbial

- The draft routine bacteria and virus surrogate monitoring plan proposes direct bacteria and virus monitoring using epifluorescence microscopy (with SYBR-green ATP measurements), which is not an approved method. Further, the analysis is expensive and does not determine organism viability. The IAP recommends that the use of epifluorescence microscopy for direct monitoring of bacteria and viruses not be included in the routine surrogate monitoring plan.

- For the component that calls for the direct monitoring of pathogens, the IAP concluded that, due to the well-known performance of the treatment train for pathogen removal and the substantial indicators analyses, monitoring for bacterial and viral pathogens may not necessary. However, the IAP recognizes the value of such monitoring from a public confidence perspective, and suggests that the proposed pathogen monitoring component be reevaluated at the next IAP meeting.

- The IAP suggests that it may be possible to reduce the monitoring frequency for *Cryptosporidium* (before and after MF/UF) by sampling for aerobic spores like *B. subtilis* as potential surrogates for *Cryptosporidium*. *B. subtilis* are much smaller than *Cryptosporidium* and, thus, would be a conservative indicator that can be

analyzed quickly and inexpensively. *B. subtilis* analyses could be performed in conjunction with the *Cryptosporidium* studies, and more frequently as potential MF/UF process performance indicators. The use of aerobic spores would be appropriate if the spores survive the prior disinfection process. This would need to be evaluated.

Constituents of Emerging Concern (CECs)

- The major purpose for the design of the monitoring strategy should be to: 1) determine which constituents are likely to either break-through or not be removed; and 2) use the information obtained as a basis to identify surrogates for operational tracking purposes at different stages of treatment. Experience at Orange County Water District's Groundwater Replenishment System and other similar projects demonstrates that many chemicals (e.g., metals and other priority pollutants) are easily handled by the treatment train if any are in the treated wastewater influent to the advanced treatment plant. In addition, breakthroughs of some chemicals such as NDMA and 1,4-dioxane (and a few others) at ng/L levels are expected, and do not *per se* indicate significant health risks. The IAP recommends that San Diego design a monitoring strategy for the pilot program that collects sufficient numbers of samples to determine appropriate surrogates for managing the processes and also provides public confidence on the effectiveness of the treatment system.

- The IAP recommends that the draft strategy include an approach for selecting appropriate surrogate constituents. Initially, screening tests should be conducted for a suite of CECs that may be present in the influent wastewater. Based on the results of the screening studies, a set of surrogate parameters can be selected that could be linked back to the constituents in the wastewater. This study should be initiated after the treatment system has been running for perhaps a minimum of 4 months and is operating at steady-state conditions. The analytical list may be drawn from the City's currently proposed monitoring list of 90 CECs, as well as other sources. The parallel analyses of chemicals and surrogate candidates would include the feed water, before and after RO, and potentially, some chemicals that survive after the advanced oxidation process (AOP). This assessment is important since it will serve as the basis for process operating decisions in the full-scale plant.

- It is doubtful that contaminants will routinely break through at concentrations that have health significance, which is one of the reasons for focusing on surrogate analyses. The IAP disagrees with the SWRCB-sponsored report entitled "Final Report: Monitoring Strategies for Chemicals of Emerging Concern (CECs) in Recycled Water" that caffeine and triclosan should be considered as health-related; however, it may be advisable to include them for monitoring process performance. That report also included NDMA and 17 β-estradiol (although it is unlikely to survive the process). They, as well as many other chemicals, would

represent potential health concerns if they occurred at higher than expected levels. Therefore, it is appropriate to have health advisory levels available in the event that any were detected.

- The IAP has some suggestions related to the monitoring strategy. DEET, carbamazepine, and primidone could be analyzed because they are ubiquitous in domestic wastewaters and refractory in nature. Among the other suggested chemicals, PFAAs might be candidates, even though their removal by RO has been well documented. 1,4-dioxane is also a good choice due to its known inefficient removal by RO. Chemicals included in the third Unregulated Contaminant Monitoring Rule, Cycle 3 (UCMR3) would best be addressed selectively, unless there is a regulatory requirement to analyze them. Chemicals like triclosan, caffeine, and sucralose and other artificial sweeteners are of no toxicological interest, but may be able to serve as surrogates. Hydrazine and quinoline are of little interest unless they are ubiquitous in the tertiary-treated wastewater and not readily removed by RO and/or AOP; hydrazine would likely not be well removed by RO, if present. Nicotine and cotinine could be considered for inclusion since they are cigarette-related and likely to be in sewage and of toxicity interest if at high enough levels in the finished water, although this is unlikely. They also are relatively low molecular weight molecules that could challenge RO, but not likely AOP. Extensive monitoring for the priority pollutants is of little value. Our understanding is that the Orange County Water District has had no detections in their extensive monitoring over several years. Perhaps a few samples could be analyzed for that group for verification and if the regulatory agencies require it. These types of analyses could also play a role in demonstrating the overall quality of the finished water to the public.

- The characteristics of wastewater can vary depending on the time of day and the loading to the wastewater treatment plant. For parameters that will be monitored using grab-samples, it is important to time sample collection to reflect the range of conditions that are likely (e.g., peak-flow, peak-loading, etc.). It is also important to ensure that the sampling program can yield statistically defensible results. Prior to initiating the routine sampling program, initial quality assurance studies should be conducted to determine the appropriate sample volumes (relates to detection limits), sampling frequency and timing, and which parameters should be monitored using grab-samples versus composite samples. The City should confer with San Diego Regional Water Quality Control Board (RWQCB) to get input on the parameters that should be measured using composite samples and whether the composites should be generated using a flow-weighted or time-based approach.

- Trihalomethanes (THMs) are a grouping of disinfection byproducts (DBPs) that are formed when chlorine is added to water containing organics. It is likely that DBPs are present in the wastewater at μg/L levels, and they may not be entirely removed by RO or AOP. THMs are currently regulated as a group at 80 μg/L in

drinking water, and it is our understanding that the RWQCB may impose more stringent requirements. It is important to have a clear understanding of any current and proposed RWQCB requirements and incorporate these considerations into the testing program.

- The Orange County Water District has experienced inconsistencies in comparing the monitoring results from grab samples versus online measurements for TOC. Thus, the City should consider relying entirely on online TOC measurements as they would be more informative – and likely more accurate – than using grab samples.

- The IAP finds that although definitive nutrient requirements for phosphorus and nitrogen have not been determined by the RWQCB, narrative and numeric nutrient requirements already included in the Basin Plan for discharges to surface water (such as San Vicente Reservoir) may allow the use of a 0.1 mg/L total phosphorus goal to determine compliance. Using the nominal N:P ratio of 10:1 to determine compliance for total nitrogen, it is possible that a 1.0 mg/L goal may be promulgated for total nitrogen to prevent eutrophication of the reservoir. The presentations to the IAP by the City of San Diego and their consultants suggests that modifications of the existing treatment process to date at the North City Water Reclamation Plant enhance denitrification and lower nitrate levels has had some success, but nitrate levels are still somewhat above 10 mg/L in the tertiary effluent. Using an 80- to 90-percent removal value for nitrate (provided at the meeting by the City's consultants) as that potentially-achieved by the RO system may yield an effluent nitrate level above the potential compliance limit for discharge to the reservoir. Therefore, the IAP suggests that more attention be paid to the operation of the existing tertiary treatment plant at the North City Water Reclamation Plant (NCWRP) to try to maximize denitrification to achieve lower the nitrate levels in the tertiary-treated water (to well below 10 mg/L) in order to demonstrate that such compliance may be achieved by the AWPF under future effluent limitation scenarios.

Source Control

- The IAP acknowledges the City's efforts to identify potential contaminants of concern in the NCWRP watershed from industries, including pharmaceutical and research facilities.

- Because the opportunity exists for the discharge of (probably small) amounts of chemical, radioactive, and biological material into the wastewater stream, it is advisable to contact each industry, particularly pharmaceutical manufacturers, hospitals, and laboratories, to raise awareness in those industries that their discharges will be feed water to the AWPF that will process the wastewater to be used for potable reuse.

- The IAP is interested in hearing more about the City's source control program. The IAP requests that a presentation on the source control program be provided at the next IAP meeting.

Appendix A: Subcommittee Meeting Attendees

Subcommittee:

- *Subcommittee Chair:* James Crook, Ph.D., P.E., Water Reuse Consultant (Boston, MA)
- Joseph A. Cotruvo, Ph.D., Joseph Cotruvo Associates (Washington, D.C.)
- Richard Gersberg, Ph.D., San Diego State University (San Diego, CA)
- Audrey D. Levine, Ph.D., P.E., DEE, U.S. Environmental Protection Agency (Washington, D.C.)
- David R. Schubert, Ph.D., The Salk Institute for Biological Studies (La Jolla, CA)

National Water Research Institute:

- Jeff Mosher, Executive Director
- Gina Melin Vartanian, Outreach and Communications Manager

City of San Diego:

- Amy Dorman
- Jeffrey Pasek
- William Pearce
- Joseph Quicho
- Marsi Steirer
- Anthony Van

City of San Diego Consultants

- Greg Bradshaw, RMC Water and Environment
- Debra Burris, DDB Engineering, Inc.
- Jay DeCarolis, Operations and Testing Manager, MWH
- Randy Hill, P.E., Project Manager, CDM
- Tom Richardson, RMC Water and Environment
- Greg Watterau, Team Leader for Membranes and Desalination, CDM

California Department of Public Health

- Brian Bernados, P.E., Recycled Water and Treatment Technology Specialist
- Heather Collins, P.E., Section Chief, Drinking Water Program, Region V (San Bernardino)
- Cindy A. Forbes, P.E., Chief, Southern California Branch
- Bob Hultquist, P.E., Chief, Drinking Water Technical Operations Section (retired)
- Sean Sterchi, Division of Drinking Water and Environmental Management

California Regional Water Quality Control Board, San Diego Region

- Brian Kelley

Appendix B: Subcommittee Meeting Agenda

City of San Diego
Water Purification Demonstration Project
Advanced Water Purification Facility (AWP)
Independent Advisory Panel (IAP)/AWP Subcommittee Meeting

Proposed Meeting Agenda
October 21, 2010
(8:30 a.m. – 5:00 p.m.)

Meeting Location	**On-Site Contacts:**
City of San Diego's	Anthony Van (City)
Environmental Monitoring &	Cell: (619) 980-9512
Technical Services (EMTS)	Tom Richardson (RMC)
Laboratory	Cell: (408) 239-6164

Goals of the Meeting

- Review the Draft Testing and Monitoring (T&M) Plan for the AWP Demonstration Facility.
- Resolve Comments on IAP Report related to the T&M Plan.
- Review Key Items Requiring input from IAP/CDPH on the Draft T&M Plan.
- Review schedule for approval of the T&M Plan.

Program		**Presenters**
8:30 am – 9:00 am	Welcome and Introduction • Meeting Objectives • T&M Plan Critical Path Schedule • IAP's Role on T&M Plan • Regulatory Context	 Marsi Steirer Anthony Van Jim Crook Tom Richardson
9:00 am – 10:00 am	Overview of the Draft T&M Plan • Objectives • Materials and Methods • Process Operations, Activities and Schedule • AWP Facility Process Evaluation • Specialty Testing • QA/QC	Jay DeCarolis
10:00 am - 10:15 am	BREAK	
10:15 am - 1:00 pm	CDPH T&M Related Comments on IAP Final Report	

	• Overview of Comments/Proposed Solutions	Greg Wetterau
	• Open Discussion	All
Noon - 12:30 pm	WORKING LUNCH	
1:00 pm - 1:15 pm	BREAK	
1:15 pm – 2:30 pm	T&M Plan Approach Key Items Requiring IAP/CDPH Input	
	• AWP Facility Treated Water Quality Goals	Jay DeCarolis
	• Monitoring of Local Contaminants based on NCWRP Collection System Catchment Investigation	Tom Richardson
	• Proposed Framework for defining criteria that will drive sampling frequency requirements to achieved statistical certainty	Jay DeCarolis
2:30 pm - 2:40 pm	Wrap up Schedule Completion and Final Approval of T&M Plan	Anthony Van
2:40 pm – 5:00 pm	IAP Subcommittee Convene	Closed Session

THE CITY OF SAN DIEGO

April 4, 2011

Ms. Heather L. Collins, P.E.
California Department of Public Health
South Coast Regional Engineer
464 West 4th Street, Suite 437
San Bernardino, CA 92401

Dear Ms. Collins:

Subject: Water Purification Demonstration Project (WPDP) - Revised Draft Testing and Monitoring Plan (TMP) for the Advanced Water Purification (AWP) Facility

The City of San Diego Public Utilities Department (City) would like to thank the Department of Public Health (CDPH), Division of Drinking Water and Environmental Management team for assisting with the review of the subject Testing and Monitoring Plan submitted on December 2, 2010. Enclosed with this letter are the City's responses to CDPH comments, which were conveyed in your letter dated January 31, 2011.

Please contact me at (619) 533-4112 if you have any questions regarding our responses, or if you need additional information on our overall WPDP effort.

Sincerely,

Marsi A. Steirer
Deputy Director, Public Utilities Department

AV/ctc

Enclosures: 1. CDPH Letter dated January 31, 2011 – Detailed comments Water Purification Demonstration Project – Revised Draft Testing and Monitoring Plan for the Advanced Water Purification Facility.

2. City's responses to comments from CDPH letter dated January 31, 2011, regarding the Draft TMP of the AWP Facility.

cc: Cindy Forbes, Southern California Branch Chief, California Department of Public Health
Sean Sterchi, San Diego District Engineer, California Department of Public Health
Brian Bernados, Senior Sanitary Engineer - Technical Specialist, California Department of Public Health
Randy Barnard, Senior Sanitary Engineer - Technical Specialist, California Department of Public Health
Bob Hultquist, Annuitant - California Department of Public Health
David W. Gibson, Executive Officer, California Regional Water Quality Control Board
Jeff Mosher, Executive Director, National Water Research Institute
Amy Dorman, Senior Civil Engineer, City of San Diego, Public Utilities Department

City of San Diego
Indirect Potable Reuse/Reservoir Augmentation Demonstration Project
Advanced Water Purification (AWP) Facility
Draft Testing and Monitoring Plan (12/2/10)

Responses to comments from the California Department of Public Health, Division of Drinking Water and Environmental Management (letter dated January 31, 2011) regarding the Draft Testing and Monitoring (T&M) Plan of the AWP Facility are listed below.

Comment No. 1: Peroxide Dose
Comment Response.
The project team agrees with the CDPH recommendation. To clarify the peroxide doses (1 and 5 mg/L) presented on page 6-4 refer to doses proposed to be tested during the proposed NDMA / 1,4 dioxane spiking experiments only. The baseline peroxide dose proposed for normal operational will be 3 mg/L, based on the dose currently approved by CDPH for the OCWD Groundwater Replenishment System. The T&M plan will be revised accordingly. Response to Comment 6 is also relevant.

Comment No. 2: CEC Overview
Comment Response.
The project team agrees and will add sucralose and cotinine to the current 91 compound CEC list to be analyzed at all sampling locations as part of the initial feed water characterization monthly for the first four months (Table 5-5). Based on occurrence and removal data gained during the initial characterization period the list of compounds shown in Table 5-5 to be measured quarterly may be modified.

Comment Number 3: Trojan Phox UV System
Comment Response

As discussed during the IAP Sub-committee meeting on 10/21/10, the project team recognizes the UV/AOP system proposed for use in the Demonstration Facility will not provide the same electric power efficiency as a full scale system to produce a given product water quality. We anticipate the demonstration unit to be more conservative in determining the EEO, electrical energy per order reduction. Regardless, the City's goals do not include developing the design criteria for the full scale UV/AOP system. However one goal is to operate the Demo scale UV/AOP system to demonstrate that it is effective for achieving 1.2 log removal of NDMA and 0.5 log removal 1,4 dioxane on these source waters. In addition, data collected from the spiking experiments will be used to compare the EEO values from the demonstration unit with the EEO values from permitted / operating full scale systems.

Comment No. 4: Effectiveness of Advanced Oxidation Process
The project team agrees a targeted chemical indicator removal demonstration of the AOP to develop a relevant surrogate parameter should be included in the test plan. See Comment Response 5 for more information.

Comment No. 5: Surrogate Indicator Framework to establish efficacy in AOP
Comment Response
In general, the project team agrees with CDPH's recommendation to develop and implement the Surrogate/Indicator approach with some validation at full-scale. The steps recommended by CDPH to demonstrate efficacy of the advanced oxidation process along with the project team's response provided in italic follow:

1. Validation monitoring during start-up. ***Response:*** *Agreed.*

2. Compliance monitoring during full-scale operation for the first twelve months of operation. ***Response:*** *Agreed.*

3. On-going compliance monitoring after the first twelve months of operation ***Response:*** *Agreed.*

4. Identification of operational parameters that is suitable to demonstrate a measurable change of a viable continuous online surrogate parameter under normal operating conditions. ***Response:*** *See comment response 8.*

5. Conduct challenge (spiking) tests with select indicator compounds to determine removal differentials under normal operating conditions using ten compounds as listed in footnote 3. Response: ***Response:*** *The UV/AOP technology being demonstrated has been proven at many facilities to be a reliable technology for reducing NDMA and 1, 4 dioxane. The City has collected useful data in 2005 on the efficacy of UV/AOP on many of the indicators listed in the CDPH letter including the target compound of NDMA. The intent of the demonstration study is to collect more information on removal efficiencies of different membrane configurations and operation data for consideration for the potential full scale AWPF.*

   However, the project team understands the concept of using the indicator/surrogate approach for compliance monitoring is new and needs some validation. As such, the project team proposes to conduct one spiking experiment after the first quarter of testing is complete to demonstrate the removal of several indicator compounds with the removal of surrogate parameters (UVA, chloramines), which can be easily measured on a frequent basis. The indicator compounds to be included in the spiking experiment will be based on occurrence data collected in the feed and product water of the AOP process with the overall goal of selecting compounds that will serve as good indicator compounds representative of wide range of characteristics for ongoing monitoring. The project team will work closely with the project advisory team including Dr. Jorg Drewes and Dr. Shane Snyder to develop the list of compounds to be included in the CEC spiking experiment. Note: The

CEC spiking experiment will be conducted under the UV/AOP conditions determined from the NDMA, 1,4 dioxane spiking experiment that provide 1.2 log removal of NDMA and 0.5 log removal of 1,4 dioxane.

6. The identified performance indicators are then monitored during start up to determine removal efficiencies under normal operating conditions. ***Response:*** *Agreed.*

7. Differentials of surrogates and indicators should be developed according to the table presented on p. 3. ***Response:*** *Agreed.*

Response to additional comments on page 4:

- CDPH Comment: add S10 as an additional sampling location for initial characterization.

  Response: *The project team accepts this recommendation.*

- CDPH Comment: add triclosan, gemfibrozil, carbamazepine, dilantin, erymthromycin, iopromide, meprobamate, naproxen, primidone, sulfamethoxazole, TCEP and trimethroprim to the monitoring plan in Table 5-6 for weekly samples over four weeks, including S10.

  Response: *The team has evaluated past monitoring results and believes it is likely to detect compounds currently listed in Table 5-6. Adding additional compounds as suggested by CDPH is defeating the purpose of using a limited list of suitable indicator compounds, a concept that CDPH endorses. However, we do propose to monitor the compounds suggested by CDPH at the same locations (S1, S6, S9, S10) monthly for the first four months, which will provide insight on their occurrence level.*

- CDPH Comment: add clofibric acid, musk ketone, TCPP and TDCPP to compounds listed in Table I-2.

  Response: *Table I-2 was intended to include clofibric acid, TCPP and TDCPP and will be modified accordingly. Additional information on the occurrence and analytical methods for the CDPH recommended compounds for monitoring follow:*

  - ***Clofibric acid*** *is a metabolite of a blood-lipid regulator that is not administered in the U.S. anymore and therefore occurrence levels are very low. It is not expected that this compound is present in recycled water.*
  - ***Musk ketone*** *is a compound that is well amendable to oxidation. Since we have other compounds with similar properties project team recommend NOT adding this compound to Table I-2.*

- ***TCPP and TCDPP*** *are chlorinated flame retardants. We have the chlorinated flame retardant TCEP in our target list as a representative of this class of compounds. Since analytical (isotope) standards are not readily available for TCPP and TDCPP, accurate determination of these compounds in recycled water can be questioned.*

- CDPH Comment: requesting to develop a list of ten UV/AOP performance indicator compounds and monitor them monthly instead of quarterly.

  Response: *Based on results of the initial characterization sampling (Table 5-5) and CEC spiking experiment, the project team will select several indicator compounds for AOP performance monitoring that are present at quantifiable levels in the RO product water. The removal of these compounds will be correlated with surrogate removal including UVA and chloramines. The surrogates will be monitored daily. The project team recommends sampling the selected indicator compounds every other month and that this frequency of sampling provides a sufficient data set to assess performance.*

- CDPH is suggesting 3D TRASAR at location S10.
  Response: See comment response 11.

Comment No. 6: NDMA and 1,4 dioxane Spiking Experiment
Comment Response
As outlined in the Section 6.2.3, the main purpose of the spiking experiment to is to confirm the flow, power and peroxide dose settings of the UV/AOP system to achieve 1.2 log NDMA removal and 0.5 log removal of 1,4 dioxane. As the RO product water will not contain concentrations sufficient to demonstrate these log removals, spiking would be required. The project team recommends the experiments be conducted as it will establish the operating conditions under which all sampling events will be conducted. The results from the spiking experiments will also be used to calculate the EEO (electrical energy per order) removal for NDMA, for comparison to measured EEO values from full scale permitted UV/AOP systems including Orange County and West Basin.

The project team will conduct the spiking experiment using the baseline dose of 3 mg/L to demonstrate the AWPF achieves the same log reduction values of permitted and operating full scale AWT facilities including Orange County and West Basin. Data will also be collected at lower doses (1 or 2 mg/L) for informational purposes only. This will provide the City preliminary data that may serve as the basis future studies to determine optimal peroxide dose. It is believed the lower doses of peroxide even at low conversion efficiency might be sufficient for destruction of trace organic chemicals given the low demand in the RO permeate.

Comment No. 7: Grab-samples versus composite samples
Comment Response

CDPH is suggesting collecting sequential grab samples for certain analytes to assess diurnal variations. The team acknowledges that certain compounds are subject to diurnal variations however the diurnal variation at NCWRP may be less significant than the Tillman Plant due to differences in hydraulic detention time and other operating conditions. In response to the CDPH comment, the project team recommends conducting two 24 hour sampling events during the 12 month operating period to collect grab samples of the RO feed every 4 hours for the following preliminary list of compounds:

1. *Caffeine*
2. *Sucralose*
3. *Total nitrogen*
4. *Nitrate*
5. *1,4 dioxane*
6. *NDMA*
7. *Total phosphorus*

The above list may be modified based on occurrence data collected during the first 4 months.

Note: the project team recommends off-setting the increased analytical requirements related to the above sampling events by reducing the sample locations shown in Table 5-4 for parameters to be collected as 24 hour composite samples to only include locations S6 (RO Feed), S7 (RO 1 permeate), S8 (RO 2 permeate). In addition, the number of NDMA and sister compound samples proposed for measurement in Table 6-3 may be reduced.

The sampling frequency of "bi-weekly" refers to once every two weeks.

Comment No. 8: Grab Samples versus on-line
Comment Response
The current UV/AOP design incorporates 1 on-line UVA-254 analyzer to be located at the UV/AOP inlet (S9) for UV process control similar to the AOP system used at OCWD GWRS. While the project team agrees on-line monitoring of UVA in the feed and effluent may be useful there are several concerns:

- *Changes in UVA removal across the UV/AOP may fluctuate and be inconsistent over the course of operation;*
- *The unique calibration of each on-line unit may mask the actual UVA removal.*

Instead of adding an online UVA meter to the UV/AOP outlet, the project team recommends during the demonstration period to collect grab samples from UV/AOP feed and effluent and measuring UVA and total chloramines using desktop meters daily (using a 10 cm cell for more accuracy). This will allow a data set to be established to assess the viability of both surrogates for UV/AOP process performance validation and make recommendations for online measurements for the potential full scale AWPF.

Comment No. 9: NCWRP Operational Changes to Reduce Effluent Total Nitrogen
Comment Response
Trussell Technologies is currently working on the North City Water Reclamation Plant Denitrification Optimization Study to assess operational changes to reduce effluent nitrogen of the NCWRP. The City will address this item under separate correspondence by early May 2011.

Comment No. 10: Testing of RO Membranes
Comment Response
The intention of Section 3.6.1 is to require that all membranes used for the demonstration project undergo direct integrity testing by the manufacturer (via vacuum decay or pressure hold testing) prior to delivery to the site. The project team will be requesting the RO suppliers to provide a statement that membranes were selected randomly from a standard production lot. The requirement that membranes used for IPR projects achieve a specified pressure decay or pressure hold rate prior to installation is something the project team would like to further discuss with CDPH.

Comment No. 11: TRASAR Challenge Testing
Comment Response
The project team agrees challenge testing of the RO membranes using the TRASAR system may provide valuable insight to the potential use of this technology to provide assurance of RO membrane integrity and possibly AOP performance. However, at this time it is NOT intended to conduct this testing as part of the current demonstration project. The City may decide to conduct TRASAR testing as part of future evaluations outside the current scope of the demonstration project.

Comment No. 12: MS2 Virus Challenge Testing
Comment Response
The project team agrees challenge testing of the RO membranes using the MS2 in conjunction with TRASAR testing could provide valuable research for the water reuse industry. However, at this time it is not planned to request from CDPH virus removal credits for the RO system and therefore it is currently not planned to conduct MS2 challenge testing. This requirement may change during the 3rd Quarter once the regulatory requirements for the full scale project become more defined. At this time the City will re-assess the possibility of such testing.

State of California—Health and Human Services Agency
California Department of Public Health

MARK B HORTON, MD, MSPH
Director

EDMUND G. BROWN JR.
Governor

January 31, 2011

Ms. Marsi Steirer
Deputy Director
City of San Diego Water Department
600 B Street, Suite 600
San Diego, CA 92101

Subject: Water Purification Demonstration Project - Revised Draft Testing and Monitoring Plan for the Advanced Water Purification (AWP) Facility

Dear Ms. Steirer:

The Department of Public Health, Division of Drinking Water and Environmental Management (Department) has reviewed the subject Testing and Monitoring Plan (TMP) submitted on December 2, 2010. Enclosed with this letter are comments on the TMP which was reviewed by our program staff.

The Department would like to thank you for allowing us additional time for our review and to provide comments on this plan. We look forward to working with your project team as this project develops.

If you have you have any comments regarding the content of this letter, please feel free to contact Brian Bernados at (619) 525-4497, Randy Barnard at (619) 525-4022, Sean Sterchi at (619) 525-4159, or myself at (909) 383-4328.

Very truly yours,

Heather L. Collins, P.E.
South Coast Regional Engineer
CDPH-DDWEM

Southern California Drinking Water Field Operations Branch, San Bernardino Region
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Enclosure - CDPH Detailed Comments Water Purification Demonstration Project - Revised Draft Testing and Monitoring Plan for the Advanced Water Purification (AWP) Facility

cc: David W. Gibson
Executive Officer
California Regional Water Quality Control Board
San Diego Region
9174 Sky Park Court, Suite 100
San Diego, CA 92123-4353

Mr. Jeffrey J. Mosher
National Water Research Institute
18700 Ward Street
P.O. Box 8096
Fountain Valley, CA 92728-8096

SUBJECT: City of San Diego - Water Purification Demonstration Project Revised Draft Testing and Monitoring Plan for the Advanced Water Purification (AWP) Facility

CDPH Drinking Water Program field and technical staff have reviewed the report referenced above and make the following comments:

Peroxide Dose

On Page 6-4, two doses are proposed for the AOP demonstration testing – one mg/L and five mg/L. On other pages other peroxide doses are mentioned. Please clarify. A dose target of one mg/L will be too low because the resultant creation of hydroxyl radicals will likely be too low to oxidize organic chemicals effectively. OCWD reports that approximately 13% of peroxide is converted to hydroxyl radicals; therefore, a higher dose should be used. CDPH recommends a dose level between 1-5 mg/L. We also would recommend that along with doses of 5 mg/l and 1 mg/l that you evaluate an additional dose between that range such as 2 or 3 mg/l. A dose of 3 mg/L is the target for current AOP projects. A strategy to develop the optimum operation of AOP and the proper dose of peroxide is important to meet the goals of the demonstration project. This will be especially important in order to address the issues regarding the AOP demonstration delineated below.

Constituents of Emerging Concern (CECs) - Overview

Findings and Recommendations of the Advanced Water Purification Facility Subcommittee Meeting, November 15, 2010 made the following comment,

> "The IAP has some suggestions related to the monitoring strategy. DEET, carbamazepine, and primidone could be analyzed because they are ubiquitous in domestic wastewaters and refractory in nature. Among the other suggested chemicals, PFAAs might be candidates, ... Chemicals like triclosan, caffeine, and sucralose and other artificial sweeteners are of no toxicological interest, but may be able to serve as surrogates. Hydrazine and quinoline are of little interest unless they are ubiquitous in the tertiary-treated wastewater and not readily removed by RO and/or AOP; hydrazine would likely not be well removed by RO, if present. Nicotine and cotinine could be considered for inclusion since they are cigarette-related and likely to be in sewage and of toxicity interest if at high enough levels in the finished water, although this is unlikely. They also are relatively low molecular weight molecules that could challenge RO, but not likely AOP."

Quarterly monitoring is proposed for these compounds in Table 5-5, except for sucralose and cotinine. CDPH recommends that they be added to Table 5-5. While sucralose is included in Table 5-6, it is to be sampled at different locations.

Trojan Phox UV system

November 30, 2010 Final Draft Testing and Monitoring Plan, Page 2-1 states the following:

> "Section 2.1 Testing and Monitoring Objectives The ultimate goal of testing and monitoring the AWP Facility is to generate the necessary data to support the regulatory approval and permitting of the proposed full-scale IPR/RA project. Specific objectives of the testing and monitoring component are provided in the following paragraphs." On Page 2-3, it states, "Validate the performance of AWP Facility unit processes using full-scale treatment equipment. . . The proposed UV/AOP demonstration system is the UV Phox Model 72AL75, which is a single chamber version of the

> reactors used at OCWD. During the initial phase of testing, the ability of the unit to achieve 1.2-log (93.7%) removal of N-Nitrosodimethylamine (NDMA) at a flow of 1 MGD will be verified. Results obtained during initial testing will establish the power setting at which to operate the system for the remainder of the operations period."

As noted previously, the Trojan Phox UV system at OCWD consists of three reactors (six chambers) per treatment train (8.75 MGD capacity). Essentially the demonstration project consists of one 72-lamp chamber that will have a lower flow, longer residence time and very different hydraulics than the full-scale; all of which affects AOP performance and efficiency. The issue of whether the results from a one-MGD demo can be used to predict actual full-scale performance, in regard to AOP, was noted in the *Final Report of the May 11-12, 2009, Meeting of the IAP,* which made the important point,

> "It is important that the unit provide treatment that will simulate the full-scale system and ensure that the UV dose is proportional to the flow. As full-scale units like the Trojan UV Phox system do not scale well"

Closed-vessel UV reactor systems are not designed to be scalable. *Final Report of the May 11-12, 2009, Meeting of the IAP* stated,

> "The scaling of the UV reactor design will require consulting with UV manufacturers. It may be possible to provide the same UV dose, but given reactor flow dynamics at different velocities, assuring the scalability of the UV system could be critical."

Since, the demonstration work will use a smaller reactor and the flow will be less than full-scale, the test plan must address flow dynamics and different velocities. While the test plan attempts to address these issues, CDPH has sufficient concerns to recommend a more targeted chemical indicator removal demonstration of the AOP to develop relevant surrogate parameters. Therefore, CDPH recommends the following Surrogate / Indicator Framework:[1]

Effectiveness of Advanced Oxidation Process

Based upon comments CDPH received from the public regarding the August 5, 2008 version of the *Groundwater Recharge Reuse DRAFT Regulation*, CDPH has been evaluating recent studies to assess the effectiveness of treatment technologies. Accordingly, CDPH is willing to consider alternative approaches to determine the efficacy of the AOP treatment train. While not necessarily the only alternative, a Surrogate / Indicator Framework should applied to this demonstration project.

Surrogate / Indicator Framework to establish efficacy in AOP

The relationship between process performance, online surrogates, and indicator chemical reduction shall be validated for advanced oxidation process. Initially, an occurrence study shall confirm detection of viable indicator compounds in the feed water to the unit process. Performance of the process shall be determined during three phases:

1. validation monitoring during piloting/start-up,
2. compliance monitoring during full-scale operation for the first twelve months of operation,
3. on-going compliance monitoring after the first twelve months of operation.

Operational parameters shall be proposed that demonstrate a measurable change of a viable continuous online surrogate parameter under normal operating conditions (i.e., UVA_{254}, fluorescence or ozone exposure)[2]. Challenge or spiking tests shall be conducted with select

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[1] Similar in concept to the San Diego IAP recommendations and the SWRCB-sponsored report entitled "*Final Report: Monitoring Strategies for Chemicals of Emerging Concern (CECs) in Recycled Water*":

[2] For example, a 50% removal of UVA_{254} measured pre-AOP and post AOP; a 50% reduction in fluorescence intensity, or an ozone CT = 10 mg/l-min.

indicator compounds to determine the removal differential under normal operating conditions. A minimum of ten indicator chemicals[3] shall be examined, during piloting/start-up, that exhibit both "good" and "intermediate" removal expected based upon research detailed in the categories below. An operational correlation shall be developed between the surrogate and the indicator. Operational parameters shall be evaluated that demonstrate a measurable change in the surrogate parameter (X_i) under normal operating conditions. In parallel, an occurrence study needs to be performed confirming detection ratios of viable indicator compounds in the feed water to the AOP. During piloting or start-up, challenge or spiking tests can be conducted with select indicator compounds (Y_i) to determine the removal differential ΔY_i under normal operating conditions.

Surrogate / indicator framework to establish efficacy in AOP		
	Surrogate Parameters	**Indicator Compounds**
Piloting and / or Start-up		
Step 1	Establish anticipated operational conditions of process; i.e., typical flow range, dosage application range, seasonal variation in critical water quality parameters, etc.	
Step 2	Select surrogate parameters that demonstrate a measurable change under normal operating conditions and quantify this differential $\Delta X_i = \lvert (X_{i,in}-X_{i,out}) \rvert$	Conduct occurrence study to confirm detection ratio of viable indicator compounds is in the feed water of unit process
Step 3		Conduct challenge or spiking study with ten representative indicator compounds during pilot- or start-up to determine the removal differentials under normal operating conditions $\Delta Y_i = (Y_{i,in}-Y_{i,out})/Y_{i,in}$
Step 4	Select viable surrogate and operational parameters for unit process	Select 3-5 indicator compounds from representative chemical structure categories with expected removal rates of 90% via AOP AND Select 3-5 indicator compounds from representative chemical structure categories with expected removal rates of 50-90% via AOP

Operational parameters shall be evaluated that demonstrate a measurable change surrogate parameter (X_i) under normal operating conditions. In parallel, an occurrence study needs to be performed confirming detection ratios of viable indicator compounds in the feed water to the unit process. During piloting or start-up of a new treatment process, challenge or spiking tests can be conducted with select indicator compounds (Y_i) to determine the removal differential ΔY_i under normal operating conditions.

[3] If present, example indicators include caffeine, estradiol, NDMA, triclosan, DEET, gemfibrozil, iopromide, sucralose, BPA, carbamazepine, atenolol, clofibric acid, dilantin, ibuprofen, meprobamate, musk ketone, naproxen, primidone, sulfamethoxazole, TCEP, TCPP, TDCPP, and trimethroprim.

Example advanced oxidation treatment removal categories for indicator compounds And Structure Typical Expected Good Removal > 90%[4]					
Hydroxy Aromatic:	*Amino / Acylamino Aromatic:*	*Nonaromatic C=C:*	*Deprotonated Amine:*	*Alkoxy Polyaromatic:*	*Alkyl Aromatic:*
Acetominophen	Sulfamethoxazole	Acetyl cedrene	Atenolol	Naproxen	Benzophenone
Atorvastatin (o-hydroxy)	Atorvastatin	Carbamazepine	Caffeine	Propranolol	Benzyl acetate
Atorvastatin (p-hydroxy)	Triclocarban	Codeine	Diclofenac		Bucinal
Benzyl salicylate		Hexylcinnamaldehyde	EDTA	*Alkoxy Aromatic:*	DEET
Bisphenol A		Methyl ionine	Erythromycin-H_2O	Gemfibrozil	Dilantin
Estrone		OTNE	Fluoxetine	Hydrocodone	Dibutyl Phthalate
Hexyl salicylate		Simvastatin hydroxy	Metoprolol		Diphenhydramine
Isobutylparaben		Terpineol	Nicotine		Galaxolide
Methyl salicylate			Norfluoxetine		Ibuprofen
Nonylphenol			Ofloxacin		Indolebutyric acid
Oxybenzone			Paraxanthine		Primidone
Propylparaben			Pentoxifylline		Tonalide
Salicyclic acid			Trimethoprim		
Triclosan					
Clorfibric Acid					

Example advanced oxidation treatment removal categories for indicator compounds And Structure <90%			
Typical Expected Intermediate Removal		Typical Expected Poor Removal	
90-50%		50-25%	< 25%
Saturated Aliphatic:	*Nitro Aromatic:*	*Nitrosamine:*	*Halogenated Aliphatic:*
Iopromide	Musk ketone	NDMA	Chloroform
Isobornyl acetate	Musk xylene		TCEP (Tris (2-chloroethyl) phosphate)
Meprobamate			TCPP (Tris (chloroisopropyl) phosphate)
Methyl dihydrojasmonate			TDCPP (Tris (1, 3-dichloropropyl) Phosphate)

November 30, 2010 Final Draft Testing and Monitoring Plan, Section 5.2.3 is generally in agreement with this approach; however, some modifications should be made as follows:

1. Add S10 in Table 5-6, sampling locations, under initial characterization (weekly for four weeks) for DEET, sucralose, NDMA, and caffeine.
2. Based upon IAP Sub-committee recommendations, chemical structures, and occurrence data from 2005 (Table 3-2), add triclosan, gemfibrozil, carbamazepine, dilantin, Erythromycin-H_2O, iopromide, meprobamate, naproxen, primidone, sulfamethoxazole,

[4] Dickenson, Drewes, Sedlak, Wert, & Snyder. Applying Surrogates and Indicators to Assess Removal Efficiency of Trace Organic Chemicals during Chemical Oxidation of Wastewaters. *Environ. Sci. & Tech.* 2009, 43, 6242-6247.

TCEP (Tris (2-chloroethyl) phosphate), and trimethroprim to Table 5-6, initial characterization (weekly for four weeks), including sampling at S10.

3. Add clofibric acid, musk ketone, TCPP, and TDCPP to Table I-2.
4. Modify Table 5-6, On-going Monitoring to Assure UV/AOP Performance by adding monthly monitoring for approximately ten chemical indicators chosen based upon the initial four weeks of sampling in Table 5-6 and the initial four months of sampling in Table 5-5. Additionally, monitor UVA (or UVT) frequently, online if possible, at the time that the indicator monitoring is conducted.
5. Consider online monitoring using the 3D TRASAR at sample location S10 to evaluate fluorescence as a potential surrogate compared to UVA_{254}.

NDMA and 1,4-Dioxane Spiking Experiment

While the special monitoring proposed in Section 6.2 "NDMA and 1,4-Dioxane Spiking Experiment" may have some value, CDPH considers it of limited application to the full-scale project. As noted above, the UV system and AOP will not be tested under relevant flow and hydraulic conditions during the demonstration project. The results will not provide sufficient demonstration of the full-scale performance. Therefore, this special testing would need to be repeated at full-scale start-up. CDPH would consider deletion of this spiking experiment in favor of the **"Surrogate / indicator framework to establish efficacy in AOP"** detailed previously. One of the stated goals of the demonstration project is to develop applicable surrogates and indicators for full-scale application. If done properly, surrogates and indicators can be identified for this project that are known to occur and in which removal can indicate efficacy of the process performance.

NDMA and 1,4-Dioxane can be monitored on a frequent basis at full-scale to ensure that the effluent levels are below the Notification Levels. Additionally, NDMA formation can be reduced either via a source control program or via modification of upstream processes to decrease NDMA formation or precursors.

Grab-Samples Versus Composite Samples

Findings and Recommendations of the Advanced Water Purification Facility Subcommittee Meeting, November 15, 2010 made the following comment,

> "The characteristics of wastewater can vary depending on the time of day and the loading to the wastewater treatment plant. For parameters that will be monitored using grab-samples, it is important to time sample collection to reflect the range of conditions that are likely (e.g., peak-flow, peak-loading, etc.). . . .Prior to initiating the routine sampling program, initial quality assurance studies should be conducted to determine the appropriate sample volumes (relates to detection limits), sampling frequency and timing, and which parameters should be monitored using grab-samples versus composite samples."

While Table 5-4 specifies some composite samples (TOC, ammonia, nitrate, total nitrogen, and total phosphorus), other compounds should be considered, such as caffeine and sucralose, which could vary significantly based upon different times of the day. Since it has been shown via diurnal monitoring at the Tillman plant in LA that NDMA can vary widely throughout the day, NDMA grab-samples may not adequately characterize the diurnal effect. Therefore, CDPH recommends that additional focused sampling be performed to capture the diurnal effect. For NDMA, this may mean picking a 24-hour period in which to collect grab samples once every four hours. This should be repeated to confirm the diurnal effect. In general, CDPH recommends a similar 24-hour monitoring period for other important chemicals, such as

nitrogen, nitrate, 1,4-dioxane, etc. With this data, a standard deviation or whisker plot can be developed to indicate the variability.

Additionally, Table 5-4 specifies "Bi-weekly" as the monitoring frequency for some constituents. Please clarify whether this means twice a week or once every two weeks.

Grab-Samples Versus Online
In Table 5-6, daily monitoring for UVA-254 nm is proposed. CDPH recommends online monitoring via a standard UVT analyzer as is commonly used in UV disinfection systems. This could serve as an online surrogate for AOP performance. Table 5-1 monitors UVT twice per day at the feed, but not at sample locations S9 and S10. Table 5-3 is confusing as both grab and online are noted for some surrogate parameters that are normally online.

NCWRP Operational Changes to Reduce Effluent Total Nitrogen
Page 3-5 to 3-6, Section 3.1.3.1 mentions the study to "assess improving the NCWRP recycled water quality by enhancing the plant's denitrification process (Trussell et al., 2010)." Please provide an update on this study and conclusions reached. CDPH is interested in which of the Trussell recommendations have been implemented or will be in the future. As stated in previous correspondence, CDPH recommends optimization of the treatment process. Additionally, the San Diego Regional Water Quality Control Board should be consulted.

Testing of RO Membranes Prior to Installation
Section 3.6 discusses the manufacturer testing prior to delivery. The RO suppliers should not hand pick the best membrane cartridges of the lot. Instead they should be randomly selected in order to indicate the performance of the average RO cartridge of the particular model. Therefore, manufacturers should supply a statement to that effect.

TRASAR Challenge Testing
Section 3.6.4 describes this potential monitoring tool. Previous piloting work in 2005 performed for the City of San Diego gave a reasonable indication that TRASAR® would provide a method to determine integrity of the RO membranes. CDPH is in favor of TRASAR® Challenge Testing, since direct integrity testing methods for RO have not been developed yet. If successful, the TRASAR® unit could provide assurance of membrane integrity, similar to the pressure decay tests used as a standard test for microfiltration and ultrafiltration type membranes.

TRASAR® is composed of fluorescent molecules. The trace leak detection (TLD) system detects TRASAR® by measuring fluorescence. Therefore, it may have potential application in monitoring other processes, including AOP.

MS2 Virus Challenge Testing
Page 3-19, Section 3.6.3 states,

> "Though it is not an objective of the testing plan to demonstrate the ability of the RO membranes to remove viruses, conducting virus challenge experiments is a powerful means of monitoring RO system integrity. Accordingly, an optional service for consideration, challenge experiments can be performed on each RO system during start up and upon completion of the target 5,000 hour test period."

While not necessarily required, CDPH would appreciate seeing and evaluating the outcome of any MS2 virus challenge testing performed on the RO processes. If this testing is performed, it

could provide valuable research for the water reuse industry, especially in conjunction with membrane integrity testing such as the proposed TRASAR testing. It should be noted that if the City of San Diego would like to obtain credit for the virus removal capability of the RO process, such a MS2 virus challenge testing scheme may provide justification. It should be noted that CDPH is in the preliminary stages of developing new regulations for surface water augmentation with recycled water and new research is encouraged.

Since there is currently no accepted integrity test for RO, awarding credit for pathogen removal may not be feasible; however, CDPH is open to new demonstration work. Referring to the EPA Membrane Filtration Guidance Manual, integrity testing must meet requirements for resolution, sensitivity, and frequency. The sensitivity of a membrane module is defined as the maximum Log Removal Value that can be reliably verified by an integrity test, which must be equal to or greater than the Cryptosporidium removal credit awarded to the module via challenge testing. The feasibility of performing a daily integrity test for RO would be of interest to CDPH.

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California Regional Water Quality Control Board
San Diego Region

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February 28, 2011

In reply refer to:
244506:JCOFRANCESCO

Ms. Marsi A. Steirer
Deputy Director, Public Utilities Department
City of San Diego
600 B Street, Suite 600, MS 906
San Diego, CA, 92101

Dear: Ms. Steirer

SUBJECT: WATER PURIFICATION DEMONSTRATION PROJECT, NOVEMBER 30, 2010 DRAFT TESTING AND MONIOTRING PLAN, AND REGULATION OF PROJECT UNDER ORDER NO. 97-03

The California Regional Water Quality Control Board, San Diego Region (San Diego Water Board) appreciates having the opportunity to review the *Final Draft Testing and Monitoring Plan, November 30, 2010* (Draft Plan). The Draft Plan provides a comprehensive approach to generating the data necessary for addressing numerous and varied concerns regarding indirect potable reuse and the quality of the product produced by an Advanced Water Purification Facility. The following comments on the Draft Plan are being provided for the City's consideration with the purpose of facilitating the NPDES permitting process.

Comments Regarding the Draft Plan

1. The monitoring that will be conducted provides an opportunity to develop data for establishing applicability of water quality-based effluent limitations for priority pollutant criteria/ objectives in a National Pollutant Discharge Elimination System (NPDES) permit. Specifically, sufficient data of the discharge is necessary to perform a reasonable potential analysis (RPA) for each of priority pollutant. The monitoring location must be representative of the quality of the product water and the monitoring be conducted according to the U.S. Environmental Protection Agency test procedures approved at 40 CFR Part 136, *Guidelines Establishing Test Procedures for Analysis of Pollutants Under the Clean Water Act* as amended.

   In general, the monitoring parameters should include all constituents having water quality objectives listed in the *Water Quality Control Plan for the San Diego Basin* (Basin Plan) for the San Vicente Reservoir.

2. The Draft Plan should include provisions for addressing the State Water Resources Control Board's (State Water Board) draft Policy for Toxicity Assessment and Control (Policy). The Policy includes a new method to determine the toxicity of effluents, statewide numeric objectives, and further standardization of toxicity provisions for National Pollutant Discharge Elimination System (NPDES) permittees. A copy of the Policy may be obtained at:

http://www.waterboards.ca.gov/water_issues/programs/state_implementation_policy/index.shtml.

3. Although as stated in the Draft Plan, the Basin Plan sets a threshold limit for total phosphorus concentration for any streams at the point of entering inland standing body surface waters, such as San Vicente Reservoir, of 0.05 milligrams phosphorus per liter (mg-P/L). San Vicente Reservoir, however, is considered a "standing body of water", not "flowing waters". Therefore, the threshold total phosphorus concentrations shall not exceed 0.025 mg/l in the Reservoir.

4. The Draft Plan should continue to be updated when necessary to implement new monitoring strategies for chemicals of emerging concern in recycled water as decided by the State Water Resource Control Board and California Department of Public Health.

Comments Regarding Order No. 97-03

As discussed in the City of San Diego's December 16, 2010 letter, the City proposes distribute a blend the effluent from the Advanced Water Purification Facility and the North City Water Reclamation Plant to reuse customers in accordance with the requirements of Order No. 97-03. The San Diego Water Board does not require a modification of Order No. 97-03 for the City's proposal because the Advanced Water Purification Facility will provide supplemental treatment to the tertiary effluent produced by the North City Water Reclamation Plant.

For questions pertaining to the above comments, please contact Joann Cofrancesco by email at jcofrancesco@waterboards.ca.gov, or by phone at 858-637-5589.

PLEASE INCLUDE "244506:JCOFRANCESCO" IN THE SUBJECT LINE OF FUTURE CORRESPONDENCE.

Sincerely,

Robert Morris

ROBERT W. MORRIS
Senior Water Resource Control Engineer
San Diego Regional Water Quality Control Board

cc: (by email):
Amy Dorman, Senior Civil Engineer, Long-Range Planning & Water Resource, ADorman@sandiego.gov
Anthony Van, Associate Engineer-Civil, Long-Range Planning & Water Resource, AVan@sandiego.gov

City of San Diego
Indirect Potable Reuse/Reservoir Augmentation Demonstration Project
Advanced Water Purification Facility

Draft Testing and Monitoring Plan (10/8/10) IAP Subcommittee Comments received letter Dated 11/15/10

Comment 1 Treatment Process
Changes in the type and dose of coagulant should be tested to evaluate water quality impacts, such as pH, conductivity, and mineral composition. As a minimum, the effects of ferric chloride coagulation, currently shown as optional, should be assessed along with other potential treatment modifications.

Comment Response
Based on consultation with the NCWRP operations, coagulant and polymers will either not be used during the AWP testing period or would be used at constant concentrations. Currently, NCWRP only uses cation polymer during plant upsets which occur on a very limited basis (i.e. 1 or 2 per year). However, coagulant dosing will be tested upstream of the UF membranes to enhance membrane productivity. The need for coagulant (type and dose) upstream of the UF system will be established by assessing baseline (i.e. no coagulant addition) fouling performance data and recommendations from the UF membrane manufacturer.

Comment 2 Treatment Process
The technical and economic feasibility of conducting partial demineralization by electrodialysis reversal (EDR) should be assessed to optimize the use of reverse osmosis (RO) or identify opportunities to use it as a back-up or supplementary system. Since RO has the capacity to handle some increased total dissolved solids (TDS) loading, it is not clear whether upstream EDR provides enough additional benefits to plant operations to justify the additional expense.

Comment Response
The AWP Demonstration Facility is designed to receive feedwater from the tertiary effluent of the NCWRP upstream of EDR. While the team agrees conducting partial demineralization using EDR upfront of the AWP treatment train may provide benefits (i.e. lower TDS and nitrate) this is not in the scope of the current demonstration testing. Should the baseline train being used at the demonstration scale not meet the nitrogen objectives, the option of using EDR for the full scale AWPF could be considered for nitrate removal, however this option would need to be compared to other possible treatment processes such as ion exchange (IX). Also, further analysis on whether the current EDR system at NCWRP would provide enough capacity for the full scale AWPF would need to be evaluated.

Comment 3 Treatment Process
The status of the existing filtration process should be evaluated in the context of projected upgrades or modifications. Since filtration will now be functioning as pretreatment for the microfiltration/ultrafiltration (MF/UF) process, its performance should be optimized in conjunction with the pilot testing.

Comment Response
The 2009 annual monitoring data from the NCWRP showed Average Daily Turbidity (NTU) from Jan. to Dec. ranged from 0.41 to 0.75 with average a yearly value of 0.56. This data indicates the plant is producing fairly consistent and good quality filter

effluent. It is our understanding that the filter process at NCWRP has been optimized over the years to achieve the current performance and that no further changes / optimization of the process will be made during the operational period of the AWP Demonstration Facility.

Comment 4 Treatment Process
In recognition of the fact that the UV reactor in the pilot plant is not representative of the UV system to be used in the full-scale AWFP, the IAP recommends that verification of the log removal requirements for NDMA and 1,4-dioxane by the advanced oxidation process (AOP), as specified in the August 4, 2008 California Department of Public Health draft groundwater recharge regulations, be performed on the full-scale facility prior to implementation of the project.

Comment Response
The project team is in agreement.

Comment 5 Treatment Process
The IAP Subcommittee was presented with some pilot plant data relating to NDMA removal. This data set was very limited and should not be considered definitive at this time. The IAP would appreciate the opportunity to review additional data related to NDMA removal as it becomes available.

Comment Response
The AWT pilot testing conducted at NCWRP in 2005 showed NDMA measured in the product water to be below the current CDPH notification limit (10 ng/L) in all samples with only 1 detection above the MDL (2 ng/L). Testing and monitoring of the AWP Demonstration facility will generate a greater number of NDMA removal results than the pilot. This information will be included in quarterly progress reports, which will be provided to the IAP to review.

Comment 6 Water Quality
The IAP suggests that, except for water quality monitoring needed at startup of the AWPF to optimize the unit processes, water quality monitoring of the full-scale AWPF not begin until the system has been stabilized and is operating at steady-state conditions to obtain representative data.

Comment Response
Please clarify the comment is referring to water quality monitoring of the <u>demonstration</u> scale AWPF and not the <u>full- scale</u> AWPF. The project team agrees it is important that the demonstration facility operation is stabilized prior to beginning extensive water quality monitoring (i.e. complete list of parameters identified for quarterly sampling). The sampling plan will be executed accordingly.

Comment 7 Microbial
The draft routine bacteria and virus surrogate monitoring plan proposes direct bacteria and virus monitoring using epifluorescence microscopy (with SYBR-green ATP measurements), which is not an approved method. Further, the analysis is expensive and does not determine organism viability. The IAP recommends that the use of epifluorescence microscopy for direct monitoring of bacteria and viruses not be included in the routine surrogate monitoring plan.

Comment Response
The project team appreciates the IAPs input and will remove direct monitoring of bacteria and viruses using epifluorescence microscopy (with SYBR-green ATP measurements).

Comment 8 Microbial
For the component that calls for the direct monitoring of pathogens, the IAP concluded that, due to the well-known performance of the treatment train for pathogen removal and the substantial indicators analyses, monitoring for bacterial and viral pathogens may not necessary. However, the IAP recognizes the value of such monitoring from a public confidence perspective, and suggests that the proposed pathogen monitoring component be reevaluated at the next IAP meeting.

Comment Response
The project team appreciates the IAP's feedback and will hold off on revising the draft plan for direct monitoring of pathogens until further feedback is provided.

Comment 9 Microbial
The IAP suggests that it may be possible to reduce the monitoring frequency for Cryptosporidium (before MF/UF) by sampling for aerobic spores like B. subtilis as potential surrogates for Cryptosporidium. B subtilis are much smaller than Cryptosporidium and thus would be a conservative indicator that can be analyzed quickly and inexpensively. B. subtilis analyses could be performed in conjunction with Cryptosporidium studies and more frequently as potential MF/UF process performance indicators. The use of aerobic spores would be appropriate if the spores service the prior disinfection process. This would need to be evaluated.

Comment Response
The project team agrees B. subtilis may serve a good surrogate for Cryptosporidium as it is smaller and should be removed by sieving. However, it is unknown if the spores will survive the addition of chloramines upstream of the MF/UF systems to have substantial levels. Also, it may be difficult to differentiate whether observations of reduced concentrations in the MF/UF filtrate is due to disinfectant contact time during filtration, or actual removal. In order to answer these questions, the project team would recommend conducting conventional microbial inactivation bench scale experiments using B. subtilis under various conditions including chloramines concentration, pH and contact time. At this time, such testing is not in the scope of the current demonstration testing.

The project team would also like to point out that the type of UF and MF membranes being used at the demonstration facility have been tested under the ***Drinking Water Membrane Testing Protocol For California Department of Public Health (CDPH) Conditional Acceptance*** *(April 2007) and received CDPH conditional approval for membrane filtration products and log removal credits. This testing includes direct challenge testing experiments with an approved Cryptosporidium and Giardia surrogate. Additionally, during the demonstration testing period daily pressure decay testing will be performed to assess membrane integrity of both UF and MF systems in accordance to the* ***EPA Membrane Filtration Guidance Manual*** *(November 2005).*

Comment 10 Constituents of Emerging Concern
The major purpose for the design of the monitoring strategy should be to: 1) determine which constituents are likely to either break-through or not be removed; and 2) use the information obtained as a basis to identify surrogates for operational tracking purposes at different stages of treatment. Experience at Orange County Water District's Groundwater Replenishment System and other similar projects demonstrates that many chemicals (e.g., metals and other priority pollutants) are easily handled by the treatment train if any are in the treated wastewater influent to the advanced treatment plant. In addition, breakthroughs of some chemicals such as NDMA and 1,4-dioxane (and a few others) at ng/L levels are expected, and do not *per se* indicate significant health risks. The IAP recommends that San Diego design a monitoring strategy for the pilot program that collects sufficient numbers of samples to determine appropriate surrogates for managing the processes and also provides public confidence on the effectiveness of the treatment system.

Comment Response
The project team agrees with the goals the IAP has provided with regards to the CEC monitoring plan and will incorporate these into the test plan. The project team has revised the CEC monitoring plan to increase the initial sampling of surrogate / indicators, and increase the list of compounds and sampling locations to be monitored on a quarterly basis based on past performance seen at the City of San Diego AWT pilot and CDPH Recommendations.

Comment 11 Constituents of Emerging Concern
The IAP recommends that the draft strategy include an approach for selecting appropriate surrogate constituents. Initially, screening tests should be conducted for a suite of CECs that may be present in the influent wastewater. Based on the results of the screening studies, a set of surrogate parameters can be selected that could be linked back to the constituents in the wastewater. This study should be initiated after the treatment system has been running for perhaps a minimum of 4 months and is operating at steady-state conditions. The analytical list may be drawn from the City's currently proposed monitoring list of 90 CECs, as well as other sources. The parallel analyses of chemicals and surrogate candidates would include the feed water, before and after RO, and potentially, some chemicals that survive after the advanced

oxidation process (AOP). This assessment is important since it will serve as the basis for process operating decisions in the full-scale plant.

Comment Response
This comment is noted and the recommendations will be implemented in the execution of the CEC monitoring plan.

Comment 12 Constituents of Emerging Concern
It is doubtful that contaminants will routinely break through at concentrations that have health significance, which is one of the reasons for focusing on surrogate analyses. The IAP disagrees with the SWRCB-sponsored report entitled "Final Report: Monitoring Strategies for Chemicals of Emerging Concern (CECs) in Recycled Water" that caffeine and triclosan should be considered as health-related; however, it may be advisable to include them for monitoring process performance. That report also included NDMA and 17 estradiol (although it is unlikely to survive the process). They, as well as many other chemicals, would represent potential health concerns if they occurred at higher than expected levels. Therefore, it is appropriate to have health advisory levels available in the event that any were detected.

Comment Response
The project team appreciates the comment and it is noted.

Comment 13 Constituents of Emerging Concern
The IAP has some suggestions related to the monitoring strategy. DEET, carbamazepine, and primidone could be analyzed because they are ubiquitous in domestic wastewaters and refractory in nature. Among the other suggested chemicals, PFAAs might be candidates, even though their removal by RO has been well documented. 1,4-dioxane is also a good choice due to its known inefficient removal by RO. Chemicals included in the third Unregulated Contaminant Monitoring Rule, Cycle 3 (UCMR3) would best be addressed selectively, unless there is a regulatory requirement to analyze them. Chemicals like triclosan, caffeine, and sucralose and other artificial sweeteners are of no toxicological interest, but may be able to serve as surrogates. Hydrazine and quinoline are of little interest unless they are ubiquitous in the tertiary-treated wastewater and not readily removed by RO and/or AOP; hydrazine would likely not be well removed by RO, if present. Nicotine and cotinine could be considered for inclusion since they are cigarette-related and likely to be in sewage and of toxicity interest if at high enough levels in the finished water, although this is unlikely. They also are relatively low molecular weight molecules that could challenge RO, but not likely AOP. Extensive monitoring for the priority pollutants is of little value. Our understanding is that the Orange County Water District has had no detections in their extensive monitoring over several years. Perhaps a few samples could be analyzed for that group for verification and if the regulatory agencies require it. These types of analyses could also play a role in demonstrating the overall quality of the finished water to the public.

Comment Response
This comment is noted and the recommendations will be implemented in the execution of the CEC and quarterly water quality monitoring plan.

Comment 14 Constituents of Emerging Concern
The characteristics of wastewater can vary depending on the time of day and the loading to the wastewater treatment plant. For parameters that will be monitored using grab-samples, it is important to time sample collection to reflect the range of conditions that are likely (e.g., peak-flow, peak-loading, etc.). It is also important to ensure that the sampling program can yield statistically defensible results. Prior to initiating the routine sampling program, initial quality assurance studies should be conducted to determine the appropriate sample volumes (relates to detection limits), sampling frequency and timing, and which parameters should be monitored using grab-samples versus composite samples. The City should confer with San Diego Regional Water Quality Control Board (RWQCB) to get input on the parameters that should be measured using composite samples and whether the composites should be generated using a flow-weighted or time-based approach.

Comment Response
The project team appreciates the IAPs suggestions with regards to water quality sampling plan. The Testing and Monitoring Plan has been updated to include a revised routine monitoring plan including the basis of the parameter selection, sampling frequency, sample collection type (grab vs. composite) and target demonstration goals. ***This information has been included in Table 5-2 and Table 5-4 located on pages 10 and 11, respectfully of this document.*** *The project team also confirmed with the NCWRP operations that the tertiary flow is constant therefore justifying the use of time weighted (as opposed to flow paced) composite sample collection. In addition, the sampling plan has been updated based on CDPH comments to assess diurnal variations, which will include conducting two 24 hour sampling events during the 12 month operating period to collect grab samples of the RO feed every 4 hours for the following preliminary list of compounds:*

- *Caffeine*
- *Sucralose*
- *Total nitrogen*
- *Nitrate*
- *1,4 dioxane*
- *NDMA*
- *Total phosphorus*

Prior to initiating the sampling plan, the project team will coordinate closely with all laboratories to ensure appropriate samples volumes are collected for each parameter to achieve method detection limits (MDLs) and reporting limits (RLs). The project team feels the revised changes to the sampling plan described above will provide statistically defensible results

Comment 15 Constituents of Emerging Concern
The Orange County Water District has experienced inconsistencies in comparing the monitoring results from grab samples versus online measurements for TOC. Thus, the City should consider relying entirely on online TOC measurements as they would be more informative – and likely more accurate – than using grab samples.

Comment Response
The project team agrees on-line TOC measurements have been reported to be more accurate and provide greater sensitivity than grab samples. The general consensus during the IAP subcommittee meeting with regards to TOC monitoring at the AWP Demonstration Facility was to have (1) one online portable TOC monitor on the combined RO product for each 24 hour period except when it is used to take grab samples from other locations (i.e. RO feed, RO 1 product, RO 2 product, UV/AOP product). During the operation period, the team will access differences (if any) between samples taken online vs. grab samples using the portable TOC monitor for a given sample location.

Comment 16 Constituents of Emerging Concern
The IAP finds that although definitive nutrient requirements for phosphorus and nitrogen have not been determined by the RWQCB, narrative and numeric nutrient requirements already included in the Basin Plan for discharges to surface water (such as San Vicente Reservoir) may allow the use of a 0.1 mg/L total phosphorus goal to determine compliance. Using the nominal N:P ratio of 10:1 to determine compliance for total nitrogen, it is possible that a 1.0 mg/L goal may be promulgated for total nitrogen to prevent eutrophication of the reservoir. The presentations to the IAP by the City of San Diego and their consultants suggests that modifications of the existing treatment process to date at the North City Water Reclamation Plant enhance denitrification and lower nitrate levels has had some success, but nitrate levels are still somewhat above 10 mg/L in the tertiary effluent. Using an 80- to 90-percent removal value for nitrate (provided at the meeting by the City's consultants) as that potentially-achieved by the RO system may yield an effluent nitrate level above the potential compliance limit for discharge to the reservoir. Therefore, the IAP suggests that more attention be paid to the operation of the existing tertiary treatment plant at the North City Water Reclamation Plant (NCWRP) to try to maximize denitrification to achieve lower the nitrate levels in the tertiary-treated water (to well below 10 mg/L) in order to demonstrate that such compliance may be achieved by the AWPF under future effluent limitation scenarios.

Comment Response
As mentioned in the Testing and Monitoring Plan Section 3.1.3.1 the City began a study in January 2008 to assess possible improvements to the NCWRP recycled water quality by enhancing the plants denitrification process. Over the course of the demonstration period, further refinements to the implemented changes are planned to occur with a focus to increase automation of the oxygen system to further reduce the plants effluent nitrate concentration. The project team will coordinate closely with

NCWRP operations staff to be sure data collected at the demonstration plant reflects these changes.

Comment 17 Source Control
The IAP acknowledges the City's efforts to identify potential contaminants of concern in the NCWRP watershed from industries, including pharmaceutical and research facilities.

Comment Response
Noted.

Comment 18 Source Control
Because the opportunity exists for the discharge of (probably small) amounts of chemical, radioactive, and biological material into the wastewater stream, it is advisable to contact each industry, particularly pharmaceutical manufacturers, hospitals, and laboratories, to raise awareness in those industries that their discharges will be feed water to the AWPF that will process the wastewater to be used for potable reuse.

Comment Response
The project team appreciates this advice. The team is preparing a workplan to address source control and will take this concept into consideration.

Comment 19 Source Control
The IAP is interested in hearing more about the City's source control program. The IAP requests that a presentation on the source control program be provided at the next IAP meeting.
Comment Response
Findings related to source control will be presented at a future IAP meeting.

Comment 20 Water Stabilization
The stability of the product water is important to ensure the integrity of the pipeline from a microbial and corrosion perspective. It would be worthwhile to consider evaluating the options for controlling biofilm growth and corrosion. Using a pipe-loop study or annular reactor to evaluate microbial growth and the effectiveness of alternative control strategies could be a valuable complement to the pilot study once the system is operating at steady-state. These tests could be used to determine the extent to which a secondary disinfectant and/or corrosion control in addition to lime treatment is needed.

Comment Response
The project team appreciates the IAP subcommittees recommendations related to water stabilization. At this time, the details of the pump station and pipeline design (pipe material, detention time, etc.) and requirements (including the need for secondary chlorination / dechlorination) for the full scale AWPF conveyance system

have not been determined. Accordingly, as part of the current demonstration testing the project team will only focus on the requirements to stabilize the AOP product water in terms of pH adjustment and lime addition for alkalinity recovery. To achieve this goal, the project team will conduct desktop modeling and bench scale testing using AOP product water collected at the demonstration facility. The City may consider additional testing as recommended by the IAP at a later stage in the demonstration project and / or during the pre-design phase of the possible full-scale AWPF.

Table 5-2 Anticipated Water Quality Goals for Regulated Constituents: San Diego AWP Facility					
Constituent	**Units**	**Proposed Demonstration Goal (average)**	**Anticipated Regulatory Limit (maximum)**	**Basis**	**Critical Beneficial Use/Issue**
Total organic carbon (TOC)	mg/L	0.5	[1]0.5	CDPH	MUN
Ammonia (unionized as N)	ug/L	25	25 or Ce=25+Dm(25)	Basin Plan	Habitat
Nitrate (as N)	mg/L	[2]1	10 or Ce=10+Dm(10)	CDPH & Basin Plan	MUN
Total nitrogen	ug/L	[2]1000	[1]5000	CDPH	MUN
			[1,2]1000	Basin Plan	Biostimulation
Total phosphorus	ug/L	[2]100	[1,2]100	Basin Plan	Biostimulation
N-nitrodisodimethylamine (NDMA)	Log reduction	> 1.2-log	[1]1.2- log	CDPH	MUN
	ng/L	Not detected	[3]0.69 or Ce=0.69+Dm(0.69)	CTR/SIP	
1,4-Dioxane	Log reduction	> 0.5-log	[1]0.5- log	CDPH	MUN
1,2-Dichloroethane	ug/L	< 0.38	[3]0.38 or Ce=0.38+Dm(0.38)	California Toxics Rule	MUN
Total trihalomethanes	ug/L	< 80	[1]80	CDPH	MUN
Bromoform	ug/L	Not detected	[3]4.3 or Ce=4.3+Dm(4.3)	California Toxics Rule	MUN
Chlorodibromomethane	ug/L	Not detected	[3]0.401 or Ce=0.401+Dm(0.401)	California Toxics Rule	MUN
Dichlorobromomethane	ug/L	Not detected	[3]0.56 or Ce=0.56+Dm(0.56)	California Toxics Rule	MUN
Halo acetic acid (HAA)	ug/L	< 60	[1]60	CDPH	MUN
Methylene chloride	ug/L	< 4.7	[3]4.7 or Ce=4.7+Dm(4.7)	California Toxics Rule	MUN
Turbidity	NTU	< 0.2	[1]0.2	CDPH	MUN
Chloride	mg/L	50	[3]50 or Ce=50+Dm(50)	Basin Plan	MUN
Total dissolved solids (TDS)	mg/L	300	[3]300 or Ce=300+Dm(300)	Basin Plan	MUN

1. Potential limit based on best available information developed to date. Value subject to change.
2. Tentative goals based on providing best available treatment economically achievable and achieving Basin Plan total nitrogen and total phosphorus objectives for flowing waters.
3. Based on simplified version for determining California Toxics Rule (CTR) permit limits for priority pollutants. Section 1.4 of the State Implementation Plan contains specific steps and procedures that take into consideration ambient background concentration, the coefficient of variation of measured concentration data, and dilution credit. In some cases, the calculated effluent limitation can be lower than the CTR criterion. Ce - effluent concentration; Dm – dilution factor.

DRAFT

Table 5-4
Certified Laboratory Routine Water Quality Monitoring Plan for the San Diego AWP Facility

Constituent	[1] Sample Location	[2] Type of Sample	[3] Analytical Method	Monitoring Frequency	[4] Total Number of Samples per location
Total organic carbon (TOC)	S6, S7, S8	24-Hour Composite	SM2540C	[5] Monthly	12
Ammonia (unionized as N)	S6, S7, S8,	24-Hour Composite	EPA 300.0	[5] Bi-weekly (once per 2 weeks	26
Nitrate (as N)	S6, S7, S8	24-Hour Composite	EPA 300/351.2	[5] Bi-weekly (once per 2 weeks	26
Total nitrogen	S6, S7, S8	24-Hour Composite	SM4500P-E	[5] Bi-weekly (once per 2 weeks)	26
Total phosphorus	S6, S7, S8	24-Hour Composite	EPA 521	Bi-weekly (once per 2 weeks	26
N-nitrodisodimethylamine (NDMA)	S6, S7, S8, S9, S10	24-Hour Composite	EPA 522 MOD	Monthly	12
1,4-Dioxane	S6, S9, S10	Grab	ML/SW 8270 mod	Monthly	12
1,2-Dichloroethane	S6, S9, S10	Grab	ML/EPA 524.2	Monthly	12
Total trihalomethanes	S6, S9, S10	Grab	ML/EPA 524.2	Monthly	12
Bromoform	S6, S9, S10	Grab	ML/EPA 524.2	Monthly	12
Chlorodibromomethane	S6, S9, S10	Grab	ML/EPA 524.2	Monthly	12
Dichlorobromomethane	S6, S9, S10	Grab	ML/EPA 524.2	Monthly	12
Trichloromethane	S6, S9, S10	Grab	ML/EPA 524.2	Monthly	12
Halo acetic acid (HAA)	S6, S9, S10	Grab	EPA 552.2	Monthly	12
Methylene chloride	S6, S9, S10	Grab	ML/EPA 524.2	Monthly	12
Turbidity	S4, S5	24-Hour Composite		Daily	365
Chloride	S6, S7, S8	24-Hour Composite	ML/EPA 300.0	Bi-weekly (once per 2 weeks	26
Total dissolved solids (TDS)	S6, S7, S8	24-Hour Composite	SM 2540C	Bi-weekly (once per 2 weeks	26
Microbial	See endnote 5	See endnote 5	See endnote 6	See endnote 6	See endnote 6

[1]. Sampling locations: S4 = MF product; S5 = UF product; S6 = RO feed; S7 = RO 1 product; S8 = RO 2 product; S9 = UV/AOP feed; S10 = UV/AOP product.
[2]. Composite samples to be collected on a time weighted basis. NCWRP is operated to provide constant tertiary flow.
[3]. MDLs, RLs, TATs, sample hold times for each method are provided in Appendix E.
[4]. Based on a 12 month testing period.
[5]. Additional samples to be analyzed 2 per week collected 3 days apart at S10 in accordance to CDPH Groundwater Recharge Reuse Draft Regulations (2008).
[6]. See Section 5.2.4, Table 5-8 for microbial sampling plan.
Note: two 24 hour sampling events during the 12 month operating period will also be conducted to assess diurnal variations by collecting grab samples of the RO feed every 4 hours for the following preliminary list of compounds: Caffeine; Sucralose; Total nitrogen, Nitrate; 1,4 dioxane; NDMA; Total phosphorus.

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Final Testing and Monitoring Plan

CDM

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Appendix B

Quarterly Testing Report No.4

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Quarterly Testing Report No. 4

January 2013

CITY OF SAN DIEGO

Indirect Potable Reuse/Reservoir Augmentation Demonstration Project
Advanced Water Purification Facility

THE CITY OF SAN DIEGO

City of San Diego
PUBLIC UTILITIES
Water & Wastewater

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Appendices

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Appendix B: Quality Control Sample Results and CEC Data Review Letter prepared by Andy Eaton, Ph.D.

Appendix C: Technical Memorandum: Summary of Third Party Data Validation of AWP Facility Quarterly Sampling Event Results.

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Abbreviations and Acronyms

Ace-K	acesulfame potassium
ADI	acceptable daily intake
ALCR	air liquid conversion ratio
ANSI	American National Standards Institute
AWP	advanced water purification
AWP Facility	advanced water purification facility
Basin Plan	Water Quality Control Plan for the San Diego Basin
Bay- Delta	Sacramento San Joaquin Bay Delta
BCM	bromochloromethane
BDCM	bromodichloromethane
C	Celsius
CAL	critical alert level
CCL3	Contaminant Candidate List 3
CCP	critical control point
CB	chlorinated backwashes
CDPH	California Department of Public Health
CEC	constituent of emerging concern
CIP	clean in place
City	City of San Diego
CLP	Contract Laboratory Program
CLP's	critical limit parameters
cm	centimeter
CSM	Colorado School of Mines
CTR	California Toxic Rule
CWA	Clean Water Act
DBCM	dibromochloromethane
DCS	distributed control system
DEET	N,N-diethyl-meta-toluamide
DBP	disinfection byproduct
DEA	Deethylatrazine
Demonstration Project	Water Purification Demonstration Project
DL	method detection limit
DLR	CDPH detection limit for reporting
DO	dissolved oxygen
DP	distribution panel
DP	differential pressure
DWEL	Drinking Water Equivalent Level
DWR	California Department of Water Resources
EDR	electrodialysis reversal
EED	electrical energy dose
EEO	electrical energy per order
EG	ethylene glycol
ENR	Engineering News Record
EPA	U. S. Environmental Protection Agency
ERD	energy recovery device

ERI	Energy Recovery, Inc.
ft^2	square feet
FWR	feedwater recovery
gfd	gallons per square foot per day
gpm	gallons per minute
H_2O_2	hydrogen peroxide
HAAs	Haloacetic Acids
HMI	human machine interface
HP	horsepower
HVAC	heating, ventilating, and air conditioning
I&C	instrumentation and controls
IAP	Independent Advisory Panel
IAW	imported raw aqueduct water
in^2	square inches
IPR	indirect potable reuse
IPR/RA	indirect potable reuse/reservoir augmentation
IRWM	Integrated Regional Water Management
KV	kilovolts
KVA	kilovolts amperes
kW	kilowatt
kWh	kilowatt hours
kWh/d	kilowatt hours per day
kWh/yr	kilowatt hours per year
L	liter
LDC	Laboratory Data Consultants, Inc.
LPHO	low pressure high output
LRV	log removal value
LRL	laboratory reporting level
LSI	Langelier Saturation Index
m	meter
MC	maintenance cleans
MCC	motor control center
MCL	maximum contaminant level
MDA	minimum detectable activity
MDL	method detection limit
MF	microfiltration
MG	million gallons
mg/L	milligrams per liter
mg/L-N	milligrams per liter as nitrogen
mg/L-P	milligrams per liter as phosphorus
mgd	million gallons per day
mL	milliliters
mL/min	milliliters per minute
min	minute
mJ/cm^2	millijoules per square centimeter
MPN	most probable number
mV	millivolt
µg/L	micrograms per liter

µg/L-P	P micrograms per liter as phosphorus
µS/cm	microsiemens per centimeter
N/A	not applicable
NE	Nautilus Environmental Laboratories
North City	North City Water Reclamation Plant
ND	not detectable or not quantifiable
NDBA	N-Nitrosodi-n-butylamine
NDEA	N-Nitrosodiethylamine
NDMA	N-Nitrosodimethylamine
NDPA	N-Nitrosodi-n-propylamine
ng/L	nanograms per liter
NL	notification level
NMEA	N-Nitrosomethylethylamine
NMOR	N-Nitrosomorpholine
NOP	net operating pressure
NPDES	National Pollution Discharge Elimination System
NPIP	N-Nitrosopiperidine
NPYR	N-Nitrosopyrrolidine
NR	not reported
NR&C	Natural Resources and Culture Committee
NTU	Nephelometric Turbidity Units
OCWD	Orange County Water District
O&M	operation and maintenance
ORP	oxidation reduction potential
PDC	power distribution cabinet
PDT	Pressure Decay Testing
PLC	programmable logic controller
Point Loma	Point Loma Wastewater Treatment Plant
ppb	parts per billion
PPCPs	pharmaceuticals and personal care products
ppm	parts per million
ppt	parts per trillion
psi	pounds per square inch
PVC	polyvinyl chloride
PVDF	polyvinylidene fluoride
Q1	Quarter 1
Q2	Quarter 2
Q3	Quarter 3
Q4	Quarter 4
QA/QC	quality assurance/quality control
RA	Reservoir Augmentation
RA	re-analyzed
Regional Board	San Diego Regional Water Quality Control Board
RL	reporting level
RO	reverse osmosis
RPD	relative percent difference
RWQCB	Regional Water Quality Control Board
SDG&E	San Diego Gas & Electric

SDI	silt density index
SDWA	Safe Drinking Water Act
SIP	State Board Policy for Implementation of Toxics Standards for Inland Surface Water, Enclosed Bays, and Estuaries of California
South Bay	South Bay Water Reclamation Plant
State Board/SWRCB	State Water Resources Control Board
STD	standard deviation
T&M Plan	Plan Testing and Monitoring Plan
TCEP	tris (2-chloroethyl) phosphate
TCPP	tris (1-chlor 2 propyl) phosphate
TDI	tolerable daily intake
TDS	total dissolved solids
THMs	trihalomethanes
Title 22	Title 22 of California Code of Regulations
TKN	Total Kjeldahl Nitrogen
TMP	transmembrane pressure
TOC	total organic carbon
TU	toxic unit
UCMR	Unregulated Contaminant Monitoring Rule
UF	ultrafiltration
UV	ultraviolet
UV/AOP	ultraviolet light disinfection and advanced oxidation
UV254	UV 254 Absorbance
UVT	ultraviolet light transmittance
VOC	volatile organic compound
Water Authority	San Diego County Water Authority
WET	Whole Effluent Toxicity
WSE	water surface elevation

Glossary

Advanced Oxidation: A set of chemical treatment processes designed to destroy organic material through the breakdown of their molecular structure. The advanced oxidation process used at the AWP Facility employs ultraviolet light and hydrogen peroxide, which break down into natural elements, such as carbon, hydrogen and nitrogen.

Advanced Water Purification Facility (AWP Facility): A facility that produces purified water by utilizing advanced treatment technologies: membrane filtration (microfiltration [MF] or ultrafiltration [UF]), reverse osmosis (RO), disinfection, and advanced oxidation.

Advanced Water Purification (AWP) Facility Study: One element of the multi-faceted Demonstration Project. The AWP Facility Study included two primary elements: (1) the design, installation, and operation of a one million gallon per day (mgd) Demonstration Facility located at North City and (2) a conceptual design and cost estimate for a potential Full-Scale Facility.

Advanced Water Purification (AWP) Facility Study Report: Final report documenting the observations and findings of the AWP Facility Study.

Analyte: a chemical substance that is the subject of chemical analysis.

Backwash: The process of reversing the direction of flow through a filtration system in order to remove contaminants that had been filtered out in a water purification process, e.g. membrane filtration. The backwash process is necessary in order to maintain the treatment capacity of membrane filtration.

Bacteriophage: Viruses present among coliform bacteria. Have a high presence in wastewater.

Ballast: An electronic device on the UV system designed to generate a constant UV intensity and maximize UV lamp life.

Blending: Mixing or combining one water source with another such as purified water with raw water sources.

California Groundwater Recharge Reuse Draft Regulations: The November 21, 2011 Groundwater Recharge Reuse Draft Regulations, which are used as a guidance document for the conceptual design of the Full-scale Facility since regulations for reservoir augmentation with purified water do not yet exist. Also referred to as the draft groundwater recharge regulations.

Clean in place: The in situ chemical cleaning of membranes that consists of soaking membranes in one or more chemical solutions (typically acid and caustic solutions) to remove accumulated foulants and restore permeability.

Concentrate: A continuous waste stream, typically containing concentrated dissolved solids, from the membrane process.

Constituent: In water, a constituent is a dissolved chemical element or compound or a suspended material that is carried in the water.

Constituents of Emerging Concerns (CECs): CECs are not regulated and include commonly used pharmaceuticals, personal care products, flame retardants and unregulated pesticides.

Contaminant: An organic or inorganic substance found in the water. Some contaminants have a health effect in people consuming the water, and thus is regulated in drinking water. Not all contaminants are unsafe. Iron and manganese are contaminants, but in excess simply causing staining. See Maximum Contaminant Level.

Critical alert limit: Measurement of a critical limit parameter that requires urgent corrective action in order for the corresponding critical control point to function as intended.

Critical control point: A point or step within the AWP Facility process train at which critical limit parameters can be monitored in order for corrective actions to be taken should critical alert limits be exceeded.

Critical limit parameter: A parameter that indicates whether or not a control measure is within the alert limit or critical alert limit for the corresponding critical control point.

Demonstration Facility: The one-mgd advanced water purification facility that was designed, installed, and operated as part of the City's Water Purification Demonstration Project.

Detection limit for the purposes of reporting (DLR): The DLR is a parameter that is set by regulation for each reportable analyte. It is not laboratory specific and it is independent of the analytical method used (in cases where several methods are approved). The DLR cannot be changed by the laboratory. It is expected that a laboratory can achieve a reporting limit (RL) that is lower than or equal to the DLR set by the California Department of Public Health (CDPH).

Disinfection: The removal, deactivation or destroying of microorganisms present in a water supply that may be harmful to humans. Commonly used disinfectants include chlorine (and its derivatives), ultraviolet (UV) light, and ozone. Chlorine and its derivatives are used to disinfect drinking water because they provide residual disinfection that protects the water as it goes through the pipes to homes and businesses.

Disinfection byproduct: A compound that is formed through the reaction of a disinfectant (chlorine, ozone, chlorine dioxide) with organic or inorganic material present in the water. Some disinfection byproducts have been found to be harmful to human health and are regulated by the EPA or under consideration for future regulation.

1, 4- Dioxane: A chemical contaminant primarily used as an industrial stabilizer to enhance performance of solvents in manufacturing processes. Commonly used in food and food additives or in personal care products such as cosmetics, deodorants, soaps and shampoos. Currently there is not a federal or state MCL; however, the CDPH has established a notification level of 1 ppb. CDPH also specifies in the 2011 Draft Groundwater Recharge Reuse Regulations that AOP systems required for direct injection applications can be designed to achieve 0.5 log

removal of 1,4-Dioxane. Alternatively, AOP sizing can be based on demonstrated log removals of select indicator compounds from different functional groups.

Drinking water: Water that meets federal drinking water standards as well as state and local water quality standards so that it is safe for human consumption. Water treatment facilities that produce drinking water require a state permit. Also referred to as potable water.

Drought: A defined period of time when rainfall and runoff in a geographic area are much less than average.

EEO-electrical energy per order: The amount of energy required to destroy 1 log order (i.e. 90%) of a given contaminant per 1000 gallons of water treated. EEO values are both reactor and water quality specific and used to baseline differences in reactor configurations and UV lamp intensities to establish comparative removals of a given constituent such as NDMA and 1,4-Dioxane.

EED -electrical energy dose: The amount of energy (kWh) dosed per 1000 gallons of water treated.

Effluent: The water leaving a water or wastewater treatment process or facility. If effluent has been treated to a high enough standard, it may be considered to be recycled water and can be used for beneficial purposes.

Endocrine disrupting compounds (EDCs): A chemical substance or mixture that alters the normal hormone functions in humans and animals. These chemicals can come from pharmaceuticals and personal care products such as detergent and synthetic hormones. They may also come from some industrial wastes and pesticides. EDCs are also contained in natural agricultural products such as soybeans, alfalfa, and natural hormones in animals.

Environmental Impact Statement / Environmental Impact Report (EIS/EIR): Detailed analysis of impacts of a project on all aspects of the natural and human environment. An EIS is required by the federal National Environmental Policy Act (NEPA) for federal permitting or use of federal funds. An EIR is required by the California Environmental Quality Act (CEQA) for local projects.

Filtrate: A continuous stream of water that passes through a filter.

Filtration: A process that separates small particles from water by using a porous barrier to trap the particles and allow the water to pass through.

Flux: The unit rate at which water passes through the membrane expressed as flow per unit of membrane area (e.g., gallons per square foot per day (gfd)).

Fouling: The accumulation of contaminants on the membrane surface, within membrane pores, or media surface that inhibits the passage of water.

Full-Scale Facility: The proposed AWP Facility for the full scale IPR/RA project. The Full Scale

Facility will have a capacity of 18 mgd and annual average purified water production of 15 mgd.

Groundwater recharge: Naturally or artificially adding water back into a groundwater basin.

Hydrogen peroxide: Chemical added in the UV disinfection/advanced oxidation step.

Imported water: A water source that originates in one hydrologic region and is transferred to another hydrologic region. In San Diego's case, water is imported from Northern California or the Colorado River and travels to this region in large above ground aqueducts or underground pipelines.

Imported raw aqueduct water: The imported raw water conveyed to the City's three Drinking Water Treatment Plants. For the AWP Facility Project, imported raw aqueduct water specifically refers to the imported water that was sampled per the Testing and Monitoring Plan. Imported raw aqueduct water was sampled at the Miramar Water Treatment Plant.

Indicator Compounds or Indicator Organisms: A common method to evaluate water or wastewater quality using representative chemicals or organisms that are characteristic of a larger group of related chemicals or organisms. Coliform bacteria are common indicator organisms, and trihalomethanes, benzene, and NDMA are examples of indicator compounds.

Indirect potable reuse (IPR): The process of blending purified water into a natural water source (groundwater basin or reservoir) that can be used as a source of drinking water.

Influent: Flow entering a process.

Inorganic chemicals: Inorganic chemicals are substances that do not contain both carbon and hydrogen. Generally, inorganic chemicals are minerals. Most minerals are not a cause for concern in water. Water contains many natural minerals from the rocks the water has come into contact with on its journey to the water treatment plant. Nutrients, such as phosphorus and nitrogen, and metals, such as calcium, iron, sodium, potassium, and zinc, are inorganic chemicals. Some inorganic chemicals, when they are too abundant, are considered contaminants in water.

Integrity monitoring: Performance evaluation of a treatment process in order to verify that the process meets its intended treatment performance on a continuous basis.

Laboratory reporting level (LRL) or Reporting Level (RL): The lowest concentration at which an analyte can be quantified and reported with an acceptable degree of accuracy. Laboratory reporting levels can vary based on the analytical method used, the laboratory, and the concentration being tested.

Maximum Contaminant Level (MCL): The highest allowable amount of a contaminant in water, established by the U.S. Environmental Protection Agency as a regulatory standard.

Membrane filtration: A type of filter used to separate particles from the water. Membrane filters are characterized by the pore openings size from the largest to the smallest pore size:

microfiltration, ultrafiltration, and nanofiltration. Membrane filters remove suspended solids, bacteria, protozoa, and other material from water.

Method detection limit (MDL) or Detection Limit (DL): The lowest concentration at which an analyte can be detected in a sample and reported with greater than 99 percent certainty using a particular analytical method.

Microfiltration (MF): A low pressure membrane filtration process where tiny, hollow straw like membranes separate small suspended particles, bacteria and other materials out of the water. MF provides the most efficient preparation of water for reverse osmosis. MF is used in commercial industries to process food, fruit juices and soda beverages; in computer chip manufacturing; and to sterilize medicines that cannot be heated.

Micron: Equal to one millionth of a meter or 1/25,400 of one inch. The eye can see particles only to about 40 microns. Used to describe the size of bacteria.

National Pollutant Discharge Elimination System (NPDES): A federal permit authorized by the Clean Water Act, Title IV, which is required for discharge of pollutants to navigable waters of the United States, and includes any discharge to surface waters: lakes, streams, rivers, bays, the ocean, wetlands, storm sewer, or tributary to any surface water body.

NDMA-N-Nitrosodimethylamine: A semi-volatile, yellow, oily liquid of low viscosity that has been extensively used in industry for several decades (USEPA, 2001). NDMA is found at low levels in numerous items of human consumption including cured meat, fish, beer, and tobacco smoke. Currently there is not a federal or state MCL; however, the CDPH has established a notification level of 10 ng/L. Until revision of the Draft Groundwater Recharge Reuse Regulations in 2011 CDPH required that AOP systems required for direct injection applications be designed to achieve 0.5 log removal of 1,4-Dioxane and 1.2 log removal of NDMA.

Non detectable and non quantifiable (ND): Laboratory sample results of a constituent reported as less than the reporting limit (RL) and detection limit (DL).

Non-potable water: Water that is not suitable for drinking because it has not been treated to drinking water standards.

North City Water Reclamation Plant (North City): Wastewater treatment plant that produces recycled water through a series of processes: primary treatment (screening and sedimentation), secondary treatment (aeration and clarification), and tertiary treatment (filtration and disinfection).

Organic chemicals: Chemicals that contain both carbon and hydrogen. There are millions of organic compounds, both naturally occurring and man-made. Naturally occurring organic compounds include amino acids (the building blocks of proteins), sugars, fats, hormones, and vitamins. All living matter is made up of natural organic chemicals. Synthetic (manmade) organic chemicals have been developed because they exhibit features that are valuable to us. These synthetic organic chemicals include herbicides, insecticides, pharmaceuticals, food coloring and flavors, personal care products, dyes, paints, adhesives, detergents, polymers, and plastics.

Osmotic pressure: The amount of pressure that must be applied to stop the natural osmosis driven flow of water across a semi-permeable membrane.

Oxidation: A treatment step often used in disinfection, where chlorine, hydrogen peroxide, ozone, or another oxidizing agent is added to water to produce a chemical reaction that removes or aids in removal of harmful substances.

Pathogens: Disease causing organisms. The general groupings of pathogens are viruses, bacteria, protozoa, and fungi.

Permeate: A continuous stream of water that passes through membrane. Typically used for water that passes through a reverse osmosis membrane (i.e., reverse osmosis permeate). Also referred to as filtrate or product.

Personal care product: Products that can be found in wastewater such as shampoos, fragrances, soap, and deodorant.

Pharmaceutically active compound: Hormone based compounds found within EDC's. Examples of these compounds include antibiotics, anti epileptic medications, heart medications, pain medications, and cancer medications, along with veterinary drugs and feed additives used for livestock.

Phenolic Compounds: A class of aromatic organic compounds commonly used in the manufacture of plastics, cosmetics, and antiseptics, and as preservatives for wood and rubber. Several of these compounds are regulated for surface water (11 compounds), drinking water (1 compound), and air (5 compounds), based on observed toxicity. Phenolic compounds are commonly found in bottled water and are sometimes classified as endocrine disrupting compounds.

Point Loma Wastewater Treatment Plant (Point Loma): Advanced primary wastewater treatment plant that discharges treated wastewater into the Pacific Ocean.

Potable water: See drinking water.

Purified water: Recycled water that has been treated to an advanced level beyond tertiary treatment, so that it can be added to water supplies ultimately used for drinking water. The treatment includes membrane filtration with microfiltration (MF) or ultrafiltration (UF), reverse osmosis (RO), and advanced oxidation that consists of disinfection with ultraviolet light (UV) and hydrogen peroxide (H2O2). Purified water may be discharged into a groundwater basin or surface water reservoir that supplies water to a drinking water treatment facility.

Quarterly Testing Reports: Four quarterly testing reports were prepared to summarize the testing data collected at the Demonstration Facility. Quarterly Testing Report No. 4 includes all of the data collected at the Demonstration Facility and is included as an appendix to the AWP Facility Project Report.

Raw water: Water that has not been treated for use. Examples of raw water are water in the Colorado River aqueduct, the State Water Project aqueduct, open reservoirs (whether filled with imported water or runoff), rivers, naturally occurring lakes and some well water.

Reactor: A vessel or tank where physical or chemical treatment processes occur**.**

Reclaimed water: See recycled water.

Recovery: Also called Feedwater Recovery is the volumetric percent of feed water that is converted to filtrate or permeate.

Recycled water: Treatment of wastewater beyond secondary treatment using tertiary filtration and chlorination. Water treated to this tertiary level is considered to be recycled water, which is suitable for many beneficial uses including irrigation or industrial processes. Recycled water meets treatment and reliability criteria established by Title 22, Chapter 4, of the California Code of Regulations.

Reservoir: A manmade lake or tank used to collect and store water.

Reservoir augmentation (RA): The process of adding purified water to a surface water reservoir. The purified water undergoes advanced treatment (membrane filtration, reverse osmosis and UV disinfection/advanced oxidation). The purified water is then blended with untreated water in a reservoir. The blended water is then treated and disinfected at a conventional drinking water treatment plant and is distributed into the drinking water delivery system. Also known as surface water augmentation.

Reverse osmosis (RO): A high pressure membrane process that forces water through the molecular structure of several sheets of thin plastic membranes to filter out minerals and contaminants, including salts, viruses, pesticides, and other materials. The RO membranes are like microscopic strainers bacteria and viruses as well as inorganic and most organic molecules cannot pass through the membranes.

Scaling: The precipitation or crystallization of salts on a surface (e.g., on the feed side of a membrane).

Specific flux: Flux per unit pressure (gfd/psi). This value is temperature corrected due to the impact of temperature on viscosity. (See definition of flux).

Spiking: A process in which a known quantity of a given constituent is added to the feed of a treatment system to test the robustness of the treatment process when ambient concentrations of the target constituent(s) is very low.

Stage: A group of membrane units operating in series. In a two stage configuration, concentrate from the first stage travels to the second where more water is produced.

Storage: Water held in a reservoir for later use.

Surface water: Water located on the Earth's surface, in a river, stream, lake, pond or surface water reservoir.

Surrogate Compounds or Surrogate Parameters: A common method used to evaluate water quality using a compound or parameter viewed as representative of a non-related class of chemicals or organisms. Surrogates are used when the analytes of interest are more difficult to quantify and measure through standard laboratory practices. Examples of surrogate parameters include turbidity, conductivity, UV254, and total organic carbon.

Tertiary effluent prior to chlorination: Tertiary effluent prior to chlorination is wastewater that has undergone primary treatment, secondary treatment, and tertiary filtration, but has not been disinfected with chlorine. This is the feed water to the AWP Facility. Sometimes referred to as recycled water even though it has not been disinfected.

Testing and Monitoring Plan (T&M Plan): This plan was prepared as part of the AWP Facility Project to outline the testing and monitoring that was conducted at the Demonstration Facility. The plan was reviewed and commented on by the Independent Advisory Panel (IAP), the California Department of Public Health (CDPH), and the San Diego Regional Water Quality Control Board (Regional Board).

Total dissolved solids (TDS): The concentration of mineral salts dissolved in water. Salinity may be measured by weight (TDS) or by electrical conductivity. Salinity and TDS are both measures of the amount of salt dissolved in water, and the terms are often used interchangeably. Generally, salinity is used when referring to water with a lot of salt (e.g., seawater), whereas TDS is used to refer to water with little salt (e.g., freshwater).

Total Organic Carbon (TOC): TOC has no health effects. However, TOC provides a medium for the formation of disinfection by-products. These by-products include trihalomethanes (THMs) and haloacetic acids (HAAS). Drinking water containing these by-products in excess of the MCL may lead to adverse health effects, liver or kidney problems, or nervous system effects, and may lead to an increased risk of cancer.

Transmembrane pressure: The difference in pressure from the feed (or feed concentrate average) to the permeate across the membrane.

Turbidity: A measure of suspended solids in water; cloudiness.

Ultrafiltration (UF): A membrane filtration process with pore openings that fall between reverse osmosis (RO) and microfiltration (MF). Also used to characterize the size of particles removed.

Ultraviolet (UV) disinfection and advanced oxidation: During ultraviolet disinfection, water is exposed to ultraviolet (UV) light, just like instruments in medical and dental offices, to provide disinfection. Additionally, ultraviolet light combined with hydrogen peroxide creates an advanced oxidation reaction that eliminates any remaining compounds in water by breaking them down into harmless compounds.

Vessel Array: Physical arrangement of pressure vessels in a reverse osmosis (RO) system. For

example, a 10 by 5 by 3 vessel array indicates a three stage RO system with 18 total vessels: stage one has 10 vessels, stage two has 5 vessels, and stage three has 3 vessels.

Wastewater: Untreated water collected in the sewer system from residences and businesses (e.g., from bathtubs, showers, bathroom sinks, clothes washers, toilets, kitchen sinks, dishwashers, and industrial processes). It consists of mostly water with some impurities. Also known as sewage.

Water Purification Demonstration Project (Demonstration Project): The second phase of the City of San Diego's Water Reuse Program. During this phase the Demonstration Facility will operate for approximately one year and will produce one million gallons of purified water per day. A study of the San Vicente Reservoir is being conducted to test the key functions of reservoir augmentation and to determine the viability of a full-scale project. No purified water was sent to the reservoir during the demonstration phase.

Water Purification Demonstration Project (Demonstration Project) Report: Final report documenting the findings of the Demonstration Project.

Water purification process: The process of using water purification technology on recycled water to produce a water supply that can be used for reservoir augmentation and ultimately for drinking water purposes. The process of water purification starts with recycled water, which has already been treated to produce a supply of water safe enough for irrigation and industrial purposes. This recycled water is further treated with water purification technology. The resulting purified water can be used to augment local reservoir supplies, which would be treated once more at a potable water treatment plant to produce drinking water.

Water purification technology: The technology used for purifying treated wastewater, including membrane filtration with microfiltration (MF) or ultrafiltration (UF), reverse osmosis (RO), and ultraviolet (UV) disinfection and advanced oxidation.

Water reuse: The planned use of recycled water that would otherwise return to the natural hydrologic (water) system for a specific beneficial purpose.

Water Quality Sampling Terminology

Field Duplicate: A portion of the collected sample volume is analyzed identically to evaluate laboratory precision, reproducibility of sample handling and analytical procedures, sample heterogeneity, and analytical procedures.

Blind Duplicate: Same as field duplicate, however the laboratory is not provided the sample location prior to analysis.

Split Sample: A portion of the collected sample volume is analyzed by a separate laboratory with overlapping capabilities utilizing identical analytical methods to evaluate laboratory accuracy, reproducibility of sample handling and analytical procedures, sample heterogeneity, and analytical procedures.

Field Blank: A sample of analyte free water (laboratory provided) is poured into the container in the field, preserved and shipped to the laboratory with field samples. The purpose is to assess contamination from field conditions during sampling.

Travel Blank: A clean sample of a matrix that is transported from the laboratory to the sampling site and transported back to the laboratory without having been exposed to sampling procedures. Typically, analyzed only for volatile compounds. The purpose is to aassess contamination introduced during shipping and field handling procedures.

Grab Sample: An individual sample collected at a selected time.

Composite Sample: Consists of grab samples of the same volume, taken from one source over a specific period at regulated times (i.e. time weighted) or at irregular intervals in irregular volumes that proportion the flow (i.e. flow weighted).

Water Measurement Terms

Milligrams per liter (mg/L) also known as parts per million (ppm): A measurement describing the amount of a substance (such as a mineral, chemical or contaminant) in a liter of water; a unit used to measure water concentrations (parts of something per million parts of water). One part per million is equal to one milligram per liter. (This term is becoming obsolete as instruments measure smaller particles.) This is equivalent to one drop of water diluted into 50 liters (roughly the fuel tank capacity of a compact car) or about thirty seconds out of a year.

Micrograms per liter (ug/L) also known as parts per billion (ppb): A frequently used measurement for water concentration (parts of something per billion parts of water). One part per billion is equivalent to one second of time in 32 years or one drop of water in a typical backyard swimming pool (a typical residential swimming pool is 30 feet by 15 feet with an average depth of 6 feet or 60 cubic meters). One thousand parts per billion is equal to one part per million.

Nanograms per liter (ng/L) also known as parts per trillion (ppt): A very high level of measurement for water concentration (parts of a constituent per trillion parts of water). This is equivalent to one drop of water diluted into 20 London Olympics swimming pools (2,500 cubic meters times 20 = 50,000 cubic meters) or about three seconds out of every 100,000 years.

Million gallons per day (mgd): This term is used to describe the flow of water treated and distributed from a treatment plant.

Acre foot (AF): A unit of water commonly used in the water industry to measure large volumes of water. It equals the volume of water required to cover one acre to a depth of one foot. An acre foot is 325,851 gallons and is considered enough water to meet the needs of two families of four with a house and yard for one year.

Executive Summary

In June 2011, the City of San Diego began operation of a three-step Advanced Water Purification (AWP) Facility to produce water suitable for indirect potable reuse from tertiary effluent (pre-chlorination) produced at the North City Water Reclamation Plant (North City). The Demonstration Facility is located at 4949 Eastgate Mall Road San Diego, CA 92121. A flow diagram of the Demonstration Facility processes and sampling locations (designated as S1 through S10) is provided in **Figure ES-1**. The Demonstration Facility was designed with a 1 million gallon per day (mgd) production capacity and consists of the following unit processes: parallel membrane filtration processes (microfiltration [MF] and ultrafiltration [UF]); parallel-two stage and three-stage reverse osmosis (RO) processes; and ultraviolet (UV) light disinfection and advanced oxidation (UV/AOP).

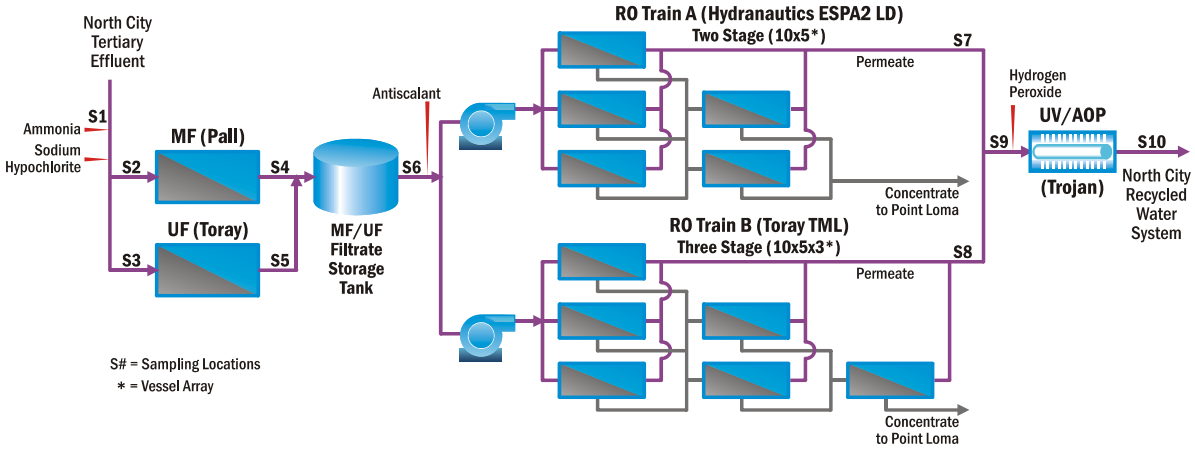

Figure ES-1 Demonstration Facility Processes

Specific objectives of the testing and monitoring program for the Demonstration Facility included:

- Demonstrate to the California Department of Public Health (CDPH) and the Regional Water Quality Control Board (RWQCB) that the proposed water purification processes will produce a final product water that meets public health and surface water augmentation criteria.
- Implement a monitoring plan for Constituents of Emerging Concern (CECs) tailored to the North City tertiary water characteristics and current recommendations of the State Water Resources Control Board (State Board).
- Demonstrate integrity monitoring techniques and performance reliability measures for the water purification processes, which can be implemented at the potential Full-Scale Facility.
- Monitor and collect operational performance and maintenance requirements of the Demonstration Facility equipment.

- Evaluate the degradation and by-product formation of nitrosamines and 1,4-dioxane by UV/AOP and compare alternative chloramines application conditions to mitigate N-Nitrosodimethlyamine (NDMA) formation.

The above objectives were met by operating the Demonstration Facility on a continuous basis for a 13.5-month period beginning in mid-June 2011 through the end of July 2012. During this time a testing and monitoring plan was implemented that specified water quality goals, materials and methods, process evaluation procedures and quality control measures. The Final Testing and Monitoring Plan (CDM Smith / MWH 2011) was reviewed and commented on by the Demonstration Project's Independent Advisory Panel (IAP), the CDPH, and the San Diego RWQCB. The operation and testing results associated with the Demonstration Facility were reported on a quarterly basis. The start and completion date for each testing period are shown in **Table ES-1**.

Table ES-1 Summary of Demonstration Facility Testing Periods

Testing Period	Testing Quarter	Test Period Start	Test Period End	Report Date
Testing Period 1	Q1	6/16/2011	10/31/2011	December 2011
Testing Period 2	Q2	11/1/2011	2/10/2012	March 2012
Testing Period 3	Q3	2/11/2012	5/14/2012	June 2012
Testing Period 4	Q4	5/15/2012	7/31/2012	September 2012

Operational Performance Monitoring

The subsections below summarize the cumulative operational performance results collected for each water purification process.

Microfiltration and Ultrafiltration Systems

Based on the similarities in operational performance and water quality performance, both MF and UF are suitable systems for membrane filtration in a Full-Scale Facility. The results of the testing showed the following:

- **Recovery:** The MF system operated at a recovery of 93 percent and experienced minimal fouling (reduction in performance). The UF system operated at 95 percent recovery and minimal fouling was observed during the Testing Periods 1 and 2; however, an increased rate of fouling was observed during the Testing Period 3. The UF system's higher recovery (i.e., less backwash waste) of 95 percent may have contributed to the increased rate of fouling.

- **Chemical Cleaning:** Two chemical cleanings were conducted on both the MF and UF systems during Testing Periods 1 through 3. These were effective at restoring the performance to the level observed when the membranes were new, which maintains efficient operations. Increased fouling of the UF system was observed during Testing Period 4.. The shorter cleaning cycle observed on the UF compared to the MF system may be due to smaller membrane pore size, which could result in

more fouling by trace organic constituent or differences in membrane cleaning procedures based on manufacturers' recommendations.

- **Energy Use:** The MF and UF system pressures and resulting energy consumption were essentially equal.

- **Water Quality:** Both the MF and UF systems consistently produced water with similar concentrations for key water quality parameters including turbidity (<0.1 NTU), total organic carbon (6.5 mg/L), and UV 254 absorbance (0.17 cm-1). Pathogen testing showed that both the MF and UF as the first step in the purification process removed bacteria to undetectable concentrations, demonstrating greater than 99.9 percent removal of coliform bacteria. Removal of measured viruses (bacteriophage) was greater for the UF system as attributed to the smaller pore size of the UF membranes compared to the MF membranes. The MF and UF systems achieved composite virus removals (Somatic plus Male Specific) greater than 99.8 percent and 99.97 percent, respectively. **Section 2.2** of this report provides additional information regarding bacteriophage removal performance of the MF and UF systems.

Reverse Osmosis Systems

Two reverse osmosis configurations were tested: Train A, a two-stage configuration; and Train B, a three-stage configuration. The different configurations were tested to compare hydraulic conditions and potential operating advantages of one configuration over the other.

- **Recovery:** During Testing Periods 1 and 2 both Trains A and B were operated at 80 percent recovery. During this time both systems operated with little to no fouling with membrane cleaning cycles (time between required cleaning) exceeding six months. Due to the successful operation at 80 percent recovery, the recovery of both systems was increased to 85 percent during Testing Period 3, which is desirable to maximize water production at the Full-Scale Facility. Train A operated for three months with little fouling under 85 percent recovery conditions; however, due to an issue with the concentrate flow meter Train B was operated at a higher recovery than anticipated (i.e. 87 to 89 percent), which lead to scaling and the need to clean after 0.6 months of operation. Upon resolving the issue, Train B was operated for a short period of time prior to the end of the testing period at 85 percent recovery with moderate fouling/scaling observed .

- **Chemical Cleanings:** Two chemical cleanings were performed for Trains A and B during Testing Periods 1 and 2. For Train A, the cleanings had little effect on the operating conditions as buildup was likely not present in significant quantities. Assessment of the Train B membrane performance before and after the cleanings showed that they were partially effective at restoring the operation to that observed when the membranes were new. Train B was cleaned (third stage only) successfully during Testing Period 3.

- **Energy Use:** The power monitors on the RO system Train A (two-stage) and Train B (three stage) showed that the three-stage configuration required on average 10 percent more energy than the two-stage configuration under similar operating conditions. The overall average energy reduction resulting from the energy recovery devices was determined to be 8 percent for Train A and 5 percent for Train B during operation at 80 percent recovery. However, the boost pressure was observed to decrease significantly when the recovery was increased to 85 percent due to the reduction of concentrate flow available. The ERD performance observed at the Demonstration Facility under the 85% FWR condition does not represent what could be achieved at the potential Full-Scale Facility.

- **Water Quality:** Both systems consistently produced water with nearly identical water quality characteristics. Nitrate rejection was better than expected for Train A, and lower than expected in Train B, resulting in identical total nitrogen concentrations from both trains.

UV/AOP System

The UV disinfection and advanced oxidation system, which includes ultraviolet light and hydrogen peroxide, was operated to achieve a target 1.2- log (94 percent) removal of NDMA as defined in the 2008 CDPH Groundwater Replenishment Reuse Draft Regulations, and 0.5-log (68 percent) removal of 1,4-Dioxane as defined in the 2008 and 2011 CDPH Groundwater Replenishment Reuse Draft Regulations. The average power level required to achieve the target NDMA removal, was approximately 68 percent, which corresponded to an average power of 12.5 kW. The target power required to achieve the target removal increased as runtime increased, attributed to a decrease in temperature during winter operation, as well a correction factor in the control system that accommodates for reduced efficiency with lamp age. The target power also increased slightly when the target chloramine dose to prevent bio-fouling on the RO membranes was increased (i.e. 1.5 mg/L to 3 mg/L) as this caused the ultraviolet light transmittance (UVT) of the RO permeate to decrease.

The average electrical energy per order (EEO) value was 0.19 kWh/1000 gallons/log removal. For the Full-Scale Facility, multiple UV vessels in series will likely be used, which may improve efficiency and further reduce the EEO. The UV intensity values measured in the Testing Period 1 were very close to values measured in Testing Period 4 at 100 percent reactor power, which indicates that lamp aging was not significant over this time period.

Water Quality Monitoring

In general two categories of parameters were monitored over the testing period: (1) contaminants selected based on regulatory considerations for the potential Full-Scale Facility and (2) non-regulated contaminants.

Regulatory Relevance of Water Quality Results

Table ES-2 provides a summary of water quality monitoring results for all contaminants monitored based on regulatory considerations for the potential Full-

Scale Facility. Overall the results showed the purified water quality consistently met or exceeded the specified requirements for guidelines. As indicated all microbial constituents (coliform and viruses) measured in the purified water were non-detect in all samples analyzed over the testing period.

Table ES- 2 Water Quality Monitoring Results of Regulated Constituents

Regulation and Guideline Group	Number of Constituents / Parameters	Total Number of Tests[1]	Purified Water Results
Primary Drinking Water MCL [2]	90	1781	√ Meets all
Secondary Drinking Water MCL [3]	18	1290	√ Meets all
Microbial [4]	4	1547	√ Non-Detect
CDPH Notification Level [5]	30	716	√ Below all
CDPH Groundwater Replenishment [6]	142	2244	√ Meets all
Reservoir Limits [7]	143	4404	√ Meets all
Total Number of Constituents / Parameters[8]	231[8]	7,523[8]	----------

Notes:
[1] The total number of tests represents the approximate number of tests conducted at all sample locations shown in Figure ES-1 and the Imported Raw Aqueduct Water.
[2] Maximum Contaminant Levels and Regulatory Dates for Drinking Water U.S. EPA VS. California November 2008.
[3] California Code of Regulation: Title 22, Division 4, Environmental Health Chapter 15. Domestic Water Quality and Monitoring Regulations Article 16. Secondary Water Standards. Purified water met all Federal and State Secondary MCLs with the exception of pH and corrosivity. The potential Full Scale Facility would include post treatment to meet these requirements.
[4] EPA Total Coliform Rule (published 29 June 1989/effective 31 December 1990). Samples from the Demonstration Facility were analyzed for the following microbial contaminants: Total coliform, Fecal Coliform, and Viruses (Somatic and Male Specific Bacteriophage).
[5] Drinking Water Notification Levels and Response Levels: An Overview. California Department of Public Health Drinking Water Program Last Update: December 14, 2010.
[6] CDPH Groundwater Replenishment Reuse DRAFT Regulation 2011. Purified water meets all numerical water quality requirements for indirect potable reuse via groundwater replenishment.
[7] EPA Numeric Criteria for Priority Pollutants Toxic Pollutants for the State of California Rule. San Diego Regional Water Quality Control Board San Diego Basin Plan Numeric objectives; note some objectives have not been defined.
[8] Because some contaminants and parameters are in multiple regulations / guidelines the total of unique parameters is less than the sum.

Non-Regulated Water Quality Results

These constituents are grouped into two main categories: those included in the 2012 EPA Unregulated Contaminant Monitoring Rule (UCMR3) and other CECs, such as pharmaceutical compounds and personal care products. Of the 111 non-regulated constituents sampled for at the Demonstration Facility, only six were found to be quantifiably detected at low levels in the purified water at any time, including three constituents from the UCMR3 list and three CECs.

Three UCMR3 list constituents, bromochloromethane, hexavalent chromium, and strontium, were quantifiable detected in the purified water. The first two of these constituents can be considered disinfection byproducts and may have been formed at

low levels within the treatment processes. The third constituent is a naturally occurring metal used as a dietary supplement and in manufacturing.

Only three CECs were detected at quantifiable concentrations in the purified water. These compounds were iohexal (contrasting agent used in x-ray), acesulfame-k (widely used artificial sweetener), and triclosan (antibacterial agent).

Section 3.6.2 and **Table 45** of this report provide a detailed discussion and summary of the results for these six constituents.

Quality Control

Several quality control (QC) procedures related to data analysis, lab testing, field sampling, sample handling and storage, and data validation were employed during the testing period. The results of this program showed the data set generated during the testing program is of high quality in terms of accuracy, precision, completeness, representativeness, and comparability.

Integrity & Critical Control Point Monitoring

The integrity and reliability of the individual water purification processes were evaluated closely during the testing period. Overall the results of the integrity monitoring plan showed the methods, frequency of testing, and response procedures were useful in verifying the integrity and reliability of the water purification processes. The findings indicate that the development of a similar monitoring and response plan during the design phase of the potential Full-Scale Facility that provides sufficient features and assurances that a foreseeable malfunction could be promptly identified and an appropriate response can be applied that would aid in assuring continuous production of high quality purified water. Results of integrity monitoring at Demonstration Facility are discussed below.

- **MF and UF.** Online continuous filtrate turbidity monitoring and daily pressure decay testing (PDT) were used. Turbidity monitoring results showed both systems achieve filtrate turbidities of less than 0.1 NTU on a consistent basis. The pressure decay rates were less than 0.1 pounds per square inch (psi) / 5 minutes. The fact that the pressure decay rates did not change over the testing period indicates no fibers were broken and the systems remained intact.

- **RO.** Prior to membrane installation, pressure or vacuum decay testing confirmed there were no defects in the membranes or membrane glue lines of each element that would inhibit performance. Post installation of the elements into the pressure vessels, conductivity probing was used to determine that there were no leaks in the interconnectors or end-caps and that the RO systems were intact and ready for operation. Lastly, during the operation the integrity of the RO systems were verified to be intact by conducting online continuous monitoring of permeate conductivity and total organic carbon.

- **UV/AOP.** Online power monitoring was done on a continuous basis. Verification and confirmation of the hydrogen peroxide dosing was also conducted. Results of

the testing detected several occurrences of changes in power resulting from ballast failures. The UV/AOP control system automatically responded by increasing the reactor power level to prevent a loss in treatment performance. The system alarms also notified the operations staff allowing them to identify and replace the faulty ballasts in a timely manner. Additionally, during a short period of the testing period air entrapment in the hydrogen peroxide dosing system resulted in the loss of peroxide dose. Again, the automatic control systems detected and signaled the operations staff via alarm. Lessons learned from the Demonstration Facility were used to identify design features for consideration at the potential Full-Scale Facility to prevent or reduce such occurrences.

UV/AOP Challenge Testing

The overall water quality goals established for the Demonstration Facility included the assessment of the ability of the UV/AOP system to achieve target removal values of two specific contaminants (NDMA and 1,4 Dioxane) based on the 2008 and 2011 Groundwater Replenishment Reuse Draft Regulations, respectively. Because these contaminants were not present in the Demonstration Facility influent or RO permeate it was necessary to dose laboratory prepared solutions of these contaminants to the influent of the UV/AOP system in order to demonstrate the target removals. The major conclusions associated with the testing follow:

- The UV/AOP system achieved 1.5-log removal (96.8 percent) of NDMA under the design flow (1 mgd), UVT (97 percent) and peroxide dose (3 mg/L) conditions. This exceeded the log-removal goal of 1.2-log removal (93.7 percent) based on the 2008 Groundwater Recharge Reuse Draft Regulations.

- The average EEO for NDMA was determined to be 0.19 kW-h/1000 gallons/order.

- The UV/AOP system achieved 0.6-log removal (74.9 percent) of 1,4-Dioxane under the design conditions. This exceeded the log-removal goal of 0.5 (68.7 percent) based on 2011 Groundwater Recharge Reuse Draft Regulations.

Chemical and Power Usage

Chemical and power usage of the Demonstration Facility was tracked closely to assess ways to to improve operational efficiency and provide a basis for estimating operation and maintenance (O&M) costs for the potential Full-Scale Facility.

Chemical usage included chemicals used on a continuous basis as part of the purification process as well as chemicals required for periodic cleaning of the membrane systems. The amount of process chemicals required during the testing period was in close agreement with what was anticipated based on the design conditions. In general, the MF and UF systems required a greater volume of cleaning chemicals per cleaning event than that required for the RO systems mainly due to differences in the configuration of the cleaning systems, and the type and concentration of chemicals used based recommendations from the membrane manufacturers.

Power usage of the AWP equipment was also closely monitored. **Figure ES-2** provides the breakdown of power usage for the individual AWP equipment based on typical daily power totals taken when the Demonstration Facility was operating at full production capacity over a 24 hour period. The breakdown includes power required for the feed pump, which was used to supply tertiary effluent prior to chlorination to the MF and UF systems.

The power required for the feed pump is higher than what would be required for a full-scale facility due to specific operational requirements associated with the Demonstration Facility as further discussed in this report. The higher use of power required for the UF system, compared to the MF system, was largely attributed to differences in the size and efficiency of the air compressors equipped on the systems.

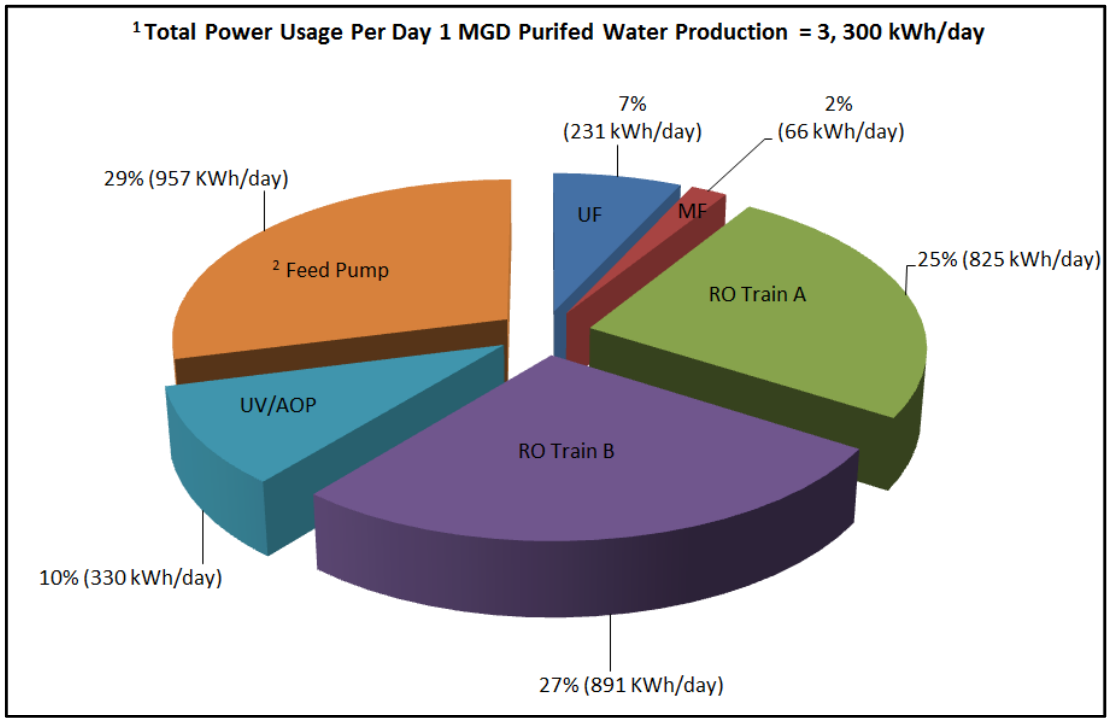

Figure ES-2 Demonstration Facility Process Power Usage

It seems the UF system air compressor was oversized and the design could be optimized for the Full-Scale Facility. The higher power use of RO Train B compared to RO Train A is largely attributed to difference in the membrane configuration (i.e. 3 Stage vs. 2 Stage) and membrane characteristics of the two systems. Train B was equipped with membranes designed for high rejection and low fouling requiring higher feed pressure, while Train A was equipped with membranes designed for energy savings, requiring lower feed pressure.

Note: [1] The total power usage per day is equivalent to 3.3 kWh/1000 gallons of purified water produced and 1,100 kWh per acre-foot of purified water produced. [2] The amount of power required for the Feed Pump is not representative (higher) of a full-scale facility due to specific operational requirements of the Demonstration Facility. Typically, the power usage for feed pumps used at full-scale facilities is accounted for in the MF or UF system power usage. Daily power usage shown does not include parasitic loads (e.g. lights, air conditioning, and ancillary equipment), which were measured to be between 3 to 5% of the equipment power usage.

Section 1
Introduction

1.1 Summary of Progress to Date

The following report provides the final progress update on the operations, testing, and monitoring component of the City of San Diego Demonstration Advanced Water Purification Facility (AWP Facility) located at 4949 Eastgate Mall Road San Diego, CA 92121. Full time operation of the AWP Facility began on June 16, 2011 which coincided with the beginning of the testing and monitoring period. Testing and monitoring was completed on July 31, 2012, representing a duration of approximately 13.5 months. Results were presented in quarterly reports over this period as summarized below. **Tables 1 and 2** respectively, provide a detailed summary of the overall AWP Facility operation schedule and quarterly monitoring periods.

- **Testing Period 1 Quarter 1 (Q1)** began on 6/16/2011 and was completed on 10/31/2011. The testing report was prepared in December 2011.
- **Testing Period 2 Quarter 2 (Q2)** began on 11/1/2011 with completion on 2/10/2012. The testing report was prepared in March 2012
- **Testing Period 3 Quarter 3 (Q3)** began on 2/11/2012 with completion on 5/14/2012. The testing report was prepared in June 2012.
- **Testing Period 4 Quarter 4 (Q4)** began on 5/15/2012 with completion on 7/31/2012. Progress for Q4 is the main focus of the current report.

During each testing period operational and water quality performance information was collected on each AWP unit process including the:

- Pall Microfiltration (MF) System,
- Toray Ultrafiltration (UF) System,
- Hydranautics ESPA2 LD Reverse Osmosis (RO) System (Train A),
- Toray TML RO System (Train B), and
- Trojan Phox Ultraviolet (UV) disinfection and advanced oxidation system (UV/AOP).

Each testing report presented the cumulative results of specific quarterly testing events, as well as routine water quality and operational data, plus the data from previous quarters. Observations included in each quarterly report focused on the most recent quarter. This current testing report (Q4) includes data collected for the entire 13.5 month start-up and testing period.

The collection of operational and water quality data of various constituents groups reported in the Q1, Q2 and Q3 Testing Reports continued during the Q4 Testing Period. The previous Testing Reports also presented the initial monthly sampling events for constituents of emerging concern (CECs), which were conducted in August, September, October and November 2011. Based on the results of the initial characterization, a select group of CECs were monitored weekly for four weeks during the Q3 testing period. A final set of CEC samples were collected conducted in tandem with the fourth quarterly sampling event conducted on 5/1/12. Results of all sampling events for the previous and current testing period are summarized in this report.

As reported in the Q1 Testing Report, prior to the initial quarterly sampling event a spiking experiment was conducted on the UV/AOP system to confirm the system was achieving the target log removal of N-Nitrosodimethylamine (NDMA). During this testing period a second spiking experiment was conducted to demonstrate the UV/AOP system achieved the target log removal of 1,4-dioxane and assess the impact of peroxide dose and electrical energy dose on removal. Results for both spiking experiments are presented and discussed in detail in this report.

During the current testing period, integrity monitoring of the various unit processes continued. This included daily pressure decay testing of the MF and UF membranes, along with online monitoring of MF/UF turbidity, RO conductivity, Total Organic Carbon (TOC), and UV/AOP power draw. Critical limit parameters and acceptable values were identified and monitored for each unit process to ensure the systems were meeting their designed treatment goals on a consistent basis. If any of the integrity monitoring indicated that unit processes were not meeting their designed treatment goals, then they were shut down for troubleshooting and repair.

Third party validation of water quality results was performed during the previous testing period. The purpose of the validation was to assess the quality of the data and review laboratory procedures to identify possible procedural alterations to be implemented for subsequent sampling events. A technical memorandum summarizing the extensive reports provided by the third party laboratory that conducted the data validation is provided in this report. Results of quality control (QC) sampling for all testing periods are summarized and assessed in this report.

1.2 Report Organization

The progress report is organized as follows:

- Executive Summary
- Section 1 Introduction
- Section 2 Operational Performance Monitoring of AWP Facility Unit Processes
- Section 3 Water Quality Monitoring Results

- Section 4 Integrity Monitoring
- Section 5 AWP Facility Chemical and Power Consumption
- Section 6 Maintenance and Equipment Issues
- Section 7 Summary and Conclusions
- Tables and Figures
- Appendix A: Final Report: Toxicity Testing Results for the City of San Diego Water Purification Demonstration Project.
- Appendix B: Quality Control Sample Results and CEC Data Review Letter prepared by Andy Eaton, Ph.D.
- Appendix C: Technical Memorandum: Summary of Third Party Data Validation of AWP Facility Quarterly Sampling Event Results.
- Appendix D: Expert Report: In review of Data for City of San Diego AWP Facility prepared by Shane Snyder, Ph.D.

Section 2
Operational Performance Monitoring of Water Purification Processes

2.1 Summary of Operations

The subsections below summarize the operational performance results collected between 6/16/11 through 7/31/12 for each water purification process. The feedwater for the purification processes was North City Water Reclamation Plant (North City) tertiary effluent (prior to chlorination). In general, the feedwater quality observed throughout the testing period was high quality in terms of general parameters that can impact operational performance of the purification processes including: turbidity, TOC, nutrients (nitrogen and phosphorus), and scale forming species. During the testing period, each process was operated continuously with minimal offline time due to routine maintenance, cleaning (membrane systems) and unscheduled minor repairs. Based on comparison of actual time to run hours (i.e. online time) the AWP Facility produced purified water greater than 87% of the time during this period.

Sections 2.2 and 2.3, respectively, compare microfiltration (MF) to ultrafiltration (UF) system performance and RO Train A to RO Train B performance.

2.1.1 Microfiltration System

The Pall Aria MF system was operated for over 8700 run hours (12 months) during the Q1 through Q4 testing periods. Membrane fouling was assessed by monitoring the temperature corrected specific flux under constant flux operation. **Figure 1** presents operational performance data including specific flux, flux, transmembrane pressure (TMP) and temperature based on daily operational readings. These parameters are plotted versus run hours; the plot also includes dates at each 1,000 run hour interval. The MF system was operated under the same steady state operating conditions throughout the testing periods. This included: target instantaneous flux = 29 gallons per square foot-day (gfd); average feedwater recovery = 93%; backwash interval = 19 minutes or production interval of 10,000 gallons; backwash duration = 96 seconds and target feedwater chloramine dose of 3 mg/L. Performance results collected during each testing period are discussed below.

Q1 Testing Period. Operational data collected on the MF system during the first testing period showed an initial overall fouling rate (percent decline in temperature corrected specific flux per month) of approximately 14% with the majority of the decline occurring between run hours 750 to 1300. A full clean in place (CIP) was conducted at run hour 2227 and was effective at restoring the temperature corrected (20 Deg C) specific flux to ~8 gallons per square foot of membrane per day (gfd)/pounds per square inch (psi). Post cleaning, the specific flux dropped steadily during the initial 120 run hours becoming steady at a value of ~5.8 gfd/psi for the remainder of the testing period.

Q2 Testing Period. During the Q2 testing period the temperature corrected specific flux remained steady at ~5.5 gfd/psi with little to no decline for approximately 2,175 hours (3.2 months) of operation.

Q3 Testing Period. During the Q3 testing period the MF system was operated for approximately 2,069 hours (Run hour 4996 to 7065) with minimal downtime. The only non-scheduled downtime occurred at run hour 6998 when the AWP Facility was shut down due to a pipe break which occurred on the downstream RO system. The AWP Facility was offline for approximately 3.5 days to make necessary repairs.

Beginning at run hour 4996 the temperature corrected specific flux remained steady at ~5.2 gfd/psi for approximately 580 hours of operation. At this time, the specific flux began to decline steadily reaching a value of 3.3 gfd/psi after 663 hours of operation. A full CIP was conducted at run hour 6239 and was effective at restoring the temperature corrected (20 Deg C) specific flux to a value close (~7.5 gfd/psi) to that achieved after the initial CIP conducted during Q1. Post cleaning, the specific flux dropped steadily as expected becoming steady at a value of ~5.6 gfd/psi for the remainder of the testing period.

Q4 Testing Period. During the Q4 testing period the MF system was operated for approximately 1643 hours (Run hour 7066 to 8709) with minimal downtime. Over this time period the temperature corrected specific flux dropped from a value of ~5.3 gfd/psi to ~4.3 gfd/psi, representing a decrease in specific flux of about 19%. A CIP was not necessary during this testing period. The overall fouling rate (% decrease in specific flux per month) starting after the completion of the last CIP (conducted during Q3) through the end of the Q4 testing period was about 12% per month. Assuming a linear fouling rate, it is projected the MF system could operate approximately 6 months before cleaning (i.e. specific flux reaches 2-3 gfd/psi) under the current operating conditions .

2.1.2 Ultrafiltration System

The Toray UF system was operated for over 8600 run hours (11.9 months) during the Q1 to Q4 testing periods. Membrane fouling was assessed by monitoring the temperature corrected specific flux under constant flux operation. **Figure 2** presents operational performance data including specific flux, flux, TMP and temperature based on daily operational readings. These parameters are plotted versus run hours; the plot also includes dates at each 1,000 run hour interval. The UF system was operated under the same steady state operating conditions throughout the testing periods. This included: target instantaneous flux = 30 gfd; average feedwater recovery = 95%; backwash frequency = 30 minutes; backwash duration = 195 seconds and target feedwater chloramine dose of 3 mg/L. Performance results collected during each testing period are discussed below.

Q1 Testing Period. Operational data collected on the UF system during the first testing period showed an initial overall fouling rate (% decline in temperature corrected specific flux per month) of approximately 25% with the majority of the

decline occurring during run hours 750 to 1400. A full CIP conducted at run hour 1729 effectively restored the specific flux to ~8.8 gfd/psi. Post cleaning the specific flux decline was gradual (~1 gfd/psi) over 1,158 run hours.

Q2 Testing Period. During the Q2 testing period the temperature corrected specific flux declined gradually to a value of ~5.5 gfd/psi between run hours 2872 to 4984 hours, representing an overall fouling rate of ~8% per month following the CIP conducted during the Q1 testing period. However, it was observed that the rate of specific flux decline increased during the latter part of the testing period starting at around run hour 4504.

During the Q2 testing period, the North City operations staff reported the introduction of a continuous low dose of ferric chloride in the influent of the tertiary filters beginning on 12/8/11 to meet the California Department of Public Health (CDPH) requirement for recycled water used in cooling towers. On 2/6/12 the North City operations staff reported the short-term use of polymer addition at the aeration basin effluent prior to secondary clarification to reduce tertiary filter effluent turbidity. Based on operational data collected to date it does not appear the use of these chemicals impacted the MF or UF system performance.

Q3 Testing Period. During the Q3 testing period the UF system was operated for approximately 2,004 hours (Run hour 4984 to 6989) with minimal downtime. The only non-scheduled downtime occurred at run hour 6923 due to the aforementioned AWP Facility shut down to repair the damaged RO permeate piping.

The steady decline in specific flux observed towards the end of the Q2 testing period continued from run hour 4984 to 5585 to a value of ~2.8 gfd/psi. At this time, a full CIP was conducted and was effective at restoring the temperature corrected (20 Deg C) specific flux to a value close (~8.3 gfd/psi) to that achieved after the initial CIP conducted during Q1. Post cleaning, the specific flux dropped steadily at a rate faster than expected for the next 716 hours of operation to a value of ~3.9 gfd/psi at run hour 6301. At this time the decline in specific flux was observed to be steady with a slight increase for ~593 hours of operation. However, for the remainder of the testing period the decline was steady to a final value of 3.5 gfd/psi at run hour 6989.

Q4 Testing period. During the current testing period the UF system was operated for approximately 1618 hours (Run hour 6990 to 8608) with minimal downtime.

The steady decline in specific flux observed towards the end of the Q3 testing period continued from run hour 6990 to 7360 to a value of ~1.9 gfd/psi. At this time, a full CIP was conducted. Based on discussions with Toray the cleaning protocol was modified from that used previously. During the previous cleanings the target pH during the citric acid step was 3, however a target of 1.5 was recommended by Toray as a possible way to extend time between cleanings. It is expected the lower pH would dissolve a larger amount of inorganic material that may have precipitated on the membranes therefore extending the time between cleanings. The CIP was effective

at restoring the temperature corrected (20 Deg C) specific flux to a value (~9.6 gfd/psi), which was higher than that achieved from previous cleanings. Post cleaning, the specific flux dropped consistently for the remainder of the testing period to a value of~5.4 gfd/psi at run hour 6806. The overall fouling rate starting after the completion of the CIP through the end of the testing period was about 26% per month. Assuming a linear fouling rate, it is projected the UF system could operate approximately 3 months between cleaning events (i.e. specific flux reaches 2-3 gfd/psi) under the current operating conditions.

2.1.3 Reverse Osmosis System

During the Q1 through Q4 testing period the RO systems (Trains A and B) were operated using combined filtrate from the membrane filtration systems for approximately 8,500 hours (11.8 months) of runtime. The RO trains were operated under similar operating conditions for the entire testing period as shown in **Table 3**. Each RO train was also equipped with an energy recovery device (ERD) by Energy Recovery, Inc. (ERI) that was designed to transfer pressure from the concentrate to the feed of the last stage. The RO trains were designed without the use of cartridge filtration as pre-treatment. RO Train A was configured as a two-stage system and utilized model ESPA2 LD membranes manufactured by Hydranautics. Likewise, RO Train B was configured as a three stage system and utilized model TML membranes manufactured by Toray. Operational performance data collected for both RO Trains during each testing period is discussed in the subsections below.

2.1.3.1 RO Train A

Operational performance parameters including net operating pressure (NOP), flux, specific flux and feedwater temperature for the RO Train A are illustrated in **Figure 3**. Membrane fouling was assessed by monitoring the decline in temperature corrected specific flux, or permeability, under constant flux operation. These parameters are plotted versus run hours; the plot also includes dates at each 1,000 run hour interval. Operational performance observed during each testing period is summarized below.

Q1 Testing Period. During the initial operation period, a decrease in the specific flux was observed prior to becoming level around run hour 900 (5 weeks). Since this decrease was predominantly in the first stage elements, it was believed that it may have been related to organic fouling or to biological regrowth. To prevent further fouling, the target feedwater concentration of chloramines was increased from 1.5 to 3.0 mg/L. Following this adjustment, the membranes operated with little to no decrease in specific flux for around 1,345 hours of operation. A full Chemical cleaning was performed on Train A on 10/14/11 (run hour 2,245). The membranes were cleaned in accordance to the manufacturer's protocol using caustic soda followed by citric acid. A summary of cleaning results for both RO Systems is provided in **Table 4**. Comparison of the specific flux measured pre and post cleaning for the 10/14/11 Train A cleaning indicates the cleaning had no effect on restoring the average membrane specific flux. These results suggest that the decrease in specific flux observed during the initial operation may have been related to conditioning of the

membranes rather than entirely from membrane fouling. It is also possible that the cleaning procedures chosen were not sufficient to entirely remove the foulant layers.

Q2 Testing Period. The corresponding run hours for the Q2 Testing period began at 2,618 and ended at 4,764 hours. During this time the temperature corrected specific flux remained steady at ~0.13 gfd/psi with little decline for approximately 2,146 hours of operation. The overall fouling rate from the previous CIP to the end of the Q3 testing period was less than 2% per month. The net operating pressure increased over the testing period due to the decrease in feedwater temperature.

The calculated efficiency of the RO Train A Turbocharger from Q1 and Q2 operation was determined to be far below optimal conditions. After several discussions with the manufacturer, a representative from the RO skid supplier (Enaqua) installed a complete set of new bearings on the device on 12/5/11 (run hour ~3,512). Upon review of performance pre and post replacement of the bearings technicians from ERI confirmed there was a hydraulic issue with the ERD and agreed to repair the unit. On 1/10/12 (run hour ~4097), a representative from Enaqua removed the device for return to ERI and installed necessary piping to allow the RO system to be operated while the device was being repaired.

Q3 Testing Period. The corresponding run hours for the Q3 Testing period began at run hour 4764 and ended at run hour 6805. The only unscheduled downtime occurred at run hour 6737 due to the aforementioned AWP Facility shut down required to repair the damaged RO permeate piping.

During the first 1,500 hours of Q3 operation the system was operated under the same target operating conditions as the previous testing periods, which were: average flux = 11.8 gfd; feedwater recovery = 80%, antiscalant dose = 3 mg/L; and chloramines dose = 3 mg/L. During this period, the temperature corrected specific flux remained steady at ~0.13 gfd/psi with little to no decline. A goal during this testing period was to assess the performance of the RO systems at an increased feedwater recovery (FWR). Prior to increasing the FWR, a full CIP was conducted to try and restore the specific flux so an accurate assessment of the impact of FWR on fouling/scaling could be made.

Due to the ineffectiveness of the CIP conducted during the Q1 testing period the cleaning protocol was modified to change the order of cleaning chemicals. During Q1 caustic was followed by citric acid. However, during this testing period citric acid was followed by caustic. In addition, the chemical soak and recirculation times were extended. Data collected before and after the cleaning showed the specific flux was restored by about 15% with all of the increase observed after the caustic cleaning, suggesting that the majority of the fouling was related to organic material. Though there was no observed increase in specific flux after the acid cleaning it is believed the acid may have removed inorganic foulants which may have coated or complexed with organic foulants allowing for effective removal of the organic foulants by the caustic.

Following completion of the CIP, the system was operated under the same target operating conditions as stated above with the exception that the FWR was increased to 85% at run hour 6314. The FWR was increased by manually adjusting the valve located on the concentrate piping to reduce the concentrate flow. The permeate flow set point was held constant to the design flow rate and not impacted by increasing the FWR. The system operated with little to no fouling as measured by the decline in overall specific flux for the remainder of the testing period.

Performance monitoring of the TurboCharger (Energy Recovery Inc. - ERI) energy recovery device (ERD) continued during the testing period. **Figure 6** presents values of Stage 1 concentrate pressure before and after the TurboCharger along with the calculated boost pressure. The unit was repaired and reinstalled at run hour 5015. Comparison of performance data pre and post repair showed that the average boost pressure increased from 8.9 to 22.9 psi as a result of the repair. It was also observed during this testing period that the average boost pressure dropped significantly (22.9 psi to 11.8 psi) when the recovery FWR increased to 85%. The drop in boost pressure would be expected with an increase in FWR as the concentrate flow into the Turbocharger is reduced.

Q4 Testing Period. The corresponding run hours for the Q4 Testing period began at run hour 6805 and ended at run hour 8458, representing 1653 hours (2.3 months) of online time. During this time system operation continued at a target feedwater recovery of 85%. The system operated for 2144 hours (3 months) during the period following the previous cleaning (conducted during Q3) to the end of the current reporting period The average fouling rate was about 2% per month as measured by the decline in temperature corrected specific flux.

Figure 4 presents values of specific flux for Stage 1 and Stage 2, respectively. As shown the values for Stage 1 were consistent over the testing period with little to no decline after the initial conditioning period, indicating minimal fouling occurred. The values for Stage 2 show a downward trend suggesting some scaling occurred. **Figure 5** shows values of differential pressure (DP) measured across Stage 1 and Stage 2. It was observed during the Q2 testing period that Stage 1 DP values were increasing slightly with runtime. During the current and previous testing periods the values remained fairly consistent indicating that membrane element feed channels are not plugging.

Performance monitoring of the TurboCharger (Energy Recovery Inc. - ERI) energy recovery device (ERD) continued during the testing period. **Figure 6** presents values of Stage 1 concentrate pressure before and after the TurboCharger along with the calculated boost pressure. The average boost pressure observed during the current reporting period was similar (~12 psi) to that observed during the Q3 testing period during operation at 85% recovery.

2.1.3.2 RO Train B

Operational performance parameters including net operating pressure (NOP), flux, specific flux and feedwater temperature for the RO Train A are illustrated in **Figure 7.** Membrane fouling was assessed by monitoring the decline in temperature corrected specific flux, or permeability, under constant flux operation. These parameters are plotted versus run hours, the plot also includes dates at each 1,000 run hour interval. Operational performance observed during each testing period is summarized below.

Q1 Testing Period. The target operating conditions for the Q1 Testing period were: average flux = 11.6 gfd; feedwater recovery= 80%, antiscalant dose = 3 mg/L; chloramines dose = 1.5 to 3 mg/L. During the initial 160 hours (1 week) of operation, the specific flux (gfd/psi @25 °C) of the new Toray TML membranes declined steadily from an initial value of 0.15 to 0.13. The specific flux further declined slightly over the next 740 run hours to ~0.12 gfd/psi. The target feed concentration of chloramines was increased from 1.5 to 3.0 mg/L (same modification as Train A) at run hour 941. The specific flux remained steady with little or no decline for the next 1,126 hours (1.6 months) of operation.

A full chemical cleaning was performed on Train B at run hour 2,027. The membranes were cleaned in accordance with the manufacturer's protocol using both caustic soda and citric acid. Assessment of the membrane performance before and after the cleaning showed the cleaning restored the specific flux by about 18% signifying the cleaning was effective. Post cleaning, the specific flux remained steady with little to no decline for the remaining 551 run hours of the testing period.

Q2 Testing Period. The corresponding run hours for the Q2 Testing period began at 2595 and ended at 4772 hours. During this time the system was operated with the same target operating conditions as the previous testing period. The temperature corrected specific flux remained steady at ~0.12 gfd/psi with little decline for approximately 2,177 hours (3 months) of operation. The overall fouling rate from the previous CIP to the end of the Q2 testing period was less than ~3% per month. As shown the net operating pressure increased over the testing period due to the decrease in feedwater temperature.

Monitoring of the TurboCharger (Energy Recovery Inc.) energy recovery device during Q2 showed the average pressure boost was 25.4 psi, which was similar to the average boost pressure observed during the previous testing period (e.g. 22.6 psi).

Q3 Testing Period. The corresponding run hours for the Q3 Testing period began at run hour 4772 and ended at run hour 6787. The only unscheduled downtime occurred at run hour 6721 due to the aforementioned AWP Facility shut down required to repair the damaged RO permeate piping.

During the first 1,525 hours of Q3 operation the system was operated under the same target operating conditions as the previous testing periods. The temperature corrected specific flux remained steady at ~0.11 gfd/psi with little to no decline. At this time a

full CIP was conducted. Due to the ineffectiveness of the CIP conducted on the RO systems during the Q1 testing period the cleaning protocol was modified as described above for RO Train A. Data collected before and after the cleaning showed the specific flux was restored by about 17%. The specific flux increased by 8% after the acid cleaning and an additional 9% after the caustic cleaning.

Following completion of the CIP the system was operated under the same target operating conditions as above with the exception that the FWR was increased to 85% at run hour 6391. During the initial 396 hours (2.3 weeks) of operation, little to no fouling was observed as measured by the decline in overall specific flux.

However, comparison of values of normalized specific flux for Stage 1, Stage 2 and Stage 3 indicated increasing the FWR to 85% resulted in the Stage 3 normalized specific flux to decline at a much faster rate than Stage 1 and Stage 2. In addition, over this time the permeate conductivity of Stage 3 increased by about 158%. These observations signify that scaling of the Stage 3 membranes occurred.

Monitoring of the TurboCharger (Energy Recovery, Inc.) energy recovery device on the Train B RO system continued during this testing period. The average boost pressure during operation at a target FWR of 80% was 23.3 psi with a noticeable decrease at run hour 5022. The decrease is due to a manual adjustment made on the concentrate valve to decrease the concentrate flow in order to maintain the target FWR. Further adjustment was made to the concentrate valve at run hour 6391 to increase the target FWR to 85%. The average boost pressure measured during operation at 85% over the remainder of the testing period was only 6.4 psi. The reduced boost pressure at 85% FWR is attributed to the lower concentrate flow.

While the ERD could have been adapted to the higher FWR conditions using a nozzle valves, the City elected not to proceed with this modification during the testing period. If it is decided to incorporate ERD's into the design of the potential Full Scale Facility consideration should be given to the use of automatic control valves and auxiliary nozzle valves to optimize the performance of the ERD's over the expected range of concentrate flow, pressure and temperature.

Q4 Testing Period. The corresponding run hours for the Q4 Testing period began at run hour 6787 and ended at run hour 8435, representing 1648 (2.3 months) of online time. During this time system operation continued at a target FWR of 85%. The decrease in the third stage specific flux observed at the end of the previous reporting period continued for the initial 938 hours (1.3 months) of operation. At run hour 7311 the third stage specific flux had dropped by 40% of the initial value observed at the start of 85% FWR operation. This drastic drop in specific flux indicated the third stage had undergone significant scaling. At this time a CIP was conducted on the third stage membranes. Results of the cleaning show the cleaning was effective at restoring the specific flux. Following the CIP the Train B was restarted at a target FWR of 80%.

Because Train B scaled at a much faster rate than Train A during operation at 85%, an investigation was undertaken to identify the possible cause. The investigation included verification of the accuracy of the flow transmitters equipped on the RO skids as well as verifying the FWR of the systems based on sulfate values measured in the feed, permeate and concentrate. The flow transmitters equipped on both RO skids were checked against measurements using an ultrasonic flow meter provided by Toray. Comparing results showed the flow transmitters were within acceptable agreement with the ultrasonic flow meter with the exception of the concentrate flow transmitter on Train B, which read 22% higher than the flow measured by the ultrasonic meter. Based on this information, recovery calculations were revised to use the permeate and feed flowmeters rather than the concentrate. In addition, sulfate mass balance calculations were performed, confirming the accuracy of the revised recovery calculations. It was therefore determined that Train B had operated at FWR between 87 and 89% instead of the targeted 85% FWR during the time the scaling was observed. In order to rectify the issue the scale factor on the concentrate flow meter was adjusted to accommodate for the measured discrepancy. The FWR was returned to 85% FWR at run hour 7942. During the following 493 hours (3 weeks) the overall specific flux declined by about 9.9% and the third stage by 25%. Because a limited amount of run time was conducted on Train B at 85% recovery it is recommended further operation be conducted to further assess the fouling rate at this recovery.

Lastly, it was confirmed that prior to changing the FWR to 85%, Train B operated at a FWR between 79 to 81% (target 80%) based on flow measurements recorded from the magmeter located on the feed pump and permeate flow transmitters equipped on the RO skid.

Figure 8 presents values of specific flux for Stage 1, Stage 2 and Stage 3, respectively. As shown the specific flux of the third stage declined much faster than Stage 1 and Stage 2 during the initial 85% FWR operating period. This decline is attributed to the aforementioned scaling event. During operation following the completion of the CIP the specific flux for Stage 1, Stage 2 and Stage 3 remained fairly constant with no significant decline observed. **Figure 9** presents values of differential pressure (DP) measured for each Stage. Overall the DP values were consistent with that expected due to hydraulic losses and indicate no plugging of the membrane feed channels occurred over the previous or current testing period. The lower DP values observed in Stage 3 during the operation at 87 to 89% FWR (Run hour 6391) is attributed to a reduction in flow to the stage as the membranes scaled.

Monitoring of the TurboCharger (Energy Recovery Inc.) energy recovery device on the Train B RO system continued during this testing period. **Figure 10** presents values of Stage 2 concentrate pressure before and after the TurboCharger along with the calculated boost pressure. As the FWR is increased the concentrate flow from Stage 2 is decreased therefore providing less flow through the ERD resulting in lower boost pressure. The average boost pressure measured during the testing period changed during operation at different FWR conditions as provided below.

- Run hour 6391 to 7311 – The average boost pressure measured during this time period was 7 psi, FWR 87 to 89%.
- Run hour 7329 to 7920 – The average boost pressure measured during this time period was 16 psi, FWR 80%.
- Run hour 7942 to 8435 – The average boost pressure measured during this time period was 12 psi, FWR 85%.

2.1.4 UV Disinfection and Advanced Oxidation

During the Q1 through Q4 testing period the UV/AOP system was operated using permeate from the RO systems for approximately 8,500 hours (11.8 months) of runtime. During normal operation, the system was operated to achieve a target log removal of NDMA and 1,4-dioxane of 1.2 (93.7%) and 0.5 (68.4%), respectively. The target hydrogen peroxide dose applied to the UV/AOP feedwater was held constant at 3 mg/L. The ultraviolet light transmittance (UVT) at the 254 nanometer wavelength measured in the feed ranged from approximately 97 % to 98.5 %, which was determined to be impacted by the chloramine residual concentration. The Trojan control system adjusted the reactor power to maintain the target log removals using an algorithm, which takes into account feed flow, temperature, UVT, and lamp age**.** **Section 2.1.4.1** presents operational UV/AOP performance results collected during each testing period. **Sections 2.1.4.2 and 2.1.4.4**, respectively, provide results from an evaluation of potential UV/AOP by-products and challenge experiments conducted on the UV/AOP system to demonstrate target removals of NDMA and 1,4-dioxane.

2.1.4.1 Operational Performance Results

Operational data for the UV/AOP system collected during the Q1 through Q4 testing period are presented in **Figures 11 and 12.**

Q1 Testing Period. Operational data collection on the UV/AOP system during the Q1 Testing period showed the ultraviolet transmittance (UVT) measured at the 254 nanometer wavelength in the feedwater decreased from 98.5% to 97.7% (run hour 916) due to the increased chloramines dose required to reduce biofouling of the RO membranes. The Trojan algorithm changes the applied power required to achieve a target log removal based on changes in inlet flow, temperature, and UVT. Therefore, when the UVT decreased the required power increased. The average reactor power level required to achieve the target NDMA removal following the drop in UVT was 67% of the maximum reactor power level (i.e. 100%) corresponding to an average present power of 12.5 kW. Based on the average inlet flow the electrical energy dose (EED) was 0.303 kWh/1000 gallons. On four occasions the reactor power increased to 100% due to ballast failures. The faulty ballasts were sent to Trojan for autopsy to determine the cause(s) of failure. Upon analysis Trojan reported three of the failures were due to blown primary fuses, which commonly result from power surges, and the fourth was due to an output failure. It is also not uncommon in the ballast industry to have a bad batch of ballasts due to defective components. Trojan noted that

installation of a transient voltage surge suppressor (TVSS) on the system may be a good idea if ballasts continue to fail in the future due to blown fuses.

The average electrical energy per order (EEO) value recorded at the Trojan HMI over the operating period was 0.260 kilowatt-hours (kW-h)/1000 gallons/ log removal. The EEO values and NDMA performance of the UV/AOP were confirmed by conducting a spiking experiment as described in **Section 2.1.4.4** which showed the unit was performing more efficiently than predicted (e.g. Average EEO was determined to be 0.188 kW-h/1000 gallons/log removal).

Q2 Testing Period. Operational data collected on the UV/AOP system during the Q2 testing period started at run hour 2,595. Overall the performance of the UV/AOP system during this testing period was similar to the previous testing period. However, a slight trend of increasing reactor power level required to achieve the target 1.2-log removal of NDMA was observed. The increase in power is likely due to the lower feedwater temperature of ~4 degrees Celsius (C) observed during the this testing period. In addition to the aforementioned factors that impact the applied power level (i.e. inlet flow, temperature and UVT) the Trojan control system also increases power with time to accommodate for lamp aging. The average reactor power level required to achieve the target NDMA removal was 71% of the maximum power level, which corresponds to an average present power of 13.0 kilowatts (kW). Based on the average inlet flow the EED was 0.317 kWh/1000 gallons. In addition, no ballast failures occurred during this testing period.

Q3 Testing Period. Operational data collected on the UV/AOP system during the Q3 testing period started at run hour 4793 and ended 6841. The reactor operated for ~2,048 hours. There were two periods of unscheduled downtime. The first occurred around run hour 6602 when the reactor was taken offline for approximately 1 to 2 hours to replace a single faulty ballast and lamp. The operations team immediately contacted Trojan to send replacement parts. The faulty parts were sent back to Trojan for autopsy (ballast only) to determine the cause of failure. The second shutdown occurred at run hour 6775 due to the aforementioned AWP Facility shut down required to repair the damaged RO permeate piping.

Starting around run hour 6263 the UVT analyzer alarmed on a frequent basis due to low flow. When these alarms occurred the UV control system automatically increased the UV power to 100%. It was determined the cause of the low flow was air entrapped in the UV inlet piping. After several attempts to remove the air by adjusting the air relief valves located upstream and downstream of the UV reactor the problem was resolved by partially closing the butterfly valve located on the UV outlet pipe to increase the backpressure in the line and installing a bubble trap upfront of the UVT analyzer.

Q4 Testing Period. Operational data collected on the UV/AOP system during the current testing period started at run hour 6841 and ended at 8549. The reactor operated for ~1,708 hours. Overall the performance of the UV/AOP system during

this testing period was similar to the previous testing periods. However, a slight trend of decreasing reactor power level required to achieve the target 1.2-log removal of NDMA was observed. As previously mentioned, the Trojan control system adjusts power based on feed temperature. The average feedwater temperature during the current testing period was ~3.3 degrees Celsius (C) higher than that observed during Q2 and Q3, which would account for the reduction in the reactor power requirement. The average reactor power level required to achieve the target NDMA removal during this testing period under normal operating conditions was 68% of the maximum power level which corresponds to an average present power of 12.5 kilowatts (kW). The EED based on the average inlet flow was of 0.303 kWh/1000 gallons. These values are in close agreement with those measured during the Q1 Testing Period suggesting the lamp ageing factor built into the Trojan control system did not have a significant impact on the EED during the Q1 to Q4 Test Period.

The UV intensity sensor equipped on the system was checked against a reference sensor during each testing period. This was done by stopping flow to the system and increasing the power to 100%. Readings of UV intensity were taken with the duty sensor. The system was then shutoff and the reference sensor was installed and the procedure was repeated. Comparison of UV intensity measurements from both sensors are provided in **Table 5**. Results showed close agreement (i.e. < 5% difference) throughout the testing period. Also, the UV intensity values measured in the Q1 testing period were very close to values measured in the Q4 testing period giving a gross indication that lamp aging was not significant over this time period. However, it is important to keep in mind the intensity sensor is only positioned at one lamp. A comprehensive assessment of lamp aging would require several lamps be sent to Trojan for analysis.

During the current testing period there were several occurrences of peroxide pump failures caused by air entrained in the dosing pumps. The first occurrence happened around run hour 7052 when the duty pump lost flow confirmation and auto switched to the standby pump. After the switch over occurred, the second pump lost flow confirmation causing the system to go into critical alarm and shut off. The system was re-started, however the pumps continued to lose flow confirmation on several occasions over the next few days. At this time, the operations team contacted Trojan to trouble shoot the issue. Several adjustments were made to the peroxide dosing system which seemed to remedy the issue. First, the degasification interval and duration (user set points) were adjusted to allow the dosing system to purge air on a more frequent basis and for a longer time period per purge. Second, a valve on the discharge side of the peroxide pumps which allows air to return to the peroxide storage tank was opened. It should also be noted that on several of the pump failure occurrences the feed flow to the UV was at reduced flow as only one RO system was in operation. Because the peroxide dose is flow paced the dose rate would be lowered automatically which may have increased the likelihood of air entrapment.

A ballast failure also occurred during this testing period, which makes a total of six ballast failures during the Q1 through Q4 testing period. Based on discussions with

Trojan, it was suggested a power monitoring study be employed to assess if the failures could be a result of power surges. In addition, it was recommended the air filters on the power distribution cabinet (PDC), which houses the ballasts, be changed on a monthly basis to prevent the cabinet temperature from getting to a level that could damage the ballasts. At the time of this report the power study was underway. In addition, the operations team initially began changing the PDC filters on a monthly basis. However, due to the amount of debris discovered on the filters over this time period, a more frequent maintenance schedule was implemented (i.e. every 2 weeks). Lastly, Trojan also sent the failed ballasts to the ballast manufacturer to determine the possible cause (s) of the failures. The initial findings were that there does not seem to be a common cause for the ballast failures. It is expected the manufacturer will provide further details as they become available.

2.1.4.2 UV/AOP By-product Evaluation

The T&M Plan takes into consideration input from the IAP, CDPH, and the RWQCB. CDPH reviewed the 2010 IAP report and suggested that the demonstration program evaluate by-products from advanced oxidation of NDMA, 1,4-dioxane, and other organic constituents present in the RO permeate. Based on information found in peer reviewed literature and past pilot testing conducted at North City, the project team recommended taking grab samples from the RO permeate (UV/AOP influent) and UV/AOP product water and measuring formaldehyde on a weekly basis during the initial eight weeks of the routine sampling period. Three additional sample sets were taken later in the testing period.

Results of the formaldehyde analyses are provided in **Table 6**. The average concentration (µg/L) in the influent (n=11) was 4.1 ± 2.5 while the product (n=11) was 9.7±2.9. While the results showed an apparent increase in concentration across the UV/AOP process, the relative change in concentration does not appear to be of health concern. The concentration measured in the UV/AOP product is nearly 10 times lower than the CDPH Notification Level (NL) of 100 µg/L. Interestingly, the concentrations of NDMA and 1,4-dioxane measured in RO permeate, which can serve as pre-cursors to formaldehyde formation, were below or near below their RL of 2 ng/L and 0.5 µg/L, respectively. During subsequent testing periods additional samples of formaldehyde were taken and analyzed as part of the overall water quality QC plan. Results from analysis conducted by a second commercial lab showed the concentration of formaldehyde in the UV/AOP product to be higher than those reported by the original lab that conducted the analysis but still lower than the NL. This is further discussed in **Section 3.5.1.2.**

2.1.4.3 Chloramine and Nitrosamines Investigation

The T&M Plan outlined specific measures to evaluate different chloramine dosing alternatives during the testing period. While chloramine dosing is required to control organic and biological fouling of the membrane components (i.e. MF, UF, and RO membranes) of the overall purification process, past studies have shown the combination of chloramines and organic pre-cursors present in wastewater are

common pathways for the formation of nitrogenous disinfection by products (DBPs) such as nitrosamines. Chloramines can be created by either sequential addition of ammonia (aqueous ammonia) or chlorine (sodium hypochlorite) directly into the feedwater or by a side stream process that pre-forms chloramines prior to application to the feedwater. The latter method has been shown to reduce the formation of some DBPs.

The T&M Plan was designed to evaluate both chloramine dosing methods with the initial condition to be sequential addition. As discussed in **Section 3.1,** routine water quality monitoring included sampling of nitrosamines on a monthly basis from various locations in the purification process including tertiary effluent (prior to chlorination), RO feed, RO permeate and UV/AOP product water. Results of nitrosamine monitoring presented in **Table 18** showed the average concentration (n=10) of NDMA measured in the tertiary effluent was 4.2 ng/L and ranged from <RL (RL=2 ng/L) to 20 ng/L. Slightly lower concentrations were measured in the RO feed with the average concentration (n=14) of 3.5 ng/L ranging from <2 ng/L to 17 ng/L. These results show that NDMA formation was not occurring under the sequential addition of chloramines.

Results also showed the RO system achieved greater 43% removal of NDMA based on average concentration in the RO permeate of <2 ng/L. All NDMA results in the UV/AOP product water were < 2 ng/L with the exception of the sample collected on 1/3/12, for which the reported result was 5.5 ng/L. Results for other nitrosamines (i.e. NDEA, NDBA, NDPA, NMEA, NMOR, NPIP, NPYR) were similar in concentration in the tertiary water and RO feed throughout the testing period further indicating nitrogenous DBP formation was not occurring. These results did not warrant the need for testing the pre-formed chloramine application and therefore sequential chloramination was continued for the remainder of the testing period.

It should be noted routine sampling results showed that both NDMA and NDEA had occasional positive hits at locations downstream of locations where no detectable levels had been observed. For NDEA, this occurred on 12/1/11, 1/3/12, and 4/23/12, where low levels of NDEA were measured in the UV/AOP product (levels were 2.5, 2.9, and 4.9 ng/L, respectively), but had been below quantifiable levels in the upstream RO product. Similarly, a 6.1 ng/L NDEA level was measured in the Train B RO permeate on 11/2/11 when no NDEA was detected in either the upstream RO feed or the downstream combined RO permeate. For NDMA, a 5.5 ng/L result was found in the UV/AOP product on 1/3/12 when concentrations had been below quantifiable levels in both the RO product and RO feed. These positive results represent the challenge of reliably monitoring nitrosamine concentrations at such low concentrations with an analytical reporting level of only 2 ng/L. It is unlikely that these results suggest that either NDMA or NDEA was formed or introduced downstream of the RO membranes or within the UV/AOP, and the vast majority of the 15 NDEA and NDMA samples were below quantifiable levels in the UV/AOP product. Similarly, all results were below the CDPH notification level of 10 ng/L for both constituents.

2.1.4.4 UV/AOP Challenge Experiments

During the course of the Q1 through Q4 testing period several challenge experiments were conducted to demonstrate the performance and efficiency of the UV/AOP system to reduce NDMA and 1, 4-Dioxane. The design criterion for the UV/AOP was based on a 1.2 log removal of NDMA and 0.5 log removal of 1,4-dioxane at a system flow rate of 1 MGD. Because the concentration of the target compounds in the North City tertiary effluent and subsequently the RO permeate were too low (i.e. <RL) to demonstrate the required log removals it was necessary to spike laboratory prepared solutions containing adequate concentrations of these compounds spiked into the UV inlet. During all spiking experiments the UV/AOP product water was sent to sewer to avoid possible contamination of the recycled water. During Q1 a spiking experiment was conducted to assess the removal of NDMA, during Q3 (and repeated during Q4) spiking experiments were conducted to assess the removal of 1,4-dioxane. Details and results of each experiment are discussed in the subsections below.

2.1.4.4.1 NDMA Spiking Experiment

Objectives and Test Procedure. NDMA was spiked upstream of the UV/AOP to demonstrate the system could achieve the target removal under the aforementioned design conditions. During this experiment the reactor power was varied between the minimum and maximum settings. The reactor was operated at the design flow rate of 1 MGD and UV transmittance (UVT) of approximately 97%. In addition, the chloramines residual present in the UV/AOP feedwater was ~ 3 mg/L. The log removal of NDMA was determined for each set point. In addition 1,4-dioxane was measured in the UV/AOP feed and product to assess removal of inherent concentrations present.

The testing equipment required to conduct the spiking experiments, shown in **Figure 13**, was comprised of the following:

- Chemical Storage tank and cover– 30 gallon black polyethylene
- Chemical Storage tank mixing rod
- Chemical dosing pump
- Hydrogen Peroxide monitoring kit
- Piping and valving to make the connections between the components

1 L of NDMA stock spiking solution prepared by a certified laboratory experienced with preparing spiking solutions.

For each sample run, three individual 1.0 L influent grab samples were taken from the influent sample port and three product grab samples were taken from the product sample port. Samples were collected in UV proof (amber glass) bottles with

preservative. Samples were sent to MWH Labs for analyses using EPA method 521 (NDMA) and 525 (1,4-dioxane). All samples were analyzed for NDMA and one (1) influent and one (1) product were analyzed from each run for 1,4-dioxane.

Concurrent to sampling, the feed UVT, product H_2O_2 concentration, feed flow, temperature, target reactor power, actual reactor power, target LRV, actual LRV EEO, and lamp hours were recorded. Documentation of the number of lamps in service was also recorded.

Control – The test plan included two runs in which the UV unit was in the off position. Samples were collected from the influent and product with and without peroxide.

- Test 1 consisted of operating the UV unit at the manufacturer's recommended power setting (approximately 64%) to achieve 1.2 log removal of NDMA at 695 gpm. The H_2O_2 was dosed at 3 mg/L. Three sets of influent and product samples were collected approximately 5 minutes apart.

- Test 2 increased the UV power setting to a target of 80% of the maximum output of the UV unit and the H_2O_2 was dosed at 3 mg/L. Three influent and three product samples were collected approximately 5 minutes apart.

- In Test 3 the UV power setting was approximately 60% (minimum power setting). Three influent and three product samples were collected approximately 5 minutes apart.

- Test 4 increased the UV power settings to 100% (maximum power setting). Three influent and three product samples were collected approximately 5 minutes apart.

A total of twenty-nine (29) NDMA and eight (8) 1,4-dioxane samples were collected and analyzed as part of this spiking experiment including samples measured in the UV/AOP influent, UV/AOP product and control samples. The spiking experiment lasted approximately four (4) hours. The first hour was used to set-up and verify that the testing and dosing apparatus were operating correctly and to give the system time to reach equilibrium. During the spiking experiment the UV/AOP product was directed to sewer. Any remaining volume in the mixing tank at the conclusion of the experiment was run through the UV unit to completely destroy any remaining chemical. Following completion of the experiment the UV/AOP product was diverted to sewer for another hour to ensure the system was completely flushed before putting the product back into the North City recycled water system.

Results. Table 7 provides analytical results of NDMA and 1,4-dioxane of samples collected during the spiking experiment. Results include measurements of the batch, control samples and three (3) influent and three (3) product samples for each power set point condition. The average influent and product concentration of NDMA (ng/L) based on results from all test conditions ranged from 737 to 847 and 5.3 to 29, respectively. The analytical data also show that the inherent feed concentration and

product concentration of 1,4-dioxane sampled during each run was non-detect (ND). Control samples yielded results as expected showing similar values of influent and product NDMA concentrations with lamps off and peroxide dosing of 0 mg/L (Control 1) and lamps off and target peroxide dose of 3 mg/L (Control 2).

The analytical lab data was used to calculate the average NDMA log removal for each reactor power set point as presented in **Figure 14**. Results indicate the Trojan system achieved between 1.5 to 2.1 log removal of NDMA over the span of power settings (minimum 60% to maximum 100%) tested. The figure also presents the average target NDMA log removal recorded from the Trojan HMI for each test condition. For each power set point (100% power setting the exception) the NDMA log removal based on measured values was higher than that predicted by the Trojan algorithm.

Using the calculated NDMA log removal values, feed flow, and power measured during each test condition, values of electrical energy per order (kWh/1000 gallons/log removal) were calculated for each test condition as presented in **Table 8**. The calculated EEO values ranged from 0.176 to 0.205 over the range of power settings tested. Results showed the calculated EEO for the 64% power set point (0.188) was lower than the average EE/0 value (0.26) displayed on the Trojan system during the operating period as presented in **Section 2.1.4.1**. The data suggest the Trojan system is operating more efficiently than predicted.

The project team consulted with Trojan regarding the discrepancy of the EEO values calculated based on spiking results compared to the values calculated by the UV/AOP system algorithm. In response, Trojan compared the EEO models of the AWPF system to the UV/AOP system used at the Orange County Water District (OCWD) Groundwater Replenishment System. Trojan reported the AWP Facility system control algorithms are more complicated than OCWD's because the program structure allows for model parameters to be modified to control the system based on alternate contaminants. Furthermore, the OCWD system model does not have peroxide control so it only determines the UV dose needed for NDMA removal.

Trojan concluded that because the AWP Facility system calculates higher EEO values than the OCWD system the AWP Facility system may achieve higher than intended NDMA log reductions. Lastly, Trojan compared the two models based on a 95% feedwater UVT and showed the AWP Facility model calculated an EEO of 0.31 while the OCWD model predicted an EEO of 0.22.

2.1.4.4.2 1,4-Dioxane Spiking Experiment

Objectives and Test Procedure. During the Q3 Testing Period a second spiking experiment was conducted on the UV/AOP. The objectives of this experiment included:

1. Demonstrate the UV/AOP reactor is achieving minimum 0.5-log removal of 1,4-dioxane under the target reactor conditions to achieve 1.2-log removal of NDMA.

2. Determine EEO of the UV/AOP reactor with respect to 1,4-dioxane.

3. Assess the impact of hydrogen peroxide dose on 1,4-dioxane removal by the UV/AOP.

4. Assess the removal of 1,4-dioxane under UV dose conditions lower than the target conditions demonstrated to achieve >1.2-log removal of NDMA.

5. Gather information on the removal of select surrogate compounds by the UV/AOP process.

The experiment included four different operating conditions (Run 1 to 4) which varied in terms of target peroxide concentration, influent flow and UV reactor power. Details are provided in **Table 9**. A summary of the test conditions follow.

- Test 1 consisted of operating the UV unit at the manufacturer's recommended power setting (approximately 64%) to achieve 1.2 log removal of NDMA at 695 gpm. The H_2O_2 was dosed at 1.5 mg/L. One influent and three product samples were collected for both NDMA and 1,4-dioxane at approximately 5 minute intervals.

- Test 2 increased the H_2O_2 dose to 3 mg/L with the same flow and UV settings as Run 1. One influent and three product samples (1,4-dioxane only) were collected at approximately 5 minute intervals.

- Test 3 increased the H_2O_2 dose to 6 mg/L with the same flow and UV settings as Run 1 and Run 2. One influent and three product samples (1,4-dioxane only) were collected at approximately 5 minute intervals.

- Test 4 decreased the UV power settings to 60% (minimum power setting). The influent flow was increased by approximately 20% to further lower the UV dose. The H_2O_2 dose was set to 3 mg/L. One influent and three product samples were collected for both NDMA and 1,4-dioxane at approximately 5 minute intervals.

The target feedwater concentrations for NDMA and 1,4-dioxane were 1,000 ng/L and 20 µg/L, respectively. It was necessary to repeat the experiment during the current testing period because it was discovered that the solvent (methanol) originally used by the lab to prepare the spiking solution significantly increased the free radical demand and therefore would reduce the removal of 1,4-dioxane. Specifically, during the original experiment 1 L of methanol was used to prepare the stock solution resulting in a much greater concentration (>60X) than the spiked amount of 1,4-dioxane. During the repeated experiment the spiking solution was prepared with a solvent of DI water mixed with only 5 mL of methanol per 1 L. Though the target compounds are highly soluble in distilled water alone, the small volume of methanol was used to serve as a wetting agent and prevent the compounds from sticking to the surface of the glass container used to prepare the spiking solution.

Results. **Table 10** summarizes the results for 1,4-dioxane and NDMA measured in the batch samples, control samples, and the UV/AOP influent and product samples for the four test conditions. **Figure 15** plots average log removal values of 1,4-dioxane and NDMA versus target peroxide dose (mg/L) for Test 2 and Test 4, in which the peroxide dose was held constant at 3 mg/L but the EED was reduced (Test 4) by lowering the reactor power level and increasing the feed flow rate. As expected, the log removal of 1,4-dioxane was reduced under the lower EED conditions due to the reduced amount of free hydroxyl radical production. The average log removal of 1,4-dioxane and NDMA were 0.6 and 1.6, respectively for Test 2 but reduced to 0.39 and 1.3, respectively for Test 4.

Average values of 1,4-dioxane EEO (kWh/1000 gallons/log reduction) were 0.50 (range=0.45 to 0.58) to 0.57 (range=0.34 to 0.70) for Test 2 and Test 4, respectively. Such results are in general agreement with EEO values determined from spiking studies conducted on the full-scale AOP system located the OCWD's Groundwater Replenishment System which ranged from 0.27 to 0.58 kWh/1000 gallons/ log removal of 1,4 Dioxane (2009 WaterReuse California Section meeting, San Diego CA). **Table 11** provides calculated values of EED (kWh/1000 gallon) for the four test conditions. EED values for Tests 1, 2, and 3 were similar (i.e. 0.302 to 0.312) but approximately 27% lower for Test 4 (i.e. 0.225).

Figure 16 plots log removal of 1,4-dioxane versus target peroxide dose for Tests 1 to 3. The results show a linear relationship between log removal and peroxide dose (R^2 = 0.99). Based on this relationship, a predicted target dose of 2.3 mg/L would be required to achieve 0.5 log removal of 1,4-dioxane. The significance of these results is that it may be possible to optimize the peroxide dose to reduce O&M costs of the UV/AOP, however the overall results show it is a balance between electrical energy and peroxide dose to determine the optimal operating conditions to meet the target removal.

2.2 Comparison of MF and UF System Performance

The MF and UF systems were operated side by side for similar runtimes to compare operational and water quality performance.

A summary of operational performance of the membrane filtration systems is provided in **Table 12**.

Operating Period 1 is defined as the operational time period between the completion of the first and second chemical cleanings. During this time, the MF system operated for 5.5 months and the UF system for 5.7 months with similar fouling rates of 11 % (average decline in specific flux per month). During this time the UF system operated with a slightly lower average TMP (4.6 psi vs. 5.0 psi); however, the UF system required a higher average feed pressure (16 psi vs. 15 psi), due to a higher permeate backpressure from the longer discharge piping between the UF system and the break tank. Backpressure on the UF averaged 11.3 psi, but averaged 8.5 psi for the MF system, located immediately adjacent to the break tank. The differences in feed

pressure should therefore not be considered representative of the two systems, but are rather the result of the unique flow configuration of the intermediate piping downstream of each system.

Operational Period 2 is defined as the operational period following the completion of the second chemical cleaning. The MF system operated for over 3.4 months with a calculated fouling rate of 12% and did not require a third cleaning through the end of the current testing period. In comparison, the UF system only operated for 2 months before requiring cleaning. During this time the fouling rate for the UF was 38%, which was significantly greater (> 3 times) than that observed on the MF system over a similar time period.

Operational Period 3 (UF only) is defined as the operational period following the completion of the third chemical cleaning. The UF system operated for 1.7 months with a lower fouling rate (26% vs. 38%) and much lower average TMP (2.7 vs. 6.8) than observed during Operational Period 2. The decrease in fouling is attributed to the lower target pH (1.5 vs. 3) used during the third cleaning as opposed to the target pH of the second cleaning.

On-site water quality monitoring of the membrane filtration systems showed that both consistently produced filtrate with similar average concentrations for turbidity (<0.1 NTU), Total Organic Carbon (6.5 mg/L), and UV 254 Absorbance (0.17 cm-1). Pathogen testing showed that both the MF and UF as the first step in the purification process removed bacteria to undetectable concentrations, demonstrating greater than 3-log (99.9 percent) removal of coliform bacteria. Removal of measured viruses (bacteriophage) was greater for the UF system, but exceeded 97 percent for both the MF and UF.

The MF and UF systems achieved concentrations of Total and Fecal Coliforms that were consistently non-detect (ND) in the filtrate from both systems; however, it was observed that the UF system achieved a slightly higher log removal of bacteriophage than the MF system, which is attributable to the smaller pore size in the UF membranes. The average log removal for Somatic (n=21) and Male Specific (n=20) Bacteriophage for the MF system were greater than 3.0 and 1.1, respectively. The average log removal of Somatic (n=21) and Male Specific Bacteriophage (n=20) for the UF system were calculated as greater than 3.7 and 2.2, respectively. No quantifiable hits of either Somatic or Male Specific Bacteriophage were recorded in the UF product, suggesting that higher log removal values may have been observed had concentrations in the feed been higher. **Section 3.15** provides further discussion of microbial monitoring results based on samples collected before and after each purification process.

2.3 Comparison of RO System Train A and Train B Operation

A comparison of operational performance of RO System Trains A and B is provided in **Table 13**. The Table is organized by operational periods as discussed below.

Operating Period 1: is defined as the operational time period between the completion of the first and second chemical cleaning. During this time the systems operated for 5.6 months (Train A) and 5.9 months (Train B) with similar fouling rates of 1.4 % and 1.6 % (average decline in specific flux per month), respectively at a target feedwater recovery of 80%. During this time, Train B operated with a higher feed pressure (e.g., 139 psi vs. 133 psi) and NOP (e.g., 104 psi vs. 98 psi). The higher pressure required for Train B is attributed to the difference in membrane type and configuration (three stages vs. two stages), as the permeabilities (specific flux) were found to be similar for both membranes and were nearly identical for the first stage elements **(see Table 13).**

Operational Period 2: is defined as the operational period following the completion of the second chemical cleaning, which was conducted at run hour 6,265 for Train A and run hour 6,297 for Train B. During this time the target feedwater recovery for both systems was 85%. Following the second cleaning Train A operated for 2,144 run hours (3 months) with little fouling (2.1 % per month). However, Train B only operated for 920 run hours (1.3 months) due to the aforementioned issue with the concentrate flow meter which led to the system being operated above the target recovery (i.e. .87 to 89%). During this time fouling rate was 15% based on the decline in the overall specific flux, however the Stage 3 fouling rate was 40%. At this time the third stage was cleaned.

Operational Period 3 (Train B only): is defined as the operational period following the cleaning of the third stage membranes. During this period the system was operated with a target recovery of 80% during which time the issue with the concentrate flow meter was investigated and resolved. During this period the system operated for 591 run hours with a modest fouling rate of 2.1%.

Operational Period 4 (Train B only): is defined as the operational period during which the system was operated at 85% recovery upon resolving the aforementioned issue with the concentrate flow meter. During this time the system operated for 493 run hours (0.7 months) with a measured fouling rate of 9.9%. Because a limited amount of run time was conducted on Train B at 85% recovery it is recommended further operation be conducted to further assess the fouling rate at this recovery.

Comparison of the power consumption monitored from RO Train A (2-Stage configuration) and Train B (3-Stage configuration) during operation at 85 percent recovery shows that the RO Train B required on average 19% more energy than RO Train A. The basis for this determination follows:

- Train A – Based on the average power consumption (67,000 kWh) and permeate flow (344 gpm) monitored over 2,144 hours of operation at 85% recovery, the average power consumption per treated flow (kWh/MG) was calculated as 1,514.

- Train B – Based on power consumption (18,500 kWh) and permeate flow (347 gpm) monitored over 493 hours of operation at 85% recovery, the average power consumption per treated flow (kWh/MG) was calculated as 1,802.

Table 14 presents water quality data of the RO System Trains A and B for several key water quality parameters. The two types of membranes were projected to differ on some water quality parameters, but both systems consistently produced permeate with similar water quality characteristics. Software projections for both membranes under-predicted the Total Dissolved Solids (TDS) and chloride rejection, with the Hydranautics ESPA2 elements (Train A) closer to projections for TDS and the Toray TML20 elements (Train B) closer for chlorides. Nitrate rejection was significantly under-predicted for the ESPA2 elements, projecting a nitrate concentration of 1.4 mg/L-N in the product, but the measured average concentration was much lower, at 0.41 mg/L-N. In contrast, the TML20 software over projected the nitrate rejection, predicting a nitrate of 0.22 mg/L-N, but the measured average concentration was 0.45 mg/L-N. Overall, there was very little difference between the permeate produced by the two RO membranes tested, in spite of the initial projections that had suggested much higher nitrogen removal with the TML20 elements.

Section 3
Water Quality Monitoring Results

An extensive water quality monitoring plan was implemented for the Water Purification Demonstration Project. The detailed water quality monitoring plan including sample locations, laboratory methods, and sampling frequencies is provided in the Final T&M Plan. For thorough water quality analysis, several different laboratories were selected to conduct analysis of samples collected during the testing. The labs utilized over the testing period were: MWH Laboratories, Weck Laboratories, Biovir Laboratories, and the AQWATEC, Laboratory at the Colorado School of Mines. In addition, Laboratory Data Consultants, Inc. (LDC) was selected to perform data validation of the laboratory analyses. Multiple laboratories were selected for specific analysis performed by labs that specialize in that area, increasing accuracy and lowering detection levels. The Final T&M Plan provides specific information on the credentials and the types of analysis each lab conducted over the testing period as well as information on an Onsite Lab used during the testing period to analyze general process parameters. The overall water quality monitoring plan included the following seven categories.

- *Routine Water Quality Monitoring*. This category included nutrients (nitrogen and phosphorus); volatile organic compounds (Trihalomethanes, Methylene Chloride, 1,2-Dichloroethane); nitrosamines; 1,4-Dioxane; and TOC. Sampling frequencies ranged from bi-weekly to monthly depending on the specific parameter.

- *Microbial Monitoring*. This category included initial daily followed by weekly sampling for Total Coliform and Fecal Coliform and initial weekly followed by monthly sampling for Somatic and Male Specific Bacteriophage.

- *Basin Plan Objectives Monitoring*. This category consisted of parameters with Basin Plan numeric objectives not addressed in other sampling categories: Total Dissolved Solids (TDS), Chloride, Sulfate, Sodium, Iron, Manganese, Boron, Color, Fluoride, Phenolic compounds, pH, Temperature, Dissolved Oxygen, and Turbidity. Sampling frequencies ranged from daily to bi-monthly.

- *Quarterly Monitoring*. This category consisted of (1) compounds with Federal and State drinking water maximum contaminant levels (MCLs); (2) compounds included on U.S. EPA's priority pollutant list; (3) compounds with current CDPH Notification Levels (NLs); (4) compounds on the US EPA's current Unregulated Contaminant Monitoring Rule (UCMR3) list; (5) compounds recommended by the IAP (lithium, benzo(k)fluoranthene, and hexavalent chromium). Samples were collected quarterly.

- *Constituents of Emerging Concern (CECs).* During the Q1 and Q2 Testing Periods, an initial characterization study was conducted based on four monthly sampling

events for 92 CECs, including pesticides, herbicides, pharmaceuticals, and ingredients in personal care products representing a wide range of chemical and physical properties. The initial characterization study included monitoring of health-based and performance-based indicators recommended by the State Water Resources Control Board's (SWRCB) expert panel on CEC monitoring for groundwater recharge projects that utilize RO/AOP. The complete report produced by the expert panel can be found online at the following website: **http://www.waterboards.ca.gov/water_issues/programs/water_recycling_policy/recycledwater_cec.shtml.** Thirty CECs were selected for monitoring as potential treatment performance indicators based on occurrence in the RO feed water as measured during the initial characterization study or CECs recommended by the IAP. Weekly samples were collected over a period of four weeks.

- *Whole Effluent Toxicity Testing*. This program, conducted during the Q2 Testing Period, consisted of acute and chronic toxicity assays for a blend of UV/AOP product and Lake Murray water (local reservoir primarily holding imported water) and a control sample. The chronic test organisms were Ceriodaphnia dubia (water flea), Pimephales promelas (fathead minnow) and Selenastrum capricornutum (green algae). The test organisms used for the acute testing were Ceriodaphnia dubia and Pimephales promelas.

- *Quality Assurance/Quality Control (QA/QC) Testing*. A QA/QC Plan was developed for the project consisting of the collection and analysis of field duplicates, blind duplicates, travel blanks, field blanks, and split samples. In addition, third-party validations were performed by Laboratory Data Consultants, Inc. (LDC) using United States Environmental Protection Agency USEPA Level IV guidelines to assess data quality and review laboratory and sample handling procedures by WECK and MWH Labs.

There was some overlap for parameters in the different categories. For example, some of the constituents included in the routine monitoring category were also assessed as part of the quarterly monitoring category. The subsections below present the results for each constituent category. **Section 3.6** summarizes the water quality results for both regulatory relevant and non-regulated constituents measured of the purified water and compares the results to the proposed demonstration goals as outlined in the Final T&M Plan. As noted in the Final T&M Plan, the goals for each parameter were established based on the anticipated regulatory requirements using the best available information at that time and may be subject to change.

3.1 Routine Water Quality Monitoring

This section provides the cumulative results of routine sampling and analysis, conducted from 8/1/11 to 7/31/12. Samples were collected at various locations throughout the purification process as identified in the general AWP Facility Process Schematic provided in **Figure 17.** As shown, ammonia hydroxide and sodium hypochlorite were added upstream of the MF and UF system to achieve a target

residual of 3 mg/L chloramines as a means of controlling biological fouling of the membrane systems.

During the Q1 Testing period, all samples were collected as grab samples; however beginning with the Q2 Testing period, 24-hour composite samples were collected (when appropriate or feasible) or by grab samples. In general, composite samples are more representative than grab samples as they capture changes in feed water quality and/or treatment performance over a given time period. The tables referenced in this section are organized by parameter, sample date, sample type (grab or composite), sample location and include statistical parameters (i.e. average, number of samples (n), maximum, minimum and standard deviation). Sample results reported as equal to or greater than the laboratory reporting level (RL) are considered to be measured concentrations. Sample results less than the RL but greater than the method detection limit (DL) were detected but not quantifiable and are noted as less than the RL value (i.e., <RL). Sample results reported as less than the DL are considered to be below levels of detection and are noted as <DL. For purposes of calculating statistical parameters, results reported below the RL were considered as 50% of the RL value and for values reported below the DL a value of 50% of the DL was used.

Based on comments from the Project's Independent Advisory Panel (IAP) as outlined in the February 2, 2012 memorandum: *Recommendation from IAP: Draft Memorandum: Findings and Recommendations of the Advanced Water Purification Facility Subcommittee, February 2, 2012*, efforts were made during the Q3 and current testing period to time sequence all sample collection. The purpose was to allow tracking of process performance in parallel with the hydraulic detention time of each reactor to monitor changes in approximately the same slug of water (i.e., plug flow) as it passes through each treatment processes.

A brief summary of the results is provided below for each constituent or constituent group monitored routinely.

3.1.1 Nitrogen and Phosphorus

Table 15 provides the results for various forms of nitrogen and Total Phosphorus from samples collected at various locations throughout the purification process during the previous and current testing periods. The majority of samples collected were 24 hour composites. The specific parameters evaluated are: Ammonia, Total Kjeldahl Nitrogen (TKN), Nitrate+Nitrite, Nitrite, Total Nitrogen, and Total Phosphorus. Total Nitrogen values were calculated by summing the concentrations of nitrate-N + nitrite-N and TKN (organically bound nitrogen + ammonia). Individual nitrate concentrations were calculated by subtracting measured concentrations of nitrite-N from measured concentrations of (nitrate-+nitrite as N). The following convention was followed for the calculations:

- If nitrite as N was below the DL of 0.010 mg/L no subtraction was done. In this case, nitrate-N was determined to be the same value as the nitrate-N + nitrite concentration.

- If nitrite as N was between the DL and the RL (0.10 mg/L) and was 10% or greater of the nitrate-N + nitrite concentration, the result was subtracted from the nitrate-N + nitrite to calculate a value for nitrate-N.

A discussion of the nutrient results to date for different parameters is provided below.

- **Ammonia –** During the previous testing periods, the average ammonia concentration (n=71) in the UV/AOP product water using grab and composite samples was 0.20 ±0.09 mg/L-N. Similar values were measured during the current testing period using composite samples with the average ammonia concentration (n=22) measured in the UV/AOP product of 0.23 ±0.04 mg/L-N. Results of ammonia samples collected during the testing period before and after each purification process indicate the RO and the UV/AOP achieved an average (n=23) removal of 77% and 50%, respectively. It should be noted that the test method for ammonia does not distinguish between free ammonia and ammonia complexes, such as monochloramine and dichloramine, which have different removal rates in both the RO and UV/AOP.

- **Total Nitrogen** - The average value of total nitrogen (n=74) reported during the previous testing periods for the UV/AOP product water using grab and composite samples was 0.80 ±0.17 mg/L-N. Slightly higher values were reported for the current testing period using composite samples with the average value of total nitrogen (n=22) of 1.10 ±0.28 mg/L-N. The total nitrogen concentration in the sample collected on 5/31/12 was 2.2 mg/L-N (predominantly TKN). The cumulative average (n=96) total nitrogen concentration from all testing periods in the UV/AOP product water was 0.87 ±0.23 mg/L-N. The demonstration goal for total nitrogen based on anticipated CDPH requirements is 5 mg/L-N.

- **Nitrate –** During the previous testing periods the average nitrate concentration (n=74) in the UV/AOP product was 0.65 ±0.11 mg/L-N. Slightly higher values were reported for the current testing period with the average nitrate concentration (n=22) of 0.99 ±0.14 mg/L-N. The average concentration (n=96) of nitrate based on cumulative results of all testing periods was 0.73 ± 0.19 mg/L-N. It was also observed over all testing periods that both RO systems achieved similar rejection of nitrate even though the Toray membranes were projected to reject more nitrate than the Hydranautics membranes The average nitrate rejection (%) for Hydranautics ESPA 2 and Toray TML (n=23) based on the total number of results from all testing periods is 96.6% and 96.3%, respectively. It was also observed that the concentration of nitrate in the RO permeate is consistently slightly lower (average 26% lower) than values measured in the UV/AOP product water. This is attributed to the oxidization of ammonia to nitrate that occurs across the UV/AOP process.

- **Total Phosphorus –** During the previous testing periods, the average value of total phosphorus (n=66) measured in the UV/AOP product water based on grab and composite samples was 19 µg/L-P (0.019 mg/L-P). During the previous

testing period, four results reported in the UV/AOP product water were higher than expected: 3/8/12, (420 µg/L-P); 3/15/12 (140 µg/L-P); 3/22/12 (140 µg/L-P); and 4/16/12 (120 µg/L-P). These results were from sampling events when samples were only taken from the UV/AOP product water. Therefore, during the current reporting period additional samples were taken at sample locations upstream (i.e. tertiary effluent prior to chlorination and RO permeate) of the UV/AOP product water. Results showed the average (n=10) concentration of total phosphorus in the tertiary effluent and RO permeate was 1,385 µg/L and <10 µg/L, respectively. These results represent an average removal of total phosphorus by the RO system of > 99.3 %. During the current testing period the average concentration (n=22) of total phosphorus measured in the UV/AOP product water was <10 µg/L-P (0.010 mg/L-P). The average concentration (n=88) of total phosphorus based on cumulative results of all testing periods based on grab and composite samples was 16 ±50 µg/L-P (0.016±0.050 mg/L-P).

3.1.2 Disinfection By-products, Methylene Chloride, 1,2-Dichloroethane, and Naphthalene

Table 16 presents results for volatile organic compounds (VOCs) including Trihalomethanes (THMs), Methylene Chloride, 1,2-Dichlorethane and Napthalene. Results for THMs include Total THMs along with individual compounds (*Dibromochloromethane, Chloroform, Bromoform and Bromodichloromethane,*). **Table 17** presents results for Haloacetic Acids (HAAs). Results for HAAs include Total HAA5, along with individual compounds (*Dibromoacetic acid, Trichloroacetic acid, Dichloroacetic acid, Monobromoacetic acid, Monochloroacetic acid*).

A discussion of the results for the various parameters listed above is provided below.

- **Total THMs –** The average (n=9) concentration of Total THMs (TTHMs) measured in the UV/AOP product water during the previous testing periods was below the RL (2 µg/L). All samples (n=3) analyzed during the current testing period were below the RL or DL (0.6 µg/L) in the UV/AOP product water making the cumulative average of all testing periods <2 µg/L. Note: Because THMs are volatile and require a short holding time, all samples were collected as grab samples. The demonstration goal for TTHM's is <80 µg/L based on the drinking water maximum contaminant level (MCL) which is anticipated to be the CDPH limit for surface water augmentation using purified water.

- **Bromoform –** All samples (n=12) analyzed in the RO permeate and UV/AOP product during the previous t testing periods and the current testing period were less than the DL (0.19 µg/L). The anticipated regulatory limit presented in the Final T&M Plan is based on the California Toxic Rule (CTR) criterion of 4.3 µg/L.

- **Dibromochloromethane (DBCM) -** All samples (n=9) analyzed in the UV/AOP product water during the previous testing periods were less than the DL=0.2 µg/L. During the current reporting period three additional monthly samples were

analyzed from the UV/AOP product. The calculated average concentration for the current reporting period is 0.14 µg/L. Two of the sample results were less than the DL. However, the third result from the 6/4/12 sampling was 0.6 µg/L. This result is questionable because results for samples collected on the same day in the tertiary effluent and RO permeate were 0.6 µg/L and <RL (0.5 µg/L), respectively. The cumulative average for this compound for all testing periods is less than the RL (0.5 µg/L), which meets the demonstration goal for DBCM of <RL (0.5 µg/L). The anticipated regulatory limit presented in the Final T&M Plan is based on the CTR criterion of 0.401 µg/L.

- **Bromodichloromethane (BDCM) –** All samples (n=9) analyzed in the UV/AOP product water during previous testing periods were less than the RL (0.5 µg/L) with the exception of samples collected on 8/1/11 (0.71 µg/L) and 3/6/12 (0.56 µg/L). During the current testing period three additional monthly samples were collected from the UV/AOP product water. Two of the sample results were less than the RL. However, the third result (sampling date 6/4/12) was 0.85 µg/L. This result is questionable because results for samples collected on the same day in the tertiary effluent and RO permeate were both lower in concentration (i.e. 0.78 µg/L and 0.66 µg/L, respectively) than the UV/AOP product water). The cumulative average of 0.33 µg/L (n=12) for this compound for all testing periods is less than the RL (0.5 µg/L), which meets the demonstration goal of less than 0.56 µg/L. The anticipated regulatory limit presented in the Final T&M Plan is based on the CTR criterion of 0.56 µg/L.

- **Methylene Chloride –** All monthly samples (n=3) analyzed during the current testing period from the UV/AOP product were below the RL (0.5 µg/L) or DL (0.14). The average (n=12) concentration in the UV/AOP product water based on cumulative results from all testing periods is less than the RL, which is below the demonstration goal of <4.7 µg/L. The anticipated regulatory limit presented in the Final T&M Plan is based on the CTR criterion of 4.7 µg/L.

- **1,2-Dichloroethane -** All monthly samples (n=12) analyzed in the UV/AOP product during all testing periods were below the DL of 0.12 µg/L, which is below the demonstration goal for this parameter of <0.38 µg/L. The anticipated regulatory limit presented in the Final T&M Plan is based on the CTR criterion of 0.38 µg/L.

- **Naphthalene –** All samples (n=3) analyzed in the RO feed and RO permeate during the previous and current reporting period were below the DL. This compound was monitored based on recommendation from the IAP for the purpose of assessing removal by the RO system. Because all samples were below the DL, removal rate by RO could not be determined.

- **HAA5, Total -** All monthly samples (n=12) analyzed in the UV/AOP product during all testing periods were below the DL (1 µg/L) in both the RO permeate and UV/AOP product water, which is below the demonstration goal for HAA5,

Total of <60 µg/L. The anticipated regulatory limit (60 µg/L) presented in the Final T&M Plan is based on the drinking water MCL which is anticipated to be the CDPH limit for surface water augmentation using recycled water.

3.1.3 Nitrosamines & 1,4-Dioxane

Tables 18 and 19 provide results for nitrosamines and 1,4-Dioxane, respectively, sampled at various locations throughout the AWP Facility. Because nitrosamines form in the presence of chloramines, all samples were collected as grab samples. All samples of 1,4-Dioxane during the previous and current testing period were collected as composites. Results are presented for NDMA and the seven other nitrosamine compounds listed below:

- N-Nitrosodiethylamine (NDEA)
- N-Nitrosodi-n-butylamine (NDBA)
- N-Nitrosodi-n-propylamine (NDPA)
- N-Nitrosomethylethylamine (NMEA)
- N-Nitrosomorpholine (NMOR)
- N-Nitrosopiperidine (NPIP)
- N-Nitrosopyrrolidine (NPYR)

A discussion of the results to date compared to the proposed demonstration goals is provided below.

- **Nitrosamines -** All routine samples (n=15) collected during all testing periods show that the concentrations of all the nitrosamines in the RO permeate were below the RL or DL. The majority of samples analyzed in the UV/AOP product water were also below the RL or DL with the exception of one sample with NDMA reported at a value of 5.5 ng/L (sample date 1/3/12). It was observed that the concentration of NDMA in the RO permeate on the same day was reported at the RL of 2 ng/L. The lab reanalyzed the UV/AOP product sample and reported the result as ND; however, the result is considered inconclusive as the sample was past the holding time required for the analytical method. On three occasions (12/1/11, 1/3/12, 4/23/12), the concentration of NDEA was also reported to be above the RL in the UV/AOP product water with concentrations measured in the RO permeate on the same day below the RL. All results for NDMA, NDEA, and NDPA measured in the UV/AOP product water were below the current CDPH drinking water Notification Levels (NL) of 10 ng/L for each chemical. It is not clear how NL-based requirements might be applied in permits for surface water augmentation projects at this time. The treatment performance goal for NDMA was 1.2 log

removal across AOP. Additional information on removal of nitrosamines is provided in **Section 2.1.4**.

- **1,4-Dioxane -** All monthly samples (n=12) collected in the RO permeate during all testing periods were below the RL of 0.5 µg/L. All samples (n=12) collected in the UV/AOP product water were below the DL of 0.040 µg/L. The average (n=11) concentration of 1,4 Dioxane measured in the RO feed water based on cumulative results from all testing periods was less than 2 µg/L. The treatment performance goal was to achieve 0.5-log removal across the AOP. This goal was demonstrated during the current reporting period by conducting challenge testing on the UV/AOP system as presented in **Section 2.1**. While CDPH has established a NL of 1 µg/L for 1,4-Dioxane, it is not clear how NL based requirements might be applied in permits for surface water augmentation projects at this time.

3.1.4 Total Organic Carbon (TOC)

Table 20 provides the results for TOC sampled at various sample locations throughout the purification process. The majority of samples collected during the current testing periods were collected as composites. Results from all testing periods (n=97) show the average TOC concentration measured in the UV/AOP product water is below the RL of 0.3 mg/L. The demonstration goal for TOC is 0.5 mg/L based on the anticipated CDPH requirement for use of recycled water for surface augmentation. The results of TOC measured before and after the RO systems show an average (n=12) removal of greater than 97.4%.

It should be noted on one occasion during the Q2 testing period (1/12/12), the TOC result for the sample collected in the UV/AOP product was reported at 1.4 mg/L. The laboratory reanalyzed the sample and confirmed the original result. However, the online TOC measured in the RO product (**see Section 4.2.1.**2) was consistently below 0.07 mg/L on the day of the sampling event, and the lab reported values in the UV/AOP product water before and after this result were consistently below the RL. Statistical analysis of the entire set of lab results for TOC measured in the UV/AOP product identified the result of 1.4 mg/L to be an outlier and is not considered representative of the TOC concentration consistently reported in the UV/AOP product water. It is likely that the high TOC value is the result of a contaminated sample or mislabeled sample bottle.

It should be noted TOC values measured online in the RO permeate throughout the testing period were much lower (**i.e. ranged from 0.02 to 0.08 mg/L**) than lab results, which were reported below the labs quantifiable limit of 0.3 mg/L. Based on discussion with the manufacturer of the online TOC analyzer, GE Power and Water, online analyzers can detect lower amounts of organics due to the fact there are no organic interferences in the measurement system. In addition, during the collection of field samples for laboratory analysis, samples can be contaminated with organics from the several sources including the sample vials themselves and carbon dioxide from the atmosphere. The operating specifications for the online analyzer used during

the demonstration project had an operating range of 0.03 µg/L to 50 mg/L with accuracy of ±2% or 0.5 µg/L, whichever is greater.

3.1.5 Microbial Monitoring

Tables 21 and 22 present results for Coliform (Total and Fecal) and naturally occurring Bacteriophage (Somatic and Male Specific), respectively, measured before and after each AWP Facility unit process. Results for total and fecal coliform samples (n=12) collected weekly during this testing period were <DL for all samples collected in the MF filtrate, UF filtrate, RO feed, RO permeate (Trains A and B) and UV/AOP product water. The cumulative number of samples collected during all testing periods from each sampling location was 85. Of these, all results were ≤DL for total and fecal coliform with the exception of 3 total coliform results reported at low concentrations: UF filtrate (2.2 MPN/100 mL, 3.6 MPN/100 mL) and RO feed (5.1 MPN/100 mL). These results are attributed to bacterial growth which occurred in the sample lines located on the filtrate/permeate side of the membranes. Upon flushing and disinfection of the lines no further detections occurred. Overall the results showed that both the MF and UF, as the first step in the purification process, removed bacteria to undetectable concentrations, demonstrating greater than 3 log (99.9 percent) removal of coliform bacteria.

The results of monthly sampling for Somatic (n=21) and Male Specific Bacteriophage (n=20) collected for each sample location for the current and previous testing periods are discussed below. EPA Method 1602 (DL=1 pfu/100 mL) was used to analyze all tertiary effluent samples while a more sensitive method, EPA Method 1601 (Present or Absent per L), was used for MF filtrate, UF filtrate, RO Permeate, and UV/AOP product. Duplicate samples were collected for these locations so that in the event detection occurred using EPA Method 1601, the laboratory could perform the analysis using EPA Method 1602. As noted in **Table 22** the samples for Somatic Bacteriophage using EPA 1601 on 5/29/12 were analyzed past the recommended hold time due to laboratory issues and therefore no bacteriophage results are presented for this sampling date. A follow up sampling was conducted on 6/18/12, however because this reduced the overall number of sample results collected during the testing period an additional sampling was conducted on 9/10/12.

Overall the results showed that both the MF and UF, as the first step in the purification process, achieved high removal of bacteriophage. The MF and UF systems achieved composite virus removals (Somatic plus Male Specific) greater than 99.8 percent and 99.97 percent, respectively. The higher removal by the UF is attributed to the smaller pore size. All bacteriophage results for the purified water were Absent. A summary of results measured over the testing period for each sampling location is below.

- **Tertiary Effluent –** During this testing period, Somatic Bacteriophage concentrations ranged from 578 to 1500 pfu/100 mL; and Male Specific Bacteriophage concentrations ranged from 4 to 9 pfu/100 mL. These results are

comparable to data collected during the prior testing periods. Somatic Bacteriophage ranged from 99 to > 3000 pfu/100 mL and Male Specific Bacteriophage ranged from > 1 to 67 pfu/100 mL.

- **UF Filtrate –** All samples of Somatic and Male Specific Bacteriophage collected during the current testing period were reported as Absence per L using EPA Method 1601 with the exception of the sample collected on 6/18/12 where the Somatic Bacteriophage was reported as Present per L. The sample was then run using EPA Method 1602 and the result was <1 pfu/100 mL. During the prior testing periods all Male Specific Bacteriophage were reported as Absence per L. For Somatic Bacteriophage, 2 samples were reported as Present per L. The samples were then run using EPA Method 1602 and the results were <1 pfu/100 mL.

- **MF Filtrate –** Somatic and Male Specific Bacteriophage collected during this testing period ranged from Absence per L to <1 pfu/100 mL. During the prior testing periods, Somatic Bacteriophage ranged from Absence per L to 10 pfu/100 mL and Male Specific Bacteriophage ranged from Absence per L to 11 pfu/100 mL. Note the higher concentration of bacteriophage in the MF filtrate compared to the UF filtrate is attributed to the difference in membrane pore size.

- **RO Permeate Trains A & B –** All samples of Somatic and Male Specific Bacteriophage during the current testing period were reported as Absence per L. During the prior testing periods, all bacteriophage samples were reported as Absence per L with the exception of the sample collected on 12/12/11 from Train A permeate. For this sample, the Male Specific Bacteriophage was reported as Present per L. The sample was then run using EPA Method 1602 and the result was <1 pfu/100 mL.

- **UV/AOP Product –** During the current and prior testing periods, all sample results for Somatic and Male Specific Bacteriophage were Absent per L.

- **Overall Log Removal Value (LRV) –** Based on sampling results , the average concentrations of Somatic (n=21) and Male Specific (20) Bacteriophage in the tertiary effluent compared to the UV/AOP product indicate the AWP Facility purification process achieved log reduction values (LRV's) greater than 4.2 and 2.2, respectively for removal of naturally occurring phage.

Overall the microbial monitoring results to date demonstrate the ability of the AWP Facility to provide a barrier to bacteria and pathogens.

3.1.6 Basin Plan Numeric Objectives

The Basin Plan Numeric Objectives are provided in **Table 23**. It should be noted that the nutrient requirements (including phosphorus and nitrogen) for the potential Full-Scale Facility have not been established at the time of this report. **Table 24** provides results for general parameters with Basin Plan Numeric Objectives not presented elsewhere in this report, including: total dissolved solids (TDS), chloride, sulfate,

sodium, iron, manganese, boron, color, fluoride and phenolic compounds. In general each of these parameters present in the RO feedwater were shown to be highly removed (>95%) by the RO systems with the exception of boron for which the average removal was only approximately 42% (similar rejection by both Train A and Train B membranes). The average concentration (229 µg/L) of boron measured in the purified water was 4 times lower than the Basin Plan Objective of 1,000 µg/L (1 mg/L).

All results collected during the Q1 through Q4 Testing Periods showed the purified water met the Basin Plan objectives with the exception of three occasions when phenolic compounds were reported above the Basin Plan Objective of 1 µg/L. The sample dates and reported results for the three occasions follow: 9/1/2011 (22 µg/L), 10/24/11 (1.9 µg/L) and 11/21/11 (2.6 µg/L). The 9/1/2011 (first sample analyzed during the Q1 Testing Period) result is considered an outlier as the sample was analyzed using method EPA 420.4 (RL=10 µg/L), which only measures total phenolics thereby making analyses prone to interferences. Subsequent samples were analyzed using method EPA 8270 which quantifies individual (14 total) phenolic compounds, with a RL of 1 µg/L. The 10/24/11 and 11/21/11 results for the purified water are also questionable as RO permeate composite samples collected on the same day were lower in concentration. The laboratory reanalyzed the samples and confirmed the results. It should also be noted, based on discussions with the laboratory that conducted the analysis, the 12/19/11 samples were re-extracted and reanalyzed past hold time due to the likelihood of lab contamination. All other results showed phenolic compounds (14 total) measured in the RO permeate and UV/AOP product during the previous and current testing periods were <1 µg/L in both the RO permeate and UV/AOP product water.

Table 25 presents on-site water quality measured in the UV/AOP product water for other constituents with Basin Plan numeric objectives including: pH, Dissolved Oxygen (DO), and Turbidity. To date, the results for DO and Turbidity meet Basin Plan objectives; the pH ranged from 5.2 to 6.5, which was within the expected range without chemical stabilization.

3.2 Quarterly Monitoring

During the current and previous testing periods, quarterly monitoring of various compound groups was conducted by collecting grab samples of the North City tertiary effluent, UV/AOP product water and imported raw aqueduct water (IAW). The specific compound groups evaluated on a quarterly basis are:

- Compounds with Federal and State Primary and Secondary Drinking Water Maximum Contaminant Levels;
- Compounds included on EPA's Priority Pollutant List as defined by the California Toxic Rule;
- Compounds with current CDPH NLs;

- Proposed Contaminants from EPA's Unregulated Contaminant Monitoring Rule (UCMR3) Assessment Monitoring (List 1 and List 2);
- Other Radionuclides (Cesium-137, Iodine-129, Iodine-131);
- Other Compounds: Lithium, benzo(k)fluoranthene, hexavalent chromium.

The results of the fourth quarter sampling event (5/1/12) for each compound group are summarized below. Note: Several compounds appear in multiple compound groups. The summary tables presented below also include data from the previous testing periods.

3.2.1 Federal and State Drinking Water MCLs

Tables 26 and 27, respectively, present results for compounds regulated under Federal and State Primary and Secondary drinking water standards. Consistent with results from the Q1, Q2, and Q3 Testing periods, the concentrations of constituents measured in the UV/AOP product water were all below MCLs for Federal and State Drinking Water Standards with the exception of pH (Federal Secondary MCL=6.5 to 8.5; there is no State MCL for pH) and corrosivity (Federal MCL= Non Corrosive; there is no State MCL for corrosivity). The AWP Facility does not include chemical stabilization as the product water is blended with tertiary recycled water for non-potable uses. Chemical stabilization at the potential Full Scale Facility would address pH and corrosivity.

3.2.2 EPA California Toxic Rule Priority Pollutants

Tables 28, 29 and 30 present results of compounds included on the EPA's Priority Pollutant list that were detected in samples collected in the NCWRP tertiary water, UV/AOP product water and IAW, respectively, during the testing periods. The EPA Priority Pollutant list (126 compounds) is provided in **Table 31** for reference. A summary of the results for each sample location follows:

- **Tertiary Effluent –** Samples analyzed showed only eight ccompounds were reported above the RL all of which were below their respective CTR criterion. During the previous testing periods a similar number of compounds were reported above the RL. A total of four results were reported above their respective CTR criterion during all testing periods. These results follow: BDCM at 1 µg/L (Q1) and 0.58 µg/L (Q2), DBCM at 0.65 µg/L (Q1), and NDMA at 2.9 ng/L (Q1).
- **UV/AOP Product Water –**Samples analyzed during the current testing period showed all compounds reported in the UV/AOP product water were at concentrations less than their RL or DL. Similar results were reported for the Q1, Q2 and Q3 Testing periods. Only one result was reported above the CTR criterion. The result was BDCM at 0.78 µg/L (CTR criterion of 0.56 µg/L) reported during the Q1 Testing period. All subsequent quarterly results for BDCM were reported as less than RL (0.5 µg/L). It was also observed the di-n-butyl phthalate results were

<DL (DL=0.24 µg/L) for all testing periods with the exception of the Q1 Testing Period with a reported results of 2.2. µg/L, which was still well below CTR criterion of 2700 µg/L. The higher value reported for Q1 may have resulted from UV light exposure to the PVC (polyvinyl chloride) piping located just downstream of the UV reactor. In general, phthalates are typically used as plasticizers and are primarily used as softening agents for PVC.

- **IAW –** Samples analyzed showed eight compounds were reported in the imported raw aqueduct water above their RLs. Of these, three compounds were reported above their CTR criterion: BDCM (19, 14, 10, and 10 µg/L), DBCM (21, 14, 14, and 15 µg/L), and bromoform (3.5, 2.9, 3.8, and 6.2 µg/L). BDCM and DBCM were reported above their criterion during all testing periods.

3.2.3 CDPH Notification Levels

Table 32 presents results of the 30 compounds with current CDPH notification levels (NLs). Overall similar results were seen for the previous testing periods. Results from the current testing period show all sample locations were below the NL's for all compounds with the exception of 1,4-Dioxane at 1.6 µg/L in the tertiary effluent, which was just above the NL of 1 µg/L. Ethylene glycol (EG) was also reported <RL (50 mg/L) in the tertiary effluent and UV/AOP product water. As noted, because the RL for EG was above the NL (14 mg/L) additional samples were collected (samples dates 8/13/12 and 8/15/12) in both the tertiary effluent and UV/AOP product water. The samples were analyzed using a more sensitive method (RL=1 mg/L). All results were <DL (DL=0.5 mg/L). The NL results also showed slightly higher concentrations of formaldehyde (Q1, Q2, Q3, Q4) were measured in the UV/AOP product water as compared to the tertiary effluent. All results were below the respective NL. Similar results were observed from analysis done as part of the routine sampling as discussed in **Section 2.1.4.3** and **Section 3.1.3**.

3.2.4 UCMR3 Compounds

Table 33 presents results of the 30 compounds proposed for the EPA's Unregulated Contaminant Monitoring Rule (UCMR3) Assessment Monitoring (List 1and List 2). EPA uses the UCMR Monitoring program to collect data for contaminants suspected to be present in drinking water, but that do not have health-based standards set under the Safe Drinking Water Act (SDWA). As shown, the reporting levels for many of these compounds are extremely low. Results from the current testing period show 27 of the compounds were <RL or <DL in the UV/AOP product water. The remaining three compounds that were found at concentrations above their RLs were bromochloromethane, hexavalent chromium and strontium. Similar results were seen for the previous testing periods with the exception of strontium which was reported <RL (0.3 µg/L) for the previous testing periods. The concentration of strontium reported in the UV/AOP product water during this testing period was 0.37 µg/L, which is just above the RL. Based on average the average concentration of quarterly sampling results values (n=4) measured in the tertiary water (443 µg/L) and the UV/AOP product water (<0.3 µg/L) the AWP achieved a high level and consistent

removal (>99.9%) of strontium during all testing periods. The average concentration of strontium measured in the IAW water was 403 µg/L. Additional information on strontium, bromochloromethane, and hexavalent chromium results is provided in **Section 3.6.2**.

3.2.5 Other Radionuclides

Radiation sources provide critical capabilities in the oil and gas, electrical power (utilities) construction, manufacturing, and food industries. They are used to treat millions of patients each year in diagnostic and therapeutic procedures and also are used in a variety of military applications. Radionuclides are commonly used for pharmaceutical research, fluorescent fixtures, wall tiles, luminous devices like exit signs, gauges and watches, electric arc welding for aircraft, petrochemical and food processing industries, test the integrity of pipe welds, nuclear power plants and propulsion systems, lighting rods, electric blanket thermostats, indicator lights in household appliances, sterilization of surgical instruments, treating cancerous tumors, biological and agricultural research, inspect airline luggage for explosives, gauge moisture content in soils, smoke detectors, analyze metal alloys, providing coloring and fluorescence in colored glazes and glassware, and more.

Radionuclides are regulated in drinking water to protect public health from potential harmful effects of radiation. Radionuclides are naturally occurring and thus commonly found in natural water supplies, particularly groundwater. Most radioactive contaminants are at levels that are low enough to not be considered a public health concern, but at higher levels long-term exposure to radionuclides in drinking water could increase the chances of developing cancer or cause toxic effects to the kidney. Radionuclides are unstable isotopes and elements that give off various types of radiation as they decay into more stable forms. Drinking water regulations are established for both Gross Alpha and Gross Beta, which represent the total measured quantity of alpha and beta radiation emitted by any radionuclides present in the water. Gross Alpha measures alpha radiation or alpha particles, which are released by large molecular weight unstable elements, such as Uranium and Radium isotopes. Gross Beta measures beta radiation or beta particles, released by numerous unstable isotopes, such as Cesium-137, Strontium-90, Tritium, and Iodine isotopes. In addition, maximum contaminant levels (MCLs) have been established for specific radionuclides, including Radium-226 and 228, Tritium, Strontium-90, and Uranium.

Measurements of radionuclides are presented in units different than other drinking water parameters. Radionuclides are commonly expressed in terms of radiation output (picocuries per liter or pCi/L) or millirems per year (a unit of ionizing radiation dose), rather than as a weight concentration, such as milligrams per liter (mg/L). In addition, sample results can often be negative and have ranges of values rather than definitive numbers, making the interpretation of the reported results seemingly more complex than other contaminants measured in water supplies. Because ambient radiation exists throughout the environment, sample values are reported in the positive when measured values are above, or negative when below the

ambient radiation in the location where testing is conducted. Radiochemical analyses of drinking water, as part of their methods, also include the determination of counting errors (CEs). CEs reflect the randomness of the natural decay of radionuclides and are a statistical expression of the variability in analytical procedures.

The California Department of Public Health (CDPH) requires measurement of Gross Beta and two specific beta emitters, Tritium and Strontium-90, in drinking water. In the event that the Gross Beta results exceed the federal standard of 4 millirems per year or the equivalent CDPH standard of 50 pCi/L, additional sampling is required for individual beta emitters, such as Cesium-137, Iodine-129, and Iodine-131. Although it was anticipated that the Gross Beta level of the purified water would be less than the Gross Beta MCL, the Testing & Monitoring Plan included quarterly monitoring of Cesium-137, Iodine-129, and Iodine-131 in the tertiary effluent, purified water, and raw imported aqueduct water to provide additional information about the purified water quality. **Table 34** presents the results for Cesium-137, Iodine-129, and Iodine-131 for Quarter 1 (Q1), Quarter 2 (Q2), Quarter 3 (Q3), Quarter 4 (Q4), and an additional sampling event on 7/9/12.

As shown in **Table 34**, the results are shown with the associated minimum detectable activity (MDA) and CEs reported by the laboratory that conducted the analysis. The MDA is defined as the smallest concentration of radioactivity in a sample that can be detected with a 5 percent probability of erroneously detecting radioactivity, when in fact none is present (Type I error) and also, a 5 percent probability of not detecting radioactivity, when in fact some is present (Type II error). Per American National Standards Institute (ANSI) Standard 13.30 (Performance Criteria for Radiobioassay), several factors affect the MDA, including the duration of the sample count, the volume of sample counted, the efficiency of the detector used, the background of the detector used, the decay during sample hold time and counting (for short-lived isotopes), and the measured radiation from the analysis. The MDA is a calculated value, which will vary for each analysis depending on the values of these factors.

Gross Beta measurements were conducted quarterly in the purified water and were less than 50 pCi/L. Consequently, individual measurements of Cesium-137, Iodine-129 and Iodine-131 were not required by regulation, but were measured anyway in accordance with the Testing & Monitoring Plan. Results from Q1, Q2, Q3 and Q4 show that Cesium-137, Iodine-129, and Iodine-131 were measured at or lower than the MDA in the purified water. If the Gross Beta did exceed 50 pCi/L, the EPA has published limits for individual beta emitting radionuclides:

http://www.epa.gov/superfund/health/contaminants/radiation/pdfs/att_d-clean.pdf

These limits are based on concentrations equivalent to an exposure of 4 millirem per year, which is the federal MCL for Gross Beta. The limits for Cesium-137, Iodine-129, and Iodine-131 are:

- Cesium-137 less than 200 pCi/L

- Iodine-129 less than 1 pCi/L
- Iodine-131 less than 3 pCi/L

The results from the quarterly sampling show that Cesium-137 was consistently below this limit in the purified water. However, the laboratory selected MDAs for Iodine-129 and Iodine-131 that were too high to confirm that the samples met the limits cited above. A fifth sampling event was conducted on 7/9/12 during which the lab targeted an MDA of less than 1 pCi/L for both Iodine-129 and Iodine-131. The results presented in Table 33 show the concentration of Iodine-129 in the purified water was below the 1 pCi/L limit and Iodine-131 was below the 3 pCi/L limit.

The Q1 and Q2 results for Cesium-137, Iodine-129, and Iodine I-131 were originally presented in Draft Quarterly Testing Report No. 2 and subsequently posted by the City on a public website. However, incorrect results were presented. The Q1 and Q2 results for Cesium-137, Iodine-129, and Iodine-131 presented in the Draft Quarterly Testing Report No. 2 (submitted to the City on 3/3/12) reflected a discrepancy that was discovered shortly after the City posted the Q1 and Q2 water quality results on the City's project website.

An example of the discrepancy between the correct data and the previously reported data is that the laboratory result of "U" reported for Iodine-131 was incorrectly converted to a value of 16 pCi/L. A result of "U" indicates that the radionuclide was not detected at a value greater than the MDA. In this example, the MDA was 16 pCi/L, meaning that if the radionuclide was present it would be at a value between 0 to less than 16 pCi/L (or negative due to background), but was not quantifiable based on the sensitivity of the test procedure. The correct Q1 and Q2 results are presented in **Table 34**, along with results from additional sampling.

3.2.6 Other Compounds

Table 35 presents results of the three other compounds included as part of the quarterly monitoring program: benzo(k)fluoranthene, hexavalent chromium, and lithium. Results from the current and previous testing periods show all the results were <RL or <DL for all compound and sample locations with the exception of lithium. Lithium was reported <RL or < DL in all UV/AOP four quarterly samples but ranged from 20 - 28 µg/L in the tertiary water and <RL to 21 µg/L in the IAW with two samples above the RL. Hexavalent chromium was also sampled as part of UCMR3 (see Section 3.2.4) and benzo(k)fluoranthene was sampled as part of the priority pollutants (Section 3.2.2).

3.3 Constituents of Emerging Concern (CEC)

3.3.1 Summary of Initial Characterization CEC Results

Table 36 presents the results of CEC samples collected monthly as part of an initial characterization period beginning in August 2011. Analyses were performed by MWH Laboratories using a liquid chromatography followed by tandem mass spectrometry (LC-MS-MS) method. The table provides the common use for each compound, sample location, sample date and reported result. Sample locations included: tertiary effluent (prior to chlorination), various locations in the AWP Facility (i.e. RO feed, RO permeate, and UV/AOP product), and imported raw aqueduct water. During this time, samples were collected for a target list of ninety-two (92) compounds, including those used in pesticides, herbicides, and pharmaceuticals and personal care products (PPCPs) representing a wide range of chemical and physical properties. Information used from the initial characterization period was intended to be used to 1) characterize the tertiary effluent, 2) identify appropriate AWP Facility performance indicator compounds to be monitored on an on-going basis, 3) assess AWP Facility unit process CEC removal performance and 4) compare AWP Facility product water quality to the City's imported raw drinking water.

Results shown in **Table 36** include three samples collected monthly during the Q1 testing period and the one monthly sample collected during the Q2 testing period. Results that were reported below the RL but above the DL are shown as <RL; for some analytes, the table indicates not reported (NR) due to QC concerns reported by the laboratory for two (2) of the 92 target compounds reducing the list to 90 compounds. Further information is provided in a brief letter provided by Dr. Andy Eaton from Eurofins Eaton Analytical Labs (formerly MWH Labs) that is located in **Appendix B**.

Results for six compounds that were re-analyzed (RA) due to discrepancies in results between several different dilutions in the original analytical runs are highlighted in yellow. The re-analyzed compounds were all from samples collected in the RO feed water on 8/15/11. Although the samples were past internal holding time, they were held refrigerated and most of the target analytes are stable for extended periods under these conditions. During the Q3 testing period the lab also investigated the results reported for the compound Deethylatrazine (DEA) from samples collected on 9/14/11. The original results of 160 ng/L and 78 ng/L, respectively reported in the UV/AOP product water and IAW were determined to be false positives and therefore the results were revised in **Table 36** as <DL (1.5 ng/L).

The results from the four month initial characterization period showed on average 41 of the 90 compounds analyzed in the tertiary water were above their RL. As expected, a similar number of compounds (average count above the RL per sampling event = 36) and concentrations were reported in the RO feed water. Of these, the majority were removed by the RO system (average count above the RL per sampling event = 3). All CECs were less than their RL or DL in the UV/AOP product water with the

exception of three results reported from the 9/14/11 sampling event. The compound name, common use, reported concentration and respective RL for each follow:

- Acesulfame-K (sugar substitute) reported at 50 ng/L (RL= 20 ng/L)
- Iohexal (contrasting agent) reported at 19 ng/L (RL= 10 ng/L)
- Triclosan (anti-microbial) reported at 19 ng/L (RL=10 ng/L).

Additional information on these three compounds is provided in **Section 3.6**. When assessing low level CEC results such as these it is important to keep in mind that analytical variability and influence of false positive / negative results become a more significant issue at minute levels. Technologies were not available to measure compounds at these low concentrations a decade ago, and there is still considerable debate about the significance of such low concentrations. As such, it is important that CEC monitoring be accompanied with robust QC sampling. The overall water quality QC sampling plan implemented during the testing periods is discussed in **Section 3.5**. As part of the CEC monitoring QC procedures several samples from each sampling location were sent to a second lab (Colorado School of Mines - CSM) for analysis during the initial characterization period. These samples were collected on the same date and time frame as samples analyzed by MWH laboratories. Results from the 41 compounds analyzed by CSM for samples collected during the initial characterization (sample date 8/15/11 and 11/8/11) are included in **Table 37**. The results showed all compounds measured in the RO permeate and UV/AOP product water were <DL with the exception of sulfamethoxazole, which was reported at the DL (1 ng/L). This compound is an antibiotic and was shown to be highly removed (99.9%) by the RO system. Overall the results from MWH and CSM laboratories were in agreement. Further discussion is provided in **Section 3.5.1.2**.

3.3.2 On-going CEC Characterization & Performance Indicators

3.3.2.1 Revised CEC Monitoring Plan

As presented in the Q2 Testing Report, the project team revised the CEC monitoring plan following completion of the four month initial characterization period presented in **Section 3.4.1**. Implementation of the revised CEC monitoring plan presented in **Table 38** began in concert with the third quarterly sampling event, which was conducted on 2/1/12. The compounds selected for monitoring were based on one or more of the following rationale:

- Toxicologically relevant and treatment performance indicator compounds recommended for monitoring by the State Water Resources Control Board (SWRCB) Expert Panel (*Monitoring Strategies for CECs in Recycled Water: Recommendations of a Science Advisory Panel, June 2010*).
- Potential treatment performance indicator compounds presented in **Table 39** that were selected based on occurrence in the RO feed water as measured during the initial characterization period.

- Additional potential treatment performance indicator compounds based on comments received from the IAP (NWRI Draft Memorandum: *Findings and Recommendations of the Advanced Water Purification Facility Subcommittee*, February 2, 2012).

3.3.2.2 Summary of Results

Results for CEC compounds measured by MWH Labs during the previous and current reporting period are presented in **Tables 40 and 41.** The tables are organized as Group A and Group B compounds, respectively.

Group A. This group contains a total of five compounds, four of which (Caffeine, 17 β-estradiol, NDMA and Triclosan) were the CECs recommended by the SWRCB expert panel based on toxicological relevance for monitoring groundwater recharge projects that use RO/AOP. This group also includes 1,4-Dioxane, which is currently presented as an option for evaluating AOP performance in the November 2011 Draft CDPH Groundwater Recharge Regulations. The Group A compounds were measured as part of the third and fourth quarterly sampling event at five sample locations: S1 (tertiary effluent), S6 (RO feed), S9 (RO permeate), S10 (UV/AOP product water) and imported raw aqueduct water.

Q3 results showed all compounds were below the RL or DL in the RO permeate and UV/AOP product water with the exception of Triclosan reported at 13 ng/L and 17 ng/L, respectively. It should be noted split samples taken from these locations and analyzed by the Colorado School of Mines (CSM) showed Tricolsan to be below the DL of 5 ng/L. Information regarding an investigation of discrepancies between CEC results reported by MWH Labs and CSM is discussed in **Section 3.5**. Triclosan is an antibacterial and antifungal agent used in a variety of consumer products, including toothpastes, deodorants, and soaps. Different DWELs have been developed for Triclosan ranging from 0.35 µg/L (350 ng/L)[1] to 2,600 µg/L (2,600,000 ng/L)[2], which are all significantly higher than the MWH Labs reported values in the RO permeate and UV/AOP product water. Note: DWELs are developed from tolerable daily intakes (TDIs) or acceptable daily intakes (ADIs), which describe a daily dose below which risks to public health are judged to be minimal, assuming repeated daily exposure over a lifetime through consumption of drinking water.

Q4 results for Group A compounds were below the RL or DL in the RO permeate and UV/AOP product water.

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[1] Environment Protection and Heritage Council, the National Health and Medical Research Council and the Natural Resource Management Ministerial Council, 2008, *Australian guidelines for water recycling augmentation of drinking water supplies*, March.

[2] Bruce, G. M.; Pleus, R. C.; Snyder, S. A. Toxicological relevance of pharmaceuticals in drinking water. *Environ. Sci. Technol.* **2010,** *44*, 5619–5626.

Group B. This group contains 37 compounds selected as potential performance indicator compounds for the RO and UV/AOP processes. Three of these compounds (Sucralose, NDMA, and DEET) were the CECs recommended by the SWRCB expert panel for performance of RO/AOP systems for groundwater recharge projects. These compounds were consistently detected in the RO feed of the AWP Facility water during the initial characterization period. Thirty additional compounds were also included in Group B based on their occurrence in pre RO/AOP waters during the initial characterization period. The four remaining compounds (Caffeine, Theobromine, Linuron and Estrone) were included based on recommendations from the IAP. The Group B compounds were measured weekly for four weeks at three sampling locations: S6 (RO feed), S9 (RO permeate), and S10 (UV/AOP product water). Results showed the average number of compounds (per sampling event) detected per location at concentrations above the RL to be: RO feed (33), RO permeate (3), UV/AOP product water (1).

3.3.3 Differential Removal of CEC Performance Indicator and Surrogate Compounds

Based on the results of the four weeks of CEC monitoring of the 37 compounds presented in **Table 41** a smaller group of CEC's were identified to serve as performance indicator compounds. The primary selection criterion was the consistency in the concentration detected in the RO feed water over the four week period. Comparison of weekly results for each of the 37 compounds showed 15 compounds had a relative percent difference (RPD) ≤ 35%. The RPD was calculated for each compound as the standard deviation divided by the average of the 4 results. The lower the RPD the less spread between the results. For example, if the results were all the same, the RPD would be zero.

Table 42 provides average (n=5) values measured in the RO feed, RO permeate and UV/AOP product water along with calculated values of differential removal (Δ Removal) of 16 selected performance indicator compounds for the RO and UV/AOP process. It should be noted that even though the NDMA results did not meet the RPD criteria (e.g. 47% vs. ≤ 35%) it has been recommended by the SWRCB expert panel as a performance indicator for RO/AOP for groundwater recharge projects and for CEC monitoring based on toxicological relevance. Furthermore, the concentration of NDMA in the RO feed was typically 10 X the DL (2 ng/L vs. 0.28 ng/L). Differential removal was calculated based on the average (n=5) concentrations measured in the feed and product of each unit process as follows:

- RO Removal = [RO Feed – RO Permeate] / [RO Feed]
- UV/AOP Removal = [UV/AOP Influent – UV/AOP Product] / [UV/AOP Influent]

For calculation purposes, for results reported below the RL, the value of the RL was used. For results reported below the DL, the value of the DL was used. The RO

process effectively removed all 16 compounds with differential removal (%) ranging from >65.5% to >99.9%. Differential removal values shown as greater than (>) indicate the average RO permeate or UV/AOP product concentrations were near or less than the RL or DL. As shown the average RO feed concentration of the various compounds ranged from 3 to 33,000 ng/L with only one compound (Acesulfame-K) with an average concentration above the RL in the RO permeate. Therefore, Acesulfame-K was the only selected performance indicator compound for which differential removal across the UV/AOP could be determined.

During the initial two weeks of the performance indicator sampling period, surrogate compounds including TOC, Conductivity, Monochloramines, and UV 254 Absorbance (UV 254) were monitored daily. **Table 43** provides the differential removal of surrogates measured for the RO and UV/AOP process. The average value of differential removal for surrogates measured for the RO and UV/AOP follow:

- RO Removal: TOC = 99.6%; UV 254 =88.8%; and Conductivity =99.0%
- UV/AOP Removal: UV 254 = 68.7%; Monochloramines = 72.8%.

It should be noted removal of UV 254 Absorbance and Monochloramines removal by the UV/AOP was observed to be similar irrespective of whether hydrogen peroxide was dosed or not. This suggests that removal of these surrogates was due to photolysis, particularly of the chloramines present in the RO permeate. This finding indicates that while removal of these surrogates is a good indication that photolysis is occurring; the results suggest they are not appropriate surrogates for AOP performance. As discussed in **Section 3.1.1**, nitrate results measured in the RO permeate and UV/AOP product water indicated that ammonia was oxidized to nitrate across the UV/AOP process. These results suggest ammonia may serve as a good UV/AOP surrogate for performance monitoring. Though lab results of ammonia measured in the RO permeate and UV/AOP during the testing period did not show consistent reduction across the UV/AOP an online ammonia analyzer may provide additional information about the possibility of ammonia as an AOP surrogate. Also, per IAP recommendation, UV Absorbance at the 228 nm wavelength was also measured in samples collected before and after the UV/AOP. Though the 228 nm wavelength is expected to provide a more sensitive measure of NDMA absorption results from field measurements showed a slight increase in UV 228 absorbance across the UV/AOP. It should be noted the NDMA concentrations in the RO permeate measured during the testing period was consistently <RL (2 ng/L).

During the current testing period the 37 Group B compounds were sampled again in concert with the Quarterly 4 sampling event conducted on 5/1/12. Results are included in **Table 40**. In addition to sampling the RO feed, RO permeate and UV/AOP, separate samples were also collected from the permeate of each RO system. The results showed both RO membranes achieved similar rejection of CECs (i.e. >99%).

3.4 Whole Effluent Toxicity (WET) Testing

3.4.1 Sampling and Test Procedure

WET testing was performed during the previous testing period utilizing both acute and chronic freshwater bioassays. All tests were performed by Nautilus Environmental (NE) Laboratories (San Diego, CA). Tests were conducted per EPA protocols: EPA/821/R-02/013 (2002) Chronic Manual and EPA/821/R-02/012 (2002) Acute Manual. The chronic test organisms included: *Ceriodaphnia dubia* (water flea), *Pimephales promelas* (fathead minnow) and *Selenastrum capricornutum* (green algae). The test organisms used for the acute testing included water flea and fathead minnow. A complete report provided by NE is provided in **Appendix A**.

The sample water was comprised of a blend of UV/AOP product water collected from the AWP Facility and raw aqueduct water collected from Lake Murray. The target total hardness of the blend was 50 mg/L resulting in a final blend of UV/AOP product water (67%) plus raw aqueduct water (33%). Prior to testing, the pH of the blended sample was raised to approximately 8.5 using sodium hydroxide. In addition, sodium thiosulfate was added to the sample to remove residual chlorine and hydrogen peroxide. Laboratory control water was EPA moderately hard mineral water (20% diluted). A reference control consisting of deionized water (67%) mixed with raw aqueduct water (33%) was also utilized.

3.4.2 Summary of Results

Overall, the results showed there was no toxicity observed in the sample for any of the acute and chronic tests performed. The laboratory did observe a statistically significant decrease (~7%) in the chronic fathead minnow growth endpoint for the sample as compared to the control sample. However, this observation was not deemed biologically relevant as it was outside of the acceptable range of sensitivity per the laboratory's Quality Control procedures. The statistical results of the UV/AOP sample follow:

- NOEC (No Observed Effect Concentration) values (% effluent) for all species and endpoints tested were reported as 100%.
- LOEC (Lowest Observed Effect Concentration) values (% effluent) for all species and endpoints tested were reported as >100%.
- Toxic Units (TU) were reported as 1.0 for all species and end points tested with the exception of the Water Flea 96-hr Acute survival TU = 0.41 and the Fathead minnow 96- hr acute survival TU=0.

3.5 Quality Assurance / Quality Control

As outlined in the Final T&M Plan, several QA/QC procedures were employed during the Q1 through Q4 testing period including data analysis, lab testing, field sampling procedures, sample handling and storage, and data validation. The overall purpose of the QA/QC program was to ensure that the water quality data are accurate and useful. Due to the significant number of variables which can impact water quality data, even the best water quality data will have errors, and it is the goal of the QA/QC program to measure and minimize these errors. Data quality is described by its accuracy, precision, completeness, representative ness, and comparability. The subsections below discuss the results of three main components of the overall QA/QC water quality program implemented during the Q1 through Q4 testing period including:

- QC Sample Collection
- Data Validation
- Sampling Procedures

3.5.1 QC Sample Collection

Field and laboratory QC samples were collected and analyzed as a quality check of sampling and analytical procedures throughout the testing period. QC sample types included:

- Field Duplicate. A portion of the collected sample volume is analyzed identically to evaluate laboratory precision, reproducibility of sample handling and analytical procedures, sample heterogeneity, and analytical procedures.
- Blind Duplicate. Same as field duplicate, however the laboratory is not provided the sample location prior to analysis.
- Split Sample. A portion of the collected sample volume is analyzed by a separate laboratory with overlapping capabilities utilizing identical analytical methods to evaluate laboratory accuracy, reproducibility of sample handling and analytical procedures, sample heterogeneity, and analytical procedures.
- Field Blank. A sample of analyte free water (laboratory provided) is poured into the container in the field, preserved and shipped to the laboratory with field samples. The purpose is to assess contamination from field conditions during sampling.
- Travel Blank: A clean sample of a matrix that is transported from the laboratory to the sampling site and transported back to the laboratory without having been exposed to sampling procedures. Typically, analyzed only for volatile compounds. The purpose is to assess contamination introduced during shipping and field handling procedures.

A summary of the QC samples collected during the Q1 through Q4 testing period is provided in **Table B-1 (Appendix B)**. For each entry, the following information is provided: sample date, QC sample type, the laboratory conducting the analysis, sample location and compounds analyzed. The results associated with QC samples are provided in **Appendix B**. A description of the results for each QC samples group is provided below.

3.5.1.1 Blind Duplicate Sample Results

During each testing period, quarterly blind duplicate samples were sent to WECK Labs for analysis for all compound groups (with the exception of CECs and UCMR3 compounds). Blind duplicate samples were sent to MWH Labs during each CEC sampling event. The specific sampling location associated with all blind duplicate samples was rotated quarterly. **Tables B-2** through **B-5 (Appendix B)** provides results for compounds detected in the original and duplicate samples for all quarterly sampling events. When comparing results the following general criteria were used to assess if the differences in results were acceptable.

1. If the result of the original sample was within two times the RL, then the difference in results between the two samples should be ± 0.5 RL or b) the relative percent difference (RPD) should be 50%, whichever is higher. For purposes of this report, RPD is defined as the difference in results divided by the average times 100%.

2. If the result of the original sample was less than two times the RL, then the difference in results between the two samples should be ± 0.5 RL or b) RPD of 20%, whichever higher.

Quarter 1 Sampling Event. Table B-2 compares the results of the original and blind duplicate (UV/AOP product water) samples collected during the Q1 quarterly sampling event conducted on 8/24/11. As shown, of the 40 compounds detected in both samples the results were in good agreement with the exception of six compounds for which the difference in results was outside the acceptance criteria. The table provides notes for each of the six compounds based on discussions with the laboratories. As indicated, the only compound that was recommended for further QC sampling was TOC. Results related to additional TOC sampling are discussed in **Section 3.5.1.2.**

Quarter 2 Sampling Event. Table B-3 compares the results of the original and blind duplicate samples (tertiary effluent) collected during the Q2 quarterly sampling event conducted on 11/8/11. As shown, of the 48 compounds detected in both samples the results were in good agreement with the exception of some of the radionuclides for which the acceptance criteria are considered not applicable because the results were analyzed with different MDAs and counting errors. QC samples for radionuclides were deemed acceptable if the difference in results was within the range of the counting errors. The table provides other notes for each compound that were just

outside the acceptable criteria based on discussions with the laboratories. As indicated, no compounds were recommended for further QC sampling.

Quarter 3 Sampling Event. Table B-4 compares the results of the original and blind duplicate samples (imported raw aqueduct water) collected during the Q3 quarterly sampling event conducted on 2/1/12. . As shown, the results for the 40 compounds reported above the RL in one or both samples were in good agreement. Comparison of radionuclide results included the counting errors as previously noted. The table provides other notes for each compound that were just outside the acceptable criteria based on discussions with the laboratories. As indicated, no compounds were recommended for further QC sampling.

Quarter 4 Sampling Event. Table B-5 compares the results of the original and blind duplicate samples (UV/AOP product water) collected during the Q4 quarterly sampling event conducted on 5/1/12. As shown, the results for the 19 compounds reported above the RL in one or both samples were in good agreement. The table provides other notes for each compound that was just outside the acceptable criteria based on discussions with the laboratories. As indicated, no compounds were recommended for further QC sampling.

CEC Sampling Events. Table B-6 compares the results of the original and blind duplicate samples collected during the four CEC sampling events (i.e. 9/14/11, 10/17/11, 11/8/11, 2/1/12, and 5/1/12). When comparing QC sample results, the general criteria presented above were slightly modified to make the maximum RPD for the Criteria 2 acceptance to be 40%. The higher degree of acceptable difference is justified based on the extremely low RLs, DLs and concentrations of CECs reported. Overall there was very good agreement between sample results for original and blind duplicate CEC samples. A summary of the results for each sampling event is provided below.

- Sampling Event 9/14/11. Of the 90 compounds for which results were reported in the RO permeate, only five were reported above the RL in the original or blind duplicate samples. Of these only two (Triclosan and Acesulfame-k) did not meet the general acceptance criteria (RPD of 106 to 109%). As noted in the table the difference warrants further QC sampling.

- Sampling Event 10/17/11. Of the 90 compounds for which results were reported in the tertiary effluent, 36 were reported above the RL in the original or blind duplicate samples. Of these, only two did not meet the general acceptance criteria (RPD's were below 90%); however, as noted in the table because the results were near the RL in one or more of the samples the difference was deemed acceptable.

- Sampling Event 11/08/11. Of the 90 compounds for which results were reported in the tertiary effluent, 37 were reported above the RL in the original or blind duplicate samples. Of these only two did not meet the general acceptance criteria (RPD's ≤70%); however, as noted in the table, the difference in results for

Acetaminophen was considered acceptable because the results were near the RL. However, the difference in results for Iopromide was just outside the acceptance criteria which did not warrant further QC sampling. A possible reason for the observed discrepancies is potential differences in the homogeneity of the samples.

- Sampling Event 2/1/12. Of the 38 compounds for which results were reported in the RO feed, 34 were reported above the RL in the original or blind duplicate samples. Of these only four did not meet the general acceptance criteria. The RPDs for these results ranged from 57% to 164%. Table B-6 provides additional information for each set of results that was outside the general acceptance criteria.

- Sampling Event 5/1/12. Of the 38 compounds for which results were reported in the UV/AOP product water, no results were reported above the RL in the original or blind duplicate samples.

3.5.1.2 Split Sample Results

Compounds Monitored Quarterly. During the Q1 Testing period, split samples of the UV/AOP product water were sent to MWH Labs for analysis for all compound groups being monitored by WECK Labs on a quarterly basis. **Table B-7 (Appendix B)** provides results for compounds that were detected in the original samples analyzed by WECK and the split samples analyzed by MWH. When comparing results the general criteria previously presented were used to assess if the difference in results were considered acceptable. As shown, of the 42 compounds detected in both samples, the results were in good agreement with the exception of 12 compounds for which the difference in results was outside the acceptance criteria. Of these, ten were reported by both laboratories to be below their RL or DL and were therefore deemed acceptable. In the Q2 Testing Report it was noted that these reported that differences suggest further QC sampling is required for TOC and Formaldehyde.

Results from split samples analyzed for TOC in the UV/AOP product water by both labs during the Q3 testing period were in agreement as <0.3 mg/L. However, the results differed for three sets of split samples analyzed for Formaldehyde (Method EPA 556) in the RO permeate and UV/AOP product water by both labs. WECK reported average (n=3) concentration of 2.7 µg/L in the RO permeate and 5.6 µg/L in the UV/AOP product water. However, MWH reported average (n=3) concentrations of 9.5 µg/L in the RO permeate and 70 µg/L in the UV/AOP product water. During the current reporting period both labs purchased and analyzed stock solutions of formaldehyde obtained from the same supplier and lot number to further investigate the discrepancies. Results of spiked stock solution at concentrations of 5 µg/L and 25 µg/L from analysis by both labs were within close agreement.

The variability observed by WECK labs in RO permeate over time is consistent with the difference in the results of the split samples, but the variability in the UV/AOP results is well outside of the variability observed by either lab in repeat analyses. It is therefore likely there is a matrix effect on the formaldehyde analysis due to the peroxide that one of the two labs is not dealing with properly. Additional analysis by

a different method might help to resolve the discrepancy. Finding these levels of formaldehyde in an AOP product is not unexpected because of the potential formation of aldehydes. Even if one uses the MWH results, they are below the CDPH notification level.

CECs: During the current and prior testing periods, split samples were sent to MWH Labs and CSM. Of the 90 CECs analyzed by MWH labs (results **shown in Table 36**), CSM analyzed 30 compounds in the split samples. **Table B-8 (Appendix B)** provides results from each lab along with RPD's. Results were compared for each compound and assigned one of the following QC categories.

- **Category 1** - comparison of lab results for the given compound showed consistent agreement (i.e., RPD's < 40% or ND);

- **Category 2** - comparison of lab results for the given compound showed consistent agreement for some results and discrepancies for others; possibly due to non-homogeneity in the samples and/or sample contamination.

- **Category 3** - comparison of lab results for the given compound showed consistent disagreement possibly due to systematic differences between laboratory analysis procedures.

- **Category 4** - Results could not be compared due to insufficient data.

Based on discussion with the labs a possible cause of the Category 2 discrepancies is the result of differences in the sample volumes used by labs. MWH Labs provides 40 mL vials for CEC collection compared to CSM, which provides 1 L bottles. Sample collection using 40 mL vials are much more sensitive to low level contamination. This may explain differences in results reported by the two labs for compounds such as DEET and Triclosan. To test this hypothesis, during the current reporting period UV/AOP product water samples and field blanks were collected in both 40 mL and 1 L bottles and analyzed by MWH Labs for a target list of 38 CECs (field blanks) and 27 CECs (UV/AOP product water). Results for the field blanks showed all compounds to be <RL in both the 1 L and 40 mL samples with 37 results <DL in the 1 L sample and 33 results less than the DL in the 40 mL sample. Results for the UV/AOP samples showed all compounds to be <RL in both the 1 L and 40 mL samples with all results also <DL in the 1 L sample and 24 results less than the DL in the 40 mL sample. While these results showed a higher number of detected compounds in the smaller sample size it was not conclusive. As a result additional field blank and UV/AOP samples were collected and analyzed during the current reporting period including samples collected in samples volumes 40 mL, 250 mL, 500 mL and 1 L. Samples were analyzed for only Triclosan and DEET and results were all <DL.

Therefore while earlier data suggest the possibility of field contamination impacting the samples due to the low sample volume, the subsequent test, which found no detects in field blanks is inconclusive. Both DEET and Triclosan are ubiquitous in the

environment and there is insufficient data to rule out possible field blank or laboratory contamination during one of the sampling periods.

To further investigate Category 3 discrepancies, MWH and CSM labs exchanged and analyzed standards for compounds analyzed using the same method by both labs. Of the standards analyzed results were in good agreement suggesting that differences in standards used by the labs are not the cause of discrepancies in results. As part of the QC for a separate research project not related to the demonstration project, both MWH and CSM labs also analyzed blind CEC samples prepared by a specialty laboratory (ERA Laboratories, Inc.) and split samples from the Santa Ana River. Each of these was also analyzed by 3 other laboratories, although not all for the same suite of analytes. Results from this study showed results from both labs were in good agreement. A brief letter provided by Dr. Andy Eaton from Eurofins Eaton Analytical Labs (formerly MWH Labs) addressing the agreement in results between MWH Labs and CSM is is provided in **Appendix B**.

Comparison of CEC results from the 5/1/12 sampling show very close agreement between the labs for RO permeate and UV/AOP product water results with all results below the RL or DL.

3.5.1.3 Travel/Field Blank Results

Due to the extremely low RLs and DLs (ng/L) of CEC compounds, travel or field banks were provided for all associated sampling events. For the initial three monthly CEC sampling events, MWH Labs provided travel blanks. The analysis of the travel blanks for the 8/24/11 sampling showed five compounds were detected at concentrations between 3.8 to 340 ng/L. Three compounds were also detected in the travel blank associated with the 9/14/11 sampling with concentrations between 4.7 to 6.2 ng/L. Subsequent to these findings, the MWH Labs investigated the potential cause of the detected compounds in the travel blanks and discovered an issue with the quality of the water used to prepare the travel blanks. Because of these findings and the fact that travel blanks provide limited information regarding contamination that may happen in the field, the travel blanks were replaced with field blanks made of highly purified deionized water starting on 2/1/12. Results of all subsequent CEC field blanks (sample dates: 2/1/12, 2/8/12, 2/15/12, 2/22/12, 5/1/12, 7/30/12) analyzed by MWH Labs during the previous and current testing period were <DL for the majority of the compounds and the rest were reported below the RL. For the split CEC samples sent to CSM, field blanks were utilized with all results to date reported below the DL for all compounds analyzed.

3.5.2 Data Validation

Third-party validation was performed on the water quality data produced from WECK Laboratory and MWH Labs for a sampling event conducted on 8/24/11 during the first testing period. The purpose of the validation was to assess data quality and review laboratory and sample handling procedures in order to identify possible procedural alterations to be implemented for subsequent sampling events.

Data validation was performed on results from samples collected from the UV/AOP product water (S10). This included the original and blind duplicate samples analyzed by WECK Labs and the split samples analyzed by MWH Labs for all compounds monitored quarterly (CEC's and UCMR3 compounds excluded). Data validation was also performed for S10 samples analyzed for CECs by MWH Labs (8/15/11 sampling event only).

Laboratory Data Consultants, Inc. (LDC) performed all data validation analyses under EPA Level IV guidelines. Level IV review is the most rigorous and is characterized by QA/QC protocols and documentation resulting in a complete qualitative and quantitative analysis of the analytical data. Data that fulfills the requirements of this level of third party validation fulfills the minimum data quality standards needed to allow the data to be used for its intended objective. The analyses were validated using the following documents applicable to each method:

- USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008.
- USEPA, CLP National Functional Guidelines for Inorganic Superfund Data Review, January 2010.
- USEPA, CLP National Functional Guidelines for Polychlorinated Dioxins / Dibenzofurans Data Review, Review, September 2005.
- Multiple Agency Radiological Laboratory Analytical Protocols (MARLAP) Manual, July 2004.

The third party validation process showed all the data validated to be acceptable. It was also confirmed that the majority of the data met the strict analytical standards of the USEPA CLP. Given the large number of parameters and control statistics analyzed, it is always likely that a handful of parameters will not quite fulfill all of the validation criteria. The project team notified the laboratories of data that did not fulfill all validation criteria and requested they make any necessary procedural changes for future analysis. A technical memorandum summarizing the extensive data validation reports prepared by LDC for analysis conducted by WECK and MWH Labs is provided in **Appendix C**.

3.5.3 Field Sampling Procedures

The following section describes the equipment and procedures utilized to collect water quality samples during the testing periods as well as components of the CEC monitoring plans incorporated to provide robust data set.

- **General Sampling Procedures.** All sampling personnel utilized clean handling techniques when processing samples such that only new powder- and phthalate-free vinyl gloves (nitrile) were worn when handling the sample bottles. Personnel wore gloves during all sample retrieval operations and changed gloves frequently,

with each change in task. After opening stainless steel sample valves and allowing water to flow for two to three minutes, personnel collected water samples from appropriate sample locations. Prior to sampling operators verified that purification processes (i.e. MF/UF/RO/UV/AOP) were operating normally under design conditions. Efforts were also made to time sequence sample collection to assess treatment performance. Samples were labeled appropriately, and placed into coolers packed with ice packs/blue ice at the conclusion of the sampling event or stored in the onsite fridge dedicated to sample storage. Personnel then shipped the sealed coolers under chain-of-custody to the contracted laboratory. The laboratory processed and analyzed the samples in accordance with their standard operating procedures. Strict adherence with the sample volume quantities, preservation methods and hold times provided by the certified laboratories for each analytical method were followed in order to meet reporting levels.

- **CEC Sampling Procedures**. Due to the common use of pharmaceuticals, the ubiquitous nature of personal care products, common use of target compounds in commercial products and the extremely low levels of detection related to CEC analysis, a number of procedures were followed and pre-cautions taken to avoid field sample contamination. Strict sampling protocols including sample collection, storage and handling procedures provided by the laboratories were reviewed and followed prior to and during all CEC sampling events. This included:

  1. Certified one time use bottles provided by the MWH and CSM Labs and used for all samples collected.

  2. Samples were only collected by trained AWP Facility operators familiar with the strict sampling protocols. Due to schedules and the number of sample locations and required timing it was not possible to have one person collect all samples, however the number of samplers used during the testing periods was limited to three.

  Use of gloves at all times during sampling. Gloves were made of 100% nitrile powder free per recommendation by State Board CEC Expert Panel. The gloves do not contain triclosan or any other CEC compounds.

  1. Based on "lessons learned" from previous CEC monitoring programs several components were incorporated into the monitoring program for the AWP Facility. These included: 1) increased number of samples 2) increased number of QC samples including: field blanks, blind duplicates, and split samples 3) use of multiple laboratories to compare results 4) frequent communication with labs to discuss any results that were not current with expectations based on anticipated treatment performance.

  2. On the day of sampling, AWP Facility operations staff avoided contact with or consumption of the products listed below.

a. Soaps, detergents, including antibacterial cleansers

b. DEET

c. Fragrances

d. Sunscreen

e. Caffeine

f. Tobacco

g. Pharmaceutical

h. Antibiotics

Microbiological Sampling Procedures. Additional procedures were taken when collecting water samples for analysis microbiological parameters including:

1. Sterilization of sample valves using a hand-held propane torch prior to collecting the grab samples.

2. Samples were stored with blue or wet ice and at a target temperature of 3-8 °C.

3. Sample collection and handling procedures were followed as specified in USEPA Methods 1602 (F- and somatic coliphage), 1682 (salmonella), and SAP 2009 Draft (E. coli O157), and method SM 9221 (coliform).

3.6 Summary of Water Quality Monitoring Results for Regulated and Non-Regulated Constituents

3.6.1 Regulated Constituents

Water quality monitoring was conducted in compliance with the Final T&M Plan to demonstrate the feasibility of an AWP Facility to reliably produce purified water that is consistently in compliance with all drinking water quality standards. Water quality goals were established for the Demonstration Facility based on existing recycled water regulations, as well as anticipated future regulatory requirements specific to the City's proposed Full Scale Facility. The overall approach to water quality monitoring was to collect water quality data at different locations throughout the Demonstration Facility water purification process to analyze process performance, and to compare purified water quality to project objectives, screening levels, and existing water supplies. A comparison of key water quality results and the Demonstration Facility goals is presented in **Table 44.** The table shows that the average concentration of all constituents measured in the purified water is below the established Demonstration Facility goals. Note results shown as ND were reported below the RL (i.e. non quantifiable) or below the DL.

3.6.2 Non-Regulated Constituents

Non-regulated constituent monitoring was conducted at various locations in the purification process and the imported raw aqueduct water. These constituents are grouped as follows:

- 30 constituents included in the original 2012 EPA Unregulated Contaminant Monitoring Rule (UCMR3) List 1 and List 2. *Note: on May 2 2012 the EPA issued the Final Rule Promulgation, which removed two constituents from the original List 1;*

- 90 other constituents of emerging concern (CECs), such as pharmaceutical compounds and personal care products;

- 1 additional constituent (lithium) as recommended for testing by the IAP;

- 5 nitrosamines beyond the three which have current NLs (i.e. NDMA, NDEA, and NDPA) as tested as part of the routine water sampling.

- 3 individual beta emitters including: Cesium-137, Iodine-129, and Iodine-131. As described in **Section 3.2.5** these compounds have CDPH drinking water regulatory requirements should Gross Beta exceed a concentration of 50 pCi/L.

The monitoring results of the above 129 constituents conducted at the Demonstration Facility, showed only six were found to be quantifiably detected in the purified water at any time, including three constituents from the UCMR3 list and three CECs. The six constituents, discussed in further detail below, are:

1. Bromochloromethane (BCM)
2. Hexavalent Chromium (Chromium-6)
3. Acesulfame Potassium (Ace-K)
4. Iohexal
5. 2,4,4′ –trichloro-2′-hydroxydiphenyl ether (triclosan)
6. Strontium

Table 45, on page 105 of the Tables and Figures, provides a summary of the six constituents, including average and maximum values measured in both the purified water and imported raw aqueduct water. It should be noted of the 129 constituents contained in the groups listed above some overlap with the 231 regulated constituents shown in **Table ES-2**. Constituents that overlap among the two groups were tested with more sensitive test methods as part of the non-regulated constituent monitoring allowing for lower levels of quantification. Accounting for overlaps, 111 discrete constituents were monitored as part of the non-regulated constituent monitoring.

Additional information on the six constituents and the potential significance of the measured concentrations are discussed below. As part of the Project Advisory Team,

Dr. Shane Snyder (Co-Director of the Arizona Laboratory for Emerging Contaminants located the University of Arizona) also reviewed the results associated with these unregulated constituents. A technical memorandum prepared by Dr. Snyder which summarizes his findings is located in **Appendix D**.

- **Bromochloromethane (BCM).** Also called Halon 1011, is used as a fire-extinguishing fluid and to suppress explosions, as well as a solvent in the manufacturing of pesticides. It may also occur as a disinfection by-product in drinking water, when chlorine used for disinfection reacts with organic material in the water. BCM was detected four times out of four samples in the purified water, with an average value of 0.225 µg/L and a maximum value of 0.250 µg/L. The Drinking Water Equivalent level (DWEL) for bromochloromethane is 40 µg/L (40,000 ng/L) (SWRCB, June 2010), which is more than 170 times higher than the concentration measured in the purified water, suggesting that the concentrations measured in the purified water do not pose a health risk for human consumption.

- **Hexavalent Chromium(Chromium-6)** Chromium is an odorless, tasteless metallic element found naturally in rocks, plants, soil and volcanic dust, and animals. Chromium is commonly found in two forms: trivalent chromium (chromium-3) and hexavalent chromium (chromium-6). Chromium is a heavy metal that occurs throughout the environment. The trivalent form is a required nutrient and has very low toxicity. The hexavalent form, also commonly known as chromium-6, is more toxic and has been known to cause cancer when inhaled. In recent scientific studies in laboratory animals, chromium-6 has also been linked to cancer when ingested.

In 2008, EPA began a rigorous and comprehensive review of chromium-6 health effects based on new scientific information. When this human health assessment is finalized, the EPA will carefully review the conclusions and consider all relevant information to determine if the current chromium standard should be revised. Currently, there is no federal or state MCL specific to the hexavalent form of chromium. Chromium-6 is regulated in drinking water through the establishment of a total chromium MCL. In California, the total chromium MCL is 50 µg/L, while the federal MCL is 100 µg/L.

Additional information on hexavalent chromium can be found at: http://www.cdph.ca.gov/certlic/drinkingwater/Pages/Chromium6.aspx .

CDPH is in the process of developing an MCL for chromium-6. Currently CDPH is collecting data associated with the risks and prevalence of chromium-6 and has established a detection limit for purposes of reporting (DLR) of 1 µg/L. This detection limit for purposes of reporting is 33 to 50 times higher than the method reporting level (RL) used by the primary laboratory where chromium-6 samples were taken during the Demonstration Facility operation. As a result, data from the

Demonstration Facility includes concentrations that are currently considered undetectable based on CDPH guidelines.

During the Demonstration Facility operation, chromium-6 samples were sent for analysis to two separate labs MWH Lab (Lab 1) and WECK Lab (Lab 2). Information about the sampling of chromium-6 is provided below:

1. For Lab 1 , the method used was EPA 218.6 (RL= 0.02 µg/L, DL=0.009 µg/L) /EPA 218.7 (RL= 0.03 µg/L, DL=0.0083 µg/L). Chromium-6 was found at quantifiable concentrations in the purified water four times out of four samples, with an average value of 0.09 µg/L and a maximum value of 0.16 µg/L. The RL (0.03 µg/L) used by the lab, using EPA 218.7, is in accordance with current UCMR3's RL. The concentration of Chromium-6 in purified water were at or below the results of UCMR monitoring from over 7,000 drinking water sources, from between 2000 to 2011, which showed Chromium-6 at or above the 1-µg/L DLR in about one-third of them. (http://www.cdph.ca.gov/certlic/drinkingwater/pages/chromium6sampling.aspx)

2. Chromium 6 was <RL or <DL in the tertiary effluent by Lab 1, suggesting that chromium-3 may have been oxidized by the advanced oxidation process to form the low levels of chromium-6 measured in the purified water.

3. Lab 2 analyzed chromium-6 using method EPA 218.6 with all results in purified water reported below detectable levels (DL=0.0059 µg/L). The Lab 2 method reporting level was 0.3 µg/L, which is higher than Lab 1. Also the Lab 2 detection limit is lower than Lab 1.

4. All results from both labs were below the CDPH detection limit (DLR) of 1 µg/L.

- **Ace-K: Acesulfame Potassium (Ace-K):** is a widely used artificial sweetener. Ace-K is used in a variety of consumables, including soft drinks, sports drinks, chewable and liquid medications, and other foods. During the testing period, Ace-K was below quantifiable levels in the purified water in seven of nine samples analyzed, with an average concentration below quantifiable levels and maximum concentration of 50 ng/L (RL=20 ng/L). Ace-K was below detectable levels in the RO permeate or RO permeate duplicate in samples collected on the same day that results in the purified water (after advanced oxidation) were reported above the RL, suggesting that even the low levels measured on these days may have resulted from sampling or analytical error. It should be noted based on concentrations measured in the RO feed and RO permeate the AWP process consistently achieved greater than 99.9% removal of Ace-K.

  The Food and Drug Administration has established an Acceptable Daily Intake for Ace-K of 50 mg/kg. Based on this, the calculated DWEL for Ace-K is 525 mg/L,

which is a concentration 10 million times greater than the maximum value reported in the purified water. This suggests that the concentrations of Ace-K measured in the purified water (and in the tertiary water before purification) do not pose a threat to public health.

- **Iohexal:** This compound is a contrasting agent used in x-ray procedures, such as coronary angiographs. Iohexal is typically injected into the body, allowing organic iodine compounds to block x-rays as they pass through the body. This allows for delineation between body structures containing iodine and structures that do not contain iodine. This compound was below quantifiably detectable levels in the purified water for eight of nine samples analyzed, with an average value of below quantifiable levels and a maximum value of 19 ng/L (RL=10 ng/L). RO permeate and RO permeate duplicate QC samples collected during the same sampling event as the single positive result were below quantifiable levels, suggesting that the single positive result may have been the result of analytical imprecision at levels near the MRL. Iohexal is not analyzed by isotope dilution due to lack of an available isotope, so this adds the potential for signal suppression or enhancement in the LC-MS-MS and may make measurements near the MRL less precise therefore he single positive result may have been the result of analytical error.

  The DWEL for this compound is 720,000 ng/L (SWRCB, June 2010), which is nearly 38,000 times higher than the maximum concentration reported in the purified water, suggesting that the concentrations measured do not pose a threat to public health.

- **Triclosan : 2,4,4′ –trichloro-2′-hydroxydiphenyl ether (triclosan):** is used as a synthetic broad-spectrum antimicrobial agent. Triclosan is used in a variety of consumer products , such as antimicrobial hand soaps, toothpaste, and over-the-counter drugs. It also functions as a material preservative in adhesives, fabrics, vinyl, plastics (toys, toothbrushes), polyethylene, polyurethane, polypropylene, floor wax emulsions, textiles (footwear, clothing), caulking compounds, sealants, rubber, carpeting, and a wide variety of other products. In commercial, institutional, and industrial equipment, triclosan is used to prevent microbial growth in conveyor belts, fire hoses, dye bath vats, HVAC coils, and ice-making equipment. Split samples collected in the RO permeate and Purified Water at the same time as one of the two positive results were found to be below detectable limits by a second lab that performed the analysis.

  Seven of nine samples analyzed for triclosan in the purified water were below the RL. A number of factors suggest that the two results (19 ng/L and 17 ng/L) above the RL in the purified water may have resulted from sample contamination. The first factor is the wide spread use of this compound in personal care products. Though careful measures (use of gloves, avoidance of products that contain tricolsan, etc.) were taken during all sampling events to minimize the possibility of field contamination, such contamination cannot be ruled out. All sample bottles used were one time use USEPA certified bottles, however, the laboratory

conducting the analysis reported that because there are no commercially available preserved containers for the CECs, bottles are preserved by lab staff prior to shipping to clients for collection. This introduces the risk of contamination. Another important factor is that duplicate quality control samples taken from both the RO permeate and Purified water (collected on the same day as one of the two samples reported above the RL) were analyzed by a second lab and reported non-detectable values (less than 2.5 ng/L). Additionally, when the first lab analyzed field blanks using two different sample volumes, no triclosan was measured in the larger volume sample. Because of the small sample volume even trace amounts of triclosan in the air could have been enough to lead to measureable values.

It should be noted that the Science Advisory Panel (State Board, 2010) recommended a more practical reporting level of 50 ng/L for Triclosan, which would suggest that all of the samples measured in the purified water should be considered below quantifiably detectable levels. Based on input received from the chair of the SAP (Jörg E. Drewes, Ph.D.) the driver for this recommendation was to avoid the issues encountered in reporting ultra-low levels of this compound. Furthermore, Dr. Drewes stated that avoiding triclosan hits in blanks is almost impossible in practical applications.

The DWEL for triclosan ranges between 350 to 2,600,000 ng/L (SWRCB, June 2010), which is 18 to nearly 137,000 times higher than the maximum concentration reported in the purified water, suggesting that no public health concerns are associated with the low levels of triclosan which may or may not have been present in the purified water.

- **Strontium:** is a naturally-occurring element and is used as a dietary supplement and in various industrial applications, such as pyrotechnics and automobile manufacturing. During the testing period strontium was < RL (0.3 µg/L) in three of the four quarterly samples analyzed from the purified water. The purified water sample taken during Q4 Testing Period was reported at 0.37 µg/L and the result was confirmed with a blind duplicate sample which was reported at 0.41 µg/L. These results are over 10,000 times lower than the EPA's Contaminant Candidate List 3 (CCL3) Health Reference Level for strontium of 4.2 mg/L. The average results from samples collected in the tertiary water during the quarterly sampling was 518 µg/L indicating the AWP process achieved greater than 99.9% removal of strontium. The average concentration in the IAW from samples collected quarterly was 405 µg/L. It should also be noted strontium-90 (the most common radioisotope of strontium), which emits beta particles during radioactive decay, was below the federal and state primary drinking water MCL in all purified water samples analyzed during the previous and current testing period.

Section 4
Integrity Monitoring

4.1 MF and UF Systems Integrity Testing

4.1.1 Pressure Decay Testing (PDT)

During the previous testing periods, monitoring of the integrity of the MF and UF systems was done by conducting daily pressure decay tests (PDT). Results indicated both membrane systems were intact (i.e. no particles larger than the membrane pore size can pass through the membrane) throughout the testing periods. Pressure decay rates measured daily over a 5 minute period for both systems were consistently below 0.1 psi/5 minutes.

PDT testing was continued at the same frequency during the current testing period. **Figures 18 and 19** present cumulative results of the PDTs performed on the MF and UF systems, respectively for all testing periods. Approximately, three hundred and fifty (350) individual PDT tests were performed on the MF and UF systems during the Q1 through Q4 testing period, the pressure decay rates were consistently below 0.1 psi/5 minutes indicating the membranes were intact with no fiber breakage over the entire testing period.

Estimates of the log removal value (LRV) of Cryptosporidium achieved by the MF and UF systems were performed based on the measured values of pressure decay. The predicted log removal values were determined using the Darcy Pipe Flow Model equation for air liquid conversion ratio (ALCR) as presented in the *EPA Membrane Filtration Guidance Manual*, 2005. This equation requires several inputs categorized as operating parameters, direct integrity test parameters, and unit and membrane characteristics. Values for these parameters were obtained from the membrane manufacturers and/or by field verification.

Based on the average pressure decay rates (psi/5 minutes) measured daily from the MF and UF systems during the previous and current testing periods the average predicted log removals were determined to be 4.69 and 5.45, respectively. Utilizing the referenced equation, the calculated pressure decay rate (psi/5 minute) corresponding to 4 LRV of Cryptosporidium for the MF and UF systems was estimated to be 0.4. Based on this estimate and the average PDT measured on both systems the predicted removal of Cryptosporidium by both the MF and UF exceeded 4 LRV.

4.1.2 Online Turbidity Monitoring

During the previous and current testing periods, the integrity of the MF and UF systems were also monitored by measuring online filtrate turbidity. Though this method does not provide the same level of sensitivity as pressure decay testing, it does provide the benefit of being an online measurement which provides continuous feedback on membrane performance.

Turbidity profiles measured for the MF and UF systems during the previous and current testing periods are provided in **Figures 20 and 21**, respectively. Average filtrate turbidities (NTU) based on readings taken twice per day from the online analyzer displays during the Q1 through Q4 testing periods were 0.05 for the MF system and 0.015 for the UF system. The lower turbidity values measured on the UF system are attributed to the fact that this system uses a laser turbidimeter (HACH Model Filter Trak 660 SC) which uses advanced incident light as opposed to the MF system which uses a conventional incandescent light turbidmeter (HACH 1720 E). The specifications on the laser turbidmeter claim the unit can detect changes in turbidity as low as 0.0003 NTU. Based on results from the demonstration testing both types (incandescent light and laser) of online turbidimeters would be appropriate for the potential Full-Scale Facility. It was also observed during testing that taking frequent routine measurements of filtrate turbidity using a desktop turbdimenter (HACH sensION156 Portable Meter) was useful to check the accuracy of the online meters and provided similar turbidity values (i.e. 0.03 to 0.06 NTU) as the HACH 1720E online turbidmeter.

The average value of the online MF/UF feed turbidity during the previous and current testing periods was 0.4 NTU. The scatter shown in the turbidity profiles is attributed to changes in the flow rate entering the turbidimeter. Around run hour 1750, the operations team began checking and adjusting (if needed) the flow resulting in more stable values (~0.2 to 0.4 NTU) for the remainder of the testing period. These values are consistent with that reported in the tertiary effluent by the North City operations team.

4.2 RO Systems Integrity Testing

Pre-Installation. Prior to delivering the RO elements to the AWP Facility the membrane manufacturers were requested to conduct pressure or vacuum decay testing on each element. Such testing is the only direct integrity method available to detect defects or damaged membranes and/or faulty glue lines. The results of the test results provided by the manufacturers are summarized in **Figure 22**. Of the 119 elements provided by Hydranautics the average vacuum decay rate was 0.37 inches Hg/min. Toray reported the 120 elements they tested had a pressure decay <0.29 inches Hg/min. By comparison, the acceptable RO element vacuum decay rate per ASTM D3923 is 6 inches Hg/min. Though the results cannot be directly compared due to differences in the test methods used by each manufacturer and that outlined in the ASTM standard, the low and precise decay rates are a good indication that the elements received for testing were free of any major defects which would inhibit performance. Lastly, in order to not skew the results generated in the AWP Facility demonstration, manufacturers were requested to provide elements that were randomly selected from a standard production lot. Each supplier confirmed this by providing letters to this affect.

Post Installation. Upon installation of the RO membranes the operations team conducted conductivity vessel probing of all vessels on the Train A and Train B systems. The purpose of this testing was to ensure that each membrane element was

installed properly with no leaks at the element interconnection or end-caps, and that they were not damaged during shipping. Conductivity was measured along each vessel at 15 locations spaced approximately 20 inches apart. These locations allowed for conductivity measurements at the end-cap connectors, element interconnections and midway of each element. The trend of conductivity measured from both Train A and Train B were indicative of intact systems. The general trend of intact RO systems being that vessel conductivity should gradually increase in the direction of flow as the feed water becomes more concentrated. In addition, conductivity should also increase from stage to stage as the concentrate from the upstream stage provides feedwater to the downstream stage. Breaches of integrity would also be signified by sharp spikes in conductivity, which were not observed during the testing.

Operation. During operation, conductivity and total organic carbon (TOC) were monitored online to provide continuous assessment of system integrity. All integrity monitoring results indicated the membrane elements and membrane systems for both Train A and Train B were intact through the all testing periods. Results of the online monitoring results of these two parameters to date are discussed below.

4.2.1 Online Monitoring

4.2.1.1 Conductivity

Figures 23 and 24 provide conductivity profiles for the Hydranautics ESPA2 LD and Toray TML RO systems, respectively. The profiles were developed from values recorded twice per day from the online analyzer displays. It should be noted the online analyzer takes continuous measurements of conductivity and the control system on the RO systems was set to shut the systems off automatically if the online permeate conductivity reached a high alarm set point of 150 uS/cm. As shown, the permeate conductivity of both systems remained well below the alarm set point during the entire Q1 through Q4 testing period. The average permeate conductivity (uS/cm) of the Hydranautics and Toray RO systems during at 80% feedwater recovery (FWR) were 18 and 21, respectively.

The permeate conductivity of both RO systems increased notably as expected when the FWR was increased from 80 to 85% corresponding to run hour 6314 (Hydranautics) and run hour 6391 (Toray). As discussed in Section 2, the Toray RO system exhibited scaling after increasing the FWR due to a faulty flow meter which resulted in operation at an even higher FWR than intended (i.e. 87-89%). **Figure 24** shows the permeate conductivity increased over this time period as expected due to concentration polarization. The average permeate conductivity (uS/cm) of the Hydranautics and Toray RO systems during the current testing period while operating at a target 85% FWR were 26 and 30, respectively. Based on the average measured feed conductivity measured over the entire Q1 through Q4 testing periods, the Hydranautics membranes achieved an average conductivity rejection (%) of 98.8 at a FWR of 80% and 98.4 at FWR of 85%. The average calculated conductivity rejection for the Toray membranes is 98.6 % during operation at 80% FWR and 98.1% at a FWR of 85%.

4.2.1.2 Total Organic Carbon (TOC)

During the Q1 testing period, TOC measured online in the combined permeate from the two RO systems during September and October 2011 was consistently between 40 to 80 ppb. The TOC analyzer (GE Sievers Model 5310) was also used to characterize the concentration and diurnal variation of TOC in the RO feedwater. **Figure 25** provides results from an eight day monitoring period conducted in August 2011; it shows the RO feed TOC concentration follows a fairly consistent diurnal pattern with values between approximately 7.5 to 8.5 ppm (7,500 to 8,500 ppb). Over a typical 24 hour period, peak TOC concentrations occurred around 6 AM and low concentrations occurred around 6 PM.

Online TOC monitoring of the combined RO permeate was conducted during the Q1, Q2, Q3 and current testing periods. **Figure 26** provides online values measured every 4 minutes and downloaded directly from the online TOC analyzer. The figure provides cumulative online data measured from 9/1/11 through 7/31/12. Overall results from the previous and current testing period have been consistently between 20 to 80 ppb. The lower concentrations may be due to lower feedwater temperatures which could result in higher rejection by the RO membranes.

As noted on **Figure 26,** during the latter part of December 2011 the location of the online analyzer was switched to the RO feedwater. The purpose of this was to confirm the diurnal characterization observed during the previous testing period. Results collected over a 15 day monitoring period (not shown) indicated the TOC ranged from between 2.0 to 7.0 ppm (2,000 to 7,000 ppb). In addition, an opposite diurnal trend was observed as compared to the Q1 testing period.

Based on follow up discussions with GE the cause of the discrepancy is speculated to have resulted from large swings in the internal cell and ambient temperature that occurred during the December monitoring period. The cell temperature measured by the instrument ranged from 12 to 28 degrees Celsius. The cell temperature measured by the instrument is generally 4-8 degrees Celsius higher than ambient temperature due to heating that occurs within the instrument. The low end of the cell temperatures recorded by the instrument in December indicates that the ambient temperature was lower than 10 Celsius, which is outside the instruments ambient temperature specification of 10 to 40 degrees Celsius. Overall results from the demonstration testing showed the instrument worked properly when operated in the operating specifications.

During the previous testing period, the operations team worked with GE to perform a series of tests and calibrations to ensure the analyzer is working properly within specifications. GE recommended replacing the tubing on the inorganic carbon removal (ICR) component of the analyzer. Upon replacing the tube, the unit passed the 10 ppm (10,000 ppb) TOC single point verification. The unit was then operated on RO feed water for a 1-week period beginning on 2/24/12. The results of the online TOC monitoring of the RO feed are presented in **Figure 27**. As shown, the concentration of TOC ranged from 6.5 to 7.5 ppm (6,500 to 7,500 ppb) and the diurnal

variation was observed to be similar to that measured during the Q1 Testing Period. The range of TOC measured in the RO feed was expected based on the typical concentrations reported in the tertiary effluent by the North City operations staff. On 3/1/12 the analyzer was operated on RO permeate for the remainder of the testing period. The concentration of TOC in the RO permeate was similar to what was measured during previous testing periods.

During the current testing period the unit was operated on RO feed water for an eight day period beginning on 7/5/12. The results of the online TOC monitoring of the RO feed are presented in Figure 28. The concentrations and diurnal variation of TOC in the RO feed water were consistent with results from previous testing periods. Prior to performing the RO feed water characterization the accuracy of the unit was confirmed by running a 10 ppm (10,000 ppb) TOC single point verification standard.

Based on the range of feed TOC concentrations (6,500 to 8500 ppb) measured during short term diurnal testing done on the RO feedwater during each testing period (when the instrument was operated within specification) and the range of TOC concentrations (20 to 80 ppb) recorded from continuous monitoring of the RO permeate, the TOC rejection by the RO membranes ranged from 98.8% to 99.8%.

4.3 Summary of Critical Control Point Monitoring Results

As outlined in the Final T&M Plan a key component of the integrity monitoring plan was to conduct critical control point (CCP) monitoring to identify any change in the performance of the treatment processes that can adversely impact the final water quality. **Table 46** provides a summary of the initial CCP monitoring plan implemented during the Demonstration Facility testing period. The specific parameters, limits, and corrective actions shown were used for the Demonstration Facility; it is expected a comparable plan would be established for the potential Full Scale Facility at a later date. The plan identified CCPs (e.g. MF/UF, RO and UV/AOP system) as well as critical limit parameters (CLP), limits and corrective actions. The values of limits and corrective actions were refined and further defined throughout the testing period. During the design phase of the potential Full-Scale Facility, the City would develop a similar monitoring and response plan that provides sufficient features and assurances that any foreseeable malfunction could be promptly identified and appropriate responses applied.

Table 47 summarizes the CCP monitoring results from the previous and current monitoring periods. During the Q1 testing period one exceedance of the established critical alert limit (CAL) for pressure decay occurred on the UF system. After further investigation, it was determined the high pressure decay rate resulted from a leak in the air piping not the actual membrane(s). Upon repair of the leak, the measured PDT results were well below the CAL for the remainder of the testing period. During the Q1 testing period, the CAL for the UV/AOP reactor power level was not met on four separate occasions each due to the ballast failures. When a single ballast failure occurs, only two of 72 total lamps are out of service, representing a ~3% decrease in

reactor present power. In response, the reactor power automatically increases to 100%. Based on the reactor performance to date it has been determined a reactor power level of approximately 70% is required to achieve the target log removal of NDMA. As a result, the occurrences of ballast failures are highly unlikely to have jeopardized the treatment performance and UV/AOP product. No exceedances of CALs were identified for any of the CLP's during the Q2 testing period.

During the Q3 Testing Period, two CAL exceedances occurred. The first incident was due to the loss of flow confirmation on the hydrogen peroxide dosing pump of the UV/AOP system. Once this occurred, the system auto switched to the stand-by pump. However, the stand-by pump also shut off due to low flow resulting from air lock, thereby causing the system to automatically shut down. The Demonstration Facility operations staff was present when the event occurred and quickly restarted the system with no issues for the remainder of the testing period. The second incident was due to a single ballast failure on the UV/AOP system. The system automatically increased power to 100 percent to accommodate power loss thereby maintaining treatment performance. An alarm notified the operations team of this occurrence, shortly after the system was taken offline and the ballast was replaced.

During the Q4 Testing Period, six CAL exceedances occurred. Five of these were due to the loss of flow confirmation on the hydrogen peroxide dosing pump of the UV/AOP system. Once this occurred, the system auto switched to the stand-by pump. On two occasions the switch to duty pump was successful and the system operated without interruption. However, on the other three occasions, the stand-by pump also shut off due to low flow resulting from air lock, thereby causing the UV/AOP system to automatically shut down. The operations staff were notified by alarms when the unit was shut down, shortly after the system was restarted after operating both pumps in manual to remove entrained air. As described in **Section 2.1.4.1**, the issue was resolved by making adjustments to the degassing interval and pulse length on the peroxide dosing skid and opening a valve on the pump skid to allow off gas to return to the peroxide storage tank.

The sixth CAL exceedance occurred due to a single ballast failure on the UV/AOP system. The system automatically increased power to 100 percent to accommodate power loss thereby maintaining treatment performance. An alarm notified the operations team of this occurrence, shortly after the system was taken offline and the ballast was replaced. As described in **Section 2.1.4.1** at the time this report was prepared a power study was underway to assess if the ballast failures experienced during the testing period are due to power surges. Also, the ballast manufacturer was in the processes of inspecting ballasts that failed during the current and previous testing periods to identify the potential cause(s) of the failures. It should be noted ballast failures are common at other UV facilities and the lessons learned at the Demonstration Facility should be considered in the design of the potential Full-Scale Facility.

Overall the CCP monitoring conducted at the Demonstration Facility proved to be a useful tool for identifying and responding to potential interruptions in treatment performance of the AWP processes. Based on the experience at the Demonstration Facility a similar plan is recommended for the potential Full Scale Facility.

Section 5
AWP Facility Chemical and Power Consumption

5.1 Chemical Consumption of AWP Facility Unit Processes

5.1.1 Process Chemicals

The AWP Facility uses four chemicals during routine operations: ammonium hydroxide, sodium hypochlorite, antiscalant, and hydrogen peroxide. Chemicals are fed into the process stream using diaphragm metering pumps. The speeds of the pumps are flow paced to maintain a constant dose when changes in flow occur. The most notable flow change throughout the AWP Facility process is the feed flow when the MF or UF system goes into backwash or PDT mode. A cylinder drawdown is done each day to make sure that each chemical is being fed accurately and in the proper quantity.

Monitoring of the chemical consumption of the AWP Facility unit processes began during the Q1 testing period and continued over the current testing period. **Table 48** provides information related to chemical usage for the MF, UF, RO and UV/AOP systems. The table provides the following information for each chemical: injection location, target feed concentration, target dose rate, estimated total amount delivered per testing period, and estimated daily consumption.

The typical daily consumption of each chemical was estimated based on full capacity production for a 24 hour day using data from the Q1 Testing period. No changes were made to the chemical dose rates during the subsequent testing periods. During the Q2, Q3, and Q4 testing periods the actual average daily usage of each chemical was determined by monitoring the level of each chemical storage tank before and after each delivery. The volume of each chemical used over the testing period was then calculated based on the difference in tank levels recorded at the beginning and end of the testing period, the total volume delivered over the testing period and the estimated storage capacity per foot of each chemical tank. The total calculated usage over the testing period was then divided by the total number of days in the testing period to estimate the average daily usage. No chemical usage above what was expected was required during any of the testing periods.

5.1.2 Membrane Cleaning Chemicals

During cleaning of the membrane systems, two additional chemicals were used: sodium hydroxide (25% w/w) and citric acid (50% w/w). These chemicals are stored in 55 gallon drums, fed into RO permeate water, and mixed in the CIP system. Based on tracking of membrane cleaning chemicals used over the testing periods it is estimated the RO systems required on average 2-3 gallons of sodium hydroxide and

citric acid per cleaning event. However, the MF and UF systems required a much larger volume of chemicals per cleaning. The MF required approximately 45 gallons of both sodium hydroxide and citric acid and 9 gallons of sodium hypochlorite per CIP. The UF system required approximately 40 gallons and 68 gallons of sodium hypochlorite and citric acid, respectively. The amount of citric acid for the UF system is based on the CIP conducted during the current testing period for which the target pH was reduced from 3 to 1.5. The amount required for previous CIPs was about 60% less.

The UF system was equipped with an additional sodium hypochlorite dosing system to allow dosing in the backwash cycle to maintain a free chlorine residual in the backwash waste stream. This chlorine is fed from a separate 55 gallon drum by a pump mounted on the UF skid. Due to persistent air locking problems, this chlorination system was disabled. Based on the performance of the UF system during the Q3 and current testing period, it was not deemed necessary to perform chlorinated backwashes under the current operating conditions.

5.2 Power Consumption of AWP Unit Processes

The power consumption of each AWP unit process was monitored during all testing periods by taking daily readings of power totals displayed on the main SCADA system. The totals are based on daily power logged by the individual power monitors (Electro Industries model Shark 200) installed in each individual unit process including the MF, UF, RO and UV/AOP systems. An additional power meter was installed during the Q2 testing period to monitor the total main power being used by the AWP Facility. The purpose of the main power meter is to capture the power usage of the various AWP Facility unit processes as well as parasitic loads such as lights, air conditioning and ancillary equipment (i.e. auto-samplers, TOC analyzer, etc.) plugged into the 120 v receptacles, which were not previously recorded.

Table 49 provides daily power totals logged from the main SCADA screen for each unit process from 8/1/11 through 7/31/12 as well as the total power reading. For days that power totals were not recorded from the meters, power usage was estimated based on the estimated runtime and typical power usage over a 24 hour period. The total kW-h per month including daily totals from all systems for the current testing period is as follows: May (partial) = 32,773 kW-h; June 55,002 kW-h; and July 57,558 kW-h. Comparison of the sum of values from the power meters for the individual unit processes to values recorded on the main power meter show the parasitic load to be approximately 3 to 5% of the total power. The average monthly power usage of the AWP equipment (not including the feed pump) based on monthly totals from 8/1/11 through 7/31/12 was 60,701 kW-h per month. The monthly usage varied based on the amount of time the AWP Facility was in operation. The monthly power consumption of the AWP equipment including the feed water pump based on 24 hour per day 7 day per week online time is estimated to be 99,000 kWh-month.

During the testing periods several other areas of power usage related to the AWP Facility were investigated as described below:

- **Power monitoring of the North City Feed pump:** The AWP Facility operations team worked with the City's independent consultant to perform short term power monitoring of the external pump that supplied feedwater to the MF and UF systems. An external power meter was connected to the feed pump for nearly nine days. Based on the total power recorded over this time period the power usage of the feed pump per day was determined to be approximately 960 kW-h / day, representing approximately 30% of the total power recorded from the power monitors on the AWP Facility unit processes for a typical 24 hour operating period. The relatively high power use of the feed pump was attributed to the fact that the pump was programmed to maintain a constant feed pressure which required the motor to ramp up and down each time the MF or UF system went offline (i.e. for backwashing or to perform a PDT). The feed pump was also designed for other high pressure equipment operated at 60 psi which required pressure reducing valves on the MF and UF inlet piping.

- **Investigation of UF Power:** Comparison of the UF and MF power meters showed the MF power total (not including raw water pump) to be approximately 70% lower than the power total of the UF system. The operations team worked with the City's independent consultant to investigate the higher power usage required by the UF system. First, the power requirement of the UF system was confirmed using an external power meter which was connected to the main supply for approximately 14 days. Based on the total power recorded over this time period, the power usage of the UF system was determined to be approximately 200 kW-h/day, which matched closely to the values logged from the power monitor equipped on the system. Next, the power usage of the air compressor on the UF system was monitored for nearly 14 days using the external power meter. Based on the total power recorded over this time period the power usage of the air compressor was determined to be 105 kW-h/day which is about 50% of the total UF power. It is expected that differences in the size and efficiency of the compressors equipped on the UF and MF may account for the discrepancy in power totals. The UF compressor is 40 HP and requires 50 amps while the MF compressor is ~8 HP and requires 7.9 amps. It should be noted both systems operated with similar values of the transmembrane pressure (TMP) and target filtrate flow rates. It was also observed that the daily UF power totals increased notably starting on 1/18/12 after the replacement of the actuator on the inlet valve. After further discussion with the manufacturer it was discovered that the new actuator is designed to bleed air on a continuous basis which would require the system's air compressor to operate more frequently. The increase in observed power total is attributed to the increased operation of the compressor.

- **RO Power Requirements –**The power demand of the RO systems was compared under different operating conditions. After startup a bypass was required on the

Train A energy recovery device (ERD) in order to accommodate the designed recovery rate of 80%. Because of this, the train used more power than it would have with a fully functioning ERD. In January 2012, the ERD was removed and bypass piping was installed. A new, fully functioning ERD was installed in February 2012. In April 2012, the recovery for both trains was adjusted to 85%. Based on comparison of typical power usage data gathered during these time periods, the following observations were made:

1. At 80% recovery, Train B (a 3 stage system) used approximately 8% more power than Train A (a 2 stage system).

2. At 80% recovery, Train A used approximately 7% more power with no ERD installed versus a fully functioning ERD. Note: Calculated values of energy reduction based on average boost pressure values measured during 80% recovery operation were 8% for Train A and 5% for Train B.

3. At 80% recovery, Train A used approximately 4% more power with a partially functioning ERD than with a fully functioning ERD.

4. At 85% recovery, Train B used approximately 19% more power than Train A.

- **Distribution of Power Requirements for AWP Facility Unit Processes:** The percent of total power attributed to each unit process was estimated based on average power measurements made on a typical 24 hour continuous operating period during the Q1 through Q4 testing periods. The average daily power use was estimated to be 3,300 kWh/day, which includes the estimated power for the raw water pump (based on a nine day monitoring period). This equates to a power usage of 3.3 kWh per 1000 gallons of purified water produced and 1,100 kWh per acre-foot of purified water produced. **Figure ES-1** (located in the Executive Summary) provides the breakdown of equipment power.

Section 6
Summary of Maintenance and Equipment Issues

6.1 Equipment Failures

In general, the AWP Facility unit processes and ancillary equipment operated without any major failures that required the AWP Facility to be offline for an extended period of time over the course of the previous and current reporting periods. **Table 50** provides a log of key equipment failures organized by month from August 2011 through July 2012. The log contains items identified during the Q4 testing period including open items identified during the Q1, Q2, and Q3 reporting periods. Each entry in the log identifies the effected equipment, brief description of the issue, action taken to resolve the issue and current status. Of the items identified, the only remaining issue is that the UF system backwash chlorine dosing pump does not hold prime due to off gassing. As previously mentioned, during the current reporting period, chlorinated backwashes (CBs) or daily maintenance cleans (MCs) were not required on the UF system. However, should the UF system be operated under more aggressive operating conditions in the future these fouling prevention measures may be required and the issue with the pump would need to be resolved. Items shown in the log designated with a "monitoring "status are items that have either been reoccurring or require routine maintenance to prevent.

6.2 Routine Maintenance

The operations team has conducted routine maintenance of the AWP Facility process equipment and site over the course of the testing periods. The routine maintenance items associated with the current reporting period follow:

- Replenishment of reagents on the online chlorine and TOC analyzer.
- Replacement of the faulty ballast and UV lamp on the UV/AOP system.
- Recalibration of the online turbidimeter located on the MF/UF feedwater and filtrate.
- Recalibration of the online pH meter located on the MF/UF feedwater.
- Accuracy, precision and linearity verification of the online TOC analyzer.
- Verification check on the TOC analyzer.
- Quarterly comparison of the UV intensity duty sensor to a reference sensor.

- General weekly cleaning of the AWP Facility site including: removal of debris and dust from the tour path, equipment and piping and display sink.
- Tightening of leaky air line fittings on the UF and MF systems.
- Tightening of minor leaks at valves, pipe fittings, dosing pump tubing, etc.
- Changing of air filters on the power distribution cabinet of the UV/AOP system.

The above items are indicative of routine maintenance conducted by the AWP Facility Operations staff during the testing periods. However, the O&M manuals for each major piece of AWP Facility equipment (i.e. MF, UF, RO systems and UV/AOP system) as well as ancillary equipment (e.g. compressors, pumps, etc.), have manufacturer-recommended maintenance schedules that should be followed to maintain the design service life of the equipment.

Section 7
Summary and Conclusions

The testing and monitoring objectives of the Demonstration Facility were met by operating the AWP processes on the North City tertiary effluent (pre-chlorination) over a 13.5 month period beginning in mid-June 2011 through the end of July 2012. The Demonstration Facility was designed to provide multiple barriers to contaminants and consisted of MF, UF, RO, and UV/AOP. Purified water was returned to the North City recycled water upstream of the chlorine contact chamber prior to distribution for use in irrigation and industry. The main components of the testing and monitoring program implemented at the Demonstration Facility follow:

- Operational Performance Monitoring
- Water Quality Monitoring
- Integrity and Critical Control Point Monitoring
- UV/AOP Challenge Testing
- Chemical and Power Usage

The following subsections summarize the major conclusions for each of the above components based on results collected over the testing and monitoring period.

7.1 Operational Performance Monitoring

Operational performance monitoring of the MF, UF, RO, and UV/AOP systems was conducted to assess the overall operation and maintenance (O&M) requirements of the systems during operation at design conditions. The major conclusions for each system follow:

- The MF system operated with cleaning cycles (production time before cleaning is required) exceeding 6 months under target average flux and recovery conditions of 29 gfd and 93%, respectively.
- The UF system operated with cleaning cycles between 3 to 6 months under target flux and recovery conditions of 30 gfd and 95%, respectively. The slightly shorter cleaning cycles associated with the UF, compared to MF, may be attributable to the smaller membrane pore size, which may be more susceptible to organic fouling, to the higher operating recovery (i.e. less frequent backwashing), or possibly to differences in membrane cleaning protocols or membrane chemistry.
- Chemical pretreatment for the MF and UF systems during production consisted of sodium hypochlorite and ammonium hydroxide to achieve target does of 3 mg/L chloramines. No chemicals were used during backwashing. No maintenance cleans (e.g. daily or weekly) were performed.

- Membrane cleanings of the MF and UF systems, performed in accordance with manufacturer's protocols, utilized three chemicals: sodium hypochlorite, sodium hydroxide (MF only) and citric acid. Cleanings were effective at restoring productivity close to values measured when the membranes were new with no indications that irreversible membrane fouling occurred over the testing period.

- The average measured power requirement for the MF and UF systems (not including feed pump energy) each operating at net filtrate production capacities of 0.72 MGD was 66 kW-h/day and 229 kW-h/day, respectively. The higher power required by the UF system was largely attributed to differences in air compressor efficiencies.

- RO Train A and RO Train B operated with cleaning cycles exceeding 6 months under design average flux (Train A = 11.9 gfd, Train B = 11.6 gfd) and feedwater recovery (FWR) of 80%.

- RO Train A operated with a 2 percent fouling rate (average decrease in normalized specific flux per month) over a 3 month period at increased FWR conditions (85%).

- RO Train B operated with a 10 percent fouling rate over a 1 month period at FWR of 85%; additional operation is required to fully assess the impact of FWR on cleaning frequency.

- Operation of the RO Trains at increased FWR is beneficial for the potential Full-Scale Facility in terms of footprint and the amount purified water production capacity (for a fixed amount of feedwater); however, the downside is the likelihood of increased O&M (including energy, pretreatment chemicals and cleaning chemicals). Testing results indicate that the 2-stage system (Train A) operated reliably at this increased FWR, however, further testing is recommended before determining whether or not an 85% FWR could be reliably maintained with a 3-stage configuration.

- The overall average energy reduction resulting from the energy recovery devices was determined to be 8 percent for Train A and 5 percent for Train B during operation at 80 percent recovery. However, the boost pressure was observed to decrease significantly when the recovery was increased to 85 percent due to the reduction of concentrate flow available. The ERD performance observed at the Demonstration Facility under the 85% FWR condition does not represent what could be achieved at the potential Full-Scale Facility. Careful consideration should be made in deciding the economic pay back of these systems for the Full-Scale Facility.

- If ERDs are deemed economical for the potential Full-Scale Facility, the design should consider the use of automatic control valves and auxiliary nozzle valves (not tested at the Demonstration Facility) to optimize the performance of the ERD's

over the expected range of recovery rates, concentrate flow, pressure and temperature.

- The chemical pretreatment requirement for the RO systems included a target dose of antiscalant (Product Name Y2K manufactured by King Lee Technologies). No pH suppression was used upstream of the RO system over the testing period.

- The UV/AOP system operated with an average applied present power of 12.5 kW and EED of 0.303 kWh/1000 gallons at the design conditions over the testing period. The average power was observed to increase slightly due to decreases in UVT resulting from increasing the chloramines dose in the RO feed water and with decreased temperature.

- Comparison of UV intensity measurement readings using both the duty and reference sensor (which measure intensity from 1 lamp only) provided a gross indication that lamp aging was not significant on the UV/AOP system over the testing period. A more detailed assessment of lamp aging would require several lamps to be returned to Trojan for analysis.

- During the testing period six ballast failures occurred on the UV/AOP system. The cause is under investigation via a power study and an assessment of the failed components by the manufacturer. These failures emphasis the importance of redundancy and other measures for use in the design of the potential Full Scale Facility.

7.2 Water Quality Monitoring

A comprehensive water quality monitoring plan was implemented during the testing and monitoring period. The overall approach of the monitoring plan was to collect water quality data at different locations throughout the Demonstration Facility to analyze process performance, and to compare the quality of the purified water to demonstration goals, screening levels, and existing water supplies. The major conclusions follow:

- Results of routine water quality sampling (i.e. sample collection frequency parameter specific including: daily, weekly, bi-weekly or monthly) showed the purified water met all parameter specific numerical water quality goals established for the Demonstration Facility. Such objectives were based on potential regulatory requirements for the Full Scale Facility.

- Results of quarterly monitoring (i.e. samples collected on 8/14/11, 11/8/11 2/1/12, and 5/1/12) for regulated contaminant groups showed the purified water quality met Federal and State Primary and Secondary MCLs, CDPH Notification Levels, and Priority Pollutant Criteria.

- Results of quarterly monitoring of 129 unregulated constituents (including 92 CECs and 30 UCMR3 compounds, resulting in a total of 111 unique constituents not included in previous testing) showed the average measured concentration for all but two contaminants in the purified water were below the RL or DL. The exceptions were Chromium VI (average concentration =0.09 µg/L, maximum 0.016 µg/L, RL=0.03 µg/L) and Bromochoromethane (average concentration of 0.225 µg/L, maximum 0.250 µg/L, RL=0.06 µg/L). Both compounds are associated with disinfection byproducts, and are commonly reported at similar (or higher) concentrations in most drinking water sources.

- Monitoring of a target list of 92 CECs monthly for 4 months upstream and downstream of each purification process showed the RO system effectively removed the majority of CECs detected in tertiary effluent. Only three of these CECs (triclosan, ACE-K, and Iohexal) were reported above the RL in the purified water (concentrations ≤20 ng/L) one or more times during the entire testing period.

- CECs that have been identified by the SWRCB's "Monitoring Strategies for Chemicals of Emerging Concern (CECs) in Recycled Water (2010)" for groundwater recharge projects, may be used as indicator compounds based on toxicological reliance (i.e. NDMA, 17 beta-estradiol, caffeine and triclosan). The concentrations of these compounds, in all RO permeate and purified water samples analyzed, were less than the recommended health-based practical MRLs.

- Microbial monitoring conducted in the purified water showed measured microbial parameters (i.e. total coliform, fecal coliform, male specific and somatic coliphage) were either not-detected or absent in samples collected during the testing period.

- Based on results of microbial monitoring conducted upstream and downstream of the MF and UF systems, the average log removal of coliforms was determined to be >3.3 (99.95%) for total coliform and >3.8 (99.98%) for fecal coliform. As no detections were found downstream of the MF or UF, higher removals may have been demonstrated had higher concentrations been present in the feed water.

- The UF system achieved a slightly higher log removal of bacteriophage than the MF system, which is attributable to the smaller pore size in the UF membranes. The log removal for Somatic and Male Specific Bacteriophage for the MF system were greater than 3.0 and 1.1, respectively. The log removal of Somatic and Male Specific Bacteriophage for the UF system were calculated as greater than 3.7 and 2.2, respectively.

- Results of microbial monitoring conducted in the tertiary effluent and purified water indicate the purification process achieved log removal values (LRV's) greater than 4.2 (99.99%) for somatic coliphage and 2.2 (99.4%) for male-specific coliphage. As no quantifiable detections were observed for either type of virus in the purified

water, higher removals may have been demonstrated had higher concentrations been present in the feed water.

- On-site water quality monitoring of the MF and UF membrane systems, showed that both systems consistently produced filtrate with similar average concentrations for turbidity (<0.1 NTU), Total Organic Carbon (6.5 mg/L), and UV 254 Absorbance (0.17 cm-1).

- Comparison of feed and permeate concentrations of measured organic, inorganic and microbial constituents from both RO systems showed similar rejection and permeate water quality over the testing period.

7.3 Integrity Monitoring

The integrity and reliability of the AWP processes was evaluated closely during the testing period. Integrity monitoring was conducted using several direct and indirect methods employed at various stages in the testing period. A critical control point (CCP) monitoring plan was also implemented to identify changes in the performance of the AWP processes that could have an adverse impact on the purified water quality.

The major conclusions follow:

- Results of daily pressure decay test conducted on the MF and UF systems showed the average pressure decay rates were consistently below 0.128 psi/5 min. indicating the membranes were intact with no fiber breakage over the entire testing period.

- Predicted log removal of Cryptosporidium values for the MF and UF systems based on the pressure decay rates were 4.7 and 5.5, respectively.

- Direct pressure / vacuum decay tests conducted on each RO element prior to delivery indicated the elements were intact with no defects prior to installation.

- Vessel probing conducted on the RO systems post element installation showed the RO systems were intact with no leaks at end caps or inter connections.

- Continuous online monitoring of conductivity and TOC showed the RO membranes were intact during operation over the testing period.

- Critical control point monitoring for the Demonstration Facility included the identification of CCPs (e.g. MF/UF, RO and UV/AOP system) as well as critical limit parameter (CLP) limits and corrective actions.

- CCP monitoring results showed all CLPs were below their limits during the testing period with the exception of reactor power level (due to occurrences of ballast failures) and peroxide dose (due to air entrained in the dosing system) associated

with the UV/AOP system. When the limits were exceeded they were detected and corrected in a timely fashion mainly via automatic controls thereby preventing a loss in purification performance.

- Overall CCP monitoring was useful to identify and respond to changes in treatment performance at the Demonstration Facility and it is recommended a similar plan be implemented at the potential Full Scale Facility.

- Based on occurrence/consistency 16 CECs were selected as performance indicator compounds. Results showed the rejection of the indicators by the RO system ranged from greater than 65.5% to greater than 99.9%. The demonstration of higher percent removals was limited by non-quantifiable concentrations in the product water and levels in the source water that were too low to demonstrate higher levels of removal.

- Only one compound (acesulfame-K) was present in the RO permeate at a quantifiable concentration to assess removal by the UV/AOP. Monitoring of easily measured bulk surrogate parameters (i.e. conductivity, TOC, Mono-chloramines, UV absorbance) showed consistent removal as expected based on the mechanisms of each process.

7.4 UV/AOP Challenge Testing

The overall water quality demonstration goals included the assessment of the ability of the UV/AOP system to achieve target removal values of two specific contaminants (NDMA and 1,4 Dioxane) based on the August 2008 and November 2011 Draft CPDH Groundwater Replenishment Regulations. Because these contaminants were not present in the Demonstration Facility influent or RO permeate it was necessary to dose laboratory prepared solutions of these contaminants to the influent of the UV/AOP system in order to demonstrate the target removals. The major conclusions associated with the testing follow:

- Results of challenge testing demonstrated the UV/AOP system achieved 1.5 log removal (96.8%) of NDMA under the design flow (1 MGD), UVT (97%) and peroxide dose (3 mg/L) conditions. This exceeded the log removal Demonstration goal of 1.2 log removal (93.7%) based on the 2008 Draft Groundwater Recharge Regulations.

- The average EEO for NDMA was determined to be 0.19 kW-h/1000 gallons/order.

- Results of challenge testing demonstrated the UV/AOP system achieved 0.6 log removal (74.9 %) of 1,4-Dioxane under the design conditions. This exceeded the log removal Demonstration goal of 0.5 (68.7%) based on the 2011 Draft Groundwater Recharge Regulations.

- Results of challenge testing showed a linear correlation between 1,4-Dioxane removal and peroxide dose (1 to 6 mg/L) under constant EED conditions (average 0.3 kWh/1000 gallons). The correlation of these parameters predicts a peroxide dose of 2.3 mg/L would achieve 0.5 log removal (68.7%) under the test conditions. These preliminary results show it may be possible to reduce peroxide dose at the potential Full Scale Facility however further investigation, testing, and discussion with CDPH would be required.

7.5 Chemical and Power Usage

Chemical and power usage of the Demonstration Facility were tracked closely during the testing and monitoring period. This information was evaluated to assess ways to to improve operational efficiency and provide a basis for estimating O&M costs for the Full Scale Facility. The conclusions follow:

- The estimated daily use of AWP process chemicals including sodium hypochlorite (13%), ammonium hydroxide (19%), antiscalant (100%), and hydrogen peroxide (30%) under design conditions were: 39 gallons, 11 gallons, 4 gallons and 8 gallons, respectively.

- The actual chemical consumption of AWP process chemicals over the testing period was consistent with estimated values; average daily usage was slightly lower due to downtime and flow paced dosing control.

- Three membrane cleaning chemicals were used. The chemicals and their concentrations were: sodium hypochlorite (13%), citric acid (50%), and sodium hydroxide (30%).

- The RO systems required on average 2 to 3 gallons of both sodium hydroxide and citric acid per cleaning event.

- The MF system required approximately 45 gallons of both sodium hydroxide and citric acid and 9 gallons of sodium hypochlorite per cleaning.

- The UF system required approximately 40 gallons and 68 gallons of sodium hypochlorite and citric acid, respectively.

- The North City feed pump used to supply the MF and UF systems used about 960 kWh/day; however the relatively high energy requirement for this pump was due to the specific operational control strategy required for the Demonstration Facility and is not representative of what would be required for the Full-Scale Facility.

- The average daily AWP equipment (including feed pump) power use measured during a typical 24 hour operating period at design conditions and 1 MGD purified water production was 3,300 kWh/day. This corresponds to 3.3 kWh/1000 gallons

of purified water produced and 1,100 kWh/acre-foot of purified water produced. Approximately, 3 to 5% additional power was measured for parasitic loads associated with the Demonstration Facility.

- The breakdown (% total daily power) of power values measured during a typical 24 hour operating period at design conditions and 1 MGD purified water production follows: UF System = 7%, MF System = 2%, RO Train A = 25%, RO Train B = 27%, UV/AOP = 10%, Feed Pump = 29%.

- The higher use of power required for the UF system, compared to the MF system, was largely attributed to differences in the size and efficiency of the air compressors equipped on the systems. It seems the UF system air compressor was oversized and the design could be optimized for the Full-Scale Facility.

- The higher power use of RO Train B compared to RO Train A is largely attributed to difference in the membrane configuration (i.e. 3 Stage vs. 2 Stage) and membrane characteristics of the two systems. Train B was equipped with membranes designed for high rejection and low fouling requiring higher feed pressure, while Train A was equipped with membranes designed for energy savings, requiring lower feed pressure.

Tables and Figures

Table 1 Summary of Demonstration Plant Schedule

Milestone	Start Date	End Date	Approximate Number of Months
Start-up Period[1]	Thursday 6/16/11	Thursday 7/15/11	1
Testing Period[2,3]	Friday 7/18/11	Tuesday 6/20/12	11
Operational Period[4]	Wednesday 6/21/12	Monday 12/18/12	6
Total	Thursday 6/16/11	Monday 12/18/12	18

Notes:

[1]125 working days after NTP (concurrent with Substantial Completion) – Start-Up and Operation Begins

[2]145 working days after NTP (20 working days after Substantial Completion) – Testing Starts (and Start-Up ends)

[3]375 working days after NTP (230 working days after Substantial Completion) – Testing Period Complete

[4]500 working days after NTP (375 working days after Substantial Completion) – Operational Period Complete

Table 2 Summary of Quarterly Monitoring Periods

Quarterly Monitoring Periods		Target Data Period Included in Quarterly Report
No.	Dates	
1	6/16/11 – 9/15/11	6/16/11 – 10/31/11
2	9/16/11 – 12/15/11	11/1/11 – 2/10/12[1]
3	12/16/11 – 3/15/12	2/11/12 – 5/14/12[1]
4	3/16/12 – 6/19/12	5/15/12 – 7/31/12[1,2]

Notes:

[1]The end date of the target data period is based on both the expected dates laboratory data will be received and the established due dates for each quarterly report. Q2 report due 3/3/12; Q3 report due 6/7/12; Q4 report due 9/12/12.

[2] Routine water quality data will continue to be collected twice a week for 6 weeks beyond the end of the Testing Period, from 6/19/12 through 7/31/12, in accordance with the Testing and Monitoring Plan.

Table 3: Summary of the RO System Operating Conditions

Parameter	Units	Value
RO Train A		
Anti-scalant dose	mg/L	3
Average flux	gfd	11.9
Feedwater recovery	%	80 to 85
RO Train B		
Anti-scalant dose	mg/L	3
Average flux	gfd	11.6
Feedwater recovery	%	80 to 85

Table 4 Summary of RO Membrane Cleaning Results

RO System	Date of Cleaning	Pre-Clean Temperature Corrected Specific Flux (gfd/psi@ 25 Deg C)	Post Clean Temperature Corrected Specific Flux (gfd/psi @ 25 Deg C)	Cleaning Effectiveness (% change in specific flux pre to post clean)	Cleaning Chemicals
Train A	10/14/11	0.14	0.14	0 %	Caustic followed by citric acid
Train A	4/26/12	0.13	0.15	15%	Citric acid followed by caustic
Train B	10/7/11	0.11	0.13	18%	Caustic followed by citric acid
Train B	4/18/12	0.12	0.14	17%	Citric acid followed by caustic
Train B (3rd Stage Only)	6/7/12	0.05	0.11	120%	Citric acid followed by caustic

Table 5 - UV Intensity Measurements Duty Sensor and Reference Sensor for the Trojan UV/AOP System

Testing Period	Date	Reactor Power (%)	Average (n=3) UV Intensity (mW/cm2) Duty Sensor	Average (n=3) UV Intensity (mW/cm2) Reference Sensor	UVT (%)	Temperature (Deg C)
Q1	9/16/2011	100	30.6	29.3	98.1	29.4
Q2	1/6/2012	100	31.0	29.8	97.1	22.9
Q3	4/24/2012	100	30.2	28.2	96.9	25.7
Q4	6/22/2012	100	28.9	28.6	97.4	28.3

Table 6 Certified Laboratory Results of Potential AOP By-products

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Formaldehyde	8/1/2011	grab	EPA 556	µg/L	0.26	2	6.4	9.6
Formaldehyde	8/8/2011	grab	EPA 556	µg/L	0.26	2	4.4	11
Formaldehyde	8/15/2011	grab	EPA 556	µg/L	0.26	2	9.7	11
Formaldehyde	8/22/2011	grab	EPA 556	µg/L	0.26	2		11
Formaldehyde	8/29/2011	grab	EPA 556	µg/L	0.26	2	<2	12
Formaldehyde	9/6/2011	grab	EPA 556	µg/L	0.26	2	3.4	13
Formaldehyde	9/12/2011	grab	EPA 556	µg/L	0.26	2	4.5	13
Formaldehyde	9/19/2011	grab	EPA 556	µg/L	0.26	2	3.3	9.9
Formaldehyde	2/1/2012	grab	EPA 556	µg/L	0.26	2	4	
Formaldehyde	2/8/2012	grab	EPA 556	µg/L	0.26	2	<2	4.6
Formaldehyde	2/15/2012	grab	EPA 556	µg/L	0.26	2	4.9	6.9
Formaldehyde	2/22/2012	grab	EPA 556	µg/L	0.26	2	2.3	5.2
n =							11	11
Average							4.2	9.7
Maximum							9.7	13
Minimum							1.0	4.6
STDev							2.4	2.9

Table 7 Spiking Experiment No. 1 UV/AOP Summary of NDMA Results

Sample Number	Sample ID	NDMA (ng/L)	1,4 Dioxane (µg/L)
1	**Batch**	6300000	
2	**Control IN - 1**	930	
3	**Control Out- 1**	870	
4	**Control IN - 2**	830	
5	**Control Out -2**	910	
	TEST 1 (64% power)		
6	**Test 1a IN**	790	
7	**Test 1 a Out**	23	
8	**Test1 b IN**	960	ND (<1)
9	**Test 1b OUT**	25	ND (<1)
10	**Test 1 c IN**	760	
11	**Test 1 C Out**	23	
	AVG IN	**837**	
	AVG OUT	**24**	
	TEST 2 (78% power)		
12	**Test 2a IN**	760	
13	**Test 2 a Out**	8.1	
14	**Test2 b IN**	800	ND (<1)
15	**Test 2b OUT**	10	ND (<1)
16	**Test 2 c IN**	750	
17	**Test 2 C Out**	8.5	
	AVG IN	**770**	
	AVG OUT	**8.9**	
	TEST 3 (60% power)		
18	**Test 3A IN**	740	
19	**Test 3A OUT**	29	
20	**Test 3B IN**	980	ND (<1)
21	**Test 3B OUT**	29	ND (<1)
22	**Test 3C IN**	820	
23	**Test 3C Out**	29	
	AVG IN	**847**	
	AVG OUT	**29**	
	TEST 4 (100% power)		
24	**Test 4A IN**	750	
25	**Test 4A OUT**	5.8	
26	**Test 4B IN**	750	ND (<1)
27	**Test 4B OUT**	5.4	ND (<1)
28	**Test 4C IN**	710	
29	**Test 4C OUT**	4.8	
	AVG IN	**737**	
	AVG OUT	**5.3**	

Table 8 Spiking Experiment No. 1 Calculated EE/O Values of the Trojan UV/AOP System

Test #	Reactor Power	UV Power (kW)	UV Feed Flow (gpm)	Time to treat 1000 gallon (min.)	[1]Measured NDMA LRV Average (n=3)	[2]EE/O Calculated (kW-h/1000 gallons/log removal)
1	60%	11.1	699	1.4	1.5	0.176
2	64%	11.8	699	1.4	1.5	0.188
3	78%	14.4	700	1.4	1.9	0.181
4	100%	17.9	694	1.4	2.1	0.205

Note:

1. Measured NDMA LRV Average values show for each test were calculated from results of 3 IN and 3 OUT samples X 4 tests = 24 total samples. An additional 5 samples were analyzed during the experiment including: (1) batch and (4) control samples for a total of 29 samples. Results for all samples are provided in Table 7.

2. EE/O (kW-h/1000 gallons/log removal) was calculated as [UV Power(kW) * (Time to treat 1000 gallons(min/1000 gallons))/60(min/hr))]/Log Removal

Table 9 Spiking Experiment 2 UV/AOP 1,4-Dioxane Test Plan

Sample ID	Target NDMA / 1,4-Dioxane LRV	Target Flowrate (gpm)	Target UVT (%)	Target spike NDMA Feed Concentration (ng/l)	Target spike 1,4-Dioxane Feed Concentration (µg/L)	Target Reactor Power (%)	Peroxide Dose (mg/L)	1,4-Dioxane Samples	NDMA Samples	Peroxide Samples (titanium oxalate method)
Batch	NA	NA	NA	NA	NA	NA	NA	1	1	
Control IN	0	695	97	1000	20	0	0	1	1	
Control OUT	0	695	97	1000	20	0	0	1	1	
Control IN	0	695	97	1000	20	0	3	1	1	1
Control OUT	0	695	97	1000	20	0	3	1	1	1
TEST 1	1.2 / 0.5	695	97	1000	20	~70	1.5	1 in, 3 out	0 in, 0 out	1 out
TEST 2	1.2 / 0.5	695	97	1000	20	~70	3	1 in, 3 out	1 in, 3 out	1 in, 1 out
TEST 3	1.2 / 0.5	695	97	1000	20	~70	6	1 in, 3 out	0 in, 0 out	1 out
TEST 4	TBD / 0.5	695+20%	97	1000	20	60	3	1 in, 3 out	1 in, 3 out	1 in, 1 out
Total number of Samples								**21**	**13**	**8**

Note:

1. Results from spiking experiment number 1 showed the reactor achieved 1.5 log removal (predicted 1.2 log removal) NDMA under the target power 60%, UVT 97% and flow conditions 695 gpm. Due to lamp aging and decrease in water temperature the reactor power level for 1.2 log removal (predicted) is now ~ 70-74%.
2. Surrogates including UV 254/UV228; and mono-chloramine will be measured on site during each run from the inlet and outlet.
3. Note the chloramines concentration in the UV/AOP inlet is typically 3 mg/L.

Table 10 Summary of Spiking Experiment 2 1,4-Dioxane Spiking Results

Sample ID	NDMA (ng/L)	1,4 Dioxane (µg/L)
Batch (mg/L)	8500000	220000
Control In - 1 (System off)	1500	27
Control Out- 1 (System off)	1600	28
Control In - 2 (UV off, 3 mg/L peroxide)	1800	27
Control Out -2 (UV off, 3 mg/L peroxide)	1800	26
TEST 1 (1.5 mg/L peroxide)		
Test 1 IN	----------	31
Test 1 a Out	----------	12
Test 1 b Out	----------	12
Test 1 c Out	----------	11
Average Out (n=3)	----------	12
TEST 2 (3 mg/L peroxide)		
Test 2 IN	2000	28
Test 2 a Out	54	6.6
Test 2 b Out	47	7.8
Test 2 c Out	55	6.9
Average Out (n=3)	52	7.1
TEST 3 (6 mg/L peroxide)		
Test 3 IN	----------	26
Test 3 a Out	----------	3
Test 3 b Out	----------	3.7
Test 3 c Out	----------	3.7
Average Out (n=3)	----------	3.5
TEST 4 (3 mg/L peroxide - lower UV dose)		
Test 4 IN	1900	21
Test 4 a Out	82	6.6
Test 4 b Out	96	8.8
Test 4 c Out	98	10
Average Out (n=3)	92.0	8.5

Table 11 Summary of Calculated EED Values Spiking Experiment 2: Test Conditions 1 to 4

Test	Target Peroxide Dose (mg/L)	Measured Peroxide Dose (mg/L)	1,4 Dioxane LRV (n=3)	NDMA LRV (N=3)	EED Calculated (Kw-h/1000 gallons)
1	1.5	1.3	0.36	-	0.307
2	3.0	2.6	0.57	1.6	0.302
3	6.0	4.9	0.88	-	0.312
4	3.0	2.5	0.39	1.3	0.225

Note:

1. Measured 1,4 Dioxane LRV Average values show for each test were calculated from results of 4 IN and 3 OUT/test samples X 4 tests = 16 total samples. An additional 5 samples were analyzed during the experiment including: (1) batch and (4) control samples for a total of 21 samples. Results for all samples are provided in Table 10.

Table 12: Summary of Membrane Filtration Operation

Operational Period following chemical cleanings	Run Time Hours (Months)	Average Feed Pressure (psi)	Average Filtrate Pressure (psi)	Total Delta H between Feed & Filtrate Pressure Transmitters (psi)	Average TMP[1] (psi)	Fouling Rate (% decrease temp. corrected specific flux per month)
MF System						
Operating Period 1 (10/6/11 to 4/5/12)	3,962 (5.5)	15.0	8.5	1.5	5.0	11
Operating Period 2 (4/6/12 to 7/31/12)	2,444 (3.4)	15.2	8.6	1.5	5.1	12
UF System						
Operating Period 1 (9/8/11 to 3/22/12)	4,138 (5.7)	16.0	11.3	1.3	3.4	11
(Operating Period 2 (3/23/12 to 5/31/12)	1,472 (2)	19.4	11.3	1.3	6.8	38
Operating Period 3 (6/2/12 to 7/31/12)	1,225 (1.7)	15.3	11.3	1.3	2.7	26

Notes:

1. TMP was calculated as Average Feed Pressure minus Average Filtrate Pressure minus total Delta H (difference in elevation between feed and filtrate pressure transmitters).
2. chemical cleanings performed on the MF system on 10/5/11 and 4/5/12.
3. chemical cleanings performed on the UF system on 9/7/11, 3/22/12, 5/31/12.

Table13: Summary of the RO System Trains A and B Operation

Operational Period following chemical cleanings	Run Time Hours (Months)	Target Feed Water Recovery (%)	Average Feed Pressure (psi)	Net operating pressure(psi)	Average Specific Flux or Permeability (gfd/psi@25 °C)	Fouling Rate (% decrease temperature corrected specific flux per month)
Train A (Two-stage)						
Operating Period 1 (10/16/11 to 4/16/12)	4,020 (5.6)	80	133	98	1st Stage: 0.12 2nd Stage: 0.14	1.4
Operating Period 2 (4/19/12 to 7/31/12)	2,144 (3)	85	124	87	1st Stage: 0.13 2nd Stage: 0.16	2.1
Train B (Three-stage)						
Operating Period 1 (10/6/11 to 4/17/12)	4,254 (5.9)	80	139	104	1st Stage: 0.12 2nd Stage: 0.13 3rd Stage: 0.10	1.6
(Operating Period 2 (4/23/12 to 6/7/12)	920 (1.3)	[1]85	138	97	1st Stage: 0.13 2nd Stage: 0.14 3rd Stage: 0.08	15 (Stage 3 =40)
[2] Operating Period 3 (6/8/12 to 7/9/12)	591 (0.8)	80	130	91	1st Stage: 0.12 2nd Stage: 0.13 3rd Stage: 0.10	2.1
Operating Period 4 (7/10/12 to 7/31/12)	493 (0.7)	85	130	88	1st Stage: 0.12 2nd Stage: 0.13 3rd Stage: 0.10	9.9

Note:

1. The actual feed water recovery during Operating Period 2 was determined to be between 87 to 89%.
2. No cleaning was performed between Operating Period 3 and Operating Period 4.

Table 14: Comparison of RO System Trains A and B Permeate Water Quality

Contaminant	Units	Number of Samples (n)	Train A Permeate (Hydranautics ESPA2) (Average ±STD)	Train B Permeate (Toray TML) (Average ±STD)
Nutrients				
Ammonia, Total	mg/L-N	20	0.39 ±0.13	0.40 ±0.14
Nitrate	mg/L-N	20	0.38 ±0.09	0.40 ±0.09
Nitrite	mg/L-N	14	0.01 ±0.03	0.01 ±0.03
Nitrogen, Total	mg/L-N	20	0.82 ±0.15	0.82 ±0.13
Phosphorus, Total	µg/L-P	21	4 ±2	4 ±3
Inorganic				
TDS	mg/L	17	14 ±2	14 ±2
Sodium	mg/L	15	3.1 ±0.7	3.1 ±0.8
Chloride	mg/L	18	2.5 ±0.5	2.4 ±0.6
Boron	mg/L	15	0.23 ±0.02	0.23 ±0.02
Manganese	mg/L	15	0.002 ±0.001	0.002 ±0.001
Fluoride	mg/L	17	0.02 ±0.01	0.02 ±0.02
Organics				
TOC	mg/L	9	0.18 ±0.01	0.18 ±0.01
UV 254	cm-1	41	0.016 ±0.00	0.016 ±0.00
Microbial				
Total / Fecal Coliform	MPN/100 mL	73	<1	<1

Table 15 Certified Laboratory Results of Nitrogen Parameters Sampled from Various Locations in the AWPF

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Ammonia as N	8/1/2011	grab	EPA 350.1	mg/L	0.048	0.1	1.2	0.19	0.21		0.12
Ammonia as N	8/4/2011	grab	EPA 350.1	mg/L	0.048	0.1					<0.1
Ammonia as N	8/8/2011	grab	EPA 350.1	mg/L	0.048	0.1					<0.1
Ammonia as N	8/11/2011	grab	EPA 350.1	mg/L	0.048	0.1					0.15
Ammonia as N	8/15/2011	grab	EPA 350.1	mg/L	0.048	0.1	1.4	0.28	0.27		0.15
Ammonia as N	8/18/2011	grab	EPA 350.1	mg/L	0.048	0.1					0.16
Ammonia as N	8/22/2011	grab	EPA 350.1	mg/L	0.048	0.1					0.2
Ammonia as N	8/25/2011	grab	EPA 350.1	mg/L	0.048	0.1					0.16
Ammonia as N	8/29/2011	grab	EPA 350.1	mg/L	0.048	0.1	1.8	0.7	0.72	0.74	0.36
Ammonia as N	9/1/2011	grab	EPA 350.1	mg/L	0.048	0.1					0.79
Ammonia as N	9/6/2011	grab	EPA 350.1	mg/L	0.048	0.1					0.16
Ammonia as N	9/8/2011	grab	EPA 350.1	mg/L	0.048	0.1					0.14
Ammonia as N	9/12/2011	grab	EPA 350.1	mg/L	0.048	0.1	1.4	0.24	0.24	0.26	0.18
Ammonia as N	9/15/2011	grab	EPA 350.1	mg/L	0.048	0.1					0.18
Ammonia as N	9/19/2011	grab	EPA 350.1	mg/L	0.048	0.1					0.17
Ammonia as N	9/22/2011	grab	EPA 350.1	mg/L	0.048	0.1					0.16
Ammonia as N	9/26/2011	grab	EPA 350.1	mg/L	0.048	0.1	1.3	0.28	0.28	0.28	0.15
Ammonia as N	9/29/2011	grab	EPA 350.1	mg/L	0.048	0.1					0.12
Ammonia as N	10/3/2011	grab	EPA 350.1	mg/L	0.048	0.1					<0.1
Ammonia as N	10/6/2011	grab	EPA 350.1	mg/L	0.048	0.1					0.18
Ammonia as N	10/10/2011	grab	EPA 350.1	mg/L	0.048	0.1	1.4	0.31	0.32	0.31	0.2
Ammonia as N	10/13/2011	grab	EPA 350.1	mg/L	0.048	0.1					<0.1
Ammonia as N	10/17/2011	composite	EPA 350.1	mg/L	0.048	0.1					0.18
Ammonia as N	10/20/2011	composite	EPA 350.1	mg/L	0.048	0.1					0.2
Ammonia as N	10/24/2011	composite	EPA 350.1	mg/L	0.048	0.1	1.4	0.33	0.46	0.37	0.25
Ammonia as N	10/31/2011	composite	EPA 350.1	mg/L	0.048	0.1					0.17
Ammonia as N	11/3/2011	composite	EPA 350.1	mg/L	0.048	0.1					0.19
Ammonia as N	11/7/2011	composite	EPA 350.1	mg/L	0.048	0.1	1.5	0.55	0.52	0.36	0.22
Ammonia as N	11/10/2011	composite	EPA 350.1	mg/L	0.048	0.1					0.19
Ammonia as N	11/14/2011	composite	EPA 350.1	mg/L	0.048	0.1					0.21
Ammonia as N	11/17/2011	composite	EPA 350.1	mg/L	0.048	0.1					0.19
Ammonia as N	11/21/2011	composite	EPA 350.1	mg/L	0.048	0.1	1.3	0.48	0.5	0.46	0.2
Ammonia as N	11/29/2011	composite	EPA 350.1	mg/L	0.048	0.1					0.2
Ammonia as N	12/1/2011	composite	EPA 350.1	mg/L	0.048	0.1					0.23
Ammonia as N	12/5/2011	composite	EPA 350.1	mg/L	0.048	0.1	1.4	0.32	0.33	0.36	0.17

Table 15 Certified Laboratory Results of Nitrogen Parameters Sampled from Various Locations in the AWPF

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Ammonia as N	12/8/2011	composite	EPA 350.1	mg/L	0.048	0.1					0.24
Ammonia as N	12/12/2011	composite	EPA 350.1	mg/L	0.048	0.1					0.18
Ammonia as N	12/15/2011	composite	EPA 350.1	mg/L	0.048	0.1					0.2
Ammonia as N	12/19/2011	composite	EPA 350.1	mg/L	0.048	0.1	1.4	0.57	0.62	0.37	0.19
Ammonia as N	12/22/2011	composite	EPA 350.1	mg/L	0.048	0.1					0.22
Ammonia as N	12/27/2011	composite	EPA 350.1	mg/L	0.048	0.1					0.2
Ammonia as N	12/29/2011	composite	EPA 350.1	mg/L	0.048	0.1					0.19
Ammonia as N	1/3/2012	composite	EPA 350.1	mg/L	0.048	0.1	1.5	0.31	0.34	0.34	0.22
Ammonia as N	1/5/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.31
Ammonia as N	1/9/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.15
Ammonia as N	1/12/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.25
Ammonia as N	1/17/2012	composite	EPA 350.1	mg/L	0.048	0.1	1.40	0.33	0.31	0.34	0.2
Ammonia as N	1/19/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.21
Ammonia as N	1/23/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.16
Ammonia as N	1/26/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.20
Ammonia as N	1/30/2012	composite	EPA 350.1	mg/L	0.048	0.1	1.40	0.3	0.32	0.32	0.20
Ammonia as N	2/2/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.33
Ammonia as N	2/9/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.19
Ammonia as N	2/14/2012	composite	EPA 350.1	mg/L	0.048	0.1	1.40	0.56	0.6	0.57	0.19
Ammonia as N	2/23/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.17
Ammonia as N	2/27/2012	composite	EPA 350.1	mg/L	0.048	0.1	1.40	0.34	0.31	0.32	
Ammonia as N	3/1/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.19
Ammonia as N	3/6/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.19
Ammonia as N	3/8/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.22
Ammonia as N	3/12/2012	composite	EPA 350.1	mg/L	0.048	0.1	1.40	0.32	0.32	0.34	0.21
Ammonia as N	3/15/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.17
Ammonia as N	3/19/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.18
Ammonia as N	3/22/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.28
Ammonia as N	3/26/2012	composite	EPA 350.1	mg/L	0.048	0.1	1.40	0.49	0.52	0.48	0.36
Ammonia as N	3/29/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.29
Ammonia as N	4/2/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.26
Ammonia as N	4/5/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.34
Ammonia as N	4/9/2012	composite	EPA 350.1	mg/L	0.048	0.1	4.40	0.41	0.33	0.34	0.24
Ammonia as N	4/12/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.15
Ammonia as N	4/16/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.14
Ammonia as N	4/23/2012	composite	EPA 350.1	mg/L	0.048	0.1	1.50			0.48	0.20
Ammonia as N	4/26/2012	composite	EPA 350.1	mg/L	0.048	0.1		0.52	0.52		0.26

Table 15 Certified Laboratory Results of Nitrogen Parameters Sampled from Various Locations in the AWPF

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Ammonia as N	4/30/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.26
Ammonia as N	5/3/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.36
Ammonia as N	5/7/2012	composite	EPA 350.1	mg/L	0.048	0.1	1.50	0.48	0.49	0.39	0.20
Ammonia as N	5/14/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.29
Ammonia as N	5/21/2012	composite	EPA 350.1	mg/L	0.048	0.1	1.70	0.50	0.56	0.54	0.25
Ammonia as N	5/24/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.21
Ammonia as N	5/29/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.19
Ammonia as N	5/31/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.20
Ammonia as N	6/4/2012	composite	EPA 350.1	mg/L	0.048	0.1	1.40	0.49	0.53	0.52	0.24
Ammonia as N	6/7/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.25
Ammonia as N	6/11/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.23
Ammonia as N	6/21/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.18
Ammonia as N	6/28/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.20
Ammonia as N	7/2/2012	composite	EPA 350.1	mg/L	0.048	0.1				0.52	0.18
Ammonia as N	7/5/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.23
Ammonia as N	7/9/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.21
Ammonia as N	7/12/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.23
Ammonia as N	7/16/2012	composite	EPA 350.1	mg/L	0.048	0.1				0.36	0.23
Ammonia as N	7/19/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.27
Ammonia as N	7/23/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.23
Ammonia as N	7/26/2012	composite	EPA 350.1	mg/L	0.048	0.1					0.21
Ammonia as N	7/30/2012	composite	EPA 350.1	mg/L	0.048	0.1				0.47	0.22
n =							23	23	23	24	93
Average							1.78	0.40	0.42	0.41	0.21
Maximum							6.00	0.70	0.72	0.74	0.79
Minimum							1.20	0.20	0.20	0.30	0.10
STDev							1.11	0.13	0.14	0.11	0.08

Note: For purposes of calculating statistical parameters, results reported below the RL were considered 0.5 X RL and results reported <DL were considered the 0.5 X DL.

Table 15 Certified Laboratory Results of Nitrogen Parameters Sampled from Various Locations in the AWPF (Cont.)

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
TKN	08/01/11	grab	EPA 351.2	mg/L	0.074	0.10	0.93	0.43	0.27		0.2
TKN	08/04/11	grab	EPA 351.2	mg/L	0.074	0.10					<0.1
TKN	08/08/11	grab	EPA 351.2	mg/L	0.074	0.10					<0.074
TKN	08/15/11	grab	EPA 351.2	mg/L	0.074	0.10	<0.074	0.37	0.33		0.13
TKN	08/18/11	grab	EPA 351.2	mg/L	0.074	0.10					0.2
TKN	08/22/11	grab	EPA 351.2	mg/L	0.074	0.10					0.11
TKN	08/25/11	grab	EPA 351.2	mg/L	0.074	0.10					<0.074
TKN	08/29/11	grab	EPA 351.2	mg/L	0.074	0.10	3.9	0.45	0.4	0.46	0.13
TKN	09/01/11	grab	EPA 351.2	mg/L	0.074	0.10					0.8
TKN	09/08/11	grab	EPA 351.2	mg/L	0.074	0.10					<0.074
TKN	09/12/11	grab	EPA 351.2	mg/L	0.074	0.10	1.1	0.29	0.28	0.32	0.13
TKN	09/19/11	grab	EPA 351.2	mg/L	0.074	0.10					0.23
TKN	09/22/11	grab	EPA 351.2	mg/L	0.074	0.10					0.25
TKN	09/26/11	grab	EPA 351.2	mg/L	0.074	0.10	<0.074	0.39	0.32	0.3	0.16
TKN	09/29/11	grab	EPA 351.2	mg/L	0.074	0.10					0.15
TKN	10/03/11	grab	EPA 351.2	mg/L	0.074	0.10					<0.074
TKN	10/06/11	grab	EPA 351.2	mg/L	0.074	0.10					<0.074
TKN	10/10/11	grab	EPA 351.2	mg/L	0.074	0.10	1.6	0.31	0.18	0.48	0.38
TKN	10/13/11	grab	EPA 351.2	mg/L	0.074	0.10					0.13
TKN	10/17/11	grab	EPA 351.2	mg/L	0.074	0.10					0.28
TKN	10/20/11	composite	EPA 351.2	mg/L	0.074	0.10					0.16
TKN	10/24/11	composite	EPA 351.2	mg/L	0.074	0.10	<0.1	0.35	0.33	0.37	0.22
TKN	10/31/11	composite	EPA 351.2	mg/L	0.074	0.10					<0.074
TKN	11/03/11	composite	EPA 351.2	mg/L	0.074	0.10					0.17
TKN	11/07/11	composite	EPA 351.2	mg/L	0.074	0.10	0.16	0.42	0.39	0.34	0.13
TKN	11/10/11	composite	EPA 351.2	mg/L	0.074	0.10					<0.074
TKN	11/14/11	composite	EPA 351.2	mg/L	0.074	0.10					<0.074
TKN	11/17/11	composite	EPA 351.2	mg/L	0.074	0.10					0.16
TKN	11/21/11	composite	EPA 351.2	mg/L	0.074	0.10	0.13	0.43	0.52	0.42	<0.1
TKN	11/29/11	composite	EPA 351.2	mg/L	0.074	0.10					0.12
TKN	12/01/11	composite	EPA 351.2	mg/L	0.074	0.10					<0.1
TKN	12/05/11	composite	EPA 351.2	mg/L	0.074	0.10	0.43	0.4	0.42	0.46	0.18
TKN	12/08/11	composite	EPA 351.2	mg/L	0.074	0.10					0.14
TKN	12/12/11	composite	EPA 351.2	mg/L	0.074	0.10					0.19
TKN	12/15/11	composite	EPA 351.2	mg/L	0.074	0.10					<0.074

Table 15 Certified Laboratory Results of Nitrogen Parameters Sampled from Various Locations in the AWPF (Cont.)

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
TKN	12/19/11	composite	EPA 351.2	mg/L	0.074	0.10	<0.074	0.37	0.38	0.4	0.13
TKN	12/22/11	composite	EPA 351.2	mg/L	0.074	0.10					0.17
TKN	12/27/11	composite	EPA 351.2	mg/L	0.074	0.10					0.12
TKN	12/29/11	composite	EPA 351.2	mg/L	0.074	0.10					<0.1
TKN	01/03/12	composite	EPA 351.2	mg/L	0.074	0.10	0.31	0.56	0.44	0.45	0.14
TKN	01/05/12	composite	EPA 351.2	mg/L	0.074	0.10					<0.1
TKN	01/09/12	composite	EPA 351.2	mg/L	0.074	0.10					<0.074
TKN	01/12/12	composite	EPA 351.2	mg/L	0.074	0.10					<0.074
TKN	01/17/12	composite	EPA 351.2	mg/L	0.074	0.10	1.20	0.35	0.32	0.41	0.18
TKN	01/19/12	composite	EPA 351.2	mg/L	0.074	0.10					0.19
TKN	01/23/12	composite	EPA 351.2	mg/L	0.074	0.10					<0.074
TKN	01/26/12	composite	EPA 351.2	mg/L	0.074	0.10					0.2
TKN	01/30/12	composite	EPA 351.2	mg/L	0.074	0.10	<0.074	0.43	0.39	0.48	0.12
TKN	02/02/12	composite	EPA 351.2	mg/L	0.074	0.10					0.18
TKN	02/06/12	composite	EPA 351.2	mg/L	0.074	0.10					0.21
TKN	02/09/12	composite	EPA 351.2	mg/L	0.074	0.10					0.14
TKN	02/14/12	composite	EPA 351.2	mg/L	0.074	0.10	0.16	0.26	0.29	0.33	<0.1
TKN	02/16/12	composite	EPA 351.2	mg/L	0.074	0.10					<0.074
TKN	02/20/12	composite	EPA 351.2	mg/L	0.074	0.10					0.12
TKN	02/23/12	composite	EPA 351.2	mg/L	0.074	0.10					0.12
TKN	02/27/12	composite	EPA 351.2	mg/L	0.074	0.10	0.35	0.37	0.35	0.38	
TKN	03/01/12	composite	EPA 351.2	mg/L	0.074	0.10					0.49
TKN	03/06/12	composite	EPA 351.2	mg/L	0.074	0.10					0.48
TKN	03/08/12	composite	EPA 351.2	mg/L	0.074	0.10					0.11
TKN	03/12/12	composite	EPA 351.2	mg/L	0.074	0.10	0.39	0.35	0.44	0.28	<0.074
TKN	03/15/12	composite	EPA 351.2	mg/L	0.074	0.10					<0.1
TKN	03/19/12	composite	EPA 351.2	mg/L	0.074	0.10					<0.074
TKN	03/22/12	composite	EPA 351.2	mg/L	0.074	0.10					0.26
TKN	03/26/12	composite	EPA 351.2	mg/L	0.074	0.10	4.40	0.54	0.6	0.51	0.27
TKN	03/29/12	composite	EPA 351.2	mg/L	0.074	0.10					0.42
TKN	04/02/12	composite	EPA 351.2	mg/L	0.074	0.10					0.32
TKN	04/05/12	composite	EPA 351.2	mg/L	0.074	0.10					0.32
TKN	04/09/12	composite	EPA 351.2	mg/L	0.074	0.10	2.80	0.41	0.38	0.38	0.31
TKN	04/12/12	composite	EPA 351.2	mg/L	0.074	0.10					0.14
TKN	04/16/12	composite	EPA 351.2	mg/L	0.074	0.10					0.36
TKN	04/23/12	composite	EPA 351.2	mg/L	0.074	0.10	0.34	0.49	0.2	0.41	<0.074
TKN	04/26/12	composite	EPA 351.2	mg/L	0.074	0.10					0.12

Table 15 Certified Laboratory Results of Nitrogen Parameters Sampled from Various Locations in the AWPF (Cont.)

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
TKN	04/30/12	composite	EPA 351.2	mg/L	0.074	0.10					0.13
TKN	05/03/12	composite	EPA 351.2	mg/L	0.074	0.10					0.12
TKN	05/07/12	composite	EPA 351.2	mg/L	0.074	0.10	1.10	0.45	0.44	0.36	0.11
TKN	05/14/12	composite	EPA 351.2	mg/L	0.074	0.10					0.21
TKN	05/21/12	composite	EPA 351.2	mg/L	0.074	0.10	0.25	0.44	0.37	0.30	<0.074
TKN	05/24/12	composite	EPA 351.2	mg/L	0.074	0.10					<0.074
TKN	05/29/12	composite	EPA 351.2	mg/L	0.074	0.10					0.21
TKN	05/31/12	composite	EPA 351.2	mg/L	0.074	0.10					1.20
TKN	06/04/12	composite	EPA 351.2	mg/L	0.074	0.10	0.89	0.51	0.26	0.16	0.11
TKN	06/07/12	composite	EPA 351.2	mg/L	0.074	0.10					<0.074
TKN	06/11/12	composite	EPA 351.2	mg/L	0.074	0.10					<0.074
TKN	06/21/12	composite	EPA 351.2	mg/L	0.074	0.10					<0.1
TKN	06/28/12	composite	EPA 351.2	mg/L	0.074	0.10					<0.074
TKN	07/02/12	composite	EPA 351.2	mg/L	0.074	0.10				0.11	<0.074
TKN	07/05/12	composite	EPA 351.2	mg/L	0.074	0.10					<0.074
TKN	07/09/12	composite	EPA 351.2	mg/L	0.074	0.10					<0.074
TKN	07/12/12	composite	EPA 351.2	mg/L	0.074	0.10					<0.074
TKN	07/16/12	composite	EPA 351.2	mg/L	0.074	0.10				0.34	<0.1
TKN	07/19/12	composite	EPA 351.2	mg/L	0.074	0.10					<0.074
TKN	07/23/12	composite	EPA 351.2	mg/L	0.074	0.10					<0.074
TKN	07/26/12	composite	EPA 351.2	mg/L	0.074	0.10					<0.074
TKN	07/30/12	composite	EPA 351.2	mg/L	0.074	0.10				<0.074	<0.074
n =							23	23	23	24	93
Average							0.90	0.41	0.36	0.35	0.15
Maximum							4.4	0.56	0.60	0.51	1.2
Minimum							0.0	0.30	0.20	0.0	0.0
STDev							1.2	0.08	0.10	0.12	0.17

Note: For purposes of calculating statistical parameters, results reported below the RL were considered 0.5 X RL and results reported <DL were considered the 0.5 X DL.

Table 15 Certified Laboratory Results of Nitrogen Parameters Sampled from Various Locations in the AWPF (Cont.)

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Nitrate + Nitrite as N	08/01/11	grab	EPA 353.2	mg/L	0.01	0.10	12	0.42	0.44		0.55
Nitrate + Nitrite as N	08/04/11	grab	EPA 353.2	mg/L	0.01	0.10					0.73
Nitrate + Nitrite as N	08/08/11	grab	EPA 353.2	mg/L	0.01	0.10					0.72
Nitrate + Nitrite as N	08/11/11	grab	EPA 353.2	mg/L	0.01	0.10					0.72
Nitrate + Nitrite as N	08/15/11	grab	EPA 353.2	mg/L	0.01	0.10	12	0.47	0.43		0.57
Nitrate + Nitrite as N	08/18/11	grab	EPA 353.2	mg/L	0.01	0.10					0.69
Nitrate + Nitrite as N	08/22/11	grab	EPA 353.2	mg/L	0.01	0.10					0.63
Nitrate + Nitrite as N	08/25/11	grab	EPA 353.2	mg/L	0.01	0.10					0.7
Nitrate + Nitrite as N	08/29/11	grab	EPA 353.2	mg/L	0.01	0.10	9.5	0.35	0.33	0.31	0.5
Nitrate + Nitrite as N	09/01/11	grab	EPA 353.2	mg/L	0.01	0.10					0.46
Nitrate + Nitrite as N	09/01/11	grab	EPA 353.2	mg/L	0.01	0.10					0.46
Nitrate + Nitrite as N	09/06/11	grab	EPA 353.2	mg/L	0.01	0.10					0.71
Nitrate + Nitrite as N	09/08/11	grab	EPA 353.2	mg/L	0.01	0.10					0.85
Nitrate + Nitrite as N	09/12/11	grab	EPA 353.2	mg/L	0.01	0.10	9.7	0.32	0.4	0.36	0.52
Nitrate + Nitrite as N	09/15/11	grab	EPA 353.2	mg/L	0.01	0.10					0.82
Nitrate + Nitrite as N	09/19/11	grab	EPA 353.2	mg/L	0.01	0.10					0.62
Nitrate + Nitrite as N	09/22/11	grab	EPA 353.2	mg/L	0.01	0.10					0.72
Nitrate + Nitrite as N	09/26/11	grab	EPA 353.2	mg/L	0.01	0.10	14	0.46	0.52	0.5	0.68
Nitrate + Nitrite as N	09/29/11	grab	EPA 353.2	mg/L	0.01	0.10					0.79
Nitrate + Nitrite as N	10/03/11	grab	EPA 353.2	mg/L	0.01	0.10					0.58
Nitrate + Nitrite as N	10/06/11	grab	EPA 353.2	mg/L	0.01	0.10					0.62
Nitrate + Nitrite as N	10/10/11	grab	EPA 353.2	mg/L	0.01	0.10	11	0.32	0.45	0.38	0.57
Nitrate + Nitrite as N	10/13/11	grab	EPA 353.2	mg/L	0.01	0.10					0.6
Nitrate + Nitrite as N	10/17/11	grab	EPA 353.2	mg/L	0.01	0.10					0.7
Nitrate + Nitrite as N	10/20/11	composite	EPA 353.2	mg/L	0.01	0.10					0.75
Nitrate + Nitrite as N	10/24/11	composite	EPA 353.2	mg/L	0.01	0.10	13	0.42	0.4	0.47	0.66
Nitrate + Nitrite as N	10/31/11	composite	EPA 353.2	mg/L	0.01	0.10					0.53
Nitrate + Nitrite as N	11/03/11	composite	EPA 353.2	mg/L	0.01	0.10					0.8
Nitrate + Nitrite as N	11/07/11	composite	EPA 353.2	mg/L	0.01	0.10	13	0.3	0.35	0.43	0.63
Nitrate + Nitrite as N	11/10/11	composite	EPA 353.2	mg/L	0.01	0.10					0.79
Nitrate + Nitrite as N	11/14/11	composite	EPA 353.2	mg/L	0.02	0.20					0.64
Nitrate + Nitrite as N	11/17/11	composite	EPA 353.2	mg/L	0.01	0.10					0.7
Nitrate + Nitrite as N	11/21/11	composite	EPA 353.2	mg/L	0.01	0.10	13	0.29	0.36	0.31	0.64
Nitrate + Nitrite as N	11/29/11	composite	EPA 353.2	mg/L	0.01	0.10					0.56
Nitrate + Nitrite as N	12/01/11	composite	EPA 353.2	mg/L	0.01	0.10					0.59

Table 15 Certified Laboratory Results of Nitrogen Parameters Sampled from Various Locations in the AWPF (Cont.)

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Nitrate + Nitrite as N	12/05/11	composite	EPA 353.2	mg/L	0.01	0.10	11	0.27	0.31	0.41	0.6
Nitrate + Nitrite as N	12/08/11	composite	EPA 353.2	mg/L	0.01	0.10					0.66
Nitrate + Nitrite as N	12/12/11	composite	EPA 353.2	mg/L	0.01	0.10					0.62
Nitrate + Nitrite as N	12/15/11	composite	EPA 353.2	mg/L	0.01	0.10					0.62
Nitrate + Nitrite as N	12/19/11	composite	EPA 353.2	mg/L	0.01	0.10	13	0.32	0.37	0.39	0.74
Nitrate + Nitrite as N	12/22/11	composite	EPA 353.2	mg/L	0.01	0.10					0.6
Nitrate + Nitrite as N	12/27/11	composite	EPA 353.2	mg/L	0.01	0.10					0.56
Nitrate + Nitrite as N	12/29/11	composite	EPA 353.2	mg/L	0.01	0.10					0.51
Nitrate + Nitrite as N	01/03/12	composite	EPA 353.2	mg/L	0.01	0.10	12	0.33	0.33	0.36	0.5
Nitrate + Nitrite as N	01/05/12	composite	EPA 353.2	mg/L	0.01	0.10					0.61
Nitrate + Nitrite as N	01/09/12	composite	EPA 353.2	mg/L	0.01	0.10					0.57
Nitrate + Nitrite as N	01/12/12	composite	EPA 353.2	mg/L	0.01	0.10					0.67
Nitrate + Nitrite as N	01/17/12	composite	EPA 353.2	mg/L	0.01	0.10	15	0.43	0.43	0.47	0.63
Nitrate + Nitrite as N	01/19/12	composite	EPA 353.2	mg/L	0.01	0.10					0.71
Nitrate + Nitrite as N	01/23/12	composite	EPA 353.2	mg/L	0.01	0.10					0.54
Nitrate + Nitrite as N	01/26/12	composite	EPA 353.2	mg/L	0.01	0.10					0.67
Nitrate + Nitrite as N	01/30/12	composite	EPA 353.2	mg/L	0.01	0.10	12	0.34	0.34	0.36	0.52
Nitrate + Nitrite as N	02/02/12	composite	EPA 353.2	mg/L	0.01	0.10					0.64
Nitrate + Nitrite as N	02/06/12	composite	EPA 353.2	mg/L	0.01	0.10					0.52
Nitrate + Nitrite as N	02/09/12	composite	EPA 353.2	mg/L	0.01	0.10					0.59
Nitrate + Nitrite as N	02/14/12	composite	EPA 353.2	mg/L	0.01	0.10	14.00	0.47	0.46	0.47	0.59
Nitrate + Nitrite as N	02/16/12	composite	EPA 353.2	mg/L	0.01	0.10					0.64
Nitrate + Nitrite as N	02/20/12	composite	EPA 353.2	mg/L	0.01	0.10					0.54
Nitrate + Nitrite as N	02/23/12	composite	EPA 353.2	mg/L	0.01	0.10					0.6
Nitrate + Nitrite as N	02/27/12	composite	EPA 353.2	mg/L	0.01	0.10	13	0.38	0.38	0.44	
Nitrate + Nitrite as N	03/01/12	composite	EPA 353.2	mg/L	0.01	0.10					0.72
Nitrate + Nitrite as N	03/06/12	composite	EPA 353.2	mg/L	0.01	0.10					0.58
Nitrate + Nitrite as N	03/08/12	composite	EPA 353.2	mg/L	0.01	0.10					0.65
Nitrate + Nitrite as N	03/12/12	composite	EPA 353.2	mg/L	0.01	0.10	12	0.32	0.44	0.79	0.57
Nitrate + Nitrite as N	03/15/12	composite	EPA 353.2	mg/L	0.01	0.10					0.78
Nitrate + Nitrite as N	03/19/12	composite	EPA 353.2	mg/L	0.01	0.10					0.58
Nitrate + Nitrite as N	03/22/12	composite	EPA 353.2	mg/L	0.01	0.10					0.66
Nitrate + Nitrite as N	03/26/12	composite	EPA 353.2	mg/L	0.01	0.10	12	0.36	0.39	0.68	0.81
Nitrate + Nitrite as N	03/29/12	composite	EPA 353.2	mg/L	0.01	0.10					0.63
Nitrate + Nitrite as N	04/02/12	composite	EPA 353.2	mg/L	0.01	0.10					0.6
Nitrate + Nitrite as N	04/05/12	composite	EPA 353.2	mg/L	0.01	0.10					0.66
Nitrate + Nitrite as N	04/09/12	composite	EPA 353.2	mg/L	0.01	0.10	6.80	0.43	0.48	0.54	0.67

Table 15 Certified Laboratory Results of Nitrogen Parameters Sampled from Various Locations in the AWPF (Cont.)

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Nitrate + Nitrite as N	04/12/12	composite	EPA 353.2	mg/L	0.01	0.10					0.74
Nitrate + Nitrite as N	04/16/12	composite	EPA 353.2	mg/L	0.01	0.10					0.66
Nitrate + Nitrite as N	04/23/12	composite	EPA 353.2	mg/L	0.01	0.10	13.00	0.63	0.64	0.74	0.91
Nitrate + Nitrite as N	04/26/12	composite	EPA 353.2	mg/L	0.01	0.10					1.20
Nitrate + Nitrite as N	04/30/12	composite	EPA 353.2	mg/L	0.01	0.10					0.83
Nitrate + Nitrite as N	05/03/12	composite	EPA 353.2	mg/L	0.01	0.10					1.00
Nitrate + Nitrite as N	05/07/12	composite	EPA 353.2	mg/L	0.01	0.10	11.00	0.53	0.65	0.61	0.77
Nitrate + Nitrite as N	05/14/12	composite	EPA 353.2	mg/L	0.01	0.10					0.93
Nitrate + Nitrite as N	05/21/12	composite	EPA 353.2	mg/L	0.01	0.10	13.00	0.56	0.68	0.88	0.96
Nitrate + Nitrite as N	05/24/12	composite	EPA 353.2	mg/L	0.01	0.10					1.30
Nitrate + Nitrite as N	05/29/12	composite	EPA 353.2	mg/L	0.01	0.10					1.00
Nitrate + Nitrite as N	05/31/12	composite	EPA 353.2	mg/L	0.01	0.10					1.00
Nitrate + Nitrite as N	06/04/12	composite	EPA 353.2	mg/L	0.01	0.10	13.00	0.67	0.80	0.88	1.00
Nitrate + Nitrite as N	06/07/12	composite	EPA 353.2	mg/L	0.01	0.10					0.88
Nitrate + Nitrite as N	06/11/12	composite	EPA 353.2	mg/L	0.01	0.10					0.93
Nitrate + Nitrite as N	06/21/12	composite	EPA 353.2	mg/L	0.01	0.10					0.98
Nitrate + Nitrite as N	06/28/12	composite	EPA 353.2	mg/L	0.01	0.10					1.00
Nitrate + Nitrite as N	07/02/12	composite	EPA 353.2	mg/L	0.01	0.10				0.77	0.94
Nitrate + Nitrite as N	07/05/12	composite	EPA 353.2	mg/L	0.01	0.10					0.92
Nitrate + Nitrite as N	07/09/12	composite	EPA 353.2	mg/L	0.01	0.10					1.40
Nitrate + Nitrite as N	07/12/12	composite	EPA 353.2	mg/L	0.01	0.10					1.00
Nitrate + Nitrite as N	07/16/12	composite	EPA 353.2	mg/L	0.01	0.10				0.73	0.90
Nitrate + Nitrite as N	07/19/12	composite	EPA 353.2	mg/L	0.01	0.10					1.10
Nitrate + Nitrite as N	07/23/12	composite	EPA 353.2	mg/L	0.01	0.10					0.95
Nitrate + Nitrite as N	07/26/12	composite	EPA 353.2	mg/L	0.01	0.10					1.10
Nitrate + Nitrite as N	07/30/12	composite	EPA 353.2	mg/L	0.01	0.10				0.67	0.91
n =							23	23	23	24	97
Average							12	0.41	0.45	0.54	0.73
Maximum							15	0.67	0.80	0.88	1.4
Minimum							6.8	0.30	0.30	0.30	0.50
STDev							1.7	0.11	0.13	0.18	0.19

Note: For purposes of calculating statistical parameters, results reported below the RL were considered 0.5 X RL and results reported <DL were considered the 0.5 X DL.

Table 15 Certified Laboratory Results of Nitrogen Parameters Sampled from Various Locations in the AWPF (cont.)

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Nitrate as N	8/1/2011	grab	EPA 353.2	mg/L	0.04	0.11	11.97	0.41	0.43		0.54
Nitrate as N	8/4/2011	grab	EPA 353.2	mg/L	0.04	0.11					0.72
Nitrate as N	8/8/2011	grab	EPA 353.2	mg/L	0.04	0.11					0.72
Nitrate as N	8/11/2011	grab	EPA 353.2	mg/L	0.04	0.11					0.72
Nitrate as N	8/15/2011	grab	EPA 353.2	mg/L	0.04	0.11	11.52	0.47	0.43		0.56
Nitrate as N	8/18/2011	grab	EPA 353.2	mg/L	0.04	0.11					0.70
Nitrate as N	8/22/2011	grab	EPA 353.2	mg/L	0.04	0.11					0.63
Nitrate as N	8/25/2011	grab	EPA 353.2	mg/L	0.04	0.11					0.70
Nitrate as N	8/29/2011	grab	EPA 353.2	mg/L	0.04	0.11	9.48	0.36	0.32	0.32	0.50
Nitrate as N	9/1/2011	grab	EPA 353.2	mg/L	0.04	0.11					0.47
Nitrate as N	9/6/2011	grab	EPA 353.2	mg/L	0.04	0.11					0.72
Nitrate as N	9/8/2011	grab	EPA 353.2	mg/L	0.04	0.11					0.86
Nitrate as N	9/12/2011	grab	EPA 353.2	mg/L	0.04	0.11	9.71	0.32	0.41	0.36	0.52
Nitrate as N	9/15/2011	grab	EPA 353.2	mg/L	0.04	0.11					0.81
Nitrate as N	9/19/2011	grab	EPA 353.2	mg/L	0.04	0.11					0.63
Nitrate as N	9/22/2011	grab	EPA 353.2	mg/L	0.04	0.11					0.72
Nitrate as N	9/26/2011	grab	EPA 353.2	mg/L	0.04	0.11	14.45	0.45	0.52	0.50	0.68
Nitrate as N	9/29/2011	grab	EPA 353.2	mg/L	0.04	0.11					0.79
Nitrate as N	10/6/2011	grab	EPA 353.2	mg/L	0.04	0.11					0.61
Nitrate as N	10/10/2011	grab	EPA 353.2	mg/L	0.04	0.11	11.29	0.32	0.45	0.38	0.56
Nitrate as N	10/13/2011	grab	EPA 353.2	mg/L	0.04	0.11					0.61
Nitrate as N	10/17/2011	grab	EPA 353.2	mg/L	0.04	0.11					0.70
Nitrate as N	10/20/2011	composite	EPA 353.2	mg/L	0.04	0.11					0.75
Nitrate as N	10/24/2011	composite	EPA 353.2	mg/L	0.04	0.11	12.65	0.43	0.41	0.47	0.65
Nitrate as N	10/31/2011	composite	EPA 353.2	mg/L	0.04	0.11					0.52
Nitrate as N	11/3/2011	composite	EPA 353.2	mg/L	0.04	0.11					0.79
Nitrate as N	11/7/2011	composite	EPA 353.2	mg/L	0.04	0.11	12.87	0.29	0.34	0.43	0.63
Nitrate as N	11/10/2011	composite	EPA 353.2	mg/L	0.04	0.11					0.79
Nitrate as N	11/14/2011	composite	EPA 353.2	mg/L	0.08	0.23					0.63
Nitrate as N	11/17/2011	composite	EPA 353.2	mg/L	0.04	0.11					0.70
Nitrate as N	11/21/2011	composite	EPA 353.2	mg/L	0.04	0.11	13.10	0.29	0.36	0.32	0.63
Nitrate as N	11/29/2011	composite	EPA 353.2	mg/L	0.04	0.11					0.56
Nitrate as N	12/1/2011	composite	EPA 353.2	mg/L	0.04	0.11					0.59
Nitrate as N	12/5/2011	composite	EPA 353.2	mg/L	0.04	0.11	11.29	0.27	0.32	0.41	0.59
Nitrate as N	12/8/2011	composite	EPA 353.2	mg/L	0.04	0.11					0.65
Nitrate as N	12/12/2011	composite	EPA 353.2	mg/L	0.04	0.11					0.61

Table 15 Certified Laboratory Results of Nitrogen Parameters Sampled from Various Locations in the AWPF (cont.)

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Nitrate as N	12/15/2011	composite	EPA 353.2	mg/L	0.04	0.11					0.63
Nitrate as N	12/19/2011	composite	EPA 353.2	mg/L	0.04	0.11	13.10	0.32	0.38	0.38	0.75
Nitrate as N	12/22/2011	composite	EPA 353.2	mg/L	0.04	0.11					0.59
Nitrate as N	12/27/2011	composite	EPA 353.2	mg/L	0.04	0.11					0.56
Nitrate as N	12/29/2011	composite	EPA 353.2	mg/L	0.04	0.11					0.50
Nitrate as N	1/3/2012	composite	EPA 353.2	mg/L	0.04	0.11	11.97	0.34	0.32	0.36	0.50
Nitrate as N	1/5/2012	composite	EPA 353.2	mg/L	0.04	0.11					0.61
Nitrate as N	1/9/2012	composite	EPA 353.2	mg/L	0.04	0.11					0.56
Nitrate as N	1/12/2012	composite	EPA 353.2	mg/L	0.04	0.11					0.68
Nitrate as N	1/17/2012	composite	EPA 353.2	mg/L	0.04	0.11	15.35	0.43	0.43	0.47	0.63
Nitrate as N	1/19/2012	composite	EPA 353.2	mg/L	0.04	0.11					0.79
Nitrate as N	1/23/2012	composite	EPA 353.2	mg/L	0.04	0.11					0.54
Nitrate as N	1/26/2012	composite	EPA 353.2	mg/L	0.04	0.11					0.68
Nitrate as N	1/30/2012	composite	EPA 353.2	mg/L	0.04	0.11	12.19	0.34	0.34	0.36	0.52
Nitrate as N	2/2/2012	composite	EPA 353.2	mg/L	0.04	0.11					0.63
Nitrate as N	2/6/2012	composite	EPA 353.2	mg/L	0.04	0.11					0.52
Nitrate as N	2/9/2012	composite	EPA 353.2	mg/L	0.04	0.11					0.59
Nitrate as N	2/14/2012	composite	EPA 353.2	mg/L	0.04	0.11	14.45	0.47	0.45	0.47	0.59
Nitrate as N	2/16/2012	composite	EPA 353.2	mg/L	0.04	0.11					0.63
Nitrate as N	2/20/2012	composite	EPA 353.2	mg/L	0.04	0.11					0.54
Nitrate as N	2/23/2012	composite	EPA 353.2	mg/L	0.04	0.11					0.61
Nitrate as N	2/27/2012	composite	EPA 353.2	mg/L	0.04	0.11	13.00	0.38	0.38	0.44	0.59
Nitrate as N	3/1/2012	composite	EPA 353.2	mg/L	0.04	0.11					0.72
Nitrate as N	3/6/2012	composite	EPA 353.2	mg/L	0.04	0.11					0.58
Nitrate as N	3/8/2012	composite	EPA 353.2	mg/L	0.04	0.11					0.65
Nitrate as N	3/12/2012	composite	EPA 353.2	mg/L	0.04	0.11	12.00	0.32	0.44	0.79	0.57
Nitrate as N	3/15/2012	composite	EPA 353.2	mg/L	0.04	0.11					0.78
Nitrate as N	3/19/2012	composite	EPA 353.2	mg/L	0.04	0.11					0.58
Nitrate as N	3/22/2012	composite	EPA 353.2	mg/L	0.04	0.11					0.66
Nitrate as N	3/26/2012	composite	EPA 353.2	mg/L	0.04	0.11	12.00	0.36	0.38	0.68	0.81
Nitrate as N	3/29/2012	composite	EPA 353.2	mg/L	0.04	0.11					0.63
Nitrate as N	4/2/2012	composite	EPA 353.2	mg/L	0.04	0.11					0.60
Nitrate as N	4/5/2012	composite	EPA 353.2	mg/L	0.04	0.11					0.66
Nitrate as N	4/9/2012	composite	EPA 353.2	mg/L	0.04	0.11	6.60	0.43	0.48	0.54	0.67
Nitrate as N	4/12/2012	composite	EPA 353.2	mg/L	0.04	0.11					0.74
Nitrate as N	4/16/2012	composite	EPA 353.2	mg/L	0.04	0.11					0.66
Nitrate as N	4/23/2012	composite	EPA 353.2	mg/L	0.04	0.11	13.00	0.63	0.64	0.74	0.91

Table 15 Certified Laboratory Results of Nitrogen Parameters Sampled from Various Locations in the AWPF (cont.)

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Nitrate as N	4/26/2012	composite	EPA 353.2	mg/L	0.04	0.11					1.20
Nitrate as N	4/30/2012	composite	EPA 353.2	mg/L	0.04	0.11					0.83
Nitrate as N	5/3/2012	composite	EPA 353.2	mg/L	0.04	0.11					1.00
Nitrate as N	5/7/2012	composite	EPA 353.2	mg/L	0.04	0.11	11.00	0.53	0.65	0.61	0.77
Nitrate as N	5/14/2012	composite	EPA 353.2	mg/L	0.04	0.11					0.93
Nitrate as N	5/21/2012	composite	EPA 353.2	mg/L	0.04	0.11	13.00	0.56	0.68	0.88	0.96
Nitrate as N	5/24/2012	composite	EPA 353.2	mg/L	0.04	0.11					1.30
Nitrate as N	5/29/2012	composite	EPA 353.2	mg/L	0.04	0.11					1.00
Nitrate as N	5/31/2012	composite	EPA 353.2	mg/L	0.04	0.11					1.00
Nitrate as N	6/4/2012	composite	EPA 353.2	mg/L	0.04	0.11	13.00	0.67	0.80	0.88	1.00
Nitrate as N	6/7/2012	composite	EPA 353.2	mg/L	0.04	0.11					0.88
Nitrate as N	6/11/2012	composite	EPA 353.2	mg/L	0.04	0.11					0.93
Nitrate as N	6/21/2012	composite	EPA 353.2	mg/L	0.04	0.11					0.98
Nitrate as N	6/28/2012	composite	EPA 353.2	mg/L	0.04	0.11					1.00
Nitrate as N	7/2/2012	composite	EPA 353.2	mg/L	0.04	0.11				0.77	0.94
Nitrate as N	7/5/2012	composite	EPA 353.2	mg/L	0.04	0.11					0.92
Nitrate as N	7/9/2012	composite	EPA 353.2	mg/L	0.04	0.11					1.40
Nitrate as N	7/12/2012	composite	EPA 353.2	mg/L	0.04	0.11					1.00
Nitrate as N	7/16/2012	composite	EPA 353.2	mg/L	0.04	0.11				0.73	0.90
Nitrate as N	7/19/2012	composite	EPA 353.2	mg/L	0.04	0.11					1.10
Nitrate as N	7/23/2012	composite	EPA 353.2	mg/L	0.04	0.11					0.95
Nitrate as N	7/26/2012	composite	EPA 353.2	mg/L	0.04	0.11					1.10
Nitrate as N	7/30/2012	composite	EPA 353.2	mg/L	0.04	0.11				0.67	0.91
n =							23	23	23	24	96
Average							12.1	0.41	0.45	0.54	0.73
Maximum							15.4	0.67	0.80	0.88	1.4
Minimum							6.60	0.30	0.30	0.30	0.50
STDev							1.83	0.11	0.13	0.18	0.19

Note: For purposes of calculating statistical parameters, results reported below the RL were considered 0.5 X RL and results reported <DL were considered the 0.5 X DL. Nitrate concentrations were calculated by subtracting measured concentrations of nitrite-N from measured concentrations of (nitrate-+nitrite as N).

Table 15 Certified Laboratory Results of Nitrogen Parameters Sampled from Various Locations in the AWPF (Cont.)

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Nitrite as N	8/15/2011	grab	EPA 353.2	mg/L	0.01	0.09	<0.09	<0.01	<0.01		<0.01
Nitrite as N	8/18/2011	grab	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	8/22/2011	grab	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	8/25/2011	grab	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	8/29/2011	grab	EPA 353.2	mg/L	0.01	0.09	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrite as N	9/1/2011	grab	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	9/1/2011	grab	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	9/6/2011	grab	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	9/8/2011	grab	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	9/12/2011	grab	EPA 353.2	mg/L	0.01	0.09	<0.09	<0.01	<0.01	<0.01	<0.01
Nitrite as N	9/15/2011	grab	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	9/19/2011	grab	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	9/22/2011	grab	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	9/26/2011	grab	EPA 353.2	mg/L	0.01	0.09	<0.09	<0.01	<0.01	<0.01	<0.01
Nitrite as N	9/29/2011	grab	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	10/6/2011	grab	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	10/10/2011	grab	EPA 353.2	mg/L	0.01	0.09	<0.09	<0.01	<0.01	<0.01	<0.01
Nitrite as N	10/13/2011	grab	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	10/17/2011	grab	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	10/20/2011	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	10/24/2011	composite	EPA 353.2	mg/L	0.01	0.09	<0.09	<0.01	<0.01	<0.01	<0.01
Nitrite as N	10/31/2011	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	11/3/2011	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	11/7/2011	composite	EPA 353.2	mg/L	0.01	0.09	<0.09	<0.01	<0.01	<0.01	<0.01
Nitrite as N	11/10/2011	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	11/14/2011	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	11/17/2011	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	11/21/2011	composite	EPA 353.2	mg/L	0.01	0.09	0.13	<0.01	<0.01	<0.01	<0.01
Nitrite as N	11/29/2011	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	12/1/2011	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	12/5/2011	composite	EPA 353.2	mg/L	0.01	0.09	<0.01	<0.01	<0.01	<0.01	<0.09
Nitrite as N	12/8/2011	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	12/12/2011	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	12/15/2011	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	12/19/2011	composite	EPA 353.2	mg/L	0.01	0.09	<0.09	<0.01	<0.01	<0.01	<0.01
Nitrite as N	12/22/2011	composite	EPA 353.2	mg/L	0.01	0.09					<0.01

Table 15 Certified Laboratory Results of Nitrogen Parameters Sampled from Various Locations in the AWPF (Cont.)

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Nitrite as N	12/27/2011	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	12/29/2011	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	1/3/2012	composite	EPA 353.2	mg/L	0.01	0.09	<0.09	<0.01	<0.01	<0.01	<0.01
Nitrite as N	1/5/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	1/9/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	1/12/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	1/17/2012	composite	EPA 353.2	mg/L	0.01	0.09	<0.09	<0.01	<0.01	<0.01	<0.01
Nitrite as N	1/19/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	1/23/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	1/26/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	1/30/2012	composite	EPA 353.2	mg/L	0.01	0.09	<0.09	<0.01	<0.01	<0.01	<0.01
Nitrite as N	2/2/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	2/6/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	2/9/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	2/14/2012	composite	EPA 353.2	mg/L	0.01	0.09	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrite as N	2/16/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	2/20/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	2/23/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	2/27/2012	composite	EPA 353.2	mg/L	0.01	0.09	<0.1	<0.1	<0.1	<0.01	<0.1
Nitrite as N	3/1/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.1
Nitrite as N	3/6/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	3/8/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	3/12/2012	composite	EPA 353.2	mg/L	0.01	0.09	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrite as N	3/15/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	3/19/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	3/22/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	3/26/2012	composite	EPA 353.2	mg/L	0.01	0.09	0.31	<0.01	<0.01	<0.01	<0.01
Nitrite as N	3/29/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	4/2/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	4/5/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	4/9/2012	composite	EPA 353.2	mg/L	0.01	0.09	0.48	<0.01	<0.01	<0.01	<0.01
Nitrite as N	4/12/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	4/16/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	4/23/2012	composite	EPA 353.2	mg/L	0.01	0.09	<0.1	<0.01	<0.01	<0.01	<0.01
Nitrite as N	4/26/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	4/30/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	5/3/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01

Table 15 Certified Laboratory Results of Nitrogen Parameters Sampled from Various Locations in the AWPF (Cont.)

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Nitrite as N	5/7/2012	composite	EPA 353.2	mg/L	0.01	0.09	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrite as N	5/14/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	5/21/2012	composite	EPA 353.2	mg/L	0.01	0.09	<0.1	<0.01	<0.01	<0.01	<0.01
Nitrite as N	5/24/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	5/29/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	5/31/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	6/4/2012	composite	EPA 353.2	mg/L	0.01	0.09	<0.1	<0.01	<0.01	<0.01	<0.01
Nitrite as N	6/7/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	6/11/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	6/21/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	6/28/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	7/2/2012	composite	EPA 353.2	mg/L	0.01	0.09				<0.01	<0.01
Nitrite as N	7/5/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	7/9/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	7/12/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	7/16/2012	composite	EPA 353.2	mg/L	0.01	0.09				<0.01	<0.01
Nitrite as N	7/19/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	7/23/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	7/26/2012	composite	EPA 353.2	mg/L	0.01	0.09					<0.01
Nitrite as N	7/30/2012	composite	EPA 353.2	mg/L	0.01	0.09				<0.01	<0.01
n =							22	22	22	24	93
Average							<0.09	<0.01	<0.01	<0.01	<0.01
Maximum							0.48	0.10	0.10	0.09	0.10
Minimum							0.0	0.0	0.0	0.0	0.0
STDev							0.1	0.0	0.0	0.0	0.0

Note: For purposes of calculating statistical parameters, results reported below the RL were considered 0.5 X RL and results reported <DL were considered the 0.5 X DL.

Table 15 Certified Laboratory Results of Nitrogen Parameters Sampled from Various Locations in the AWPF (Cont.)

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Nitrogen, Total - N	8/1/2011	grab	Various	mg/L	0.074	0.1	13	0.85	0.71		0.75
Nitrogen, Total - N	8/4/2011	grab	Various	mg/L	0.074	0.1					0.8
Nitrogen, Total - N	8/8/2011	grab	Various	mg/L	0.074	0.1					0.8
Nitrogen, Total - N	8/11/2011	grab	Various	mg/L	0.074	0.1					0.98
Nitrogen, Total - N	8/15/2011	grab	Various	mg/L	0.074	0.1	12	0.85	0.76		0.7
Nitrogen, Total - N	8/18/2011	grab	Various	mg/L	0.074	0.1					0.88
Nitrogen, Total - N	8/22/2011	grab	Various	mg/L	0.074	0.1					0.74
Nitrogen, Total - N	8/25/2011	grab	Various	mg/L	0.074	0.1					0.7
Nitrogen, Total - N	8/29/2011	grab	Various	mg/L	0.074	0.1	13	0.81	0.73	0.77	0.63
Nitrogen, Total - N	9/1/2011	grab	Various	mg/L	0.074	0.1					1.3
Nitrogen, Total - N	9/6/2011	grab	Various	mg/L	0.074	0.1					0.71
Nitrogen, Total - N	9/8/2011	grab	Various	mg/L	0.074	0.1					0.85
Nitrogen, Total - N	9/12/2011	grab	Various	mg/L	0.074	0.1	11	0.62	0.68	0.68	0.65
Nitrogen, Total - N	9/15/2011	grab	Various	mg/L	0.074	0.1					0.82
Nitrogen, Total - N	9/19/2011	grab	Various	mg/L	0.074	0.1					0.85
Nitrogen, Total - N	9/22/2011	grab	Various	mg/L	0.074	0.1					0.97
Nitrogen, Total - N	9/26/2011	grab	Various	mg/L	0.074	0.1	14	0.84	0.84	0.8	0.84
Nitrogen, Total - N	9/29/2011	grab	Various	mg/L	0.074	0.1					0.94
Nitrogen, Total - N	10/3/2011	grab	Various	mg/L	0.074	0.1					0.58
Nitrogen, Total - N	10/6/2011	grab	Various	mg/L	0.074	0.1					0.62
Nitrogen, Total - N	10/10/2011	grab	Various	mg/L	0.074	0.1	13	0.63	0.63	0.86	0.95
Nitrogen, Total - N	10/13/2011	grab	Various	mg/L	0.074	0.1					0.73
Nitrogen, Total - N	10/17/2011	grab	Various	mg/L	0.074	0.1					0.98
Nitrogen, Total - N	10/20/2011	composite	Various	mg/L	0.074	0.1					0.91
Nitrogen, Total - N	10/24/2011	composite	Various	mg/L	0.074	0.1	13	0.84	0.79	0.84	0.87
Nitrogen, Total - N	10/31/2011	composite	Various	mg/L	0.074	0.1					0.53
Nitrogen, Total - N	11/3/2011	composite	Various	mg/L	0.074	0.1					0.97
Nitrogen, Total - N	11/7/2011	composite	Various	mg/L	0.074	0.1	13	0.65	0.67	0.77	0.76
Nitrogen, Total - N	11/10/2011	composite	Various	mg/L	0.074	0.1					0.79
Nitrogen, Total - N	11/14/2011	composite	Various	mg/L	0.074	0.2					0.64
Nitrogen, Total - N	11/17/2011	composite	Various	mg/L	0.074	0.1					0.86
Nitrogen, Total - N	11/21/2011	composite	Various	mg/L	0.074	0.1	13	0.72	0.88	0.73	0.74
Nitrogen, Total - N	11/29/2011	composite	Various	mg/L	0.074	0.1					0.68
Nitrogen, Total - N	12/1/2011	composite	Various	mg/L	0.074	0.1					0.68
Nitrogen, Total - N	12/5/2011	composite	Various	mg/L	0.074	0.1	12	0.66	0.73	0.87	0.77

Table 15 Certified Laboratory Results of Nitrogen Parameters Sampled from Various Locations in the AWPF (Cont.)

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Nitrogen, Total - N	12/8/2011	composite	Various	mg/L	0.074	0.1					0.8
Nitrogen, Total - N	12/12/2011	composite	Various	mg/L	0.074	0.1					0.8
Nitrogen, Total - N	12/15/2011	composite	Various	mg/L	0.074	0.1					0.62
Nitrogen, Total - N	12/19/2011	composite	Various	mg/L	0.074	0.2	13	0.69	0.76	0.78	0.87
Nitrogen, Total - N	12/22/2011	composite	Various	mg/L	0.074	0.2					0.76
Nitrogen, Total - N	12/27/2011	composite	Various	mg/L	0.074	0.2					0.68
Nitrogen, Total - N	12/29/2011	composite	Various	mg/L	0.074	0.2					0.6
Nitrogen, Total - N	1/3/2012	composite	Various	mg/L	0.074	0.2	12	0.9	0.77	0.8	0.65
Nitrogen, Total - N	1/5/2012	composite	Various	mg/L	0.074	0.2					0.71
Nitrogen, Total - N	1/9/2012	composite	Various	mg/L	0.074	0.2					0.57
Nitrogen, Total - N	1/12/2012	composite	Various	mg/L	0.074	0.2					0.67
Nitrogen, Total - N	1/17/2012	composite	Various	mg/L	0.074	0.2	17	0.78	0.76	0.88	0.82
Nitrogen, Total - N	1/19/2012	composite	Various	mg/L	0.074	0.2					0.9
Nitrogen, Total - N	1/23/2012	composite	Various	mg/L	0.074	0.2					0.54
Nitrogen, Total - N	1/26/2012	composite	Various	mg/L	0.074	0.2					0.87
Nitrogen, Total - N	1/30/2012	composite	Various	mg/L	0.074	0.2	12	0.77	0.74	0.84	0.63
Nitrogen, Total - N	2/2/2012	composite	Various	mg/L	0.074	0.2					0.82
Nitrogen, Total - N	2/6/2012	composite	Various	mg/L	0.074	0.2					0.72
Nitrogen, Total - N	2/9/2012	composite	Various	mg/L	0.074	0.2					0.73
Nitrogen, Total - N	2/14/2012	composite	Various	mg/L	0.074	0.2	15	0.74	0.74	0.8	0.67
Nitrogen, Total - N	2/16/2012	composite	Various	mg/L	0.074	0.2					0.64
Nitrogen, Total - N	2/20/2012	composite	Various	mg/L	0.074	0.2					0.65
Nitrogen, Total - N	2/23/2012	composite	Various	mg/L	0.074	0.2					0.72
Nitrogen, Total - N	2/27/2012	composite	Various	mg/L	0.074	0.2	13	0.74	0.73	0.82	
Nitrogen, Total - N	3/1/2012	composite	Various	mg/L	0.074	0.2					1.2
Nitrogen, Total - N	3/6/2012	composite	Various	mg/L	0.074	0.2					1.1
Nitrogen, Total - N	3/8/2012	composite	Various	mg/L	0.074	0.2					0.76
Nitrogen, Total - N	3/12/2012	composite	Various	mg/L	0.074	0.2	13	0.66	0.88	1.1	0.57
Nitrogen, Total - N	3/15/2012	composite	Various	mg/L	0.074	0.2					0.88
Nitrogen, Total - N	3/19/2012	composite	Various	mg/L	0.074	0.2					0.58
Nitrogen, Total - N	3/22/2012	composite	Various	mg/L	0.074	0.2					0.92
Nitrogen, Total - N	3/26/2012	composite	Various	mg/L	0.074	0.2	16	0.9	0.99	1.2	1.1
Nitrogen, Total - N	3/29/2012	composite	Various	mg/L	0.074	0.2					1
Nitrogen, Total - N	4/2/2012	composite	Various	mg/L	0.074	0.2					0.92
Nitrogen, Total - N	4/5/2012	composite	Various	mg/L	0.074	0.2					0.98
Nitrogen, Total - N	4/9/2012	composite	Various	mg/L	0.074	0.2	9.6	0.84	0.86	0.92	0.98
Nitrogen, Total - N	4/12/2012	composite	Various	mg/L	0.074	0.2					0.88

Table 15 Certified Laboratory Results of Nitrogen Parameters Sampled from Various Locations in the AWPF (Cont.)

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Nitrogen, Total - N	4/16/2012	composite	Various	mg/L	0.074	0.2					1
Nitrogen, Total - N	4/23/2012	composite	Various	mg/L	0.074	0.2	14	1.1	0.84	1.2	0.91
Nitrogen, Total - N	4/26/2012	composite	Various	mg/L	0.074	0.2					1.30
Nitrogen, Total - N	4/30/2012	composite	Various	mg/L	0.074	0.2					0.96
Nitrogen, Total - N	5/3/2012	composite	Various	mg/L	0.075	1.2					1.20
Nitrogen, Total - N	5/7/2012	composite	Various	mg/L	0.074	0.2	12.00	0.98	1.10	0.97	0.88
Nitrogen, Total - N	5/14/2012	composite	Various	mg/L	0.074	0.2					1.10
Nitrogen, Total - N	5/21/2012	composite	Various	mg/L	0.074	0.2	13.00	1.00	1.00	1.20	0.96
Nitrogen, Total - N	5/24/2012	composite	Various	mg/L	0.074	0.2					1.30
Nitrogen, Total - N	5/29/2012	composite	Various	mg/L	0.074	0.2					1.20
Nitrogen, Total - N	5/31/2012	composite	Various	mg/L	0.074	0.2					2.20
Nitrogen, Total - N	6/4/2012	composite	Various	mg/L	0.074	0.2	14.00	1.20	1.10	1.00	1.20
Nitrogen, Total - N	6/7/2012	composite	Various	mg/L	0.074	0.2					0.88
Nitrogen, Total - N	6/11/2012	composite	Various	mg/L	0.074	0.2					0.93
Nitrogen, Total - N	6/21/2012	composite	Various	mg/L	0.074	0.2					1.10
Nitrogen, Total - N	6/28/2012	composite	Various	mg/L	0.074	0.2					1.00
Nitrogen, Total - N	7/2/2012	composite	Various	mg/L	0.074	0.2				0.89	0.94
Nitrogen, Total - N	7/5/2012	composite	Various	mg/L	0.074	0.2					0.92
Nitrogen, Total - N	7/9/2012	composite	Various	mg/L	0.074	0.2					1.40
Nitrogen, Total - N	7/12/2012	composite	Various	mg/L	0.074	0.2					1.00
Nitrogen, Total - N	7/16/2012	composite	Various	mg/L	0.074	0.2				1.10	0.98
Nitrogen, Total - N	7/19/2012	composite	Various	mg/L	0.074	0.2					1.10
Nitrogen, Total - N	7/23/2012	composite	Various	mg/L	0.074	0.2					0.95
Nitrogen, Total - N	7/26/2012	composite	Various	mg/L	0.074	0.2					1.10
Nitrogen, Total - N	7/30/2012	composite	Various	mg/L	0.074	0.2				0.67	0.91
n =							23	23	23	24	96
Average							13	0.82	0.81	0.90	0.87
Maximum							17	1.2	1.1	1.2	2.2
Minimum							9.6	0.60	0.60	0.70	0.50
STDev							1.5	0.15	0.13	0.16	0.23

Note: For purposes of calculating statistical parameters, results reported below the RL were considered 0.5 X RL and results reported <DL were considered the 0.5 X DL.

Table 15 Certified Laboratory Results of Total Phosphorus Sampled from Various Locations in the AWPF

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Total Phosphorus-P	8/1/2011	grab	EPA 365.1	µg/L	35	250	2200	11	11		
Total Phosphorus-P	8/15/2011	grab	EPA 365.1	µg/L	1.4	10	1100	<10	<10		<10
Total Phosphorus-P	8/18/2011	grab	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	8/22/2011	grab	EPA 365.1	µg/L	1.4	10					<1.4
Total Phosphorus-P	8/25/2011	grab	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	8/29/2011	grab	EPA 365.1	µg/L	1.4	10	1100	<10	<10	<10	<10
Total Phosphorus-P	9/1/2011	grab	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	9/6/2011	grab	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	9/8/2011	grab	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	9/12/2011	grab	EPA 365.1	µg/L	1.4	10	320	<1.4	<1.4	<10	<1.4
Total Phosphorus-P	9/15/2011	grab	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	9/19/2011	grab	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	9/22/2011	grab	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	9/26/2011	grab	EPA 365.1	µg/L	1.4	10	2100	<10	<10	<10	<10
Total Phosphorus-P	9/29/2011	grab	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	10/3/2011	grab	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	10/6/2011	grab	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	10/10/2011	grab	EPA 365.1	µg/L	1.4	10	2500	<10	<10	<10	<10
Total Phosphorus-P	10/10/2011	grab	EPA 365.1	µg/L	1.4	10	2000	<10	<10		
Total Phosphorus-P	10/13/2011	grab	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	10/17/2011	grab	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	10/20/2011	composite	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	10/24/2011	composite	EPA 365.1	µg/L	1.4	10	1800	<10	<10	<10	<10
Total Phosphorus-P	10/31/2011	composite	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	11/3/2011	composite	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	11/7/2011	composite	EPA 365.1	µg/L	1.4	10	1200	<1.4	<1.4	<10	<10
Total Phosphorus-P	11/10/2011	composite	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	11/14/2011	composite	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	11/17/2011	composite	EPA 365.1	µg/L	1.4	10					<1.4
Total Phosphorus-P	11/21/2011	composite	EPA 365.1	µg/L	1.4	10	1600	<1.4	<1.4	<1.4	<1.4
Total Phosphorus-P	11/29/2011	composite	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	12/5/2011	composite	EPA 365.1	µg/L	1.4	10	1200	<10	<10	<10	<10
Total Phosphorus-P	12/01/2011	composite	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	12/8/2011	composite	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	12/12/2011	composite	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	12/15/2011	composite	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	12/19/2011	composite	EPA 365.1	µg/L	1.4	10	1700	<10	<10	14	<10
Total Phosphorus-P	12/22/2011	composite	EPA 365.1	µg/L	1.4	10					<10

Table 15 Certified Laboratory Results of Total Phosphorus Sampled from Various Locations in the AWPF

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Total Phosphorus-P	12/27/2011	composite	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	12/29/2011	composite	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	1/3/2012	composite	EPA 365.1	µg/L	1.4	10	300	<10	<10	<10	<10
Total Phosphorus-P	1/5/2012	composite	EPA 365.1	µg/L	70	500					940
Total Phosphorus-P	1/9/2012	composite	EPA 365.1	µg/L	1.4	10					14
Total Phosphorus-P	1/12/2012	composite	EPA 365.1	µg/L	1.4	10					<1.4
Total Phosphorus-P	1/17/2012	composite	EPA 365.1	µg/L	1.4	10	430.00	<1.4	<1.4	<10	20
Total Phosphorus-P	1/19/2012	composite	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	1/23/2012	composite	EPA 365.1	µg/L	1.4	10					45
Total Phosphorus-P	1/26/2012	composite	EPA 365.1	µg/L	1.4	10					18
Total Phosphorus-P	1/30/2012	composite	EPA 365.1	µg/L	1.4	10	430	<10	<10	280	21
Total Phosphorus-P	2/2/2012	composite	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	2/9/2012	composite	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	2/14/2012	composite	EPA 365.1	µg/L	1.4	10	560	<10	<1.4	<10	<10
Total Phosphorus-P	2/23/2012	composite	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	2/27/2012	composite	EPA 365.1	µg/L	1.4	10	1800	<10	<1.4	<10	
Total Phosphorus-P	3/1/2012	composite	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	3/6/2012	composite	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	3/8/2012	composite	EPA 365.1	µg/L	1.4	10					420
Total Phosphorus-P	3/12/2012	composite	EPA 365.1	µg/L	1.4	10	1900	<10	<1.4	<10	<10
Total Phosphorus-P	3/15/2012	composite	EPA 365.1	µg/L	1.4	10					140
Total Phosphorus-P	3/19/2012	composite	EPA 365.1	µg/L	1.4	10					26
Total Phosphorus-P	3/22/2012	composite	EPA 365.1	µg/L	1.4	10					140
Total Phosphorus-P	3/26/2012	composite	EPA 365.1	µg/L	1.4	10	1400	<10	<10	<10	11
Total Phosphorus-P	3/29/2012	composite	EPA 365.1	µg/L	1.4	10					22
Total Phosphorus-P	4/2/2012	composite	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	4/5/2012	composite	EPA 365.1	µg/L	1.4	10					15
Total Phosphorus-P	4/9/2012	composite	EPA 365.1	µg/L	1.4	10	490	<10	<1.4	<10	<10
Total Phosphorus-P	4/12/2012	composite	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	4/16/2012	composite	EPA 365.1	µg/L	1.4	10					120
Total Phosphorus-P	4/23/2012	composite	EPA 365.1	µg/L	1.4	10	910	<10	<10	<10	<10
Total Phosphorus-P	4/26/2012	composite	EPA 365.1	µg/L	1.4	10					11
Total Phosphorus-P	4/30/2012	composite	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	5/3/2012	composite	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	5/7/2012	composite	EPA 365.1	µg/L	1.4	10	1000.00	<1.4	<10	<10	<10
Total Phosphorus-P	5/14/2012	composite	EPA 365.1	µg/L	1.4	10					29.00
Total Phosphorus-P	5/21/2012	composite	EPA 365.1	µg/L	1.4	10	680.00	<1.4	<1.4	<10	<10

Table 15 Certified Laboratory Results of Total Phosphorus Sampled from Various Locations in the AWPF

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Total Phosphorus-P	5/24/2012	composite	EPA 365.1	µg/L	1.4	10	1100.00			<10	<10
Total Phosphorus-P	5/29/2012	composite	EPA 365.1	µg/L	1.4	10	870.00			<10	<10
Total Phosphorus-P	5/31/2012	composite	EPA 365.1	µg/L	1.4	10	1100.00			23.00	<10
Total Phosphorus-P	6/4/2012	composite	EPA 365.1	µg/L	1.4	10	1400.00	<10	<10	<10	<10
Total Phosphorus-P	6/7/2012	composite	EPA 365.1	µg/L	1.4	10	1900.00			<10	14.00
Total Phosphorus-P	6/11/2012	composite	EPA 365.1	µg/L	1.4	10	1600.00			<10	<10
Total Phosphorus-P	6/21/2012	composite	EPA 365.1	µg/L	1.4	10	2100.00			<10	<10
Total Phosphorus-P	6/28/2012	composite	EPA 365.1	µg/L	1.4	10	2100.00			<10	<10
Total Phosphorus-P	7/2/2012	composite	EPA 365.1	µg/L	1.4	10				<10	<10
Total Phosphorus-P	7/5/2012	composite	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	7/9/2012	composite	EPA 365.1	µg/L	1.4	10					<1.4
Total Phosphorus-P	7/12/2012	composite	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	7/16/2012	composite	EPA 365.1	µg/L	1.4	10				<10	<10
Total Phosphorus-P	7/19/2012	composite	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	7/23/2012	composite	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	7/26/2012	composite	EPA 365.1	µg/L	1.4	10					<10
Total Phosphorus-P	7/30/2012	composite	EPA 365.1	µg/L	1.4	10				<10	<10
n =							31	24	24	31	88
Average							1320	<10	<10	15	16
Maximum							2500	11	11	280	420
Minimum							300	0.70	0.70	0.70	0.70
STDev							630	2.4	2.6	49	50

Note: For purposes of calculating statistical parameters, results reported below the RL were considered 0.5 X RL and results reported <DL were considered the 0.5 X DL. . The result shown for S10 (940 µg/L) on 1/5/2012 is considered an outlier and ommitted for determination of statistical parameters. Data flags provided in the original laboratory reports are not shown.

Table 16 Certified Laboratory Results of Trihalomethanes, Methylene Chloride, 1, 2 Dichloroethane, and Napthalene

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S1 (tertiary effluent)	S6 (RO Feed)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
THMs, Total	8/1/2011	grab	EPA 524.2	µg/L	0.60	2.0		3.7	2.1	<2
THMs, Total	9/1/2011	grab	EPA 524.2	µg/L	0.60	2.0	<0.6		<0.6	<0.6
THMs, Total	10/3/2011	grab	EPA 524.2	µg/L	0.60	2.0	<2		<0.6	<0.6
THMs, Total	11/2/2011	grab	EPA 524.2	µg/L	0.60	2.0	<2		<0.6	<0.6
THMs, Total	12/1/2011	grab	EPA 524.2	µg/L	0.60	2.0	<0.6	<2	<0.6	<0.6
THMs, Total	1/3/2012	grab	EPA 524.2	µg/L	0.60	2.0	<0.6	<2	<0.6	<0.6
THMs, Total	2/1/2012	grab	EPA 524.2	µg/L	0.60	2.0	<0.6	<0.6	<0.6	<0.6
THMs, Total	3/6/2012	grab	EPA 524.2	µg/L	0.60	2.0	3	3.1	<2	<2
THMs, Total	4/2/2012	grab	EPA 524.2	µg/L	0.60	2.0	<0.6	<0.6	<0.6	<0.6
THMs, Total	5/1/2012	grab	EPA 524.2	µg/L	0.60	2.0	<2	<2	<0.6	<0.6
THMs, Total	6/4/2012	grab	EPA 524.2	µg/L	0.60	2.0	<2	<2		<2
THMs, Total	7/2/2012	grab	EPA 524.2	µg/L	0.60	2.0	<2			<0.6
n =							11	8	10	12
Average							<2	<2	<2	<0.6
Maximum							3	4	2	1
Minimum							0.3	0.3	0.3	0.3
STDev							0.8	1	0.6	0.3
Methylene chloride	8/1/2011	grab	EPA 524.2	µg/L	0.14	0.50		<0.14	<0.5	<0.5
Methylene chloride	9/1/2011	grab	EPA 524.2	µg/L	0.14	0.50	0.72		0.62	0.59
Methylene chloride	10/3/2011	grab	EPA 524.2	µg/L	0.14	0.50	<0.5		<0.5	<0.5
Methylene chloride	11/2/2011	grab	EPA 524.2	µg/L	0.14	0.50	<0.14		<0.14	<0.14
Methylene chloride	12/1/2011	grab	EPA 524.2	µg/L	0.14	0.50	<0.5	<0.5	<0.5	<0.5
Methylene chloride	1/3/2012	grab	EPA 524.2	µg/L	0.14	0.50	<0.5	<0.5	<0.5	<0.5
Methylene chloride	2/1/2012	grab	EPA 524.2	µg/L	0.14	0.50	<0.5	<0.5	<0.5	<0.5
Methylene chloride	3/6/2012	grab	EPA 524.2	µg/L	0.14	0.50	<0.5	<0.5	<0.14	<0.14
Methylene chloride	4/2/2012	grab	EPA 524.2	µg/L	0.14	0.50	<0.5	<0.5	<0.5	<0.5
Methylene chloride	5/1/2012	grab	EPA 524.2	µg/L	0.14	0.50	<0.5	<0.5	<0.5	<0.5
Methylene chloride	6/4/2012	grab	EPA 524.2	µg/L	0.14	0.50	<0.14	<0.14		<0.14
Methylene chloride	7/2/2012	grab	EPA 524.2	µg/L	0.14	0.50	<0.14			<0.14
n =							11.0	8.0	10.0	12.0
Average							<0.5	<0.5	<0.5	<0.5
Maximum							0.7	0.3	0.6	0.6
Minimum							0.1	0.1	0.1	0.1
STDev							0.2	0.1	0.1	0.1

Table 16 Certified Laboratory Results of Trihalomethanes, Methylene Chloride, 1, 2 Dichloroethane, and Napthalene

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S1 (tertiary effluent)	S6 (RO Feed)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Dibromochloromethane	8/1/2011	grab	EPA 524.2	µg/L	0.20	0.50		1	<0.5	<0.20
Dibromochloromethane	9/1/2011	grab	EPA 524.2	µg/L	0.20	0.50	<0.20		<0.20	<0.20
Dibromochloromethane	10/3/2011	grab	EPA 524.2	µg/L	0.20	0.50	<0.5		<0.5	<0.20
Dibromochloromethane	11/2/2011	grab	EPA 524.2	µg/L	0.20	0.50	0.51		<0.5	<0.20
Dibromochloromethane	12/1/2011	grab	EPA 524.2	µg/L	0.20	0.50	<0.5	<0.5	<0.20	<0.20
Dibromochloromethane	1/3/2012	grab	EPA 524.2	µg/L	0.20	0.50	<0.5	<0.5	<0.5	<0.20
Dibromochloromethane	2/1/2012	grab	EPA 524.2	µg/L	0.20	0.50	<0.5	<0.5	<0.20	<0.20
Dibromochloromethane	3/6/2012	grab	EPA 524.2	µg/L	0.20	0.50	0.8	0.84	<0.5	<0.20
Dibromochloromethane	4/2/2012	grab	EPA 524.2	µg/L	0.20	0.50	<0.5	<0.20	<0.20	<0.20
Dibromochloromethane	5/1/2012	grab	EPA 524.2	µg/L	0.20	0.50	0.53	<0.5	<0.2	<0.2
Dibromochloromethane	6/4/2012	grab	EPA 524.2	µg/L	0.20	0.50	0.6	<0.5		0.6
Dibromochloromethane	7/2/2012	grab	EPA 524.2	µg/L	0.20	0.50	<0.5			<0.2
n =							11	8	10	12
Average							<0.5	<0.5	<0.2	<0.2
Maximum							0.8	1.0	0.3	0.6
Minimum							0.1	0.1	0.1	0.1
STDev							0.2	0.3	0.1	0.1
Chloroform	8/1/2011	grab	EPA 524.2	µg/L	0.12	0.5		1.3	1.3	1.1
Chloroform	9/1/2011	grab	EPA 524.2	µg/L	0.12	0.5	<0.12		<0.12	<0.12
Chloroform	10/3/2011	grab	EPA 524.2	µg/L	0.12	0.5	0.89		0.52	<0.5
Chloroform	11/2/2011	grab	EPA 524.2	µg/L	0.12	0.5	<0.5		<0.12	<0.12
Chloroform	12/1/2011	grab	EPA 524.2	µg/L	0.12	0.5	<0.5	0.61	<0.12	<0.12
Chloroform	1/3/2012	grab	EPA 524.2	µg/L	0.12	0.5	<0.5	0.71	<0.5	<0.12
Chloroform	2/1/2012	grab	EPA 524.2	µg/L	0.12	0.5	<0.5	<0.5	<0.12	<0.12
Chloroform	3/6/2012	grab	EPA 524.2	µg/L	0.12	0.5	1.1	1.1	1	0.97
Chloroform	4/2/2012	grab	EPA 524.2	µg/L	0.12	0.5	<0.5	<0.5	<0.12	<0.12
Chloroform	5/1/2012	grab	EPA 524.2	µg/L	0.12	0.5	<0.5	0.67	<0.12	<0.12
Chloroform	6/4/2012	grab	EPA 524.2	µg/L	0.12	0.5	<0.5	<0.5		<0.5
Chloroform	7/2/2012	grab	EPA 524.2	µg/L	0.12	0.5	0.68			<0.5
n =							11	8	10	12
Average							<0.5	0.6	<0.5	<0.5
Maximum							1	1	1	1
Minimum							0.1	0.3	0.1	0.1
STDev							0.3	0.4	0.5	0.4

Table 16 Certified Laboratory Results of Trihalomethanes, Methylene Chloride, 1, 2 Dichloroethane, and Napthalene

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S1 (tertiary effluent)	S6 (RO Feed)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Bromoform	8/1/2011	grab	EPA 524.2	µg/L	0.19	0.5		<0.19	<0.19	<0.19
Bromoform	9/1/2011	grab	EPA 524.2	µg/L	0.19	0.5	<0.19		<0.19	<0.19
Bromoform	10/3/2011	grab	EPA 524.2	µg/L	0.19	0.5	<0.19		<0.19	<0.19
Bromoform	11/2/2011	grab	EPA 524.2	µg/L	0.19	0.5	<0.19		<0.19	<0.19
Bromoform	12/1/2011	grab	EPA 524.2	µg/L	0.19	0.5	<0.19	<0.19	<0.19	<0.19
Bromoform	1/3/2012	grab	EPA 524.2	µg/L	0.19	0.5	<0.19	<0.19	<0.19	<0.19
Bromoform	2/1/2012	grab	EPA 524.2	µg/L	0.19	0.5	<0.19	<0.19	<0.19	<0.19
Bromoform	3/6/2012	grab	EPA 524.2	µg/L	0.19	0.5	<0.19	<0.19	<0.19	<0.19
Bromoform	4/2/2012	grab	EPA 524.2	µg/L	0.19	0.5	<0.19	<0.19	<0.19	<0.19
Bromoform	5/1/2012	grab	EPA 524.2	µg/L	0.19	0.5	<0.19	<0.19	<0.19	<0.19
Bromoform	6/4/2012	grab	EPA 524.2	µg/L	0.19	0.5	<0.19	<0.19		<0.19
Bromoform	7/2/2012	grab	EPA 524.2	µg/L	0.19	0.5	<0.19			<0.19
n =							11	8	10	12
Average							<0.19	<0.19	<0.19	<0.19
Maximum							0.10	0.10	0.10	0.10
Minimum							0.10	0.10	0.10	0.10
STDev							0.0	0.0	0.0	0.0
Bromodichloromethane	8/1/2011	grab	EPA 524.2	µg/L	0.090	0.5		1.4	0.84	0.71
Bromodichloromethane	9/1/2011	grab	EPA 524.2	µg/L	0.090	0.5	<0.090		<0.090	<0.090
Bromodichloromethane	10/3/2011	grab	EPA 524.2	µg/L	0.090	0.5	0.71		<0.5	<0.5
Bromodichloromethane	11/2/2011	grab	EPA 524.2	µg/L	0.090	0.5	0.71		<0.5	<0.5
Bromodichloromethane	12/1/2011	grab	EPA 524.2	µg/L	0.090	0.5	<0.5	0.52	<0.5	<0.5
Bromodichloromethane	1/3/2012	grab	EPA 524.2	µg/L	0.090	0.5	<0.5	0.59	<0.5	<0.5
Bromodichloromethane	2/1/2012	grab	EPA 524.2	µg/L	0.090	0.5	<0.5	0.57	<0.5	<0.5
Bromodichloromethane	3/6/2012	grab	EPA 524.2	µg/L	0.090	0.5	1.1	1.2	0.71	0.56
Bromodichloromethane	4/2/2012	grab	EPA 524.2	µg/L	0.090	0.5	<0.5	<0.5	<0.090	<0.090
Bromodichloromethane	5/1/2012	grab	EPA 524.2	µg/L	0.090	0.5	0.53	0.59	<0.5	<0.5
Bromodichloromethane	6/4/2012	grab	EPA 524.2	µg/L	0.090	0.5	0.78	0.66		0.85
Bromodichloromethane	7/2/2012	grab	EPA 524.2	µg/L	0.090	0.5	0.61			<0.5
n =							11	8	10	12
Average							<0.5	0.7	<0.5	<0.5
Maximum							1.1	1.4	0.8	0.9
Minimum							0.0	0.3	0.0	0.0
STDev							0.3	0.4	0.3	0.2

Table 16 Certified Laboratory Results of Trihalomethanes, Methylene Chloride, 1, 2 Dichloroethane, and Napthalene

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S1 (tertiary effluent)	S6 (RO Feed)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
1,2-Dichloroethane	8/1/2011	grab	EPA 524.2	µg/L	0.12	0.5		<0.12	<0.12	<0.12
1,2-Dichloroethane	9/1/2011	grab	EPA 524.2	µg/L	0.12	0.5	<0.12		<0.12	<0.12
1,2-Dichloroethane	10/3/2011	grab	EPA 524.2	µg/L	0.12	0.5	<0.12		<0.12	<0.12
1,2-Dichloroethane	11/2/2011	grab	EPA 524.2	µg/L	0.12	0.5	<0.12		<0.12	<0.12
1,2-Dichloroethane	12/1/2011	grab	EPA 524.2	µg/L	0.12	0.5	<0.12	<0.12	<0.12	<0.12
1,2-Dichloroethane	1/3/2012	grab	EPA 524.2	µg/L	0.12	0.5	<0.12	<0.12	<0.12	<0.12
1,2-Dichloroethane	2/1/2012	grab	EPA 524.2	µg/L	0.12	0.5	<0.12	<0.12	<0.12	<0.12
1,2-Dichloroethane	3/6/2012	grab	EPA 524.2	µg/L	0.12	0.5	<0.12	<0.12	<0.12	<0.12
1,2-Dichloroethane	4/2/2012	grab	EPA 524.2	µg/L	0.12	0.5	<0.12	<0.12	<0.12	<0.12
1,2-Dichloroethane	5/1/2012	grab	EPA 524.2	µg/L	0.12	0.5	<0.12	<0.12	<0.12	<0.12
1,2-Dichloroethane	6/4/2012	grab	EPA 524.2	µg/L	0.12	0.5	<0.12	<0.12		<0.12
1,2-Dichloroethane	7/2/2012	grab	EPA 524.2	µg/L	0.12	0.5	<0.12			<0.12
n =							11	8	10	12
Average							<0.12	<0.12	<0.12	<0.12
Maximum							0.1	0.1	0.1	0.1
Minimum							0.1	0.1	0.1	0.1
STDev							0.0	0.0	0.0	0.0
Naphthalene	4/2/2012	Grab	EPA 524.2	µg/L	0.42	0.5	<0.42	<0.42	<0.42	<0.42
Naphthalene	5/1/2012	Grab	EPA 524.2	µg/L	0.42	0.5	<0.42	<0.42	<0.42	<0.42
Naphthalene	6/4/2012	Grab	EPA 524.2	µg/L	0.42	0.5	<0.42	<0.42		<0.42
Naphthalene	7/2/2012	Grab	EPA 524.2	µg/L	0.42	0.5	<0.42			<0.42
n =							4	3	2	4
Average							<0.42	<0.42	<0.42	<0.42
Maximum							0.2	0.2	0.2	0.2
Minimum							0.2	0.2	0.2	0.2
STDev							0.0	0.0	0.0	0.0

Note: For purposes of calculating statistical parameters, results reported below the RL were considered 0.5 X RL and results reported <DL were considered the 0.5 X DL.

Table 17 Certified Laboratory Results of Haloacetic Acids

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S1 (tertiary effluent)	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Monochloroacetic acid (mcaa)	8/4/2011	grab	EPA 552.2	µg/L	0.32	2.0		<0.32				<0.32
Monochloroacetic acid (mcaa)	9/1/2011	grab	EPA 552.2	µg/L	0.32	2.0	<0.32	<0.32	<0.32	<0.32	<0.32	<0.32
Monochloroacetic acid (mcaa)	10/3/2011	grab	EPA 552.2	µg/L	0.32	2.0	<0.32		<0.32	<0.32	<0.32	<0.32
Monochloroacetic acid (mcaa)	10/4/2011	grab	EPA 552.2	µg/L	0.32	2.0		<0.32				
Monochloroacetic acid (mcaa)	11/2/2011	composite	EPA 552.2	µg/L	0.32	2.0	<0.32	<0.32	<0.32	<0.32	<0.32	<0.32
Monochloroacetic acid (mcaa)	12/1/2011	composite	EPA 552.2	µg/L	0.32	2.0	<0.32	<0.32	<0.32	<0.32	<0.32	<0.32
Monochloroacetic acid (mcaa)	1/3/2012	composite	EPA 552.2	µg/L	0.32	2.0	<0.32	<0.32	<0.32	<0.32	<0.32	<0.32
Monochloroacetic acid (mcaa)	2/1/2012	composite	EPA 552.2	µg/L	0.32	2.0	<0.32	<0.32	<0.32	<0.32	<0.32	<0.32
Monochloroacetic acid (mcaa)	3/6/2012	composite	EPA 552.2	µg/L	0.32	2.0	<0.32	<0.32	<0.32	<0.32	<0.32	<0.32
Monochloroacetic acid (mcaa)	4/2/2012	composite	EPA 552.2	µg/L	0.32	2.0	<0.32	<0.32	<0.32	<0.32	<0.32	<0.32
Monochloroacetic acid (mcaa)	5/1/2012	composite	EPA 552.2	µg/L	0.32	2.0	<0.32	<0.32	<0.32	<0.32	<0.32	<0.32
Monochloroacetic acid (mcaa)	6/4/2012	composite	EPA 552.2	µg/L	0.32	2.0	<0.32	<0.32	<0.32	<0.32	<0.32	<0.32
Monochloroacetic acid (mcaa)	7/2/2012	composite	EPA 552.2	µg/L	0.32	2.0	<0.32	<0.32			<0.32	<0.32
n =							11	12	10	10	11	12
Average							<0.32	<0.32	<0.32	<0.32	<0.32	<0.32
Maximum							0.3	0.3	0.3	0.3	0.3	0.2
Minimum							0.2	0.2	0.2	0.2	0.2	0.2
STDev							0.1	0.1	0.1	0.1	0.1	0.0
Monobromoacetic acid (mbaa)	8/4/2011	grab	EPA 552.2	µg/L	0.21	1.0		<0.21				<0.21
Monobromoacetic acid (mbaa)	9/1/2011	grab	EPA 552.2	µg/L	0.21	1.0	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21
Monobromoacetic acid (mbaa)	10/3/2011	grab	EPA 552.2	µg/L	0.21	1.0	<0.21		<0.21	<0.21	<0.21	<0.21
Monobromoacetic acid (mbaa)	10/4/2011	grab	EPA 552.2	µg/L	0.21	1.0		<0.21				
Monobromoacetic acid (mbaa)	11/2/2011	composite	EPA 552.2	µg/L	0.21	1.0	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21
Monobromoacetic acid (mbaa)	12/1/2011	composite	EPA 552.2	µg/L	0.21	1.0	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21
Monobromoacetic acid (mbaa)	1/3/2012	composite	EPA 552.2	µg/L	0.21	1.0	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21
Monobromoacetic acid (mbaa)	2/1/2012	composite	EPA 552.2	µg/L	0.21	1.0	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21
Monobromoacetic acid (mbaa)	3/6/2012	composite	EPA 552.2	µg/L	0.21	1.0	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21
Monobromoacetic acid (mbaa)	4/2/2012	composite	EPA 552.2	µg/L	0.21	1.0	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21
Monobromoacetic acid (mbaa)	5/1/2012	composite	EPA 552.2	µg/L	0.21	1.0	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21
Monobromoacetic acid (mbaa)	6/4/2012	composite	EPA 552.2	µg/L	0.21	1.0	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21
Monobromoacetic acid (mbaa)	7/2/2012	composite	EPA 552.2	µg/L	0.21	1.0	<0.21	<0.21			<0.21	<0.21
n =							11	12	10	10	11	12
Average							<0.21	<0.21	<0.21	<0.21	<0.21	<0.21
Maximum							0.2	0.2	0.2	0.2	0.2	0.2
Minimum							0.1	0.1	0.1	0.1	0.1	0.1
STDev							0.0	0.0	0.0	0.0	0.0	0.0

Table 17 Certified Laboratory Results of Haloacetic Acids

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S1 (tertiary effluent)	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Dichloroacetic acid (dcaa)	8/4/2011	grab	EPA 552.2	µg/L	0.41	1		5.8				<0.41
Dichloroacetic acid (dcaa)	9/1/2011	grab	EPA 552.2	µg/L	0.41	1	<0.41	<0.41	<0.41	<1	<0.41	<0.41
Dichloroacetic acid (dcaa)	10/3/2011	grab	EPA 552.2	µg/L	0.41	1	<0.41		<0.41	<0.41	<0.41	<0.41
Dichloroacetic acid (dcaa)	10/4/2011	grab	EPA 552.2	µg/L	0.41	1		7.1				
Dichloroacetic acid (dcaa)	11/2/2011	composite	EPA 552.2	µg/L	0.41	1	<0.41	8.1	<0.41	<0.41	<0.41	<0.41
Dichloroacetic acid (dcaa)	12/1/2011	composite	EPA 552.2	µg/L	0.41	1	<0.41	5.7	<0.41	<0.41	<0.41	<0.41
Dichloroacetic acid (dcaa)	1/3/2012	composite	EPA 552.2	µg/L	0.41	1	<0.41	5.4	<0.41	<0.41	<0.41	<0.41
Dichloroacetic acid (dcaa)	2/1/2012	composite	EPA 552.2	µg/L	0.41	1	<0.41	6.9	<0.41	<0.41	<0.41	<0.41
Dichloroacetic acid (dcaa)	3/6/2012	composite	EPA 552.2	µg/L	0.41	1	<0.41	7.3	<0.41	<0.41	<0.41	<0.41
Dichloroacetic acid (dcaa)	4/2/2012	composite	EPA 552.2	µg/L	0.41	1	<0.41	6.9	<0.41	<0.41	<0.41	<0.41
Dichloroacetic acid (dcaa)	5/1/2012	composite	EPA 552.2	µg/L	0.41	1	<0.41	5	<0.41	<0.41	<0.41	<0.41
Dichloroacetic acid (dcaa)	6/4/2012	composite	EPA 552.2	µg/L	0.41	1	<0.41	6.6	<0.41	<0.41	<0.41	<0.41
Dichloroacetic acid (dcaa)	7/2/2012	composite	EPA 552.2	µg/L	0.41	1	<0.41	6.4			<0.41	<0.41
n =							11	12	10	10	11	12
Average							<0.41	6	<0.41	<0.41	<0.41	<0.41
Maximum							0.2	8	0.2	0.5	0.2	0.2
Minimum							0.2	0.2	0.2	0.2	0.2	0.2
STDev							0.0	2	0.0	0.1	0.0	0.0
Trichloroacetic acid (tcaa)	8/4/2011	grab	EPA 552.2	µg/L	0.22	1.0		6.9				<0.22
Trichloroacetic acid (tcaa)	9/1/2011	grab	EPA 552.2	µg/L	0.22	1.0	1.2	1.7	<0.22	<0.22	<0.22	<0.22
Trichloroacetic acid (tcaa)	10/3/2011	grab	EPA 552.2	µg/L	0.22	1.0	1.6		<0.22	<0.22	<0.22	<0.22
Trichloroacetic acid (tcaa)	10/4/2011	grab	EPA 552.2	µg/L	0.22	1.0		2				
Trichloroacetic acid (tcaa)	11/2/2011	composite	EPA 552.2	µg/L	0.22	1.0	1.4	1.6	<0.22	<0.22	<0.22	<0.22
Trichloroacetic acid (tcaa)	12/1/2011	composite	EPA 552.2	µg/L	0.22	1.0	2.1	2.9	<0.22	<0.22	<0.22	<0.22
Trichloroacetic acid (tcaa)	1/3/2012	composite	EPA 552.2	µg/L	0.22	1.0	3.5	4.4	<0.22	<0.22	<0.22	<0.22
Trichloroacetic acid (tcaa)	2/1/2012	composite	EPA 552.2	µg/L	0.22	1.0	4.6	4.1	<0.22	<0.22	<0.22	<0.22
Trichloroacetic acid (tcaa)	3/6/2012	composite	EPA 552.2	µg/L	0.22	1.0	4.2	5.1	<0.22	<0.22	<0.22	<0.22
Trichloroacetic acid (tcaa)	4/2/2012	composite	EPA 552.2	µg/L	0.22	1.0	<0.22	3.4	<0.22	<0.22	<0.22	<0.22
Trichloroacetic acid (tcaa)	5/1/2012	composite	EPA 552.2	µg/L	0.22	1.0	2.3	2.9	<0.22	<0.22	<0.22	<0.22
Trichloroacetic acid (tcaa)	6/4/2012	composite	EPA 552.2	µg/L	0.22	1.0	1.4	3.2	<0.22	<0.22	<0.22	<0.22
Trichloroacetic acid (tcaa)	7/2/2012	composite	EPA 552.2	µg/L	0.22	1.0	2.5	3.4			<0.22	<0.22
n =							11	12	10	10	11	12
Average							2.3	3.5	<0.22	<0.22	<0.22	<0.22
Maximum							4.6	6.9	0.1	0.1	0.1	0.1
Minimum							0.1	1.6	0.1	0.1	0.1	0.1
STDev							1.4	1.5	0.0	0.0	0.0	0.0
Dibromoacetic acid (dbaa)	8/4/2011	grab	EPA 552.2	µg/L	0.13	1.0		<1				<0.13

Table 17 Certified Laboratory Results of Haloacetic Acids

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S1 (tertiary effluent)	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Dibromoacetic acid (dbaa)	9/1/2011	grab	EPA 552.2	µg/L	0.13	1.0	<0.13	<1	<0.13	<0.13	<0.13	<0.13
Dibromoacetic acid (dbaa)	10/3/2011	grab	EPA 552.2	µg/L	0.13	1.0	<0.13		<0.13	<0.13	<0.13	<0.13
Dibromoacetic acid (dbaa)	10/4/2011	grab	EPA 552.2	µg/L	0.13	1.0		<1				
Dibromoacetic acid (dbaa)	11/2/2011	composite	EPA 552.2	µg/L	0.13	1.0	<0.13	<1	<0.13	<0.13	<0.13	<0.13
Dibromoacetic acid (dbaa)	12/1/2011	composite	EPA 552.2	µg/L	0.13	1.0	<0.13	<1	<0.13	<0.13	<0.13	<0.13
Dibromoacetic acid (dbaa)	1/3/2012	composite	EPA 552.2	µg/L	0.13	1.0	<0.13	<1	<0.13	<0.13	<0.13	<0.13
Dibromoacetic acid (dbaa)	2/1/2012	composite	EPA 552.2	µg/L	0.13	1.0	<0.13	<1	<0.13	<0.13	<0.13	<0.13
Dibromoacetic acid (dbaa)	3/6/2012	composite	EPA 552.2	µg/L	0.13	1.0	<0.13	<1	<0.13	<0.13	<0.13	<0.13
Dibromoacetic acid (dbaa)	4/2/2012	composite	EPA 552.2	µg/L	0.13	1.0	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13
Dibromoacetic acid (dbaa)	5/1/2012	composite	EPA 552.2	µg/L	0.13	1.0	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13
Dibromoacetic acid (dbaa)	6/4/2012	composite	EPA 552.2	µg/L	0.13	1.0	<0.13	1.3	<0.13	<0.13	<0.13	<0.13
Dibromoacetic acid (dbaa)	7/2/2012	composite	EPA 552.2	µg/L	0.13	1.0	<0.13	1.1			<0.13	<0.13
n =							11	12	10	10	11	12
Average							<0.13	<1	<0.13	<0.13	<0.13	<0.13
Maximum							0.1	1	0.1	0.1	0.1	0.1
Minimum							0.1	0.1	0.1	0.1	0.1	0.1
STDev							0.0	0.3	0.0	0.0	0.0	0.0
HAA5, Total	8/4/2011	grab	EPA 552.2	µg/L	NA	1.0		13				<1
HAA5, Total	9/1/2011	grab	EPA 552.2	µg/L	NA	1.0	1.2	1.7	<1	<1	<1	<1
HAA5, Total	10/3/2011	Grab	EPA 552.2	µg/L	NA	1.0	1.6		<1	<1	<1	<1
HAA5, Total	10/4/2011	Grab	EPA 552.2	µg/L	NA	1.0		9.1				
HAA5, Total	11/2/2011	composite	EPA 552.2	µg/L	NA	1.0	1.4	9.7	<1	<1	<1	<1
HAA5, Total	12/1/2011	composite	EPA 552.2	µg/L	NA	1.0	2.1	8.6	<1	<1	<1	<1
HAA5, Total	1/3/2012	composite	EPA 552.2	µg/L	NA	1.0	3.5	9.8	<1	<1	<1	<1
HAA5, Total	2/1/2012	composite	EPA 552.2	µg/L	NA	1.0	4.6	11	<1	<1	<1	<1
HAA5, Total	3/6/2012	composite	EPA 552.2	µg/L	NA	1.0	4.2	12	<1	<1	<1	<1
HAA5, Total	4/2/2012	composite	EPA 552.2	µg/L	NA	1.0	<1	10	<1	<1	<1	<1
HAA5, Total	5/1/2012	composite	EPA 552.2	µg/L	NA	1.0	2.3	7.8	<1	<1	<1	<1
HAA5, Total	6/4/2012	composite	EPA 552.2	µg/L	NA	1.0		11	<1	<1	<1	<1
HAA5, Total	7/2/2012	composite	EPA 552.2	µg/L	NA	1.0	2.5	11			<1	<1
n =							11	12	10	10	11	12
Average							2.3	9.6	<1	<1	<1	<1
Maximum							4.6	13	0.5	0.5	0.5	0.5
Minimum							0.0	1.7	0.0	0.0	0.0	0.0
STDev							1.4	2.9	0.0	0.0	0.0	0.0

Note: For purposes of calculating statistical parameters, results reported below the RL were considered 0.5 X RL and results reported below the DL were considered the 0.5 X DL.

Table 18 Certified Laboratory Results of Nitrosamines

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S1 (tertiary effluent)	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
N-Nitrosodiethylamine (NDEA)	8/1/2011	grab	EPA 521	ng/L	0.72	2.0		<0.72	<0.72	<0.72	<0.72	<0.72
N-Nitrosodiethylamine (NDEA)	9/1/2011	grab	EPA 521	ng/L	0.72	2.0	<2	<2	<2	<0.72	<2	<0.72
N-Nitrosodiethylamine (NDEA)	10/3/2011	grab	EPA 521	ng/L	0.72	2.0	<0.72	<2	<0.72	<0.72	<0.72	<0.72
N-Nitrosodiethylamine (NDEA)	11/2/2011	grab	EPA 521	ng/L	0.72	2.0	<2.3	<0.72	<0.72	6.1	<0.72	<0.72
N-Nitrosodiethylamine (NDEA)	12/1/2011	grab	EPA 521	ng/L	0.72	2.0	<2	2.6	<0.72	<0.72	<0.72	2.5
N-Nitrosodiethylamine (NDEA)	1/3/2012	grab	EPA 521	ng/L	0.72	2.0	11	7.9	<2	<0.72	<2	2.9
N-Nitrosodiethylamine (NDEA)	2/1/2012	grab	EPA 521	ng/L	0.72	2.0	<2	<2	<0.72	<2	<2	<2
N-Nitrosodiethylamine (NDEA)	2/8/2012	grab	EPA 521	ng/L	0.72	2.0	<2	<0.72			<2	<2
N-Nitrosodiethylamine (NDEA)	2/15/2012	grab	EPA 521	ng/L	0.72	2.0	<0.72	<2			<0.72	<0.72
N-Nitrosodiethylamine (NDEA)	2/22/2012	grab	EPA 521	ng/L	0.72	2.0	<0.72	3.4			<2	<0.72
N-Nitrosodiethylamine (NDEA)	3/6/2012	grab	EPA 521	ng/L	0.72	2.0	<0.72	<2		<0.72	<0.72	<0.72
N-Nitrosodiethylamine (NDEA)	4/2/2012	grab	EPA 521	ng/L	0.72	2.0	<2	<2	<0.72	<0.72		
N-Nitrosodiethylamine (NDEA)	4/23/2012	grab	EPA 521	ng/L	0.72	2.0					<2	4.9
N-Nitrosodiethylamine (NDEA)	5/1/2012	grab	EPA 521	ng/L	0.72	2.0	<2	<0.72	<0.72	<0.72	<0.72	<0.72
N-Nitrosodiethylamine (NDEA)	6/4/2012	grab	EPA 521	ng/L	0.72	2.0	<0.72	<0.8	<0.72	<0.72	<0.72	<0.72
N-Nitrosodiethylamine (NDEA)	7/2/2012	grab	EPA 521	ng/L	0.72	2.0	<0.72	<0.72			<0.72	<0.72
n =							14	15	11	11	15	15
Average							<2	<2	<0.72	<2	<0.72	<2
Maximum							11	7.9	1.0	6.1	1.0	4.9
Minimum							0.40	0.40	0.1	0.40	0.40	0.40
STDev							2.8	2.0	0.30	1.7	0.30	1.3
N-Nitrosodimethylamine (NDMA)	8/1/2011	grab	EPA 521	ng/L	0.28	2.0		3.8	<2	<2	<2	<0.28
N-Nitrosodimethylamine (NDMA)	9/1/2011	grab	EPA 521	ng/L	0.28	2.0	3.6	6.3	<2	2.6	<2	<2
N-Nitrosodimethylamine (NDMA)	10/3/2011	grab	EPA 521	ng/L	0.28	2.0	<2	6.1	<2	<2	<2	<2
N-Nitrosodimethylamine (NDMA)	10/18/2011	grab	EPA 521	ng/L	0.28	2.0						
N-Nitrosodimethylamine (NDMA)	11/2/2011	grab	EPA 521	ng/L	0.28	2.0	3.2	2.3	ND	<2	ND	<0.28
N-Nitrosodimethylamine (NDMA)	12/1/2011	grab	EPA 521	ng/L	0.28	2.0	2.1	2.1	<2	2.3	<2	<0.28
N-Nitrosodimethylamine (NDMA)	1/3/2012	grab	EPA 521	ng/L	0.28	2.0	7.6	<2	<2	<2	<2	5.5
N-Nitrosodimethylamine (NDMA)	2/1/2012	grab	EPA 521	ng/L	0.28	2.0	<2	2.9	<2	<2	ND	<2
N-Nitrosodimethylamine (NDMA)	2/8/2012	grab	EPA 521	ng/L	0.28	2.0		<2			<2	<0.28
N-Nitrosodimethylamine (NDMA)	2/15/2012	grab	EPA 521	ng/L	0.28	2.0		<2			<2	<2
N-Nitrosodimethylamine (NDMA)	2/22/2012	grab	EPA 521	ng/L	0.28	2.0		<2			<2	<2
N-Nitrosodimethylamine (NDMA)	3/6/2012	grab	EPA 521	ng/L	0.28	2.0	<2	<2		<2	<2	<0.28
N-Nitrosodimethylamine (NDMA)	4/2/2012	grab	EPA 521	ng/L	0.28	2.0	20	17	7.9	8.7		
N-Nitrosodimethylamine (NDMA)	4/23/2012	grab	EPA 521	ng/L	0.28	2.0					ND	<0.28
N-Nitrosodimethylamine (NDMA)	5/1/2012	grab	EPA 521	ng/L	0.28	2.0						<2

Table 18 Certified Laboratory Results of Nitrosamines

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S1 (tertiary effluent)	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
N-Nitrosodimethylamine (NDMA)	6/4/2012	grab	EPA 521	ng/L	0.28	2.0	<2	<2.2	<0.28	<2	<0.28	<0.28
N-Nitrosodimethylamine (NDMA)	7/2/2012	grab	EPA 521	ng/L	0.28	2.0	<2	<2			<2	<2
n =							10	14	9	10	14	15
Average							4.2	3.5	<2.0	2.1	<2.0	<2.0
Maximum							20	17	7.9	8.7	2.0	5.5
Minimum							1.0	1.0	0.10	1.0	0.10	0.10
STDev							5.9	4.3	2.4	2.4	0.60	1.3
N-Nitrosodi-n-butylamine (NDBA)	8/1/2011	grab	EPA 521	ng/L	0.59	2.0		<2	<0.59	<0.59	<0.59	<0.59
N-Nitrosodi-n-butylamine (NDBA)	9/1/2011	grab	EPA 521	ng/L	0.59	2.0	<0.59	<2	<0.59	<0.59	<0.59	<0.59
N-Nitrosodi-n-butylamine (NDBA)	10/3/2011	grab	EPA 521	ng/L	0.59	2.0	<0.59	<2	<0.59	<0.59	<0.59	<0.59
N-Nitrosodi-n-butylamine (NDBA)	11/2/2011	grab	EPA 521	ng/L	0.59	2.0	<0.59	<0.59	<0.59	<0.59	<0.59	<0.59
N-Nitrosodi-n-butylamine (NDBA)	12/1/2011	grab	EPA 521	ng/L	0.59	2.0	<2	<0.59	<0.59	<0.59	<2	<0.59
N-Nitrosodi-n-butylamine (NDBA)	1/3/2012	grab	EPA 521	ng/L	0.59	2.0	<0.59	<0.59	<0.59	<0.59	<0.59	<0.59
N-Nitrosodi-n-butylamine (NDBA)	2/1/2012	grab	EPA 521	ng/L	0.59	2.0	<0.59	<0.59	<2	<0.59	<0.59	<2
N-Nitrosodi-n-butylamine (NDBA)	2/8/2012	grab	EPA 521	ng/L	0.59	2.0		<0.59			<2	<0.59
N-Nitrosodi-n-butylamine (NDBA)	2/15/2012	grab	EPA 521	ng/L	0.59	2.0		<0.59			<0.59	<0.59
N-Nitrosodi-n-butylamine (NDBA)	2/22/2012	grab	EPA 521	ng/L	0.59	2.0		<0.59			<0.59	<0.59
N-Nitrosodi-n-butylamine (NDBA)	3/6/2012	grab	EPA 521	ng/L	0.59	2.0	<0.59	<0.59		<0.59	<0.59	<0.59
N-Nitrosodi-n-butylamine (NDBA)	4/2/2012	grab	EPA 521	ng/L	0.59	2.0	<0.59	<0.59	<0.59	<0.59		
N-Nitrosodi-n-butylamine (NDBA)	4/23/2012	grab	EPA 521	ng/L	0.59	2.0					<0.59	<0.59
N-Nitrosodi-n-butylamine (NDBA)	5/1/2012	grab	EPA 521	ng/L	0.59	2.0	<0.59	<0.59	<0.59	<0.59	<0.59	<0.59
N-Nitrosodi-n-butylamine (NDBA)	6/4/2012	grab	EPA 521	ng/L	0.59	2.0	<0.59	<2.2	<0.59	<2	<0.59	<2
N-Nitrosodi-n-butylamine (NDBA)	7/2/2012	grab	EPA 521	ng/L	0.59	2.0	<0.59	<0.59			<0.59	<0.59
n =							11	15	10	11	15	15
Average							<0.59	<0.59	<0.59	<0.59	<0.59	<0.59
Maximum							1.0	1.1	1.0	1.0	1.0	1.0
Minimum							0.3	0.3	0.3	0.3	0.3	0.3
STDev							0.2	0.3	0.2	0.2	0.2	0.2

Table 18 Certified Laboratory Results of Nitrosamines

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S1 (tertiary effluent)	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
N-Nitrosodi-n-propylamine (NDPA)	8/1/2011	grab	EPA 521	ng/L	0.35	2.0		<0.35	<0.35	<0.35	<0.35	<0.35
N-Nitrosodi-n-propylamine (NDPA)	9/1/2011	grab	EPA 521	ng/L	0.35	2.0	<0.35	<0.35	<0.35	<0.35	<0.35	<0.35
N-Nitrosodi-n-propylamine (NDPA)	10/3/2011	grab	EPA 521	ng/L	0.35	2.0	<0.35	<0.35	<0.35	<0.35	<0.35	<0.35
N-Nitrosodi-n-propylamine (NDPA)	11/2/2011	grab	EPA 521	ng/L	0.35	2.0	<0.35	<0.35	<0.35	<0.35	<0.35	<0.35
N-Nitrosodi-n-propylamine (NDPA)	12/1/2011	grab	EPA 521	ng/L	0.35	2.0	<0.35	<0.35	<0.35	<0.35	<0.35	<0.35
N-Nitrosodi-n-propylamine (NDPA)	1/3/2012	grab	EPA 521	ng/L	0.35	2.0	<0.35	<0.35	<0.35	<0.35	<0.35	<0.35
N-Nitrosodi-n-propylamine (NDPA)	2/1/2012	grab	EPA 521	ng/L	0.35	2.0	<0.35	<0.35	<0.35	<0.35	<0.35	<0.35
N-Nitrosodi-n-propylamine (NDPA)	2/8/2012	grab	EPA 521	ng/L	0.35	2.0		<0.35			<0.35	<0.35
N-Nitrosodi-n-propylamine (NDPA)	2/15/2012	grab	EPA 521	ng/L	0.35	2.0		<0.35			<0.35	<0.35
N-Nitrosodi-n-propylamine (NDPA)	2/22/2012	grab	EPA 521	ng/L	0.35	2.0		<0.35			<0.35	<0.35
N-Nitrosodi-n-propylamine (NDPA)	3/6/2012	grab	EPA 521	ng/L	0.35	2.0	<0.35	<0.35		<0.35	<0.35	<0.35
N-Nitrosodi-n-propylamine (NDPA)	4/2/2012	grab	EPA 521	ng/L	0.35	2.0	<0.35	<0.35	<0.35	<0.35		
N-Nitrosodi-n-propylamine (NDPA)	4/23/2012	grab	EPA 521	ng/L	0.35	2.0					<0.35	<0.35
N-Nitrosodi-n-propylamine (NDPA)	5/1/2012	grab	EPA 521	ng/L	0.35	2.0	<0.35	<0.35	<0.35	<0.35	<0.35	<0.35
N-Nitrosodi-n-propylamine (NDPA)	6/4/2012	grab	EPA 521	ng/L	0.35	2.0	<0.35	<0.39	<0.35	<0.35	<0.35	<0.35
N-Nitrosodi-n-propylamine (NDPA)	7/2/2012	grab	EPA 521	ng/L	0.35	2.0	<0.35	<0.35			<0.35	<0.35
n =							11	15	10	11	15	15
Average							<0.35	<0.35	<0.35	<0.35	<0.35	<0.35
Maximum							0.2	0.2	0.2	0.2	0.2	0.2
Minimum							0.2	0.2	0.2	0.2	0.2	0.2
STDev							0.0	0.0	0.0	0.0	0.0	0.0
N-Nitrosomethylethylamine (NMEA)	8/1/2011	grab	EPA 521	ng/L	0.28	2.0		<0.28	<0.28	<0.28	<0.28	<0.28
N-Nitrosomethylethylamine (NMEA)	9/1/2011	grab	EPA 521	ng/L	0.28	2.0	<0.28	<0.28	<0.28	<0.28	<0.28	<0.28
N-Nitrosomethylethylamine (NMEA)	10/3/2011	grab	EPA 521	ng/L	0.28	2.0	<0.28	<0.28	<0.28	<0.28	<0.28	<0.28
N-Nitrosomethylethylamine (NMEA)	11/2/2011	grab	EPA 521	ng/L	0.28	2.0	<0.28	<0.28	<0.28	<0.28	<0.28	<0.28
N-Nitrosomethylethylamine (NMEA)	12/1/2011	grab	EPA 521	ng/L	0.28	2.0	<2	<0.28	<0.28	<2	<0.28	<2
N-Nitrosomethylethylamine (NMEA)	1/3/2012	grab	EPA 521	ng/L	0.28	2.0	<0.28	<0.28	<0.28	<0.28	<0.28	<0.28
N-Nitrosomethylethylamine (NMEA)	2/1/2012	grab	EPA 521	ng/L	0.28	2.0	<0.28	<0.28	<0.28	<0.28	<0.28	<0.28
N-Nitrosomethylethylamine (NMEA)	2/8/2012	grab	EPA 521	ng/L	0.28	2.0		<0.28			<0.28	<0.28
N-Nitrosomethylethylamine (NMEA)	2/15/2012	grab	EPA 521	ng/L	0.28	2.0		<0.28			<0.28	<0.28
N-Nitrosomethylethylamine (NMEA)	2/22/2012	grab	EPA 521	ng/L	0.28	2.0		<0.28			<0.28	<0.28
N-Nitrosomethylethylamine (NMEA)	3/6/2012	grab	EPA 521	ng/L	0.28	2.0	<0.28	<0.28		<0.28	<0.28	<0.28
N-Nitrosomethylethylamine (NMEA)	4/2/2012	grab	EPA 521	ng/L	0.28	2.0	<0.28	<0.28	<0.28	<0.28		
N-Nitrosomethylethylamine (NMEA)	4/23/2012	grab	EPA 521	ng/L	0.28	2.0					<0.28	<0.28
N-Nitrosomethylethylamine (NMEA)	5/1/2012	grab	EPA 521	ng/L	0.28	2.0	<0.28	<0.28	<0.28	<0.28	<0.28	<0.28
N-Nitrosomethylethylamine (NMEA)	6/4/2012	grab	EPA 521	ng/L	0.28	2.0	<0.28	<0.31	<0.28	<0.28	<0.28	<0.28

Table 18 Certified Laboratory Results of Nitrosamines

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S1 (tertiary effluent)	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
N-Nitrosomethylethylamine (NMEA)	7/2/2012	grab	EPA 521	ng/L	0.28	2.0	<0.28	<0.28			<0.28	<0.28
n =							11	15	10	11	15	15
Average							<0.28	<0.28	<0.28	<0.28	<0.28	<0.28
Maximum							1.0	0.2	0.2	1.0	0.2	1.0
Minimum							0.1	0.1	0.1	0.1	0.1	0.1
STDev							0.3	0.0	0.0	0.3	0.0	0.2
N-Nitrosomorpholine (NMOR)	8/1/2011	grab	EPA 521	ng/L	0.47	2.0		20	<0.47	<2	<2	<0.47
N-Nitrosomorpholine (NMOR)	9/1/2011	grab	EPA 521	ng/L	0.47	2.0	25	23	<0.47	<0.47	<2	<0.47
N-Nitrosomorpholine (NMOR)	10/3/2011	grab	EPA 521	ng/L	0.47	2.0	17	21	<0.47	<2	<2	<0.47
N-Nitrosomorpholine (NMOR)	11/2/2011	grab	EPA 521	ng/L	0.47	2.0	25	25	<2.2	<2	<2.3	<0.47
N-Nitrosomorpholine (NMOR)	12/1/2011	grab	EPA 521	ng/L	0.47	2.0	23	19	<2	<2	<2	<0.47
N-Nitrosomorpholine (NMOR)	1/3/2012	grab	EPA 521	ng/L	0.47	2.0	17	14	<0.47	<0.47	<0.47	<0.47
N-Nitrosomorpholine (NMOR)	2/1/2012	grab	EPA 521	ng/L	0.47	2.0	28	28	<2	<2	<2	<2
N-Nitrosomorpholine (NMOR)	2/8/2012	grab	EPA 521	ng/L	0.47	2.0		34			<2	<0.47
N-Nitrosomorpholine (NMOR)	2/15/2012	grab	EPA 521	ng/L	0.47	2.0		17			<0.47	<0.47
N-Nitrosomorpholine (NMOR)	2/22/2012	grab	EPA 521	ng/L	0.47	2.0		22			<0.47	<0.47
N-Nitrosomorpholine (NMOR)	3/6/2012	grab	EPA 521	ng/L	0.47	2.0	26	30		<2	<2	<0.47
N-Nitrosomorpholine (NMOR)	4/2/2012	grab	EPA 521	ng/L	0.47	2.0	8.8	7.7	<2	<2		
N-Nitrosomorpholine (NMOR)	4/23/2012	grab	EPA 521	ng/L	0.47	2.0					<2	<0.47
N-Nitrosomorpholine (NMOR)	5/1/2012	grab	EPA 521	ng/L	0.47	2.0	15	13	<2	<0.47	<2	<0.47
N-Nitrosomorpholine (NMOR)	6/4/2012	grab	EPA 521	ng/L	0.47	2.0	19	23	<2	<2	<2	<0.47
N-Nitrosomorpholine (NMOR)	7/2/2012	grab	EPA 521	ng/L	0.47	2.0	12	14			<2	<0.47
n =							11	15	10	11	15	15
Average							20	21	<2.0	<2.0	<2.0	<0.47
Maximum							28	34	1.1	1.0	1.2	1.0
Minimum							8.8	7.7	0.2	0.2	0.2	0.2
STDev							6.3	7.0	0.4	0.4	0.3	0.2
N-Nitrosopiperidine (NPIP)	8/1/2011	grab	EPA 521	ng/L	0.71	2.0		<0.71	<0.71	<0.71	<0.71	<0.71
N-Nitrosopiperidine (NPIP)	9/1/2011	grab	EPA 521	ng/L	0.71	2.0	<0.71	<0.71	<0.71	<0.71	<0.71	<0.71
N-Nitrosopiperidine (NPIP)	10/3/2011	grab	EPA 521	ng/L	0.71	2.0	<0.71	<0.71	<0.71	<0.71	<0.71	<0.71
N-Nitrosopiperidine (NPIP)	11/2/2011	grab	EPA 521	ng/L	0.71	2.0	<0.71	<0.71	<0.71	<0.71	<0.71	<0.71
N-Nitrosopiperidine (NPIP)	12/1/2011	grab	EPA 521	ng/L	0.71	2.0	<0.71	<0.71	<0.71	<0.71	<0.71	<0.71
N-Nitrosopiperidine (NPIP)	1/3/2012	grab	EPA 521	ng/L	0.71	2.0	<0.71	<0.71	<0.71	<0.71	<0.71	<0.71
N-Nitrosopiperidine (NPIP)	2/1/2012	grab	EPA 521	ng/L	0.71	2.0	<0.71	<0.71	<0.71	<0.71	<0.71	<0.71
N-Nitrosopiperidine (NPIP)	2/8/2012	grab	EPA 521	ng/L	0.71	2.0		<0.71			<0.71	<0.71
N-Nitrosopiperidine (NPIP)	2/15/2012	grab	EPA 521	ng/L	0.71	2.0		<0.71			<0.71	<0.71
N-Nitrosopiperidine (NPIP)	2/22/2012	grab	EPA 521	ng/L	0.71	2.0		<0.71			<0.71	<0.71

Table 18 Certified Laboratory Results of Nitrosamines

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S1 (tertiary effluent)	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
N-Nitrosopiperidine (NPIP)	3/6/2012	grab	EPA 521	ng/L	0.71	2.0	<0.71	<0.71		<0.71	<0.71	<0.71
N-Nitrosopiperidine (NPIP)	4/2/2012	grab	EPA 521	ng/L	0.71	2.0	<0.71	<0.71	<0.71	<0.71		
N-Nitrosopiperidine (NPIP)	4/23/2012	grab	EPA 521	ng/L	0.71	2.0					<0.71	<0.71
N-Nitrosopiperidine (NPIP)	5/1/2012	grab	EPA 521	ng/L	0.71	2.0	<0.71	<0.71	<0.71	<0.71	<0.71	<0.71
N-Nitrosopiperidine (NPIP)	6/4/2012	grab	EPA 521	ng/L	0.71	2.0	<0.71	<0.79	<0.71	<0.71	<0.71	<0.71
N-Nitrosopiperidine (NPIP)	7/2/2012	grab	EPA 521	ng/L	0.71	2.0	<0.71	<0.71			<0.71	<0.71
n =							11	15	10	11	15	15
Average							<0.71	<0.71	<0.71	<0.71	<0.71	<0.71
Maximum							0.4	0.4	0.4	0.4	0.4	0.4
Minimum							0.4	0.4	0.4	0.4	0.4	0.4
STDev							0.0	0.0	0.0	0.0	0.0	0.0
N-Nitrosopyrrolidine (NPYR)	8/1/2011	grab	EPA 521	ng/L	0.66	2.0		<0.66	<0.66	<0.66	<0.66	<0.66
N-Nitrosopyrrolidine (NPYR)	9/1/2011	grab	EPA 521	ng/L	0.66	2.0	<0.66	<0.66	<0.66	<0.66	<0.66	<0.66
N-Nitrosopyrrolidine (NPYR)	10/3/2011	grab	EPA 521	ng/L	0.66	2.0	<0.66	<0.66	<0.66	<0.66	<0.66	<0.66
N-Nitrosopyrrolidine (NPYR)	11/2/2011	grab	EPA 521	ng/L	0.66	2.0	<0.66	<0.66	<0.66	<0.66	<0.66	<0.66
N-Nitrosopyrrolidine (NPYR)	12/1/2011	grab	EPA 521	ng/L	0.66	2.0	<0.66	<0.66	<0.66	<0.66	<0.66	<0.66
N-Nitrosopyrrolidine (NPYR)	1/3/2012	grab	EPA 521	ng/L	0.66	2.0	<0.66	<0.66	<0.66	<0.66	<0.66	<0.66
N-Nitrosopyrrolidine (NPYR)	2/1/2012	grab	EPA 521	ng/L	0.66	2.0	<0.66	<0.66	<0.66	<0.66	<0.66	<0.66
N-Nitrosopyrrolidine (NPYR)	2/8/2012	grab	EPA 521	ng/L	0.66	2.0		<0.66			<0.66	<0.66
N-Nitrosopyrrolidine (NPYR)	2/15/2012	grab	EPA 521	ng/L	0.66	2.0		<0.66			<0.66	<0.66
N-Nitrosopyrrolidine (NPYR)	2/22/2012	grab	EPA 521	ng/L	0.66	2.0		<0.66			<0.66	<0.66
N-Nitrosopyrrolidine (NPYR)	3/6/2012	grab	EPA 521	ng/L	0.66	2.0	<0.66	<0.66		<0.66	<0.66	<0.66
N-Nitrosopyrrolidine (NPYR)	4/2/2012	grab	EPA 521	ng/L	0.66	2.0	<2	<0.66	<0.66	<0.66		
N-Nitrosopyrrolidine (NPYR)	4/23/2012	grab	EPA 521	ng/L	0.66	2.0					<0.66	<0.66
N-Nitrosopyrrolidine (NPYR)	5/1/2012	grab	EPA 521	ng/L	0.66	2.0	<0.66	<0.66	<0.66	<0.66	<0.66	<0.66
N-Nitrosopyrrolidine (NPYR)	6/4/2012	grab	EPA 521	ng/L	0.66	2.0	<2	<2.2	<0.66	<0.66	<0.66	<0.66
N-Nitrosopyrrolidine (NPYR)	7/2/2012	grab	EPA 521	ng/L	0.66	2.0	<0.66	<0.66			<0.66	<0.66
n =							11	15	10	11	15	15
Average							<0.66	<0.66	<0.66	<0.66	<0.66	<0.66
Maximum							1.0	1.1	0.4	0.3	0.4	0.3
Minimum							0.3	0.3	0.3	0.3	0.3	0.3
STDev							0.3	0.2	0.0	0.0	0.0	0.0

Note: For purposes of calculating statistical parameters, results reported below the RL were considered 0.5 X RL and results reported <DL were considered the 0.5 X DL.

Table 19 Certified Laboratory Results of 1,4-Dioxane

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
1,4-Dioxane	8/1/2011	grab	EPA 8270M	µg/L	0.040	0.50	1.9			<0.040	<0.040
1,4-Dioxane	9/1/2011	grab	EPA 8270M	µg/L	0.040	0.50	1.6	<0.040	<0.040	<0.040	<0.040
1,4-Dioxane	10/3/2011	grab	EPA 8270M	µg/L	0.040	0.50	1.8	<0.040	<0.040	<0.040	<0.040
1,4-Dioxane	11/2/2011	composite	EPA 8270M	µg/L	0.040	0.50	1.0	<0.040	<0.040	<0.040	<0.040
1,4-Dioxane	12/1/2011	composite	EPA 8270M	µg/L	0.040	0.50	1.2	<0.040	<0.5	<0.5	<0.040
1,4-Dioxane	1/3/2012	composite	EPA 8270M	µg/L	0.040	0.50	1.3	<0.040	<0.5	<0.040	<0.040
1,4-Dioxane	2/1/2012	composite	EPA 8270M	µg/L	0.040	0.50	1.2	<0.040	<0.040	<0.5	<0.040
1,4-Dioxane	3/6/2012	composite	EPA 8270M	µg/L	0.040	0.50	1.4	<0.040	<0.040	<0.040	<0.040
1,4-Dioxane	4/2/2012	composite	EPA 8270M	µg/L	0.040	0.50	1.4	<0.040	<0.040	<0.040	<0.046
1,4-Dioxane	5/1/2012	composite	EPA 8270M	µg/L	0.040	0.50	1.5	<0.04	<0.04	<0.04	<0.04
1,4-Dioxane	6/4/2012	composite	EPA 8270M	µg/L	0.040	0.50	1.3			<0.04	<0.04
1,4-Dioxane	7/2/2012	composite	EPA 8270M	µg/L	0.040	0.50				<0.04	<0.04
n =							11	9	9	12	12
Average							1.4	<0.040	<0.50	<0.50	<0.040
Maximum							1.9	0.02	0.25	0.25	0.03
Minimum							1.0	0.02	0.02	0.02	0.02
STDev							0.27	0.00	0.10	0.09	0.00

Note: For purposes of calculating statistical parameters, results reported below the RL were considered 0.5 X RL and results reported <DL were considered the 0.5 X DL.

Table 20 Certified Laboratory Results of Total Organic Carbon (TOC)

Parameter	Sample Date	[1] Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Total Organic Carbon (TOC)	8/1/2011	grab	SM5310C	mg/l	0.009	0.3	6		0.31		0.35
Total Organic Carbon (TOC)	8/4/2011	grab	SM5310C	mg/l	0.009	0.3		0.46		<0.3	<0.3
Total Organic Carbon (TOC)	8/8/2011	grab	SM5310C	mg/l	0.009	0.3					0.45
Total Organic Carbon (TOC)	8/11/2011	grab	SM5310C	mg/l	0.009	0.3					0.45
Total Organic Carbon (TOC)	8/15/2011	grab	SM5310C	mg/l	0.009	0.3					0.9
Total Organic Carbon (TOC)	8/18/2011	grab	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	8/22/2011	grab	SM5310C	mg/l	0.009	0.3					0.66
Total Organic Carbon (TOC)	8/25/2011	grab	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	8/29/2011	grab	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	9/1/2011	grab	SM5310C	mg/l	0.009	0.3	7.2	<0.3	0.34	0.31	0.32
Total Organic Carbon (TOC)	9/6/2011	grab	SM5310C	mg/l	0.009	0.3					0.41
Total Organic Carbon (TOC)	9/8/2011	grab	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	9/12/2011	grab	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	9/15/2011	grab	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	9/19/2011	grab	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	9/22/2011	grab	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	9/26/2011	grab	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	9/29/2011	grab	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	10/3/2011	grab	SM5310C	mg/l	0.009	0.3		<0.3	<0.3	<0.009	<0.3
Total Organic Carbon (TOC)	10/4/2011	grab	SM5310C	mg/l	0.009	0.3	5				
Total Organic Carbon (TOC)	10/6/2011	grab	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	10/10/2011	grab	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	10/13/2011	grab	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	10/17/2011	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	10/20/2011	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	10/24/2011	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	10/31/2011	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	11/2/2011	composite	SM5310C	mg/l	0.009	0.3	4.3	<0.3	<0.3	<0.3	
Total Organic Carbon (TOC)	11/3/2011	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	11/7/2011	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	11/10/2011	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	11/14/2011	composite	SM5310C	mg/l	0.009	0.3					<0.3

Table 20 Certified Laboratory Results of Total Organic Carbon (TOC)

Parameter	Sample Date	[1] Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Total Organic Carbon (TOC)	11/17/2011	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	11/21/2011	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	11/29/2011	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	12/1/2011	composite	SM5310C	mg/l	0.009	0.3	5.8	<0.3	<0.3	<0.3	<0.3
Total Organic Carbon (TOC)	12/5/2011	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	12/8/2011	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	12/12/2011	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	12/15/2011	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	12/19/2011	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	12/22/2011	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	12/27/2011	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	12/29/2011	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	1/3/2012	composite	SM5310C	mg/l	0.009	0.3	6.5	<0.3	<0.3	<0.3	<0.3
Total Organic Carbon (TOC)	1/5/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	1/9/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	1/12/2012	composite	SM5310C	mg/l	0.009	0.3					[2] 1.4
Total Organic Carbon (TOC)	1/17/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	1/19/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	1/23/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	1/26/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	1/30/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	2/1/2012	composite	SM5310C	mg/l	0.018	0.6	5.8	<0.3	<0.3	<0.3	
Total Organic Carbon (TOC)	2/2/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	2/6/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	2/9/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	2/14/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	2/16/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	2/20/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	2/22/2012	composite	SM5310C	mg/l	0.009	0.3	6.4			<0.3	<0.3
Total Organic Carbon (TOC)	2/23/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	2/27/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	3/1/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3

Table 20 Certified Laboratory Results of Total Organic Carbon (TOC)

Parameter	Sample Date	[1] Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Total Organic Carbon (TOC)	3/6/2012	composite	SM5310C	mg/l	0.009	0.3	6	<0.3	<0.3	<0.3	<0.3
Total Organic Carbon (TOC)	3/8/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	3/12/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	3/15/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	3/19/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	3/22/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	3/26/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	3/29/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	4/2/2012	composite	SM5310C	mg/l	0.009	0.3	7	<0.3	<0.3	<0.3	<0.3
Total Organic Carbon (TOC)	4/5/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	4/9/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	4/12/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	4/16/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	4/23/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	4/26/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	5/1/2012	composite	SM5310C	mg/l	0.009	0.3	5.3	<0.3	<0.3	<0.3	<0.3
Total Organic Carbon (TOC)	5/3/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	5/7/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	5/14/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	5/21/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	5/24/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	5/29/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	5/31/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	6/4/2012	composite	SM5310C	mg/l	0.009	0.3	4.3	<0.3	<0.3	<0.3	<0.3
Total Organic Carbon (TOC)	6/11/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	6/21/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	6/28/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	7/2/2012	composite	SM5310C	mg/l	0.009	0.3				<0.3	<0.3
Total Organic Carbon (TOC)	7/5/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	7/9/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	7/12/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	7/16/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3

Table 20 Certified Laboratory Results of Total Organic Carbon (TOC)

Parameter	Sample Date	[1] Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Total Organic Carbon (TOC)	7/19/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	7/23/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	7/26/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
Total Organic Carbon (TOC)	7/30/2012	composite	SM5310C	mg/l	0.009	0.3					<0.3
n =							12	11	11	16	97
[3] Average							6	<0.3	<0.3	<0.3	<0.3
Maximum							7	0.5	0.3	0.3	1
Minimum							4	0.2	0.2	0.0	0.2
STDev							0.9	0.1	0.1	0.1	0.2

Note:

1. The result of 1.4 mg/L was determined to be an outlier and is not representative of the TOC concentration consistently measured in the UV/AOP product water. TOC measured online upstream of the UV/AOP system on the day of the sampling event was below 0.07 mg/L.

2. All S7 and S8 samples were grab samples.

3. For purposes of calculating statistical parameters, results reported below the RL were considered 0.5 X RL and results reported ND were considered the DL.

Table 21 Certified Laboratory Results of Total and Fecal Coliform

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S1 (tertiary effluent)	S4 (MF Filtrate)	S5 (UF Filtrate)	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S10 (UV/AOP Product)
Total Coliform	8/2/2011	grab	[1]SM 9223B	NA	1	1	Present	<1	<1	<1	<1	<1	<1
E. coli	8/2/2011	grab	[1]SM 9223B	NA	1	1	Present	<1	<1	<1	<1	<1	<1
Total Coliform	8/3/2011	grab	[1]SM 9223B	NA	1	1	Present	<1	<1	<1	<1	<1	<1
E. coli	8/3/2011	grab	[1]SM 9223B	NA	1	1	Present	<1	<1	<1	<1	<1	<1
Total Coliform	8/4/2011	grab	[1]SM 9223B	NA	1	1	Present	<1	<1	<1	<1	<1	<1
E. coli	8/4/2011	grab	[1]SM 9223B	NA	1	1	Present	<1	<1	<1	<1	<1	<1
Total Coliform	8/8/2011	grab	[1]SM 9223B	NA	1	1	Present	<1	<1	<1	<1	<1	<1
E. coli	8/8/2011	grab	[1]SM 9223B	NA	1	1	Present	<1	<1	<1	<1	<1	<1
Total Coliform	8/9/2011	grab	[1]SM 9223B	NA	1	1	Present	<1	<1	<1	<1	<1	<1
E. coli	8/9/2011	grab	[1]SM 9223B	NA	1	1	Present	<1	<1	<1	<1	<1	<1
Total Coliform	8/10/2011	grab	[1]SM 9223B	NA	1	1	>2419.6	<1	<1	<1	<1	1	<1
E. coli	8/10/2011	grab	[1]SM 9223B	NA	1	1	>2419.6	<1	<1	<1	<1	<1	<1
Total Coliform	8/11/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	5000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	8/11/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	3000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	8/12/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	5000	<1.1	<1.1	5.1	<1.1	<1.1	<1.1
Fecal Coliform	8/12/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	5000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	8/15/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	9000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	8/15/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	1700	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	8/16/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	17000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	8/16/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	3000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	8/17/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	11000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	8/17/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	1700	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	8/18/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	16000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	8/18/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	16000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	8/19/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	3000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	8/19/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	3000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	8/22/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	2400	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	8/22/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	900	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	8/23/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	2200	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	8/23/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	2200	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	8/24/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	9000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1

Table 21 Certified Laboratory Results of Total and Fecal Coliform

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S1 (tertiary effluent)	S4 (MF Filtrate)	S5 (UF Filtrate)	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S10 (UV/AOP Product)
Fecal Coliform	8/24/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	3000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	8/25/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	3500	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	8/25/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	1600	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	8/26/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	30000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	8/26/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	530	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	8/30/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	5000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	8/30/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	5000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	8/31/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	50000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	8/31/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	16000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	8/29/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	17000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	8/29/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	7000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	8/31/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	50000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	8/31/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	16000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	9/1/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	3000	<1.1	2.2	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	9/1/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	2400	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	9/2/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	3000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	9/2/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	3000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	9/6/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	1600	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	9/6/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	900	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	9/8/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	3000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	9/8/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	500	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	9/12/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	5000	<1.1	1.1	<1.1	<1.1	1.1	<1.1
Fecal Coliform	9/12/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	1100	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	9/13/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	16000	<1.1	3.6	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	9/13/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	5000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	9/14/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	22000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	9/14/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	5000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	9/15/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	3000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	9/15/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	11000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	9/16/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	16000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	9/16/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	9000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	9/19/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	2400	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1

Table 21 Certified Laboratory Results of Total and Fecal Coliform

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S1 (tertiary effluent)	S4 (MF Filtrate)	S5 (UF Filtrate)	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S10 (UV/AOP Product)
Fecal Coliform	9/19/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	900	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	9/20/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	9000	<1.1	<1.1	<1.1	<1.1	1.1	<1.1
Fecal Coliform	9/20/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	2200	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	9/21/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	2400	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	9/21/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	2400	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	9/22/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	3000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	9/22/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	900	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	9/23/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	5000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	9/23/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	1600	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	9/26/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	1700	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	9/26/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	900	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	10/3/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	1600	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	10/3/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	240	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	10/10/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	1100	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	10/10/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	700	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	10/17/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	5000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	10/17/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	2400	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	10/24/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	2400	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	10/24/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	2400	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	10/31/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	1600	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	10/31/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	500	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	11/7/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	500	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	11/7/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	240	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	11/15/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	5000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	11/15/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	700	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	11/21/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	2400	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	11/21/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	500	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	11/29/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	330	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	11/29/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	80	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	12/6/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	1700	<1.1	<1.1	<1.1	<1.1	1.1	<1.1
Fecal Coliform	12/6/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	170	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	12/12/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	2200	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1

Table 21 Certified Laboratory Results of Total and Fecal Coliform

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S1 (tertiary effluent)	S4 (MF Filtrate)	S5 (UF Filtrate)	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S10 (UV/AOP Product)
Fecal Coliform	12/12/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	500	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	12/19/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	500	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	12/19/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	80	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	12/27/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	2400	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	12/27/2011	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	1600	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	1/3/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	5000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	1/3/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	500	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	1/9/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	16000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	1/9/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	5000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	1/18/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	1500	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	1/18/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	300	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	1/23/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	700	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	1/23/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	240	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	1/30/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	5000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	1/30/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	500	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	2/2/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	ND	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	2/2/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	ND	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	2/6/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	5000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	2/6/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	300	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	2/9/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	ND	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	2/9/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	ND	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	2/14/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	5000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	2/14/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	300	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	2/16/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	ND	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	2/16/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	ND	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	2/20/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	1600	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	2/20/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	300	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	2/23/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	ND	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	2/23/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	ND	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	2/27/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	1700	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	2/27/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	900	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	3/1/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	ND	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1

Table 21 Certified Laboratory Results of Total and Fecal Coliform

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S1 (tertiary effluent)	S4 (MF Filtrate)	S5 (UF Filtrate)	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S10 (UV/AOP Product)
Fecal Coliform	3/1/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	ND	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	3/6/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	1700	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	3/6/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	500	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	3/8/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	ND	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	3/8/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	ND	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	3/12/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	2800	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	3/12/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	700	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	3/15/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	ND	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	3/15/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	ND	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	3/19/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	16000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	3/19/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	2200	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	3/22/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	ND	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	3/22/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	ND	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	3/26/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	5000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	3/26/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	3000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	3/29/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	ND	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	3/29/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	ND	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	4/2/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	1100	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	4/2/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	11000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	4/5/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	ND	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	4/5/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	ND	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	4/9/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	3000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	4/9/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	300	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	4/12/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	ND	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	4/12/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	ND	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	4/16/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	16000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	4/16/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	2400	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	4/23/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	2400	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	4/23/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	500	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	4/26/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	ND	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	4/26/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	ND	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	4/30/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	900	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1

Table 21 Certified Laboratory Results of Total and Fecal Coliform

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S1 (tertiary effluent)	S4 (MF Filtrate)	S5 (UF Filtrate)	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S10 (UV/AOP Product)
Fecal Coliform	4/30/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	300	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	5/7/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	220	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	5/7/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	1700	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	5/21/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	16000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	5/21/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	30000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	5/29/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	5000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	5/29/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	30000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	6/4/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	2200	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	6/4/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	7000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	6/11/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	5000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	6/11/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	5000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	6/18/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	900	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	6/18/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	16000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	7/2/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	5000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	7/2/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	2200	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	7/9/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	5000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	7/9/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	2400	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	7/16/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	60000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	7/16/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	16000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	7/23/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	48000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	7/23/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	10000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	7/30/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	48000	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	7/30/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	500	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Total Coliform	9/17/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	4400	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Fecal Coliform	9/17/2012	grab	SM 9221B/E	MPN/100 ml	1.1	1.1	1400	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1

Note:

1. SM 9223B analyses were performed as present or absent from 8/2/2011 to 8/9/2011 and quantifiable on 8/10/2011.

Table 22 Certified Laboratory Results of Somatic & Male Specific Bacteriophage

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S1 (tertiary effluent)	S4 (MF Filtrate)	S5 (UF Filtrate)	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S10 (UV/AOP Product)
Bacteriophage, Somatic	8/8/2011	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	3000	<1	NP	NP	NP	NP	NP
Bacteriophage, Somatic	8/8/2011	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	P	A	A	A	A	A
Bacteriophage, Male Specific	8/8/2011	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	30	NP	NP	NP	NP	NP	NP
Bacteriophage, Male Specific	8/8/2011	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	A	A	A	A	A	A
Bacteriophage, Somatic	8/15/2011	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	3000	NP	NP	NP	NP	NP	NP
Bacteriophage, Somatic	8/15/2011	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	A	A	A	A	A	A
Bacteriophage, Male Specific	8/15/2011	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	67	NP	NP	NP	NP	NP	NP
Bacteriophage, Male Specific	8/15/2011	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	A	A	A	A	A	A
Bacteriophage, Somatic	8/22/2011	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	3000	NP	NP	NP	NP	NP	NP
Bacteriophage, Somatic	8/22/2011	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	A	A	A	A	A	A
Bacteriophage, Male Specific	8/22/2011	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	15	<1	NP	NP	NP	NP	NP
Bacteriophage, Male Specific	8/22/2011	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	P	A	A	A	A	A
Bacteriophage, Somatic	8/29/2011	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	630	NP	NP	NP	NP	NP	NP
Bacteriophage, Somatic	8/29/2011	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	A	A	A	A	A	A
Bacteriophage, Male Specific	8/29/2011	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	<1	NP	NP	<1	NP	NP	NP
Bacteriophage, Male Specific	8/29/2011	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	A	A	P	A	A	A
Bacteriophage, Somatic	9/12/2011	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	840	NP	<1	<1	NP	NP	NP
Bacteriophage, Somatic	9/12/2011	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	A	P	P	A	A	A
Bacteriophage, Male Specific	9/12/2011	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	7	NP	NP	NP	NP	NP	NP
Bacteriophage, Male Specific	9/12/2011	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	A	A	A	A	A	A
Bacteriophage, Somatic	9/19/2011	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	99	NP	NP	NP	NP	NP	NP
Bacteriophage, Somatic	9/19/2011	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	A	A	A	A	A	A
Bacteriophage, Somatic	9/26/2011	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	720	NP	NP	NP	NP	NP	NP
Bacteriophage, Somatic	9/26/2011	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	A	A	A	A	A	A
Bacteriophage, Male Specific	9/26/2011	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	32	NP	NP	NP	NP	NP	NP
Bacteriophage, Male Specific	9/26/2011	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	A	A	A	A	A	A
Bacteriophage, Somatic	10/10/2011	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	1090	1	NP	<1	NP	NP	NP
Bacteriophage, Somatic	10/10/2011	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	P	A	P	A	A	A
Bacteriophage, Male Specific	10/10/2011	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	19	<1	NP	1	NP	NP	NP
Bacteriophage, Male Specific	10/10/2011	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	P	A	P	A	A	A
Bacteriophage, Somatic	10/17/2011	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	300	10	NP	4	NP	NP	NP
Bacteriophage, Somatic	10/17/2011	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	P	A	P	A	A	A
Bacteriophage, Male Specific	10/17/2011	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	12	11	NP	NP	NP	NP	NP
Bacteriophage, Male Specific	10/17/2011	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	P	A	A	A	A	A
Bacteriophage, Somatic	10/25/2011	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	629	3	NP	<1	NP	NP	NP

Table 22 Certified Laboratory Results of Somatic & Male Specific Bacteriophage

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S1 (tertiary effluent)	S4 (MF Filtrate)	S5 (UF Filtrate)	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S10 (UV/AOP Product)
Bacteriophage, Somatic	10/25/2011	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	P	A	P	A	A	A
Bacteriophage, Male Specific	10/25/2011	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	23	NP	NP	NP	NP	NP	NP
Bacteriophage, Male Specific	10/25/2011	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	A	A	A	A	A	A
Bacteriophage, Somatic	11/7/2011	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	1200	2	<1	<1	NP	NP	NP
Bacteriophage, Somatic	11/7/2011	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	P	P	P	A	A	A
Bacteriophage, Male Specific	11/7/2011	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	7	5	NP	<1	NP	NP	NP
Bacteriophage, Male Specific	11/7/2011	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	P	A	P	A	A	A
Bacteriophage, Male Specific	11/15/2011	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	17	<1	NP	<1	NP	NP	NP
Bacteriophage, Male Specific	11/15/2011	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	P	A	P	A	A	A
Bacteriophage, Somatic	11/15/2011	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	3000	<1	<1	1	NP	NP	NP
Bacteriophage, Somatic	11/15/2011	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	P	P	P	A	A	A
Bacteriophage, Male Specific	12/12/2011	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	20	4	NP	2	<1	NP	NP
Bacteriophage, Male Specific	12/12/2011	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	P	A	P	P	A	A
Bacteriophage, Somatic	12/12/2011	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	2100	2	NP	<1	NP	NP	NP
Bacteriophage, Somatic	12/12/2011	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	P	A	P	A	A	A
Bacteriophage, Male Specific	1/9/2012	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	10	3	NP	<1	NP	NP	NP
Bacteriophage, Male Specific	1/9/2012	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	P	A	P	A	A	A
Bacteriophage, Somatic	1/9/2012	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	3000	<1	NP	NP	NP	NP	NP
Bacteriophage, Somatic	1/9/2012	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	P	A	A	A	A	A
Bacteriophage, Male Specific	2/13/2012	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	9	<1	NP	NP	NP	NP	NP
Bacteriophage, Male Specific	2/13/2012	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	P	A	A	A	A	A
Bacteriophage, Somatic	2/13/2012	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	810	2	<1	NP	NP	NP	NP
Bacteriophage, Somatic	2/13/2012	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	P	P	A	A	A	A
Bacteriophage, Male Specific	3/12/2012	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	<1	NP	NP	NP	NP	NP	NP
Bacteriophage, Male Specific	3/12/2012	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	A	A	A	A	A	A
Bacteriophage, Somatic	3/12/2012	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	>3000	NP	NP	NP	NP	NP	NP
Bacteriophage, Somatic	3/12/2012	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	A	A	A	A	A	A
Bacteriophage, Male Specific	4/9/2012	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	12	1	NP	<1	NP	NP	NP
Bacteriophage, Male Specific	4/9/2012	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	P	A	P	A	A	A
Bacteriophage, Somatic	4/9/2012	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	630	2	NP	28	NP	NP	NP
Bacteriophage, Somatic	4/9/2012	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	P	A	P	A	A	A
Bacteriophage, Male Specific	6/18/2012	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	4	NP	NP	NP	NP	NP	NP
Bacteriophage, Male Specific	6/18/2012	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	A	A	A	A	A	A
Bacteriophage, Somatic	6/18/2012	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	578	<1	<1	NP	NP	NP	NP
Bacteriophage, Somatic	6/18/2012	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	P	P	A	A	A	A

Table 22 Certified Laboratory Results of Somatic & Male Specific Bacteriophage

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S1 (tertiary effluent)	S4 (MF Filtrate)	S5 (UF Filtrate)	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S10 (UV/AOP Product)
Bacteriophage, Male Specific	7/9/2012	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	6	NP	NP	25	NP	NP	NP
Bacteriophage, Male Specific	7/9/2012	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	A	A	P	A	A	A
Bacteriophage, Somatic	7/9/2012	grab	EPA 1602 (821-R-01-029)	pfu/100 ml	1/100 mL	1/100 mL	1500	NP	NP	NP	NP	NP	NP
Bacteriophage, Somatic	7/9/2012	grab	EPA 1601 (821-R-01-030)	P/A per L	P/A per L	P/A per L	NP	A	A	A	A	A	A

Note:

1. NP=not performed. A=absent. P= present.
2. A sample set was collected on 5/29/12 however results are not valid because EPA 1601 Somatic Coliphage Phage analysis were made past the recommended holdtime due to a lab issue.

Table 23 Basin Plan Number Water Quality Objectives

Constituent	Water Quality Objective
Total Dissolved Solids	300 mg/L
Chloride	50 mg/L
Sulfate	65 mg/L
Percent Sodium	60%
Iron	0.3 mg/L
Manganese	0.05 mg/L
Boron	1.0 mg/L
Turbidity	20 NTU
Color	20 color units
Fluoride	1.0 mg/L
Nutrients	-Total Phosphorus less than 0.025 mg/L -Natural ratios of total nitrogen to total phosphorus are to be upheld, if no data is available a ratio (N:P) of 10:1 is to be used.
Ammonia (unionized as N)	0.025 mg/L
Fecal Coliform	-Not less than 5 samples every 30 days -Sampling shall not exceed a log mean of 200/100mL -No more than 10% of samples during any 30 day period shall exceed 400/100mL
Dissolved Oxygen	- not less than 6.0 mg/L -annual mean DO shall not be less than 7.0 mg/L more than 10% of the time
pH	-change in pH level shall not exceed 0.5 units -pH shall not be depressed below 6.5 nor raised above 8.5
Phenolic Compounds	1.0 µg/L

Note:

1. Water Quality Control Plan for the San Diego Basin California Regional Water Quality Control Board San Diego Region September 8, 1994. http://www.waterboards.ca.gov/sandiego/water_issues/programs/basin_plan/

Table 24 Certified Laboratory Results of Select General Inorganic Parameters with Basin Plan Numeric Objectives

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Total Dissolved Solids	8/15/2011	grab	SM2540C	mg/l	4	10	810	13	15		14
Total Dissolved Solids	8/29/2011	grab	SM2540C	mg/l	4	10	770	13	12	11	14
Total Dissolved Solids	9/12/2011	grab	SM2540C	mg/l	4	10	820	17	15	13	19
Total Dissolved Solids	9/26/2011	grab	SM2540C	mg/l	4	10	750	12	11		15
Total Dissolved Solids	9/29/2011	grab	SM2540C	mg/l	4	10					11
Total Dissolved Solids	10/10/2011	grab	SM2540C	mg/l	4	10	740	15	13		11
Total Dissolved Solids	10/24/2011	composite	SM2540C	mg/l	4	10	680	13	18		15
Total Dissolved Solids	11/7/2011	composite	SM2540C	mg/l	4	10	700	18	13		17
Total Dissolved Solids	11/21/2011	composite	SM2540C	mg/l	4	10	600	16	11		13
Total Dissolved Solids	12/5/2011	composite	SM2540C	mg/l	4	10	890	13	17		19
Total Dissolved Solids	12/19/2011	composite	SM2540C	mg/l	4	10	540	14	17		13
Total Dissolved Solids	1/3/2012	composite	SM2540C	mg/l	4	10	660	11	14		11
Total Dissolved Solids	1/17/2012	composite	SM2540C	mg/l	4	10	800	11	12		13
Total Dissolved Solids	2/14/2012	composite	SM2540C	mg/l	4	10	770	12	15		15
Total Dissolved Solids	2/27/2012	composite	SM2540C	mg/l	4	10					17
Total Dissolved Solids	3/12/2012	composite	SM2540C	mg/l	4	10	800	17	12		15
Total Dissolved Solids	3/26/2012	composite	SM2540C	mg/l	4	10	690	13	14		11
Total Dissolved Solids	4/9/2012	composite	SM2540C	mg/l	4	10	750	11	15		16
Total Dissolved Solids	4/23/2012	composite	SM2540C	mg/l	4	10	800	11	12		<10
Total Dissolved Solids	5/7/2012	composite	SM2540C	mg/l	4	10	790	15	16		11
Total Dissolved Solids	5/21/2012	composite	SM2540C	mg/l	4	10	770	17	11		13
Total Dissolved Solids	6/4/2012	composite	SM2540C	mg/l	4	10	800	11	15		13
Total Dissolved Solids	7/2/2012	composite	SM2540C	mg/l	4	10					11
Total Dissolved Solids	7/16/2012	composite	SM2540C	mg/l	4	10	930	13	12		11
Total Dissolved Solids	7/30/2012	composite	SM2540C	mg/l	4	10					14
n =							21	21	21	2	25
Average							760	14	14	12	14
Maximum							930	18	18	13	19
Minimum							540	11	11	11	10
STDev							89	2.3	2.1	1.4	2.6

Table 24 Certified Laboratory Results of Select General Inorganic Parameters with Basin Plan Numeric Objectives

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Chloride, Total	8/15/2011	Composite	300.0_Cl Water	mg/l	0.1	0.5	250	2.5	2.2		2.8
Chloride, Total	8/29/2011	Composite	300.0_Cl Water	mg/l	0.1	0.5	240	2.1	2	2.1	2.9
Chloride, Total	9/12/2011	Composite	300.0_Cl Water	mg/l	0.1	0.5	260	2.2	2	2.2	2.7
Chloride, Total	9/26/2011	Composite	300.0_Cl Water	mg/l	0.1	0.5	260	2.4	2.3		2.9
Chloride, Total	10/10/2011	Composite	300.0_Cl Water	mg/l	0.1	0.5	240	2.2	2.1		2.8
Chloride, Total	10/24/2011	Composite	300.0_Cl Water	mg/l	0.1	0.5	270	2	1.8		3.3
Chloride, Total	11/7/2011	Composite	300.0_Cl Water	mg/l	0.1	0.5	240	2.6	2.5		2.9
Chloride, Total	11/21/2011	Composite	300.0_Cl Water	mg/l	0.1	0.5	260	2.3	1.9		2.8
Chloride, Total	12/5/2011	Composite	300.0_Cl Water	mg/l	0.1	0.5	240	2.2	2.2		2.7
Chloride, Total	12/19/2011	Composite	300.0_Cl Water	mg/l	0.1	0.5	270	2.5	2.4		2.8
Chloride, Total	1/3/2012	Composite	300.0_Cl Water	mg/l	0.1	0.5	260	2.4	2.1		2.6
Chloride, Total	1/17/2012	Composite	300.0_Cl Water	mg/l	0.1	0.5	280	1.9	1.7		2.8
Chloride, Total	1/30/2012	Composite	300.0_Cl Water	mg/l	0.1	0.5	250	2.1	2		2.6
Chloride, Total	2/14/2012	Composite	300.0_Cl Water	mg/l	0.1	0.5	270	2.3	2		2.8
Chloride, Total	2/27/2012	Composite	300.0_Cl Water	mg/l	0.1	0.5					2.9
Chloride, Total	3/12/2012	Composite	300.0_Cl Water	mg/l	0.1	0.5	280	2.3	2.2		3.1
Chloride, Total	3/26/2012	Composite	300.0_Cl Water	mg/l	0.1	0.5	270	2.2	2.2		3.1
Chloride, Total	4/9/2012	Composite	300.0_Cl Water	mg/l	0.1	0.5	270	2.5	2.3		3
Chloride, Total	4/23/2012	Composite	300.0_Cl Water	mg/l	0.1	0.5	280	3.4	3.1		3.7
Chloride, Total	5/7/2012	Composite	300.0_Cl Water	mg/l	0.1	0.5	270	3.6	3.6		4.1
Chloride, Total	5/21/2012	Composite	300.0_Cl Water	mg/l	0.1	0.5	270	3.3	3.4		3.9
Chloride, Total	6/4/2012	Composite	300.0_Cl Water	mg/l	0.1	0.5	290	3.4	3.6		4.3
Chloride, Total	7/2/2012	Composite	300.0_Cl Water	mg/l	0.1	0.5					4.1
Chloride, Total	7/16/2012	Composite	300.0_Cl Water	mg/l	0.1	0.5					3.9
Chloride, Total	7/30/2012	Composite	300.0_Cl Water	mg/l	0.1	0.5					4
n =							21	21	21	2	25
Average							260	2.5	2.4	2.2	3.2
Maximum							290	3.6	3.6	2.2	4.3
Minimum							240	1.9	1.7	2.1	2.6
STDev							15	0.50	0.60	0.10	0.60

Table 24 Certified Laboratory Results of Select General Inorganic Parameters with Basin Plan Numeric Objectives

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Sulfate as SO4	8/15/2011	grab	EPA 300.0	mg/l	0.1	0.5	170	<0.5	<0.5		<0.1
Sulfate as SO4	8/29/2011	grab	EPA 300.0	mg/l	0.1	0.5	140	<0.5	<0.1	<0.5	<0.5
Sulfate as SO4	9/12/2011	grab	EPA 300.0	mg/l	0.1	0.5	160	<0.1	<0.1	<0.1	<0.5
Sulfate as SO4	9/26/2011	grab	EPA 300.0	mg/l	0.1	0.5	150	<0.1	<0.5		<0.5
Sulfate as SO4	10/10/2011	grab	EPA 300.0	mg/l	0.1	0.5	130	<0.5	<0.5		<0.1
Sulfate as SO4	10/24/2011	composite	EPA 300.0	mg/l	0.1	0.5	140	<0.5	<0.1		<0.5
Sulfate as SO4	11/7/2011	composite	EPA 300.0	mg/l	0.1	0.5	130	<0.5	<0.1		0.58
Sulfate as SO4	11/21/2011	composite	EPA 300.0	mg/l	0.1	0.5	150	<0.5	<0.5		<0.5
Sulfate as SO4	12/5/2011	composite	EPA 300.0	mg/l	0.1	0.5	130	<0.1	<0.5		<0.5
Sulfate as SO4	12/19/2011	composite	EPA 300.0	mg/l	0.1	0.5	140	<0.5	<0.1		<0.5
Sulfate as SO4	1/3/2012	composite	EPA 300.0	mg/l	0.1	0.5	130	<0.1	<0.1		<0.1
Sulfate as SO4	1/17/2012	composite	EPA 300.0	mg/l	0.1	0.5	170	<0.1	<0.1		<0.5
Sulfate as SO4	2/14/2012	composite	EPA 300.0	mg/l	0.1	0.5	150	<0.1	<0.5		<0.5
Sulfate as SO4	2/27/2012	composite	EPA 300.0	mg/l	0.1	0.5					<0.5
Sulfate as SO4	3/12/2012	composite	EPA 300.0	mg/l	0.1	0.5	170	<0.1	<0.5		<0.5
Sulfate as SO4	3/26/2012	composite	EPA 300.0	mg/l	0.1	0.5	170	<0.5	<0.1		<0.5
Sulfate as SO4	4/9/2012	composite	EPA 300.0	mg/l	0.1	0.5	160	<0.5	<0.1		1.1
Sulfate as SO4	4/23/2012	composite	EPA 300.0	mg/l	0.1	0.5	180	<0.5	<0.1		<0.5
Sulfate as SO4	5/7/2012	composite	EPA 300.0	mg/l	0.1	0.5	180	<0.5	<0.5		<0.5
Sulfate as SO4	5/21/2012	composite	EPA 300.0	mg/l	0.1	0.5	170	<0.5	<0.1		<0.5
Sulfate as SO4	6/4/2012	composite	EPA 300.0	mg/l	0.1	0.5	200	<0.5	<0.1		<0.5
Sulfate as SO4	7/2/2012	composite	EPA 300.0	mg/l	0.1	0.5					<0.5
Sulfate as SO4	7/9/2012	composite	EPA 300.0	mg/l	0.1	0.5	190	<0.5	<0.5		
Sulfate as SO4	7/16/2012	composite	EPA 300.0	mg/l	0.1	0.5	180	<0.5	<0.5		<0.5
Sulfate as SO4	7/23/2012	composite	EPA 300.0	mg/l	0.1	0.5	200	<0.5	<0.5		
Sulfate as SO4	7/30/2012	composite	EPA 300.0	mg/l	0.1	0.5	170	<0.5	<0.5		<0.5
n =							24	24	24	2	24
Average							160	<0.5	<0.5	<0.5	<0.5
Maximum							200	0.3	0.3	0.3	1.1
Minimum							130	0.1	0.1	0.1	0.1
STDev							22	0.1	0.1	0.1	0.2

Table 24 Certified Laboratory Results of Select General Inorganic Parameters with Basin Plan Numeric Objectives

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Sodium, Total	8/15/2011	grab	EPA 200.7	mg/l	0.015	0.5	170	3.3	3.1		3.3
Sodium, Total	8/29/2011	grab	EPA 200.7	mg/l	0.015	0.5				3.8	3.8
Sodium, Total	9/12/2011	grab	EPA 200.7	mg/l	0.015	0.5				3.3	3.3
Sodium, Total	9/26/2011	grab	EPA 200.7	mg/l	0.015	0.5					3.1
Sodium, Total	10/10/2011	grab	EPA 200.7	mg/l	0.015	0.5	170	3.2	3.4		3.2
Sodium, Total	10/24/2011	composite	EPA 200.7	mg/l	0.015	0.5	160	3.1	3.1		3.3
Sodium, Total	11/7/2011	composite	EPA 200.7	mg/l	0.015	0.5	150	2.7	2.7		2.8
Sodium, Total	11/21/2011	composite	EPA 200.7	mg/l	0.015	0.5	160	2.6	2.6		2.8
Sodium, Total	12/5/2011	composite	EPA 200.7	mg/l	0.015	0.5	160	2.4	2.4		2.6
Sodium, Total	12/19/2011	composite	EPA 200.7	mg/l	0.015	0.5	170	2.6	2.7		2.8
Sodium, Total	1/3/2012	composite	EPA 200.7	mg/l	0.015	0.5	160	2.4	2.4		2.4
Sodium, Total	1/17/2012	composite	EPA 200.7	mg/l	0.015	0.5	170	2.8	2.6		2.8
Sodium, Total	2/14/2012	composite	EPA 200.7	mg/l	0.015	0.5	160	2.4	2.4		2.4
Sodium, Total	2/27/2012	composite	EPA 200.7	mg/l	0.015	0.5	160	2.4	2.4		2.6
Sodium, Total	3/12/2012	composite	EPA 200.7	mg/l	0.015	0.5	180	3	3		3
Sodium, Total	3/26/2012	composite	EPA 200.7	mg/l	0.015	0.5	160	2.9	3.1		3.1
Sodium, Total	4/9/2012	composite	EPA 200.7	mg/l	0.015	0.5	180	3.1	3.1		3.3
Sodium, Total	4/23/2012	composite	EPA 200.7	mg/l	0.015	0.5	180	3.7	3.4		3.9
Sodium, Total	5/7/2012	composite	EPA 200.7	mg/l	0.015	0.5	170	3.7	4		4
Sodium, Total	5/21/2012	composite	EPA 200.7	mg/l	0.015	0.5	180	4.3	4.5		4.6
Sodium, Total	6/4/2012	composite	EPA 200.7	mg/l	0.015	0.5	190	4.6	5.1		5.3
Sodium, Total	7/2/2012	composite	EPA 200.7	mg/l	0.015	0.5					4.5
Sodium, Total	7/16/2012	composite	EPA 200.7	mg/l	0.015	0.5					4.6
Sodium, Total	7/30/2012	composite	EPA 200.7	mg/l	0.015	0.5					4.8
n =							18	18	18	2	24
Average							170	3.1	3.1	3.6	3.4
Maximum							190	4.6	5.1	3.8	5.3
Minimum							150	2.4	2.4	3.3	2.4
STDev							10	0.70	0.80	0.40	0.80

Table 24 Certified Laboratory Results of Select General Inorganic Parameters with Basin Plan Numeric Objectives

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Iron, Total	8/15/2011	grab	EPA 200.7	µg/L	1.1	10	55	<1.1	<1.1		<1.1
Iron, Total	8/29/2011	grab	EPA 200.7	mg/l	0.001	0.01				<0.001	<0.001
Iron, Total	9/12/2011	grab	EPA 200.7	µg/L	1.1	10				<1.1	<1.1
Iron, Total	9/26/2011	grab	EPA 200.7	mg/l	0.001	0.01					<0.001
Iron, Total	10/10/2011	grab	EPA 200.7	mg/l	0.001	0.01	54	<0.001	<0.001		<0.001
Iron, Total	10/24/2011	composite	EPA 200.7	µg/L	1.1	10	66	<1.1	<1.1		<10
Iron, Total	11/7/2011	composite	EPA 200.7	µg/L	1.1	10	50	<10	<10		<10
Iron, Total	11/21/2011	composite	EPA 200.7	µg/L	1.1	10	85	<1.1	<1.1		<10
Iron, Total	12/5/2011	composite	EPA 200.7	µg/L	1.1	10	72	0.018	<10		<10
Iron, Total	12/19/2011	composite	EPA 200.7	µg/L	1.1	10	68	<10	<10		<10
Iron, Total	1/3/2012	composite	EPA 200.7	µg/L	1.1	10	59	<10	<1.1		<1.1
Iron, Total	1/17/2012	composite	EPA 200.7	µg/L	1.1	10	67	<10	<1.1		<10
Iron, Total	2/14/2012	composite	EPA 200.7	µg/L	1.1	10	63	<10	<10		<1.1
Iron, Total	2/27/2012	composite	EPA 200.7	µg/L	1.1	10	53	<10	<10		<10
Iron, Total	3/12/2012	composite	EPA 200.7	µg/L	1.1	10	70	<1.1	<1.1		<10
Iron, Total	3/26/2012	composite	EPA 200.7	µg/L	1.1	10	73	<10	<1.1		<10
Iron, Total	4/9/2012	composite	EPA 200.7	µg/L	1.1	10	75	<1.1	<1.1		<1.1
Iron, Total	4/23/2012	composite	EPA 200.7	µg/L	1.1	10	47	<1.1	<1.1		<1.1
Iron, Total	5/7/2012	composite	EPA 200.7	µg/L	1.1	10	54	<1.1	<1.1		<10
Iron, Total	5/21/2012	composite	EPA 200.7	µg/L	1.1	10	68	<1.1	<10		<1.1
Iron, Total	6/4/2012	composite	EPA 200.7	µg/L	1.1	10	57	<0.0011	<0.0011		<0.0011
Iron, Total	7/2/2012	composite	EPA 200.7	µg/L	1.1	10					<0.01
Iron, Total	7/16/2012	composite	EPA 200.7	µg/L	1.1	10					<0.0011
Iron, Total	7/30/2012	composite	EPA 200.7	µg/L	1.1	10					<1.1
n =							18	18	18	2	24
Average							63	<10	<10	<1.1	<10
Maximum							85	10	10	0.60	10
Minimum							47	0.0	0.0	0.0	0.0
STDev							10	2.9	2.8	0.40	2.8

Table 24 Certified Laboratory Results of Select General Inorganic Parameters with Basin Plan Numeric Objectives

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Manganese, Total	8/15/2011	grab	EPA 200.7	µg/L	2.6	5	87	<2.6	<2.6		<2.6
Manganese, Total	8/29/2011	grab	EPA 200.7	mg/l	0.003	0.01				<0.003	<0.003
Manganese, Total	9/12/2011	grab	EPA 200.7	µg/L	2.6	5				<2.6	<2.6
Manganese, Total	9/26/2011	grab	EPA 200.7	mg/l	0.003	0.01					<0.003
Manganese, Total	10/10/2011	grab	EPA 200.7	mg/l	0.003	0.01	0.081	<0.003	<0.003		<0.003
Manganese, Total	10/24/2011	composite	EPA 200.7	µg/L	2.6	5	95	<2.6	<2.6		<2.6
Manganese, Total	11/7/2011	composite	EPA 200.7	µg/L	2.6	5	77	<2.6	<2.6		<2.6
Manganese, Total	11/21/2011	composite	EPA 200.7	µg/L	2.6	5	69	<2.6	<2.6		<2.6
Manganese, Total	12/5/2011	composite	EPA 200.7	µg/L	2.6	5	0.085	<2.6	<2.6		<2.6
Manganese, Total	12/19/2011	composite	EPA 200.7	µg/L	2.6	5	66	<2.6	<2.6		<2.6
Manganese, Total	1/3/2012	composite	EPA 200.7	µg/L	2.6	5	94	<2.6	<2.6		<2.6
Manganese, Total	1/17/2012	composite	EPA 200.7	µg/L	2.6	5	98	<2.6	<2.6		<2.6
Manganese, Total	2/14/2012	composite	EPA 200.7	µg/L	2.6	5	72	<2.6	<2.6		<2.6
Manganese, Total	2/27/2012	composite	EPA 200.7	µg/L	2.6	5	76	<5	<5		<5
Manganese, Total	3/12/2012	composite	EPA 200.7	µg/L	2.6	5	85	<2.6	<2.6		<2.6
Manganese, Total	3/26/2012	composite	EPA 200.7	µg/L	2.6	5	0.091	<0.0026	<0.0026		<0.0026
Manganese, Total	4/9/2012	composite	EPA 200.7	µg/L	2.6	5	120	<2.6	<2.6		<2.6
Manganese, Total	4/23/2012	composite	EPA 200.7	µg/L	2.6	5	0.09	<2.6	<2.6		<0.0026
Manganese, Total	5/7/2012	composite	EPA 200.7	µg/L	2.6	5	83	<2.6	<2.6		<2.6
Manganese, Total	5/21/2012	composite	EPA 200.7	µg/L	2.6	5	96	<2.6	<2.6		<2.6
Manganese, Total	6/4/2012	composite	EPA 200.7	µg/L	2.6	5	0.1	<0.0026	<0.0026		<0.0026
Manganese, Total	7/2/2012	composite	EPA 200.7	µg/L	2.6	5					<0.0026
Manganese, Total	7/16/2012	composite	EPA 200.7	µg/L	2.6	5					<2.6
Manganese, Total	7/30/2012	composite	EPA 200.7	µg/L	2.6	5					<2.6
n =							18	18	18	2	24
Average							62	<2.6	<2.6	<2.6	<2.6
Maximum							120	5.0	5.0	1.3	5.0
Minimum							0.10	0.0	0.0	0.0	0.0
STDev							42	1.1	1.1	0.90	1.0

Table 24 Certified Laboratory Results of Select General Inorganic Parameters with Basin Plan Numeric Objectives

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Boron, Total	8/1/2011	grab	EPA 200.7	µg/L	1	10	410				
Boron, Total	8/15/2011	grab	EPA 200.7	µg/L	1	10	410	230	220		220
Boron, Total	8/29/2011	grab	EPA 200.7	µg/L	1	10				230	240
Boron, Total	9/12/2011	grab	EPA 200.7	µg/L	1	10				280	280
Boron, Total	9/26/2011	grab	EPA 200.7	µg/L	1	10					230
Boron, Total	10/10/2011	grab	EPA 200.7	µg/L	1	10	390	210	220		220
Boron, Total	10/24/2011	composite	EPA 200.7	µg/L	1	10	430	260	260		240
Boron, Total	11/7/2011	composite	EPA 200.7	µg/L	1	10	370	230	230		200
Boron, Total	11/21/2011	composite	EPA 200.7	µg/L	1	10	380	220	210		200
Boron, Total	12/5/2011	composite	EPA 200.7	µg/L	1	10	360	190	180		180
Boron, Total	12/19/2011	composite	EPA 200.7	µg/L	1	10	400	210	200		200
Boron, Total	1/3/2012	composite	EPA 200.7	µg/L	1	10	390	220	210		220
Boron, Total	1/17/2012	composite	EPA 200.7	µg/L	1	10	400	220	210		210
Boron, Total	2/14/2012	composite	EPA 200.7	µg/L	1	10	400	200	190		200
Boron, Total	2/27/2012	composite	EPA 200.7	µg/L	1	10	400	210	220		200
Boron, Total	3/12/2012	composite	EPA 200.7	µg/L	1	10	410	230	230		210
Boron, Total	3/26/2012	composite	EPA 200.7	µg/L	1	10	390	230	230		210
Boron, Total	4/9/2012	composite	EPA 200.7	µg/L	1	10	400	220	210		210
Boron, Total	4/23/2012	composite	EPA 200.7	µg/L	1	10	390	260	250		240
Boron, Total	5/7/2012	composite	EPA 200.7	µg/L	1	10	440	270	270		290
Boron, Total	5/21/2012	composite	EPA 200.7	µg/L	1	10	400	260	260		250
Boron, Total	6/4/2012	composite	EPA 200.7	µg/L	1	10	410	280	270		260
Boron, Total	7/2/2012	composite	EPA 200.7	µg/L	1	10					260
Boron, Total	7/16/2012	composite	EPA 200.7	µg/L	1	10					280
Boron, Total	7/30/2012	composite	EPA 200.7	µg/L	1	10					250
n =							19	18	18	2	24
Average							400	230	230	255	230
Maximum							440	280	270	280	290
Minimum							360	190	180	230	180
STDev							19	25	27	35	30

Table 24 Certified Laboratory Results of Select General Inorganic Parameters with Basin Plan Numeric Objectives

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Color	8/15/2011	grab	SM2120B	CU		3	20	<3	<3		<3
Color	8/29/2011	grab	SM2120B	CU		3				<3	<3
Color	9/12/2011	grab	SM2120B	CU		3				<3	<3
Color	9/26/2011	grab	SM2120B	CU		3				<3	<3
Color	10/10/2011	grab	SM2120B	CU		3				<3	<3
Color	10/24/2011	composite	SM2120B	CU		3				<3	<3
Color	11/7/2011	composite	SM2120B	CU		3				<3	<3
Color	11/21/2011	composite	SM2120B	CU		3				<3	<3
Color	12/5/2011	composite	SM2120B	CU		3				<3	<3
Color	12/19/2011	composite	SM2120B	CU		3				<3	<3
Color	1/3/2012	composite	SM2120B	CU		3				<3	<3
Color	1/17/2012	composite	SM2120B	CU		3				<3	<3
Color	2/14/2012	composite	SM2120B	CU		3				<3	<3
Color	2/27/2012	composite	SM2120B	CU		3				<3	<3
Color	3/12/2012	composite	SM2120B	CU		3				<3	<3
Color	3/26/2012	composite	SM2120B	CU		3				<3	<3
Color	4/9/2012	composite	SM2120B	CU		3				<3	<3
Color	4/23/2012	composite	SM2120B	CU		3				<3	<3
Color	5/7/2012	composite	SM2120B	CU		3				<3	<3
Color	5/21/2012	composite	SM2120B	CU		3				<3	<3
Color	6/4/2012	composite	SM2120B	CU		3				<3	<3
Color	7/2/2012	composite	SM2120B	CU		3					<3
Color	7/16/2012	composite	SM2120B	CU		3					<3
Color	7/30/2012	composite	SM2120B	CU		3					<3
n =							1	1	1	20	24
Average							20	<3	<3	<3	<3
Maximum							20	3	3	3	3
Minimum							20	0	0	0	0
STDev										0	0

Table 24 Certified Laboratory Results of Select General Inorganic Parameters with Basin Plan Numeric Objectives

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S6 (RO Feed)	S7 (RO Perm. Train A)	S8 (RO Perm. Train B)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Fluoride, Total	8/15/2011	grab	EPA 300.0	mg/l	0.02	0.1	0.67	<0.02	<0.02		<0.02
Fluoride, Total	8/29/2011	grab	EPA 300.0	mg/l	0.02	0.1	0.58	<0.02	<0.02	<0.02	<0.1
Fluoride, Total	9/12/2011	grab	EPA 300.0	mg/l	0.02	0.1	0.61	<0.02	<0.02	<0.02	<0.02
Fluoride, Total	9/26/2011	grab	EPA 300.0	mg/l	0.02	0.1	0.65	<0.1	<0.1		<0.1
Fluoride, Total	10/10/2011	grab	EPA 300.0	mg/l	0.02	0.1	0.61	<0.02	<0.02		<0.1
Fluoride, Total	10/24/2011	composite	EPA 300.0	mg/l	0.02	0.1	0.56	<0.1	<0.1		<0.1
Fluoride, Total	11/7/2011	composite	EPA 300.0	mg/l	0.02	0.1	0.64	<0.02	<0.02		<0.02
Fluoride, Total	11/21/2011	composite	EPA 300.0	mg/l	0.02	0.1	0.61	<0.02	<0.02		<0.02
Fluoride, Total	12/5/2011	composite	EPA 300.0	mg/l	0.02	0.1	0.55	<0.02	<0.02		<0.02
Fluoride, Total	12/19/2011	composite	EPA 300.0	mg/l	0.02	0.1	0.59	<0.02	<0.02		<0.02
Fluoride, Total	1/3/2012	composite	EPA 300.0	mg/l	0.02	0.1	0.52	<0.02	<0.02		<0.02
Fluoride, Total	1/17/2012	composite	EPA 300.0	mg/l	0.02	0.1	0.56	<0.02	<0.1		<0.1
Fluoride, Total	2/14/2012	composite	EPA 300.0	mg/l	0.02	0.1	0.56	<0.1	<0.1		<0.02
Fluoride, Total	2/27/2012	composite	EPA 300.0	mg/l	0.02	0.1					<0.1
Fluoride, Total	3/12/2012	composite	EPA 300.0	mg/l	0.02	0.1	0.6	<0.02	<0.1		<0.1
Fluoride, Total	3/26/2012	composite	EPA 300.0	mg/l	0.02	0.1	0.72	<0.02	<0.02		<0.02
Fluoride, Total	4/9/2012	composite	EPA 300.0	mg/l	0.02	0.1	0.68	<0.02	<0.02		<0.02
Fluoride, Total	4/23/2012	composite	EPA 300.0	mg/l	0.02	0.1	0.69	<0.02	<0.02		<0.02
Fluoride, Total	5/7/2012	composite	EPA 300.0	mg/l	0.02	0.1	0.76	<0.02	<0.02		<0.02
Fluoride, Total	5/21/2012	composite	EPA 300.0	mg/l	0.02	0.1	0.63	<0.02	<0.02		<0.02
Fluoride, Total	6/4/2012	composite	EPA 300.0	mg/l	0.02	0.1	0.67	<0.02	<0.02		<0.02
Fluoride, Total	7/2/2012	composite	EPA 300.0	mg/l	0.02	0.1					<0.02
Fluoride, Total	7/16/2012	composite	EPA 300.0	mg/l	0.02	0.1					<0.1
Fluoride, Total	7/30/2012	composite	EPA 300.0	mg/l	0.02	0.1					<0.02
n =							20	20	20	2	24
Average							0.6	<0.02	<0.02	<0.02	<0.02
Maximum							0.8	0.1	0.1	0.0	0.1
Minimum							0.5	0.0	0.0	0.0	0.0
STDev							0.1	0.0	0.0	0.0	0.0

Table 24 Certified Laboratory Results of Select General Inorganic Parameters with Basin Plan Numeric Objectives

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Phenolics (Total)	9/1/2011	grab	EPA 420.4	mg/l	0.004	0.01		0.022
Phenolics (14 compounds)	10/10/2011	grab	EPA 8270C-SIM	µg/L	varies	varies	<1	<1
Phenolics (13 compounds)	10/24/2011	composite	EPA 8270C-SIM	µg/L	varies	varies	<1	<1
Phenol	10/24/2011	composite	EPA 8270C-SIM	µg/L	0.35	1	1.4	1.9
Phenolics (13 compounds)	11/17/2011	composite	EPA 8270C-SIM	µg/L	varies	varies	<1	<1
Phenol	11/7/2011	composite	EPA 8270C-SIM	µg/L	0.35	1	<1	<1
Phenolics (13 compounds)	11/21/2011	composite	EPA 8270C-SIM	µg/L	varies	varies	<1	<1
Phenol	11/21/2011	composite	EPA 8270C-SIM	µg/L	0.35	1	<1	2.6
Phenolics (13 compounds)	12/5/2011	composite	EPA 8270C-SIM	µg/L	varies	varies	<1	<1
Phenol	12/5/2011	composite	EPA 8270C-SIM	µg/L	0.35	1	<1	<1
Phenolics[1] (14 compounds)	12/19/2011	composite	EPA 8270C-SIM	µg/L	varies	varies	<1	<1
Phenolics (14 compounds)	1/3/2012	composite	EPA 8270C-SIM	µg/L	varies	varies	<1	<1
Phenolics (12 compounds)	1/17/2012	composite	EPA 8270C-SIM	µg/L	varies	varies	<1	<1
2,4-Dichlorophenol	1/17/2012	composite	EPA 8270C-SIM	µg/L	0.51	1	<1	<1
4,6-Dinitro-2-methylphenol	1/17/2012	composite	EPA 8270C-SIM	µg/L	0.14	1	<1	<1
Phenolics (14 compounds)	1/23/2012	composite	EPA 8270C-SIM	µg/L	varies	varies	<1	<1
Phenolics (14 compounds)	2/14/2012	Composite	EPA 8270C-SIM	µg/L	varies	varies	<1	<1
Phenolics (14 compounds)	2/27/2012	Composite	EPA 8270C-SIM	µg/L	varies	varies	<1	<1
Phenolics (14 compounds)	3/12/2012	Composite	EPA 8270C-SIM	µg/L	varies	varies	<1	<1
Phenolics (14 compounds)	3/26/2012	Composite	EPA 8270C-SIM	µg/L	varies	varies	<1	<1
Phenolics (14 compounds)	4/9/2012	Composite	EPA 8270C-SIM	µg/L	varies	varies	<1	<1

Table 24 Certified Laboratory Results of Select General Inorganic Parameters with Basin Plan Numeric Objectives

Parameter	Sample Date	Sample Type	Method	Units	DL	RL	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
Phenolics (14 compounds)	4/23/2012	Composite	EPA 8270C-SIM	µg/L	varies	varies	<1	<1
Phenolics (14 compounds)	5/7/2012	Composite	EPA 8270C-SIM	µg/L	varies	varies	<1	<1
Phenolics (14 compounds)	5/21/2012	Composite	EPA 8270C-SIM	µg/L	varies	varies	<1	<1
Phenolics (14 compounds)	6/4/2012	Composite	EPA 8270C-SIM	µg/L	varies	varies	<1	<1
Phenolics (14 compounds)	7/2/2012	Composite	EPA 8270C-SIM	µg/L	varies	varies		<1
Phenolics (14 compounds)	7/16/2012	Composite	EPA 8270C-SIM	µg/L	varies	varies		<1
Phenolics (14 compounds)	7/30/2012	Composite	EPA 8270C-SIM	µg/L	varies	varies		<1

1. Samples were re-extracted and reanalyzed past hold time due reported lab contamination

Table 25 On-site Laboratory UV/AOP Product Water Results of General Parameters with Basin Plan Numeric Objectives

Sample Date	Method	Parameter Measured @ S10 UV/AOP Product			
		pH	Temperature, Deg C	DO, mg/L	Turbidity, NTU
8/11/2011	HACH sensION156 Portable Meter	5.79	26.8		0.04
8/12/2011	HACH sensION156 Portable Meter	5.77	26		0.05
8/13/2011	HACH sensION156 Portable Meter	5.8	26.9		0.07
8/14/2011	HACH sensION156 Portable Meter	5.88	26.7		0.04
8/15/2011	HACH sensION156 Portable Meter	5.86	23.6		0.05
8/16/2011	HACH sensION156 Portable Meter	5.88	22.4		0.04
8/17/2011	HACH sensION156 Portable Meter	5.72	21		0.04
8/18/2011	HACH sensION156 Portable Meter	5.75	21.5		0.04
8/19/2011	HACH sensION156 Portable Meter	5.71	25.7		0.04
8/21/2011	HACH sensION156 Portable Meter				0.04
8/22/2011	HACH sensION156 Portable Meter	5.79	27		0.05
8/23/2011	HACH sensION156 Portable Meter	5.87	27.2		0.04
8/24/2011	HACH sensION156 Portable Meter	5.7	24.7		0.08
8/25/2011	HACH sensION156 Portable Meter	5.74	26		0.05
8/26/2011	HACH sensION156 Portable Meter	5.82	26.4		0.06
8/27/2011	HACH sensION156 Portable Meter	5.85	27.8		0.05
8/28/2011	HACH sensION156 Portable Meter	5.86	27.7		0.06
8/29/2011	HACH sensION156 Portable Meter	5.92	25.4		0.03
8/30/2011	HACH sensION156 Portable Meter	6.15	25.6		0.06
8/31/2011	HACH sensION156 Portable Meter	6.32	23.7		0.05
9/1/2011	HACH sensION156 Portable Meter	6.45	21.6		0.04
9/2/2011	HACH sensION156 Portable Meter	6.31	21.9		0.05
9/3/2011	HACH sensION156 Portable Meter	5.86	25.6		0.04
9/4/2011	HACH sensION156 Portable Meter	5.76	27.2		0.03
9/6/2011	HACH sensION156 Portable Meter	5.87	27.8		0.05
9/7/2011	HACH sensION156 Portable Meter	5.68	30		0.04
9/8/2011	HACH sensION156 Portable Meter	5.76	28.8		0.05
9/12/2011	HACH sensION156 Portable Meter	5.91	24.7		0.06
9/13/2011	HACH sensION156 Portable Meter	5.73	27.9	7.34	0.03
9/14/2011	HACH sensION156 Portable Meter	5.67	25.7		0.04
9/15/2011	HACH sensION156 Portable Meter	5.76	22.1	7.55	0.04
9/16/2011	HACH sensION156 Portable Meter	5.77	23.9		0.05
9/17/2011	HACH sensION156 Portable Meter	6.4	25.6		0.05
9/18/2011	HACH sensION156 Portable Meter	5.89	23.1	7.07	0.03
9/19/2011	HACH sensION156 Portable Meter	5.82	23.7		0.05
9/20/2011	HACH sensION156 Portable Meter	5.75	25.5	7.3	0.03

Table 25 On-site Laboratory UV/AOP Product Water Results of General Parameters with Basin Plan Numeric Objectives

Sample Date	Method	Parameter Measured @ S10 UV/AOP Product			
		pH	Temperature, Deg C	DO, mg/L	Turbidity, NTU
9/21/2011	HACH sensION156 Portable Meter	5.92	27.4		0.03
9/22/2011	HACH sensION156 Portable Meter	5.78	21.3	7.41	0.04
9/23/2011	HACH sensION156 Portable Meter	5.74	24.6		0.04
9/24/2011	HACH sensION156 Portable Meter	5.88	26.6		0.05
9/26/2011	HACH sensION156 Portable Meter	5.73	24.1		0.06
9/27/2011	HACH sensION156 Portable Meter	5.69	21.8	6.96	0.06
9/28/2011	HACH sensION156 Portable Meter	5.65	20.4		0.05
9/29/2011	HACH sensION156 Portable Meter	5.91	20.3	6.77	0.05
9/30/2011	HACH sensION156 Portable Meter	5.86	22		0.05
10/1/2011	HACH sensION156 Portable Meter	6.15	27.1		0.07
10/2/2011	HACH sensION156 Portable Meter	6.27	27.8	6.39	0.07
10/3/2011	HACH sensION156 Portable Meter	5.83	27.9		0.04
10/4/2011	HACH sensION156 Portable Meter	5.63	20.8	7.1	0.07
10/5/2011	HACH sensION156 Portable Meter	5.61	20.3		0.06
10/6/2011	HACH sensION156 Portable Meter	5.5	22.1	7.12	0.03
10/9/2011	HACH sensION156 Portable Meter	5.54	26.4	6.72	0.04
10/10/2011	HACH sensION156 Portable Meter	5.63	26.7		0.03
10/11/2011	HACH sensION156 Portable Meter	5.79	27.1		0.05
10/12/2011	HACH sensION156 Portable Meter	5.53	24.3	7.03	0.05
10/13/2011	HACH sensION156 Portable Meter	5.47	26.8	7.47	0.06
10/14/2011	HACH sensION156 Portable Meter	5.45	26.7		0.06
10/15/2011	HACH sensION156 Portable Meter	5.91	26.7		0.05
10/16/2011	HACH sensION156 Portable Meter	5.95	26.5	7.15	0.06
10/17/2011	HACH sensION156 Portable Meter	6.39	27.5		0.06
10/19/2011	HACH sensION156 Portable Meter	5.6	26.6	9.54	0.04
10/20/2011	HACH sensION156 Portable Meter	5.43	26.6	6.58	0.07
10/21/2011	HACH sensION156 Portable Meter	5.48	26.6		0.06
10/22/2011	HACH sensION156 Portable Meter	5.52	26.5		0.04
10/23/2011	HACH sensION156 Portable Meter	5.46	25.7		0.06
10/24/2011	HACH sensION156 Portable Meter	5.65	26.3		0.04
10/25/2011	HACH sensION156 Portable Meter	5.54	26.3		0.05
10/26/2011	HACH sensION156 Portable Meter	5.5	26.3		0.05
10/27/2011	HACH sensION156 Portable Meter	5.46	26.3		0.06
10/28/2011	HACH sensION156 Portable Meter	5.43	26.4		0.05
10/29/2011	HACH sensION156 Portable Meter	5.63	26.3		0.04
10/30/2011	HACH sensION156 Portable Meter	5.77	26	7.89	0.04
10/31/2011	HACH sensION156 Portable Meter	5.51	26		0.04

Table 25 On-site Laboratory UV/AOP Product Water Results of General Parameters with Basin Plan Numeric Objectives

Sample Date	Method	Parameter Measured @ S10 UV/AOP Product			
		pH	Temperature, Deg C	DO, mg/L	Turbidity, NTU
11/1/2011	HACH sensION156 Portable Meter	5.46	26.3	6.85	0.06
11/2/2011	HACH sensION156 Portable Meter	5.46	26.4		0.04
11/3/2011	HACH sensION156 Portable Meter	5.53	25.6	7.3	0.05
11/4/2011	HACH sensION156 Portable Meter	5.64	19.1		0.04
11/5/2011	HACH sensION156 Portable Meter	5.58	25.5		0.05
11/6/2011	HACH sensION156 Portable Meter	5.72	24.7	7.79	0.10
11/7/2011	HACH sensION156 Portable Meter	6.28	26		0.04
11/8/2011	HACH sensION156 Portable Meter	5.41	24.9	7.63	0.04
11/9/2011	HACH sensION156 Portable Meter	5.50	22		0.05
11/10/2011	HACH sensION156 Portable Meter	5.51	21.6	7.68	0.05
11/11/2011	HACH sensION156 Portable Meter	5.82	21.1		0.04
11/12/2011	HACH sensION156 Portable Meter	5.37	21.3		0.05
11/13/2011	HACH sensION156 Portable Meter	5.58	25.2	7.67	0.06
11/16/2011	HACH sensION156 Portable Meter	5.32	21.5		0.06
11/17/2011	HACH sensION156 Portable Meter	5.40	24.8	7.55	0.05
11/18/2011	HACH sensION156 Portable Meter	5.49	19.6		0.05
11/19/2011	HACH sensION156 Portable Meter	5.42	22.2		0.05
11/20/2011	HACH sensION156 Portable Meter	5.50	23.5	7.47	0.05
11/21/2011	HACH sensION156 Portable Meter	5.49	24.5		0.05
11/22/2011	HACH sensION156 Portable Meter	5.26	18.8	7.54	0.05
11/23/2011	HACH sensION156 Portable Meter	5.42	18.4		0.04
11/25/2011	HACH sensION156 Portable Meter	5.48	24.1		0.05
11/26/2011	HACH sensION156 Portable Meter	5.40	24.7		0.04
11/27/2011	HACH sensION156 Portable Meter	5.43	24.8	7.59	0.05
11/28/2011	HACH sensION156 Portable Meter	5.42	24.8		0.04
11/29/2011	HACH sensION156 Portable Meter	5.44	24	7.44	0.05
11/30/2011	HACH sensION156 Portable Meter	5.37	24.1		0.05
12/1/2011	HACH sensION156 Portable Meter	5.48	21.7	7.19	0.04
12/2/2011	HACH sensION156 Portable Meter	5.41	17.9		0.05
12/3/2011	HACH sensION156 Portable Meter	5.33	23.5		0.04
12/4/2011	HACH sensION156 Portable Meter	5.39	23.5	7.25	0.05
12/5/2011	HACH sensION156 Portable Meter	5.53	19.2		0.05
12/6/2011	HACH sensION156 Portable Meter	5.35	15.9	7.31	0.05
12/7/2011	HACH sensION156 Portable Meter	5.36	22.7		0.04
12/8/2011	HACH sensION156 Portable Meter	5.42	23.4	7.3	0.04
12/9/2011	HACH sensION156 Portable Meter	5.25	19		0.05
12/10/2011	HACH sensION156 Portable Meter	5.47	23.4		

Table 25 On-site Laboratory UV/AOP Product Water Results of General Parameters with Basin Plan Numeric Objectives

Sample Date	Method	Parameter Measured @ S10 UV/AOP Product			
		pH	Temperature, Deg C	DO, mg/L	Turbidity, NTU
12/11/2011	HACH sensION156 Portable Meter	5.43	23.1	7.38	
12/12/2011	HACH sensION156 Portable Meter	5.38	23.1		
12/13/2011	HACH sensION156 Portable Meter	5.47		7.28	0.05
12/14/2011	HACH sensION156 Portable Meter	5.38	21.9		0.04
12/15/2011	HACH sensION156 Portable Meter	5.24	22.7	7.78	0.05
12/16/2011	HACH sensION156 Portable Meter	5.46	17.1		0.04
12/17/2011	HACH sensION156 Portable Meter	5.39	23.4		0.04
12/18/2011	HACH sensION156 Portable Meter	5.42	22.3	7.91	0.04
12/19/2011	HACH sensION156 Portable Meter	5.39	22.9		0.05
12/20/2011	HACH sensION156 Portable Meter	5.48	16.3	7.67	0.04
12/21/2011	HACH sensION156 Portable Meter	5.39	22.2		0.05
12/22/2011	HACH sensION156 Portable Meter	5.39	22.8	7.58	0.04
12/23/2011	HACH sensION156 Portable Meter	5.41	22		0.04
12/26/2011	HACH sensION156 Portable Meter	5.35	23.2		0.04
12/27/2011	HACH sensION156 Portable Meter	5.32	23.3	7.83	0.05
12/28/2011	HACH sensION156 Portable Meter	5.38	23.1		0.05
12/29/2011	HACH sensION156 Portable Meter	5.52	23.1	7.92	0.05
12/30/2011	HACH sensION156 Portable Meter	5.52	20.8		0.04
12/31/2011	HACH sensION156 Portable Meter	5.29	23		0.04
1/2/2012	HACH sensION156 Portable Meter	5.36	23.1		0.04
1/3/2012	HACH sensION156 Portable Meter	5.37	21.1	7.96	0.04
1/4/2012	HACH sensION156 Portable Meter	5.43	22.2		0.04
1/5/2012	HACH sensION156 Portable Meter	5.35	22.9	8	0.04
1/6/2012	HACH sensION156 Portable Meter	5.43	21.3		0.04
1/7/2012	HACH sensION156 Portable Meter	5.33	23.1		0.04
1/8/2012	HACH sensION156 Portable Meter	5.35	23	7.9	0.04
1/9/2012	HACH sensION156 Portable Meter	5.47	23		0.04
1/10/2012	HACH sensION156 Portable Meter	5.27	20.5	7.81	0.05
1/12/2012	HACH sensION156 Portable Meter	5.28	20.9	7.77	0.05
1/13/2012	HACH sensION156 Portable Meter	5.40	22.2		0.05
1/14/2012	HACH sensION156 Portable Meter	5.42	22.7		0.05
1/15/2012	HACH sensION156 Portable Meter	5.46	22.6	7.47	0.04
1/16/2012	HACH sensION156 Portable Meter	5.56	21.7		0.05
1/17/2012	HACH sensION156 Portable Meter	5.58	21.4	7.76	0.04
1/18/2012	HACH sensION156 Portable Meter	5.46	22.2		0.05
1/19/2012	HACH sensION156 Portable Meter	5.44	18	7.82	0.04
1/20/2012	HACH sensION156 Portable Meter	5.50			0.04

Table 25 On-site Laboratory UV/AOP Product Water Results of General Parameters with Basin Plan Numeric Objectives

Sample Date	Method	Parameter Measured @ S10 UV/AOP Product			
		pH	Temperature, Deg C	DO, mg/L	Turbidity, NTU
1/21/2012	HACH sensION156 Portable Meter	5.50	22.4		0.03
1/22/2012	HACH sensION156 Portable Meter	5.81	22.7	7.58	0.04
1/23/2012	HACH sensION156 Portable Meter	5.57	22		0.04
1/24/2012	HACH sensION156 Portable Meter	5.27	18.8	7.97	0.04
1/25/2012	HACH sensION156 Portable Meter	5.37	22.6		0.06
1/26/2012	HACH sensION156 Portable Meter	5.31	21.7	8.09	0.04
1/27/2012	HACH sensION156 Portable Meter	5.31	19.4		0.05
1/28/2012	HACH sensION156 Portable Meter	5.37	22.9		0.06
1/29/2012	HACH sensION156 Portable Meter	5.27	23	7.8	0.05
1/30/2012	HACH sensION156 Portable Meter	5.61	22.4		0.05
1/31/2012	HACH sensION156 Portable Meter	5.25	21.8	7.53	0.04
2/1/2012	HACH sensION156 Portable Meter	5.25	22.2		0.05
2/2/2012	HACH sensION156 Portable Meter	5.26	21.5	7.78	0.04
2/3/2012	HACH sensION156 Portable Meter	5.31			0.05
2/4/2012	HACH sensION156 Portable Meter	5.43	22.4		0.05
2/5/2012	HACH sensION156 Portable Meter	5.36	22.1	7.92	0.05
2/6/2012	HACH sensION156 Portable Meter	5.59	22.8		0.05
2/7/2012	HACH sensION156 Portable Meter	5.39	22.4	7.99	0.05
2/8/2012	HACH sensION156 Portable Meter	5.55	22.6		0.04
2/9/2012	HACH sensION156 Portable Meter	5.95	22.4		0.06
2/10/2012	HACH sensION156 Portable Meter	5.75	21.5		0.04
2/11/2012	HACH sensION156 Portable Meter				
2/12/2012	HACH sensION156 Portable Meter				
2/13/2012	HACH sensION156 Portable Meter	5.95	21.3		
2/14/2012	HACH sensION156 Portable Meter	5.53	22.2	7.72	0.05
2/15/2012	HACH sensION156 Portable Meter	5.31	22.5		0.05
2/16/2012	HACH sensION156 Portable Meter	5.47	21.7		0.04
2/18/2012	HACH sensION156 Portable Meter	5.46	22.1		0.05
2/19/2012	HACH sensION156 Portable Meter	5.45	22.1	7.93	0.04
2/20/2012	HACH sensION156 Portable Meter				0.04
2/22/2012	HACH sensION156 Portable Meter	5.40	22.4		0.04
2/23/2012	HACH sensION156 Portable Meter	5.91	22.8	7.93	0.03
2/24/2012	HACH sensION156 Portable Meter	5.60	21.5		0.03
2/25/2012	HACH sensION156 Portable Meter	5.41	22.2		0.04
2/26/2012	HACH sensION156 Portable Meter	5.43	22.4	7.91	0.04
2/27/2012	HACH sensION156 Portable Meter	5.57	22.3		0.04
2/28/2012	HACH sensION156 Portable Meter	5.23	17.1		

Table 25 On-site Laboratory UV/AOP Product Water Results of General Parameters with Basin Plan Numeric Objectives

Sample Date	Method	Parameter Measured @ S10 UV/AOP Product			
		pH	Temperature, Deg C	DO, mg/L	Turbidity, NTU
2/29/2012	HACH sensION156 Portable Meter	5.25	21.7		0.03
3/1/2012	HACH sensION156 Portable Meter	5.28	21.8	7.9	0.05
3/2/2012	HACH sensION156 Portable Meter	5.43	22.1		0.03
3/3/2012	HACH sensION156 Portable Meter	5.66	22.3		0.03
3/5/2012	HACH sensION156 Portable Meter	5.93	22.5		0.04
3/6/2012	HACH sensION156 Portable Meter	5.32	22	7.87	0.04
3/7/2012	HACH sensION156 Portable Meter	5.52	22.3		0.04
3/8/2012	HACH sensION156 Portable Meter	5.77	22.2	8.13	0.04
3/9/2012	HACH sensION156 Portable Meter	5.51	22.8		0.05
3/10/2012	HACH sensION156 Portable Meter	6.11	23		0.04
3/11/2012	HACH sensION156 Portable Meter	5.56	22.7	7.99	0.03
3/12/2012	HACH sensION156 Portable Meter	5.58	22.6		0.04
3/13/2012	HACH sensION156 Portable Meter	5.47	22.3	7.91	0.04
3/14/2012	HACH sensION156 Portable Meter	5.51	22.1		0.04
3/15/2012	HACH sensION156 Portable Meter	5.53	21.2	7.84	0.04
3/16/2012	HACH sensION156 Portable Meter	5.48	22.2		0.04
3/17/2012	HACH sensION156 Portable Meter	5.55	22.8		0.05
3/18/2012	HACH sensION156 Portable Meter	5.54	21.7	7.92	0.04
3/19/2012	HACH sensION156 Portable Meter	5.84	20.6		0.04
3/20/2012	HACH sensION156 Portable Meter	6.13	21.6	7.84	0.04
3/21/2012	HACH sensION156 Portable Meter	5.69	21.7		0.03
3/22/2012	HACH sensION156 Portable Meter	5.92	22	7.92	0.04
3/23/2012	HACH sensION156 Portable Meter	5.73	22		0.04
3/24/2012	HACH sensION156 Portable Meter	5.63	22		0.03
3/25/2012	HACH sensION156 Portable Meter	5.80	22.6	8.09	0.04
3/26/2012	HACH sensION156 Portable Meter	5.85	22.2		0.05
3/27/2012	HACH sensION156 Portable Meter	6.01	20.5	7.91	0.05
3/28/2012	HACH sensION156 Portable Meter	5.86	20.3		0.04
3/29/2012	HACH sensION156 Portable Meter	5.76	21.9	7.7	0.04
3/30/2012	HACH sensION156 Portable Meter	5.71	22		0.04
3/31/2012	HACH sensION156 Portable Meter	5.80	22.6		0.04
4/1/2012	HACH sensION156 Portable Meter	5.79	20.9	7.82	0.04
4/2/2012	HACH sensION156 Portable Meter	6.05	22.2		0.04
4/3/2012	HACH sensION156 Portable Meter	5.86	22.8	7.7	0.05
4/4/2012	HACH sensION156 Portable Meter	5.92	22.7		0.04
4/5/2012	HACH sensION156 Portable Meter	5.99	21.8	7.59	0.05
4/6/2012	HACH sensION156 Portable Meter	5.62	22.5		0.04

Table 25 On-site Laboratory UV/AOP Product Water Results of General Parameters with Basin Plan Numeric Objectives

Sample Date	Method	Parameter Measured @ S10 UV/AOP Product			
		pH	Temperature, Deg C	DO, mg/L	Turbidity, NTU
4/7/2012	HACH sensION156 Portable Meter	5.87	22.7		0.04
4/8/2012	HACH sensION156 Portable Meter	5.38	23.4	7.86	0.04
4/9/2012	HACH sensION156 Portable Meter	5.62	23.5		0.04
4/10/2012	HACH sensION156 Portable Meter	5.57	23	7.88	0.04
4/11/2012	HACH sensION156 Portable Meter	5.53	22.8		0.04
4/12/2012	HACH sensION156 Portable Meter	5.41	22.7	7.65	0.05
4/13/2012	HACH sensION156 Portable Meter	5.44	22.3		0.04
4/14/2012	HACH sensION156 Portable Meter	5.51	22.7		0.05
4/15/2012	HACH sensION156 Portable Meter	5.55	22.8	7.95	0.03
4/16/2012	HACH sensION156 Portable Meter	5.53	23.4		0.05
4/17/2012	HACH sensION156 Portable Meter	5.25	23.2	7.45	0.05
4/19/2012	HACH sensION156 Portable Meter	5.43	23.3		0.04
4/20/2012	HACH sensION156 Portable Meter	5.44	23.4	7.81	0.04
4/21/2012	HACH sensION156 Portable Meter	5.49	23.7		0.05
4/22/2012	HACH sensION156 Portable Meter	5.43	23.2	7.83	0.04
4/23/2012	HACH sensION156 Portable Meter	5.65	23.8		0.03
4/24/2012	HACH sensION156 Portable Meter	5.93	22.9	7.88	0.04
4/25/2012	HACH sensION156 Portable Meter	5.57	23.3		0.04
4/26/2012	HACH sensION156 Portable Meter	5.52	23.8	7.98	0.04
4/27/2012	HACH sensION156 Portable Meter	5.49	23.3		0.04
4/28/2012	HACH sensION156 Portable Meter	5.46	23.9		0.03
4/29/2012	HACH sensION156 Portable Meter	5.44	23.3	7.92	0.04
4/30/2012	HACH sensION156 Portable Meter	5.63	23.9		0.05
5/1/2012	HACH sensION156 Portable Meter	5.62	24.2	7.52	0.08
5/2/2012	HACH sensION156 Portable Meter	5.56	23.6		0.04
5/3/2012	HACH sensION156 Portable Meter	5.54	23.6	7.37	0.04
5/4/2012	HACH sensION156 Portable Meter	5.61	23.7		0.04
5/5/2012	HACH sensION156 Portable Meter	5.70	24.1		0.05
5/6/2012	HACH sensION156 Portable Meter	5.63	23.9	7.45	0.04
5/7/2012	HACH sensION156 Portable Meter	5.64	24		0.04
5/12/2012	HACH sensION156 Portable Meter	5.62	24.6		0.05
5/13/2012	HACH sensION156 Portable Meter	5.75	24.8	7.69	0.04
5/14/2012	HACH sensION156 Portable Meter	5.56	25		0.04
5/15/2012	HACH sensION156 Portable Meter	5.49	24.6	7.46	0.04
5/16/2012	HACH sensION156 Portable Meter	5.57	24.9		0.04
5/17/2012	HACH sensION156 Portable Meter	5.56	24.7	7.5	0.04
5/18/2012	HACH sensION156 Portable Meter	5.62	24.7		0.04

Table 25 On-site Laboratory UV/AOP Product Water Results of General Parameters with Basin Plan Numeric Objectives

Sample Date	Method	Parameter Measured @ S10 UV/AOP Product			
		pH	Temperature, Deg C	DO, mg/L	Turbidity, NTU
5/19/2012	HACH sensION156 Portable Meter	5.70	25.2		0.04
5/20/2012	HACH sensION156 Portable Meter	5.68	25.1	7.6	0.04
5/21/2012	HACH sensION156 Portable Meter	5.66	25.3		0.04
5/23/2012	HACH sensION156 Portable Meter	5.63	25.1		0.04
5/25/2012	HACH sensION156 Portable Meter	5.66	24.7		0.04
5/28/2012	HACH sensION156 Portable Meter	5.64	25.4		0.04
5/29/2012	HACH sensION156 Portable Meter	5.70	25.8	7.51	0.04
5/30/2012	HACH sensION156 Portable Meter	5.65	24.7		0.04
6/2/2012	HACH sensION156 Portable Meter	5.69	25.8		0.04
6/3/2012	HACH sensION156 Portable Meter	5.75	25.9	6.87	0.05
6/4/2012	HACH sensION156 Portable Meter	5.66	25.9		0.05
6/5/2012	HACH sensION156 Portable Meter	5.66	25.4	7.87	0.06
6/6/2012	HACH sensION156 Portable Meter	5.63	25.7		0.05
6/7/2012	HACH sensION156 Portable Meter	5.52	26.1		0.05
6/9/2012	HACH sensION156 Portable Meter	5.62	26.1		0.05
6/10/2012	HACH sensION156 Portable Meter	5.79	26	7.28	0.04
6/11/2012	HACH sensION156 Portable Meter	5.86	25.7		0.05
6/12/2012	HACH sensION156 Portable Meter	5.76	25.6	7.58	0.05
6/13/2012	HACH sensION156 Portable Meter	5.57	25.4		0.05
6/14/2012	HACH sensION156 Portable Meter	5.60	25.5	7.43	0.05
6/16/2012	HACH sensION156 Portable Meter	5.70	25.8		0.04
6/17/2012	HACH sensION156 Portable Meter	5.66	25.6	7.37	0.04
6/18/2012	HACH sensION156 Portable Meter	5.73	26		0.06
6/20/2012	HACH sensION156 Portable Meter	5.62	26.2		0.04
6/21/2012	HACH sensION156 Portable Meter	5.64	26.3	7.27	0.06
6/22/2012	HACH sensION156 Portable Meter	5.65	26.4		0.04
6/26/2012	HACH sensION156 Portable Meter	5.60	26.5	7.36	0.05
6/27/2012	HACH sensION156 Portable Meter	5.55	26.6		0.05
6/28/2012	HACH sensION156 Portable Meter	5.82	25.2	6.74	0.06
7/2/2012	HACH sensION156 Portable Meter	5.72	26.8		0.05
7/3/2012	HACH sensION156 Portable Meter	6.05	26	7.26	0.05
7/5/2012	HACH sensION156 Portable Meter	6.02	26	7.32	0.05
7/6/2012	HACH sensION156 Portable Meter	5.68	26.5		0.04
7/10/2012	HACH sensION156 Portable Meter	5.72	27.2	6.93	0.04
7/11/2012	HACH sensION156 Portable Meter	5.65	27.4		0.04
7/12/2012	HACH sensION156 Portable Meter	5.69	27.3		0.04
7/13/2012	HACH sensION156 Portable Meter	5.68	27.2		0.04

Table 25 On-site Laboratory UV/AOP Product Water Results of General Parameters with Basin Plan Numeric Objectives

Sample Date	Method	Parameter Measured @ S10 UV/AOP Product			
		pH	Temperature, Deg C	DO, mg/L	Turbidity, NTU
7/16/2012	HACH sensION156 Portable Meter	5.85	27.2		0.05
7/17/2012	HACH sensION156 Portable Meter	5.74	27.4	7.05	0.04
7/18/2012	HACH sensION156 Portable Meter	5.83	27.5		0.05
7/19/2012	HACH sensION156 Portable Meter	5.78	27.8		0.04
7/20/2012	HACH sensION156 Portable Meter	5.78	27.7		0.05
7/23/2012	HACH sensION156 Portable Meter	5.82	27.7		0.04
7/24/2012	HACH sensION156 Portable Meter	5.81	27.5	7.42	0.05
7/25/2012	HACH sensION156 Portable Meter	5.75	27.5		0.04
7/26/2012	HACH sensION156 Portable Meter	5.65	27.6	7.26	0.04
7/27/2012	HACH sensION156 Portable Meter	5.69	27.5		0.06
7/31/2012	HACH sensION156 Portable Meter	6.04	27.9	7.32	0.05
n =		301	298	109	298
Average		5.6	24	7.6	0.05
Maximum		6.5	30	9.5	0.10
Minimum		5.2	16	6.4	0.03
STDev		0.2	2.4	0.4	0.01

Table 26 Summary of Compounds with Federal and State Primary Drinking Water Standards Results

Parameter	Method	Units	DL	RL	Quarter 1: 08/24/2011			Quarter 2: 11/08/2011			Quarter 3: 2/1/2012			Quarter 4: 5/1/2012			[1] Federal Drinking Water MCL	[1] CDPH Drinking Water MCL
					S1 (tertiary effluent)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water	S1 (tertiary effluent)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water	S1 (tertiary effluent)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water	S1 (tertiary effluent)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water		
1,1,1-Trichloroethane	EPA 524.2	µg/L	0.11	0.5	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	200	200
1,1,2,2-Tetrachloroethane	EPA 524.2	µg/L	0.2	0.5	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	-	1
1,1,2-Trichloroethane	EPA 524.2	µg/L	0.19	0.5	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	5	5
1,1-Dichloroethane	EPA 524.2	µg/L	0.12	0.5	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	-	5
1,1-Dichloroethene	EPA 524.2	µg/L	0.16	0.5	<0.16	<0.16	<0.16	<0.16	<0.16	<0.16	<0.16	<0.16	<0.16	<0.16	<0.16	<0.16	7	6
1,2,4-Trichlorobenzene	EPA 524.2	µg/L	0.17	0.5	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	70	5
1,2-Dibromo-3-chloropropane	EPA 504.1	µg/L	0.0034	0.01	<0.0034	<0.0034	<0.0034	<0.0034	<0.0034	<0.0034	<0.0034	<0.0034	<0.0034	<0.0034	<0.0034	<0.0034	0.2	0.2
1,2-Dibromoethane (EDB)	EPA 504.1	µg/L	0.0054	0.02	<0.0054	<0.0054	<0.0054	<0.0054	<0.0054	<0.0054	<0.0054	<0.0054	<0.02	<0.0054	<0.0054	<0.0054	0.05	0.05
1,2-Dichloroethane	EPA 524.2	µg/L	0.12	0.5	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	5	0.5
1,2-Dichloropropane	EPA 524.2	µg/L	0.13	0.5	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	5	5
1,3-Dichloropropene, Total	EPA 524.2	µg/L	0.15	0.5	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	-	0.5
2,3,7,8-Tetra CDD	EPA 1613B mod.	pg/L	1.9	10	<10	<9.5	<9.3	<10	<10	<9.8	<9.7	<9.5	<9.5	<5.2	<5.2	<5.2	30	30
2,4,5-TP (Silvex)	EPA 515.3	µg/L	0.09	0.2	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	50	50
2,4-D	EPA 515.3	µg/L	0.07	0.4	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	70	70
Alachlor	EPA 525.2	µg/L	0.022	0.1	<0.022	<0.022	<0.022	<0.022	<0.022	<0.022	<0.022	<0.022	<0.022	<0.022	<0.022	<0.022	2	2
Aluminum, Total	EPA 200.8	µg/L	0.61	5	11	<5	37	8.8	<5	26	16	<5	29	6.1	<5	16	-	1000
Antimony, Total	EPA 200.8	µg/L	0.04	0.5	0.58	<0.04	<0.5	0.53	<0.5	<0.5	<0.5	<0.04	<0.5	<0.5	<0.04	<0.5	6	6
Arsenic, Total	EPA 200.8	µg/L	0.036	0.4	0.97	<0.036	2.5	0.98	<0.036	2.3	0.62	<0.036	2	0.77	<0.4	2.2	10	10
Asbestos	EPA 100.2	MFL	NA	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	7	7
Atrazine	EPA 525.2	µg/L	0.034	0.1	<0.034	<0.034	<0.034	<0.034	<0.034	<0.034	<0.034	<0.034	<0.034	<0.034	<0.034	<0.034	3	1
Barium, Total	EPA 200.8	µg/L	0.03	0.5	22	<0.03	39	18	<0.03	39	21	<0.03	47	20	<0.5	70	2000	1000
Bentazon	EPA 515.3	µg/L	0.11	2	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	-	18
Benzene	EPA 524.2	µg/L	0.15	0.5	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	5	1
Benzo (a) pyrene	EPA 525.2	µg/L	0.07	0.1	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07	0.2	0.2
Beryllium, Total	EPA 200.8	µg/L	0.088	0.1	<0.088	<0.088	<0.088	<0.088	<0.088	<0.088	<0.088	<0.088	<0.088	<0.088	<0.088	<0.088	4	4
Bis(2-ethylhexyl)adipate	EPA 525.2	µg/L	0.1	5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	400	400
Bis(2-ethylhexyl)phthalate	EPA 525.2	µg/L	1.1	3	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<3	<1.1	6	4
Bromate	EPA 326.0	µg/L	1.2	2.5	<1.2	<0.25	<0.25	<0.25	<0.25	<0.25	<0.5	<0.5	<0.5	<0.25	<0.25	<0.25	10	10
Cadmium, Total	EPA 200.8	µg/L	0.02	0.1	<0.02	<0.02	<0.02	<0.1	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	5	5
Carbofuran	EPA 531.1	µg/L	0.59	2	<0.59	<0.59	<0.59	<0.59	<0.59	<0.59	<0.59	<0.59	<0.59	<0.59	<0.59	<0.59	40	18
Carbon tetrachloride	EPA 524.2	µg/L	0.12	0.5	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	5	0.5
Chlordane (tech)	EPA 508	µg/L	0.066	0.1	<0.066	<0.066	<0.066	<0.066	<0.066	<0.066	<0.066	<0.066	<0.066	<0.066	<0.066	<0.066	2	0.1
Chlorite	EPA 300.1	µg/L	0.7	10	<0.7	<0.7	<0.7	<0.7	<10	<0.7	<0.7	<0.7	<0.7	<1.4	<0.7	<0.7	1000	1000
Chlorobenzene	EPA 524.2	µg/L	0.15	0.5	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	100	70
Chromium, Total	EPA 200.8	µg/L	0.074	0.2	0.25	<0.074	<0.2	0.56	<0.074	<0.2	0.52	<0.074	<0.2	0.28	<0.074	<0.2	100	50
cis-1,2-Dichloroethene	EPA 524.2	µg/L	0.11	0.5	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	70	6
Copper, Total	EPA 200.8	µg/L	0.27	0.5	1.6	<0.27	2.6	1.8	<0.27	4.1	1.7	<0.27	3	1.6	<0.27	3.1	1300a	1300a
Cyanide, Total	EPA 335.4	µg/L	2.7	5	<2.7	<2.7	<2.7	<2.7	<2.7	<2.7	<2.7	<2.7	<2.7	<2.7	<2.7	<2.7	200	150
Dalapon	EPA 515.3	µg/L	0.1	0.4	<0.4	<0.1	<0.1	<0.1	<0.1	<0.1	<0.4	<0.1	<0.1	<0.1	<0.1	<0.1	200	200
Dinoseb	EPA 515.3	µg/L	0.14	0.4	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	7	7
Diquat	EPA 549.2	µg/L	0.9	4	<0.9	<0.9	<0.9	<4	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	20	20
Endothall	EPA 548.1	µg/L	3.5	45	<3.5	<3.5	<3.5	<3.5	<3.5	<3.5	<3.5	<3.5	<3.5	<3.5	<3.5	<3.5	100	100
Endrin	EPA 508	µg/L	0.002	0.01	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	2	2
Ethylbenzene	EPA 524.2	µg/L	0.21	0.5	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	700	300

Table 26 Summary of Compounds with Federal and State Primary Drinking Water Standards Results

Parameter	Method	Units	DL	RL	Quarter 1: 08/24/2011			Quarter 2: 11/08/2011			Quarter 3: 2/1/2012			Quarter 4: 5/1/2012			[1] Federal Drinking Water MCL	[1] CDPH Drinking Water MCL
					S1 (tertiary effluent)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water	S1 (tertiary effluent)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water	S1 (tertiary effluent)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water	S1 (tertiary effluent)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water		
Fluoride, Total	EPA 300.0	mg/l	0.02	0.1	0.61	<0.1	0.14	0.63	<0.02	0.16	0.54	<0.02	0.13	0.71	<0.02	0.25	4	2
Freon 113	EPA 524.2	µg/L	0.27	5	<0.27	<0.27	<0.27	<0.27	<0.27	<0.27	<0.27	<0.27	<0.27	<0.27	<0.27	<0.27	-	1200
gamma-BHC (Lindane)	EPA 508	µg/L	0.0015	0.01	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	0.2	0.2
Glyphosate	EPA 547	µg/L	1.8	5	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	700	700
[2] Gross Alpha	EPA 900.0	pCi/L	NA	NA	0.016+/-0.16 (MDA=0.016)	0.94+/-0.404 (MDA=0.601)	2.1+/-0.77 (MDA=1.089)	5.78+/-0.393 (MDA=0.016)	-2.0+/-0.582 (MDA=0.886)	0.31+/-0.584 (MDA=1)	0.016+/-0.15 (MDA=0.016)	-0.30+/-0.47 (MDA=0.801)	2.3+/-0.68 (MDA=1)	0.016+/-0.164 (MDA=0.016)	0.16+/-0.529 (MDA=0.927)	1.02+/-0.222 (MDA=0.016)	15 pCi/L	15 pCi/L
[3] Gross Beta	EPA 900.0	pCi/L	NA	NA	21+/-1.096 (MDA=1.117)	-0.59+/-0.578 (MDA=0.968)	1.7+/-0.626 (MDA=0.991)	24+/-1.329 (MDA=1.365)	-1.4+/-0.575 (MDA=0.922)	2.8+/-0.75 (MDA=1.191)	7.6+/-0.84 (MDA=1.1096)	0.28+/-0.532 (MDA=0.902)	3.2+/-0.537 (MDA=0.808)	3.4+/-0.829 (MDA=1.25)	0.62+/-0.531 (MDA=0.884)	5+/-0.83 (MDA=1.215)	4 mrem/ yr	50 pCi/L 4 mrem/ yr
HAA5, Total	EPA 552.2	µg/L		1	2.6	<1	2.5	1.5	<1	2.7	4	<1	5.7	2.1	<1	3.6	60	60
Heptachlor	EPA 508	µg/L	0.0009	0.01	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	0.4	0.01
Heptachlor epoxide	EPA 508	µg/L	0.0011	0.01	<0.0011	<0.0011	<0.0011	<0.0011	<0.0011	<0.0011	<0.0011	<0.0011	<0.0011	<0.0011	<0.0011	<0.0011	0.2	0.01
Hexachlorobenzene	EPA 508	µg/L	0.003	0.01	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.01	<0.003	<0.003	<0.003	<0.003	<0.003	1	1
Hexachlorocyclopentadiene	EPA 508	µg/L	0.014	0.05	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	50	50
Lead, Total	EPA 200.8	µg/L	0.011	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.011	<0.2	<0.2	<0.011	<0.2	15a	15a
Mercury, Total	EPA 245.1	µg/L	0.0039	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.0039	<0.0039	<0.0039	2	2
Methoxychlor	EPA 508	µg/L	0.0044	0.01	<0.0044	<0.0044	<0.0044	<0.0044	<0.0044	<0.0044	<0.0044	<0.0044	<0.0044	<0.0044	<0.0044	<0.0044	40	30
Methyl tert-butyl ether (MTBE)	EPA 524.2	µg/L	0.19	2	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	-	13
Methylene chloride	EPA 524.2	µg/L	0.14	0.5	<0.5	<0.5	<0.14	<0.14	<0.14	<0.14	<0.5	<0.5	<0.14	<0.5	<0.5	<0.14	5	5
Molinate	EPA 525.2	µg/L	0.039	0.1	<0.039	<0.039	<0.039	<0.039	<0.039	<0.039	<0.039	<0.039	<0.039	<0.039	<0.039	<0.039	-	20
Nickel, Total	EPA 200.8	µg/L	0.13	0.8	3.6	<0.13	1.2	3.5	<0.13	1.5	4.4	<0.13	1.1	3.2	<0.13	1.2	-	100
Nitrate as NO3	EPA 353.2	mg/l	0.36	1	73	3.1	1.6	70	2.9	1.5	69	3	1.3	66	4.3	<1	(as N) 10	(as NO3) 45
Nitrite as N	EPA 353.2	µg/L	10	100	<100	<10	<10	<100	<10	<10	<100	<10	<100	<100	<10	<10	1000	1000
NO2+NO3 as N	EPA 353.2	µg/L	20	200	17000	700	370	16000	660	350	16000	670	300	15000	970	200	10000	10000
o-Dichlorobenzene	EPA 524.2	µg/L	0.19	0.5	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	600	600
Oxamyl	EPA 531.1	µg/L	0.48	2	<0.48	<0.48	<0.48	<0.48	<0.48	<0.48	<0.48	<0.48	<0.48	<0.48	<0.48	<0.48	200	50
PCBs, Total	EPA 508	µg/L	0.049	0.5	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	<0.049	0.5	0.5
p-Dichlorobenzene	EPA 524.2	µg/L	0.18	0.5	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	75	5
Pentachlorophenol	EPA 515.3	µg/L	0.04	0.2	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	1	1
Perchlorate	EPA 314.0	µg/L	0.95	2	5.8	<0.95	<0.95	4.9	<0.95	<0.95	12	<0.95	<0.95	9.8	<0.95	<0.95	-	6
Picloram	EPA 515.3	µg/L	0.05	0.6	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	500	500
[4]Radium 226	EPA 903.1	pCi/L	NA	NA	0.433+/-0.278 (MDA=0.439)	0.118+/-0.172 (MDA=0.439)	0.078+/-0.153 (MDA=0.439)	0.108+/-0.259 (MDA=0.439)	0.000+/-0.21 (MDA=0.439)	0.053+/-0.233 (MDA=0.439)	0.241+/-0.341 (MDA=0.439)	0.048+/-0.282 (MDA=0.439)	0.00+/-0.265 (MDA=0.439)	0.265+/-0.267 (MDA=0.354)	0.22+/-0.259 (MDA=0.354)	0.572+/-0.311 (MDA=0.354)	5	5
[4]Radium 228	EPA Ra-05	pCi/L	NA	NA	0.00+/-0.631 (MDA=0.322)	0.207+/-0.707 (MDA=0.277)	0.00+/-0.563 (MDA=0.205)	0.000+/-0.562 (MDA=0.276)	0.000+/-0.484 (MDA=0.204)	0.000+/-0.625 (MDA=0.322)	0.00+/-0.453 (MDA=0.205)	0.00+/-0.418 (MDA=0.203)	0.00+/-0.702 (MDA=0.261)	0.25+/-0.431 (MDA=0.25)	0.2+/-0.495 (MDA=0.2)	0.203+/-0.464 (MDA=0.203)	5	5
Selenium, Total	EPA 200.8	µg/L	0.28	0.4	0.56	<0.28	<0.4	0.57	<0.28	<0.4	0.48	<0.28	0.43	1.1	<0.28	0.87	50	50
Simazine	EPA 525.2	µg/L	0.015	0.1	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	4	4
Strontium 90	EPA 905.0	pCi/L		NA	0.00+/-0.471 (MDA=0.676)	0.00+/-0.411 (MDA=0.675)	0.00+/-0.435 (MDA=0.675)	0.183+/-0.223 (MDA=0.675)	0.152+/-0.215 (MDA=0.675)	0.579+/-0.31 (MDA=0.676)	0.00+/-0.267 (MDA=0.636)	0.062+/-0.287 (MDA=0.636)	0.218+/-0.283 (MDA=0.636)	0.636+/-0.508 (MDA=0.636)	0.636+/-0.546 (MDA=0.636)	0.636+/-0.469 (MDA=0.636)	8	8
Styrene	EPA 524.2	µg/L	0.19	0.5	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	100	100
Tetrachloroethene	EPA 524.2	µg/L	0.18	0.5	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	5	5
Thallium, Total	EPA 200.8	µg/L	0.009	0.2	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.2	<0.2	<0.2	<0.2	<0.009	<0.009	2	2
Thiobencarb	EPA 525.2	µg/L	0.025	0.1	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	-	70
THMs, Total	EPA 524.2	µg/L	0.6	2	3	2.2	54	<2	<0.6	38	<0.6	<0.6	33	<2	<0.6	36	80	80

Table 26 Summary of Compounds with Federal and State Primary Drinking Water Standards Results

Parameter	Method	Units	DL	RL	Quarter 1: 08/24/2011			Quarter 2: 11/08/2011			Quarter 3: 2/1/2012			Quarter 4: 5/1/2012			[1] Federal Drinking Water MCL	[1] CDPH Drinking Water MCL
					S1 (tertiary effluent)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water	S1 (tertiary effluent)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water	S1 (tertiary effluent)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water	S1 (tertiary effluent)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water		
Toluene	EPA 524.2	µg/L	0.14	0.5	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14	<0.5	<0.14	<0.14	1000	150
Toxaphene	EPA 508	µg/L	0.066	1	<0.066	<0.066	<0.066	<0.066	<0.066	<0.066	<0.066	<0.066	<0.066	<0.066	<0.066	<0.066	3	3
trans-1,2-Dichloroethene	EPA 524.2	µg/L	0.11	0.5	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	<0.11	100	10
Trichloroethene	EPA 524.2	µg/L	0.18	0.5	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	5	5
Trichlorofluoromethane	EPA 524.2	µg/L	0.18	0.5	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	-	150
Tritium[5]	EPA 906.0	pCi/L	NA	NA	0.00+/-246 (MDA=423)	0.00+/-242 (MDA=423)	0.00+/-244 (MDA=423)	0.000+/-417 (MDA=714)	0.00+/-421 (MDA=714)	0.00+/-422 (MDA=714)	126+/-268 (MDA=437)	0+/-267 (MDA=437)	0.00+/-261 (MDA=437)	505+/-303 (MDA=505)	25.7+/-305 (MDA=505)	505+/-301 (MDA=505)	20000	20000
Uranium Rad[5]	EPA 200.8	pCi/L	0.019	0.13	0.17	<0.019	0.92	<0.13	<0.019	0.96	0.16	<0.019	1.3	0.31	<0.019	2.2	20.1	20
Vinyl chloride	EPA 524.2	µg/L	0.18	0.5	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	2	0.5
Xylenes, Total	EPA 524.2	µg/L	0.33	0.5	<0.33	<0.33	<0.33	<0.33	<0.33	<0.33	<0.33	<0.33	<0.33	<0.33	<0.33	<0.33	10000	1750

Note:

1. California Department of Public Health, *Maximum Contaminant Levels and Regulatory Dates for Drinking Water U.S. EPA Vs California*, November 2008. http://www.cdph.ca.gov/certlic/drinkingwater/pages/chemicalcontaminants.aspx
2. Gross Alpha Radioactivity is simply a measurement of all alpha activity present, regardless of specific radionuclide source. Gross measurements are used as a method to screen samples for relative levels of radioactivity.
3. Gross Beta Radioactivity is simply a measurement of all beta activity present, regardless of specific radionuclide source. Gross measurements are used as a method to screen samples for relative levels of radioactivity.
4. MCL for Radium 226 and Radium 228 is expressed as Combined Radium (226+228)
5. Refer to **Section 3.2.5 URs** for how to interpret MDAs and Counting Errors.
6. Results shown as less than (<VALUE) indicate the reported result was less than the RL or DL. In some instances, the RL and/or DL varied during the testing period due to laboratory QC procedures or changes in method procedures.

Table 27 Summary of Compounds with Federal and State Secondary Drinking Water Standards Results

Parameter	Method	Units	DL	RL	Quarter 1: 08/24/2011			Quarter 2: 11/08/2011			Quarter 3: 2/1/2012			Quarter 4: 5/1/2012			Federal Drinking Water MCL	CDPH Drinking Water MCL
					S1 (tertiary effluent)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water	S1 (tertiary effluent)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water	S1 (tertiary effluent)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water	S1 (tertiary effluent)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water		
Aluminum, Total	EPA 200.8	µg/L	0.61	5	11	<5	37	8.8	<5	26	16	<5	29	6.1	<5	16	50 to 200	200
Chloride, Total	EPA 300.0	mg/l	1	5	250	<5	61	240	<5	54	260	<5	63	270	<5	71	250	250
Color	SM2120B	Color Units	NA	3	20	<3	<3	20	<3	<3	15	<3	<3	15	<3	<3	15	15
Copper, Total	EPA 200.8	µg/L	0.27	0.5	1.6	<0.27	2.6	1.8	<0.27	4.1	1.7	<0.27	3	1.6	<0.27	3.1	1000	1000
Iron, Total	EPA 200.7	µg/L	1.1	10	93	<1.1	22	73	<1.1	33	110	<1.1	35	69	<1.1	18	300	300
Langelier Index @ 20 C	EPA 200.2	N/A	-10.0	-10.0	<-10	-6.64	<-10	<-10	-6.69	<-10	-0.832	-6.59	-0.483	-0.784	-6.15	-0.112	Non Corrosive	----------
Manganese, Total	EPA 200.8	µg/L	0.11	0.2	110	<0.11	23	70	<0.11	5.7	93	0.37	4.3	72	<0.2	2.8	50	50
MBAS	SM 5540 C	mg/l	0.019	0.05	0.063	<0.019	<0.05	<0.05	<0.019	<0.019	0.054	<0.019	<0.019	0.07	<0.019	<0.019	0.5	0.5
Methyl tert-butyl ether (MTBE)	EPA 524.2	µg/L	0.19	2	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	<0.19	----------	5
pH water	General Preparation	Units	0.1	0.1	7.08	5.82	7.48	7.04	5.99	7.4	6.99	5.75	7.52	6.91	5.89	7.62	6.5-8.5	----------
Silver, Total	EPA 200.8	µg/L	0.027	0.2	<0.027	<0.027	<0.027	<0.027	<0.027	<0.027	<0.027	<0.027	<0.027	0.21	<0.2	<0.2	100	100
Specific Conductance (EC)	SM2510B	umhos/cm	0.47	4	1500	22	470	1100	16	370	1400	20	520	1500	26	670	NR	900
Sulfate as SO4	EPA 300.0	mg/l	0.1	0.5	170	<0.1	61	130	<0.5	56	150	<0.1	73	180	<0.5	130	250	250
Thiobencarb	EPA 525.2	µg/L	0.025	0.1	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	----------	1
Threshold Odor Number	EPA 140.1	T.O.N.	NA	1	10	<1	<1	2	<1	2	20	<1	<1	10	<1	<1	3	3
Total Dissolved Solids	SM2540C	mg/l	4	10	850	16	280	760	16	380	710	13	270	650	11	290	500	500
Turbidity	EPA 180.1	NTU	0.024	0.1	0.35	<0.024	0.61	<0.024	<0.024	<0.024	0.17	<0.024	0.35	<0.024	<0.024	<0.024	5	5
Zinc, Total	EPA 200.8	µg/L	1.1	5	66	<1.1	5.5	48	<1.1	<5	100	<1.1	<5	36	<1.1	<5	5000	5000

Note:

1. NR=not regulated. California Code of Regulation Title 22. Division 4. Environmental Health Chapter 15. Domestic Water Quality and Monitoring Regulations Article 16.
2. Results shown as less than (<VALUE) indicate the reported result was less than the RL or DL. In some instances, the RL and/or DL varied during the testing period due to laboratory QC procedures or changes in method procedures.

Table 28 Summary of Detected Priority Pollutant Results North City Tertiary Effluent (Pre-chlorination)

Parameter	Method	Units	DL	RL	Quarter 1: 08/24/2011	Quarter 2: 11/08/2011	Quarter 3: 02/01/2012	Quarter 4: 05/01/2012	Fresh Water Criterion Continuous Conc. Aquatic (µg/L)	Human Health (10-6) risk for carcinogens) For the Consumption of: Water & Organisms (µg/L)
2,3,7,8-Tetra CDD	EPA 1613B mod.	pg/L	varies	10	<10	<10	<9.7	<5.2		0.000000013 c
Antimony, Total	EPA 200.8	µg/L	0.04	0.5	0.58	0.53	<0.5	<0.5		14 a,s
Arsenic, Total	EPA 200.8	µg/L	0.036	0.4	0.97	0.98	0.62	0.77	150 i,m,w	
Asbestos	EPA 100.2	MFL	0	0.2	<0.2	<0.2	<0.2	<0.2		7,000,000 fibers/L k,s
Bromodichloromethane	EPA 524.2	µg/L	0.09	0.5	1	0.58	<0.5	0.51		0.56 a,c
Cadmium, Total	EPA 200.8	µg/L	0.02	0.1	<0.02	<0.1	<0.02	<0.02	2.2 e,i,m,w	n
Chloroform	EPA 524.2	µg/L	0.12	0.5	1.4	0.8	<0.5	0.52	Reserved	Reserved
Chromium, Total (Cr (III) + Cr(VI))	EPA 200.8	µg/L	0.074	0.2	0.25	0.56	0.52	0.28	11 i,m,w (Cr(VI))/180 e,i,m,o(Cr(III))	n
Copper, Total	EPA 200.8	µg/L	0.27	0.5	1.6	1.8	1.7	1.6	9.0 e,i,m,w	1300
Dibromochloromethane	EPA 524.2	µg/L	0.2	0.5	0.65	<0.5	<0.5	<0.5		0.401 a,c
Lead, Total	EPA 200.8	µg/L	0.011	0.2	<0.2	<0.2	<0.2	<0.2	2.5 e,i,m	n
Mercury, Total	EPA 245.1	µg/L	0.0039	0.05	<0.05	<0.05	<0.05	<0.0039	[Reserved]	0.050 a
Methylene chloride	EPA 524.2	µg/L	0.14	0.5	<0.5	<0.14	<0.5	<0.5		4.7 a,c
Nickel, Total	EPA 200.8	µg/L	0.13	0.8	3.6	3.5	4.4	3.2	52 e,i,m,w	610 a
Selenium, Total	EPA 200.8	µg/L	0.28	0.4	0.56	0.57	0.48	1.1	5.0 q	n
Thallium, Total	EPA 200.2	µg/L	0.009	0.2	<0.009	<0.009	<0.2	<0.2		
Zinc, Total	EPA 200.8	µg/L	1.1	5	66	48	100	36	120 e,i,m,w	
N-Nitrosodimethylamine	EPA 521	ng/l	0.14	2	2.9	<2	<0.14	<0.14		0.00069 a,c,s

Note:

1. Footnotes are defined in Federal Register / Vol. 65, No. 97/Thursday, May 18, 2000/Rules and Regulations. The complete list of priority pollutants analyzed is provided in Table 31.
2. Results shown as less than (<VALUE) indicate the reported result was less than the RL or DL. In some instances, the RL and/or DL varied during the testing period due to laboratory QC procedures or changes in method procedures.

Table 29 Summary of Detected Priority Pollutant Results UV/AOP Product Water

Parameter	Method	Units	DL	RL	Quarter 1: 08/24/2011	Quarter 2: 11/08/2011	Quarter 3: 02/01/2012	Quarter 4: 05/01/2012	Fresh Water Criterion Continuous Conc. Aquatic (µg/L)	Human Health (10-6) risk for carcinogens) For the Consumption of: Water & Organisms (µg/L)
2,3,7,8-Tetra CDD	EPA 1613B mod.	pg/L	varies	10	<9.5	<10	<9.5	<5.2		0.000000013 c
Antimony, Total	EPA 200.8	µg/L	0.04	0.5	<0.04	<0.5	<0.04	<0.04		14 a,s
Arsenic, Total	EPA 200.8	µg/L	0.036	0.4	<0.036	<0.036	<0.036	<0.4	150 i,m,w	
Asbestos	EPA 100.2	MFL	0	0.2	<0.2	<0.2	<0.2	<0.2		7,000,000 fibers/L k,s
Bromodichloromethane	EPA 524.2	µg/L	0.09	0.5	0.78	<0.5	<0.5	<0.5		0.56 a,c
Chloroform	EPA 524.2	µg/L	0.12	0.5	1.4	<0.5	<0.12	<0.5	Reserved	Reserved
Diethyl phthalate	EPA 625	µg/L	0.15	1	<1	<0.15	<0.15	<0.15		23000 a,s
Dimethyl phthalate	EPA 625	µg/L	0.18	1	<1	<0.18	<0.18	<0.18		313000 s
Di-n-butyl phthalate	EPA 625	µg/l	0.24	1	2.2	<0.24	<0.24	<0.24		2700 a,s
Lead, Total	EPA 200.8	µg/L	0.011	0.2	<0.2	<0.2	<0.011	<0.011	2.5 e,i,m	n
Mercury, Total	EPA 245.1	µg/L	0.0039	0.05	<0.05	<0.05	<0.05	<0.0039	[Reserved]	0.050 a
Methylene chloride	EPA 524.2	µg/L	0.14	0.5	<0.5	<0.14	<0.5	<0.5		4.7 a,c
N-Nitrosodimethylamine	EPA 521	ng/l	0.14	2	<0.14	<0.14	<0.14	<0.14		0.00069 a,c,s
Silver, Total	EPA 200.8	µg/L	0.027	0.2	<0.027	<0.027	<0.027	<0.2		

Note:

1. Footnotes are defined in Federal Register / Vol. 65, No. 97/Thursday, May 18, 2000/Rules and Regulations. The complete list of priority pollutants analyzed is provided in Table 31.
2. Results shown as less than (<VALUE) indicate the reported result was less than the RL or DL. In some instances, the RL and/or DL varied during the testing period due to laboratory QC procedures or changes in method procedures.

Table 30 Summary of Detected Priority Pollutant Results Imported Raw Aqueduct Water

Parameter	Method	Units	DL	RL	Quarter 1: 08/24/2011	Quarter 2: 11/08/2011	Quarter 3: 02/01/2012	Quarter 4: 05/01/2012	[1] Fresh Water Criterion Continuous Conc. Aquatic (µg/L)	[1] Human Health (10-6) risk for carcinogens) For the Consumption of: Water & Organisms (µg/L)
2,3,7,8-Tetra CDD	EPA 1613B mod.	pg/L	varies	10	<9.3	<9.8	<9.5	<5.2		0.000000013 c
Antimony, Total	EPA 200.8	µg/L	0.04	0.5	<0.5	<0.5	<0.5	<0.5		14 a,s
Arsenic, Total	EPA 200.8	µg/L	0.036	0.4	2.5	2.3	2	2.2	150 i,m,w	
Asbestos	EPA 100.2	MFL	0	0.2	<0.2	<0.2	<0.2	<0.2		7,000,000 fibers/L k,s
Bis(2-ethylhexyl)phthalate	EPA 625	µg/L	2.3	5	<2.3	<2.3	<2.3	<5		
Bromodichloromethane	EPA 524.2	µg/L	0.09	0.5	19	14	10	10		0.56 a,c
Bromoform	EPA 524.2	µg/L	0.19	0.5	3.5	2.9	3.8	6.2		4.3 a,c
Chloroform	EPA 524.2	µg/L	0.12	0.5	11	6.6	4.8	4.8	Reserved	Reserved
[2] Chromium, Total (Cr (III) + Cr(VI))	EPA 200.8	µg/L	0.074	0.2	<0.2	<0.2	<0.2	<0.2	11 i,m,w (Cr(VI))/180 e,i,m,o(Cr(III))	n
Copper, Total	EPA 200.8	µg/L	0.27	0.5	2.6	4.1	3	3.1	9.0 e,i,m,w	1300
Dibromochloromethane	EPA 524.2	µg/L	0.2	0.5	21	14	14	15		0.401 a,c
Heptachlor epoxide	EPA 508	µg/L	0.0011	0.01	<0.0011	<0.0011	<0.0011	<0.0011	0.0038 g	0.0001 a,c
Lead, Total	EPA 200.8	µg/L	0.011	0.2	<0.2	<0.2	<0.2	<0.2	2.5 e,i,m	n
Mercury, Total	EPA 245.1	µg/L	0.0039	0.05	<0.05	<0.05	<0.05	<0.0039	[Reserved]	0.050 a
Nickel, Total	EPA 200.8	µg/L	0.13	0.8	1.2	1.5	1.1	1.2	52 e,i,m,w	610 a
Nitrobenzene	EPA 625	µg/L	0.36	1	<0.36	<0.36	<0.36	<0.36		17 a,s
Phenanthrene	EPA 625	µg/L	0.32	1	<0.32	<0.32	<0.32	<0.32		
Pyrene	EPA 625	µg/L	0.25	1	<0.25	<0.25	<0.25	<0.25		960 a
Selenium, Total	EPA 200.8	µg/L	0.28	0.4	<0.4	<0.4	0.43	0.87	5.0 q	n
Silver, Total	EPA 200.8	µg/L	0.027	0.2	<0.027	<0.027	<0.027	<0.2		
Vinyl chloride	EPA 524.2	µg/L	0.18	0.5	<0.18	<0.18	<0.18	<0.18		2 c,s
Zinc, Total	EPA 200.8	µg/L	1.1	5	5.5	<5	<5	<5	120 e,i,m,w	

Note:

1. Footnotes are defined in Federal Register / Vol. 65, No. 97/Thursday, May 18, 2000/Rules and Regulations. Data flags provided in the original laboratory reports are not shown. The complete list of priority pollutants analyzed is provided in Table 31.
2. Lab 2 condcuted these analysis. Hexavalent Chromium results are presented in Table 33 (Lab 1) and Table 33 (Lab 2). Cr (III) = Trivalent chromium is determined based on calculation of Total Chromium minus Cr VI (hexavalent chromium).
3. Results shown as less than (<VALUE) indicate the reported result was less than the RL or DL. In some instances, the RL and/or DL varied during the testing period due to laboratory QC procedures or changes in method procedures.

Table 31 Numeric Criteria for Priority Toxic Pollutants for the State of California; Rule

A		B Freshwater		C Saltwater		D Human Health (10^{-6} risk for carcinogens) For consumption of:	
# Compound	CAS Number	Criterion Maximum Conc. [d] B1	Criterion Continuous Conc. [d] B2	Criterion Maximum Conc. [d] C1	Criterion Continuous Conc. [d] C2	Water & Organisms (µg/L) D1	Organisms Only (µg/L) D2
1. Antimony	7440360					14 a,s	4300 a,t
2. Arsenic [b]	7440382	340 i,m,w	150 i,m,w	69 i,m	36 i,m		
3. Beryllium	7440417					n	n
4. Cadmium [b]	7440439	4.3 e,i,m,w,x	2.2 e,i,m,w	42 i,m	9.3 i,m	n	n
5a. Chromium (III)	16065831	550 e,i,m,o	180 e,i,m,o			n	n
5b. Chromium (VI) [b]	18540299	16 i,m,w	11 i,m,w	1100 i,m	50 i,m	n	n
6. Copper [b]	7440508	13 e,i,m,w,x	9.0 e,i,m,w	4.8 i,m	3.1 i,m	1300	
7. Lead [b]	7439921	65 e,i,m	2.5 e,i,m	210 i,m	8.1 i,m	n	n
8. Mercury [b]	7439976	[Reserved]	[Reserved]	[Reserved]	[Reserved]	0.050 a	0.051 a
9. Nickel [b]	7440020	470 e,i,m,w	52 e,i,m,w	74 i,m	8.2 i,m	610 a	4600 a
10. Selenium [b]	7782492	[Reserved] p	5.0 q	290 i,m	71 i,m	n	n
11. Silver [b]	7440224	3.4 e,i,m		1.9 i,m			
12. Thallium	7440280					1.7 a,s	6.3 a,t
13. Zinc [b]	7440666	120 e,i,m,w,x	120 e,i,m,w	90 i,m	81 i,m		
14. Cyanide [b]	57125	22 o	5.2 o	1 r	1 r	700 a	220,000 a,j
15. Asbestos	1332214					7,000,000 fibers/L k,s	
16. 2,3,7,8-TCDD (Dioxin)	1746016					0.000000013 c	0.000000014 c
17. Acrolein	107028					320 s	780 t
18. Acrylonitrile	107131					0.059 a,c,s	0.66 a,c,t
19. Benzene	71432					1.2 a,c	71 a,c
20. Bromoform	75252					4.3 a,c	360 a,c
21. Carbon Tetrachloride	56235					0.25 a,c,s	4.4 a,c,t
22. Chlorobenzene	108907					680 a,s	21,000 a,j,t
23. Chlorodibromomethane	124481					0.401 a,c	34 a,c
24. Chloroethane	75003						
25. 2-Chloroethylvinyl Ether	110758						

Table 31 Numeric Criteria for Priority Toxic Pollutants for the State of California; Rule (Cont.)

A		B Freshwater		C Saltwater		D Human Health (10^{-6} risk for carcinogens) For consumption of:	
# Compound	CAS Number	Criterion Maximum Conc. [d] B1	Criterion Continuous Conc. [d] B2	Criterion Maximum Conc. [d] C1	Criterion Continuous Conc. [d] C2	Water & Organisms (µg/L) D1	Organisms Only (µg/L) D2
26. Chloroform	67663					[Reserved]	[Reserved]
27. Dichlorobromomethane	75274					0.56 a,c	46 a,c
28. 1,1-Dichloroethane	75343						
29. 1,2-Dichloroethane	107062					0.38 a,c,s	99 a,c,t
30. 1,1-Dichloroethylene	75354					0.057 a,c,s	3.2 a,c,t
31. 1,2-Dichloropropane	78875					0.52 a	39 a
32. 1,3-Dichloropropylene	542756					10 a,s	1,700 a,t
33. Ethylbenzene	100414					3,100 a,s	29,000 a,t
34. Methyl Bromide	74839					48 a	4,000 a
35. Methyl Chloride	74873					n	n
36. Methylene Chloride	75092					4.7 a,c	1,600 a,c
37. 1,1,2,2-Tetrachloroethane	79345					0.17 a,c,s	11 a,c,t
38. Tetrachloroethylene	127184					0.8 c,s	8.85 c,t
39. Toluene	108883					6,800 a	200,000 a
40. 1,2-Trans-Dichloroethylene	156605					700 a	140,000 a
41. 1,1,1-Trichloroethane	71556					n	n
42. 1,1,2-Trichloroethane	79005					0.60 a,c,s	42 a,c,t
43. Trichloroethylene	79016					2.7 c,s	81 c,t
44. Vinyl Chloride	75014					2 c,s	525 c,t
45. 2-Chlorophenol	95578					120 a	400 a
46. 2,4-Dichlorophenol	120832					93 a,s	790 a,t
47. 2,4-Dimethylphenol	105679					540 a	2,300 a
48. 2-Methyl-4,6-Dinitrophenol	534521					13.4 s	765 t
49. 2,4-Dinitrophenol	51285					70 a,s	14,000 a,t
50. 2-Nitrophenol	88755						
51. 4-Nitrophenol	100027						
52. 3-Methyl-4-Chlorophenol	59507						
53. Pentachlorophenol	87865	19 f,w	15 f,w	13	7.9	0.28 a,c	8.2 a,c,j
54. Phenol	108952					21,000 a	4,600,000 a,j,t
55. 2,4,6-Trichlorophenol	88062					2.1 a,c	6.5 a,c
56. Acenaphthene	83329					1,200 a	2,700 a
57. Acenaphthylene	208968						
58. Anthracene	120127					9,600 a	110,000 a

Table 31 Numeric Criteria for Priority Toxic Pollutants for the State of California; Rule (Cont.)

A		B Freshwater		C Saltwater		D Human Health (10^{-6} risk for carcinogens) For consumption of:	
# Compound	CAS Number	Criterion Maximum Conc. [d] B1	Criterion Continuous Conc. [d] B2	Criterion Maximum Conc. [d] C1	Criterion Continuous Conc. [d] C2	Water & Organisms (µg/L) D1	Organisms Only (µg/L) D2
59. Benzidine	92875					0.00012 a,c,s	0.00054 a,c,t
60. Benzo(a)Anthracene	56553					0.0044 a,c	0.049 a,c
61. Benzo(a)Pyrene	50328					0.0044 a,c	0.049 a,c
62. Benzo(b)Fluoranthene	205992					0.0044 a,c	0.049 a,c
63. Benzo(ghi)Perylene	191242						
64. Benzo(k)Fluoranthene	207089					0.0044 a,c	0.049 a,c
65. Bis(2-Chloroethoxy)Methane	111911						
66. Bis(2-Chloroethyl)Ether	111444					0.031 a,c,s	1.4 a,c,t
67. Bis(2-Chloroisopropyl)Ether	39638329					1,400 a	170,000 a,t
68. Bis(2-Ethylhexyl)Phthalate	117817					1.8 a,c,s	5.9 a,c,t
69. 4-Bromophenyl Phenyl Ether	101553						
70. Butylbenzyl Phthalate	85687					3,000 a	5,200 a
71. 2-Chloronaphthalene	91587					1,700 a	4,300 a
72. 4-Chlorophenyl Phenyl Ether	7005723						
73. Chrysene	218019					0.0044 a,c	0.049 a,c
74. Dibenzo(a,h)Anthracene	53703					0.0044 a,c	0.049 a,c
75. 1,2 Dichlorobenzene	95501					2,700 a	17,000 a
76. 1,3 Dichlorobenzene	541731					400	2,600
77. 1,4 Dichlorobenzene	106467					400	2,600
78. 3,3'-Dichlorobenzidine	91941					0.04 a,c,s	0.077 a,c,t
79. Diethyl Phthalate	84662					23,000 a,s	120,000 a,t
80. Dimethyl Phthalate	131113					313,000 s	2,900,000 t
81. Di-n-Butyl Phthalate	84742					2,700 a,s	12,000 a,t
82. 2,4-Dinitrotoluene	121142					0.11 c,s	9.1 c,t
83. 2,6-Dinitrotoluene	606202						
84 Di-n-Octyl Phthalate	117840						
85. 1,2-Diphenylhydrazine	122667					0.040 a,c,s	0.54 a,c,t
86. Fluoranthene	206440					300 a	370 a
87. Fluorene	86737					1,300 a	14,000 a
88. Hexachlorobenzene	118741					0.00075 a,c	0.00077 a,c
89. Hexachlorobutadiene	87683					0.44 a,c,s	50 a,c,t
90. Hexachlorocyclopentadiene	77474					240 a,s	17,000 a,j,t
91. Hexachloroethane	67721					1.9 a,c,s	8.9 a,c,t

Table 31 Numeric Criteria for Priority Toxic Pollutants for the State of California; Rule (Cont.)

A		B Freshwater		C Saltwater		D Human Health (10^{-6} risk for carcinogens) For consumption of:	
# Compound	CAS Number	Criterion Maximum Conc. [d] B1	Criterion Continuous Conc. [d] B2	Criterion Maximum Conc. [d] C1	Criterion Continuous Conc. [d] C2	Water & Organisms (µg/L) D1	Organisms Only (µg/L) D2
92. Indeno(1,2,3-cd) Pyrene	193395					0.0044 a,c	0.049 a,c
93. Isophorone	78591					8.4 c,s	600 c,t
94. Naphthalene	91203						
95. Nitrobenzene	98953					17 a,s	1,900 a,j,t
96. N-Nitrosodimethylamine	62759					0.00069 a,c,s	8.1 a,c,t
97. N-Nitrosodi-n-Propylamine	621647					0.005 a	1.4 a
98. N-Nitrosodiphenylamine	86306					5.0 a,c,s	16 a,c,t
99. Phenanthrene	85018						
100. Pyrene	129000					960 a	11,000 a
101. 1,2,4-Trichlorobenzene	120821						
102. Aldrin	309002	3 g		1.3 g		0.00013 a,c	0.00014 a,c
103. alpha-BHC	319846					0.0039 a,c	0.013 a,c
104. beta-BHC	319857					0.014 a,c	0.046 a,c
105. gamma-BHC	58899	0.95 w		0.16 g		0.019 c	0.063 c
106. delta-BHC	319868						
107. Chlordane	57749	2.4 g	0.0043 g	0.09 g	0.004 g	0.00057 a,c	0.00059 a,c
108. 4,4'-DDT	50293	1.1 g	0.001 g	0.13 g	0.001 g	0.00059 a,c	0.00059 a,c
109. 4,4'-DDE	72559					0.00059 a,c	0.00059 a,c
110. 4,4'-DDD	72548					0.00083 a,c	0.00084 a,c
111. Dieldrin	60571	0.24 w	0.056 w	0.71 g	0.0019 g	0.00014 a,c	0.00014 a,c
112. alpha-Endosulfan	959988	0.22 g	0.056 g	0.034 g	0.0087 g	110 a	240 a
113. beta-Endosulfan	33213659	0.22 g	0.056 g	0.034 g	0.0087 g	110 a	240 a
114. Endosulfan Sulfate	1031078					110 a	240 a
115. Endrin	72208	0.086 w	0.036 w	0.037 g	0.0023 g	0.76 a	0.81 a,j
116. Endrin Aldehyde	7421934					0.76 a	0.81 a,j
117. Heptachlor	76448	0.52 g	0.0038 g	0.053 g	0.0036 g	0.00021 a,c	0.00021 a,c
118. Heptachlor Epoxide	1024573	0.52 g	0.0038 g	0.053 g	0.0036 g	0.00010 a,c	0.00011 a,c
119-125. Polychlorinated biphenyls (PCBs)			0.014 u		0.03 u	0.00017 c,v	0.00017 c,v
126. Toxaphene	8001352	0.73	0.0002	0.21	0.0002	0.00073 a,c	0.00075 a,c
Total Number of Criteria [h]		22	21	22	20	92	90

Note: Footnotes are defined in Federal Register / Vol. 65, No. 97/Thursday, May 18, 2000/Rules and Regulations.

Table 32 Summary of Compounds with CDPH Drinking Water Notification Levels Results

Parameter	Method	Units	DL	RL	Quarter 1: 08/24/2011			Quarter 2: 11/08/2011			Quarter 3: 02/01/2012			Quarter 4: 05/01/2012			CDPH Drinking Water Notification Level [1]
					S1 (tertiary effluent)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water	S1 (tertiary effluent)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water	S1 (tertiary effluent)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water	S1 (tertiary effluent)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water	
1,2,3-Trichloropropane	SRL 524M-TCP	µg/L	0.0012	0.005	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	0.005
1,2,4-Trimethylbenzene	EPA 524.2	µg/L	0.2	0.5	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	330
1,3,5-Trimethylbenzene	EPA 524.2	µg/L	0.17	0.5	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	330
1,4-Dioxane	EPA 8270M	µg/L	0.04	0.5	1.8	<0.04	<0.04	5.6	<0.04	<0.04	1.2	<0.04	<0.04	1.6	<0.04	<0.04	1
2,4,6-Trinitrotoluene	EPA 8330A	µg/L	0.2	2	<0.2	<0.2	<0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.5	<0.1	<0.1	1
2-Chlorotoluene	EPA 524.2	µg/L	0.15	0.5	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	140
4-Chlorotoluene	EPA 524.2	µg/L	0.15	0.5	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	140
Methyl isobutyl Ketone (MIBK)	EPA 524.2	µg/L	0.56	5	<0.56	<0.56	<0.56	<0.56	<0.56	<0.56	<0.56	<0.56	<0.56	<0.56	<0.56	<0.56	120
Boron, Total	EPA 200.8	µg/L	0.28	1	400	240	160	340	210	130	360	200	140	370	290	150	1000
Carbon Disulfide	EPA 524.2	µg/L	0.13	0.5	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	<0.13	160
Chlorate	EPA 300.1	µg/L	0.95	10	16	<0.95	<0.95	580	<10	<10	88	<0.95	<10	14	<0.95	13	800
Diazinon	EPA 525.2	µg/L	0.096	0.1	<0.096	<0.096	<0.096	<0.096	<0.096	<0.096	<0.096	<0.096	<0.096	<0.096	<0.096	<0.096	1.2
Dichlorodifluoromethane (Freon 12)	EPA 524.2	µg/L	0.12	0.5	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	1000
[2]Ethylene glycol	EPA 8015B	mg/l	11	50	<11	<11	<11	<11	<11	<11	<11	<11	<11	<50	<50	<50	14
Formaldehyde	EPA 556	µg/L	0.26	2	6.8	8.9	5	6	11	2.8	8.2	5.7	2.7	8.5	6.5	2.5	100
HMX	EPA 8330A	µg/L	3	10	<3	<0.59	<0.59	<1.5	<0.3	<0.3	<1.5	<0.3	<0.3	<1.5	<0.3	<0.3	350
Isopropylbenzene	EPA 524.2	µg/L	0.18	0.5	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	770
Manganese, Total	EPA 200.8	µg/L	0.11	0.2	110	<0.11	23	70	<0.11	5.7	93	0.37	4.3	72	<0.2	2.8	500
Naphthalene	EPA 524.2	µg/L	0.42	0.5	<0.42	<0.42	<0.42	<0.42	<0.42	<0.42	<0.42	<0.42	<0.42	<0.42	<0.42	<0.42	17
n-Butylbenzene	EPA 524.2	µg/L	0.29	0.5	<0.29	<0.29	<0.29	<0.29	<0.29	<0.29	<0.29	<0.29	<0.29	<0.29	<0.29	<0.29	260
N-Nitrosodiethylamine	EPA 521	ng/l	0.72	2	<2	<0.72	<0.72	<0.72	<0.72	3.3	<2	5.7	<0.72	<2	4.9	<0.72	10
N-Nitrosodimethylamine	EPA 521	ng/l	0.28	2.2	2.9	<2	<0.28	<2	<0.28	<0.28	<2	<2	<0.28	5.2	<2.2	<2	10
N-Nitrosodi-n-propylamine	EPA 521	ng/l	0.35	2.2	<0.35	<0.35	<0.35	<0.35	<0.35	<0.35	<0.35	<0.35	<0.35	<0.35	<2.2	<0.35	10
n-Propylbenzene	EPA 524.2	µg/L	0.18	0.5	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	260
Propachlor	EPA 508	µg/L	0.01	0.05	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	90
RDX	EPA 8330A	µg/L	0.32	2	<0.32	<0.32	<0.32	<0.16	<0.16	<0.16	<0.8	<0.16	<0.16	<0.8	<0.16	<0.16	0.3
sec-Butylbenzene	EPA 524.2	µg/L	0.24	0.5	<0.24	<0.24	<0.24	<0.24	<0.24	<0.24	<0.24	<0.24	<0.24	<0.24	<0.24	<0.24	260
Tert-butyl alcohol	EPA 524.2	µg/L	0.45	2	<0.45	<0.45	<0.45	<2	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	12
tert-Butylbenzene	EPA 524.2	µg/L	0.18	0.5	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	<0.18	260
Vanadium, Total	EPA 200.8	µg/L	0.047	0.5	1.1	<0.5	2.6	<0.047	<0.047	1.3	0.8	<0.5	2.7	0.81	<0.047	2.8	50

Note:

1. CDPH Drinking Water Notification Levels Last Update: December 14, 2010. For notes on toxicological enpoints, references, history, and other information visit: http://www.cdph.ca.gov/certlic/drinkingwater/Pages/default.aspx.
2. Additonal testing was conducted for ethylene glycol at sample locations S1 and S10 using a more sensitive method (EPA 8270 C DL=0.5 mg/L; RL= 1 mg/L). Samples from each location were collected on 8/13/12 and 8/15/12. All results were <0.5 mg/L.
3. Results shown as less than (<VALUE) indicate the reported result was less than the RL or DL. In some instances, the RL and/or DL varied during the testing period due to laboratory QC procedures or changes in method procedures.

Table 33 Summary of Proposed Contaminants EPA's Unregulated Contaminant Monitoring Rule (UCMR 3) Assessment Monitoring (List 1and List 2) Results

Parameter	Method	Units	DL	RL	Quarter 1: 08/24/2011			Quarter 2: 11/08/2011			Quarter 3: 03/08/2012			Quarter 4: 05/01/2012		
					S1 (tertiary effluent)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water	S1 (tertiary effluent)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water	S1 (tertiary effluent)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water	S1 (tertiary effluent)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water
1,1-Dichloroethane	EPA 524.3	ng/L	10	30	<10	<10	<10	**<10**	**<10**	**<10**	<10	<10	<10	<10	<10	<10
1,2,3-Trichloropropane	EPA 524.3	ng/L	4.6	30	<4.6	<4.6	<4.6	**<4.6**	**<4.6**	**<4.6**	<4.6	<4.6	<4.6	<4.6	<4.6	<4.6
1,3-butadiene	EPA 524.3	ng/L	37	100	<37	<37	<37	**<37**	**<37**	**<37**	<37	<100	<37	<37	<37	<37
1,4-Dioxane	EPA 522	µg/L	0.035	0.070	0.95	<0.035	<0.035	4.2	<0.070	<0.035	0.97	<0.035	<0.035	1.2	<0.035	<0.070
17 alpha-ethynylestradiol	EPA 539	µg/L	0.00010	0.00040	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
17-beta-Estradiol	EPA 539	µg/L	0.00010	0.00090	<0.00090	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00090	<0.00010	<0.00010	<0.00090	<0.00010	<0.00010
4-androstene-3,17-dione	EPA 539	µg/L	0.000040	0.00030	0.0012	<0.000040	<0.00030	0.0018	<0.00030	<0.00030	0.0032	<0.000040	<0.00030	0.0032	<0.000040	<0.00030
Bromochloromethane (BCM)	EPA 524.3	ng/L	5.5	60	220	230	<60	**260**	**190**	**<5.5**	230	230	78	170	250	79
Bromomethane	EPA 524.3	ng/L	35	200	<35	<35	<35	**<35**	**<35**	**<200**	<35	<35	<35	<35	<35	<35
Chlorate	UCMR 300.1	µg/L	2.0	20	<20	<2.0	<2.0	580	<20	<2.0	28	<2.0	<20	<20	<2.0	<20
Chlorodifluoromethane	EPA 524.3	ng/L	6.8	80	<80	<80	<80	**<80**	**<80**	**<80**	<80	<80	<80	<6.8	<6.8	<6.8
Chloromethane	EPA 524.3	ng/L	6.0	200	<200	<6.0	<200	**<6.0**	**<200**	**<200**	<6.0	<6.0	<6.0	<200	<200	<6.0
Chromium	UCMR 200.8	µg/L	0.021	0.30	1.1	<0.021	0.37	<0.3	**<0.021**	<0.021	<0.30	<0.30	**<0.021**	0.35	<0.021	<0.15
Cobalt	UCMR 200.8	µg/L	0.28	1.0	<1.0	<0.28	<0.28	<1.0	**<0.28**	<0.28	<1.0	<0.28	**<0.28**	<1.0	<0.28	<0.28
Equilin	EPA 539	µg/L	0.00040	0.0040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040	<0.00040
Estriol	EPA 539	µg/L	0.00020	0.00080	<0.00080	<0.00020	<0.00020	<0.00020	<0.00020	<0.00080	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Estrone	EPA 539	µg/L	0.00020	0.0020	0.0047	<0.00020	<0.0020	<0.0020	<0.00020	<0.00020	0.0043	<0.00020	<0.00020	0.0038	<0.00020	0.87
Hexavalent chromium(Dissolved)	EPA 218.6/218.7	µg/L	0.0090	0.020	<0.0090	0.090	0.052	<0.0090	0.083	0.045	<0.030	0.040	0.048	<0.030	0.16	<0.030
Molybdenum	UCMR 200.8	µg/L	0.057	1.0	8.0	<0.057	2.1	7.5	**<0.057**	2.1	5.6	<0.057	**<0.057**	6.2	<0.50	3.6
n-Propylbenzene	EPA 524.3	ng/L	5.4	30	<5.4	<5.4	<5.4	**<5.4**	**<5.4**	**<5.4**	<5.4	<5.4	<5.4	<5.4	<5.4	<5.4
Perfluoro octanesulfonic acid - PFOS	EPA 537	µg/L	0.0023	0.040	<0.040	<0.0023	<0.0023	<0.040	<0.0023	<0.0023	<0.040	<0.0023	<0.0023	<0.040	<0.0023	<0.0023
Perfluoro-1-butanesulfonic acid -PFBS	EPA 537	µg/L	0.0018	0.090	<0.090	<0.0018	<0.090	<0.090	<0.0018	<0.0018	<0.090	<0.0018	<0.0018	<0.090	<0.0018	<0.0018
Perfluoro-1-hexanesulfonic acid - PFHxS	EPA 537	µg/L	0.0020	0.030	<0.030	<0.0020	<0.0020	<0.030	<0.0020	<0.0020	<0.030	<0.0020	<0.0020	<0.030	<0.0020	<0.0020
Perfluoroheptanoic acid - PFHpA	EPA 537	µg/L	0.0031	0.010	0.032	<0.0031	<0.0031	0.036	<0.010	<0.0031	0.023	<0.0031	<0.0031	0.026	<0.0031	<0.0031
Perfluoro-n-nonanoic acid -PFNA	EPA 537	µg/L	0.0022	0.020	<0.020	<0.0022	<0.0022	0.020	<0.0022	<0.0022	<0.020	<0.0022	<0.0022	<0.020	<0.0022	<0.0022
Perfluorooctanoic acid - PFOA	EPA 537	µg/L	0.0035	0.020	0.17	<0.0022	<0.0022	0.29	<0.0035	<0.0022	0.21	<0.0035	<0.0035	0.23	<0.0035	<0.0035
sec-Butylbenzene	EPA 524.3	ng/L	1.5	40	<1.5	<1.5	<1.5	**<1.5**	**<1.5**	**<1.5**	<40	<40	<40	<1.5	<1.5	<1.5
Strontium	UCMR 200.8	µg/L	0.016	0.30	580	<0.30	280	400	**<0.30**	290	480	<0.30	430	310	0.37	610
Testosterone	EPA 539	µg/L	0.000020	0.00010	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.00010	<0.00010	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020
Vanadium	UCMR 200.8	µg/L	0.011	0.20	1.2	<0.011	2.3	<0.20	<0.011	2.6	<0.20	<0.011	**<0.011**	0.79	<0.011	2.4

Note: Shaded results are from resamples collected on 1/18/2012 and 3/14/2012. Resampling was required due to lab error and /or QC failures that occurred during analyses of original samples. Data flags provided in the original laboratory reports are not shown. On May 2, 2012, the EPA issued the Final Rule Promulgation, which removed two compounds from the original List 1. These compounds are n-Propylbenzene and sec-Butylbenzene. Results shown as less than (<VALUE) indicate the reported result was less than the RL or DL. In some instances, the RL and/or DL varied during the testing period due to laboratory QC procedures or changes in method procedures.

Table 34 Summary of Other Radionuclides Results

Parameter	Method	Units	Sample Date: 08/24/2011			Sample Date: 11/08/2011			Sample Date: 02/01/2012			Sample Date: 05/01/2012			Sample Date: 7/9/2012		
			S1 Tertiary Effluent	S10 AWPF Product	Imported Raw Aqueduct Water	S1 Tertiary Effluent	S10 AWPF Product	Imported Raw Aqueduct Water	S1 Tertiary Effluent	S10 AWPF Product	Imported Raw Aqueduct Water	S1 Tertiary Effluent	S10 AWPF Product	Imported Raw Aqueduct Water	S1 Tertiary Effluent	S10 AWPF Product	Imported Raw Aqueduct Water
Cesium - 137	Gamma Ray Spectrometry	pCi/L	-5.05+/-8.2 (MDA=11.1)	0.900+/-7.9 (MDA=10.2)	-3.88+/-6.7 (MDA=13.4)	-6.60+/-16 (MDA=16.7)	-3.33+/-5.8 (MDA=16.0)	-3.88+/-13 (MDA=13.1)	-0.840+/-13 (MDA=23.1)	-9.60+/-14 (MDA=23.7)	2.32+/-13 (MDA=18.5)	-1.46+/-10 (MDA=20.3)	-2.18+/-11 (MDA=15.0)	0.180+/-0.64 (MDA=1.25)	not sampled	not sampled	not sampled
Iodine - 129	X-Ray Spectrometry	pCi/L	0.834+/-3.1 (MDA=3.86)	0.087+/-2.4 (MDA=3.25)	-1.20+/-2.5 (MDA=3.38)	-0.415+/-1.1 (MDA=2.40)	-1.63+/-3.6 (MDA=4.17)	-0.031+/-0.93 (MDA=2.10)	3.31+/-3.0 (MDA=3.86)	-2.17+/-2.4 (MDA=3.47)	-1.54+/-3.0 (MDA=4.10)	-0.783+/-0.95 (MDA=2.16)	-0.990+/-1.9 (MDA=3.73)	-1.30+/-1.9 (MDA=3.61)	0.046+/-0.25 (MDA=0.572)	0.092+/-0.28 (MDA=0.636)	0.110+/-0.21 (MDA=0.462)
Iodine - 131	Gamma Ray Spectrometry	pCi/L	46.6+/-16 (MDA=18.2)	1.79+/-12 (MDA=16.0)	0.720+/-9.9 (MDA=26.4)	15.6+/-27 (MDA=27.9)	-15.6+/-20 (MDA=21.6)	-7.28+/-16 (MDA=18.5)	-2.08+/-5.7 (MDA=11.3)	-1.99+/-25 (MDA=23.0)	-4.10+/-7.0 (MDA=11.2)	-6.45+/-21 (MDA=38.7)	-5.97+/-16 (MDA=24.6)	0.610+/-1.2 (MDA=2.48)	3.03+/-1.4 (MDA=1.64)	-0.044+/-0.11 (MDA=0.154)	-0.001+/-0.12 (MDA=0.162)

Note:

1. MDA is the Minimum Detectable Activity @ 95% confidence interval. Table 26 provides results for nuclide parameters regulated in drinking water including: Gross Beta (Examples of beta emitters include: Cesium 137, Iodine 129 and Iodine 131), Gross Alpha, Radium 226, Radium 228, Tritium, Strontium 90, and Uranium
2. Refer to **Section 3.2.5 URs** for how to interpret MDAs and Counting Errors.

Table 35 Summary of Other Measured Compounds Results

Parameter	Method	Units	DL	RL	Quarter 1: 08/24/2011			Quarter 2: 11/08/2011			Quarter 3: 02/01/2012			Quarter 4: 05/01/2012		
					S1 (tertiary effluent)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water	S1 (tertiary effluent)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water	S1 (tertiary effluent)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water	S1 (tertiary effluent)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water
Benzo (k) fluoranthene	EPA 525.2	µg/L	0.09	0.5	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09
Hexavalent chromium(Dissolved)	EPA 218.6	µg/L	0.0059	0.3	<0.0059	<0.0059	<0.3	<0.0059	<0.0059	<0.0059	<0.0059	<0.0059	<0.3	<0.0059	<0.0059	<0.3
Lithium, Total	EPA 200.7	µg/L	1.4	10	26	<1.4	<10	20	<1.4	<10	23	<10	14	28	<10	21

Note: Results shown as less than (<VALUE) indicate the reported result was less than the RL or DL. In some instances, the RL and/or DL varied during the testing period due to laboratory QC procedures or changes in method procedures.

Table 36 Summary of Initial Characterization Results of Chemical of Emerging Concern (CECs) Analyzed by MWH Laboratories 4 X Monthly Samples

Compound Name	Common Use	Method	Units	DL	RL	8/15/2011					9/14/2011					10/17/2011					11/8/2011				
						S1 (tertiary effluent) 9/1/11	S6 (RO Feed)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water	S1 (tertiary effluent)	S6 (RO Feed)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water	S1 (tertiary effluent)	S6 (RO Feed)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water (10/18/11)	S1 (tertiary effluent)	S6 (RO Feed)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water
1,7-Dimethylxanthine	Caffeine Degradant	LC-MS-MS	ng/L	3.4	10	<10	5.4	<3.4	<3.4	<3.4	<3.4	<10	<3.4	<3.4	<3.4	<3.4	<3.4	<3.4	<3.4	<3.4	<3.4	<3.4	<3.4	<3.4	<3.4
2,4-D	Herbicide	LC-MS-MS	ng/L	5	5	49	<5	<5	<5	9.8	2000	2200	6.4	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
4-nonylphenol - semi quantitative	Surfactant	LC-MS-MS	ng/L	50	100	1400	780	<50	<50	280	410	480	<100	<100	<100	200	260	<50	<50	<50	330	470	<50	<50	<50
4-tert-Octylphenol	Surfactant	LC-MS-MS	ng/L	6.9	50	<50	<50	<6.9	<6.9	<6.9	<50	<50	<6.9	<6.9	<6.9	<50	<50	<6.9	<6.9	<6.9	<6.9	<6.9	<6.9	<6.9	<6.9
Acesulfame-K	Sugar Substitute	LC-MS-MS	ng/L	20	20	27000	26000	40	<20	370	29000	29000	65	50	360	33000	33000	66	<20	360	28000	27000	<20	<20	280
Acetaminophen	Analgesic	LC-MS-MS	ng/L	3	5	<3	<3	<3	<3	<3	<5	<3	<3	<3	<3	<3	<3	<3	<3	<3	10	8.3	<3	<3	<3
Albuterol	Anti Asthmatic	LC-MS-MS	ng/L	2.4	5	9.6	6.6	<2.4	<5	<5	8.1	6.5	<2.4	<2.4	<2.4	9.9	7.6	<2.4	<2.4	<2.4	10	<2.4	<2.4	<2.4	<2.4
Amoxicillin (semi-quantitative)	Antibiotic	LC-MS-MS	ng/L	6.4	20	1400	90	<6.4	<6.4	<6.4	470	220	<6.4	<6.4	<6.4	960	61	24	<20	<6.4	320	48	<6.4	<6.4	<6.4
Andorostenedione	Steroid Hormone	LC-MS-MS	ng/L	1.7	5	<1.7	5.1	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7
Atenolol	Beta Blocker	LC-MS-MS	ng/L	3.9	5	670	210	<3.9	<3.9	<3.9	250	250	7.7	<3.9	<3.9	59	74	<3.9	<3.9	<3.9	150	150	<3.9	<3.9	<3.9
Atrazine	Triazine Herbicide	LC-MS-MS	ng/L	2.3	5	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3
Azithromycin	Antibiotic	LC-MS-MS	ng/L	10	20	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Bendroflumethiazide	Triazide	LC-MS-MS	ng/L	4.4	5	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4
Bezafibrate	Lipid Regulator	LC-MS-MS	ng/L	3.5	5	6	<3.5	<3.5	<3.5	<3.5	7.6	6	<3.5	<3.5	<3.5	<3.5	<3.5	<3.5	<3.5	<3.5	<3.5	<3.5	<3.5	<3.5	<3.5
BPA	Plasticizer	LC-MS-MS	ng/L	7.2	10	<7.2	<7.2	<7.2	<7.2	<7.2	74	81	<7.2	<7.2	<7.2	<7.2	<7.2	<7.2	<7.2	<7.2	<7.2	<7.2	<7.2	<7.2	<7.2
Bromacil	Herbicide	LC-MS-MS	ng/L	3.2	5	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<5	<3.2	<3.2	<3.2	<3.2	<3.2
Butalbital	Analgesic-NSAID	LC-MS-MS	ng/L	2.9	5	16	16	<2.9	<2.9	<5	39	29	<2.9	<2.9	<2.9	25	28	<2.9	<2.9	<2.9	21	15	<2.9	<2.9	<2.9
Butylparaben	Preservative	LC-MS-MS	ng/L	3.3	5	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3
Caffeine	Stimulant	LC-MS-MS	ng/L	4.3	5	77	28	<4.3	<4.3	22	61	<5	<4.3	<4.3	<4.3	36	6.5	<4.3	<4.3	<4.3	20	6.7	<4.3	<4.3	<4.3
Carbadox	Antibiotic	LC-MS-MS	ng/L	4.2	5	8.6	<4.2	<4.2	<4.2	<4.2	13	30	<4.2	<4.2	<4.2	5.7	8.8	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2
Carbamazepine	Anti Seizure	LC-MS-MS	ng/L	1.2	5	300	170	<1.2	<1.2	<5	190	190	<5	<1.2	<5	190	180	<5	<1.2	<5	170	160	<1.2	<1.2	<5
Carisoprodol	Muscle Relaxant	LC-MS-MS	ng/L	1.2	5	150	200	<1.2	<1.2	<5	42	43	<1.2	<1.2	<1.2	62	69	<1.2	<1.2	<1.2	52	60	<1.2	<1.2	<1.2
Chloramphenicol	Antibiotic	LC-MS-MS	ng/L	3.1	10	<3.1	<3.1	<3.1	<3.1	<3.1	<10	12	<3.1	<3.1	<3.1	<3.1	<3.1	<3.1	<3.1	<3.1	<3.1	<3.1	<3.1	<3.1	<3.1
Chloridazon	Enzyme	LC-MS-MS	ng/L	1.6	5	<5	<1.6	<1.6	<1.6	<1.6	<1.6	<5	<1.6	<1.6	<1.6	<1.6	<1.6	<1.6	<1.6	<1.6	<1.6	<1.6	<1.6	<1.6	<1.6
Chlorotoluron	Herbicide	LC-MS-MS	ng/L	0.89	5	<0.89	<0.89	<0.89	<0.89	<0.89	<0.89	<0.89	<0.89	<0.89	<0.89	<0.89	<0.89	<0.89	<0.89	<0.89	<0.89	<0.89	<0.89	<0.89	<0.89
Cimetidine	H2 Blocker	LC-MS-MS	ng/L	2.7	5	62	<5	<2.7	<2.7	<2.7	22	<5	<2.7	<2.7	<2.7	12	<2.7	<2.7	<2.7	<2.7	<2.7	<2.7	<2.7	<2.7	<2.7
Clofibric Acid	Anti Cholesterol	LC-MS-MS	ng/L	5	5	<5	7.9	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Cotinine	Nicotine Degradate	LC-MS-MS	ng/L	4.8	10	44	33	<10	<10	<10	<10	20	<4.8	<4.8	<4.8	25	11	<4.8	<4.8	<4.8	31	18	<4.8	<4.8	<4.8
Cyanazine	Triazine Herbicide	LC-MS-MS	ng/L	1.7	5	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7
DACT	Triazine Degradate	LC-MS-MS	ng/L	3.9	5	36	27	<3.9	<3.9	<3.9	32	21	<3.9	<3.9	<3.9	26	13	<3.9	<3.9	<3.9	21	<3.9	<3.9	<3.9	<5
Deethylatrazine	Triazine Degradate	LC-MS-MS	ng/L	1.5	5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5
DEET	Mosquito Repellant	LC-MS-MS	ng/L	1.1	10	30	180	<1.1	<1.1	<10	63	40	<10	<1.1	<10	180	170	<1.1	<1.1	<10	160	170	<10	<10	12

Table 36 Summary of Initial Characterization Results of Chemical of Emerging Concern (CECs) Analyzed by MWH Laboratories 4 X Monthly Samples

Compound Name	Common Use	Method	Units	DL	RL	8/15/2011					9/14/2011					10/17/2011					11/8/2011				
						S1 (tertiary effluent) 9/1/11	S6 (RO Feed)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water	S1 (tertiary effluent)	S6 (RO Feed)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water	S1 (tertiary effluent)	S6 (RO Feed)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water (10/18/11)	S1 (tertiary effluent)	S6 (RO Feed)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water
Dehydronifedipine	Heart Medication	LC-MS-MS	ng/L	1.4	5	160	280	<5	<5	6	120	120	<1.4	<5	<5	360	400	<1.4	<1.4	<5	40	47	<1.4	<1.4	<1.4
DIA	Triazine Degradate	LC-MS-MS	ng/L	2.4	5	5.5	<5	<2.4	<2.4	<2.4	<5	<5	<2.4	<2.4	<2.4	<5	6.7	<2.4	<2.4	<2.4	<5	<5	<2.4	<2.4	<5
Diazepam	Valium - Antianxiety	LC-MS-MS	ng/L	2.1	5	<5	<5	<2.1	<2.1	<2.1	<5	<5	<2.1	<2.1	<2.1	<2.1	<5	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1
Diclofenac	Anti Inflammatory	LC-MS-MS	ng/L	3.3	5	60	58	<3.3	<3.3	<3.3	59	63	<3.3	<3.3	<3.3	59	67	<3.3	<3.3	<3.3	95	70	<3.3	<3.3	<3.3
Dilantin	Anti Seizure	LC-MS-MS	ng/L	13	20	86	82	<13	<13	<13	79	70	<13	<13	<13	110	82	<13	<13	<13	130	110	<13	<13	<13
Diuron	Herbicide	LC-MS-MS	ng/L	1.8	5	42	75	<5	<5	52	60	47	<1.8	<1.8	60	74	70	<5	<5	66	61	68	<1.8	<1.8	110
Erythromycin	Antibiotic	LC-MS-MS	ng/L	4	10	45	23	<4	<4	<4	58	48	<4	<4	<4	25	28	<4	<4	<4	45	57	<4	<4	<4
Estradiol	Estrogenic Hormone	LC-MS-MS	ng/L	4.4	5	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4	<4.4
Estrone	Estrogenic Hormone	LC-MS-MS	ng/L	3.9	5	16	21	<3.9	<3.9	<3.9	10	9.2	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9
Ethinyl Estradiol - 17 alpha	Contraceptive Hormone	LC-MS-MS	ng/L	3.3	5	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3
Ethylparaben	Preservative	LC-MS-MS	ng/L	11	20	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11
Flumeqine	Antibiotic	LC-MS-MS	ng/L	7.1	10	<7.1	<10	<10	<7.1	<10	<7.1	<7.1	<7.1	<7.1	<7.1	<7.1	<7.1	<7.1	<7.1	<7.1	<7.1	<7.1	<7.1	<7.1	<7.1
Fluoxetine	Antidepressant	LC-MS-MS	ng/L	10	10	34	59	<10	<10	<10	50	43	<10	<10	<10	39	28	<10	<10	<10	28	21	<10	<10	<10
Gemfibrozil	Lipid Regulator	LC-MS-MS	ng/L	2.5	5	68	62	<2.5	<2.5	<2.5	73	64	<2.5	<2.5	<2.5	34	33	<2.5	<2.5	<2.5	28	24	<2.5	<2.5	<2.5
Hydrazine	Anti Depressant	LC-MS-MS	ng/L	2.5	5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5
Ibuprofen	Analgesic-NSAID	LC-MS-MS	ng/L	8.6	15	<8.6	<8.6	<8.6	<8.6	<8.6	20	<15	<15	<8.6	<8.6	<8.6	<8.6	<8.6	<15	<8.6	<8.6	<8.6	<8.6	<8.6	<8.6
Iohexal	X-ray Contrast Agent	LC-MS-MS	ng/L	7.7	10	3100	4500	<7.7	<7.7	41	9500	8700	<10	19	55	4500	3900	<7.7	<7.7	41	4100	6000	<7.7	<7.7	34
Iopromide	X-ray Contrast Agent	LC-MS-MS	ng/L	1.6	5	140	<5	<1.6	<1.6	<5	93	100	<1.6	<1.6	<1.6	<5	<1.6	<1.6	<1.6	<1.6	27	33	<1.6	<1.6	<1.6
Isobutylparaben	Preservative	LC-MS-MS	ng/L	4.2	5	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2
Isoproturon	Herbicide	LC-MS-MS	ng/L	12	100	<12	<12	<12	<12	<12	<12	<12	<12	<12	<12	<12	<12	<12	<12	<12	<100	<100	<12	<12	<12
Ketoprofen	Anti Inflammatory	LC-MS-MS	ng/L	2.6	5	10	15	<2.6	<2.6	<2.6	11	15	<2.6	<2.6	<2.6	38	24	<2.6	<2.6	<2.6	<5	<2.6	<2.6	<2.6	<2.6
Ketorolac	Anti Inflammatory	LC-MS-MS	ng/L	2.1	5	16	<5	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<5	<5	<2.1	<2.1	<2.1	<5	<2.1	<2.1	<2.1	<2.1
Lidocaine	Analgesic	LC-MS-MS	ng/L	1.1	5	78	310	<1.1	<1.1	<1.1	100	110	<1.1	<1.1	<1.1	90	95	<5	<1.1	<1.1	120	130	<1.1	<1.1	<1.1
Lincomycin	Antibiotic	LC-MS-MS	ng/L	1.7	10	<10	<10	<1.7	<1.7	<1.7	<10	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7	<10	<1.7	<1.7	<1.7	<1.7
Linuron	Herbicide	LC-MS-MS	ng/L	2.8	5	<5	9.2	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	6.3	<2.8	<2.8	<2.8	<2.8
Lopressor	Beta Blocker	LC-MS-MS	ng/L	5.1	20	400	300	<5.1	<5.1	<5.1	280	300	<5.1	<5.1	<5.1	<5.1	<5.1	<5.1	<5.1	<5.1	270	270	<5.1	<5.1	<5.1
Meclofenamic Acid	Anti Inflammatory	LC-MS-MS	ng/L	4.7	5	<4.7	<4.7	<4.7	<4.7	<4.7	<4.7	<4.7	<4.7	<4.7	<4.7	<4.7	<4.7	<4.7	<4.7	<4.7	<4.7	<4.7	<4.7	<4.7	<4.7
Meprobamate	Anti Anxiety	LC-MS-MS	ng/L	2	5	110	200	<5	<5	<5	130	130	<2	<2	<2	92	99	<2	<2	<2	120	120	<2	<2	<5
Metazachlor	Herbicide	LC-MS-MS	ng/L	1.3	5	<1.3	<1.3	<1.3	<1.3	<1.3	<1.3	<1.3	<1.3	<1.3	<1.3	<1.3	<1.3	<1.3	<1.3	<1.3	<1.3	<1.3	<1.3	<1.3	<1.3
Methylparaben	Preservative	LC-MS-MS	ng/L	11	20	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<20	<20	<11	<11	<11	<11	<11	<11
Naproxen	Analgesic-NSAID	LC-MS-MS	ng/L	8.5	10	<8.5	23	<8.5	<8.5	<8.5	<8.5	<8.5	<8.5	<8.5	<8.5	13	12	<8.5	<8.5	<8.5	19	21	<8.5	<8.5	<8.5
Nifedipine	Calcium Blocker	LC-MS-MS	ng/L	12	20	48	<12	<12	<12	<12	<12	<12	<12	<12	<12	40	<20	<12	<12	<12	57	<20	<12	<12	<12
Norethisterone	Steroid Hormone	LC-MS-MS	ng/L	2.3	5	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<2.3	<5	<2.3	<2.3	<2.3	<2.3
Oxolinic acid	Antibiotic	LC-MS-MS	ng/L	2.5	10	19	<2.5	<2.5	<10	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<10	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5
Pentoxifylline	Blood Thinner	LC-MS-MS	ng/L	1.5	5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5
Phenazone	Analgesic	LC-MS-MS	ng/L	5	5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5

Table 36 Summary of Initial Characterization Results of Chemical of Emerging Concern (CECs) Analyzed by MWH Laboratories 4 X Monthly Samples

Compound Name	Common Use	Method	Units	DL	RL	8/15/2011					9/14/2011					10/17/2011					11/8/2011				
						S1 (tertiary effluent) 9/1/11	S6 (RO Feed)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water	S1 (tertiary effluent)	S6 (RO Feed)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water	S1 (tertiary effluent)	S6 (RO Feed)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water (10/18/11)	S1 (tertiary effluent)	S6 (RO Feed)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water
Primidone	Anti Convulsant	LC-MS-MS	ng/L	4.8	5	110	96	<4.8	<4.8	<4.8	83	88	<4.8	<4.8	<4.8	76	86	<4.8	<4.8	<4.8	65	62	<4.8	<4.8	<4.8
Progesterone	Steroid Hormone	LC-MS-MS	ng/L	2.9	5	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9
Propazine	Triazine Herbicide	LC-MS-MS	ng/L	1.8	5	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8	<1.8
Propylparaben	Preservative	LC-MS-MS	ng/L	2.9	5	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9	<2.9
Quinoline	Organophosphate Pesticide	LC-MS-MS	ng/L	2.5	5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5
Simazine	Triazine Herbicide	LC-MS-MS	ng/L	1.2	5	7.6	5.1	<1.2	<1.2	10	8.4	8	<1.2	<1.2	15	11	9	<1.2	<1.2	14	7.4	7.7	<1.2	<1.2	11
Sucralose	Sugar Substitute	LC-MS-MS	ng/L	42	100	48000	20000	<42	<42	410	34000	31000	<42	<42	300	50000	55000	200	<42	310	26000	22000	<100	<100	380
Sulfachloropyridazine	Sulfa Antibiotic	LC-MS-MS	ng/L	2.1	5	<2.1	<5	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<5	<2.1	<2.1	<2.1	<2.1
Sulfadiazine	Sulfa Antibiotic	LC-MS-MS	ng/L	3.9	5	<3.9	9.6	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<5	<5	<3.9	<3.9	<3.9
Sulfadimethoxine	Sulfa Antibiotic	LC-MS-MS	ng/L	1.6	5	<1.6	<1.6	<5	<5	<5	<1.6	<1.6	<1.6	<5	<1.6	<1.6	<1.6	<1.6	<1.6	<1.6	<1.6	<1.6	<1.6	<1.6	<1.6
Sulfamerazine	Sulfa Antibiotic	LC-MS-MS	ng/L	4.6	5	16	<4.6	<4.6	<4.6	<4.6	<4.6	<4.6	<4.6	<4.6	<4.6	<4.6	<4.6	<4.6	<4.6	<4.6	<4.6	<4.6	<4.6	<4.6	<4.6
Sulfamethazine	Sulfa Antibiotic	LC-MS-MS	ng/L	1.5	5	<5	<1.5	<5	<5	<5	<1.5	<1.5	<1.5	<1.5	<1.5	<5	<5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5
Sulfamethizole	Sulfa Antibiotic	LC-MS-MS	ng/L	3.2	5	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2
Sulfamethoxazole	Sulfa Antibiotic	LC-MS-MS	ng/L	2.8	5	820	870	<2.8	<2.8	<2.8	480	410	<2.8	<2.8	<2.8	470	580	<2.8	<2.8	<2.8	780	740	<2.8	<2.8	<5
Sulfathiazole	Sulfa Antibiotic	LC-MS-MS	ng/L	2.4	5	<2.4	<5	<5	<5	<5	<2.4	<2.4	<2.4	<2.4	<2.4	<2.4	<2.4	<2.4	<2.4	<2.4	<2.4	<2.4	<2.4	<2.4	<2.4
TCEP	Flame Retardant	LC-MS-MS	ng/L	3.2	10	160	180	<5	<5	5.5	380	380	<3.2	<3.2	<3.2	520	550	<3.2	<10	13	410	370	<3.2	<3.2	<3.2
TCPP	Flame Retardant	LC-MS-MS	ng/L	20	5	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
TDCPP	Flame Retardant	LC-MS-MS	ng/L	20	100	500	NR	<20	<20	<20	650	710	<20	<20	<20	710	600	<20	<20	<20	320	130	<20	<20	<20
Testosterone	Steroid Hormone	LC-MS-MS	ng/L	2.5	5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5
Theobromine	Caffeine Degradant	LC-MS-MS	ng/L	3.2	10	<3.2	400	19	<10	54	25	42	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2	31	<3.2	<3.2	<3.2	<3.2	<3.2
Theophylline	Anti Asthmatic	LC-MS-MS	ng/L	4.8	10	<4.8	<4.8	<4.8	<4.8	<4.8	57	48	<4.8	<4.8	<4.8	<4.8	<4.8	<4.8	<4.8	<4.8	<4.8	<4.8	<4.8	<4.8	<4.8
Triclosan	Antibacterial	LC-MS-MS	ng/L	6.3	10	120	68	20	<6.3	<10	44	37	34	19	<6.3	140	120	29	<6.3	<6.3	84	60	12	<6.3	<6.3
Trimethoprim	Antibiotic	LC-MS-MS	ng/L	1.8	5	150	200	<1.8	<1.8	<1.8	100	120	<5	<1.8	<1.8	200	220	<5	<1.8	<1.8	120	120	<1.8	<1.8	<1.8
Warfarin	Anticoagulant	LC-MS-MS	ng/L	4.1	5	<5	<5	<4.1	<4.1	<4.1	<4.1	<4.1	<4.1	<4.1	<4.1	<4.1	<4.1	<4.1	<4.1	<4.1	<4.1	<4.1	<4.1	<4.1	<4.1
Count						43	39	3	0	11	41	40	4	3	5	35	34	4	0	7	36	32	1	0	6
Maximum						48000	26000	40	0	410	34000	31000	65	50	360	50000	55000	200	0	360	28000	27000	12	0	380
Minimum						5.5	5.1	19	0	5.5	7.6	6	6.4	19	15	5.7	6.5	24	0	13	6.3	6.7	12	0	11

Notes:

1. NR (not reported) due to batch lab QC concerns. QC indicates the method was not reliable for these compounds duirng the testing period.
2. Results in yellow highlight were from re-analysis conducted due to issues with original analysis.
3. Results shown as less than (<VALUE) indicate the reported result was less than the RL or DL. In some instances, the RL and/or DL varied during the testing period due to laboratory QC procedures or changes in method procedures.

Table 37 Colorado School of Mines CEC Summary Results

			8/15/2011					11/8/2011					
Compound	Units	Method	Detection Limit (S6)	S6	Detection Limit (S9 and S10)	S9	S10	DL	S1	S6	S9	S10	IAW
Acetaminophen	ng/L	ESI Positive	20	BDL	1	BDL	BDL	1	BDL	BDL	BDL	BDL	BDL
Amitriptyline	ng/L	ESI Positive	20	26.8	1	BDL	BDL	1	30	23.8	BDL	BDL	BDL
Atenolol	ng/L	ESI Positive	20	455	1	BDL	BDL	1	172	174	BDL	BDL	BDL
Atrazine	ng/L	ESI Positive	20	BDL	1	BDL	BDL	1	BDL	BDL	BDL	BDL	BDL
Benzophenone	ng/L	ESI Positive	200	260	10	BDL	BDL	25	BDL	BDL	BDL	BDL	BDL
Caffeine	ng/L	ESI Positive	50	BDL	2.5	BDL	BDL	2.5	23.1	17.1	BDL	BDL	6.4
Carbamazepine	ng/L	ESI Positive	20	243	2.5	BDL	BDL	1	244	241	BDL	BDL	2
Cimetidine[3]	ng/L	ESI Positive	20	BDL	1	BDL	BDL	1	BDL	BDL	BDL	BDL	BDL
DEET	ng/L	ESI Positive	20	327	2.5	BDL	BDL	2.5	248	255	BDL	BDL	BDL
Diazepam	ng/L	ESI Positive	20	BDL	1	BDL	BDL	1	3	3	BDL	BDL	BDL
Dilantin	ng/L	ESI Positive	20	156	5	BDL	BDL	5	112	113	BDL	BDL	BDL
Diphenhydramine	ng/L	ESI Positive	20	509	0	BDL	BDL	1	374	361	BDL	BDL	BDL
Fluoexetine	ng/L	ESI Positive	20	32.1	1	BDL	BDL	1	43.4	28	BDL	BDL	BDL
Hydrocodone	ng/L	ESI Positive	20	75.6	2.5	BDL	BDL	2.5	69.3	65.5	BDL	BDL	BDL
Meprobamate	ng/L	ESI Positive	20	295	1	BDL	BDL	1	290	287	BDL	BDL	4
Norfluoxetine	ng/L	ESI Positive	20	BDL	2.5	BDL	BDL	2.5	16.8	17	BDL	BDL	BDL
Oxybenzone	ng/L	ESI Positive	20	35.6	5	BDL	BDL	5	8.5	7.5	BDL	BDL	BDL
Primidone	ng/L	ESI Positive	20	110	1	BDL	BDL	1	85.9	88.8	BDL	BDL	2
Sulfamethoxazole	ng/L	ESI Positive	20	1563	1	BDL	BDL	1	1630	1310	1	BDL	BDL
Trimethoprim	ng/L	ESI Positive	20	248	1	BDL	BDL	1	153	160	BDL	BDL	BDL
TCEP	ng/L	ESI Positive	20	683	2.5	BDL	BDL	5	401	403	BDL	BDL	BDL
TCPP	ng/L	ESI Positive	20	3750	2.5	BDL	BDL	10	2840	2640	BDL	BDL	BDL
TDCPP	ng/L	ESI Positive	20	1338	10	BDL	BDL	10	1250	1080	BDL	BDL	BDL

Note: BDL = Below Detection Limit

Table 37 Colorado School of Mines CEC Summary Result (cont.)

			8/15/2011				11/8/2011					
Compound	Units	Method	Detection Limit	S6	S9	S10	DL	S1	S6	S9	S10	IAW
Bisphenol A	ng/L	ESI Negative	5	BDL	BDL	BDL	10	BDL	BDL	BDL	BDL	BDL
Diclofenac	ng/L	ESI Negative	1	184	BDL	BDL	1	138	139	BDL	BDL	BDL
Gemfibrizol	ng/L	ESI Negative	2.5	73.9	BDL	BDL	5	37.6	36.1	BDL	BDL	BDL
Ibuprofen	ng/L	ESI Negative	5	BDL	BDL	BDL	10	BDL	BDL	BDL	BDL	BDL
Ketoprofen	ng/L	ESI Negative	25	BDL	BDL	BDL	25	BDL	BDL	BDL	BDL	BDL
Methylparaben	ng/L	ESI Negative	5	15.2	BDL	BDL	5	8.3	5.9	BDL	BDL	BDL
Naproxen	ng/L	ESI Negative	2.5	27.7	BDL	BDL	1	23.5	24.2	BDL	BDL	BDL
4-n-Nonylphenol	ng/L	ESI Negative	25	BDL	BDL	BDL	25	BDL	BDL	BDL	BDL	BDL
Propylparaben	ng/L	ESI Negative	2.5	BDL	BDL	BDL	1	BDL	BDL	BDL	BDL	BDL
Sucralose[1]	ng/L	ESI Negative	50	NA	NA	NA	NA	NA	NA	NA	NA	NA
Triclocarban	ng/L	ESI Negative	2.5	81.5	BDL	BDL	5	113	106	BDL	BDL	BDL
Triclosan	ng/L	ESI Negative	1	96.1	BDL	BDL	5	79.3	69	BDL	BDL	BDL
Estradiol 17B	ng/L	APCI (steroids)	5	BDL	BDL	BDL	5	BDL	BDL	BDL	BDL	BDL
Estriol	ng/L	APCI (steroids)	5	BDL	BDL	BDL	5	BDL	BDL	BDL	BDL	BDL
Estrone	ng/L	APCI (steroids)	5	BDL[2]	BDL	BDL	5	BDL	BDL	BDL	BDL	BDL
Ethynylestradiol	ng/L	APCI (steroids)	2.5	BDL	BDL	BDL	5	BDL	BDL	BDL	BDL	BDL
Progesterone	ng/L	APCI (steroids)	2.5	BDL	BDL	BDL	2.5	BDL	BDL	BDL	BDL	BDL
Testosterone	ng/L	APCI (steroids)	1	BDL	BDL	BDL	1	BDL	BDL	BDL	BDL	BDL

Notes (provided by lab):

1. Results for 8/15/11 sucralose not reported due to lab issue
2. Estrone signal in the 8/15/11 S6 sample marginally failed the QC criteria due to high background noise in the sample. Calculated concentration was at 23 ppt.
3. presence in the 2/1/12 S1 sample is likely due to contamination
4. BDL = Below Detection Limit

Table 38 Revised CEC Monitoring Plan

CEC Contaminant Group	[1] Sampling Locations	Rationale for Monitoring
Initial Feed Water Characterization (sample monthly for the first four months) – COMPLETE.		
List of 91 CECs analyzed by MWH Laboratories	S1, S6, S9, S10 Imported Aqueduct Water	1. Characterize NCWRP tertiary water. 2. Identify appropriate indicator constituents. 3. Assess AWP unit process CEC removal performance. 4. Compare water quality of AWP to imported water.
1, 4-Dioxane	S1, S6, S9, S10 Imported Aqueduct Water	
NDMA	S1, S6, S9, S10 Imported Aqueduct Water	
List for On-going Characterization (Quarters 3 and 4)		
Caffeine	S1, S6, S9, S10 Imported Aqueduct Water	• Compounds prioritized based on toxicological evidence. Measured environmental concentration (MEC) greater than monitoring trigger level (MTL), as developed in SWRCB, 2010. • Ongoing characterization of NCWRP tertiary water. 5. Assess AWP unit process CEC removal performance. • Compare water quality of AWP to imported water.
E2 (17β-Estradiol)	S1, S6, S9, S10 Imported Aqueduct Water	
NDMA	S1, S6, S9, S10 Imported Aqueduct Water	
Triclosan	S1, S6, S9, S10 Imported Aqueduct Water	
1,4-Dioxane	S1, S6, S9, S10 Imported Aqueduct Water	• Revised Draft CDPH Groundwater Recharge Regulations specify the AOP be sized to achieve 0.5 log removal of 1,4-Dioxane for direction injection applications. Alternatively, AOP sizing can be based on demonstrated log removals of select indicator compounds from different functional groups.
Potential Performance Indicator Compounds (sample weekly for 4 weeks to assess differential removal along with surrogate parameters)		
Sucralose	S6, S9, S10	• Identified for surface spreading and direct injection operations as viable performance indicator compounds along with certain surrogate parameters (SWRCB, 2010). These compounds were also detected in the RO feed consistently during the initial feed water characterization period with low variability (Relative Standard Deviation <100 %.)
NDMA	S6, S9, S10	
DEET	S6, S9, S10	
Additional 30 CEC compounds (See Table 39)	S6, S9,S10	• These compounds were also consistently present in the RO feed during the initial feed water characterization period with low variability. Based on the 4 weeks of sample results a shorter list of RO and UV/AOP performance indicator compounds will be recommended for continued monitoring. The 30 compound list may also serve useful for periodic monitoring of source water quality.
Caffeine	S6, S9, S10	• Recommendation from IAP: Draft Memorandum: Findings and Recommendations of the Advanced Water Purification Facility Subcommittee, February 2, 2012.
Theobromine	S6, S9, S10	
Linuron	S6, S9, S10	
Estrone	S6, S9, S10	

Note: S1 = tertiary effluent; S6 = RO feed; S9=RO permeate; S10=UV/AOP product.

Table 39 Potential performance indicator compounds to be monitored weekly for 4 weeks

Compound Name	
Butalbital	**TDCPP**
Erythromycin	**Diclofenac**
Simazine	Albuterol
Primidone	Ketoprofen
Lidocaine	Naproxen
4-nonylphenol - semi quantitative	DACT
Gemfibrozil	**Lopressor**
Amoxicillin (semi-quantitative)	Fluoxetine
Atenolol	**Acesulfame-K**
Carbamazepine	Dilantin
Diuron	**Meprobamate**
Triclosan	**Iohexal**
Cotinine	**Dehydronifedipine**
TCEP	**Sulfamethoxazole**
Carisoprodol	**Trimethoprim**

Note: compounds in bold were detected in the RO feed at concentrations greater than 10 times the detection limit in 50% or more of the samples measured during the initial characterization period.

Table 40 Summary of Results for Group A (on-going characterization) CECs for Quarter 3 and Quarter 4

Parameter	Method	Units	DL	RL	Quarter 3: 2/1/2012					Quarter 4: 5/1/2012				
					S1 (tertiary effluent)	S6 (RO Feed)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water	S1 (tertiary effluent)	S6 (RO Feed)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)	Imported Raw Aqueduct Water
Triclosan	LC-MS-MS	ng/L	6.3	10	79	74	13	17	ND	35	28	<6.3	<6.3	<6.3
Estradiol	LC-MS-MS	ng/L	4	5	ND	ND	ND	ND	11	<4.4	<5	<4.4	<4.4	<4.4
Caffeine	LC-MS-MS	ng/L	4	5	59	9.8	ND	ND	ND	53	<4.3	<4.3	<4.3	<4.3
N-Nitroso-dimethylamine (NDMA)	EPA 521	ng/L	0.28	2	<2	3.2	ND	<2	ND	11	<2	<2	<2	<2
1,4 dioxane	EPA 8270M	ng/L	0.04	0.5	1.2	1.2	<0.5	ND	ND	1.6	1.5	<0.04	<0.04	<0.04

Note: Detections of triclosan at S9 and S10 are based on results from analysis conducted by MWH Labs. Results of split samples analyzed by Colorado School of Mines Lab reported triclosan to be ND (DL=5 ng/L) for both S9 and S10. Results shown as less than (<VALUE) indicate the reported result was less than the RL or DL. In some instances, the RL and/or DL varied during the testing period due to laboratory QC procedures or changes in method procedures.

Table 41 Summary of Results for Group B (Potential Performance Indicators) CECs 4X Weekly Samples

Parameter	Method	Units	DL	RL	2/1/2012			2/8/2012			2/15/2012			2/22/2012			5/1/2012				
					S6 (RO Feed)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)	S6 (RO Feed)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)	S6 (RO Feed)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)	S6 (RO Feed)	S9 (RO Perm. Combined)	S10 (UV/AOP Product)	S6 (RO Feed)	S7	S8	S9 (RO Perm. Combined)	S10 (UV/AOP Product)
4-nonylphenol - semi quantitative	LC-MS-MS	ng/L	50	100	<50	<50	<50	<100	<50	<50	<50	<50	<50	1800	<100	<100	520	<50	<100	<50	<50
Acesulfame-K	LC-MS-MS	ng/L	20	20	48000	31	<20	31000	<20	<20	44000	<20	31	37000	42	<20	6400	<20	<20	<20	<20
Albuterol	LC-MS-MS	ng/L	2.4	5	12	<2.4	<2.4	24	<2.4	<2.4	16	<2.4	<2.4	<2.4	<2.4	<2.4	18	<2.4	<2.4	<5	<2.4
Amoxicillin (semi-quantitative)	LC-MS-MS	ng/L	6.4	20	270	<6.4	<6.4	280	<6.4	<6.4	120	<6.4	<6.4	260	<6.4	<6.4	150	<6.4	<6.4	<6.4	<6.4
Atenolol	LC-MS-MS	ng/L	3.9	5	42	<3.9	<3.9	110	<3.9	<3.9	60	<3.9	<3.9	89	<3.9	<3.9	43	<3.9	<3.9	<3.9	<3.9
Butalbital	LC-MS-MS	ng/L	2.9	5	<2.9	<2.9	<2.9	<2.9	<2.9	<5	<2.9	<2.9	<2.9	180	<2.9	<2.9	9.9	<2.9	<2.9	<2.9	<2.9
Caffeine	LC-MS-MS	ng/L	4.3	5	9.8	<4.3	<5	19	8.5	<4.3	7.9	<4.3	<4.3	25	<4.3	<4.3	<4.3	<5	<4.3	<4.3	<4.3
Carbamazepine	LC-MS-MS	ng/L	1.2	5	190	<5	<1.2	200	<1.2	<1.2	190	<1.2	<1.2	180	<1.2	<1.2	210	<1.2	<1.2	<1.2	<1.2
Carisoprodol	LC-MS-MS	ng/L	1.2	5	780	<1.2	<1.2	79	<1.2	<1.2	48	<1.2	<1.2	30	<1.2	<1.2	60	<1.2	<1.2	<1.2	<1.2
Cotinine	LC-MS-MS	ng/L	4.8	10	15	<4.8	<4.8	49	<4.8	<4.8	34	<4.8	<4.8	83	72	<10	60	<4.8	<4.8	<4.8	<4.8
DACT	LC-MS-MS	ng/L	3.9	5	11	<3.9	<3.9	19	<3.9	<3.9	27	<3.9	<3.9	<3.9	<3.9	<3.9	58	<3.9	<5	<5	<3.9
DEET	LC-MS-MS	ng/L	1.1	10	260	<10	<10	67	<10	<10	70	<10	<10	100	<10	<10	210	<10	<10	<10	<10
Dehydronifedipine	LC-MS-MS	ng/L	1.4	5	140	<5	<1.4	62	<1.4	<1.4	49	<1.4	<1.4	240	<5	<1.4	210	<5	<1.4	<1.4	<1.4
Diclofenac	LC-MS-MS	ng/L	3.3	5	18	<3.3	<3.3	35	<3.3	<3.3	<5	<3.3	<3.3	120	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3
Dilantin	LC-MS-MS	ng/L	13	20	110	<13	<13	130	<13	<13	120	<13	<13	82	<13	<13	140	<13	<13	<13	<13
Diuron	LC-MS-MS	ng/L	1.8	5	92	<1.8	<1.8	57	<1.8	<1.8	68	<1.8	<5	89	<1.8	<1.8	80	<1.8	<1.8	<1.8	<1.8
Erythromycin	LC-MS-MS	ng/L	4	10	90	<4	<4	210	<4	<4	120	<4	<4	<10	<4	<4	61	<4	<4	<4	<4
Estrone	LC-MS-MS	ng/L	3.9	5	15	<3.9	<5	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9	<3.9
Fluoxetine	LC-MS-MS	ng/L	10	10	100	<10	<10	120	<10	<10	100	<10	<10	67	<10	<10	31	<10	<10	<10	<10
Gemfibrozil	LC-MS-MS	ng/L	2.5	5	79	<2.5	<5	100	<2.5	<2.5	39	<2.5	<2.5	130	<2.5	<2.5	52	<2.5	<2.5	<2.5	<2.5
Iohexal	LC-MS-MS	ng/L	7.7	10	40000	24	<7.7	18000	<7.7	<7.7	2300	<7.7	<7.7	15000	<10	<7.7	6700	<7.7	<7.7	<7.7	<7.7
Ketoprofen	LC-MS-MS	ng/L	2.6	5	75	<2.6	<2.6	31	<2.6	<2.6	13	<2.6	<2.6	28	<2.6	<2.6	17	<2.6	<2.6	<2.6	<2.6
Lidocaine	LC-MS-MS	ng/L	1.1	5	220	<1.1	<1.1	150	<1.1	<1.1	120	<1.1	<1.1	220	<1.1	<1.1	120	<1.1	<1.1	<1.1	<1.1
Linuron	LC-MS-MS	ng/L	2.8	5	210	<2.8	<2.8	<5	<2.8	<2.8	<5	<2.8	<2.8	<2.8	<2.8	<2.8	6.5	<2.8	<2.8	<2.8	<2.8
Lopressor	LC-MS-MS	ng/L	5.1	20	200	<5.1	<5.1	480	<5.1	<5.1	390	<5.1	<5.1	400	<20	<5.1	210	<5.1	<5.1	<5.1	<5.1
Meprobamate	LC-MS-MS	ng/L	2	5	550	<2	<2	140	<2	<2	96	<2	<2	220	<2	<2	160	<2	<2	<2	<2
Naproxen	LC-MS-MS	ng/L	8.5	10	<8.5	<8.5	<8.5	<8.5	<8.5	<8.5	<8.5	<8.5	<8.5	11	<8.5	<8.5	<8.5	<8.5	<8.5	<8.5	<8.5
N-Nitroso-dimethylamine (NDMA)	EPA 521	ng/L	0.96	2	3.2	<0.96	<0.96	<2	<0.96	<0.96	1.9	0.58	0.4	1.4	0.53	0.36	6.1	-	-	<2	2.1
Primidone	LC-MS-MS	ng/L	4.8	5	93	<4.8	<4.8	100	<4.8	<4.8	110	<4.8	<4.8	120	<4.8	<4.8	97	<4.8	<4.8	<4.8	<4.8
Simazine	LC-MS-MS	ng/L	1.2	5	15	<1.2	<1.2	8.5	<1.2	<1.2	9.1	<1.2	<1.2	24	<1.2	<1.2	<5	<1.2	<1.2	<1.2	<1.2
Sucralose	LC-MS-MS	ng/L	42	100	45000	<100	<42	81000	<100	<42	62000	<42	<42	37000	<42	<42	48000	<42	<42	<42	<42
Sulfamethoxazole	LC-MS-MS	ng/L	2.8	5	1200	<2.8	<2.8	1100	<2.8	<2.8	700	<2.8	<2.8	860	<2.8	<2.8	870	<2.8	<2.8	<2.8	<2.8
TCEP	LC-MS-MS	ng/L	3.2	10	400	<3.2	<3.2	290	<3.2	<3.2	280	<3.2	<3.2	220	12	<3.2	270	<10	<3.2	<3.2	<10
TCPP	LC-MS-MS	ng/L	20	100	1600	<20	<20	2600	<20	<100	1400	<20	<20	2000	160	<100	2300	<20	<20	<20	<20
TDCPP	LC-MS-MS	ng/L	20	100	270	<20	<20	1100	<20	<20	910	<20	<20	930	<100	<20	780	<20	<20	<20	<100
Theobromine	LC-MS-MS	ng/L	3.2	10	<3.2	<3.2	<3.2	86	<3.2	<10	25	<10	<10	<3.2	<3.2	<3.2	<3.2	<10	<10	<3.2	<10
Triclosan	LC-MS-MS	ng/L	6.3	10	74	13	17	47	<6.3	<10	44	<6.3	<6.3	47	<6.3	<6.3	28	<6.3	<6.3	<6.3	<6.3
Trimethoprim	LC-MS-MS	ng/L	1.8	5	450	<5	<5	410	<5	<1.8	210	<1.8	<1.8	280	<1.8	<1.8	280	<1.8	<1.8	<1.8	<1.8

Note: Results shown as less than (<VALUE) indicate the reported result was less than the RL or DL. In some instances, the RL and/or DL varied during the testing period due to laboratory QC procedures or changes in method procedures.

Table 42 Summary of Differential Removal of Performance Indicator Compounds

No.	Compound	Method	Units	DL	RL				RO	UV/AOP
						Avg RO Feed (n = 5)	Avg RO Perm. (n = 5)	Avg UV/AOP (n = 5)	Δ Removal	Δ Removal
1	Acesulfame-K	LC-MS-MS	ng/L	20	20	33000	<27	<22	>99.9%	>16.5%
2	Amoxicillin (semi-quantitative)	LC-MS-MS	ng/L	6.4	20	220	<6.4	<6.4	>97%	-
3	Carbamazepine	LC-MS-MS	ng/L	1.2	5	190	<5	<1.2	>99%	-
4	Dilantin	LC-MS-MS	ng/L	13	20	120	<13	<13	>88.8%	-
5	Diuron	LC-MS-MS	ng/L	1.8	5	77	<1.8	<5	>97.7%	-
6	Fluoxetine	LC-MS-MS	ng/L	10	10	84	<10	<10	>88%	-
7	Lidocaine	LC-MS-MS	ng/L	1.1	5	170	<1.1	<1.1	>99.3%	-
8	Lopressor	LC-MS-MS	ng/L	5.1	20	340	<20	<5.1	>97.6%	-
9	N-Nitroso-dimethylamine (NDMA)	EPA 521	ng/L	0.96	2	3	<2	<0.96	>65.5%	-
10	Primidone	LC-MS-MS	ng/L	4.8	5	100	<4.8	<4.8	>95.4%	-
11	Sucralose	LC-MS-MS	ng/L	42	100	55000	<100	<42	>99.9%	-
12	Sulfamethoxazole	LC-MS-MS	ng/L	2.8	5	950	<2.8	<2.8	>99.7%	-
13	TCEP	LC-MS-MS	ng/L	3.2	10	300	<10	<10	>98.3%	-
14	TCPP	LC-MS-MS	ng/L	20	100	2000	<100	<100	>97.6%	-
15	Triclosan	LC-MS-MS	ng/L	6.3	10	48	<10	<10	>84.1%	-
16	Trimethoprim	LC-MS-MS	ng/L	1.8	5	330	<5	<5	>99.1%	-

Note: For calculating average concentrations, results reported below the RL were considered the value of the RL and for values reported below the DL the value of the DL was used. Dashes shown for the UV/AOP Differential Removal indicate the average concentration in the RO permeate and UV/AOP product were below the RL or DL and therefore removal could not be quantified.

Table 43 Summary of Differential Removal of Surrogate Compounds

No.	Surrogate	RO	UV/AOP
		Δ Removal (%)	Δ Removal (%)
1	TOC	99.6%	NA
2	UV 254	88.8%	68.7%
3	Monochloramines	----------	72.8%
4	Conductivity	99.0%	NA

Table 44 Comparison of Key Water Quality Results and Demonstration Goals

Constituent	Units	RL	[d]Purified Water Results			Water Quality Goal[b]
			Number of Samples	Average Concentration[a]	Maximum Concentration	
Nitrate as N	mg/L	0.11	100	0.73	1.4	1
Nitrite as N	mg/L	0.09	97	ND	ND	1
Ammonia as N (unionized)	mg/L	varies[c]	93	ND	0.021	0.025
Phosphorus, Total	mg/L	0.01	88	0.016	0.420	0.10
Nitrogen, Total	mg/L	0.1	96	0.87	2.2	1
Bromoform	µg/L	0.5	16	ND	0.1	0.5
Methylene Chloride	µg/L	0.50	16	ND	0.59	4.7
Trihalomethanes, Total	µg/L	2.0	16	ND	ND	80
Bromodichloromethane	µg/L	0.5	16	ND	0.85	0.56
Dibromochloromethane	µg/L	0.5	16	ND	0.6	0.5
Haloacetic Acids (HAA5)	µg/L	1	16	ND	ND	60
N-Nitrosodiethylamine	ng/L	2	19	ND	5.7	10
N-Nitrosodimethylamine (NDMA)	ng/L	2	19	ND	5.5	2
1,4-Dioxane	µg/L	0.5	16	ND	ND	1
1,2-Dichloroethane	µg/L	0.5	16	ND	ND	0.5
Total Organic Carbon	mg/L	0.3	97	ND	1.4	0.5
Total Dissolved Solids	mg/L	10	29	13.7	19	300
Chloride	mg/L	0.5	29	3.10	4.3	50
Sulfate	mg/L	0.5	28	ND	1.10	65
Boron	mg/L	0.01	28	0.230	0.290	1.0
Turbidity	NTU	-	298	0.05	0.10	0.2

Notes:

a. **Average concentration calculation assumes non-quantifiable results are half of the reporting level and non-detectable results are half of the detection limit.**
b. **See Testing and Monitoring Plan, Table 5-2 (Appendix A).**
c. **Unionized values of ammonia were estimated based on USEPA's *Aqueous Ammonia Equilibrium – Tabulation of Percent Un-ionized Ammonia (EPA-600/3-79-091)* using average values of temperature and pH measured on-site.**
d. **Results shown as ND are non-quantifiable or non-detectable.**

Acronyms:
RL – Method reporting level
ND – Not detectable or not quantifiable, shown for all values below method reporting level
mg/L – milligrams per liter, equivalent to parts per million (ppm)
µg/L – micrograms per liter, equivalent to parts per billion (ppb)
ng/L – nanograms per liter, equivalent to parts per trillion (ppt)
NTU – Nephelometric Turbidity Units

Table 45: Other Non-Regulated Constituents Detected in Purified Water and Imported Raw Aqueduct Water

Note: ***Of the 111 additional non-regulated constituents measured at the Demonstration Facility, only six were found to be quantifiably detected at any time in the purified water.***

Constituent	Classification/ Common Use	Units	RL	[c]Purified Water			[c]Imported Raw Aqueduct Water		
				Number of Samples	Average Concentration[a]	Maximum Concentration	Number of Samples	Average Concentration[a]	Maximum Concentration
Bromochloromethane	UCMR3 Disinfection byproduct	µg/L	0.06	4	0.225	0.250	4	ND	0.08
Chromium (VI)[b]	UCMR3 Disinfection byproduct, industrial byproduct	µg/L	0.02	4	0.09	0.16	4	0.047	0.052
Acesulfame-K	CEC Sugar Substitute	ng/L	20	9	ND	50	4	343	370
Iohexal	CEC X-ray contrast agent	ng/L	10	9	ND	19	4	43	55
Triclosan	CEC Antibacterial	ng/L	10	9	ND	19	5	ND	ND
Strontium	UCMR3 Alkaline earth Metal	µg/L	0.3	4	ND	0.37	4	405	610

Notes:

a. Average concentration calculation assumes non-quantifiable results are half of the reporting level and non-detectable results are half of the detection limit.

b. Three Chromium (VI) samples were sent to another lab and all results were ND (DL = 0.0059 µg/L). The CDPH Detection Limit for purposes of Reporting (DLR) is 1 µg/L.

c. Results shown as ND are non-quantifiable or non-detectable.

Acronyms:
RL – Method reporting level
ND – Not detectable or not quantifiable, shown for all values below method reporting level
µg/L – micrograms per liter, equivalent to parts per billion (ppb)
ng/L – nanograms per liter, equivalent to parts per trillion (ppt)

Table 46 Summary of Critical Control Point Monitoring Plan for the San Diego AWPF

Critical Control Point	Critical Limit Parameter	Monitoring Frequency	[1]Alert Limit	[1]Critical Limit	[1]Example Corrective Actions
MF/UF	Pressure Decay	1 per day	Value above baseline that approaches Critical limit.	0.4 psi / 5 min. based on the maximum decay predicted to achieve 4 log removal Cryptosporidium.	Confirm Results. Assess fiber breakage. Isolate/ repair/replace damaged membrane.
RO	TOC, Conductivity	Continuous	% change of measured concentration in combined RO permeate.	Online permeate conductivity = 150 µs/cm. Online permeate TOC = 100 ppb or greater for five consecutive measurements.	Automatic shutdown (conductivity). Monitor individual RO trains. Verify analyzer accuracy. Conduct vessel probing.
UV/AOP	Reactor Power Level	Continuous	100% (2 to 7 lamp failures or 1 to 3 ballast failures).	0% (8 or more lamp failures or 4 ballast failures).	System alarm. Automatic increase of reactor power to 100% or system shutdown. Check / replace lamps and/or ballasts.
UV/AOP	Hydrogen peroxide dose rate Continuous (flow confirmation)	1 per day by draw down Continuous flow confirmation	minimum dose (~22 ml/min.) to provide 3 mg/L peroxide	0 ml/min. indicating pump failure or loss of flow confirmation,	Check dosing system. Recalibrate pump. Auto switch to standby pump.

Note:

1. Specific limit values are based on baseline performance observed at the Demonstration Facility. During the design phase of the potential Full-Scale Facility, it is anticipated that the City would develop a similar monitoring and response plan that provides sufficient features and assurances that any foreseeable malfunction could be promptly identified and appropriate response applied.

Table 47 Summary of Critical Control Point Monitoring Results for the San Diego AWPF

Critical Control Point	Critical Limit Parameter	Monitoring Frequency	Number of Exceedances Above Limits				Notes
			Q1	Q2	Q3	Q4	
MF/UF	Pressure Decay	1 per day	1 (UF)	0	0	0	Pressure decay above limit due to leak in air piping not membrane integrity. Repair made, PDT repeated and passed.
RO	TOC, Conductivity	Continuous	0	0	0	0	None.
UV/AOP	Reactor Power Level	Continuous	4	0	1	1	Exceedances due to occurrences of single failed ballasts. System automatically increased power to 100% to accommodate power loss.
UV/AOP	Hydrogen peroxide dose	1 per day (draw down) Continuous (flow confirmation)	0	0	1	5	Q3 -Duty pump auto switched to standby pump and standby pump shutoff, due to low flow (air lock). System automatic shutdown. Restarted shortly after issue self-resolved. Q4 - Pump failures due to air locking. Adjustments made to degas interval and return off gas piping.

Table 48 Chemical Consumption of the Various AWP Unit Processes

Chemical	Concentration (w/w)	Injection Location	Target Dose (mg/L)	Dose Rate (mL/min)	Total Amount Delivered Quarter 1: 5/3/11 to 10/31/11 (gal)	Total Amount Delivered Quarter 2: 11/1/11 to 2/10/12 (gal)	Total Amount Delivered Quarter 3: 2/11/12 to 5/14/12 (gal)	Total Amount Delivered Quarter 4: 5/15/12 to 7/31/12 (gal)
Ammonium Hydroxide	19%	MF/UF Feed	1.5	38	1593	1007	1208	865
Sodium Hypochlorite	13%	MF/UF Feed	3.8	110	4229	2932	3464	2455
Antiscalant	100%	RO Feed	3	10	440	275	220	212
Hydrogen Peroxide	30%	UV Feed	3	22	1784	869	550	550

Chemical	Estimated Daily Consumption Quarter 1 based on 24 hour runtime (gal)	Estimated Average Daily Consumption Quarter 2 (gal)	Estimated Average Daily Consumption Quarter 3 (gal)	Estimated Average Daily Consumption Quarter 4 (gal)	Delivery Interval (Weeks)
Ammonium Hydroxide	11	10	12.4	11.9	3
Sodium Hypochlorite	24 (@ 2 mg/L target dose 7-1-11 to 8-9-11); 39 (@3 mg/L target dose 8-10-11 to 10-31-11)	30	34.7	33.8	1.5
Antiscalant	4	2.7	3.2	2.1	5
Hydrogen Peroxide	8	5.8	7.8	7	6

Note: Target dose rate is based on feed flow (MGD): MF+UF = 1.58; RO=1.25; UV=1. The total amount of chemical delivered for each quarter is based the measured volume delivered as reported by the Brenntag represenative at the time of delivery with the exception of hydrogen peroxide which was calcuated based the difference in tank level before and after each delivery. The estimated Average Daily Consumption for Q2, Q3 and Q4 was determined from differences in chemical tank levels recorded at the start and end of the testing period and the total amount delivered over the testing period.

Table 49 Power Totals of the Various AWP Unit Processes

Date	Daily Power Totals (wH) from Power Meters (August 2011-July 2012)							Comments
	UF	MF	RO Train A	RO Train B	UV/AOP	Total Power Usage for AWPF Process Skids (wH)	Total AWPF Main Power Usage (wH)	
8/1/11	177175	69382	154749	785020	275289	1461615	NA	RO A power meter reading low.
8/2/11	174969	71411	270270	820177	273271	1610098	NA	RO A power meter reading low.
8/3/11	164713	62367	207498	642896	214921	1292395	NA	RO A power meter reading low.
8/4/11	0	0	0	0	0	0	NA	Offline for North City filter mudball chlorination
8/5/11		0	0	0	0	0	NA	Offline for North City filter mudball chlorination
8/6/11	0	0	0	0	0	0	NA	Offline for North City filter mudball chlorination
8/7/11	105975	3197	0	0	21600	130772	NA	RO systems offline.
8/8/11	153239	50077	190139	260084	199665	853204	NA	RO A power meter reading low.
8/9/11	166572	76340	268418	827364	280904	1619598	NA	RO A power meter reading low.
8/10/11	168510	76306	285679	802415	281882	1614792	NA	RO A power meter reading low.
8/11/11	158422	73287	507055	761544	270528	1770836	NA	Electrician swapped 2 wires on RO A power meter.
8/12/11	172002	72739	786253	840360	286875	2158229	NA	
8/13/11	164452	70661	769482	820144	264656	2089395	NA	
8/14/11	144236	47229	507716	540324	243933	1483438	NA	
8/15/11	154829	67876	743783	791380	274836	2032704	NA	
8/16/11	157357	71481	784927	835420	302400	2151585	NA	
8/17/11	146844	71754	783901	833325	300013	2135837	NA	
8/18/11	144077	71502	794484	838166	302465	2150694	NA	
8/19/11						0	NA	Totals not recorded.
8/20/11	124587	29478	290233	309204	109878	863380	NA	
8/21/11	118133	17433	173358	160102	67017	536043	NA	
8/22/11	133286	50326	551012	569555	208435	1512614	NA	
8/23/11	148203	74411	811023	829978	301956	2165571	NA	
8/24/11	154231	72283	805821	856534	302195	2191064	NA	
8/25/11	149646	72297	806455	858888	310680	2197966	NA	
8/26/11	148074	58773	647053	675318	244696	1773914	NA	
8/27/11						0	NA	Totals not recorded.
8/28/11	154274	72920	799079	854588	311392	2192253	NA	
8/29/11	160316	72549	805315	848794	302346	2189320	NA	
8/30/11	155077	72399	816466	861770	302412	2208124	NA	
8/31/11	153396	72574	819239	862184	298566	2205959	NA	
TOTAL (kW-h)	**3953**	**1621**	**14379**	**18086**	**6553**	**44591**	NA	
9/1/11	150591	71884	822969	849608	268390	2163442	NA	
9/2/11	141659	66237	741020	755582	237032	1941530	NA	

Table 49 Power Totals of the Various AWP Unit Processes

Date	Daily Power Totals (wH) from Power Meters (August 2011-July 2012)							Comments
	UF	MF	RO Train A	RO Train B	UV/AOP	Total Power Usage for AWPF Process Skids (wH)	Total AWPF Main Power Usage (wH)	
9/3/11	137444	53834	591336	612258	184835	1579707	NA	
9/4/11						0	NA	Totals not available.
9/5/11	107038	3089	0	0	0	110127	NA	RO and UV/AOP offline.
9/6/11	128629	88037	562688	580606	186182	1546142	NA	
9/7/11	178902	191669	796060	542594	274407	1983632	NA	UF cleaning.
9/8/11						0	NA	Blackout occurred at 3:30 p.m. Offline for weekend
9/9/11						0	NA	Offline due to blackout
9/10/11						0	NA	Offline due to blackout
9/11/11	43260	0	0	0	0	43260	NA	Offline due to blackout
9/12/11	121213	50852	525600	458486	178267	1334418	NA	Back online at ~8 A.M.
9/13/11	174005	72443	814238	859576	263788	2184050	NA	
9/14/11	170557	72086	826192	862508	262035	2193378	NA	
9/15/11	175543	71458	834726	863430	261465	2206622	NA	
9/16/11	163775	62254	726872	743700	238493	1935094	NA	
9/17/11	171963	72249	840096	863858	267446	2215612	NA	
9/18/11	176938	70673	839302	863892	265498	2216303	NA	
9/19/11	171889	71472	835564	846810	271549	2197284	NA	
9/20/11	167910	71943	837178	814944	269463	2161438	NA	
9/21/11	173320	71865	840548	826312	268666	2180711	NA	
9/22/11	173608	70729	828866	832392	264021	2169616	NA	
9/23/11						0	NA	Totals not available.
9/24/11	194134	71068	838174	811920	201340	2116636	NA	
9/25/11	195343	70878	832254	804412	4	1902891	NA	UV/AOP offline.
9/26/11	193885	71214	804784	767424	194237	2031544	NA	
9/27/11	190600	71366	835984	805804	282694	2186448	NA	
9/28/11	169839	40928	462392	451376	173747	1298282	NA	
9/29/11	174505	51536	520864	561296	209871	1518072	NA	
9/30/11	180890	58670	622260	672508	237928	1772256	NA	
TOTAL (kW-h)	**4027**	**1668**	**17180**	**17051**	**5261**	**45188**	NA	
10/1/11	172270	71720	816800	849632	300201	2210623	NA	
10/2/11	174610	71950	813808	846920	337770	2245058	NA	
10/3/11	181130	71260	810744	844152	331570	2238856	NA	
10/4/11						0	NA	Totals not available.
10/5/11	180010	77960	810744	3612	318560	1390886	NA	MF cleaning. RO B offline.

Table 49 Power Totals of the Various AWP Unit Processes

Date	Daily Power Totals (wH) from Power Meters (August 2011-July 2012)							Comments
	UF	MF	RO Train A	RO Train B	UV/AOP	Total Power Usage for AWPF Process Skids (wH)	Total AWPF Main Power Usage (wH)	
10/6/11	179870	163170	823136	607880	306130	2080186	NA	RO B Cleaning.
10/7/11	181190	328000	812024	263412	314110	1898736	NA	RO B Cleaning.
10/8/11						0	NA	Totals not available.
10/9/11	195070	64620	830600	824432	337490	2252212	NA	
10/10/11	198260	62610	815200	814184	352790	2243044	NA	
10/11/11	200490	64100	824320	828432	350530	2267872	NA	
10/12/11	201950	64070	802168	835616	294820	2198624	NA	
10/13/11	209210	43200	650692	719760	261660	1884522	NA	
10/14/11	203640	216800	243188	822336	227770	1713734	NA	RO A Cleaning. (MF/RO A/UV offline)
10/15/11	205610	154040	296972	829672	118420	1604714	NA	RO A Cleaning. (MF/RO A/UV offline)
10/16/11	199630	64350	814980	838960	304300	2222220	NA	
10/17/11	198400	64560	814832	837464	302420	2217676	NA	
10/18/11	190220	56580	719648	739600	265780	1971828	NA	All systems offline for ~ 4 hours.
10/19/11	200870	63840	822300	844800	302340	2234150	NA	
10/20/11	200650	63440	823960	846064	303800	2237914	NA	
10/21/11	185450	54270	674788	700952	276240	1891700	NA	All systems offline for ~ 3 hours.
10/22/11	197810	63930	809192	846880	362210	2280022	NA	
10/23/11	194730	63460	807568	845760	311430	2222948	NA	
10/24/11	191690	63070	806584	844008	304990	2210342	NA	
10/25/11	194180	62810	812520	850880	302610	2223000	NA	
10/26/11	190480	63000	806728	845136	301720	2207064	NA	
10/27/11	190810	63720	817688	859104	304480	2235802	NA	
10/28/11	182170	57490	746472	783920	276400	2046452	NA	
10/29/11	188780	63140	824152	866568	305230	2247870	NA	
10/30/11	177060	53160	678688	711600	244740	1865248	NA	
10/31/11	194310	63670	820288	859520	298030	2235818	NA	
TOTAL (kW-h)	**5561**	**2438**	**21951**	**22211**	**8619**	**60779**	NA	
11/1/11	199080	63260	826400	865336	333772	2287848	NA	
11/2/11	192000	58030	746280	781184	275416	2052910	NA	All systems offline for ~2 hours.
11/3/11	197890	64040	832344	872424	306584	2273282	NA	
11/4/11	171680	44060	567168	593936	212868	1589712	NA	All systems offline for ~8 hours.
11/5/11	140795	35850	498769	548883	181349	1405647	NA	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
11/6/11	196160	62360	847048	886792	313860	2306220	NA	

Table 49 Power Totals of the Various AWP Unit Processes

Date	Daily Power Totals (wH) from Power Meters (August 2011-July 2012)							Comments
	UF	MF	RO Train A	RO Train B	UV/AOP	Total Power Usage for AWPF Process Skids (wH)	Total AWPF Main Power Usage (wH)	
11/7/11	199020	63570	844960	884672	313200	2305422	NA	
11/8/11	202120	63170	855552	897256	311212	2329310	NA	
11/9/11	165105	42040	584887	643654	212661	1648348	NA	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
11/10/11	157930	32750	393912	405496	146784	1136872	NA	All systems offline for ~13 hours.
11/11/11	158623	40390	561923	618382	204311	1583628	NA	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
11/12/11	158623	40390	561923	618382	204311	1583628	NA	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
11/13/11	158623	40390	561923	618382	204311	1583628	NA	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
11/14/11	181330	51400	693800	715344	251344	1893218	NA	All systems offline for ~5 hours.
11/15/11	148660	41940	498892	502728	189416	1381636	NA	All systems offline for ~10 hours.
11/16/11	144240	26980	319268	332760	119920	943168	NA	All systems offline for ~15 hours.
11/17/11	145890	22590	260308	260608	97560	786956	NA	All systems offline for ~17 hours.
11/18/11	156820	32730	384012	442840	154840	1171242	NA	All systems offline for ~12 hours. Total AWPF Power Meter Installed.
11/19/11	205690	62320	858300	897944	300852	2325106	2452280	
11/20/11	207820	62030	860536	900576	300212	2331174	2461540	
11/21/11	206470	61900	867816	907632	325200	2369018	2496990	
11/22/11	204720	61630	875704	914952	356040	2413046	2542740	
11/23/11	244113	62158	864772	951661	314425	2437129	2556849	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
11/24/11	203850	61730	870944	911264	436920	2484708	2616290	
11/25/11	207110	61560	863920	904248	432752	2469590	2597210	
11/26/11	202060	60890	875064	914760	434248	2487022	2618050	
11/27/11	207050	61430	868504	909288	434740	2481012	2614940	
11/28/11	211570	61620	869200	909864	361280	2413534	2545380	
11/29/11	217290	61350	875540	916688	299892	2370760	2501650	
11/30/11	200170	61410	875704	914832	298068	2350184	2477260	
TOTAL (kW-h)	**5593**	**1566**	**21265**	**22443**	**8328**	**59195**	**NA**	

Table 49 Power Totals of the Various AWP Unit Processes

	Daily Power Totals (wH) from Power Meters (August 2011-July 2012)							Comments
Date	UF	MF	RO Train A	RO Train B	UV/AOP	Total Power Usage for AWPF Process Skids (wH)	Total AWPF Main Power Usage (wH)	
12/1/11	206210	55830	778264	813840	267052	2121196	2236112	All systems offline for ~3 hours.
12/2/11	213390	61100	884864	922928	302068	2384350	2500536	
12/3/11	223180	61030	801808	838088	275480	2199586	2319144	RO Trains and UV offline for ~3 hours.
12/4/11	202450	61360	884432	925496	304252	2377990	2501068	
12/5/11	188950	59890	741376	901856	294760	2186832	2305920	UF and ROA offline for ~4 hours.
12/6/11	201290	60770	869408	932992	301568	2366028	2487720	
12/7/11	190510	60740	833504	937712	301208	2323674	2441092	
12/8/11	189320	57720	832880	890296	285392	2255608	2375200	All systems offline for ~1 hour.
12/9/11	186670	55670	810336	862792	277440	2192908	2310536	All systems offline for ~2 hours.
12/10/11	217020	61210	883824	943168	302728	2407950	2532384	
12/11/11	217970	60970	883656	941936	302272	2406804	2529368	
12/12/11	210410	60530	872808	930560	298128	2372436	2499232	
12/13/11	212540	62050	887680	943360	302292	2407922	2512840	
12/14/11	207080	61420	892152	946424	304612	2411688	2536696	
12/15/11	197880	61090	890200	939256	301088	2389514	2511720	
12/16/11	190080	51480	726960	769512	246752	1984784	2099864	All systems offline for ~4 hours.
12/17/11	206570	54770	778768	825224	263280	2128612	2245824	All systems offline for ~3 hours.
12/18/11	216410	61240	890968	946408	303608	2418634	2545344	
12/19/11	213990	61960	891232	946616	303672	2417470	2545072	
12/20/11	185170	43490	619712	657592	211568	1717532	1826304	All systems offline for ~7 hours.
12/21/11	180810	41970	589264	623336	205400	1640780	1746208	All systems offline for ~8 hours.
12/22/11	211690	63130	888896	943952	306792	2414460	2542416	
12/23/11	165550	49620	705440	746528	241656	1908794	2016672	All systems offline for ~5 hours.
12/24/11	236010	60095	836066	920070	303987	2356228	2471975	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
12/25/11	196540	61820	892312	946744	305200	2402616	2521992	
12/26/11	200860	61030	899616	949472	303092	2414070	2536656	
12/27/11	193100	61420	902928	950336	303492	2411276	2530784	
12/28/11	193660	60800	909304	952520	303328	2419612	2546936	
12/29/11	239048	60868	846831	931917	307901	2386566	2503803	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
12/30/11	199720	53800	775680	818560	263852	2111612	2227360	All systems offline for ~3 hours.
12/31/11	243100	61900	861184	947712	313120	2427016	2546240	Power totals not available. Values estimated

Table 49 Power Totals of the Various AWP Unit Processes

Date	Daily Power Totals (wH) from Power Meters (August 2011-July 2012)							Comments
	UF	MF	RO Train A	RO Train B	UV/AOP	Total Power Usage for AWPF Process Skids (wH)	Total AWPF Main Power Usage (wH)	
								based on runtime and typical power usage for 24 hour period.
TOTAL (kW-h)	**6337**	**1811**	**25762**	**27547**	**8907**	**70365**	**74053**	
1/1/12	210870	61330	895440	948720	306432	2422792	2550712	
1/2/12	210870	61290	896248	949424	305388	2423220	2551456	
1/3/12	213840	61390	877672	937760	301620	2392282	2522992	
1/4/12	216520	61700	892608	947888	303592	2422308	2553648	
1/5/12	212100	61120	895768	950368	304776	2424132	2558856	
1/6/12	194900	51820	731960	772304	257224	2008208	2125112	All systems offline for ~5 hours.
1/7/12	212300	61270	898584	950192	309028	2431374	2557264	
1/8/12	204230	62110	904952	951936	309060	2432288	2554896	
1/9/12	206940	62970	905584	951920	311232	2438646	2559944	
1/10/12	162030	34190	484688	551376	182136	1414420	1515768	All systems offline for ~10 hours. Energy recovery device removed from RO Train A.
1/11/12	113400	6440	9816	8816	11760	150232	221592	Systems offline for ERD maintenance.
1/12/12	173412	39350	569488	576752	193640	1552642	1661320	All systems offline for ~9 hours.
1/13/12	192656	59470	921472	946208	302172	2421978	2546944	
1/14/12	188904	60000	926504	954512	301300	2431220	2549808	
1/15/12	204708	60510	931680	953824	305900	2456622	2576352	
1/16/12	204260	60540	931304	955136	305188	2456428	2580400	
1/17/12	208672	57900	886480	867776	290744	2311572	2429648	
1/18/12	254888	60450	937496	955200	309408	2517442	2634832	Positioner on UF feed valve controller replaced.
1/19/12	267432	60530	939224	955184	311592	2533962	2654848	
1/20/12	245968	18620	733080	747696	246976	1992340	2133616	All systems offline for ~5 hours.
1/21/12	266550	60760	931936	954112	311632	2524990	2662048	
1/22/12	265340	60760	932880	954976	312408	2526364	2647504	
1/23/12	259820	60470	937256	954304	315760	2527610	2653248	
1/24/12	262020	60660	934400	954656	310440	2522176	2643376	
1/25/12	266040	60830	936960	954464	310112	2528406	2654512	
1/26/12	266120	59940	923280	935840	304992	2490172	2619808	
1/27/12	231260	57980	496280	886368	276240	1948128	2063248	
1/28/12	226840	62610	489360	956368	295920	2031098	2145840	
1/29/12	250920	60890	928616	956448	315176	2512050	2633104	
1/30/12	240400	51150	762712	785056	261240	2100558	2213680	All systems offline for ~4 hours.
1/31/12	267348	61400	928240	958528	314384	2529900	2657568	

Table 49 Power Totals of the Various AWP Unit Processes

Date	Daily Power Totals (wH) from Power Meters (August 2011-July 2012)							Comments
	UF	MF	RO Train A	RO Train B	UV/AOP	Total Power Usage for AWPF Process Skids (wH)	Total AWPF Main Power Usage (wH)	
TOTAL (kW-h)	**6902**	**1720**	**25372**	**27084**	**8797**	**69876**	**73634**	
2/1/12	266864	60190	928600	957712	312388	2525754	2651936	
2/2/12	263280	60270	928904	956528	315240	2524222	2642992	
2/3/12	254416	54520	823528	849328	280628	2262420	2378288	
2/4/12	239048	60868	846831	931917	307901	2386566	2503803	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
2/5/12	262320	60350	934344	957632	316420	2531066	2650592	
2/6/12	262860	60860	929640	956864	316440	2526664	2649680	
2/7/12	268440	60950	929352	956784	313320	2528846	2666944	
2/8/12	269060	60710	933360	958640	313460	2535230	2666080	
2/9/12	269928	60890	937600	958688	309220	2536326	2667232	
2/10/12	256532	51780	775936	794768	261300	2140316	2251232	All systems offline for ~4 hours.
2/11/12	264612	61390	936064	958000	317392	2537458	2657888	
2/12/12	264840	60790	930496	956896	318028	2531050	2652992	
2/13/12	262928	60830	928032	956208	317988	2525986	2649296	
2/14/12	267688	60410	932080	956720	318532	2535430	2657200	
2/15/12	261852	60540	931392	943600	311508	2508892	2630880	
2/16/12	260680	58030	898768	909872	298160	2425510	2544224	
2/17/12	246440	59870	747568	755584	249584	2059046	2156112	
2/18/12	266020	61100	940368	954688	315560	2537736	2659424	
2/19/12	267780	61100	938592	954832	320120	2542424	2665120	
2/20/12	251612	52490	774320	809904	271856	2160182	2273808	
2/21/12	262056	61390	862000	957728	318960	2462134	2581136	
2/22/12	258832	60550	861552	958992	316652	2456578	2586976	
2/23/12	260840	60400	847072	873648	290900	2332860	2455520	
2/24/12	261432	61620	872352	955680	316760	2467844	2592416	
2/25/12	260268	61190	872128	955264	316352	2465202	2587824	
2/26/12	259040	61320	868592	952840	320344	2462136	2585280	
2/27/12	243759	61416	788134	885108	320021	2298439	2405254	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
2/28/12	259536	60390	867296	948624	315296	2451142	2574256	
2/29/12	261112	61250	878144	957024	317632	2475162	2597808	
TOTAL (kW-h)	**7554**	**1737**	**25643**	**26880**	**8918**	**70733**	**74242**	

Table 49 Power Totals of the Various AWP Unit Processes

Date	Daily Power Totals (wH) from Power Meters (August 2011-July 2012)							Comments
	UF	MF	RO Train A	RO Train B	UV/AOP	Total Power Usage for AWPF Process Skids (wH)	Total AWPF Main Power Usage (wH)	
3/1/12	259900	61360	875760	956400	318176	2471596	2598560	
3/2/12	249700	55080	758144	828960	278464	2170348	2284544	
3/3/12	252680	55850	794624	869456	293600	2266210	2382416	
3/4/12	172448	5370	4672	4560	11632	198682	267184	UF Critical alarm shut down plant (Bray air valve)
3/5/12	199532	32940	414061	456848	15728	1119109	1360848	
3/6/12	241612	61210	844544	899632	315536	2362534	2484128	
3/7/12	226948	49930	670400	738000	250872	1936150	2044992	
3/8/12	239300	61740	866112	952640	322672	2442464	2561504	
3/9/12	236740	56410	776480	858944	287360	2215934	2333472	
3/10/12	246132	61820	851368	948416	313560	2421296	2546304	
3/11/12	244640	61580	851360	948496	318648	2424724	2548736	
3/12/12	244760	61990	844560	948816	318400	2418526	2541856	
3/13/12	244868	62100	848800	948160	309296	2413224	2535264	
3/14/12	245740	61900	848480	949376	309992	2415488	2539468	
3/15/12	244940	62130	846576	948432	313048	2415126	2537312	
3/16/12	245280	61500	843552	948960	313328	2412620	2533920	
3/17/12	243300	62010	844192	946080	313504	2409086	2530240	
3/18/12	243760	61680	853632	948928	316272	2424272	2543168	
3/19/12	242700	61750	854640	948352	315488	2422930	2542720	
3/20/12	240360	60470	851952	937152	307568	2397502	2518336	
3/21/12	243100	61900	861184	947712	313120	2427016	2546240	
3/22/12	204528	342470	857712	481664	288640	2175014	2312320	
3/23/12	199472	290286	838352	418128	281344	2027582	2167104	
3/24/12	244072	61870	863200	951312	316248	2436702	2558432	
3/25/12	240536	62270	862176	951456	314352	2430790	2550944	
3/26/12	243652	61270	861856	950256	317288	2434322	2554752	
3/27/12	239012	58050	832736	935792	297136	2362726	2476608	
3/28/12	244640	52700	871072	1024640	314856	2507908	2639616	
3/29/12	243768	52310	870432	1019616	319552	2505678	2636480	
3/30/12	233552	56210	779840	914912	286456	2270970	2386720	
3/31/12	240368	59140	863152	1024384	304200	2491244	2607456	
TOTAL (kW-h)	**7342**	**2277**	**24706**	**26606**	**8896**	**69828**	**73672**	
4/1/12	244100	62050	863680	1085504	317360	2572694	2695872	
4/2/12	243040	61870	860768	1043136	316728	2525542	2651552	

Table 49 Power Totals of the Various AWP Unit Processes

Date	Daily Power Totals (wH) from Power Meters (August 2011-July 2012)							Comments
	UF	MF	RO Train A	RO Train B	UV/AOP	Total Power Usage for AWPF Process Skids (wH)	Total AWPF Main Power Usage (wH)	
4/3/12	240892	61770	860272	1057616	315192	2535742	2662400	
4/4/12	238968	238810	836208	1028688	307040	2649714	2770432	
4/5/12	244872	182990	685936	981968	306192	2401958	2520320	
4/6/12	236208	105050	772480	893552	286088	2293378	2408160	
4/7/12	242280	62060	849232	1036224	312176	2501972	2626080	
4/8/12	245368	62600	846288	1037232	311976	2503464	2625760	
4/9/12	243840	62090	839232	1023536	312296	2480994	2604960	
4/10/12	243192	62340	840304	1009312	308448	2463596	2583712	
4/11/12	245632	62040	842048	1007008	305584	2462312	2584512	
4/12/12	245256	62850	839728	1002528	306104	2456466	2574592	
4/13/12	235712	56920	753232	900544	272400	2218808	2331616	
4/14/12	243560	61990	847840	1010224	307696	2471310	2590432	
4/15/12	246060	61800	846368	1006304	315624	2476156	2597248	
4/16/12	245692	598720	441216	991952	301160	2578740	2741728	RO A offline for approximately 12 hours for cleaning; Extra power usage at MF due to heating CIP water
4/17/12	244200	462370	286368	990336	303840	2287114	2436064	RO A offline for approximately 15 hours for cleaning; Extra power usage at MF due to heating CIP water
4/18/12	230128	297120	293888	349072	110408	1280616	1992000	All systems offline for approx. 3 hours; RO B offline for approximately 16 hours for cleaning; Extra power usage at MF due to heating CIP water
4/19/12	243808	125610	840291	445648	303684	1959041	2043456	RO B offline for approximately 12 hours for cleaning; Extra power usage at MF due to heating CIP water. Power total for RO A not available, usage estimated based on runtime and typical power usage.
4/20/12	234452	55680	735254	832384	283008	2140778	2215936	All systems offline for approximately 3 hours. Power total for RO A not available, usage estimated based on runtime and typical power usage.
4/21/12	243932	61880	840291	939776	319488	2405367	2468192	Power total for RO A not available, usage estimated based on runtime and typical power usage.
4/22/12	239948	58080	770267	882080	300768	2251143	2332896	All systems offline for approximately 2 hours.

Table 49 Power Totals of the Various AWP Unit Processes

Date	Daily Power Totals (wH) from Power Meters (August 2011-July 2012)							Comments
	UF	MF	RO Train A	RO Train B	UV/AOP	Total Power Usage for AWPF Process Skids (wH)	Total AWPF Main Power Usage (wH)	
								Power total for RO A not available, usage estimated based on runtime and typical power usage.
4/23/12	244188	61180	840291	907808	316152	2369619	2426752	Power total for RO A not available, usage estimated based on runtime and typical power usage.
4/24/12	233512	56560	735254	779120	275896	2080342	2150784	All systems offline for approximately 3 hours. Power total for RO A not available, usage estimated based on runtime and typical power usage.
4/25/12	243392	62030	778624	874640	302256	2260942	2376704	Power total for RO A not available, usage estimated based on runtime and typical power usage.
4/26/12	243048	61520	778928	876576	300992	2261064	2378816	
4/27/12	213289	53739	689618	774470	280018	2011134	2104597	All systems offline for approximately 3 hours. Power totals not available. Usage estimated based on runtime and typical power usage.
4/28/12	243428	61540	780128	876480	315912	2277488	2393600	
4/29/12	242632	60930	780528	877488	345992	2307570	2426432	
4/30/12	240312	56930	745024	823552	327069	2192887	2311680	All systems offline for approximately 1 hour
TOTAL (kW-h)	**7225**	**3401**	**22720**	**27345**	**8988**	**69678**	**73627**	
5/1/12	244000	61470	775296	874272	318192	2273230	2391488	
5/2/12	242880	61360	777760	879024	359032	2320056	2438208	
5/3/12	244888	61380	773072	874992	357496	2311828	2429216	
5/4/12	237040	56910	686048	794784	314104	2088886	2199936	All systems offline for approxmiately 2 hours
5/5/12	243480	60830	771648	875664	293872	2245494	2361664	
5/6/12	245480	61460	772912	879472	290848	2250172	2366720	
5/7/12	142193	35826	459745	516313	186679	1340756	1403065	All sytems offline for approximately 10 hours. Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
5/8/12	0	0	0	0	0	0	0	All systems offline all day
5/9/12	0	0	0	0	0	0	0	All systems offline all day
5/10/12	0	0	0	0	0	0	0	All systems offline all day
5/11/12	152349	38385	492584	553193	200013	1436524	1503284	All systems offline for approximately 9 hours. Power totals not available. Values estimated

Table 49 Power Totals of the Various AWP Unit Processes

Date	Daily Power Totals (wH) from Power Meters (August 2011-July 2012)							Comments
	UF	MF	RO Train A	RO Train B	UV/AOP	Total Power Usage for AWPF Process Skids (wH)	Total AWPF Main Power Usage (wH)	
								based on runtime and typical power usage for 24 hour period.
5/12/12	198680	62740	766224	872080	296536	2196260	2313600	
5/13/12	198380	62110	764800	873264	295544	2194098	2310528	
5/14/12	197780	61930	759328	871808	295680	2186526	2302976	
5/15/12	192988	62560	762288	876864	296528	2191228	2308544	
5/16/12	193944	62900	762416	873760	293104	2186124	2304960	
5/17/12	190600	55960	719248	789808	264656	2020272	2133408	
5/18/12	172125.3	55823.8	676644.2	775462.0	260129.8	1940185	2045652.0	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
5/19/12	197904	62310	817312	875584	293264	2246374	2360800	
5/20/12	193216	62170	814192	868608	292896	2231082	2347040	
5/21/12	200144	61940	811200	864240	297432	2234956	2351456	
5/22/12	196416	62300	818912	867536	296936	2242100	2360000	
5/23/12	196772	62270	820032	872080	280304	2231458	2345376	
5/24/12	195588	61720	819472	871952	292352	2241084	2358016	
5/25/12	197612	54280	710544	679152	237944	1879532	1982592	All systems offline for ~3 hours; ROB and UV offline for ~5 hours
5/26/12								
5/27/12	180680	35810	442816	479568	164312	1303186	1395424	All systems offline for ~11 hours
5/28/12	154347	50058	606756	695367	233262	1739790	1834364	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period. All systems offline ~ 5 hours.
5/29/12	154347	50058	606756	695367	233262	1739790	1834364	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period. All systems offline ~ 5 hours.
5/30/12	188780	231900	786720	872080	306656	2386136	2502624	Extra power usage on MF due to heating of water for UF CIP
5/31/12	177068	285150	364800	853488	279184	1959690	2113184	UF and ROA offline for ~13 hours due to UF cleaning; Extra power usage on MF due to heating of water for UF CIP
TOTAL (kW-h)	**5330**	**1942**	**19140**	**21676**	**7530**	**55617**	**58598**	
6/1/12	171593	199139	692067	844410	270463	2177671	2279565	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.

Table 49 Power Totals of the Various AWP Unit Processes

Date	Daily Power Totals (wH) from Power Meters (August 2011-July 2012)							Comments
	UF	MF	RO Train A	RO Train B	UV/AOP	Total Power Usage for AWPF Process Skids (wH)	Total AWPF Main Power Usage (wH)	
6/2/12	195472	61680	789280	882624	306784	2235840	2351936	
6/3/12	192328	61660	784432	888944	307104	2234468	2357280	
6/4/12	191472	62040	780416	887264	306912	2228104	2339360	
6/5/12	192840	61440	780752	924640	306632	2266304	2382848	
6/6/12	194256	225440	783472	955936	306184	2465288	2580640	Extra power usage on MF due to heating water for ROB CIP
6/7/12	193672	206870	771984	287168	178672	1638366	1745888	MF and ROB offline for ~17 hours, UV offline for ~9 hours; Extra power usage on MF due to heating water for ROB CIP
6/8/12	81749	94873	329711	402290	128852	1037475	1086019	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period. All systems offline ~ 14 hours.
6/9/12	195800	61360	768512	914272	289416	2229360	2346176	
6/10/12	192720	62080	760928	906752	297752	2220232	2336832	
6/11/12	192160	57680	709040	847584	278160	2084624	2198144	All systems offline for ~2 hours
6/12/12	186976	44900	538336	643904	193656	1607772	1707936	All systems offline for ~7 hours
6/13/12	195144	62400	760880	911040	293600	2223064	2338880	
6/14/12	197608	61500	765648	918464	294976	2238196	2353696	
6/15/12	140856	43190	530512	637696	203840	1556094	1648640	All systems offline for ~7 hours
6/16/12	194096	63030	762384	915008	289344	2223862	2341888	
6/17/12	198912	63070	758896	912224	290128	2223230	2342144	
6/18/12	195512	62910	743760	869216	286992	2158390	2278560	
6/19/12	175960	27660	311440	370368	125976	1011404	1099520	All systems offline for ~14 hours due to leak at chlorine pump
6/20/12	185944	44850	540592	639200	212632	1623218	1728032	All systems offline for ~7 hours due to leak at chlorine pump
6/21/12	198024	62110	758400	902496	293648	2214678	2336000	
6/22/12	191312	52960	632768	748832	254056	1879928	1991200	All systems offline for ~4 hours
6/23/12	168320	52794	644640	767122	249601	1882476	1985600	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period. All systems offline ~4 hours.
6/24/12	161752	4710	4320	3904	11736	186422	254592	All systems offline all day
6/25/12	173080	26080	272048	317600	114584	903392	990816	All systems offline for ~15 hours
6/26/12	0	0	0	0	0	0	0	Power Outage plant shutdown
6/27/12	195016	61690	754192	888736	299000	2198634	2318880	
6/28/12	196408	61270	753328	888032	298856	2197894	2315232	

Table 49 Power Totals of the Various AWP Unit Processes

Date	Daily Power Totals (wH) from Power Meters (August 2011-July 2012)							Comments
	UF	MF	RO Train A	RO Train B	UV/AOP	Total Power Usage for AWPF Process Skids (wH)	Total AWPF Main Power Usage (wH)	
6/29/12	172266	53739	660731	778878	262122	1927736	2030651	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period. All systems offline ~3 hours for maintenance.
6/30/12	172266	53739	660731	778878	262122	1927736	2030651	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period. All systems offline ~3 hours for maintenance.
TOTAL (kW-h)	**5294**	**2057**	**18804**	**21633**	**7214**	**55002**	**58098**	
7/1/12	196080	61530	748160	890592	305432	2201794	2321408	Shutdown for ~2hrs due to pump failure.
7/2/12	201600	61110	745968	887264	303472	2199414	2321472	
7/3/12	180859	56419	693690	817729	275197	2023894	2131943	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period. All systems offline ~2 hours.
7/4/12	193360	61200	751520	894976	894976	2796032	2318080	
7/5/12	0	0	0	0	0	0	0	Plant shutdown due to pump failures & EDR exercises
7/6/12	0	0	0	0	0	0	0	Plant shutdown all weekend due to comm. Failures
7/7/12	0	0	0	0	0	0	0	Plant shutdown all weekend due to comm. Failures
7/8/12	0	0	0	0	0	0	0	Plant shutdown all weekend due to comm. Failures
7/9/12	185136	39430	457504	540192	540192	1762454	1512256	Plant shutdown all weekend due to comm. Failures
7/10/12	193720	55610	665296	774976	774976	2464578	2076416	
7/11/12	197656	61120	738112	861312	296784	2154984	2276032	
7/12/12	196784	61480	739328	866816	294720	2159128	2281344	
7/13/12	179975.4	56228.6	676177.1	792775.5	269546.0	1974702	2086479	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
7/14/12	179975.4	56228.6	676177.1	792775.5	269546.0	1974702	2086479	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
7/15/12	198480	60740	736368	858240	293688	2147516	2265600	
7/16/12	197352	60350	738448	860032	292096	2148278	2264768	

Table 49 Power Totals of the Various AWP Unit Processes

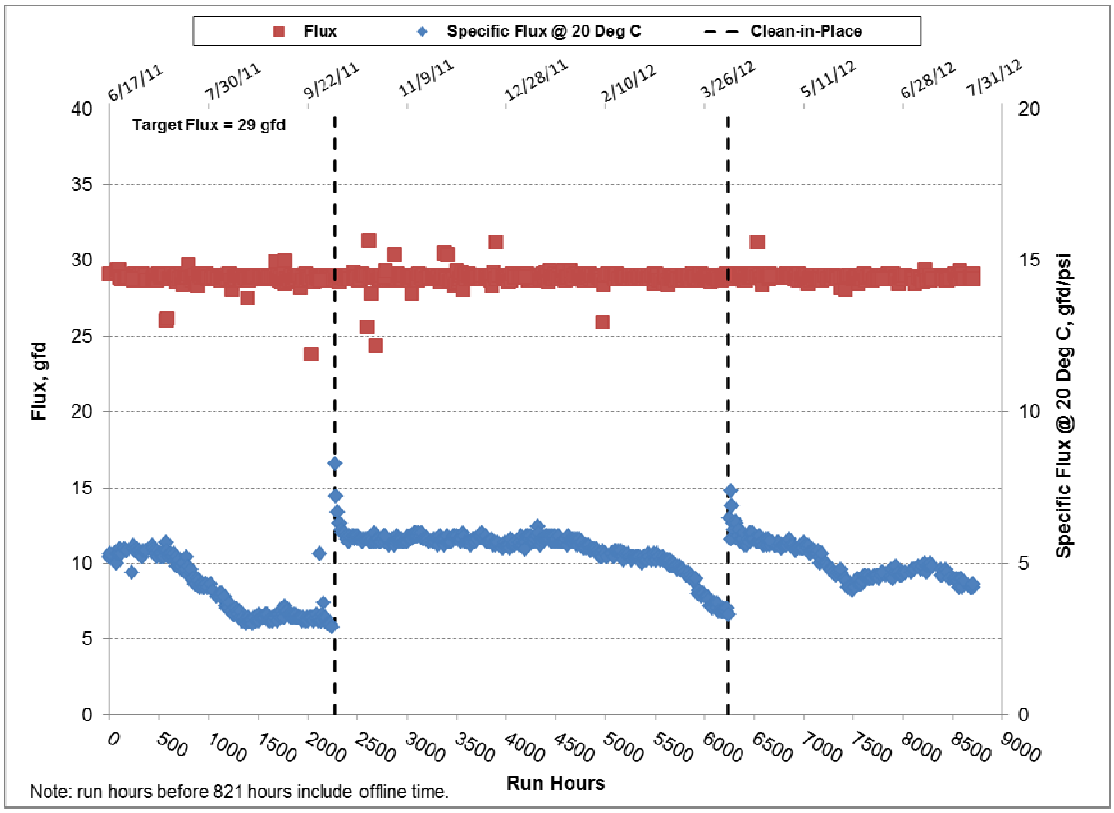
Date	Daily Power Totals (wH) from Power Meters (August 2011-July 2012)							Comments
	UF	MF	RO Train A	RO Train B	UV/AOP	Total Power Usage for AWPF Process Skids (wH)	Total AWPF Main Power Usage (wH)	
7/17/12	196960	61350	746112	870400	294984	2169806	2286592	
7/18/12	193464	60480	748800	874368	296856	2173968	2295936	
7/19/12	189304	55550	675040	786144	268320	1974358	2093056	
7/20/12	193320	60900	743360	865920	294632	2158132	2277568	
7/21/12	193320	60900	743360	865920	294632	2158132	2277568	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
7/22/12	197592	61300	743776	876040	293424	2172132	2283264	
7/23/12	194792	60420	743328	869120	291856	2159516	2279936	
7/24/12	190976	48760	588160	688096	231080	1747072	1858176	Plant shutdown ~5 hrs due to pump failure while operator not present
7/25/12	194464	60700	745968	878144	294824	2174100	2291264	
7/26/12	198288	60480	742096	871552	295184	2167600	2286208	
7/27/12	185069	56448	692623	813449	275505	2023093	2133794	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
7/28/12	185069	56448	692623	813449	275505	2023093	2133794	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
7/29/12	196928	60620	737920	863840	293712	2153020	2270208	
7/30/12	198392	60270	735520	862400	291488	2148070	2265408	
7/31/12	201760	60780	734832	861920	289488	2148780	2265728	
TOTAL (kW-h)	**5211**	**1577**	**19180**	**22498**	**9092**	**57558**	**59241**	

Table 50 Equipment Maintenance / Failure Log Q4 Testing Period

Month / Year	Equipment	Description of Issue	Action	Status
August 2011 – July 2012	UF System	Backwash chlorine pump loose prime.	Tubing has been rerouted and foot valve replaced. H2O Innovations looking at installing a recirculation line to prevent air locking of chemical.	open
May 2012	UVT analyzer	Lamp failed.	Replaced lamp.	closed
May 2012	Hydrogen Peroxide Pumps	Multiple no flow alarms on peroxide pumps causing a latched alarm and reactor shutdown.	Changed degas interval and length of time; Opened vent valve on peroxide pump skid.	monitoring
June 2012	Antiscalant Pump	Crack found in pump skid piping.	Replaced cracked pipe section.	closed
June 2012	Sodium Hypochlorite Pump	Pressure relief valve on pump skid steadily dripping due to a crack in the plug.	Cracked plug removed and replaced.	closed
June 2012	RO Train B	Discovered concentrate flow meter to be reading ~20 gpm higher than actual flow based on comparison to strap on flow meter and concentrate conductivity readings; This caused the calculated recovery to be lower than the actual recovery.	Scaled flow transmitter equipped on RO skid to display correct flows. Confirmed FWR based on sulfate rejection.	closed
June 2012	UV/AOP System	Ballast failure.	Replaced ballast.	Power study and failure diagnostic in progress.
July 2012	Feed Pumps	Feed pumps faulted.	Reset alarms.	closed
July 2012	Programmable Logic Controller Fault (PLC-101)	Plant continued to shut-down due to PLC communication failures.	Data transferred from PLC-101 to AWP operations computer to increase hard drive capacity. Also cleared communication ports.	closed
July 2012	Feed Pumps	No flow from Penasquitos pump station caused low flow in the North City feed pump wet wells which caused AWP feed pump to shut down.	Reset alarms.	closed
July 2012	Feed Pumps	Pumps faulted on a low wet well level alarm. North City operators discovered this caused by a PLC issue and not actual low levels.	Reset alarms.	closed

Note:

1. The table includes items from previous Testing Periods that remained open during the Q4 Reporting Period.



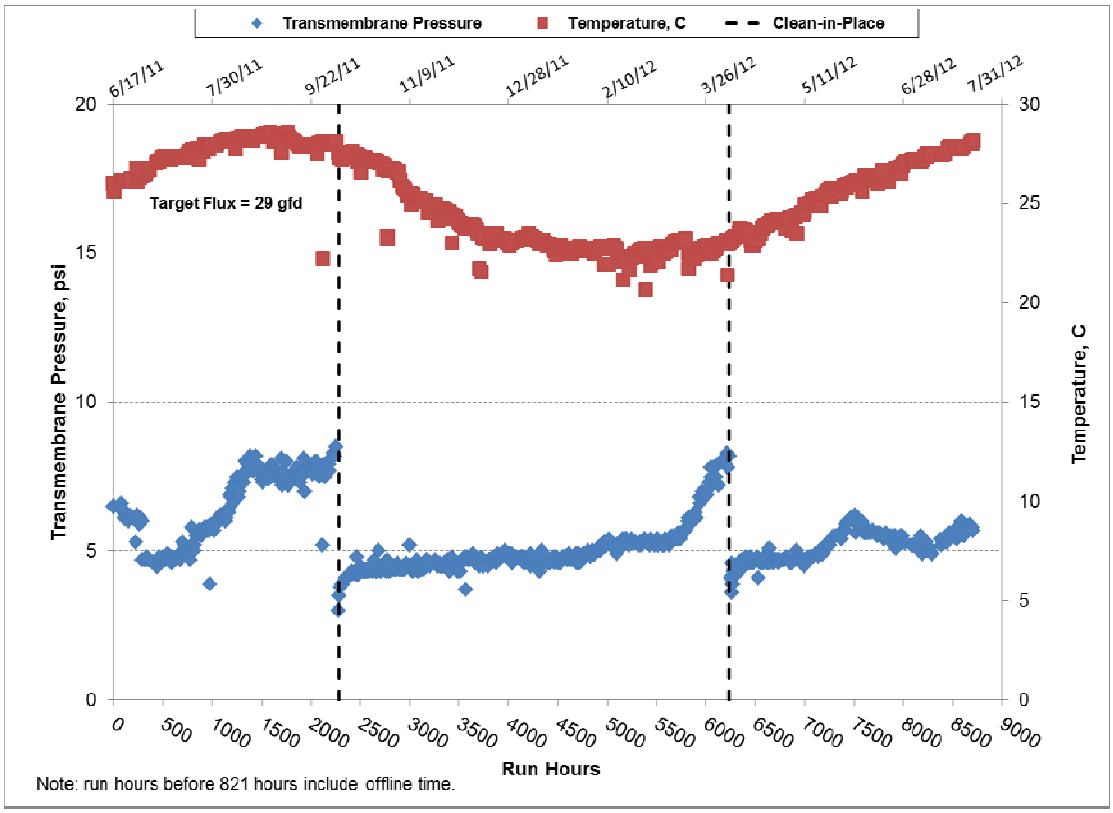


Figure 1 Pall Microfiltration System Operating Data

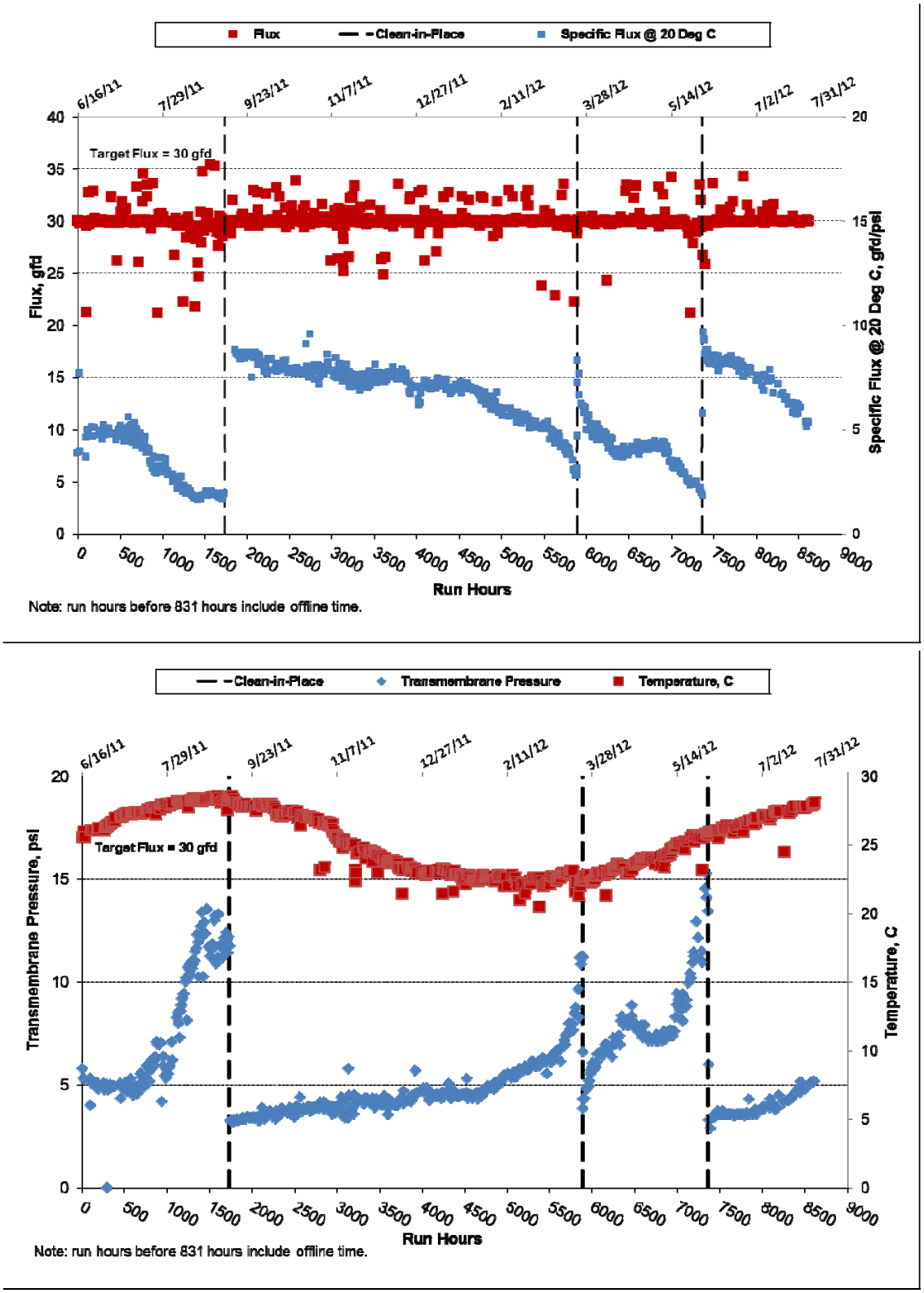
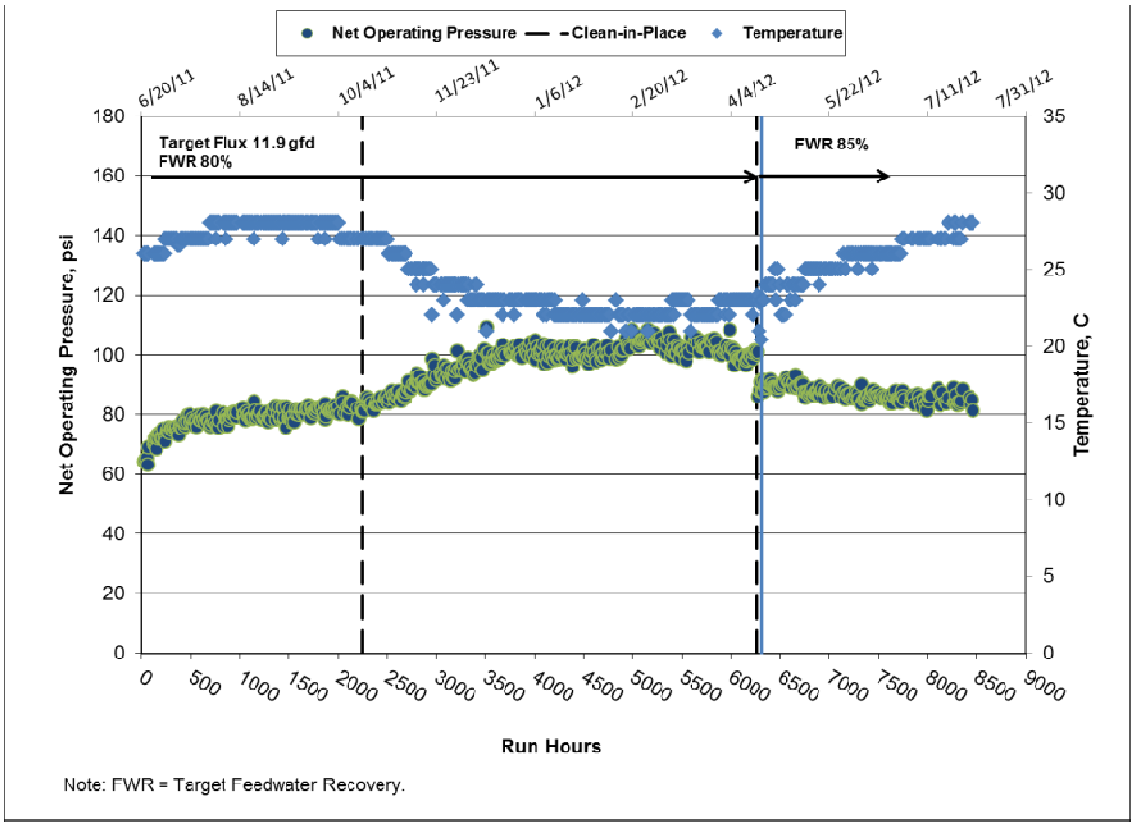


Figure 2 Toray Ultrafiltration Operating Data



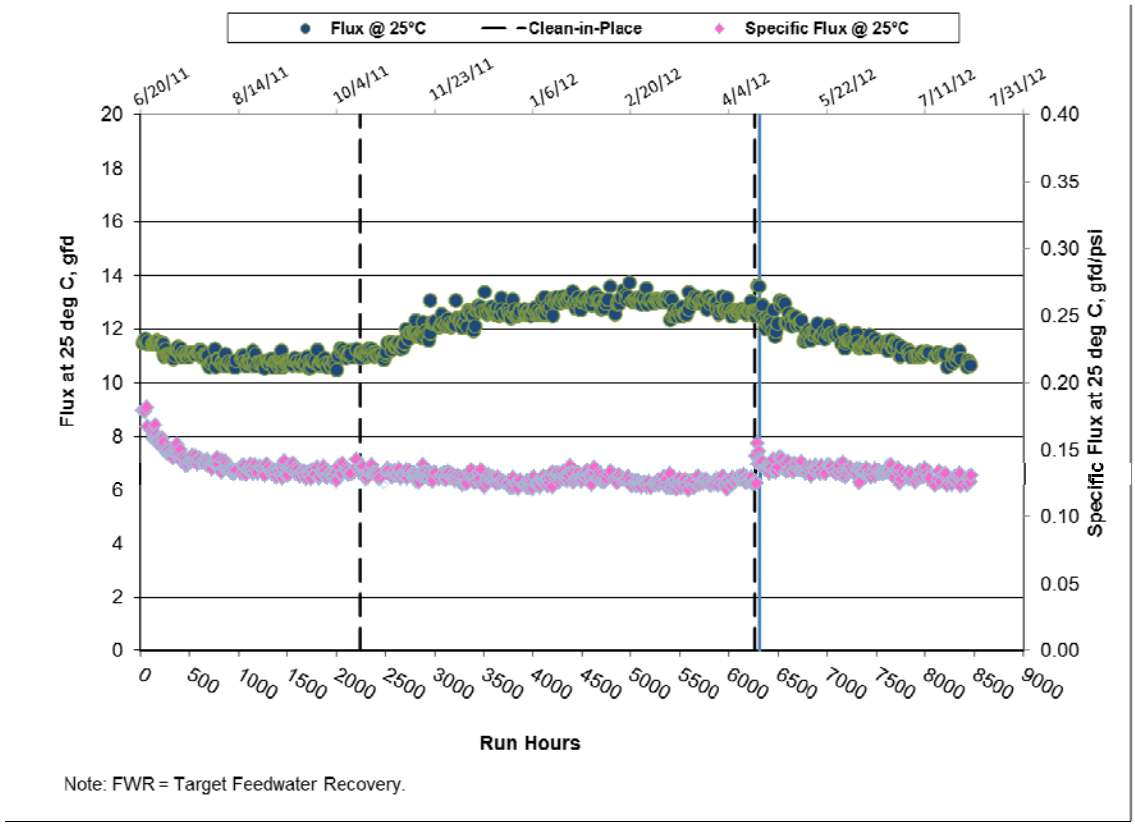


Figure 3 Membrane Performance of the Hydranautics ESPA 2 LD RO Membrane Systrem

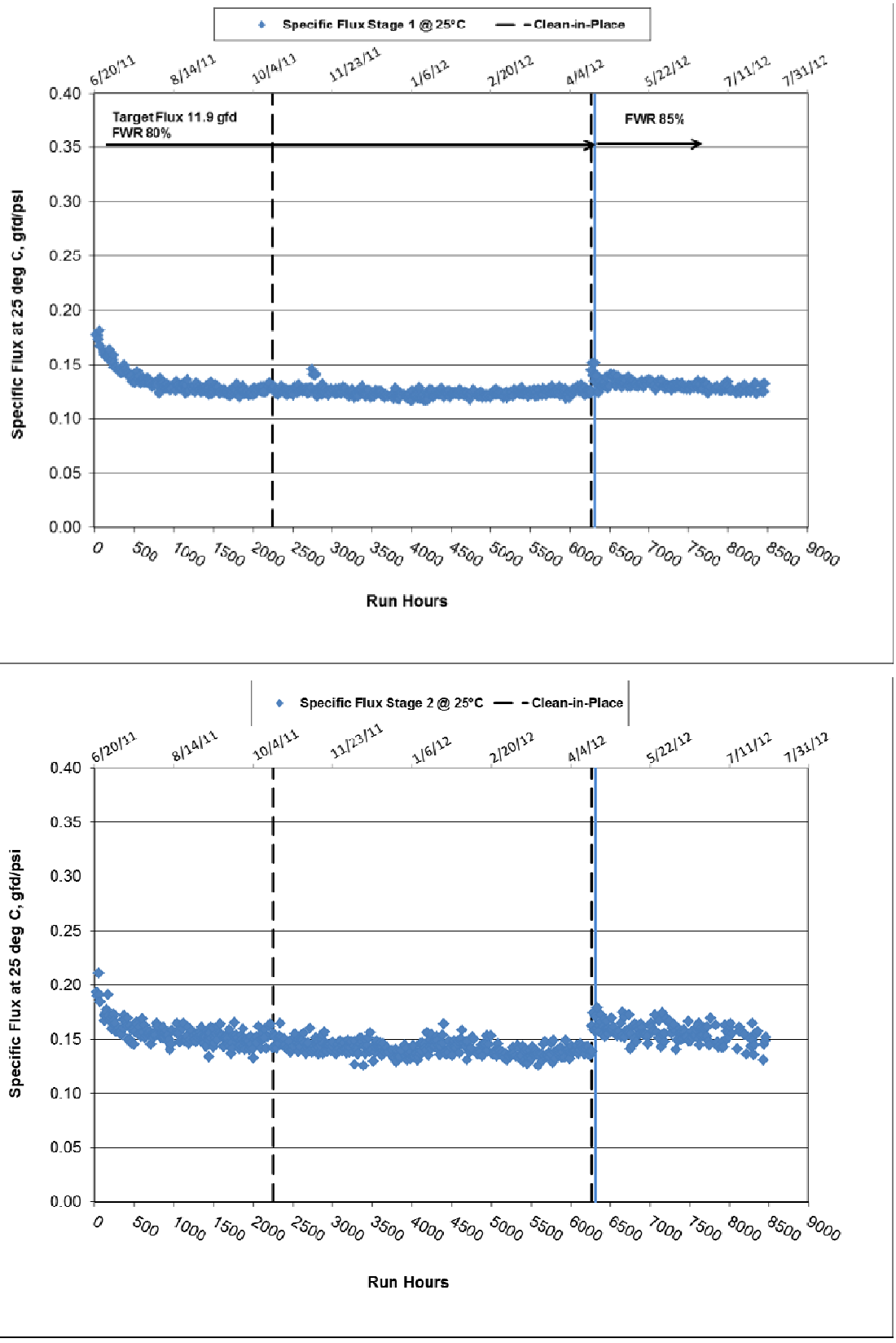


Figure 4 Comparison of Temperature Corrected Specific Flux Stage 1 (Top) and Stage 2 (Bottom) of the Hydranautics ESPA2 LD RO Membrane System

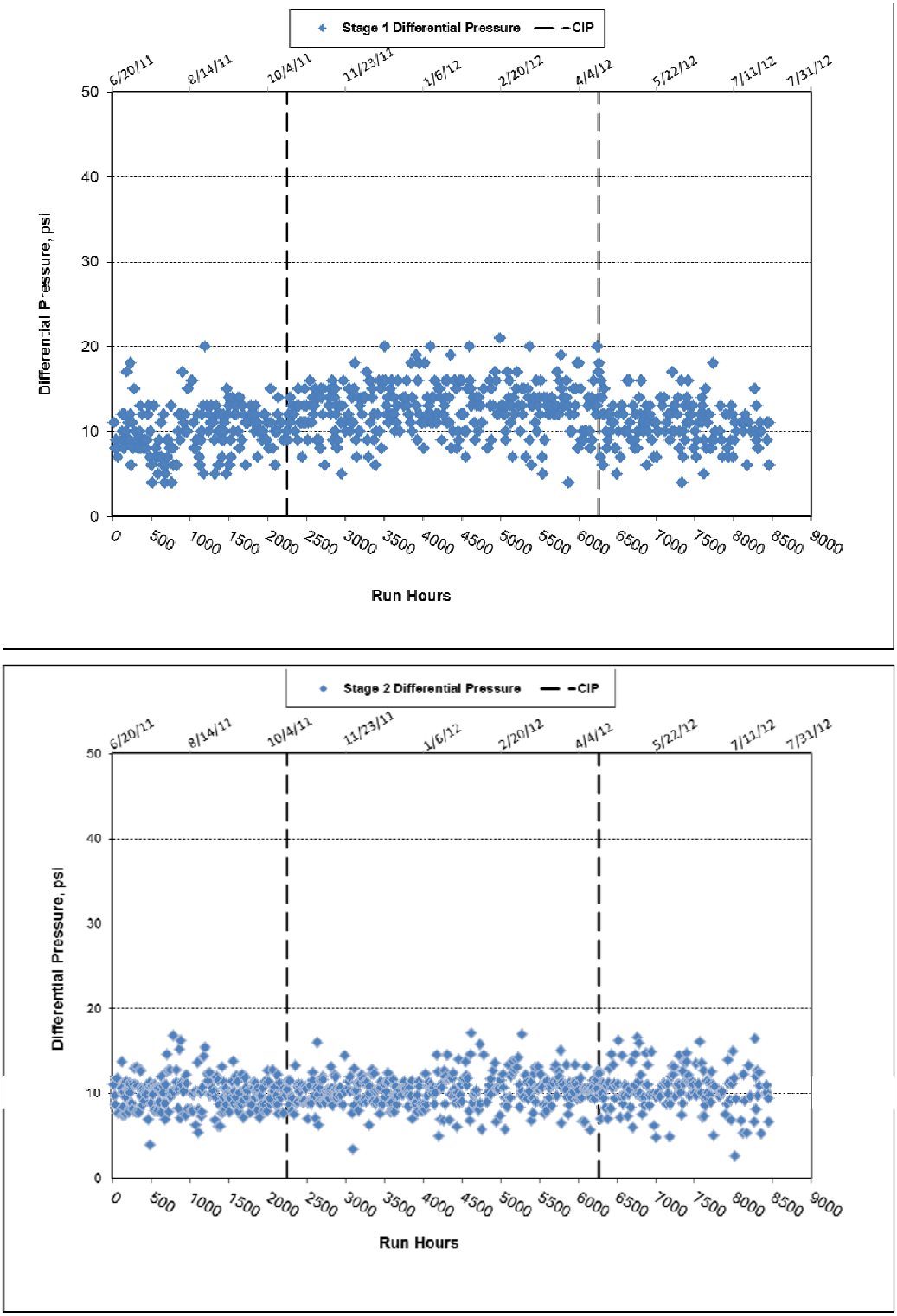


Figure 5 Differntial Pressure (DP) of the Hydranautics ESPA2 LD RO Membrane System

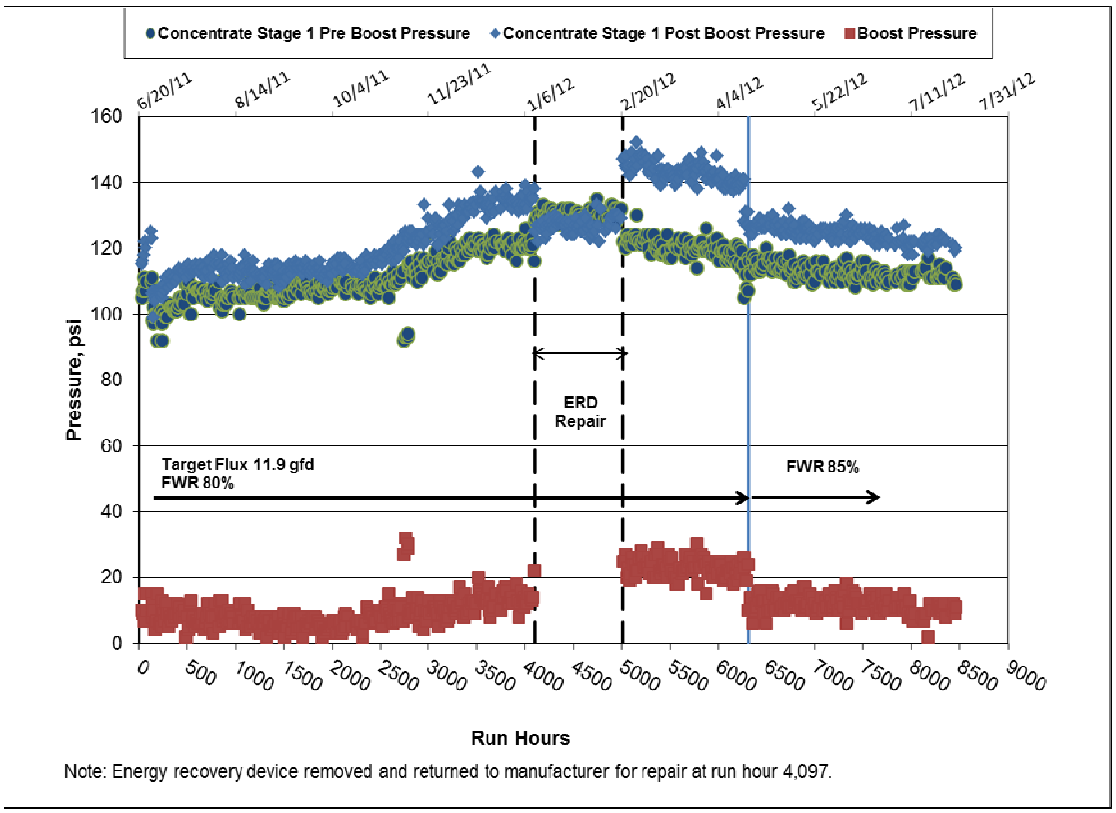


Figure 6 Energy Recovery Performance of the Hydranautics ESPA2 LD RO Membrane System

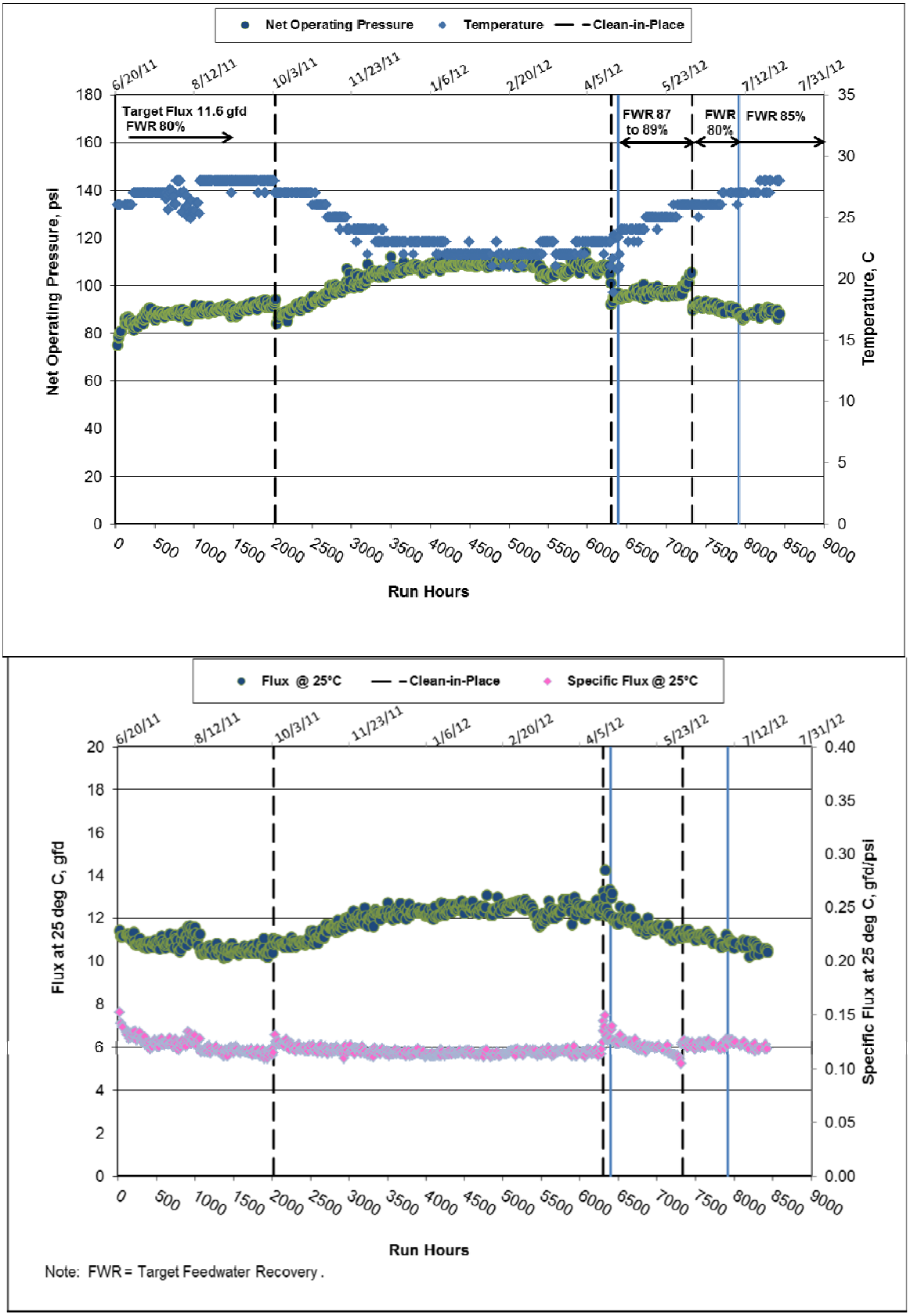


Figure 7 Membrane Performance of the Toray TML RO Membrane System

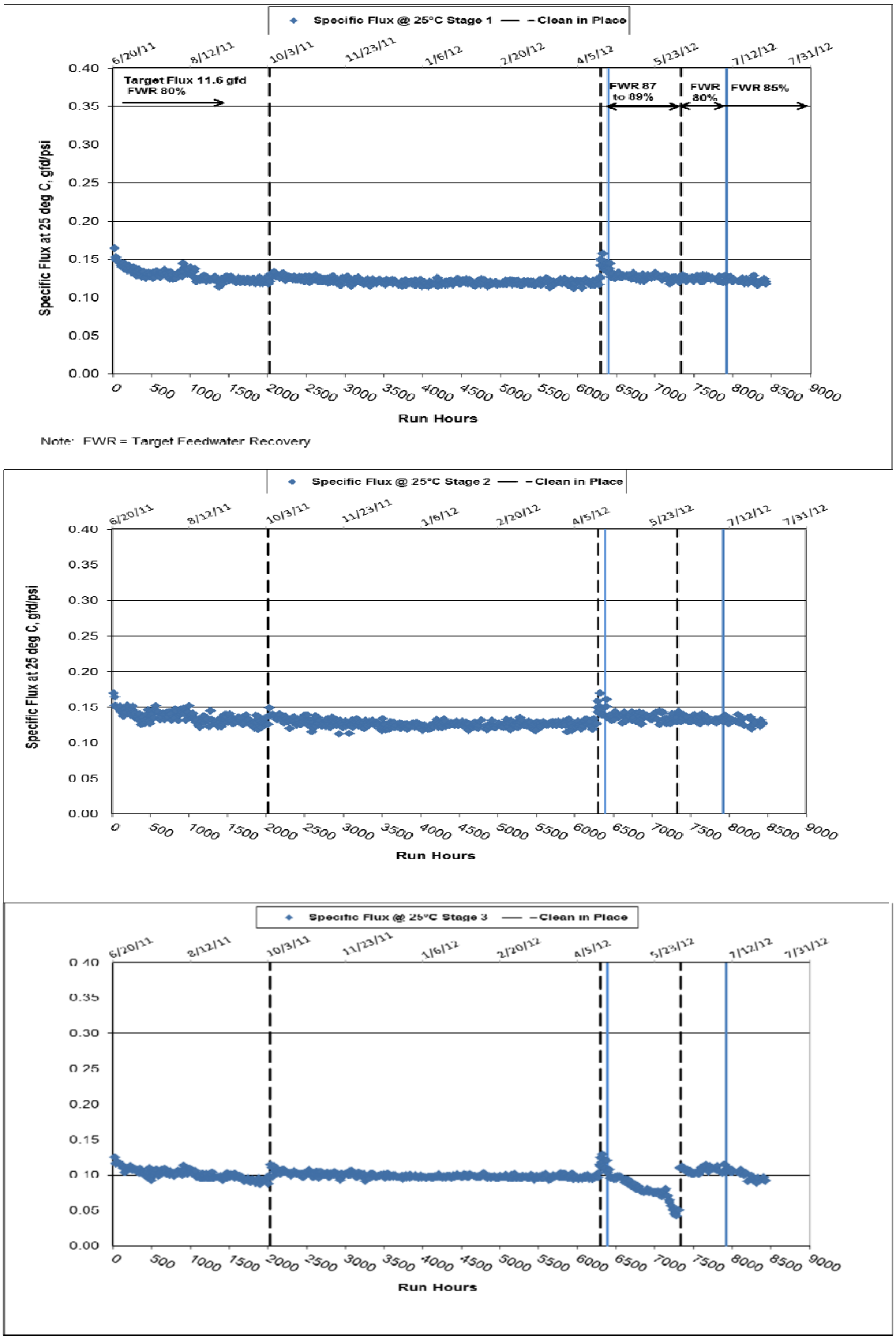


Figure 8 Comparison of Temperature Corrected Specific Flux by Stage 1 (Top), Stage 2 (Mid), Stage 3 (Bottom) of the TML RO Membrane System

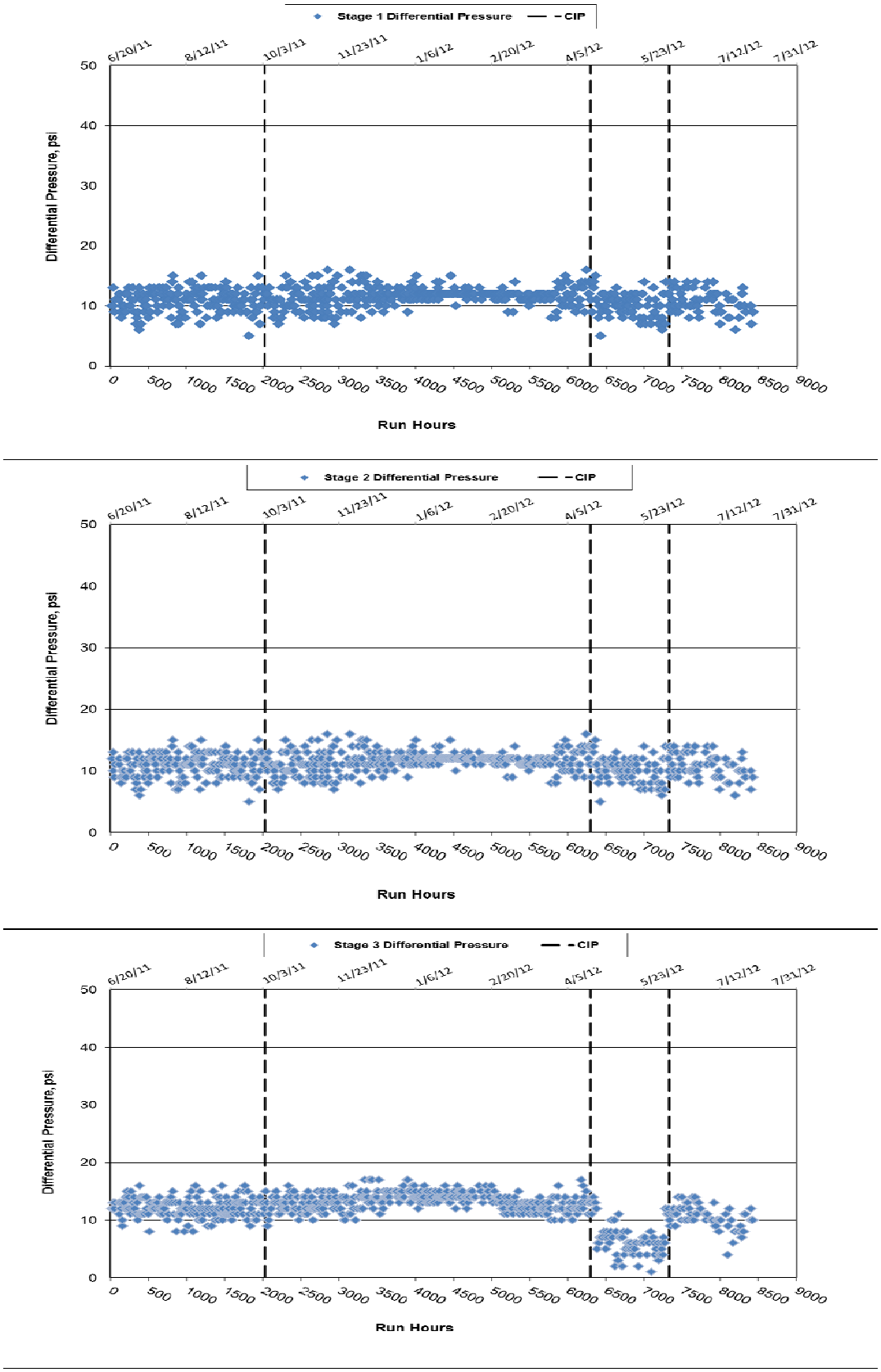


Figure 9 Differential Pressure (DP) of the Toray TML RO Membrane System

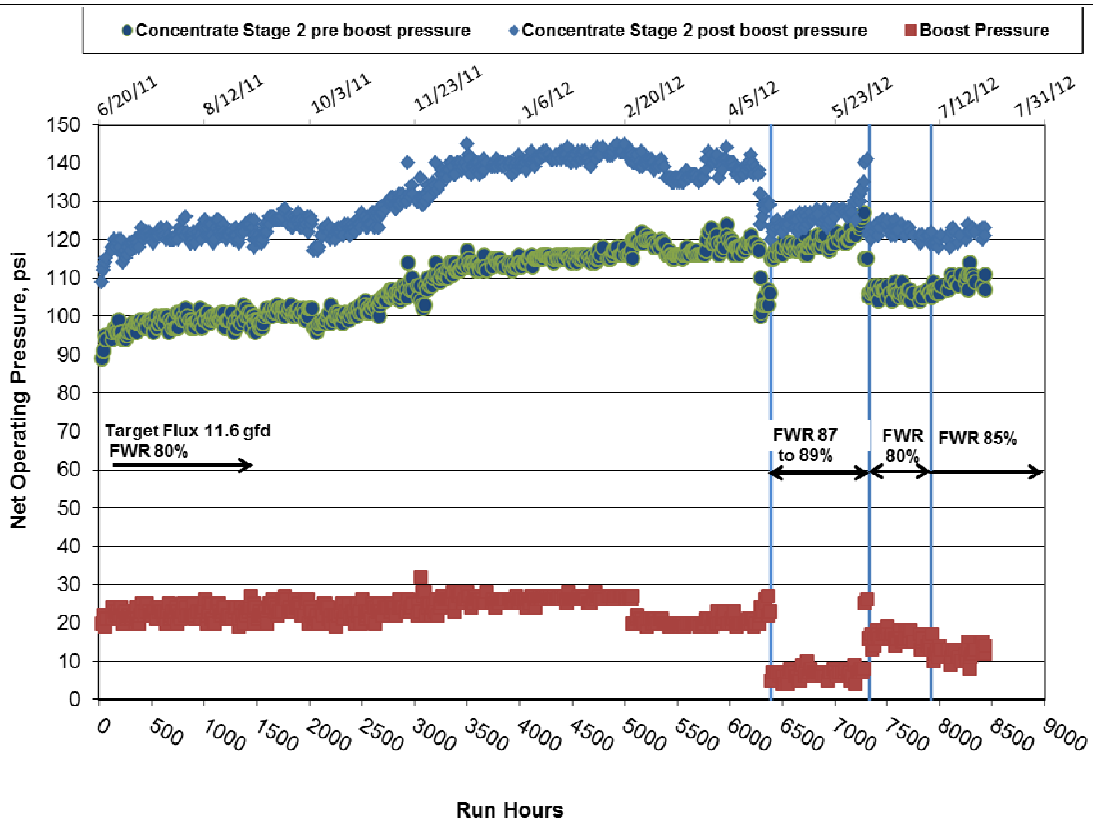


Figure 10 Energy Recovery Performance of the Toray TML RO Membrane System

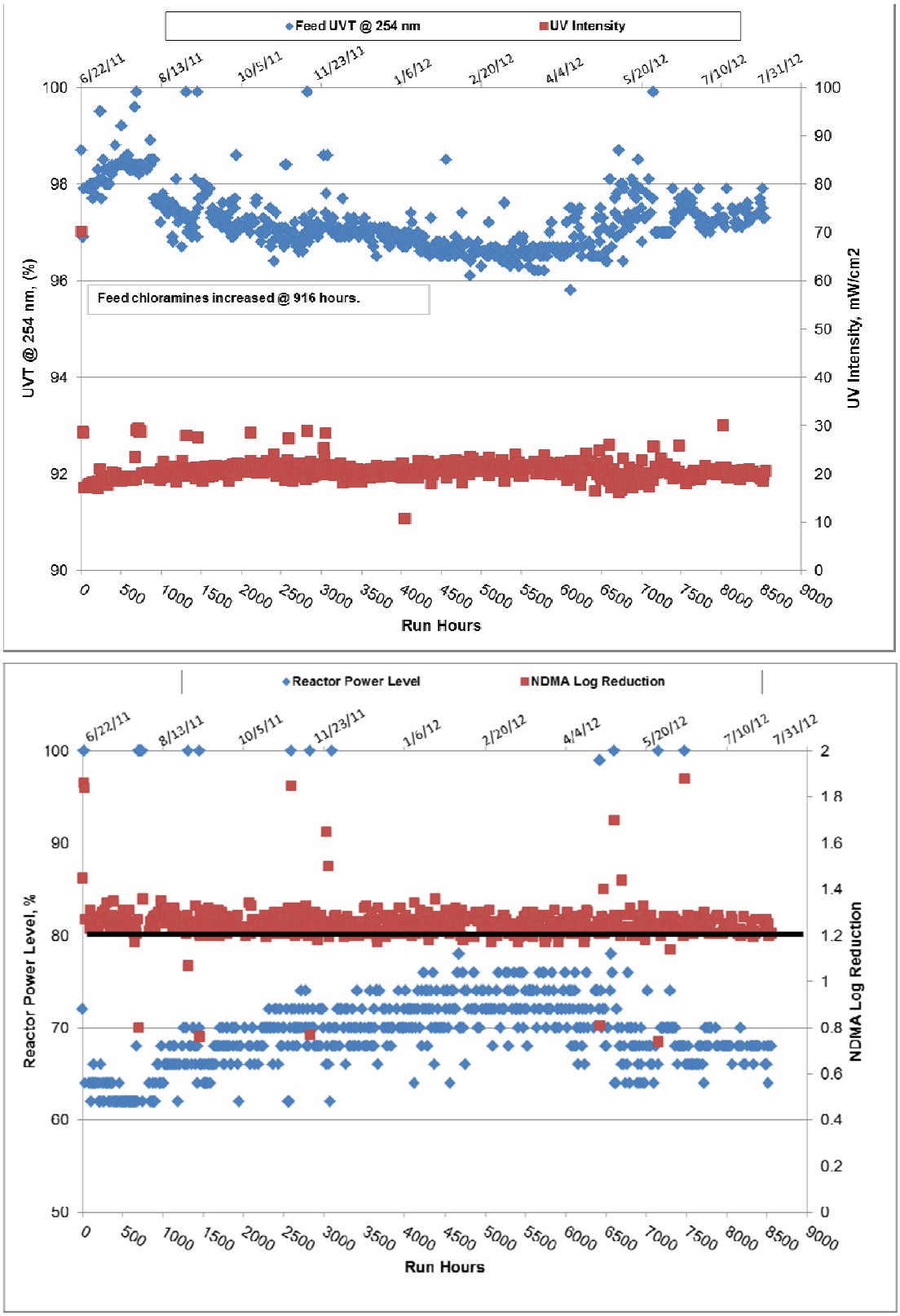


Figure 11 Trojan UV/AOP Operating Data

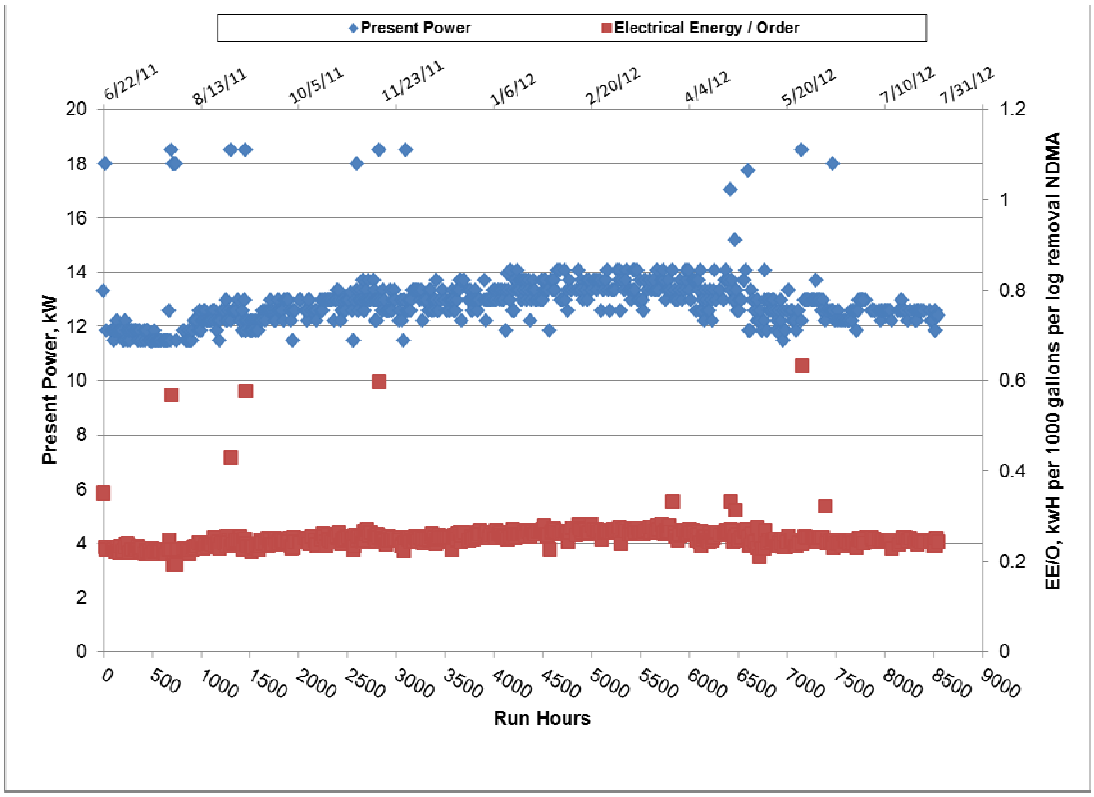


Figure 12 UV/AOP Electrical Energy per Order based on Trojan Algorithm

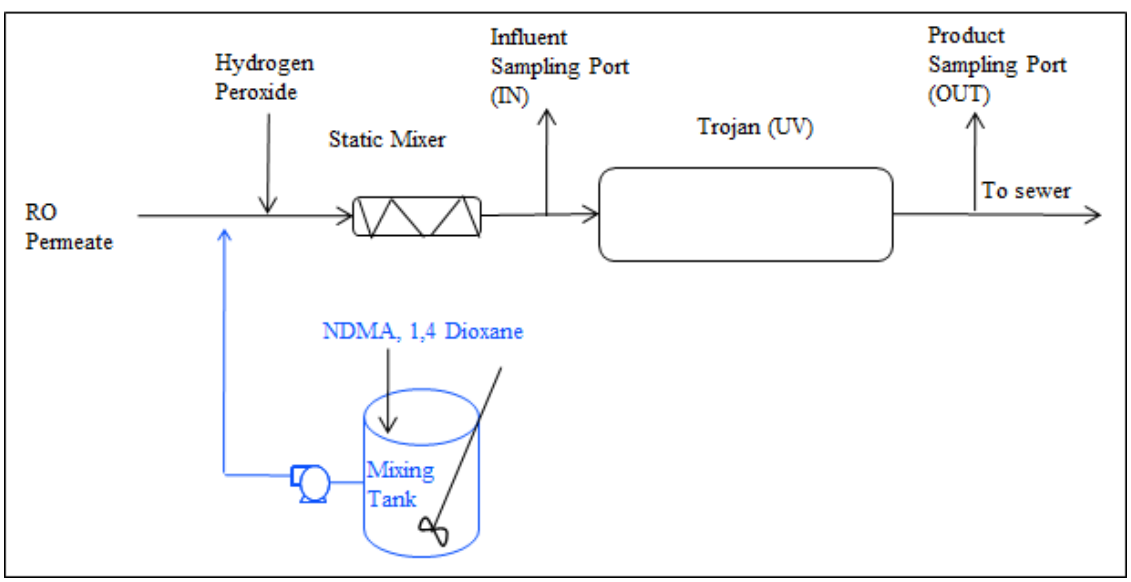
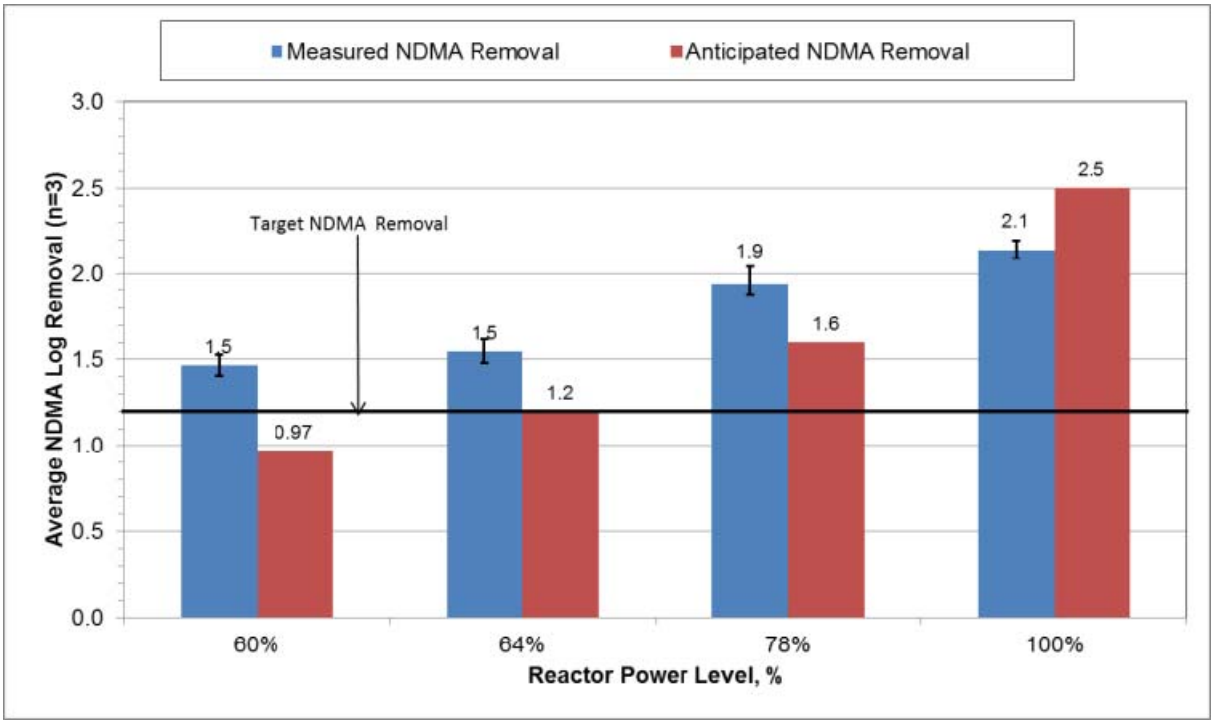
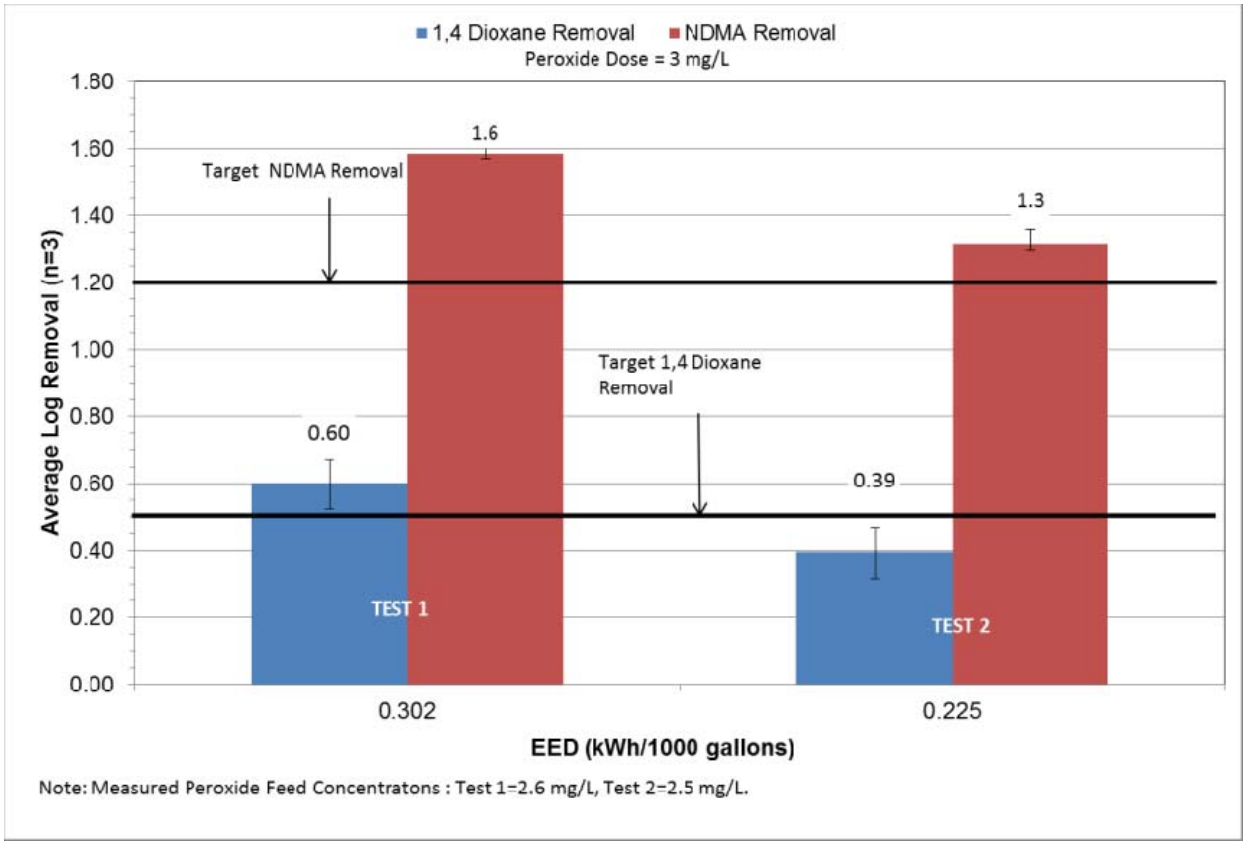


Figure 13 Spiking Experiment Set Up



Note: Log removal values were calculated as ($-LOG_{10}(OUT/IN)$) based on concentrations of IN and OUT samples provided in Table 7.

Figure 14 Trojan UV/AOP NDMA Spiking Experiment No. 1Results



Note: Log removal values were calculated as ($-LOG_{10}(OUT/IN)$) based on concentrations of IN and OUT samples provided in Table 10.

Figure 15 Trojan UV/AOP 1,4 Dioxane Spiking Experiment No. 2Results

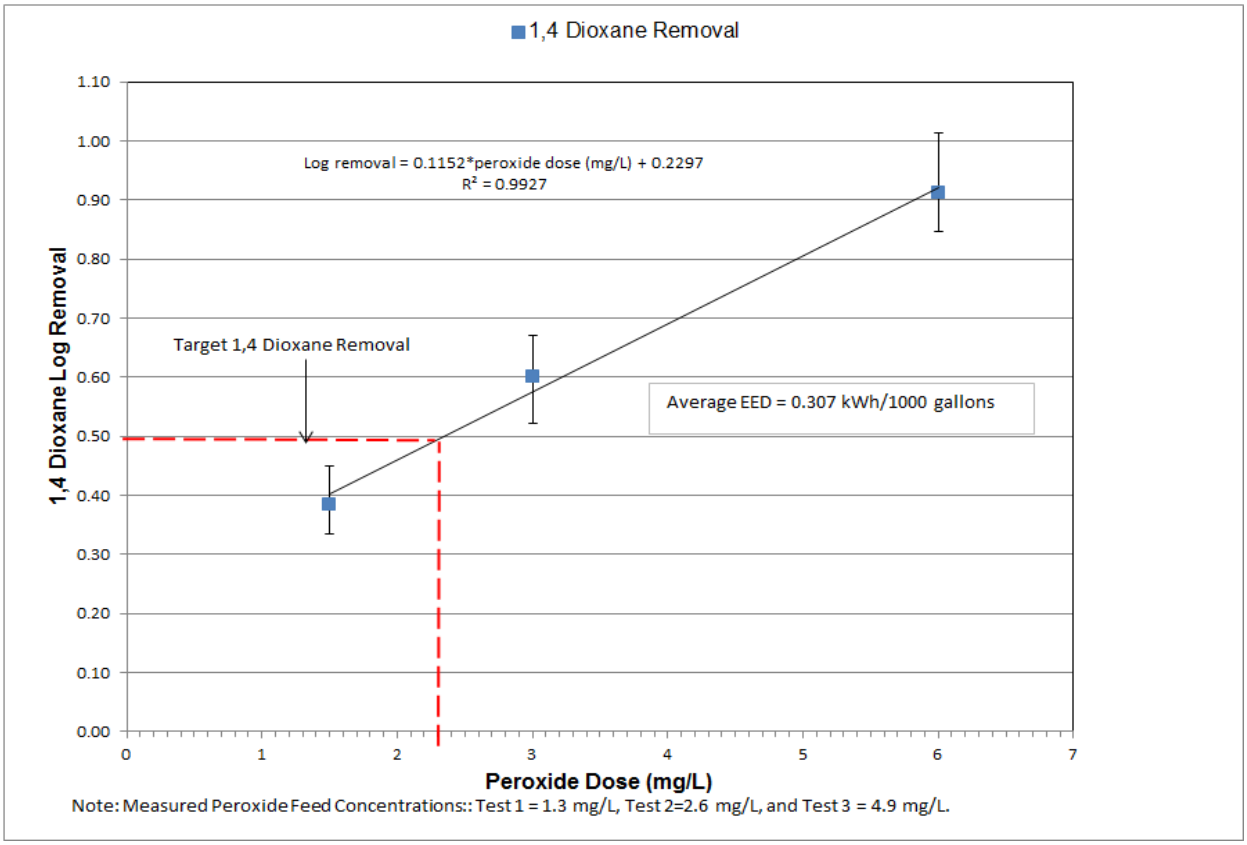


Figure 16 Trojan UV/AOP 1,4 Dioxane Spiking Experiment 2 LRV vs. Target Peroxide Dose

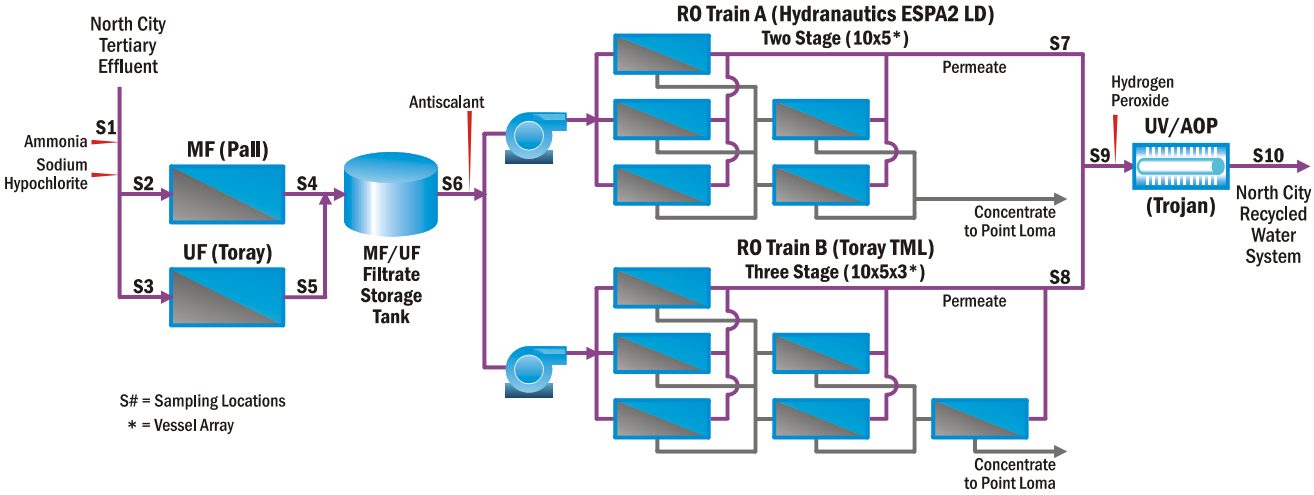


Figure 17 AWP Facility Process Schematic (S# indicates sampling location)

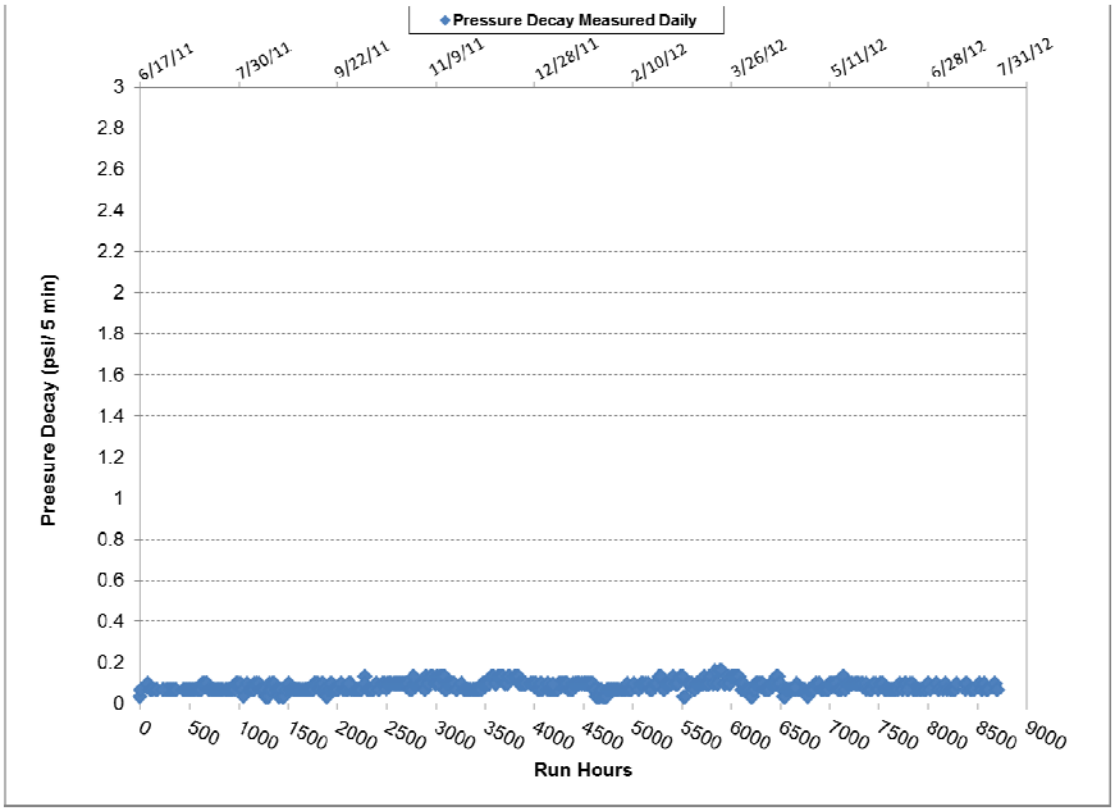


Figure 18 Pressure Decay Test (PDT) Values of the Pall Microfiltration System

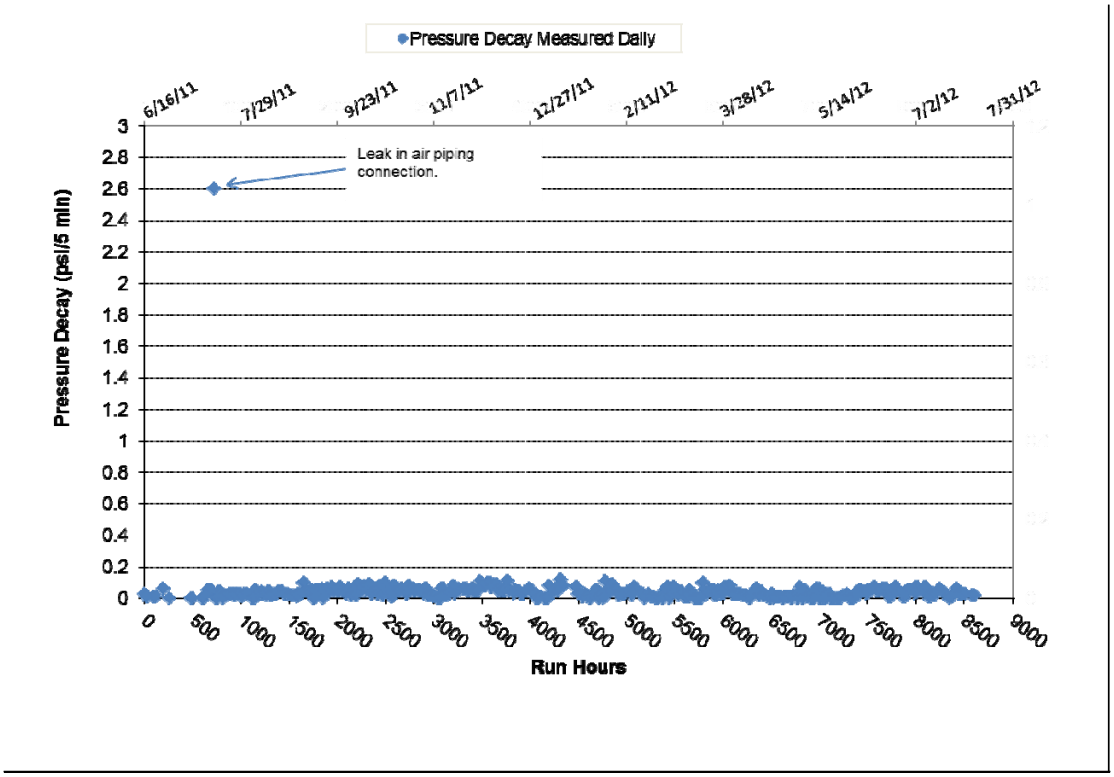


Figure 19 Pressure Decay Test (PDT) Values of the Toray Ultrafiltration System

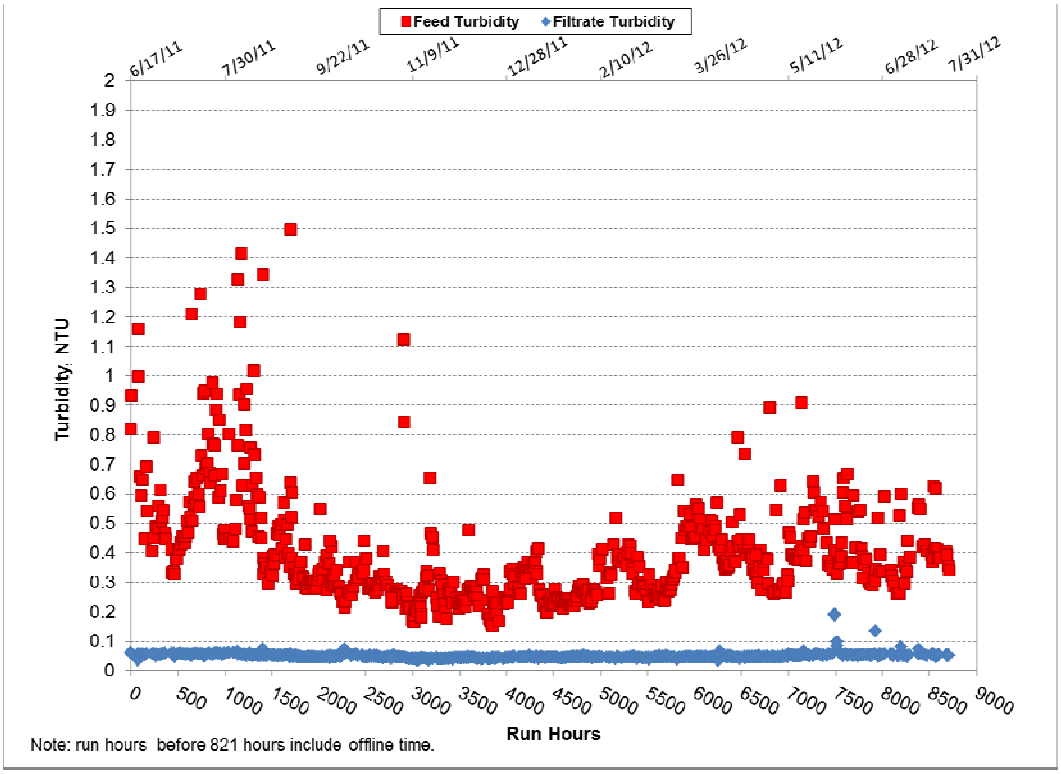


Figure 20 Turbidity Profile of the Pall Microfiltration System

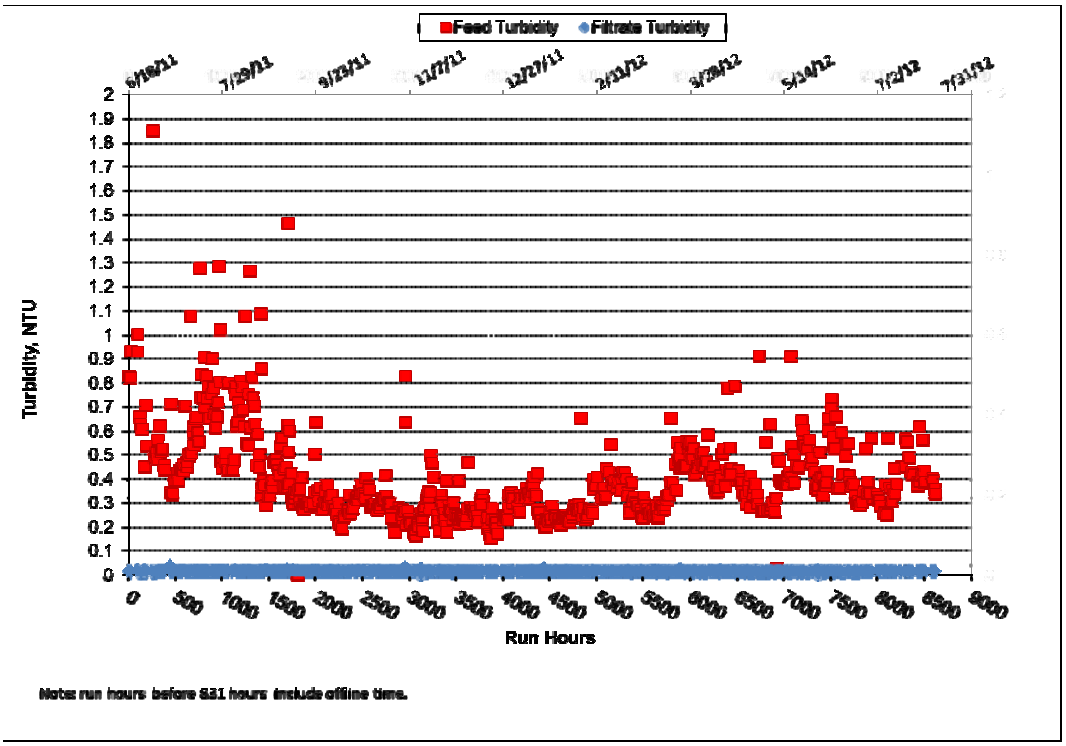


Figure 21 Turbidity Profile of the Toray Ultrafiltration System

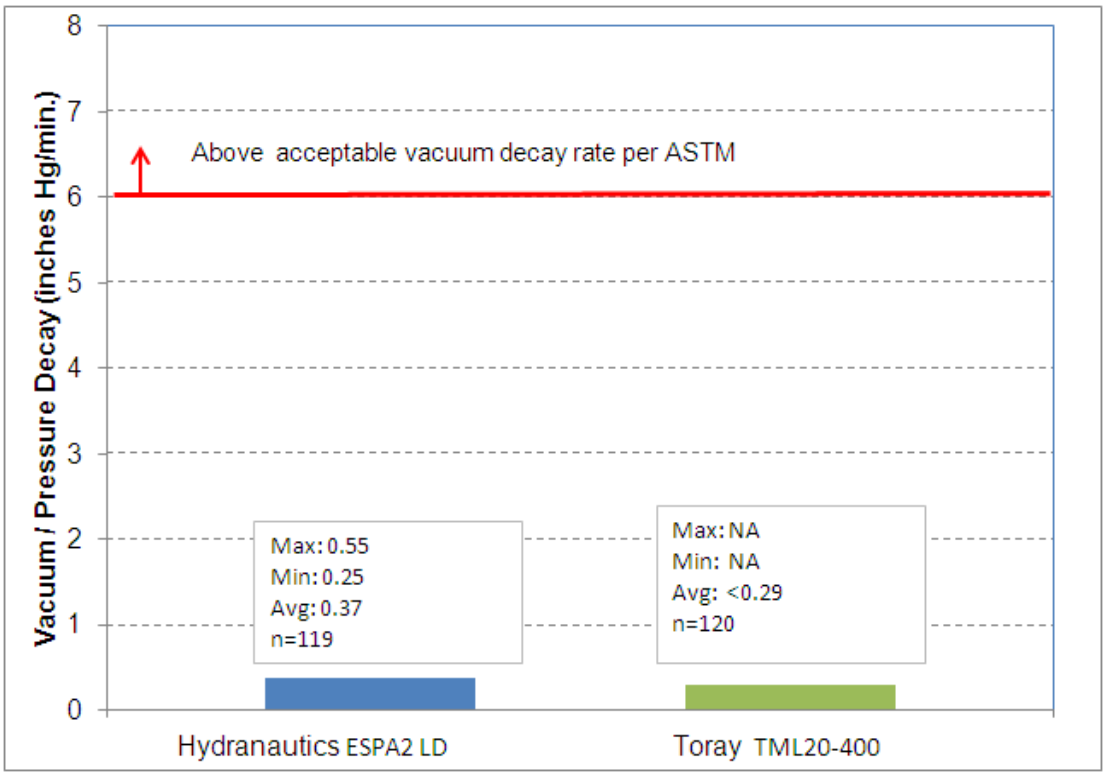


Figure 22 Pre-delivery RO Element Pressure / Vacuum Decay Test Results

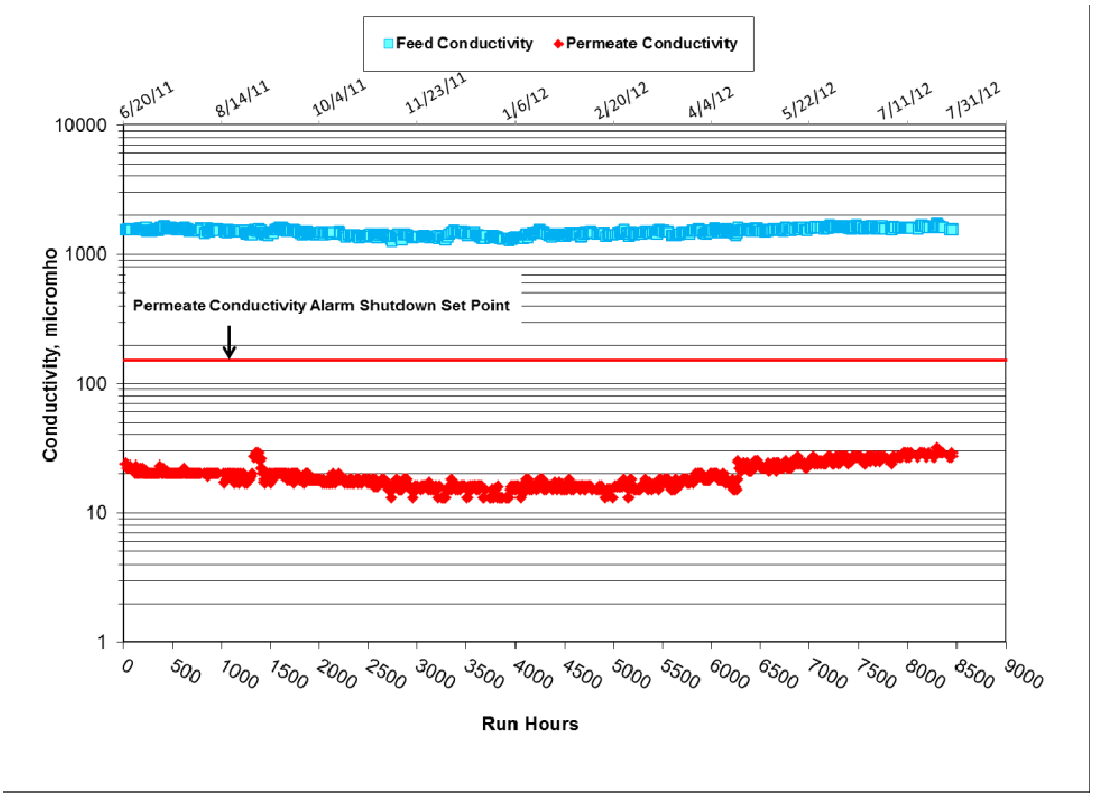


Figure 23 Conductivity Profile of the Hydranautics ESPA2 LD RO Membrane System

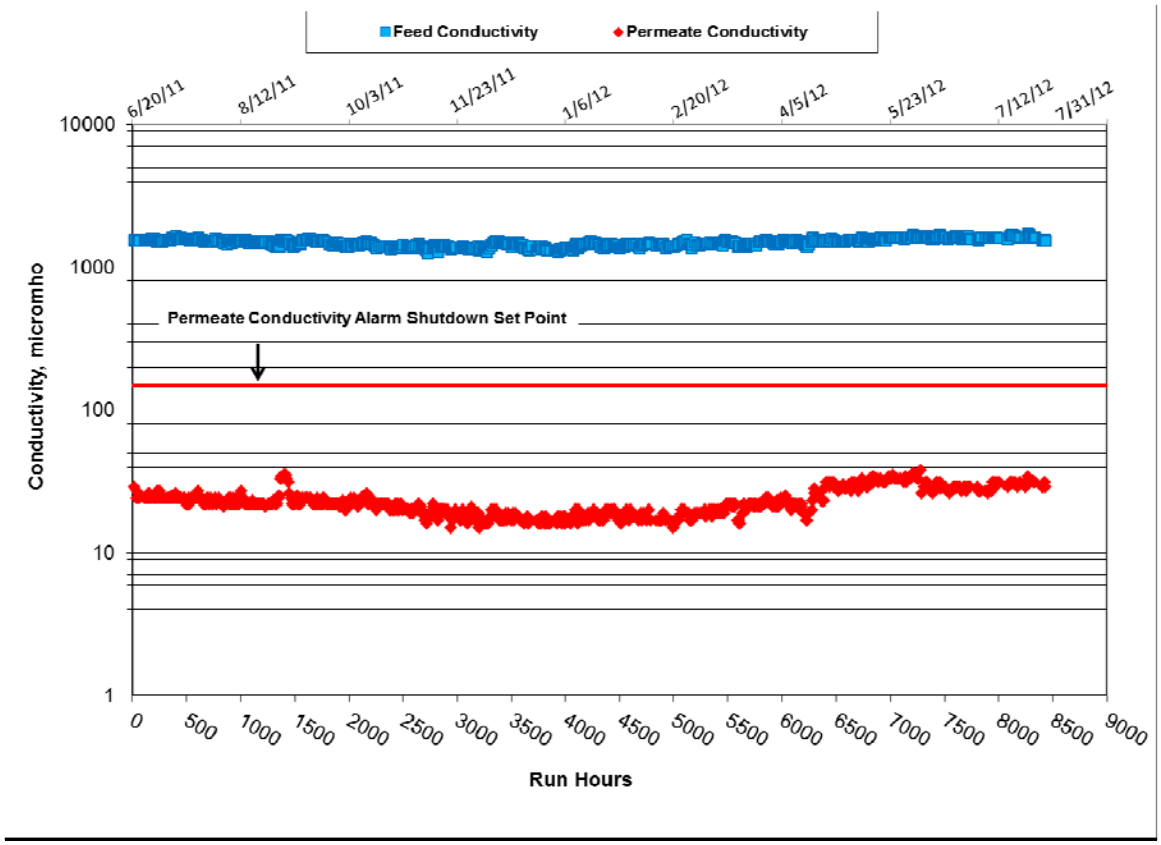


Figure 24 Conductivity Profile of the Toray TML RO Membrane System

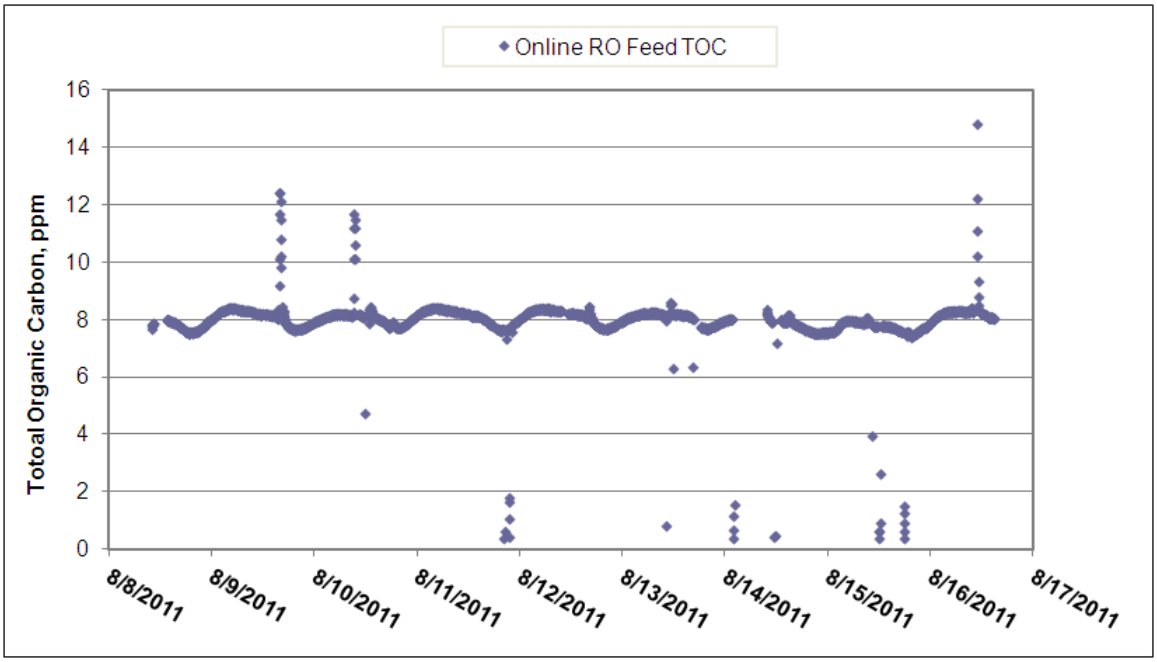


Figure 25 Online TOC Monitoring Results of RO Feed during Q1 Testing Period

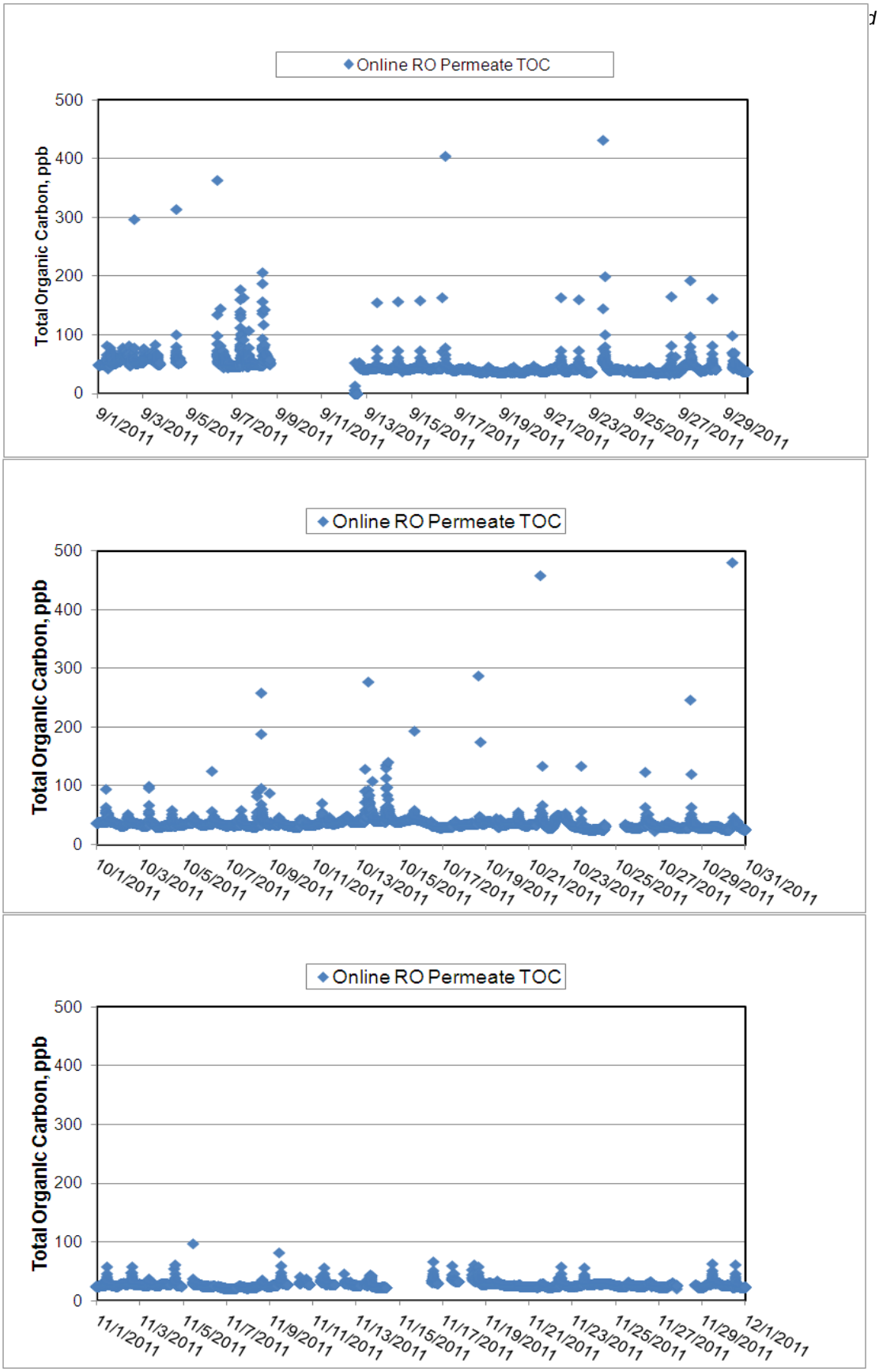
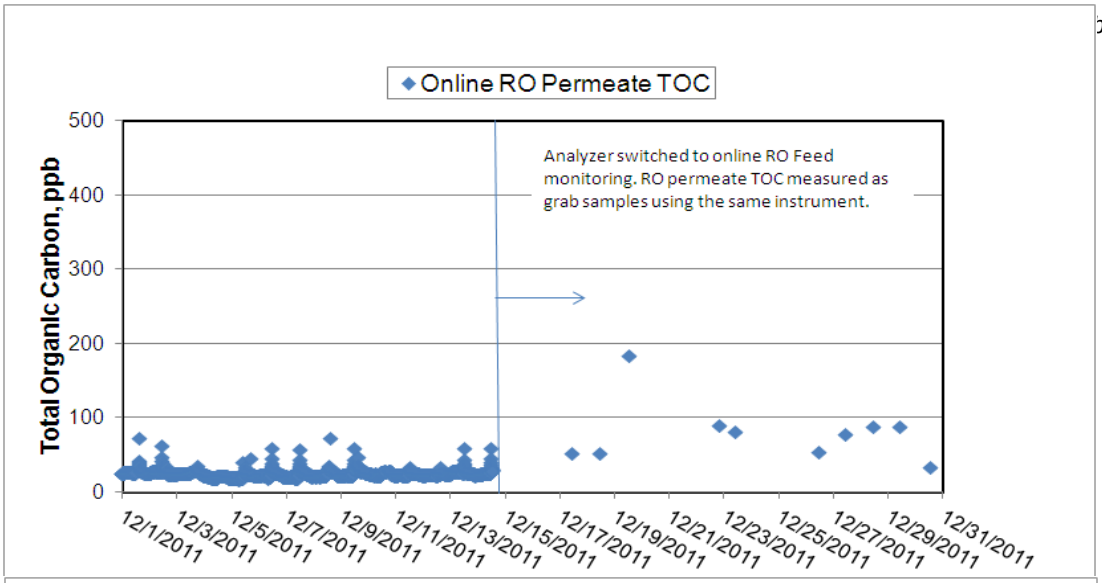
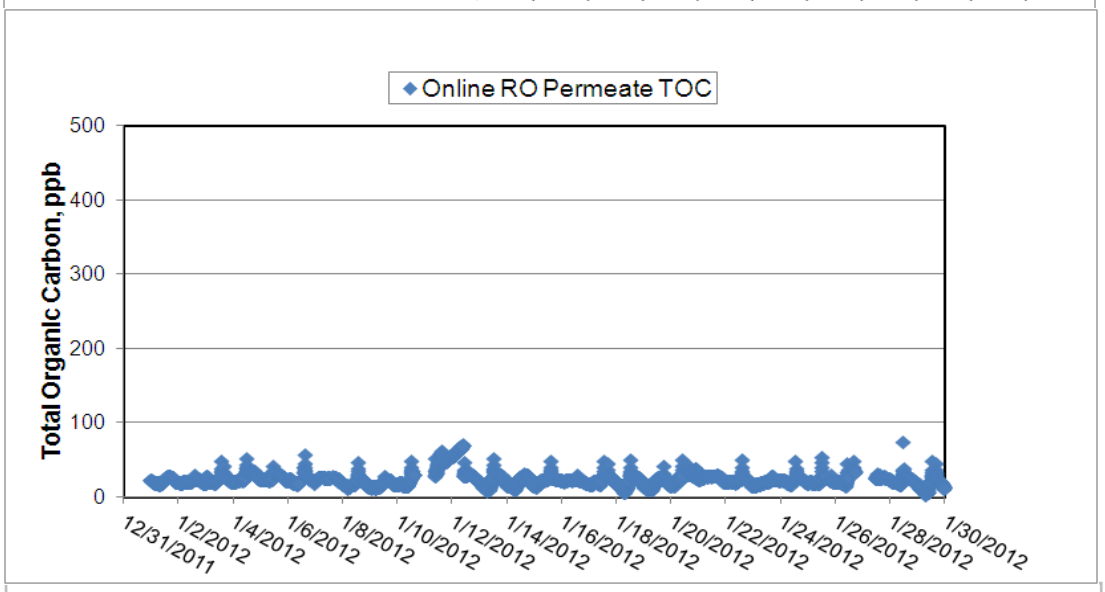


Figure 26 Online TOC Monitoring Results of RO Permeate





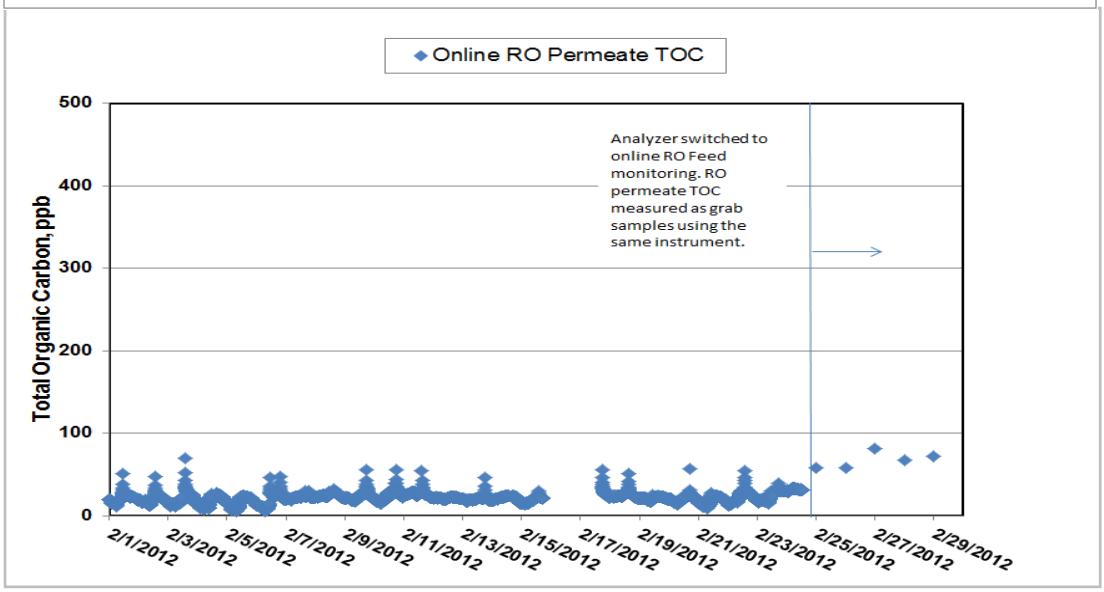


Figure 26 Online TOC Monitoring Results of RO Permeate (Cont.)

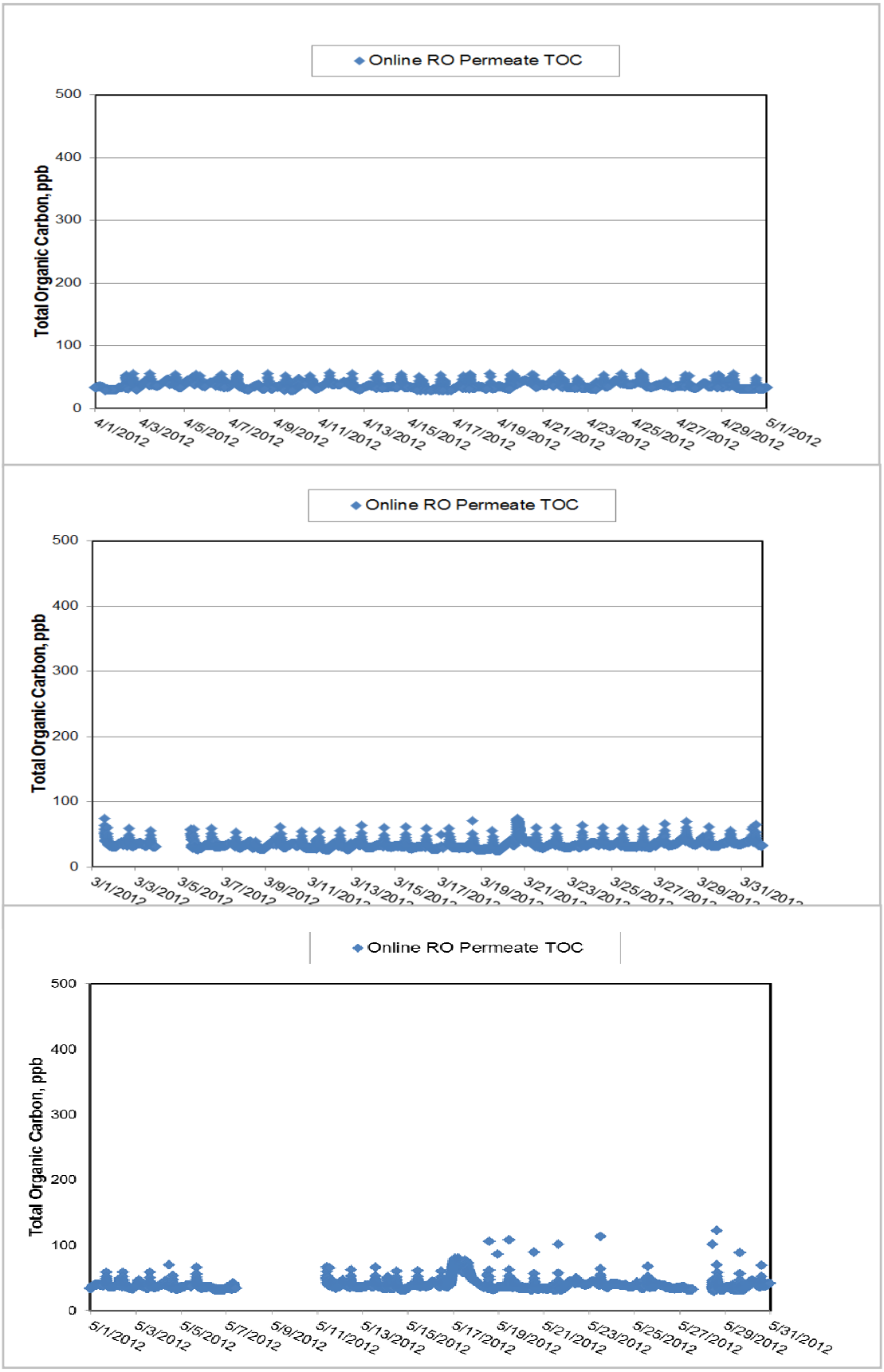
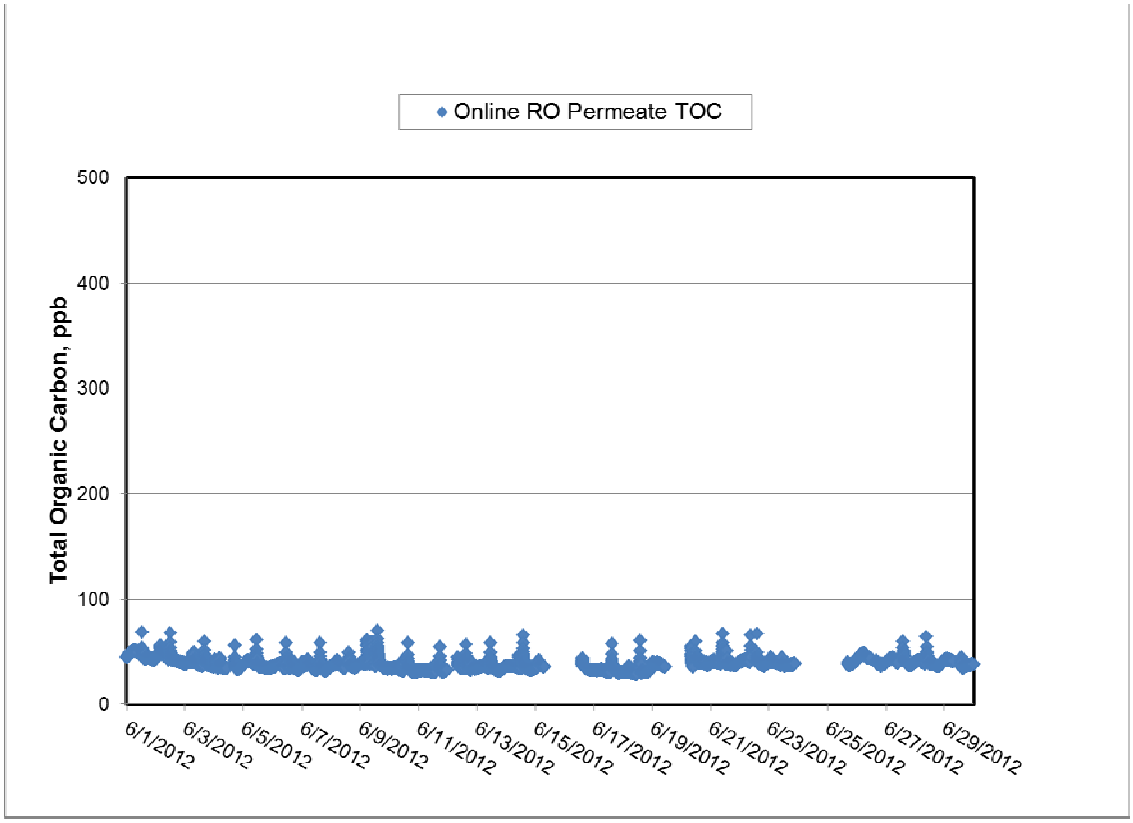


Figure 26 Online TOC Monitoring Results of RO Permeate (Cont.)



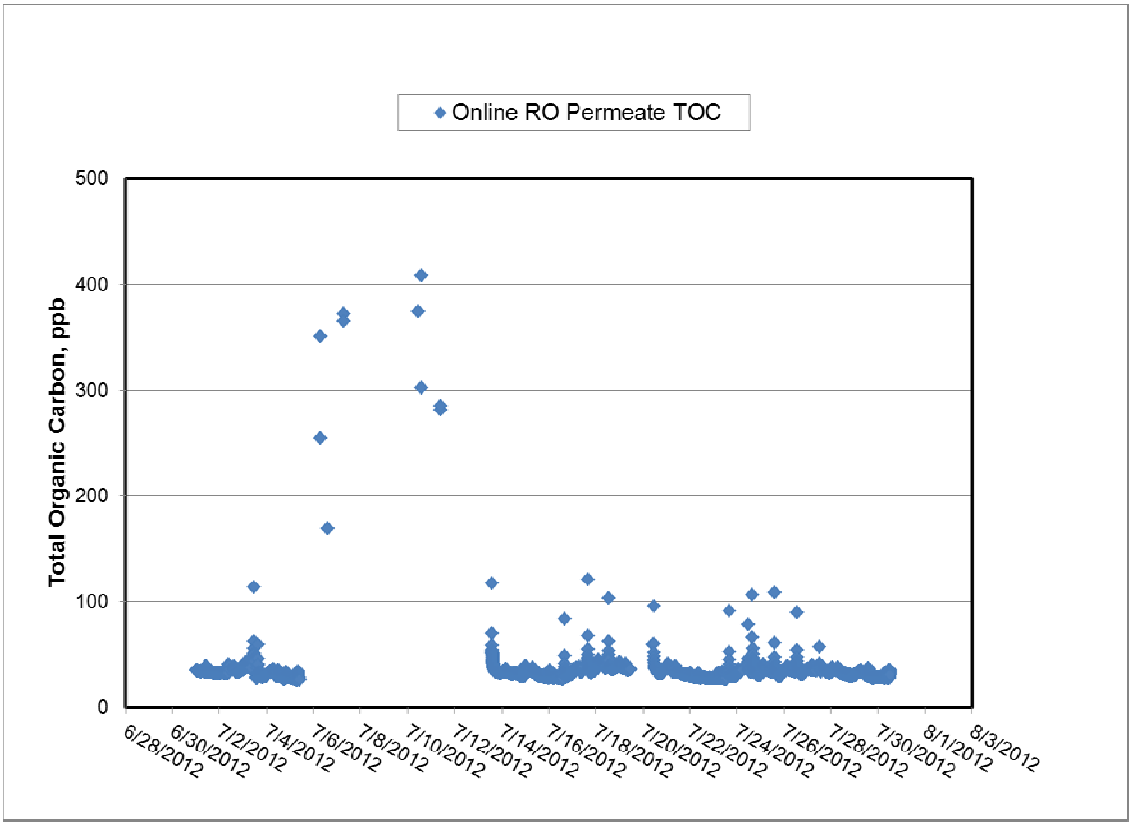


Figure 26 Online TOC Monitoring Results of RO Permeate (Cont.)

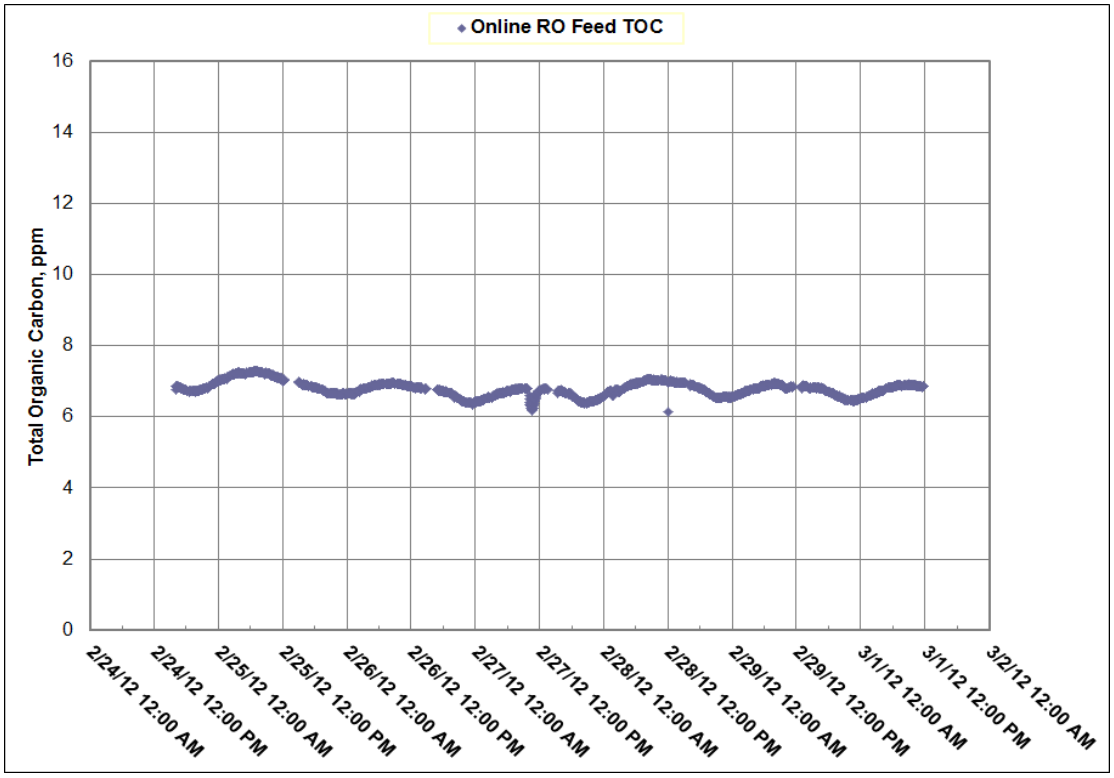


Figure 27 Online TOC Monitoring Results of RO Feed during Q3 Testing Period

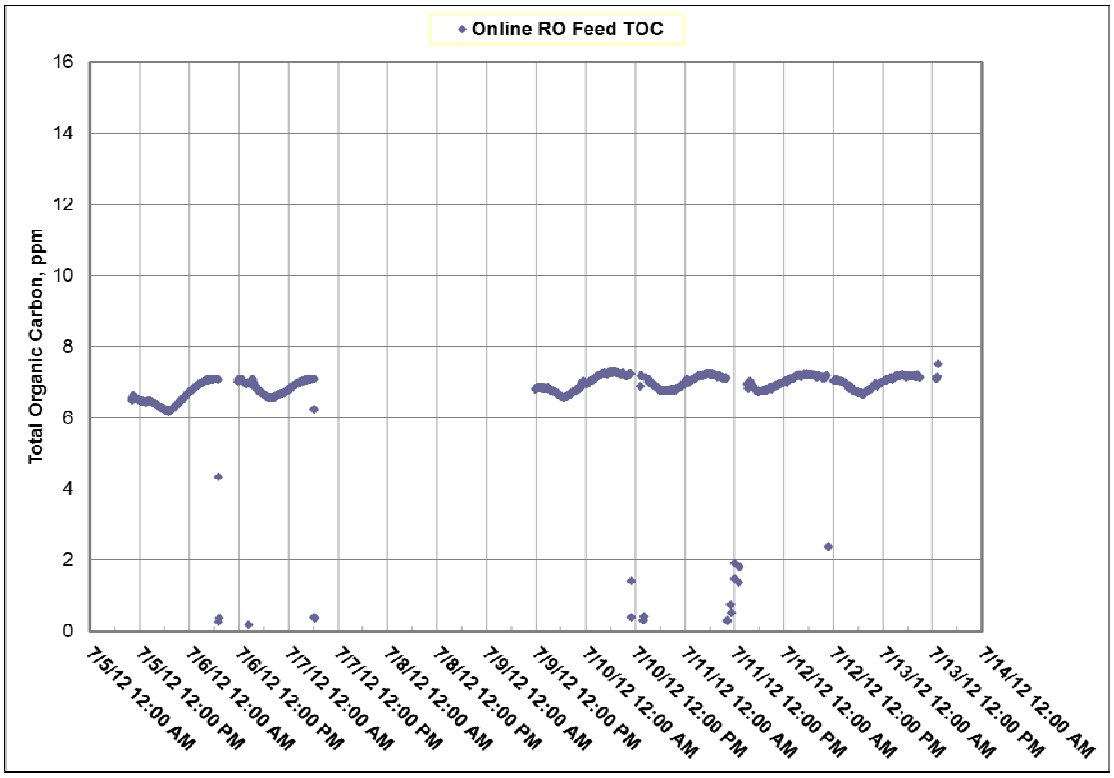


Figure 28 Online TOC Monitoring Results of RO Feed during Q4 Testing Period

Appendix A

Final Report: Toxicity Testing Results for the City of San Diego Water Purification Demonstration Project.

Nautilus Environmental

Toxicity Testing Results for the City of San Diego Water Purification Demonstration Project – Advanced Water Purification Facility (AWPF)

Monitoring Period: November 2011

Prepared for:	**MWH Americas, Inc.** **9444 Farnham Street, Ste. 300** **San Diego, CA 92117**
Test Laboratory:	**Nautilus Environmental** **4340 Vandever Avenue** **San Diego, CA 92120**
Submitted:	**December 16, 2011**

Data Quality Assurance:

- **Nautilus Environmental is a state certified laboratory under the California Department of Health Services – Environmental Laboratory Accreditation Program (ELAP), Certificate No. 1802.**
- **All test results included in this report have met internal Quality Assurance requirements, as well as all minimum acceptability criteria required by the EPA protocols. Any deviations have been noted in the report.**
- **All data have been reviewed and verified.**

Results Verified By: Steve Carlson **Date:** 12-16-11

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4340 Vandever Ave.
San Diego, CA 92120
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fax: 858-587-3961

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Burnaby, British Columbia
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fax: 604-603-9381

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Sample Information

Client:	MWH Americas, Inc.
Project Name:	City of San Diego Water Purification Demonstration Project – Advanced Water Purification Facility (AWPF)
Sample Collection Dates:	11/14/11, 07:20; 11/16/11, 08:50; and 11/18/11, 07:19
Sample Receipt Dates:	11/14/11, 10:55; 11/16/11, 09:25; and 11/18/11, 09:00
Sample/Test Material:	UV/advanced oxidized product (UV/AOP) water
Aqueduct/Dilution Water:	Grab sample from Lake Murray water
Sample Mixture:	The UV/AOP water was mixed with the aqueduct water to achieve a hardness of 50 mg/L. This mixture ended up being a ratio of 67% UV/AOP and 33% Aqueduct. This mixture represented the 100% sample tested.
Sample Treatment:	Prior to testing, the pH of the sample mixture was raised to approximately 8.5 by adding Sodium Hydroxide (NaOH). Then, Sodium Thiosulfate (STS) was added to remove any residual chlorine or peroxide.
Sample Receipt WQ Parameters:	Summarized in Table 1 (see Appendix C for details).
Mixture/Treatment Process:	Summarized in Table 2 (see Appendix C for details).

Table 1. Water Quality Parameters Measured upon Sample Receipt

WQ Parameters	Lake Murray Aqueduct	Sample A (11/14/11)	Sample B (11/16/11)	Sample C (11/18/11)
Nautilus Log No.	11-0952	11-0951	11-0960	11-0976
Receipt Temperature (°C)	13.8	13.5	20.6	15.6
Dissolved Oxygen (mg/L)	9.3	9.8	6.5	8.9
pH	8.00	5.68	5.61	5.27
Conductivity (µS/cm)	684	19	20	23
Alkalinity (mg/L $CaCO_3$)	95	<1	3	3
Hardness (mg/L $CaCO_3$)	170	<1	1	7
Total Chlorine (mg/L)*	0.06	0.57	0.70	0.53

* Total chlorine was measured with a HACH colorimetric meter. Therefore, readings could have picked up peroxide or other interferences, in addition to true chlorine measurements. Information provided by the client suggests that each of the A, B, and C samples contained approximately 3.0 mg/L peroxide.

Table 2. Mixture and Sample Treatment WQ Measurements

Mixing & WQ Parameters	Sample A (10/31/11)	Sample B (11/2/11)	Sample C (11/4/11)
Mixture Percentage of Aqueduct Water	33%	33%	33%
Mixture Percentage of UV/AOP Water	67%	67%	67%
Final Hardness of Mixture (mg/L)	51	52	53
Initial pH of Mixture	7.07	7.04	7.12
Final pH (after adjusting with NaOH)	8.48	8.40	8.47
Dissolved Oxygen (mg/L)	8.9	9.0	8.7
Conductivity (µS/cm)	302	294	283
Alkalinity (mg/L)	39	38	43
Total Dissolved Solids (mg/L)	145	141	131
Initial Free Chlorine (mg/L)	0.18	0.04	0.14
Final Free Chlorine (after treating with STS)*	0.02	0.02	0.03

* The STS added to the sample should have removed any residual chlorine or peroxide.

All Test Procedures

Test Concentrations:	Sample Water, Lab Control, and Reference Control
Sample Water:	Final mixture of UV/AOP water (67%) + Aqueduct water (33%)
Lab Control Water:	EPA moderately hard mineral water (20% diluted)
Reference Control Water:	Deionized water (67%) mixed with Aqueduct water (33%)
Protocols Used:	EPA/821/R-02/013 (2002) Chronic Manual EPA/821/R-02/012 (2002) Acute Manual
Statistical Analysis Software:	CETIS, version 1.8.0.12

Chronic Water Flea Test Specifications

Test Start Date, Time:	11/15/11, 15:25
Test End Date, Time:	11/22/11, 14:45
Test Organism:	*Ceriodaphnia dubia* (water flea)
Test Organism Source; Age:	In-house culture; < 24 hr
Test Acceptability Criteria:	Mean control survival ≥ 80%; mean number of offspring ≥ 15 per surviving adult female; and 60% or more of the surviving control females must produce three broods.

Chronic Larval Fish Test Specifications

Test Start Date, Time:	11/15/11, 15:25
Test End Date, Time:	11/22/11, 15:15
Test Organism:	*Pimephales promelas* (fathead minnow)
Test Organism Source; Age:	Aquatic Biosystems (Fort Collins, CO); 1 day
Test Acceptability Criteria:	Mean control survival ≥ 80% Mean control biomass ≥ 0.25 mg

Chronic Green Algae Test Specifications

Test Start Date, Time:	11/17/11, 16:35
Test End Date, Time:	11/21/11, 14:50
Test Organism:	*Selenastrum capricornutum* (green algae)
Test Organism Source; Age:	In-house Culture; 7 days old
Nutrient Addition:	A macro- and micronutrient solution was added to all sample concentrations to ensure any observed decreases in algal growth was due to toxic constituents present in the sample rather than a nutrient deficiency.
Sample Filtering:	The sample was 0.45- µm filtered prior to testing, per protocol. This is done to remove any native algae that might compete for lighting and nutrients. The unfiltered sample is also tested concurrently for comparison purposes.
Test Acceptability Criteria:	Mean control density of ≥ 1×10^6 cells/ml, and ≤ 20% variability among control replicates (CV)

Acute Water Flea Test Specifications

Test Start Date, Time:	11/15/11, 15:20
Test End Date, Time:	11/19/11, 13:45
Test Organism:	*Ceriodaphnia dubia* (water flea)
Test Organism Source; Age:	In-house culture; < 24 hr
Test Acceptability Criteria:	Mean control survival ≥ 90%

Acute Larval Fish Test Specifications

Test Start Date, Time:	11/15/11, 15:20
Test End Date, Time:	11/19/11, 14:00
Test Organism:	*Pimephales promelas* (fathead minnow)
Test Organism Source; Age:	Aquatic Biosystems (Fort Collins, CO); 10 days old
Test Acceptability Criteria:	Mean control survival ≥ 90%

Results

A summary of the statistical results are presented in Table 3, while the test data are summarized in Tables 4 and 5. In general, there was no toxicity observed in the sample with any of the acute or chronic tests performed. However, there was a statistically significant 7% decrease in the chronic fathead minnow growth endpoint, when compared to the lab control. This was not deemed as biologically relevant since it was outside the acceptable range of sensitivity (see QA section). Moreover, there was no significant difference in growth compared to the reference control (DI and Aqueduct water). Thus, there is no evidence that the sample was associated with any adverse effects.

Interestingly, the only significant effect observed during this round of testing was between the reference control and the lab control with the chronic water flea reproduction endpoint. There was a 33% decrease in reproduction found in the reference control when compared to the lab control. It is not clear whether this decrease is the result of an interaction between the deionized water and the aqueduct water, a contamination issue with the deionized water or the dilution cup used in preparing this concentration, or an intrinsic response to the aqueduct water itself. However, no adverse effects were observed with the actual sample (i.e. mixture of UV/AOP and Aqueduct water) being tested. Thus, the no observed effect concentration (NOEC) is reported as 100% sample for all acute and chronic tests performed. Raw data and statistical analyses for the chronic toxicity tests are presented in Appendix A, and the acute toxicity tests are presented in Appendix B. Sample receipt information and chain-of-custody forms can be found in Appendices C and D, respectively.

Table 3. Summary of Statistical Results for the UV/AOP Sample

Species & Endpoint	NOEC (% effluent)	LOEC (% effluent)	Toxic Units
Water Flea:			
96-hr Acute Survival	100	>100	0.41
Chronic Survival	100	>100	1.0
Chronic Reproduction	100	>100	1.0
Fathead minnow:			
96-hr Acute Survival	100	>100	0.0
Chronic Survival	100	>100	1.0
Chronic Growth (biomass)	100	>100	1.0
Green algae:			
Chronic Growth (cell density)	100	>100	1.0

NOEC = the highest Concentration tested that results in No Observed Effect
LOEC = the Lowest Observed Effect Concentration (the next concentration higher than the NOEC)
Acute Toxic Units (TU_a) = Log (100 - %survival) ÷ 1.7
Chronic Toxic Units (TU_c) = 100 ÷ NOEC

Table 4. Summary of Chronic Toxicity Test Results

Test Concentration (%)	Fathead Minnow		Water flea		Green algae
	Chronic Survival (%)	Chronic Biomass (mg)	Chronic Survival (%)	Mean No. of Offspring	Chronic Cell Density (10^6 cells/ml)
Lab Control	95.0	0.307	100	27.3	3.26
Reference	97.5	0.287 *	90	18.4 *	3.32
Sample	92.5	0.285 *	100	26.7	3.23 [a]

* An asterisk indicates a statistically significant difference compared to the lab control (see QA section)
[a] The results for the filtered sample is reported above. The cell density in the unfiltered sample was 3.26 x 10^6 cells/ml.

Table 5. Summary of Acute Toxicity Test Results

Test Concentration (%)	Fathead Minnow	Water flea
	Chronic Survival (%)	Chronic Survival (%)
Lab Control	95	100
Reference	100	100
Sample	100	95

Quality Assurance/Quality Control

All samples were received the same day as collected, and were immediately placed in cold storage until used in testing. All tests were initiated within the required 36-hour holding time. There were no deviations to the test protocol procedures, and the lab control for each test performed met the minimum acceptability criteria. Therefore, all test results were deemed valid for reporting purposes.

The chronic fathead minnow test had some unusual statistical results. The survival and mean growth data met test acceptability criteria. However, the percent minimum significant difference (PMSD) value was only 5.0%, which is below the test acceptability criteria. Due to low replicate variability, the power to detect a statistical difference for this test was greater than typical. The PMSD value, which is a measure of test sensitivity, was less than the lower 10th percentile value determined by EPA for the fathead minnow test during a nationwide inter-laboratory variability study (EPA 2000 and 2002). This lower bound is used as guidance to appropriately address small differences not likely to be biologically meaningful when statistical power is greater than typical. If the PMSD for a test is below the lower limit, and the difference in biological response in a sample concentration relative to that in the control is less than the PMSD lower bound, then this difference is not considered statistically significant. The difference between fathead growth in the lab control and UV/AOP sample was only 7.0%, which is below the lower PMSD bound of 12%. Thus, this difference is not considered statistically significant according to EPA (2002), and this is deemed a false-positive test result. Therefore, this test result is being reported as no observed effect in the sample (NOEC = 100%).

A similar result occurred in the chronic *Selenastrum* algae test. The PMSD value for the test was only 5.0%, and the acceptable range is between 9.1% and 29%. Thus, we had very tight data again with the *Selenastrum* test. However, with this set of data there was less than a 3.0% difference between the sample and the lab control, and it did not result in being statistically significant. Therefore, the PMSD value does not apply in this case.

References

USEPA. 2000. Understanding and Accounting for Method Variability in Whole Effluent Toxicity Applications Under the National Pollutant Discharge Elimination System. United States Environmental Protection Agency Office of Wastewater Management (EPA-833-R-00-003).

USEPA. 2002. Methods for Measuring the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms. Pages 51-52, section 10.2.8.2.5. Fourth Edition. United States Environmental Protection Agency Office of Water, Washington DC (EPA-821-R-02-013).

Appendix A

Chronic Test Data & Statistical Analyses

Chronic Water Flea

CETIS Summary Report

Report Date: 02 Dec-11 14:00 (p 1 of 1)
Test Code: 1111-S169 | 05-3100-9565

Ceriodaphnia 7-d Survival and Reproduction Test — **Nautilus Environmental (CA)**

Batch ID:	01-5082-4520	**Test Type:**	Reproduction-Survival (7d)	**Analyst:**	
Start Date:	15 Nov-11 15:25	**Protocol:**	EPA/821/R-02-013 (2002)	~~**Diluent:**~~ Control KC	Diluted Mineral Water (8:2)
Ending Date:	22 Nov-11 14:45	**Species:**	Ceriodaphnia dubia	**Brine:**	Not Applicable
Duration:	6d 23h	**Source:**	In-House Culture	**Age:**	<24h

Sample ID:	13-3622-2924	**Code:**	11-0951	**Client:**	MWH Labs
Sample Date:	14 Nov-11 07:20	**Material:**	~~POTW~~ Effluent Sample	**Project:**	
Receive Date:	14 Nov-11 10:55	**Source:**	MWH Labs		
Sample Age:	32h	**Station:**	SD AWPF		

Comparison Summary

Analysis ID	Endpoint	NOEL	LOEL	TOEL	PMSD	TU	Method
16-0378-0972	7d Survival Rate	100	>100	N/A	N/A	1	Fisher Exact Test
12-5459-5171	Reproduction	100	>100	N/A	14.9%	1	Wilcoxon Rank Sum Two-Sample Test

Test Acceptability

Analysis ID	Endpoint	Attribute	Test Stat	TAC Limits	Overlap	Decision
16-0378-0972	7d Survival Rate	Control Resp	1	0.8 - NL	Yes	Passes Acceptability Criteria
12-5459-5171	Reproduction	Control Resp	27.3	15 - NL	Yes	Passes Acceptability Criteria
12-5459-5171	Reproduction	PMSD	0.1493	0.13 - 0.47	Yes	Passes Acceptability Criteria

7d Survival Rate Summary

Conc-%	Control Type	Count	Mean	95% LCL	95% UCL	Min	Max	Std Err	Std Dev	CV%	%Effect
0	Rec. Water	10	0.9	0.7819	1	0	1	0.1	0.3162	35.14%	0.0%
0	Lab Control	10	1	1	1	1	1	0	0	0.0%	-11.11%
100		9	1	1	1	1	1	0	0	0.0%	-11.11%

Reproduction Summary

Conc-%	Control Type	Count	Mean	95% LCL	95% UCL	Min	Max	Std Err	Std Dev	CV%	%Effect
0	Rec. Water	10	18.4	14.27	22.53	0	34	3.493	11.05	60.04%	0.0%
0	Lab Control	10	27.3	25.49	29.11	15	32	1.535	4.855	17.78%	-48.37%
100		9	26.67	24.66	28.67	14	33	1.787	5.362	20.11%	-44.93%

7d Survival Rate Detail

Conc-%	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
0	Rec. Water	1	1	1	1	0	1	1	1	1	1
0	Lab Control	1	1	1	1	1	1	1	1	1	1
100		1	1	1	1	1		1	1	1	1

Reproduction Detail

Conc-%	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
0	Rec. Water	24	33	34	19	0	16	8	26	9	15
0	Lab Control	31	31	28	15	29	29	32	26	26	26
100		26	30	28	24	28		29	33	14	28

CETIS Analytical Report

Report Date: 02 Dec-11 14:00 (p 1 of 1)
Test Code: 1111-S169 | 05-3100-9565

Ceriodaphnia 7-d Survival and Reproduction Test — **Nautilus Environmental (CA)**

Analysis ID:	16-0378-0972	**Endpoint:**	7d Survival Rate	**CETIS Version:**	CETISv1.8.0
Analyzed:	02 Dec-11 13:58	**Analysis:**	Single 2x2 Contingency Table	**Official Results:**	Yes

Data Transform	Zeta	Alt Hyp	MC Trials	Test Result
Untransformed		C > T	Not Run	Sample passes 7d survival rate endpoint

Fisher Exact Test

Control	vs	Conc-%	Test Stat	P-Value	Decision(0.05)
Lab Control		100	1	1.0000	Non-Significant Effect

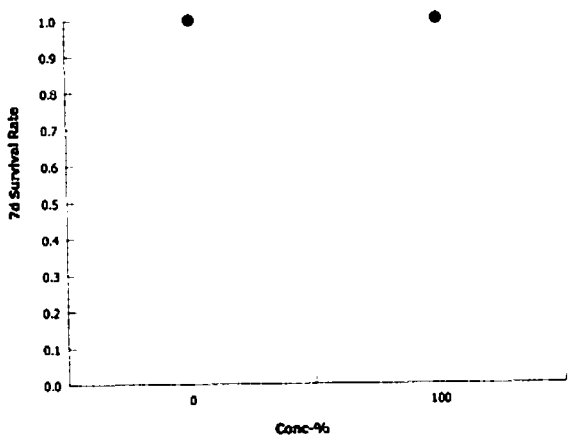
Data Summary

Conc-%	Control Type	No-Resp	Resp	Total
0	Lab Control	10	0	10
100		9	0	9

7d Survival Rate Detail

Conc-%	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
0	Lab Control	1	1	1	1	1	1	1	1	1	1
100		1	1	1	1	1	1	1	1	1	

Graphics



Analyst: SC QA: KL 12/14/11

CETIS Analytical Report

Report Date: 02 Dec-11 13:59 (p 1 of 1)
Test Code: 1111-S169 | 05-3100-9565

Ceriodaphnia 7-d Survival and Reproduction Test — Nautilus Environmental (CA)

Analysis ID:	12-5459-5171	Endpoint:	Reproduction	CETIS Version:	CETISv1.8.0
Analyzed:	02 Dec-11 13:58	Analysis:	Nonparametric-Two Sample	Official Results:	Yes

Data Transform	Zeta	Alt Hyp	MC Trials	Test Result	PMSD
Untransformed	0	C > T	Not Run	Sample passes reproduction endpoint	14.9%

Wilcoxon Rank Sum Two-Sample Test

Control	vs	Conc-%	Test Stat	Critical	DF	Ties	P-Value	Decision(α:5%)
Lab Control		100	85		17	3	0.3598	Non-Significant Effect

ANOVA Table

Source	Sum Squares	Mean Square	DF	F Stat	P-Value	Decision(α:5%)
Between	1.9	1.9	1	0.07306	0.7902	Non-Significant Effect
Error	442.1	26.00588	17			
Total	444	27.90588	18			

Distributional Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:1%)
Variances	Variance Ratio F	1.22	6.693	0.7681	Equal Variances
Distribution	Shapiro-Wilk W Normality	0.7993	0.8605	0.0011	Non-normal Distribution

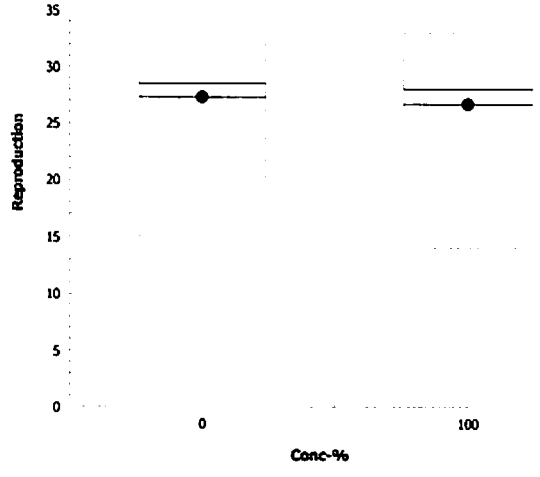
Reproduction Summary

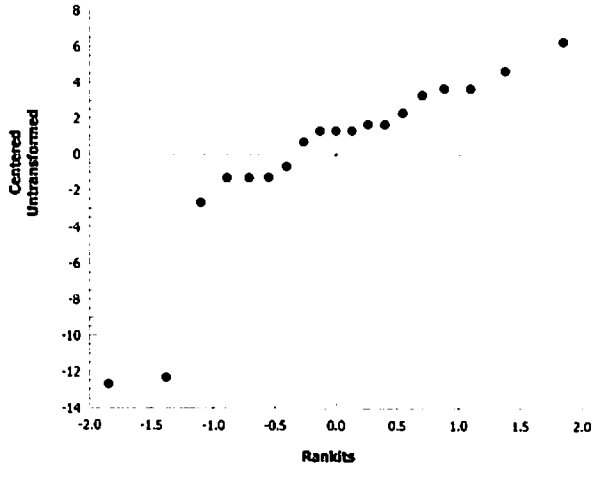
Conc-%	Control Type	Count	Mean	95% LCL	95% UCL	Min	Max	Std Err	Std Dev	CV%	%Effect
0	Lab Control	10	27.3	25.45	29.15	15	32	1.535	4.855	17.78%	0.0%
100		9	26.67	24.63	28.71	14	33	1.787	5.362	20.11%	2.32%

Reproduction Detail

Conc-%	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
0	Lab Control	31	31	28	15	29	29	32	26	26	26
100		26	30	28	24	28	29	33	14	28	

Graphics





CETIS Analytical Report

(Lab Control vs Reference Control)

Report Date: 02 Dec-11 14:00 (p 1 of 1)
Test Code: 1111-S169 | 05-3100-9565

Nautilus Environmental (CA)

Ceriodaphnia 7-d Survival and Reproduction Test

Analysis ID: 10-6389-5593 | Endpoint: Reproduction | CETIS Version: CETISv1.8.0
Analyzed: 02 Dec-11 13:59 | Analysis: Parametric-Two Sample | Official Results: Yes

Data Transform	Zeta	Alt Hyp	MC Trials	Test Result	PMSD
Untransformed	0	C > T	Not Run	Sample fails reproduction endpoint	24.2%

Equal Variance t Two-Sample Test

Control	vs	Control	Test Stat	Critical	DF	MSD	P-Value	Decision(α:5%)
Lab Control		Rec. Water	2.332	1.734	18	6.617	0.0157	Significant Effect

ANOVA Table

Source	Sum Squares	Mean Square	DF	F Stat	P-Value	Decision(α:5%)
Between	396.05	396.05	1	5.44	0.0315	Significant Effect
Error	1310.5	72.80556	18			
Total	1706.55	468.8555	19			

Distributional Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:1%)
Variances	Variance Ratio F	5.179	6.541	0.0223	Equal Variances
Distribution	Shapiro-Wilk W Normality	0.962	0.866	0.5845	Normal Distribution

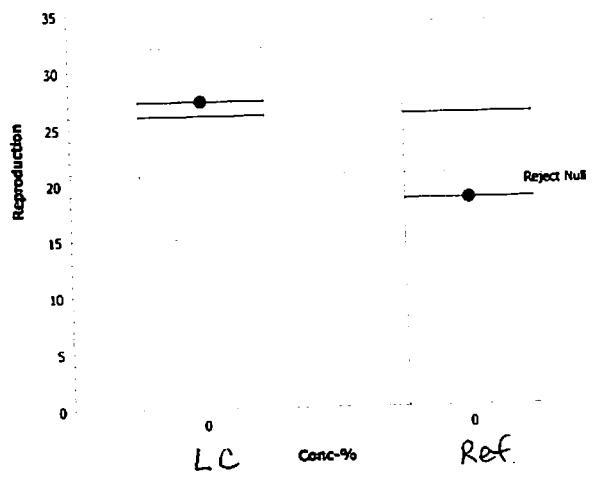
Reproduction Summary

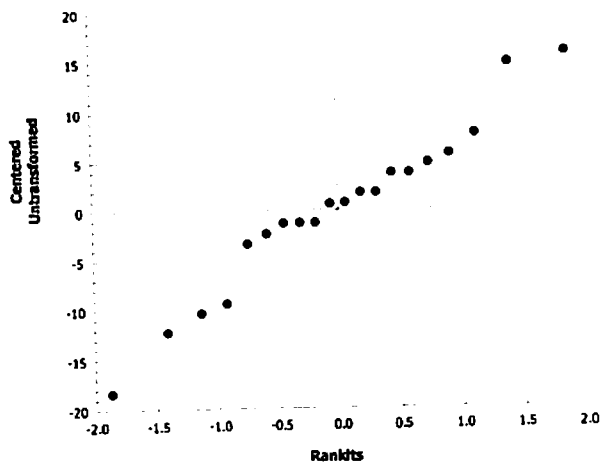
Conc-%	Control Type	Count	Mean	95% LCL	95% UCL	Min	Max	Std Err	Std Dev	CV%	%Effect
0	Rec. Water	10	18.4	14.2	22.6	0	34	3.493	11.05	60.04%	0.0%
0	Lab Control	10	27.3	25.45	29.15	15	32	1.535	4.855	17.78%	-48.37%

Reproduction Detail

Conc-%	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
0	Lab Control	31	31	28	15	29	29	32	26	26	26
0	Rec. Water	24	33	34	19	0	16	8	26	9	15

Graphics





Freshwater Chronic Bioassay | **Daphnid Survival and Reproduction Datasheet**

Test Species: ***C. dubia***

Client/Sample ID: MWH / Effluent | **Start Date/Time:** 11/15/2011 1525

Test Number: 1111-5169 | **End Date/Time:** 11/22/2011 1445

Conc.	Rep	Rand #	Daily Reproduction/ Survival 1	2	3	4	5	6	7	8	Total	QC
LC	1	8	0	0	5	0	11	15	0		31	
	2	29	0	0	4	0	11	16	16/B		31	
	3	26	0	0	0	4	9	0	15		28	
	4	14	0	0	0	4	11	0	0		15	
	5	5	0	0	0	6	10	0	13		29	
	6	27	0	0	0	3	10	0	16		29	
	7	21	0	0	4	0	10	0	18		32	
	8	6	0	0	0	4	7	0	15		26	
	9	11	0	0	0	4	11	0	11		26	11
	10	3	0	0	0	3	9	0	14		26	
		Tech:	JF	JF	AD	AD	JG	AD	JW			AD

Conc.	Rep	Rand #	Daily Reproduction/ Survival 1	2	3	4	5	6	7	8	Total	QC
100 ~~10000~~%	1	25	0	0	0	5	8	0	13		26	
	2	15	0	0	5	0	11	14	0		30	
	3	10	0	0	6	0	10	12	12/B		28	12
	4	24	0	0	0	0	11	13	0		24	
	5	2	0	0	0	4	11	0	13		28	
	6	20	0	0	LIP	—	—	—	—		LIP	ES
	7	1	0	0	2	0	8	19	0		29	
	8	19	0	0	0	6	11	16	0		33	
	9	4	0	0	0	0	4	0	10		14	
	10	17	0	0	0	3	10	0	15		28	

Conc.	Rep	Rand #	Daily Reproduction/ Survival 1	2	3	4	5	6	7	8	Total	QC
RC	1	12	0	0	0	0	4	4	16		24	
	2	16	0	0	5	0	12	16	0		33	
	3	23	0	0	0	6	11	17	0		34	
	4	13	0	0	0	3	3	13	0		19	
	5	22	0/d	—	—	—	—	—	—		0/d	
	6	28	0	0	0	0	5	0	11		16	
	7	9	0	0	0	0	2	0	0		8	
	8	7	0	0	0	6	9	11	0		26	
	9	18	0	0	0	5	0	0	4		9	
	10	30	0	0	0	0	6	0	9		15	8

Neonates for each replicate were blocked across concentrations at test initiation

Rep:	1	2	3	4	5	6	7	8	9	10
Board:	57									→
Cup:	43	44	47	48	50	53	54	57	58	60

Initiated By: JF **Verified By:** JP

Time Fed/Test Solution Renewed (day):
(0) 1525 (1) 1400 (2) 1245 (3) 1230 (4) 1335 (5) 1350 (6) 1225 (7) _____

Notes: d = dead; M = male; LIP = lost in progress; B = 4th brood (only the first 3 broods are included in total)

QC Check: 12-1-11 _____ **Final Review:** KL 12-14-11

Nautilus Environmental, LLC. 4340 Vandever Avenue. San Diego, CA 92120.

Freshwater Chronic Bioassay | **Water Quality Measurements**

Client: MWH | Test Species: *C. dubia*

Sample ID: ~~RO-Treated~~ Effluent | Start Date/Time: 11/15/2011 1525

Test No: 1111-5169 | End Date/Time: 11/22/2011 1445

Concentration	Lab Control							
Day	0	1	2	3	4	5	6	7
Initial								
pH	8.27	8.23	8.04	8.29	8.22	8.26	8.26	
DO (mg/L)	7.4	8.3	8.5	8.0	7.7	8.3	7.6	
Cond. (µmhos/cm)	193	190	195	194	193	200	196	
Temp (°C)	25.2	24.8	24.7	24.4	25.2	25.8	24.8	
Final								
pH		8.08	8.15	8.22	8.23	8.20	8.25	8.12
DO (mg/L)		8.0	8.0	8.3	7.8	8.3	8.7	8.0
Temp (°C)		25.0	24.7	24.1	24.0	25.1	24.2	24.3

Concentration	100%							
Day	0	1	2	3	4	5	6	7
Initial								
pH	8.56	8.54	8.40	8.48	8.51	8.40	8.45	
DO (mg/L)	8.8	8.0	9.0	8.0	8.5	8.9	8.9	
Cond. (µmhos/cm)	303	302	294	301	255	221	283	
Temp (°C)	25.2	25.7	26.0	25.8	25.4	25.9	25.0	
Final								
pH		8.00	8.00	8.00	7.90	7.96	~~8.01~~ 7.86	7.97 7.87
DO (mg/L)		7.9	7.9	8.3	7.7	8.2	8.8	8.0
Temp (°C)		25.0	24.7	24.1	24.0	25.1	24.2	24.3

Concentration	Reference Control							
Day	0	1	2	3	4	5	6	7
Initial								
pH	8.41	8.56	8.43 ~~8.27~~	8.32	8.48	8.40	8.52	
DO (mg/L)	7.7	8.1	~~8.8~~ 8.6	8.1	8.4	8.9	9.0	
Cond. (µmhos/cm)	260	248	~~257~~ 251	251	303	247	259	
Temp (°C)	25.7	24.9	24.9	24.5	25.4	25.8	25.3	
Final								
pH		7.89	7.90	7.90	7.98	7.86	7.93	7.82
DO (mg/L)		8.0	8.0	8.3	7.9	8.0	8.7	8.2
Temp (°C)		25.0	24.7	24.1	24.0	25.1	24.2	24.3

	0	1	2	3	4	5	6	7
Analysts: Initial:	JVV	JF	ES/JF	ES	ES	SL	ES	
Final:		JVV	JF	AD	AD	SL	AD	LN
Dilutions made by:	JF/PA	JV/JP	JF/PA	AD/ES	JF	JG	JP	
Sample Used (A, B, C):	A	A	B	B	B	C	C	

Comments:

Animal Source/Date Received: Internal / NA | Animal Age at Initiation: <24 hours

Sample Log-In Numbers: A: 11-0951 B: 11-0960 C: 11-0976

QC Check: 12-1-11 | Final Review: KL 12-14-11

Chronic Fathead minnow

CETIS Summary Report

Report Date: 02 Dec-11 14:20 (p 1 of 1)
Test Code: 1111-S170 | 09-6925-3834

Fathead Minnow 7-d Larval Survival and Growth Test — Nautilus Environmental (CA)

Batch ID:	08-5879-3857	Test Type:	Growth-Survival (7d)	Analyst:	
Start Date:	15 Nov-11 15:25	Protocol:	EPA/821/R-02-013 (2002)	~~Diluent:~~ Control	Diluted Mineral Water (8:2)
Ending Date:	22 Nov-11 15:15	Species:	Pimephales promelas	Brine:	Not Applicable
Duration:	7d	Source:	Aquatic Biosystems, CO	Age:	1d

Sample ID:	07-7437-1488	Code:	11-0951	Client:	MWH Labs
Sample Date:	14 Nov-11 07:20	Material:	~~Groundwater~~ Effluent Sample	Project:	
Receive Date:	14 Nov-11 10:55	Source:	MWH Labs		
Sample Age:	32h	Station:	SD AWPF		

Comparison Summary

Analysis ID	Endpoint	NOEL	LOEL	TOEL	PMSD	TU	Method
06-6625-6678	7d Survival Rate	100	>100	N/A	13.9%	1	Equal Variance t Two-Sample Test
16-3753-6868	Mean Dry Biomass-mg	100 ~~<100~~	>100	N/A	4.97%	~~>1~~ 1	Equal Variance t Two-Sample Test

Test Acceptability

Analysis ID	Endpoint	Attribute	Test Stat	TAC Limits	Overlap	Decision
06-6625-6678	7d Survival Rate	Control Resp	0.95	0.8 - NL	Yes	Passes Acceptability Criteria
16-3753-6868	Mean Dry Biomass-mg	Control Resp	0.3065	0.25 - NL	Yes	Passes Acceptability Criteria
16-3753-6868	Mean Dry Biomass-mg	PMSD	0.04971	0.12 - 0.3	Yes	Below Acceptability Criteria *

7d Survival Rate Summary

Conc-%	Control Type	Count	Mean	95% LCL	95% UCL	Min	Max	Std Err	Std Dev	CV%	%Effect
0	Rec. Water	4	0.975	0.9563	0.9937	0.9	1	0.025	0.05	5.13%	0.0%
0	Lab Control	4	0.95	0.9127	0.9873	0.8	1	0.05	0.1	10.53%	2.56%
100		4	0.925	0.8892	0.9608	0.8	1	0.04787	0.09574	10.35%	5.13%

Mean Dry Biomass-mg Summary

Conc-%	Control Type	Count	Mean	95% LCL	95% UCL	Min	Max	Std Err	Std Dev	CV%	%Effect
0	Rec. Water	4	0.287	0.2839	0.2901	0.276	0.296	0.004123	0.008246	2.87%	0.0%
0	Lab Control	4	0.3065	0.3013	0.3117	0.294	0.323	0.006958	0.01392	4.54%	-6.79%
100		4	0.2852	0.2826	0.2879	0.279	0.292	0.003614	0.007228	2.53%	0.61%

7d Survival Rate Detail

Conc-%	Control Type	Rep 1	Rep 2	Rep 3	Rep 4
0	Rec. Water	0.9	1	1	1
0	Lab Control	1	1	0.8	1
100		1	1	0.8	0.9

Mean Dry Biomass-mg Detail

Conc-%	Control Type	Rep 1	Rep 2	Rep 3	Rep 4
0	Rec. Water	0.288	0.276	0.288	0.296
0	Lab Control	0.323	0.296	0.313	0.294
100		0.292	0.279	0.291	0.279

* See QA section of report.

The PMSD value was only 5.0%, which is below the test acceptability range of 12–30%. This result indicates the data was very tight with low variability. This usually results in over-sensitive statistical results and leads to False Positive readings. If we look at the low bar of the PMSD acceptable range, which is 12%, we would need to see at least a 12% difference in growth to deem a result as being biologically relevant. In this case, there was less than a 7.0% difference, which we believe to be a False Positive result. Therefore, we are reporting this as no effect in the 100% sample.

CETIS Analytical Report

Report Date: 02 Dec-11 14:20 (p 1 of 2)
Test Code: 1111-S170 | 09-6925-3834

Fathead Minnow 7-d Larval Survival and Growth Test — Nautilus Environmental (CA)

Analysis ID:	16-3753-6868	Endpoint:	Mean Dry Biomass-mg	CETIS Version:	CETISv1.8.0
Analyzed:	02 Dec-11 14:18	Analysis:	Parametric-Two Sample	Official Results:	Yes

Data Transform	Zeta	Alt Hyp	MC Trials	Test Result	PMSD
Untransformed	0	C > T	Not Run	Sample fails mean dry biomass-mg endpoint	4.97%

Equal Variance t Two-Sample Test

Control	vs	Conc-%	Test Stat	Critical	DF	MSD	P-Value	Decision(α:5%)
Lab Control		100*	2.71	1.943	6	0.01524	0.0175	Significant Effect

ANOVA Table

Source	Sum Squares	Mean Square	DF	F Stat	P-Value	Decision(α:5%)
Between	0.0009031296	0.0009031296	1	7.345	0.0351	Significant Effect
Error	0.0007377589	0.0001229598	6			
Total	0.001640889	0.001026089	7			

Distributional Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:1%)
Variances	Variance Ratio F	3.707	47.47	0.3104	Equal Variances
Distribution	Shapiro-Wilk W Normality	0.9102	0.6451	0.3556	Normal Distribution

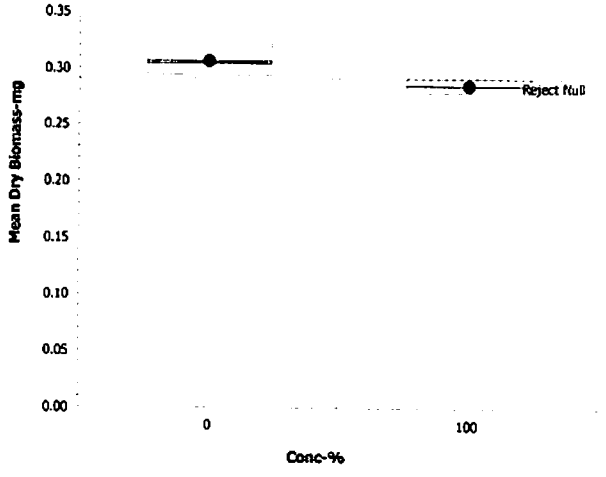
Mean Dry Biomass-mg Summary

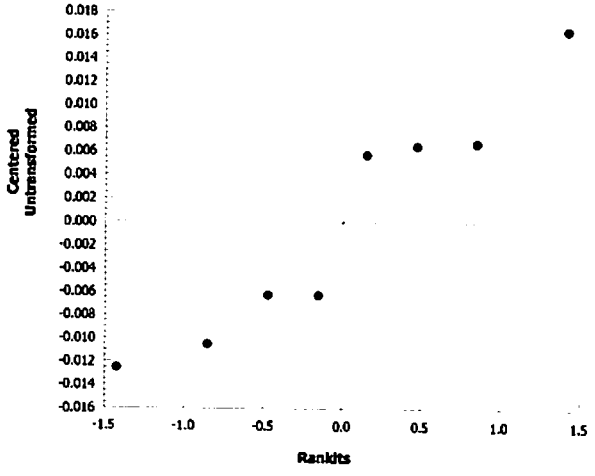
Conc-%	Control Type	Count	Mean	95% LCL	95% UCL	Min	Max	Std Err	Std Dev	CV%	%Effect
0	Lab Control	4	0.3065	0.3012	0.3118	0.294	0.323	0.006958	0.01392	4.54%	0.0%
100		4	0.2852	0.2825	0.288	0.279	0.292	0.003614	0.007228	2.53%	6.93%

Mean Dry Biomass-mg Detail

Conc-%	Control Type	Rep 1	Rep 2	Rep 3	Rep 4
0	Lab Control	0.323	0.296	0.313	0.294
100		0.292	0.279	0.291	0.279

Graphics





Analyst: SC QA: KL12-14-11

Fathead Minnow 7-d Larval Survival and Growth Test — **Nautilus Environmental (CA)**

Analysis ID:	06-6625-6678	**Endpoint:**	7d Survival Rate	**CETIS Version:**	CETISv1.8.0
Analyzed:	02 Dec-11 14:17	**Analysis:**	Parametric-Two Sample	**Official Results:**	Yes

Data Transform	Zeta	Alt Hyp	MC Trials	Test Result	PMSD
Angular (Corrected)	0	C > T	Not Run	Sample passes 7d survival rate endpoint	13.9%

Equal Variance t Two-Sample Test

Control	vs	Conc-%	Test Stat	Critical	DF	MSD	P-Value	Decision(α:5%)
Lab Control		100	0.3848	1.943	6	0.2057	0.3568	Non-Significant Effect

ANOVA Table

Source	Sum Squares	Mean Square	DF	F Stat	P-Value	Decision(α:5%)
Between	0.003319917	0.003319917	1	0.1481	0.7136	Non-Significant Effect
Error	0.1344935	0.02241559	6			
Total	0.1378134	0.0257355	7			

Distributional Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:1%)
Variances	Variance Ratio F	1.076	47.47	0.9534	Equal Variances
Distribution	Shapiro-Wilk W Normality	0.7948	0.6451	0.0252	Normal Distribution

7d Survival Rate Summary

Conc-%	Control Type	Count	Mean	95% LCL	95% UCL	Min	Max	Std Err	Std Dev	CV%	%Effect
0	Lab Control	4	0.95	0.912	0.988	0.8	1	0.05	0.1	10.53%	0.0%
100		4	0.925	0.8886	0.9614	0.8	1	0.04787	0.09574	10.35%	2.63%

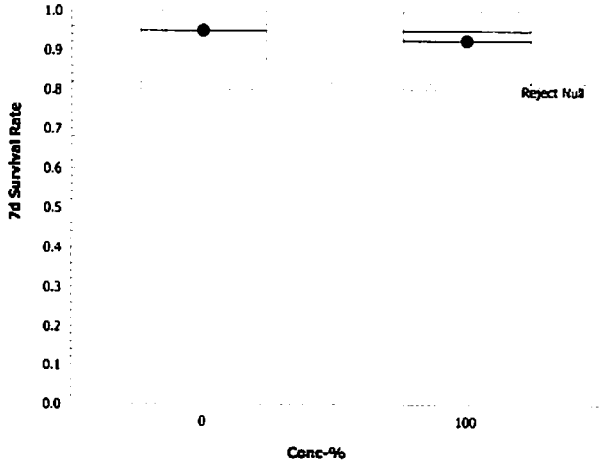
Angular (Corrected) Transformed Summary

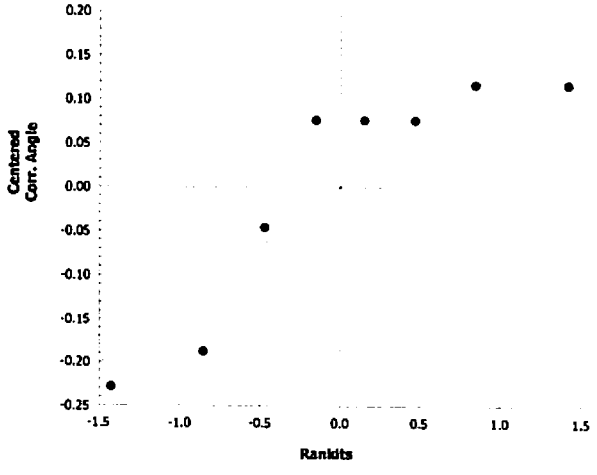
Conc-%	Control Type	Count	Mean	95% LCL	95% UCL	Min	Max	Std Err	Std Dev	CV%	%Effect
0	Lab Control	4	1.336	1.278	1.394	1.107	1.412	0.07622	0.1524	11.41%	0.0%
100		4	1.295	1.239	1.351	1.107	1.412	0.07348	0.147	11.35%	3.05%

7d Survival Rate Detail

Conc-%	Control Type	Rep 1	Rep 2	Rep 3	Rep 4
0	Lab Control	1	1	0.8	1
100		1	1	0.8	0.9

Graphics





Fathead Minnow 7-d Larval Survival and Growth Test — Nautilus Environmental (CA)

Analysis ID:	05-1519-7731	Endpoint:	Mean Dry Biomass-mg	CETIS Version:	CETISv1.8.0
Analyzed:	02 Dec-11 14:19	Analysis:	Parametric-Two Sample	Official Results:	Yes

Data Transform	Zeta	Alt Hyp	MC Trials	Test Result	PMSD
Untransformed	0	C > T	Not Run	Sample fails mean dry biomass-mg endpoint	5.13%

Equal Variance t Two-Sample Test

Control	vs	Control	Test Stat	Critical	DF	MSD	P-Value	Decision(α:5%)
Lab Control		Rec. Water	2.411	1.943	6	0.01572	0.0263	Significant Effect

ANOVA Table

Source	Sum Squares	Mean Square	DF	F Stat	P-Value	Decision(α:5%)
Between	0.0007604932	0.0007604932	1	5.813	0.0525	Non-Significant Effect
Error	0.0007850142	0.0001308357	6			
Total	0.001545507	0.0008913289	7			

Distributional Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:1%)
Variances	Variance Ratio F	2.848	47.47	0.4129	Equal Variances
Distribution	Shapiro-Wilk W Normality	0.9184	0.6451	0.4166	Normal Distribution

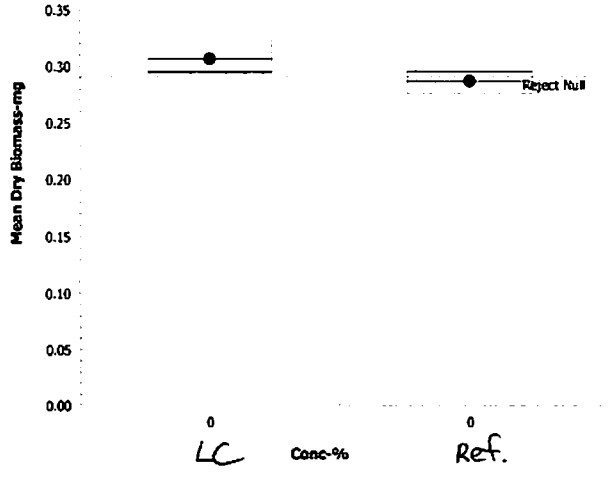
Mean Dry Biomass-mg Summary

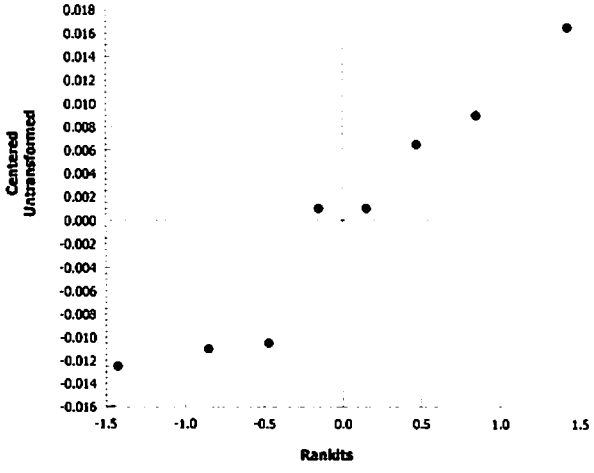
Conc-%	Control Type	Count	Mean	95% LCL	95% UCL	Min	Max	Std Err	Std Dev	CV%	%Effect
0	Rec. Water	4	0.287	0.2839	0.2901	0.276	0.296	0.004123	0.008246	2.87%	0.0%
0	Lab Control	4	0.3065	0.3012	0.3118	0.294	0.323	0.006958	0.01392	4.54%	-6.79%

Mean Dry Biomass-mg Detail

Conc-%	Control Type	Rep 1	Rep 2	Rep 3	Rep 4
0	Lab Control	0.323	0.296	0.313	0.294
0	Rec. Water	0.288	0.276	0.288	0.296

Graphics





CETIS Analytical Report (Reference Control vs 100% Sample)

Report Date: 02 Dec-11 14:20 (p 1 of 2)
Test Code: 1111-S170 | 09-6925-3834

Fathead Minnow 7-d Larval Survival and Growth Test — Nautilus Environmental (CA)

Analysis ID:	00-7707-0425	Endpoint:	Mean Dry Biomass-mg	CETIS Version:	CETISv1.8.0
Analyzed:	02 Dec-11 14:19	Analysis:	Parametric-Two Sample	Official Results:	Yes

Data Transform	Zeta	Alt Hyp	MC Trials	Test Result	PMSD
Untransformed	0	C > T	Not Run	Sample passes mean dry biomass-mg endpoin	8.71%

Equal Variance t Two-Sample Test

Control	vs	Conc-%	Test Stat	Critical	DF	MSD	P-Value	Decision(α:5%)
Rec. Water		100	0.3192	1.943	6	0.01065	0.3802	Non-Significant Effect

ANOVA Table

Source	Sum Squares	Mean Square	DF	F Stat	P-Value	Decision(α:5%)
Between	6.12599E-06	6.12599E-06	1	0.1019	0.7604	Non-Significant Effect
Error	0.0003607558	6.012597E-05	6			
Total	0.0003668818	6.625196E-05	7			

Distributional Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:1%)
Variances	Variance Ratio F	1.301	47.47	0.8337	Equal Variances
Distribution	Shapiro-Wilk W Normality	0.9298	0.6451	0.5141	Normal Distribution

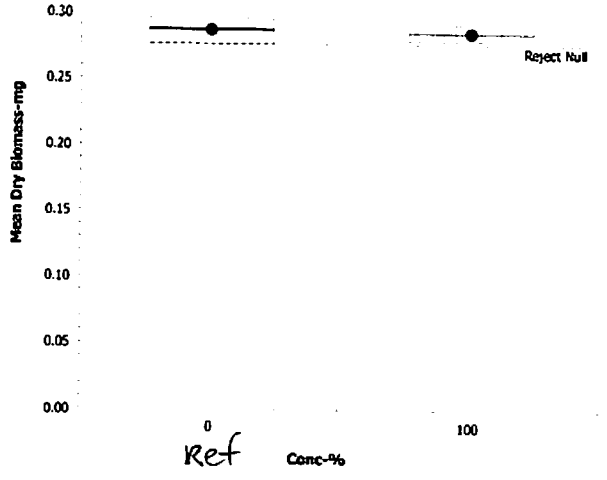
Mean Dry Biomass-mg Summary

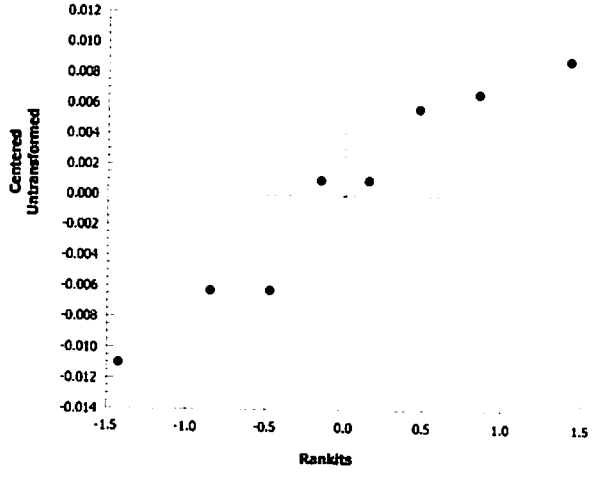
Conc-%	Control Type	Count	Mean	95% LCL	95% UCL	Min	Max	Std Err	Std Dev	CV%	%Effect
0	Rec. Water	4	0.287	0.2839	0.2901	0.276	0.296	0.004123	0.008246	2.87%	0.0%
100		4	0.2852	0.2825	0.288	0.279	0.292	0.003614	0.007228	2.53%	0.61%

Mean Dry Biomass-mg Detail

Conc-%	Control Type	Rep 1	Rep 2	Rep 3	Rep 4
0	Rec. Water	0.288	0.276	0.288	0.296
100		0.292	0.279	0.291	0.279

Graphics





Freshwater Chronic Bioassay **Larval Fish Survival**

Client: MWH

Sample ID: ~~RO Treated~~ Effluent

Test No.: 1111-5170

Test Species: *P. promelas*

Start Date/Time: 11/15/2011 1525

End Date/Time: 11/22/2011 1515

Conc. (%)	Rep.	Rand #	Test Day / No. Organisms Alive								Percent Survival
			0	1	2	3	4	5	6	7	
Lab Control	a	6	10	10	10	10	10	10	10	10	100
	b	5	10	10	10	10	10	10	10	10	100
	c	12	10	10	10	8	8	8	8	8	80
	d	7	10	10	10	10	10	10	10	10	100
100	a	4	10	10	10	10	10	10	10	10	100
	b	3	10	10	10	10	10	10	10	10	100
	c	10	10	10	10	8	8	8	8	8	80
	d	11	10	10	10	10	9	9	9	9	90
Reference Control	a	2	10	JP ~~9~~ 10	10	10	10	10	9	9	90
	b	8	10	10	10	10	10	10	10	10	100
	c	9	10	10	10	10	10	10	10	10	100
	d	1	10	10	10	10	10	10	10	10	100
Initial Counts QC'd by: JF	Tech Initials		JG	JP	JP	JP	JF	SL	JP	KF	
	Time		1525	1400	1210	1030	1335	1320	1200	1515	

Time Fed (day):	0	1	2	3	4	5	6
morning:	–	0815	0830	0830	0930	0850	0830
midday:	–	1210	1220	1220	1145	1205	1215
evening:	–	1450	1710	1500	1515	1530	1450

Comments:

Drying Oven Info

Tare wt. Initials/Date: AD 11/22/11

Date/Time in: 11/22/11 1530

Date/Time out: ~~11/23/11~~ 11/28/11 1415

Temp (°C): ~~25°~~ AD ~~68~~ 66

QC Check: JC 12-1-11

Final Review: KL 12-14-11

Nautilus Environmental, LLC. 4340 Vandever Avenue. San Diego, CA 92120.

Freshwater Chronic Bioassay **Larval Fish Weights**

Client: MWH **Test Species:** *Pimephales promelas*

Sample ID: ~~Re-treated~~ EC Effluent **Start Date/Time:** ####### 11/15/11 1525

Test No.: 1111-5170 **End Date/Time:** 11/22/11 1515

Conc. (%)	Rep.	pan weight (mg)	pan + fish weight (mg)	organism weight (mg)
LC	a	30.08	33.31	3.23
	b	29.11	32.07	2.96
	c	29.44	32.57	3.13
	d	29.70	32.64	2.94
RC	a	29.61	32.49	2.88
	b	28.79	31.55	2.76
	c	29.77	32.65	2.88
	d	30.35	33.31	2.96
100	a	30.63	33.55	2.92
	b	28.95	31.74	2.79
	c	30.85	33.76	2.91
	d	31.38	34.17	2.79
	a			0
	b			0
	c			0
	d			0
	a			0
	b			0
	c			0
	d			0
	a			0
	b			0
	c			0
	d			0
	a			0
	b			0
	c			0
	d			0

Tech Initials:	AD	AG
Date/Time:	11/22/2011 1010	11/28/2011 1415

QC Check: SC 12-1-11

Final Review: KL 12-14-11

Freshwater Chronic Bioassay | **Water Quality Measurements**

Client: MWH | Test Species: *P. promelas*

Sample ID: ~~RO Treated~~ Effluent | Start Date/Time: 11/15/2011 1525

Test No: 1111-5170 | End Date/Time: 11/22/2011 1515

Concentration	Lab Control							
Day	0	1	2	3	4	5	6	7
Initial								
pH	8.28	8.23	8.05	8.28	~~7.87~~ 8.16 ES	8.26	8.26	
DO (mg/L)	7.3	8.3	8.5	7.4	7.6	8.3	7.6	
Cond. (µmhos/cm)	184	190	194	194	199	200	196	
Temp (°C)	25.8	24.8	24.0	25.4	25.4	25.8	24.8	
Final								
pH		8.18	8.19	7.93	7.87	8.04	7.97	7.91
DO (mg/L)		7.5	6.4	6.5	6.6	7.6	7.5	7.1
Temp (°C)		25.8	25.6	25.6	25.4	25.0	24.4	25.4

Concentration	100%							
Day	0	1	2	3	4	5	6	7
Initial								
pH	8.45	8.54	8.40	8.40	8.44	8.40	8.45	
DO (mg/L)	8.9	8.0	7.0	8.9	8.9	8.9	8.9	
Cond. (µmhos/cm)	305 ~~345~~	302	294	294 JVV	~~25~~ 295	221	283	
Temp (°C) JF	25.1	25.7	26.0	25.1	24.6	25.9	25.0	
Final								
pH		8.06	7.87	7.10	7.45	7.84	7.64	7.64
DO (mg/L)		7.9	6.5	4.8	6.4	7.5	7.1	6.8
Temp (°C)		25.6	24.7	25.1	25.3	25.1	24.4	25.2

Concentration	Reference Control							
Day	0	1	2	3	4	5	6	7
Initial								
pH	8.41	8.56	8.43	8.41	8.44	8.40	8.52	
DO (mg/L)	8.3	8.1	8.6	8.3	8.2	8.9	9.0	
Cond. (µmhos/cm)	244	248	251	250	295	247	259	
Temp (°C)	24.7	24.9	26.0	25.9	25.5	25.8	25.3	
Final								
pH		7.91	7.90	7.56	7.56	7.81	7.42	7.67
DO (mg/L)		8.0	6.6	6.5	6.2	7.1	6.5	6.7
Temp (°C)		25.5	25.1	25.5	25.5	25.0	24.6	25.4

	0	1	2	3	4	5	6	7
Analysts: Initial:	JVV	JF	JF	ES	~~ES~~ ES	SL	ES	
Final:		JF	JF	ES	ES	SL	ES	JP
Dilutions made by:	PA	JVV/JP	AD	AD	JVV	SG	JP	
Sample Used (A, B, C):	A	A	B	B	B	C	C	

Comments:

Animal Source/Date Received: ABS 11/15/11 | Animal Age at Initiation: 1 Day

Sample Log-In Numbers: A: 11-0951 B: 11-0960 C: 11-0976

QC Check: SC 12-1-11 | Final Review: KC 12-14-11

Chronic Green Algae

CETIS Summary Report

Report Date: 02 Dec-11 13:43 (p 1 of 1)
Test Code: 1111-S171 | 17-8340-7840

Selenastrum Growth Test — **Nautilus Environmental (CA)**

Batch ID:	20-8375-1066	**Test Type:**	Cell Growth	**Analyst:**	
Start Date:	17 Nov-11 16:35	**Protocol:**	EPA/821/R-02-013 (2002)	**Diluent:** (control)	Very Hard Water
Ending Date:	21 Nov-11 14:50	**Species:**	Selenastrum capricornutum	**Brine:**	Not Applicable
Duration:	94h	**Source:**	In-House Culture	**Age:**	7d

Sample ID:	18-5518-5944	**Code:**	11-0960	**Client:**	MWH Labs
Sample Date:	16 Nov-11 08:50	**Material:**	Effluent Sample	**Project:**	
Receive Date:	16 Nov-11 09:25	**Source:**	MWH Labs		
Sample Age:	32h	**Station:**	MWH		

Comparison Summary

Analysis ID	Endpoint	NOEL	LOEL	TOEL	PMSD	TU	Method
13-8700-5396	Cell Density	100	>100	N/A	5.05%	1	Equal Variance t Two-Sample Test

Test Acceptability

Analysis ID	Endpoint	Attribute	Test Stat	TAC Limits	Overlap	Decision
13-8700-5396	Cell Density	Control CV	0.0511	NL - 0.2	Yes	Passes Acceptability Criteria
13-8700-5396	Cell Density	Control Resp	3.26E+6	1.00E+6 - NL	Yes	Passes Acceptability Criteria
13-8700-5396	Cell Density	PMSD	0.05049	0.091 - 0.29	Yes	Below Acceptability Criteria *

Cell Density Summary

Conc-%	Control Type	Count	Mean	95% LCL	95% UCL	Min	Max	Std Err	Std Dev	CV%	%Effect
0	Rec. Water	4	3.317E+6	3.301E+6	3.333E+6	3.280E+6	3.379E+6	2.151E+4	4.301E+4	1.3%	0.0%
0	Lab Control	4	3.260E+6	3.198E+6	3.322E+6	3.116E+6	3.494E+6	8.329E+4	1.666E+5	5.11%	1.72%
100		4	3.231E+6	3.219E+6	3.243E+6	3.206E+6	3.275E+6	1.542E+4	3.084E+4	0.95%	2.59%
101		4	3.259E+6	3.249E+6	3.268E+6	3.229E+6	3.289E+6	1.279E+4	2.558E+4	0.79%	1.76%

Cell Density Detail

Conc-%	Control Type	Rep 1	Rep 2	Rep 3	Rep 4
0	Rec. Water	3.308E+6	3.301E+6	3.280E+6	3.379E+6
0	Lab Control	3.494E+6	3.172E+6	3.116E+6	3.258E+6
100		3.206E+6	3.275E+6	3.229E+6	3.214E+6
101		3.267E+6	3.229E+6	3.249E+6	3.289E+6

101 = 100% sample unfiltered

* See QA section of report.

CETIS Analytical Report

Report Date: 02 Dec-11 13:43 (p 1 of 1)
Test Code: 1111-S171 | 17-8340-7840

Selenastrum Growth Test — **Nautilus Environmental (CA)**

Analysis ID:	13-8700-5396	**Endpoint:**	Cell Density	**CETIS Version:**	CETISv1.8.0
Analyzed:	02 Dec-11 13:41	**Analysis:**	Parametric-Two Sample	**Official Results:**	Yes

Data Transform	Zeta	Alt Hyp	MC Trials	Test Result	PMSD
Untransformed	0	C > T	Not Run	Sample passes cell density endpoint	5.05%

Equal Variance t Two-Sample Test

Control	vs	Conc-%	Test Stat	Critical	DF	MSD	P-Value	Decision(α:5%)
Lab Control		100	0.3424	1.943	6	164600	0.3719	Non-Significant Effect

ANOVA Table

Source	Sum Squares	Mean Square	DF	F Stat	P-Value	Decision(α:5%)
Between	1682000000	1682000000	1	0.1172	0.7437	Non-Significant Effect
Error	86094000000	14349000000	6			
Total	87775990000	16031000000	7			

Distributional Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:1%)
Variances	Variance Ratio F	29.17	47.47	0.0203	Equal Variances
Distribution	Shapiro-Wilk W Normality	0.8806	0.6451	0.1907	Normal Distribution

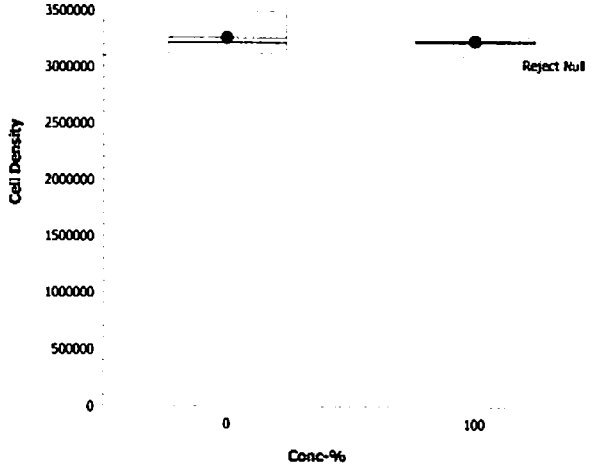
Cell Density Summary

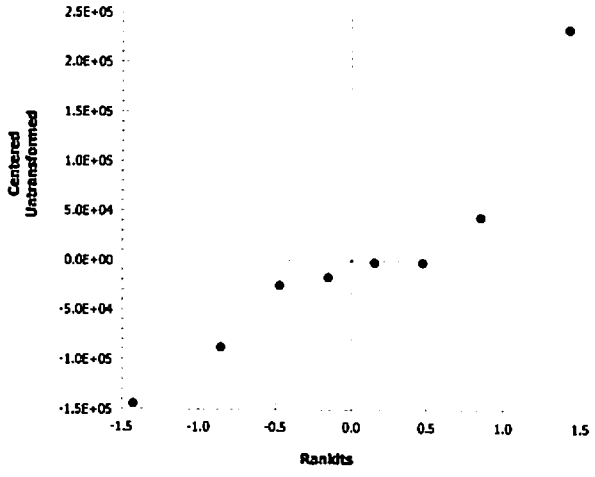
Conc-%	Control Type	Count	Mean	95% LCL	95% UCL	Min	Max	Std Err	Std Dev	CV%	%Effect
0	Lab Control	4	3.260E+6	3.197E+6	3.323E+6	3.116E+6	3.494E+6	8.329E+4	1.666E+5	5.11%	0.0%
100		4	3.231E+6	3.219E+6	3.243E+6	3.206E+6	3.275E+6	1.542E+4	3.084E+4	0.95%	0.89%

Cell Density Detail

Conc-%	Control Type	Rep 1	Rep 2	Rep 3	Rep 4
0	Lab Control	3.494E+6	3.172E+6	3.116E+6	3.258E+6
100		3.206E+6	3.275E+6	3.229E+6	3.214E+6

Graphics





Fluorometric & Microscopic Determination of Cell Density
Turner Fluorometer Model TD-700

Test Species: *S. capricornutum*

Client : MWH

Start Date/Time: 11/17/2011 1635

Sample ID: ~~Ro-Treated~~ Effluent KC

End Date/Time: 11/21/2011 1450

Test No: 1111-5171

Analyst: VG

Random Number	Cell Density (fluorometric) (cells/ml *10^5)	Dilution	Cell Density (microscopic) (cells/ml *10^4)
Blank		NA	
Cal Check 1 (NEW, Solid)	0.00/~~2.94~~ 2.83 JG		
69	32.06		
70	32.75		
71	32.14		
72	32.58		
73	33.08		
74	32.29		
75	32.29		
76	32.89		
77	32.80		
78	33.79		
79	32.67		
80	31.72		
81	34.94		
82	32.49		
Cal Check 2 (NEW, Solid)	0.00/2.80		
100% filtered blank	0.00		
100% unfiltered blank	1.62		
83	31.16		
84	33.07		
UNFILTERED A	41.63		
UNFILT. B	42.34		
UNFILT. C	42.16		
UNFILT. D	41.13		

Comments: ALL REPS WERE SCRAPED FOR ATTACHED ALGAE PRIOR TO READINGS

QC Check: SC 12-1-11

Final Review: KL 12/14/11

CETIS Test Data Worksheet

Report Date: 17 Nov-11 09:37 (p 1 of 1)
Test Code: 17-8340-7840/~~6A4CA4E0~~ 1111-5171

Selenastrum Growth Test — **Nautilus Environmental (CA)**

Start Date: 17 Nov-11 **Species:** Selenastrum capricornutum **Sample Code:** ~~6E93E418~~ 11-0960
End Date: 21 Nov-11 **Protocol:** EPA/821/R-02-013 (2002) **Sample Source:** MWH Labs
Sample Date: 16 Nov-11 **Material:** Effluent Sample **Sample Station:** MWH

Conc-%	Code	Rep	Pos *	Cell Density	Absorbance	Biomass	Chlorophyll a	Notes
0	LC	1	81					* Random # Position
0	LC	2	80					
0	LC	3	83					
0	LC	4	72					
0	R	1	73					
0	R	2	84					
0	R	3	77					
0	R	4	78					
100		1	69					
100		2	70					
100		3	74					
100		4	71					
101		1	79					
101		2	75					
101		3	82					
101		4	76					

combined sample outlet

QC-JW

Freshwater Chronic Bioassay | **Algal Growth Inhibition Worksheet**

Client/Sample ID : MWH/RO-Treated Eff. | **Test Species:** *S. capricornutum*

Test No: 1111-5171 | **Start Date/Time:** 11/17/2011 1635

Analyst: AD/JVV | **End Date/Time:** 11/21/2011 1450

Culture Used (circle one): Nutrient Enriched DI Water (NEW) / (Very Hard Water (VHW))

Date Stock Culture Started: 11/10/11 Culture Age: 7d

Culture subsample inspected for algal cell health? AD/JVV (initials) bacteria/invasive algal species present? Y / N

Stock Cell Density Measurements: AD ~~40.01~~ 44.86

45.53

45.65

45.94

45.53

Mean: 45.50

(mean no. * 100,000)/(500,000) = x (dilution factor): 9.1

Prepare inoculum according to the dilution factor. This yields a solution with the desired cell density of 500,000 cells/ml.

dil. factor 9.1

-1.0 part Sele stock = 20 ml

8.1 part(s) NEW = 162 ml

Inoculate 1 ml into 3 initial count flasks containing 50 ml of NEW, stir and count on the hemacytometer. Flasks should contain a final density of 10,000 cells/ml ± 10%.

Inoculum Cell Density Confirmation Counts: 2, 1, 0 Mean: 1

Location in Environmental Chamber (All replicates in each test must be on the same shelf; do not split up tests among shelves):

Shelf Number	Measured Light Intensity Range (must be between 360 and 440 ft-c)	Random Number Range
1	360 - 437	41 - 68
2		
3	363 - 438	25-32, 68-84
4		
5		
~~NOB~~	361 - 438	1 - ~~40~~ AD 24 33-40

Are lights on 24 hour cycle? (Y) / N

Comments:

QC Check: SL 12-1-11 Final Review: KL 12-14-11

Freshwater Chronic Bioassay

Water Quality Measurements
Algal Growth Inhibition

Client : MWH Labs

Test Species: *S. capricornutum*

Sample ID: ~~RO Treated~~ Effluent

Start Date/Time: 11/17/2011 1635

Sample Log No.: 11- 0960

End Date/Time: 11/21/2011 1450

Dilutions made by: JVV

Test No: 1111-5171

Concentration (%)	Initial Readings D.O. (mg/L)	Initial Readings Conductivity (umhos-cm)	Initial Readings Alkalinity (mg/L)	Initial Readings Hardness (mg/L)	Final Readings D.O. (mg/L)	Final Readings Conductivity (umhos-cm)
Lab Control	7.1	275	98	106	8.6	165
Reference Control	6.7	325	43	70	8.6	336
Combined Sample filt	6.6	370	54	72	8.6	382
Combined Sample unfilt	8.1	372	53	72	8.6	384

		0 Hour	24 Hour Q1	48 Hour Q1	72 Hour	96 Hour
pH/Temperature (°C):	LC	8.10 /24.1	8.39 /28.4	8.75/26.9	9.04 /24.8	9.33 /24.6
pH/Temperature (°C):	RC	8.42 /24.4	8.15 /28.6	8.73/26.3	9.12 /25.6	9.53/24.8
pH/Temperature (°C):	Combined Sample filt	8.45/24.5	8.15 /28.9	8.69/27.4	9.26 /25.3	9.58 /25.0
pH/Temperature (°C):	Combined Sample unfilt	8.44/24.7	8.19 /28.9	8.71/27.7	9.25 /25.4	9.62/25.1
pH/Temperature (°C):		/	/	/	/	/
pH/Temperature (°C):		/	/	/	/	/
pH/Temperature (°C):		/	/	/	/	/
	Technician:	JVV	JP	JF	SL	JG

Comments:

QC Check: BC 12-1-11

Final Review: KL 12-14-11

Nautilus Environmental, LLC. 4340 Vandever Avenue. San Diego, CA 92120.

Appendix B

Acute Test Data & Statistical Analyses

Acute Water Flea

CETIS Summary Report

Report Date: 02 Dec-11 14:32 (p 1 of 1)
Test Code: 1111-S172 | 11-6228-7568

Ceriodaphnia 96-h Acute Survival Test — **Nautilus Environmental (CA)**

Batch ID:	02-9009-2692	**Test Type:**	Survival (96h)	**Analyst:**	
Start Date:	15 Nov-11 15:20	**Protocol:**	EPA/821/R-02-012 (2002)	**~~Diluent~~ Control:**	Diluted Mineral Water (8:2)
Ending Date:	19 Nov-11 13:45	**Species:**	Ceriodaphnia dubia	**Brine:**	Not Applicable
Duration:	94h	**Source:**	In-House Culture	**Age:**	<24h

Sample ID:	16-9114-1243	**Code:**	11-0951	**Client:**	MWH Labs
Sample Date:	14 Nov-11 07:20	**Material:**	~~Stormwater~~ Effluent sample	**Project:**	
Receive Date:	14 Nov-11 10:55	**Source:**	MWH Labs		
Sample Age:	32h	**Station:**	SD AWPF		

Comparison Summary

Analysis ID	Endpoint	NOEL	LOEL	TOEL	PMSD	TU	Method
12-6272-1334	96h Survival Rate	100	>100	N/A	11.2%	0.41	Wilcoxon Rank Sum Two-Sample Test

Test Acceptability

Analysis ID	Endpoint	Attribute	Test Stat	TAC Limits	Overlap	Decision
12-6272-1334	96h Survival Rate	Control Resp	1	0.9 - NL	Yes	Passes Acceptability Criteria

96h Survival Rate Summary

Conc-%	Control Type	Count	Mean	95% LCL	95% UCL	Min	Max	Std Err	Std Dev	CV%	%Effect
0	Rec. Water	4	1	1	1	1	1	0	0	0.0%	0.0%
0	Lab Control	4	1	1	1	1	1	0	0	0.0%	0.0%
100		4	0.95	0.9127	0.9873	0.8	1	0.05	0.1	10.53%	5.0%

96h Survival Rate Detail

Conc-%	Control Type	Rep 1	Rep 2	Rep 3	Rep 4
0	Rec. Water	1	1	1	1
0	Lab Control	1	1	1	1
100		1	0.8	1	1

CETIS Analytical Report

Report Date: 02 Dec-11 14:32 (p 1 of 1)
Test Code: 1111-S172 | 11-6228-7568

Ceriodaphnia 96-h Acute Survival Test — **Nautilus Environmental (CA)**

Analysis ID:	12-6272-1334	**Endpoint:**	96h Survival Rate	**CETIS Version:**	CETISv1.8.0
Analyzed:	02 Dec-11 14:32	**Analysis:**	Nonparametric-Two Sample	**Official Results:**	Yes

Data Transform	Zeta	Alt Hyp	MC Trials	Test Result	PMSD
Angular (Corrected)	0	C > T	Not Run	Sample passes 96h survival rate endpoint	11.2%

Wilcoxon Rank Sum Two-Sample Test

Control	vs	Conc-%	Test Stat	Critical	DF	Ties	P-Value	Decision(α:5%)
Lab Control		100	16		6	1	0.3429	Non-Significant Effect

ANOVA Table

Source	Sum Squares	Mean Square	DF	F Stat	P-Value	Decision(α:5%)
Between	0.007088488	0.007088488	1	1	0.3559	Non-Significant Effect
Error	0.04253092	0.007088488	6			
Total	0.04961941	0.01417698	7			

Distributional Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:1%)
Variances	Mod Levene Equality of Variance	1	13.75	0.3559	Equal Variances
Distribution	Shapiro-Wilk W Normality	0.7065	0.6451	0.0027	Non-normal Distribution

96h Survival Rate Summary

Conc-%	Control Type	Count	Mean	95% LCL	95% UCL	Min	Max	Std Err	Std Dev	CV%	%Effect
0	Lab Control	4	1	1	1	1	1	0	0	0.0%	0.0%
100		4	0.95	0.912	0.988	0.8	1	0.05	0.1	10.53%	5.0%

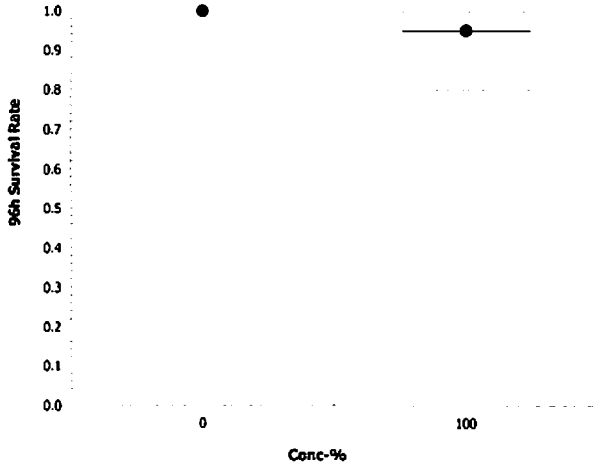
Angular (Corrected) Transformed Summary

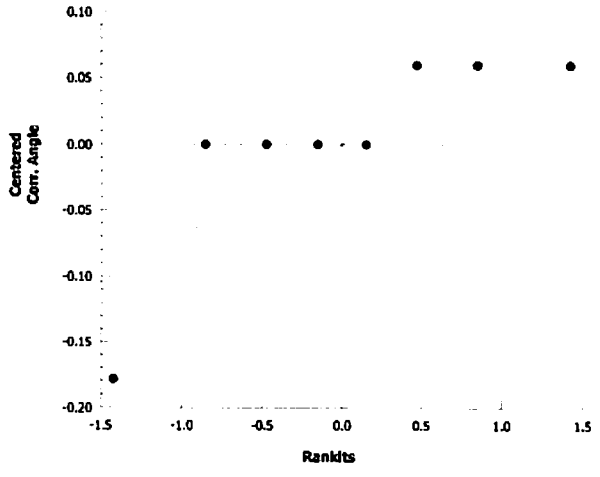
Conc-%	Control Type	Count	Mean	95% LCL	95% UCL	Min	Max	Std Err	Std Dev	CV%	%Effect
0	Lab Control	4	1.345	1.345	1.345	1.345	1.345	0	0	0.0%	0.0%
100		4	1.286	1.24	1.331	1.107	1.345	0.05953	0.1191	9.26%	4.43%

96h Survival Rate Detail

Conc-%	Control Type	Rep 1	Rep 2	Rep 3	Rep 4
0	Lab Control	1	1	1	1
100		1	0.8	1	1

Graphics





96-hour Freshwater Acute Bioassay
Static-Renewal Conditions

Water Quality Measurements
& Test Organism Survival

Client: MWH
Sample ID: ~~RO-treated~~ Effluent
Test No.: 1111-5172

Test Species: *C. dubia*
Start Date/Time: 11/15/2011 1520
End Date/Time: 11/19/2011 1345

	Tech Initials				
	0	24	48	72	96
Counts:	JP	JP	JP	ES	JW
Readings:	JV	JF	JF	ES	ES
Dilutions made by:	PA		AD		

Concentration (%)	Rep	Number of Live Organisms					Conductivity (µmhos/cm)					Temperature (°C)					Dissolved Oxygen (mg/L)					pH (units)				
		0	24	48	72	96	0	24	48	72	96	0	24	48	72	96	0	24	48	72	96	0	24	48	72	96
	A	5	5	5	5	5	194	195	i 193	196	197	25.1	26.0	i 24.0	25.1	25.1	7.8	7.9	i 7.5	7.5	7.4	8.25	8.33	i 8.00	8.23	8.27
Lab Control	B	5	5	5	5	5			i 219					i 24.3					i 8.1					i 8.29		
	C	5	5	5	5	5																				
	D	5	5	~~4~~ 5	5	5																				
	A	5	5	5	5	5	302	306	i 298	320	325	25.0	26.0	i 24.2	24.9	25.1	8.9	8.0	i 8.3	7.8	7.9	8.45	8.19	i 8.60	8.02	8.65
100%	B	5	~~3~~ 4	4	4	4			i 344					i 24.3					i 8.2					i 8.20		
	C	5	5	5	5	5																				
	D	5	5	5	5	5																				
	A	5	5	5	5	5	249	248	i 246	258	258	25.9	26.0	i 24.8	25.3	25.4	8.0	8.0	i 8.4	7.6	7.6	8.41	8.04	i 8.46	8.01	8.07
Reference	B	5	5	5	5	5			i 282					i 24.3					i 8.2					i 8.10		
Control	C	5	5	5	5	5																				
	D	5	5	5	5	5																				
	A	~~5~~ 5 JP							i					i					i					i		
	B	~~5~~ 5							f					f					f					f		
	C	~~5~~ 5																								
	D	~~5~~ 5																								

Initial Counts QC'd by: JF

Animal Source/Date Received: Internal / NA

Age at Initiation: < 24 hours

	Feeding Times				
	0	24	48	72	96
AM:	–	–	1235	–	–
PM:	–	–	–	–	–

Comments: i = initial reading in fresh test solution, f = final reading in test chamber prior to renewal

Organisms fed prior to initiation, circle one (y / n)

QC Check: SC 12-1-11

Final Review: KL 12-14-11

Nautilus Environmental, LLC. 4340 Vandever Avenue. San Diego, CA 92120.

Acute Fathead Minnow

CETIS Summary Report

Report Date: 02 Dec-11 14:45 (p 1 of 1)
Test Code: 1111-S173 | 18-0461-7389

Fathead Minnow 96-h Acute Survival Test — **Nautilus Environmental (CA)**

Batch ID:	10-6545-1767	**Test Type:**	Survival (96h)	**Analyst:**	
Start Date:	15 Nov-11 15:20	**Protocol:**	EPA/821/R-02-012 (2002)	**Diluent:**	Not Applicable
Ending Date:	19 Nov-11 14:00	**Species:**	Pimephales promelas	**Brine:**	Not Applicable
Duration:	95h	**Source:**	Aquatic Biosystems, CO	**Age:**	10d

Sample ID:	01-3036-2812	**Code:**	11-0951	**Client:**	MWH Labs
Sample Date:	14 Nov-11 07:20	**Material:**	~~POTW~~ FC Effluent Sample	**Project:**	
Receive Date:	14 Nov-11 10:55	**Source:**	MWH Labs		
Sample Age:	32h	**Station:**	SD AWPF		

Comparison Summary

Analysis ID	Endpoint	NOEL	LOEL	TOEL	PMSD	TU	Method
06-3388-2429	96h Survival Rate	100	>100	N/A	10.8%	10.0	Wilcoxon Rank Sum Two-Sample Test

Test Acceptability

Analysis ID	Endpoint	Attribute	Test Stat	TAC Limits	Overlap	Decision
06-3388-2429	96h Survival Rate	Control Resp	0.95	0.9 - NL	Yes	Passes Acceptability Criteria

96h Survival Rate Summary

Conc-%	Control Type	Count	Mean	95% LCL	95% UCL	Min	Max	Std Err	Std Dev	CV%	%Effect
0	Rec. Water	4	1	1	1	1	1	0	0	0.0%	0.0%
0	Lab Control	4	0.95	0.9127	0.9873	0.8	1	0.05	0.1	10.53%	5.0%
100		4	1	1	1	1	1	0	0	0.0%	0.0%

96h Survival Rate Detail

Conc-%	Control Type	Rep 1	Rep 2	Rep 3	Rep 4
0	Rec. Water	1	1	1	1
0	Lab Control	1	1	0.8	1
100		1	1	1	1

CETIS Analytical Report

Report Date: 02 Dec-11 14:45 (p 1 of 1)
Test Code: 1111-S173 | 18-0461-7389

Fathead Minnow 96-h Acute Survival Test — **Nautilus Environmental (CA)**

Analysis ID:	06-3388-2429	**Endpoint:**	96h Survival Rate	**CETIS Version:**	CETISv1.8.0
Analyzed:	02 Dec-11 14:43	**Analysis:**	Nonparametric-Two Sample	**Official Results:**	Yes

Data Transform	Zeta	Alt Hyp	MC Trials	Test Result	PMSD
Angular (Corrected)	0	C > T	Not Run	Sample passes 96h survival rate endpoint	10.8%

Wilcoxon Rank Sum Two-Sample Test

Control	vs	Conc-%	Test Stat	Critical	DF	Ties	P-Value	Decision(α:5%)
Lab Control		100	20		6	1	0.6571	Non-Significant Effect

ANOVA Table

Source	Sum Squares	Mean Square	DF	F Stat	P-Value	Decision(α:5%)
Between	0.007088488	0.007088488	1	1	0.3559	Non-Significant Effect
Error	0.04253092	0.007088488	6			
Total	0.04961941	0.01417698	7			

Distributional Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:1%)
Variances	Mod Levene Equality of Variance	1	13.75	0.3559	Equal Variances
Distribution	Shapiro-Wilk W Normality	0.7065	0.6451	0.0027	Non-normal Distribution

96h Survival Rate Summary

Conc-%	Control Type	Count	Mean	95% LCL	95% UCL	Min	Max	Std Err	Std Dev	CV%	%Effect
0	Lab Control	4	0.95	0.912	0.988	0.8	1	0.05	0.1	10.53%	0.0%
100		4	1	1	1	1	1	0	0	0.0%	-5.26%

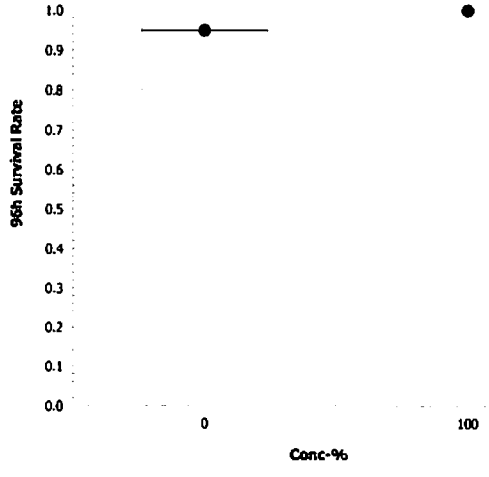
Angular (Corrected) Transformed Summary

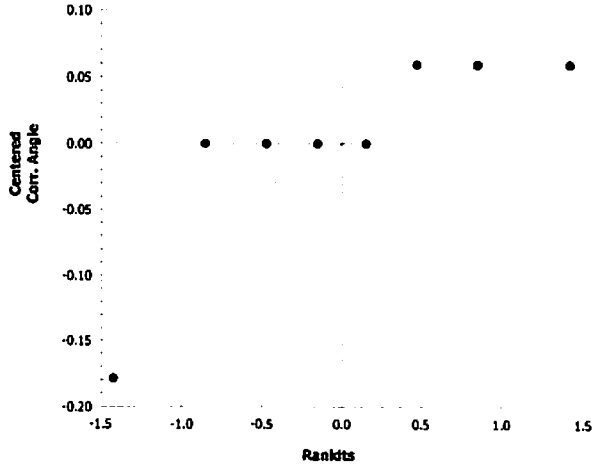
Conc-%	Control Type	Count	Mean	95% LCL	95% UCL	Min	Max	Std Err	Std Dev	CV%	%Effect
0	Lab Control	4	1.286	1.24	1.331	1.107	1.345	0.05953	0.1191	9.26%	0.0%
100		4	1.345	1.345	1.345	1.345	1.345	0	0	0.0%	-4.63%

96h Survival Rate Detail

Conc-%	Control Type	Rep 1	Rep 2	Rep 3	Rep 4
0	Lab Control	1	1	0.8	1
100		1	1	1	1

Graphics





96-hour Freshwater Acute Bioassay
Static-Renewal Conditions

Water Quality Measurements
& Test Organism Survival

Client: MWH
Sample ID: ~~RO treated~~ Effluent
Test No.: 1111-S173

Test Species: *P. promelas*
Start Date/Time: 11/15/2011 1520
End Date/Time: 11/19/2011 1400

Tech Initials	0	24	48	72	96
Counts:	JG	JP	JF	JP	JF
Readings:	JW	JF	JF	ES	ES
Dilutions made by:	PA		AD		

Concentration (%)	Rep	Number of Live Organisms 0	24	48	72	96	Conductivity (µmhos/cm) 0	24	48	72	96	Temperature (°C) 0	24	48	72	96	Dissolved Oxygen (mg/L) 0	24	48	72	96	pH (units) 0	24	48	72	96
	A	5	5	5	5	5	195	204	i 195	198	206	25.6	25.9	i 24.2	25.4	24.0	7.2	7.5	i 6.9	7.4	7.7	8.25	8.11	i 8.07	8.07	8.16
Lab Control	B	5	5	5	5	5			i 207					i 25.1					i 6.5					i 8.01		
	C	5	5	5	5	4																				
	D	5	5	5	5	5																				
	A	5	5	5	5	5	305	313	i 303	321	343	25.2	25.7	i 26.0	25.3	23.8	8.0	7.7	i 8.1	6.7	8.0	8.60	7.97	i 8.60	7.56	7.84
100%	B	5	5	5	5	5			i 317					i 25.1					i 6.4					i 7.84		
	C	5	5	5	5	5																				
	D	5	5	5	5	5																				
	A	5	5	5	5	5	247	260	i 248	265	279	25.1	25.3	i 25.3	24.9	23.8	8.2	7.8	i 8.5	7.3	7.9	8.43	7.83	i 8.46	7.79	8.03
Reference	B	5	5	5	5	5			i 217					i 25.0					i 6.6					i 7.76		
Control	C	5	5	5	5	5																				
	D	5	5	5	5	5																				
	A	~~5~~							i					i					i					i		
	B	~~5~~	JW						f					f					f					f		
	C	~~5~~																								
	D	~~5~~																								

Initial Counts QC'd by: AG
Animal Source/Date Received: ABS 11/15/11
Age at Initiation: 10 days

Feeding Times	0	24	48	72	96
AM:	–	–	0830	–	–
PM:	–	–	–	–	–

Comments: i = initial reading in fresh test solution, f = final reading in test chamber prior to renewal
Organisms fed prior to initiation, circle one (y / n)

QC Check: CZ 11/21/11
Final Review: SC 12-1-11

Nautilus Environmental, LLC. 4340 Vandever Avenue. San Diego, CA 92120.

Appendix C

Sample Receipt Information

& Mixing Worksheet

Nautilus Environmental
4340 Vandever Avenue
San Diego, CA 92120

Client: MWH
Sample ID: San Diego AWPF
Test ID No(s).: 1111-S169 to 174

Sample Check-In Information

	Lake Murray	SIO Effluent	SIO Eff.	SIO Eff.
Sample (A, B, C):	Aquaduct	A	B	C
Log-in No. (11-xxxx):	0952	0951	0960	0976
Sample Collection Date & Time:	11/14/11 0928	11/14/11 0720	11/16/11 0850	11/18/11 0719
Sample Receipt Date & Time:	11/14/11 1055 →		11/16/11 0925	11/18/11 0900
Number of Containers & Container Type:	2-10L cubis	1-4L cubi	1-4L cubi	1-4L cubi
Approx. Total Volume Received (L):	~20L	~4L	≈3.5L	~4L
Check-in Temperature (°C)	13.8	13.5	20.6	15.6
Temperature OK? [1]	(Y) N	(Y) N	(Y) N	(Y) N
DO (mg/L)	ES ~~6.84~~ 9.3	9.8	6.5	8.9
pH (units)	8.00	~~6~~ ES 5.68	5.61	5.27
Conductivity (µS/cm)	684	18.6	20	22.6
TDS (mg/L)	329	8.0	9.6	11.0
Alkalinity (mg/L)*	95	0.0	3	3
Hardness (mg/L)* a	170	0.0	1	7
Total Chlorine (mg/L)	0.06	0.57	0.70	0.53
Technician Initials	ES	ES	ES	LN

Sample Description:
Lake Murray: colorless, clear, odorless, no debris
SIO A: colorless, clear, odorless, no debris
SIO B: Clear, colorless, odorless, no debris
SIO C: colorless, clear, odorless, no debris

COC Complete (Y/N)?
A ✓ B ✓ C ✓

Filtration? Y (N)
Pore Size: _____
Organisms or Debris

Salinity Adjustment? Y (N)
Artificial Salts: target ppt: _____
Hypersaline Brine: target ppt: _____
Tests: _____
pH Adjustment? Y N (see worksheet)

	A	B	C
Initial pH:			
Amount of HCl added:			
Final pH:			

Cl_2 Adjustment? Y N (see worksheet)

	A (SIO Eff)	B (SIO Eff)	C
Initial Free Cl_2:	0.32	~~0.70~~ 0.14	0.28
STS added:			
Final Free Cl_2:			

Test Performed: Ceriio Acute & Chronic
Laboratory Control: 20% diluted mineral water (8:2) Alkalinity: 80 Hardness: 86
Reference Control: DI water + Aquaduct water Alkalinity: 41-48 Hardness: 52-54

Test Performed: Fathead Acute & Chronic
Laboratory Control: 20% diluted mineral water (8:2) Alkalinity: 80 Hardness: 86
Reference Control: DI water + Aquaduct water Alkalinity: 41-48 Hardness: 52-54

Additional Comments: _____

Notes: [1] Temperature of sample should be 0-6°C, if received more than 24 hours past collection time.
* = mg/L as CaCO3, a = Measured for freshwater samples only, NA = Not Applicable

QC Check: BC 12-1-11
Final Review: KL 12-4-11

Nautilus Environmental
4340 Vandever Avenue
San Diego, CA 92120

Client: MWH - SD AWPF
Sample ID: MIXING WORKSHEET
Test ID No(s).: 1111-5169 to 174

Sample Check-In Information

Sample Mixtures (A, B, C):	Aquaduct + "A" Sample	Aquaduct + "B" Sample	Aquaduct + "C" Sample	Reference Control A	Reference Control B	Reference Control C
Percent Aquaduct Water (%):	33	33	33	34	34	34
Percent ~~RO treated~~ UV/AOP SC Sample (%):	67	67	67	66	66	66
Final Hardness of Mixture (aim for 50 mg/L):	51 mg/L	52 mg/L	53 mg/L	52 mg/L	53 mg/L	54 mg/L
Initial pH (units):	7.07	7.04	7.12	7.87	7.94	8.02
Adjust to pH 8.5 with NaOH	11 drops 1.0N NaOH	13 drops 1.0N NaOH	14 drops 1.0N NaOH	5 drops 1.0N NaOH	3 drops 1.0 NaOH	4 drops 1.0N NaOH
Final pH (units):	8.48	8.40	8.47	8.54	8.43	8.54
DO (mg/L)	8.9	9.0	8.7	8.0	8.6	8.5
Conductivity (µS/cm)	302	294	283	249	251	246
TDS (mg/L)	145	141	131	119	121	117
Alkalinity (mg/L)	39	JF ~~>1000~~ 38	43	41	JF ~~>~~ 46	48
Initial Free Chlorine (mg/L)	0.18	0.04	0.14	<0.02	<0.02	0.03
Add STS* to dechlorinate:	100mg → 4.5L	100mg → 4.5L	100mg → 4.5L	—	—	—
Final Free Chlorine (mg/L)	0.02	0.02	0.03	—	—	—
Technician Initials	[illegible]	PA/JF	[illegible]	[illegible]	PA/JF	[illegible]

Test Performed: Ceriodaphnia and Fathead (Acute + Chronic)

Laboratory Control: 20% diluted mineral water (8:2) Alkalinity: 80 Hardness: 86

Reference Control: DI water + Aquaduct water Alkalinity: 41-48 Hardness: 52-54

Additional Comments:

Test Performed: _____

Laboratory Control: 20% diluted mineral water (8:2) Alkalinity: _____ Hardness: _____

Reference Control: DI water + Aquaduct water Alkalinity: _____ Hardness: _____

Notes:

* Sodium Thiosulfate (STS) should remove both chlorine and peroxide.

QC Check: SC 12-1-11

Final Review: KL 12-14-11

Appendix D

Chain-of-Custody Forms

And Data Qualifier Codes

Nautilus Environmental
4340 Vandever Avenue
San Diego, CA 92120
Phone 858.587.7333
Fax 858.587.3961

Chain of Custody

Date 11/14/11 Page 1 of 1

Sample Collection By: Michelle Berens / James Wright

Report to:		Invoice To:	
Company	MWH	Company	
Address	9444 Farnham St, Suite 300	Address	
City/State/Zip	San Diego, CA 92123	City/State/Zip	
Contact	Jay DeCarolis	Contact	
Phone	619-204-2537	Phone	
Email	james.decarolis@mwhglobal.com	Email	

ANALYSES REQUIRED

	SAMPLE ID	DATE	TIME	MATRIX	CONTAINER TYPE	NO. OF CONTAINERS	COMMENTS	~~[illegible]~~	WET Toxicity	Receipt Temperature (°C)
1	S10_11-14-11	11/14/11	7:20	water	1 gal	1	peroxide = 3 mg/L ; pH = 5.51		X	13.5
2					plastic		temp = 22.5°C ; Free Cl_2 = 0.05 mg/L			
3							tot Cl_2 = 1.04 mg/L ; cond = 16.89 mS/cm			
4	Lake Murray_11-14-11	11/14/11	9:28	water	3	2			X	13.8
5					2.5 gal					
6					plastic					
7										
8										
9										
10										

PROJECT INFORMATION		SAMPLE RECEIPT	
Client:	MWH	Total No. of Containers	3
PO No.:		Received Good Condition?	✓
Shipped Via:		Matches Test Schedule?	✓

SPECIAL INSTRUCTIONS/COMMENTS:

RELINQUISHED BY (CLIENT)	RECEIVED BY (COURIER)
(Signature) [signature] (Time) 10:55	(Signature) (Time)
(Printed Name) James Wright (Date) 11/14/11	(Printed Name) (Date)
(Company) MWH	(Company)

RELINQUISHED BY (COURIER)	RECEIVED BY (LABORATORY)
(Signature) (Time)	(Signature) [signature] (Time) 1055
(Printed Name) (Date)	(Printed Name) Elli Slaughter (Date) 11/14/11
(Company)	(Company) Nautilus Log In No. 11-0951 -0952

Additional costs maybe required for sample disposal or storage.
Payment Net 30 unless otherwise contracted.

DISTRIBUTION: WHITE - Nautilus Environmental, COLOR - Originator

Nautilus Environmental
4340 Vandever Avenue
San Diego, CA 92120
Phone 858.587.7333
Fax 858.587.3961

Chain of Custody

Date 11/16/11 Page 1 of 1

Sample Collection By: Michelle Ryan / James Wright

Report to:

Company	MWH
Address	9444 Spectrum St Ste 300
City/State/Zip	San Diego, CA 92123
Contact	Jay DeCarolis
Phone	619-204-2537
Email	James.decarolis@mwhglobal.com

Invoice To:

Company	
Address	
City/State/Zip	
Contact	
Phone	
Email	

ANALYSES REQUIRED

	SAMPLE ID	DATE	TIME	MATRIX	CONTAINER TYPE	NO. OF CONTAINERS	COMMENTS	WET TOXICITY	Receipt Temperature (°C)
1	S10 - 11-16-11	11/16/2011	8:50	W	1 gal plastic	1	free Cl 0.02 mg/L	X	20.6
2							total Cl 0.39 mg/L		
3							pH 5.38		
4							conductivity 18.98 µS/cm		
5							H_2O_2 3 mg/L		
6									
7									
8									
9									
10									

PROJECT INFORMATION		SAMPLE RECEIPT	
Client:	MWH	Total No. of Containers	1
PO No.:		Received Good Condition?	Y
Shipped Via:		Matches Test Schedule?	Y

SPECIAL INSTRUCTIONS/COMMENTS:

RELINQUISHED BY (CLIENT)		RECEIVED BY (COURIER)	
(Signature)	(Time) 0925	(Signature)	(Time)
(Printed Name) James Wright	(Date) 11/16/11	(Printed Name)	(Date)
(Company) MWH		(Company)	

RELINQUISHED BY (COURIER)		RECEIVED BY (LABORATORY)	
(Signature)	(Time)	(Signature) Jessica Anderson	(Time) 0925
(Printed Name)	(Date)	(Printed Name) Jessica Andersen	(Date) 11/16/11
(Company)		(Company) 11-0960	

Additional costs maybe required for sample disposal or storage.
Payment Net 30 unless otherwise contracted.

DISTRIBUTION: WHITE - Nautilus Environmental, COLOR - Originator

Nautilus Environmental
4340 Vandever Avenue
San Diego, CA 92120
Phone 858.587.7333
Fax 858.587.3961

Chain of Custody

Date 11/18/11 Page 1 of 1

Sample Collection By: Michelle Berens

Report to:

Company	MWH
Address	9444 Farnham St Ste 300
City/State/Zip	San Diego, CA 92123
Contact	Jay DeCarolis
Phone	619-204-2557
Email	james.decarolis@mwhglobal.com

Invoice To:

Company	
Address	
City/State/Zip	
Contact	
Phone	
Email	

ANALYSES REQUIRED

	SAMPLE ID	DATE	TIME	MATRIX	CONTAINER TYPE	NO. OF CONTAINERS	COMMENTS	NET Tox	Receipt Temperature (°C)
1	S10-11-18-11	11/18/11	0719	W	1 gal poly	1	pH = 5.60 temp = 21.1°C	X	5.6
2							free Cl_2 = 0.04 mg/L		
3							tot Cl_2 = 0.72 mg/L		
4							peroxide = 3.0 mg/L		
5							conductivity = ~~355~~ 18.44 µS/cm		
6									
7									
8									
9									
10									

PROJECT INFORMATION		SAMPLE RECEIPT	
Client:	MWH	Total No. of Containers	1
PO No.:		Received Good Condition?	✓
Shipped Via:		Matches Test Schedule?	✓

SPECIAL INSTRUCTIONS/COMMENTS:

RELINQUISHED BY (CLIENT)	RECEIVED BY (COURIER)
(Signature) (Time) 0900	(Signature) (Time)
(Printed Name) James Wright (Date) 11/18/11	(Printed Name) (Date)
(Company) MWH	(Company)

RELINQUISHED BY (COURIER)	RECEIVED BY (LABORATORY)
(Signature) (Time)	(Signature) (Time) 0900
(Printed Name) (Date)	(Printed Name) Ashley Donohue (Date) 11/18/11
(Company)	(Company) Nautilus 11-0976

Additional costs maybe required for sample disposal or storage.
Payment Net 30 unless otherwise contracted.

DISTRIBUTION: WHITE - Nautilus Environmental, COLOR - Originator

Nautilus Environmental

Glossary of Qualifier Codes:

Q1 - Temperatures out of recommended range; corrective action taken and recorded in Test Temperature Correction Log

Q2 - Temperatures out of recommended range; no action taken, test terminated same day

Q3 - Sample aerated prior to initiation or renewal due to dissolved oxygen (D.O.) levels below 6.0 mg/L

Q4 - Test aerated; D.O. levels dropped below 4.0 mg/L

Q5 - Test initiated with aeration due to an anticipated drop in D.O.

Q6 - Airline obstructed or fell out of replicate and replaced; drop in D.O. occurred

Q7 - Salinity out of recommended range; refer to QA section of report

Q8 - Spilled test chamber/ Unable to recover test organism(s)

Q9 - Inadequate sample volume remaining, 50% renewal performed

Q10 - Inadequate sample volume remaining, no renewal performed

Q11 - Sample out of holding time; refer to QA section of report

Q12 - Replicate(s) not initiated; excluded from data analysis

Q13 - Survival counts not recorded due to poor visibility or heavy debris

Appendix B

Quality Control Sample Results & Project Advisory Team Expert Review Memorandum Dr. Andy Eaton

Table B-1 Summary of QC Samples Collected Q1, Q2, Q3, and Q4 Testing Periods

Date	Laboratory	QC Sample Type	Sample Location (s)	Compounds
8/15/2011	CSM / MWH	split	S6, S9, S10	CEC's
8/15/2011	CSM	field blank	NA	CEC's
8/24/2011	WECK	blind duplicate	S10	Compounds monitored quarterly
8/24/2011	MWH / WECK	split	S10	Compounds monitored quarterly
9/1/2011	MWH	travel blank	NA	CEC's
9/14/2011	MWH	blind duplicate	S9	CEC's
9/14/2011	MWH	travel blank	NA	CEC's
10/17/2011	MWH	blind duplicate	S1	CEC's
10/17/2011	MWH	travel blank	NA	CEC's
11/2/2011	MWH /WECK	split	S1, S6, S7, S8, S9, S10	1,4 dioxane, NDMA
11/8/2011	WECK	blind duplicate	S1	Compounds monitored quarterly
11/8/2011	MWH	blind duplicate	S1	CEC's
11/8/3011	MWH	travel blank	NA	CEC's
11/8/2011	CSM / MWH	split	S1, S6, S9, S10, Imported	CEC's
11/8/2011	CSM	field blank	NA	CEC's
2/1/2012	CSM	field blank	NA	CEC's
2/1/2012	MWH	field blank	NA	CEC's
2/1/2012	CSM / MWH	split	S1, S6, S9, S10, Imported	CEC's
2/1/2012	MWH	blind duplicate	S6	CEC's
2/1/2012	WECK	blind duplicate	Imported Water	Compounds monitored quarterly
2/1/2012	MWH / WECK	spilt	S6, S9, S10	NDMA
2/8/2012	MWH / WECK	split	S9, S10	Formaldehyde
2/8/2012	MWH / WECK	spilt	S6, S9, S10	NDMA
2/8/2012	MWH	field blank	NA	CEC's
2/15/2012	MWH	field blank	NA	CEC's
2/15/2012	MWH / WECK	split	(S9, 10) / (S6, S9, S10)	Formaldehyde, TOC
2/22/2012	MWH	field blank	NA	CEC's
2/22/2012	MWH / WECK	split	(S9, 10) / (S10)	Formaldehyde, TOC
5/1/2012	WECK	blind duplicate	S10	Compounds monitored quarterly
5/1/2012	CSM	field blank	NA	CEC's
5/1/2012	MWH	field blank	NA	
5/1/2012	MWH	blind duplicate	S10	CEC's
5/1/2012	CSM / MWH	split	S6, S9, S10	CEC's
5/1/2012	MWH	field blank (1 L and 40 mL)	NA	CEC's
5/1/2012	MWH	duplicate (1 L and 40 mL)	S10	CEC's
7/30/2012	MWH	field blank (40 mL, 250 mL, 500 mL, 1 L)	NA	Triclosan, DEET
7/30/2012	MWH	duplicate (40 mL, 250 mL, 500 mL, 1 L)	S10	Triclosan, DEET

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Table B-2 Summary of Blind Duplicate Samples from Quarterly Sampling Event Number 1 Results (8/24/11)

No.	Compound	MDL	RL	S10 Grab	Blind Duplicate	Difference	RPD (Actual)	RPD (Acceptance Criteria 1a & 2a)	RPD (Acceptance Criteria 2a & 2b)	Governing RPD	PASS / FAIL	NOTES
1	Bromodichloromethane	0.09	0.5	0.78	0.76	0.02	3%	32%	50%	50%	PASS	
2	Chloroform	0.12	0.5	1.4	1.5	0.1	7%	17%	20%	20%	PASS	
3	Methylene chloride	0.14	0.5	0.2	0.21	0.01	5%	122%	50%	122%	PASS	
4	THM's, Total	0.6	2	2.2	2.3	0.1	4%	44%	50%	50%	PASS	
5	2-Butanone	0.72	5	0.72	0.96	0.24	29%	298%	50%	298%	PASS	
6	Diethylphthalate	0.15	1	0.98	0.15	0.83	147%	88%	50%	88%	FAIL	Deemed acceptable as both results were below the RL.
7	Dimethylphthalate	0.07	2	0.21	0.07	0.14	100%	714%	50%	714%	PASS	
8	Di-n-butylphthalate	0.24	1	2.2	0.24	1.96	161%	41%	20%	41%	FAIL	Phthalates are prone to field and lab contamination and possible cause for poor precision.
9	Diethylphthalate	0.22	2	0.31	0.22	0.09	34%	377%	50%	377%	PASS	
10	Aluminum	0.61	5	3.6	7.5	3.9	70%	45%	50%	50%	FAIL	Original sample below the RL. Follow up with lab required.
11	Boron	0.28	1	240	240	0	0%	0%	20%	20%	PASS	
12	Calcium	0.016	0.1	0.025	0.033	0.008	28%	172%	50%	172%	PASS	
13	Lithium	1.4	10	1.4	1.4	0	0%	357%	50%	357%	PASS	
14	Lead	0.011	0.2	0.03	0.05	0.02	50%	250%	50%	250%	PASS	
15	Mercury	0.0039	0.05	0.016	0.014	0.002	13%	167%	50%	167%	PASS	
16	Potassium	0.081	0.1	0.31	0.47	0.16	41%	13%	20%	20%	FAIL	Poor precision, but difference is reasonable for the method at the low concentrations.
17	Sodium	0.015	0.5	3.2	3.3	0.1	3%	8%	20%	20%	PASS	
18	Vanadium	0.047	0.5	0.05	0.22	0.17	126%	185%	50%	185%	PASS	
19	Chloride	0.1	0.5	2.8	2.8	0	0%	9%	20%	20%	PASS	
20	Fluoride	0.02	0.1	0.025	0.02	0.005	22%	222%	50%	222%	PASS	
21	Sulfate	0.1	0.5	0.1	0.16	0.06	46%	192%	50%	192%	PASS	
22	Total anions	0.02	0.078	0.18	0.19	0.01	5%	21%	20%	21%	PASS	
23	Total cations	0.0045	0.038	0.15	0.16	0.01	6%	12%	20%	20%	PASS	
24	pH (units)	0.1	0.1	5.82	5.96	0.14	2%	1%	20%	20%	PASS	
25	Odor	1	1	1	1	0	0%	50%	50%	50%	PASS	
26	Nitrate	0.18	0.5	3.1	3.1	0	0%	8%	20%	20%	PASS	
27	Nitrite/Nitrate as N	10	100	700	700	0	0%	7%	20%	20%	PASS	
28	Total dissolved solids	4	10	16	14	2	13%	33%	50%	50%	PASS	
29	Specific Conductance	0.23	2	22	22	0	0%	5%	20%	20%	PASS	
30	Total organic carbon	0.009	0.3	0.86	0.48	0.38	57%	22%	20%	22%	FAIL	Suggests either inhomogeneity or a problem with the method at these methods. Additional split samples collected. Issue resolved.
31	Total alkalinity	0.56	2	2.6	3	0.4	14%	36%	50%	50%	PASS	
32	Bicarbonate alkalinity	0.56	2	3.2	3.6	0.4	12%	29%	50%	50%	PASS	
33	Langelier Index @20C	-10	-10	-6.64	-6.32	0.32	-5%	77%	20%	77%	PASS	
34	Langelier Index @60C	-10	-10	-6.1	-5.79	0.31	-5%	84%	20%	84%	PASS	
35	Acetaldehyde	0.34	2	0.8	0.37	0.43	74%	171%	50%	171%	PASS	
36	Cyclohexanone	0.38	2	0.72	1.1	0.38	42%	110%	50%	110%	PASS	
37	Formaldehyde	0.26	2	8.9	9.4	0.5	5%	11%	20%	20%	PASS	
38	N-Nitrosodimethylamine	0.28	2	0.35	0.28	0.07	22%	317%	50%	317%	PASS	

Note: Criteria 1 = a) If the result of the original sample was within 2 X RL then the difference in results between the two samples should be ± 1/2 RL or b) the relative percent difference (RPD) should be 50%), whichever is higher. Criteria 2 = a) If the result of the original sample was >2 X RL then the difference in results between the two samples should be ± 1/2 RL or b) RPD of 20%, whichever higher.

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Table B-3 Summary of Blind Duplicate Samples from Quarterly Sampling Event Number 2 Results (11/8/11)

No.	Compound	MDL	RL	Units	S1 Sample	Blind Duplicate	Difference	RPD (Actual)	RPD (Acceptance Criteria 1a & 2a)	RPD (Acceptance Criteria 2a & 2b)	Governing RPD	PASS / FAIL	NOTES
1	Aluminum, Total	0.61	5	ug/l	8.8	9	0.2	2%	28%	50%	50%	PASS	
2	Antimony, Total	0.04	0.5	ug/l	0.53	0.52	0.01	2%	48%	50%	50%	PASS	
3	Arsenic, Total	0.036	0.4	ug/l	0.98	0.96	0.02	2%	21%	20%	21%	PASS	
4	Barium, Total	0.03	0.5	ug/l	18	18	0	0%	1%	20%	20%	PASS	
5	Chromium, Total	0.074	0.2	ug/l	0.56	0.58	0.02	4%	18%	20%	20%	PASS	
6	Copper, Total	0.27	0.5	ug/l	1.8	1.8	0	0%	14%	20%	20%	PASS	
7	Fluoride, Total	0.04	0.2	mg/l	0.63	0.63	0	0%	16%	20%	20%	PASS	
8	Gross Alpha	0	0	pCi/L	5.78+/-0.393 MDA=0.016	3.74+/-0.32 MDA=0.016	2.04	43%	0%	20%	20%	NA	Criteria not applicable results provided with different counting errors and MDAs.
9	HAA5, Total		1	ug/l	1.5	1.6	0.1	6%	32%	50%	50%	PASS	
10	Nickel, Total	0.13	0.8	ug/l	3.5	3.6	0.1	3%	11%	20%	20%	PASS	
11	Nitrate as NO3	0.36	1	mg/l	70	70	0	0%	1%	20%	20%	PASS	
12	NO2+NO3 as N	20	200	ug/l	16000	16000	0	0%	1%	20%	20%	PASS	
13	Perchlorate	0.95	2	ug/l	4.9	5.2	0.3	6%	20%	20%	20%	PASS	
14	Selenium, Total	0.28	0.4	ug/l	0.57	0.5	0.07	13%	37%	50%	50%	PASS	
15	Aluminum, Total	0.61	5	ug/l	8.8	9	0.2	2%	28%	50%	50%	PASS	
16	Chloride, Total	1	5	mg/l	240	240	0	0%	1%	20%	20%	PASS	
17	Color		3	Color Units	20	20	0	0%	8%	20%	20%	PASS	
18	Copper, Total	0.27	0.5	ug/l	1.8	1.8	0	0%	14%	20%	20%	PASS	
19	Iron, Total	1.1	10	ug/l	73	72	1	1%	7%	20%	20%	PASS	
20	Manganese, Total	0.11	0.2	ug/l	70	71	1	1%	0%	20%	20%	PASS	
21	Specific Conductance (EC)	0.23	2	umhos/cm	1100	1100	0	0%	0%	20%	20%	PASS	
22	Sulfate as SO4	1	5	mg/l	130	130	0	0%	2%	20%	20%	PASS	
23	Threshold Odor Number		1	T.O.N.	2	1	1	67%	33%	50%	50%	FAIL	Poor precision, but difference is reasonable for the method at the low concentrations.
24	Total Dissolved Solids	4	10	mg/l	760	680	80	11%	1%	20%	20%	PASS	
25	Zinc, Total	1.1	5	ug/l	48	49	1	2%	5%	20%	20%	PASS	
26	Antimony, Total	0.04	0.5	ug/l	0.53	0.52	0.01	2%	48%	50%	50%	PASS	
27	Arsenic, Total	0.036	0.4	ug/l	0.98	0.96	0.02	2%	21%	20%	21%	PASS	
28	Bromodichloromethane	0.09	0.5	ug/l	0.58	0.59	0.01	2%	43%	50%	50%	PASS	
29	Chloroform	0.12	0.5	ug/l	0.8	0.83	0.03	4%	31%	50%	50%	PASS	
30	Chromium, Total	0.074	0.2	ug/l	0.56	0.58	0.02	4%	18%	20%	20%	PASS	
31	Copper, Total	0.27	0.5	ug/l	1.8	1.8	0	0%	14%	20%	20%	PASS	
32	Nickel, Total	0.13	0.8	ug/l	3.5	3.6	0.1	3%	11%	20%	20%	PASS	
33	Selenium, Total	0.28	0.4	ug/l	0.57	0.5	0.07	13%	37%	50%	50%	PASS	
34	Zinc, Total	1.1	5	ug/l	48	49	1	2%	5%	20%	20%	PASS	
35	1,4-Dioxane	0.04	0.5	ug/l	5.6	5.8	0.2	4%	4%	20%	20%	PASS	
36	Boron, Total	0.28	1	ug/l	340	350	10	3%	0%	20%	20%	PASS	
37	Chlorate	1.9	20	ug/l	580	650	70	11%	2%	20%	20%	PASS	
38	Formaldehyde	0.26	2	ug/l	6	6.4	0.4	6%	16%	20%	20%	PASS	
39	Manganese, Total	0.11	0.2	ug/l	70	71	1	1%	0%	20%	20%	PASS	
40	N-Nitrosodiethylamine	0.72	2	ng/l	2	2.4	0.4	18%	45%	50%	50%	PASS	
41	N-Nitrosodimethylamine	0.28	2	ng/l	2	2.1	0.1	5%	49%	50%	50%	PASS	
42	N-Nitrosodi-n-propylamine	0.35	2	ng/l	2	3.4	1.4	52%	37%	50%	50%	FAIL	Sample result at RL, RPD close to criteria.
43	Lithium, Total	1.4	10	ug/l	20	22	2	10%	24%	50%	50%	PASS	

Note: Criteria 1 = a) If the result of the original sample was within 2 X RL then the difference in results between the two samples should be ± 1/2 RL or b) the relative percent difference (RPD) should be 50%), whichever is higher. Criteria 2 = a) If the result of the original sample was >2 X RL then the difference in results between the two samples should be ± 1/2 RL or b) RPD of 20%, whichever higher.

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Table B-4 Summary of Blind Duplicate Samples from Quarterly Sampling Event Number 3 Results (2/1/12)

No.	Compound	MDL	RL	Units	Imported Aquifer Water	Blind Duplicate	Difference	RPD (Actual)	RPD (Criteria 1)	RPD (Criteria 2)	Governing RPD	PASS / FAIL	NOTES
1	Aluminum, Total	0.61	5	ug/l	29	29	0	0%	9%	20%	20%	PASS	
2	Arsenic, Total	0.036	0.4	ug/l	2	2	0	0%	10%	20%	20%	PASS	
3	Barium, Total	0.03	0.5	ug/l	47	48	1	2%	1%	20%	20%	PASS	
4	Copper, Total	0.27	0.5	ug/l	3	3.1	0.1	3%	8%	20%	20%	PASS	
5	Fluoride, Total	0.02	0.1	mg/l	0.13	0.12	0.01	8%	40%	50%	50%	PASS	
6	Gross Alpha			pCi/L	2.3+/-0.68 MDA=1	1.5+/-0.642 MDA=1	0.8	42%	0%	20%	20%	NA	Criteria not applicable results provided with different counting errors and MDAs. Results deemed acceptable.
8	HAA5, Total		1	ug/l	5.7	5.4	0.3	5%	9%	20%	20%	PASS	
9	Nickel, Total	0.13	0.8	ug/l	1.1	1.1	0	0%	36%	50%	50%	PASS	
10	Nitrate as NO3	0.18	0.5	mg/l	1.3	1.3	0	0%	19%	20%	20%	PASS	
11	NO2+NO3 as N	0.01	0.1	mg/l	0.3	0.29	0.01	3%	17%	20%	20%	PASS	
14	Selenium, Total	0.28	0.4	ug/l	0.43	0.4	0.03	7%	48%	50%	50%	PASS	
16	THMs, Total	0.6	2	ug/l	33	35	2	6%	3%	20%	20%	PASS	
18	Uranium Rad	0.019	0.13	pCi/L	1.3	1.3	0	0%	5%	20%	20%	PASS	
19	Aluminum, Total	0.61	5	ug/l	29	29	0	0%	9%	20%	20%	PASS	
20	Chloride, Total	1	5	mg/l	63	63	0	0%	4%	20%	20%	PASS	
21	Copper, Total	0.27	0.5	ug/l	3	3.1	0.1	3%	8%	20%	20%	PASS	
22	Iron, Total	1.1	10	ug/l	35	37	2	6%	14%	20%	20%	PASS	
23	Manganese, Total	0.11	0.2	ug/l	4.3	4.4	0.1	2%	2%	20%	20%	PASS	
24	Specific Conductance (EC)	0.47	4	umhos/cm	520	520	0	0%	0%	20%	20%	PASS	
25	Sulfate as SO4	1	5	mg/l	73	73	0	0%	3%	20%	20%	PASS	
26	Total Dissolved Solids	4	10	mg/l	270	270	0	0%	2%	20%	20%	PASS	
27	Turbidity	0.024	0.1	NTU	0.35	0.47	0.12	29%	12%	20%	20%	FAIL	Poor precision, but difference is reasonable for the method at the low concentrations.
28	Arsenic, Total	0.036	0.4	ug/l	2	2	0	0%	10%	20%	20%	PASS	
29	Bromodichloromethane	0.09	0.5	ug/l	11	10	1	10%	2%	20%	20%	PASS	
30	Bromoform	0.19	0.5	ug/l	4	3.8	0.2	5%	6%	20%	20%	PASS	
31	Chloroform	0.12	0.5	ug/l	4.8	4.8	0	0%	5%	20%	20%	PASS	
32	Copper, Total	0.27	0.5	ug/l	3.1	3	0.1	3%	8%	20%	20%	PASS	
33	Dibromochloromethane	0.2	0.5	ug/l	15	14	1	7%	2%	20%	20%	PASS	
34	Nickel, Total	0.13	0.8	ug/l	1.1	1.1	0	0%	36%	50%	50%	PASS	
35	Selenium, Total	0.28	0.4	ug/l	0.4	0.43	0.03	7%	48%	50%	50%	PASS	
36	Boron, Total	0.28	1	ug/l	140	140	0	0%	0%	20%	20%	PASS	
37	Formaldehyde	0.26	2	ug/l	2.7	2.4	0.3	12%	39%	50%	50%	PASS	
38	Manganese, Total	0.11	0.2	ug/l	4.3	4.4	0.1	2%	2%	20%	20%	PASS	
39	Vanadium, Total	0.047	0.5	ug/l	2.7	2.8	0.1	4%	9%	20%	20%	PASS	
40	Lithium, Total	1.4	10	ug/l	14	13	1	7%	37%	50%	50%	PASS	

Note: Criteria 1 = a) If the result of the original sample was within 2 X RL then the difference in results between the two samples should be ± 1/2 RL or b) the relative percent difference (RPD) should be 50%), whichever is higher. Criteria 2 = a) If the result of the original sample was >2 X RL then the difference in results between the two samples should be ± 1/2 RL or b) RPD of 20%, whichever higher.

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Table B-5 Summary of Blind Duplicate Samples from Quarterly Sampling Event Number 4 Results (5/1/12)

No.	Compound	MDL	RL	Units	S10 Sample	Blind Duplicate	Difference	RPD (Actual)	RPD (Criteria 1)	RPD (Criteria 2)	Governing RPD	PASS / FAIL	NOTES
1	Aluminum, Total	0.61	5	ug/l	5	9.1	4.1	58%	35%	50%	50%	FAIL	S10 Result at RL. RPD close to acceptance criteria.
2	Alkalinity as CaCO3	0.56	2	mg/l	3.4	2	1.4	52%	37%	50%	50%	FAIL	Blind Dupe at RL. RPD close to acceptance criteria.
3	Barium, Total	0.03	0.5	ug/l	0.5	0.7	0.2	33%	42%	50%	50%	PASS	
4	Bicarbonate Alkalinity as HCO3	0.56	2	mg/l	4.1	2.4	1.7	52%	31%	20%	31%	FAIL	RPD governing criteria 2 deemed applicable
5	Boron, Total	0.28	1	ug/l	290	290	0	0%	0%	20%	20%	PASS	
6	Chloride, Total	0.1	0.5	mg/l	3.9	3.8	0.1	3%	6%	20%	20%	PASS	
7	Formaldehyde	0.26	2	ug/l	6.5	6.5	0	0%	15%	20%	20%	PASS	
8	Manganese, Total	0.11	0.2	ug/l	0.2	0.22	0.02	10%	48%	50%	50%	PASS	
9	Nitrate as NO3	0.18	0.5	mg/l	4.3	4.3	0	0%	6%	20%	20%	PASS	
11	N-Nitrosodiethylamine	0.8	2.2	ng/l	4.9	2.2	2.7	76%	31%	20%	31%	FAIL	Follow up with lab required. UV/AOP should have removed NDEA.
12	NO2+NO3 as N	0.01	0.1	mg/l	0.97	0.98	0.01	1%	5%	20%	20%	PASS	
13	pH	0.1	0.1	Units	5.89	6.09	0.2	3%	1%	20%	20%	PASS	
14	Potassium, Total	0.081	0.1	mg/l	0.5	0.47	0.03	6%	10%	20%	20%	PASS	
15	Sodium, Total	0.015	0.5	mg/l	4.1	4.1	0	0%	6%	20%	20%	PASS	
16	Specific Conductance (EC)	0.23	2	umhos/cm	26	27	1	4%	4%	20%	20%	PASS	
17	Total Anions	0.02	0.078	meq/l	0.25	0.22	0.03	13%	17%	20%	20%	PASS	
18	Total Cations	0.0045	0.038	meq/l	0.2	0.2	0	0%	10%	20%	20%	PASS	
19	Total Dissolved Solids	4	10	mg/l	11	13	2	17%	42%	50%	50%	PASS	

Note: Criteria 1 = a) If the result of the original sample was within 2 X RL then the difference in results between the two samples should be ± 1/2 RL or b) the relative percent difference (RPD) should be 50%), whichever is higher. Criteria 2 = a) If the result of the original sample was >2 X RL then the difference in results between the two samples should be ± 1/2 RL or b) RPD of 20%, whichever higher.

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Table B-6 Summary of Blind Duplicate Samples from Monthly CEC Sampling Results

				Sample Date: 9/14/2011							
No.	Compound	MDL	RL	S9 (RO Perm. Combined)	S9 (Dupe)	RPD	RPD (Acceptance Criteria 1a & 2a)	RPD (Acceptance Criteria 1b & 2b)	Governing RPD	PASS / FAIL	NOTES
1	Oxolinic acid	2.46	5	5	7.1	35%	41%	50%	50%	PASS	
2	Atenolol	3.88	5	7.7	5	43%	39%	50%	50%	PASS	
3	Triclosan	6.32	10	34	10	109%	23%	40%	40%	FAIL	Additional QC sampling conducted.
4	Acesulfame-K	20	20	65	20	106%	24%	40%	40%	FAIL	Additional QC sampling conducted.
5	2,4-D	4.98	5	6.4	5	25%	44%	50%	50%	PASS	
				Sample Date: 10/17/2011							
No.	Compound	MDL	RL	S1 (tertiary effluent)	S1 (tertiary effluent DUPE)	RPD	RPD (Acceptance Criteria 1a & 2a)	RPD (Acceptance Criteria 1b & 2b)	Governing RPD	PASS / FAIL	NOTES
1	Butalbital	2.9	5	25	27	8%	10%	40%	40%	PASS	
2	DIA	2.45	5	5	5.7	13%	47%	50%	50%	PASS	
3	Erythromycin	4.03	10	25	32	25%	18%	40%	40%	PASS	
4	Simazine	1.23	5	11	10	10%	24%	40%	40%	PASS	
5	Primidone	5.66	5	76	70	8%	3%	40%	40%	PASS	
6	DEET	1.08	2	180	160	12%	1%	40%	40%	PASS	
7	TDCPP	5	100	710	880	21%	6%	40%	40%	PASS	
8	Lidocaine	1.11	5	90	90	0%	3%	40%	40%	PASS	
9	Diclofenac	3.3	5	59	71	18%	4%	40%	40%	PASS	
10	Albuterol	2.45	5	9.9	8.7	13%	27%	50%	50%	PASS	
11	Nifedipine	12.4	20	40	37	8%	26%	50%	50%	PASS	
12	Ketoprofen	2.59	5	38	33	14%	7%	40%	40%	PASS	
13	Naproxen	8.51	10	13	14	7%	37%	50%	50%	PASS	
14	4-nonylphenol - semi quantitative	50	100	200	230	14%	23%	50%	50%	PASS	
15	Gemfibrozil	2.47	5	34	33	3%	7%	40%	40%	PASS	
16	Amoxicillin (semi-quantitative)	6.39	20	960	800	18%	1%	40%	40%	PASS	
17	Atenolol	3.88	5	59	71	18%	4%	40%	40%	PASS	
18	Carbamazepine	1.21	5	190	200	5%	1%	40%	40%	PASS	
19	Diuron	1.8	5	74	77	4%	3%	40%	40%	PASS	
20	Triclosan	6.32	10	140	150	7%	3%	40%	40%	PASS	
21	DACT	3.92	5	26	10	89%	14%	40%	40%	FAIL	Results below or close to RL deemed acceptable.
22	Cotinine	4.85	10	25	10	86%	29%	40%	40%	FAIL	Results below or close to RL deemed acceptable.
23	Cimetidine	2.71	5	12	14	15%	19%	40%	40%	PASS	
24	TCEP	3.18	5	520	520	0%	0%	40%	40%	PASS	
25	Fluoxetine	10	10	39	43	10%	12%	40%	40%	PASS	
26	Acesulfame-K	20	20	33000	33000	0%	0%	40%	40%	PASS	
27	Sucralose	42.2	100	50000	52000	4%	0%	40%	40%	PASS	
28	Dilantin	12.6	20	110	96	14%	10%	40%	40%	PASS	
29	Meprobamate	2.03	5	92	88	4%	3%	40%	40%	PASS	
30	Caffeine	4.31	5	36	28	25%	8%	40%	40%	PASS	
31	Iohexal	7.74	10	4500	4100	9%	0%	40%	40%	PASS	
32	Dehydronifedipine	1.35	5	360	380	5%	1%	40%	40%	PASS	
33	Carbadox	4.19	5	5.7	5.7	0%	44%	50%	50%	PASS	
34	Sulfamethoxazole	2.82	5	470	490	4%	1%	40%	40%	PASS	
35	Trimethoprim	1.81	5	200	260	26%	1%	40%	40%	PASS	
36	Carisoprodol	1.19	5	62	67	8%	4%	40%	40%	PASS	

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Table B-6 Summary of Blind Duplicate Samples from Monthly CEC Sampling Results (Cont.)

				Sample Date: 11/8/2011							
No.	Compound	MDL	RL	S1 (tertiary effluent)	S1 (dupe)	RPD	RPD (Acceptance Criteria 1a & 2a)	RPD (Acceptance Criteria 1b & 2b)	Governing RPD	PASS / FAIL	NOTES
1	Butalbital	2.9	5	21	17	21%	13%	40%	40%	PASS	
2	Acetaminophen	3.01	5	10	5	67%	33%	50%	50%	FAIL	Results below or close to RL deemed acceptable.
3	Erythromycin	4.03	10	45	55	20%	10%	40%	40%	PASS	
4	Simazine	1.23	5	7.4	8	8%	32%	50%	50%	PASS	
5	Primidone	5.66	5	65	66	2%	4%	40%	40%	PASS	
6	DEET	1.08	2	160	180	12%	1%	40%	40%	PASS	
7	TDCPP	5	100	320	260	21%	17%	40%	40%	PASS	
8	Lidocaine	1.11	5	120	140	15%	2%	40%	40%	PASS	
9	Diclofenac	3.3	5	95	65	38%	3%	40%	40%	PASS	
10	Albuterol	2.45	5	10	12	18%	23%	50%	50%	PASS	
11	Nifedipine	12.4	20	57	51	11%	19%	40%	40%	PASS	
12	Naproxen	8.51	10	19	22	15%	24%	50%	50%	PASS	
13	4-nonylphenol - semi quantitative	50	100	330	440	29%	13%	40%	40%	PASS	
14	Gemfibrozil	2.47	5	28	23	20%	10%	40%	40%	PASS	
15	Amoxicillin (semi-quantitative)	6.39	20	320	400	22%	3%	40%	40%	PASS	
16	Atenolol	3.88	5	150	140	7%	2%	40%	40%	PASS	
17	Carbamazepine	1.21	5	170	180	6%	1%	40%	40%	PASS	
18	Diuron	1.8	5	61	64	5%	4%	40%	40%	PASS	
19	Linuron	2.84	5	6.3	5.6	12%	42%	50%	50%	PASS	
20	Triclosan	6.32	10	84	78	7%	6%	40%	40%	PASS	
21	DACT	3.92	5	21	22	5%	12%	40%	40%	PASS	
22	Cotinine	4.85	10	31	37	18%	15%	40%	40%	PASS	
23	Lopressor	5.14	20	270	280	4%	4%	40%	40%	PASS	
24	TCEP	3.18	5	410	340	19%	1%	40%	40%	PASS	
25	Fluoxetine	10	10	28	35	22%	16%	40%	40%	PASS	
26	Acesulfame-K	20	20	28000	35000	22%	0%	40%	40%	PASS	
27	Sucralose	42.2	100	26000	29000	11%	0%	40%	40%	PASS	
28	Dilantin	12.6	20	130	120	8%	8%	40%	40%	PASS	
29	Meprobamate	2.03	5	120	120	0%	2%	40%	40%	PASS	
30	Caffeine	4.31	5	20	21	5%	12%	40%	40%	PASS	
31	Meclofenamic Acid	4.66	5	5	5.5	10%	48%	50%	50%	PASS	
32	Iohexal	7.74	10	4100	4700	14%	0%	40%	40%	PASS	
33	Dehydronifedipine	1.35	5	40	41	2%	6%	40%	40%	PASS	
34	Sulfamethoxazole	2.82	5	780	690	12%	0%	40%	40%	PASS	
35	Iopromide	1.59	5	27	56	70%	6%	40%	40%	FAIL	Results below or close to RL deemed acceptable.
36	Trimethoprim	1.81	5	120	120	0%	2%	40%	40%	PASS	
37	Carisoprodol	1.19	5	52	56	7%	5%	40%	40%	PASS	

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Table B-6 Summary of Blind Duplicate Samples from Monthly CEC Sampling Results (Cont.)

				Sample Date: 2/1/2012							
No.	Compound	MDL	RL	S6	S6 Duplicate	RPD	RPD (Acceptance Criteria 1a & 2a)	RPD (Acceptance Criteria 1b & 2b)	Governing RPD	PASS / FAIL	NOTES
1	Acesulfame-K	20	20	48000	52000	8%	0%	40%	40%	PASS	
2	Albuterol	2.4	5	12	14	15%	19%	40%	40%	PASS	
3	Amoxicillin (semi-quantitative)	6.4	20	270	250	8%	4%	40%	40%	PASS	
4	Atenolol	3.9	5	42	33	24%	7%	40%	40%	PASS	
5	Butalbital	2.9	5	5	51	164%	9%	50%	50%	FAIL	Low value is suspect – not consistent with historical data.
6	Caffeine	4.3	5	9.8	10	2%	25%	50%	50%	PASS	
7	Carbamazepine	1.2	5	190	200	5%	1%	40%	40%	PASS	
8	Carisoprodol	1.2	5	780	1400	57%	0%	40%	40%	FAIL	May reflect heterogeneity between samples for this compound or possible dilution.
9	Cotinine	4.8	10	15	15	0%	33%	50%	50%	PASS	
10	DACT	3.9	5	11	8.2	29%	26%	40%	40%	PASS	
11	DEET	1.1	10	260	200	26%	2%	40%	40%	PASS	
12	Dehydronifedipine	1.4	5	140	160	13%	2%	40%	40%	PASS	
13	Diclofenac	3.3	5	18	16	12%	15%	40%	40%	PASS	
14	Dilantin	13	20	110	78	34%	11%	40%	40%	PASS	
15	Diuron	1.8	5	92	96	4%	3%	40%	40%	PASS	
16	Erythromycin	4	10	90	90	0%	6%	40%	40%	PASS	
17	Estrone	3.9	5	15	27	57%	12%	40%	40%	FAIL	No obvious reason for difference. May be inhomogeneity in sample.
18	Fluoxetine	10	10	100	92	8%	5%	40%	40%	PASS	
19	Gemfibrozil	2.5	5	79	86	8%	3%	40%	40%	PASS	
20	Iohexal	7.7	10	40000	46000	14%	0%	40%	40%	PASS	
21	Ketoprofen	2.6	5	75	60	22%	4%	40%	40%	PASS	
22	Lidocaine	1.1	5	220	260	17%	1%	40%	40%	PASS	
23	Linuron	2.8	5	210	170	21%	1%	40%	40%	PASS	
24	Lopressor	5.1	20	200	200	0%	5%	40%	40%	PASS	
25	Meprobamate	2	5	550	380	37%	1%	40%	40%	PASS	
26	Primidone	4.8	5	93	98	5%	3%	40%	40%	PASS	
27	Simazine	1.2	5	15	14	7%	17%	40%	40%	PASS	
28	Sucralose	42	100	45000	55000	20%	0%	40%	40%	PASS	
29	Sulfamethoxazole	2.8	5	1200	1200	0%	0%	40%	40%	PASS	
30	TCEP	3.2	10	400	390	3%	1%	40%	40%	PASS	
31	TCPP	20	100	1600	1900	17%	3%	40%	40%	PASS	
32	TDCPP	20	100	270	100	92%	27%	40%	40%	FAIL	Many of the flame retardants are semi-quantitative due to poor chromatographic resolutions.
33	Triclosan	6.3	10	74	69	7%	7%	40%	40%	PASS	
34	Trimethoprim	1.8	5	450	400	12%	1%	40%	40%	PASS	

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Table B-6 Summary of Blind Duplicate Samples from Monthly CEC Sampling Results (Cont.)

				Sample Date: 5/1/2012							
No.	Compound	MDL	RL	S10	S10 Duplicate	RPD	RPD (Acceptance Criteria 1a & 2a)	RPD (Acceptance Criteria 1b & 2b)	Governing RPD	PASS / FAIL	NOTES
1	4-nonylphenol - semi quantitative	50	100	<50	<50	0%	NA	40%	NA	PASS	
2	Acesulfame-K	20	20	<20	<20	0%	NA	40%	NA	PASS	
3	Albuterol	2.4	5	<2.4	<5	0%	NA	40%	NA	PASS	
4	Amoxicillin (semi-quantitative)	6.4	20	<6.4	<6.4	0%	NA	40%	NA	PASS	
5	Atenolol	3.9	5	<3.9	<3.9	0%	NA	40%	NA	PASS	
6	Butalbital	2.9	5	<2.9	<2.9	0%	NA	40%	NA	PASS	
7	Caffeine	4.3	5	<4.3	<4.3	0%	NA	40%	NA	PASS	
8	Carbamazepine	1.2	5	<1.2	<1.2	0%	NA	40%	NA	PASS	
9	Carisoprodol	1.2	5	<1.2	<1.2	0%	NA	40%	NA	PASS	
10	Cotinine	4.8	10	<4.8	<4.8	0%	NA	40%	NA	PASS	
11	DACT	3.9	5	<3.9	<3.9	0%	NA	40%	NA	PASS	
12	DEET	1.1	10	<10	<10	0%	NA	40%	NA	PASS	
13	Dehydronifedipine	1.4	5	<1.4	<1.4	0%	NA	40%	NA	PASS	
14	Diclofenac	3.3	5	<3.3	<3.3	0%	NA	40%	NA	PASS	
15	Dilantin	13	20	<13	<13	0%	NA	40%	NA	PASS	
16	Diuron	1.8	5	<1.8	<1.8	0%	NA	40%	NA	PASS	
17	Erythromycin	4	10	<4	<4	0%	NA	40%	NA	PASS	
18	Estradiol	4.4	5	<4.4	<4.4	0%	NA	40%	NA	PASS	
19	Estrone	3.9	5	<3.9	<3.9	0%	NA	40%	NA	PASS	
20	Fluoxetine	10	10	<10	<10	0%	NA	40%	NA	PASS	
21	Gemfibrozil	2.5	5	<2.5	<2.5	0%	NA	40%	NA	PASS	
22	Iohexal	7.7	10	<7.7	<7.7	0%	NA	40%	NA	PASS	
23	Ketoprofen	2.6	5	<2.6	<2.6	0%	NA	40%	NA	PASS	
24	Lidocaine	1.1	5	<1.1	<1.1	0%	NA	40%	NA	PASS	
25	Linuron	2.8	5	<2.8	<2.8	0%	NA	40%	NA	PASS	
26	Lopressor	5.1	20	<5.1	<5.1	0%	NA	40%	NA	PASS	
27	Meprobamate	2	5	<2	<2	0%	NA	40%	NA	PASS	
28	Naproxen	8.5	10	<8.5	<8.5	0%	NA	40%	NA	PASS	
29	Primidone	4.8	5	<4.8	<4.8	0%	NA	40%	NA	PASS	
30	Simazine	1.2	5	<1.2	<1.2	0%	NA	40%	NA	PASS	
31	Sucralose	42	100	<42	<42	0%	NA	40%	NA	PASS	
32	Sulfamethoxazole	2.8	5	<2.8	<2.8	0%	NA	40%	NA	PASS	
33	TCEP	3.2	10	<10	<3.2	0%	NA	40%	NA	PASS	
34	TCPP	20	100	<20	<20	0%	NA	40%	NA	PASS	
35	TDCPP	20	100	<100	<20	0%	NA	40%	NA	PASS	
36	Theobromine	3.2	10	<10	<3.2	0%	NA	40%	NA	PASS	
37	Triclosan	6.3	10	<6.3	<6.3	0%	NA	40%	NA	PASS	
38	Trimethoprim	1.8	5	<1.8	<1.8	0%	NA	40%	NA	PASS	

Note: Criteria 1 = a) If the result of the original sample was within 2 X RL then the difference in results between the two samples should be ± 1/2 RL or b) the relative percent difference (RPD) should be 50%), whichever is higher. Criteria 2 = a) If the result of the original sample was >2 X RL then the difference in results between the two samples should be ± 1/2 RL or b) RPD of 40%, whichever higher. A total of 89 compounds were analyzed per sampling event. Results are only provided for compounds in which a value was reported above the ≥RL in the original or blind duplicate sample.

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Table B-7 Summary of Split Samples from Quarterly Sampling Event Number 1 Results WECK and MWH Lab (8/24/11)

No.	Compound	MDL	RL	S10 Grab Result	DL	S10 Split Result	Difference	RPD (Actual)	RPD (Criteria 1)	RPD (Criteria 2)	Governing RPD	PASS / FAIL	NOTES
1	Bromodichloromethane	0.09	0.5	0.78	0.5	0.76	0.02	3%	32%	50%	50%	PASS	
2	Chloroform	0.12	0.5	1.4	0.5	1.3	0.1	7%	19%	20%	20%	PASS	
3	Methylene chloride	0.14	0.5	0.2	0.5	0.5	0.3	86%	71%	50%	71%	FAIL	Acceptable both results at below the RL or DL.
4	THM's, Total	0.6	2	2.2	0.5	2	0.2	10%	48%	50%	50%	PASS	
8	Diethylphthalate	0.22	2	0.31	0.5	0.5	0.19	47%	247%	50%	247%	PASS	
12	Aluminum	0.61	5	3.6	20	20	16.4	139%	21%	50%	50%	FAIL	Acceptable both results at below the RL or DL.
13	Boron	0.28	1	240	0.28	210	30	13%	0%	20%	20%	PASS	
14	Calcium	0.016	0.1	0.025	1	1	0.975	190%	10%	50%	50%	FAIL	Acceptable both results at below the RL or DL.
15	Lead	0.011	0.2	0.03	0.5	0.5	0.47	177%	38%	50%	50%	FAIL	Acceptable both results at below the RL or DL.
16	Mercury	0.0039	0.05	0.016	0.2	0.2	0.184	170%	23%	50%	50%	FAIL	Acceptable both results at below the RL or DL.
17	Potassium	0.081	0.1	0.31	1	1	0.69	105%	8%	20%	20%	FAIL	Acceptable both results at below the RL or DL.
18	Sodium	0.015	0.5	3.2	1	3.4	0.2	6%	8%	20%	20%	PASS	
21	Chloride	0.1	0.5	2.8	1	20	17.2	151%	2%	20%	20%	FAIL	Acceptable both results at below the RL or DL.
22	Fluoride	0.02	0.1	0.025	0.05	0.05	0.025	67%	133%	50%	133%	PASS	
24	Total anions	0.02	0.078	0.18	0.001	0.16	0.02	12%	23%	20%	23%	PASS	
25	Total cations	0.0045	0.038	0.15	0.001	0.15	0	0%	13%	20%	20%	PASS	
26	pH (units)	0.1	0.1	5.82	0.1	5.8	0.02	0%	1%	20%	20%	PASS	
27	Odor	1	1	1	1	1	0	0%	50%	50%	50%	PASS	
28	Nitrate	0.18	0.5	3.1	0.44	2.8	0.3	10%	8%	20%	20%	PASS	
29	Nitrite/Nitrate as N	10	100	700	100	650	50	7%	7%	20%	20%	PASS	
30	Total dissolved solids	4	10	16	10	14	2	13%	33%	50%	50%	PASS	
31	Specific Conductance	0.23	2	22	2	20	2	10%	5%	20%	20%	PASS	
32	Total organic carbon	0.009	0.3	0.86	0.3	0.3	0.56	97%	26%	20%	26%	FAIL	Difference in results warrants additional QC sampling. Completed.
33	Total alkalinity	0.56	2	2.6	2	2.3	0.3	12%	41%	50%	50%	PASS	
34	Bicarbonate alkalinity	0.56	2	3.2	2	2.9	0.3	10%	33%	50%	50%	PASS	
36	Langelier Index @60C	-10	-10	-6.1	-14	-5	1.1	-20%	90%	20%	90%	PASS	
37	Turbidity	0.024	0.1	0.024	0.05	0.068	0.044	96%	109%	50%	109%	PASS	
38	Gross Alpha	0.38	0.601	0.94	3	3	2.06	105%	15%	50%	50%	FAIL	Acceptable both results at below the RL or DL.
39	HAA5 Total		1	1	2	2	1	67%	33%	50%	50%	FAIL	Acceptable both results at below the RL or DL.
40	Acetaldehyde	0.34	2	0.8	1	1	0.2	22%	111%	50%	111%	PASS	
41	Formaldehyde	0.26	2	8.9	5	51	42.1	141%	3%	20%	20%	FAIL	Difference in results warrants additional QC sampling. Completed.
42	N-Nitrosodimethylamine	0.28	2	0.35	2	2	1.65	140%	85%	50%	85%	FAIL	Acceptable both results at below the RL or DL.

Note: Criteria 1 = a) If the result of the original sample was within 2 X RL then the difference in results between the two samples should be ± 1/2 RL or b) the relative percent difference (RPD) should be 50%), whichever is higher. Criteria 2 = a) If the result of the original sample was >2 X RL then the difference in results between the two samples should be ± 1/2 RL or b) RPD of 20%, whichever higher.

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Table B-8 Summary of Split Samples Results for CEC's (Samples Dates: 8/15/11, 11/8/11, 2/1/12, 5/1/12)

			Sample Date												
			8/15/2011				11/8/2011								
No.	Compound	Units	MWH Lab (RO Feed)	CSM Lab (RO Feed)	MWH-CSM S6	RPD (%)	MWH Lab (Tertiary Effluent)	CSM (Tertiary Effluent	MWH-CSM S1	RPD (%)	MWH Lab (RO Feed)	CSM Lab (RO Feed)	MWH-CSM S6	RPD	Assigned QC Assessment Category (1, 2 or 3)
1	4-n-Nonylphenol	ng/L	780	25	755	**188%**	330	25	305	**172%**	470	25	445	**180%**	3
2	Acetaminophen	ng/L	ND	ND		**-------**	10	1	9	**164%**	8.3	1	7.3	**157%**	3
3	Atenolol	ng/L	210	455	245	**74%**	150	172	22	**14%**	150	174	24	**15%**	2
4	Atrazine	ng/L	ND	ND		**------**	ND	ND		**------**	ND	ND		**------**	1
5	Caffeine	ng/L	28	50	22	**56%**	20	23.1	3.1	**14%**	6.7	17.1	10.4	**87%**	2
6	Carbamazepine	ng/L	170	243	73	**35%**	170	244	74	**36%**	160	241	81	**40%**	1
7	Cimetidine	ng/L	ND	ND		**------**	ND	ND		**------**	ND	ND		**------**	1
8	DEET	ng/L	180	327	147	**58%**	160	248	88	**43%**	170	255	85	**40%**	3
9	Diazepam	ng/L	ND	ND		**------**	2.06	3	0.94	**37%**	2.06	3	0.94	**37%**	1
10	Diclofenac	ng/L	58	184	126	**104%**	95	138	43	**37%**	70	139	69	**66%**	3
11	Dilantin	ng/L	82	156	74	**62%**	130	112	18	**15%**	110	113	3	**3%**	1
12	Estradiol 17B	ng/L	ND	ND		**------**	ND	ND		**------**	ND	ND		**------**	1
13	Estrone	ng/L	21	5	16	**123%**	ND	ND		**------**	ND	ND		**------**	2
14	Fluoexetine	ng/L	59	32.1	26.9	**59%**	28	43.4	15.4	**43%**	21	28	7	**29%**	2
15	Gemfibrizol	ng/L	62	73.9	11.9	**18%**	28	37.6	9.6	**29%**	24	36.1	12.1	**40%**	1
16	Ibuprofen	ng/L	ND	ND		**------**	ND	ND		**------**	ND	ND		**------**	1
17	Ketoprofen	ng/L	15	25	10	**50%**	ND	ND		**------**	ND	ND		**------**	2
18	Meprobamate	ng/L	200	295	95	**38%**	120	290	170	**83%**	120	287	167	**82%**	3
19	Methylparaben	ng/L	11.4	15.2	3.8	**29%**	11.4	8.3	3.1	**31%**	11.4	5.9	5.5	**64%**	1
20	Naproxen	ng/L	23	27.7	4.7	**19%**	19	23.5	4.5	**21%**	21	24.2	3.2	**14%**	1
21	Primidone	ng/L	96	110	14	**14%**	65	85.9	20.9	**28%**	62	88.8	26.8	**36%**	1
22	Progesterone	ng/L	ND	ND		**------**	ND	ND		**------**	ND	ND		**-------**	1
23	Propylparaben	ng/L	ND	ND		**------**	ND	ND		**------**	ND	ND		**------**	1
24	Sucralose	ng/L	20000	**------**		**------**	26000	**------**		**------**	22000	**------**		**------**	4
25	Sulfamethoxazole	ng/L	870	1563	693	**57%**	780	1630	850	**71%**	740	1310	570	**56%**	3
26	TCEP	ng/L	180	683	503	**117%**	410	401	9	**2%**	370	403	33	**9%**	1
27	TCPP	ng/L	------	------	------	**------**	------	------	------	**------**	------	------	------	**------**	4
28	TDCPP	ng/L	5	1338	1333	**199%**	320	1250	930	**118%**	130	1080	950	**157%**	3
29	Testosterone	ng/L	ND	ND		**------**	ND	ND		**------**	ND	ND		**-------**	1
30	Triclosan	ng/L	68	96.1	28.1	**34%**	84	79.3	4.7	**6%**	60	69	9	**14%**	2
31	Trimethoprim	ng/L	200	248	48	**21%**	120	153	33	**24%**	120	160	40	**29%**	1

Note: Assigned QC Assessment Categories: 1 =comparison of lab results for the given compound showed consistent agreement (i.e. RPD's < 40% or ND); 2 = comparison of lab results for the given compound showed consistent agreement for some results and discrepancies for others; possibly due to inhomogeneity in the samples and / or sample contamination. 3=comparison of lab results for the given compound showed consistent disagreement possibly due to systematic differences between laboratory analysis procedures 4) Results could not be compared due to insufficient data. 3. The potential for systematic analytical differences was evaluated by having CSM participate in a project for SAWPA that involved a total of 5 labs. Memorandum from Dr. Andy Eaton.

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Table B-8 Summary of Split Samples Results for CEC's (Samples Dates: 8/15/11, 11/8/11, 2/1/12, 5/1/12) (continued)

No.	Compound	Units	2/1/2012															Assigned QC Assessment Category (1, 2 or 3)
			MWH Lab (RO Feed)	CSM Lab (RO Feed)	CSM Lab (RO Feed)	MWH-CSM	MWH Dupe-CSM	RPD (%)	RPD Dupe	MWH Lab (RO Permeate Combined)	CSM Lab (RO Permeate Combined)	MWH-CSM	RPD (%)	MWH Lab (UV/AOP Product)	CSM Lab (UV/AOP Product)	MWH-CSM	RPD (%)	
1	4-n-Nonylphenol	ng/L	ND	<100	ND			------		ND	ND		------	ND	ND		------	3
2	Acetaminophen	ng/L																3
3	Atenolol	ng/L	42	33	101	5900%	68	**83%**	1.014925373	ND	ND		------	ND	ND		------	2
4	Atrazine	ng/L	------	------	------	------	------	------	------	------	------		------				------	1
5	Caffeine	ng/L	9.8	10	24.9	1510%	14.9	**87%**	0.853868195	ND	ND		------	<5	ND		------	2
6	Carbamazepine	ng/L	190	200	242	5200%	42	**24%**	0.190045249	<5	ND		------	ND	ND		------	1
7	Cimetidine	ng/L	------	------	------	------	------	------	------	------	------		------	------	------		------	1
8	DEET	ng/L	260	200	58.7	20130%	141.3	**126%**	1.092385002	<6	ND		------	<6	ND		------	3
9	Diazepam	ng/L	------	------	------	------	------	------	------	------	------		------				------	1
10	Diclofenac	ng/L	18	16	145	12700%	129	**156%**	1.602484472	ND	ND		------	ND	ND		------	3
11	Dilantin	ng/L	110	78	127	1700%	49	**14%**	0.47804878	ND	ND		------	ND	ND		------	1
12	Estradiol 17B	ng/L	------	------	------	------	------	------	------	------	------		------	------	------		------	1
13	Estrone	ng/L	15	27	ND			------		ND	ND		------	<5	ND		------	2
14	Fluoexetine	ng/L	100	92	46.8	5320%	45.2	**72%**	0.65129683	ND	ND		------	ND	ND		------	2
15	Gemfibrizol	ng/L	79	86	70.1	890%	15.9	**12%**	0.203715567	ND	ND		------	<5	ND		------	1
16	Ibuprofen	ng/L	------	------	------	------	------	------	------	------	------		------				------	1
17	Ketoprofen	ng/L	75	60	ND			------		ND	ND		------	ND	ND		------	2
18	Meprobamate	ng/L	550	380	308	24200%	72	**56%**	0.209302326	ND	ND		------	ND	ND		------	3
19	Methylparaben	ng/L	------	------	------	------	------	------	------	------	------		------				------	1
20	Naproxen	ng/L	ND	ND	8.72			------		ND	ND		------	ND	ND		------	1
21	Primidone	ng/L	93	98	122	2900%	24	**27%**	0.218181818	ND	ND		------	ND	ND		------	1
22	Progesterone	ng/L	------	------	------	------	------	------	------	------	------		------				------	1
23	Propylparaben	ng/L	------	------	------	------	------	------	------	------	------		------				------	1
24	Sucralose	ng/L	45000	55000	-------			------	#VALUE!	<100			------	ND			------	4
25	Sulfamethoxazole	ng/L	1200	1200	1770	57000%	570	**38%**	0.383838384	ND	ND		------	ND	ND		------	3
26	TCEP	ng/L	400	390	456	5600%	66	**13%**	0.156028369	ND	ND		------	ND	ND		------	1
27	TCPP	ng/L	1600	1900	291	1309	1609	**138%**	1.468735737	ND	ND		------	ND	ND		------	4
28	TDCPP	ng/L	270	<100	156	11400%	#VALUE!	**54%**	#VALUE!	ND	ND		------	ND	ND		------	3
29	Testosterone	ng/L	------	------	------	------	------	------	------	------	------		------				------	1
30	Triclosan	ng/L	74	69	42.3	3170%	26.7	**55%**	0.479784367	13	ND		------	17	ND		------	2
31	Trimethoprim	ng/L	450	400	510	6000%	110	**13%**	0.241758242	<5	ND		------	<5	ND		------	1

Note: Assigned QC Assessment Categories: 1 =comparison of lab results for the given compound showed consistent agreement (i.e. RPD's < 40% or ND); 2 = comparison of lab results for the given compound showed consistent agreement for some results and discrepancies for others; possibly due to inhomogeneity in the samples and / or sample contamination. 3=comparison of lab results for the given compound showed consistent disagreement possibly due to systematic differences between laboratory analysis procedures 4) Results could not be compared due to insufficient data. 3. The potential for systematic analytical differences was evaluated by having CSM participate in a project for SAWPA that involved a total of 5 labs. Memorandum from Dr. Andy Eaton.

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Table B-8 Summary of Split Samples Results for CEC's (Samples Dates: 8/15/11, 11/8/11, 2/1/12, 5/1/12) (continued)

No.	Compound	Units	5/1/2012												Assigned QC Assessment Category (1, 2 or 3)
			MWH Lab (RO Feed)	CSM Lab (RO Feed)	MWH-CSM	RPD (%)	MWH Lab (RO Permeate Combined)	CSM Lab (RO Permeate Combined)	MWH-CSM	RPD (%)	MWH Lab (UV/AOP Product)	CSM Lab (UV/AOP Product)	MWH-CSM	RPD (%)	
1	4-n-Nonylphenol	ng/L	520	25	495	**182%**	ND	BDL	------	**------**	ND	BDL	------	**------**	3
2	Acetaminophen	ng/L	-	BDL	------	**------**	ND	BDL	------	**------**	ND	BDL	------	**------**	3
3	Atenolol	ng/L	43	74.1	31	**53%**	ND	BDL	------	**------**	ND	BDL	------	**------**	2
4	Atrazine	ng/L	-	BDL	------	**------**	ND	BDL	------	**------**	ND	BDL	------	**------**	1
5	Caffeine	ng/L	4.3	24.5	20	**140%**	ND	BDL	------	**------**	ND	BDL	------	**------**	2
6	Carbamazepine	ng/L	210	192	18	**9%**	ND	BDL	------	**------**	ND	BDL	------	**------**	1
7	Cimetidine	ng/L	-	BDL	------	**------**	ND	BDL	------	**------**	ND	BDL	------	**------**	1
8	DEET	ng/L	210	222	12	**6%**	<10	BDL	------	**------**	<10	BDL	------	**------**	3
9	Diazepam	ng/L	-	BDL	------	**------**	ND	BDL	------	**------**	ND	BDL	------	**------**	1
10	Diclofenac	ng/L	3.3	129	126	**190%**	ND	BDL	------	**------**	ND	BDL	------	**------**	3
11	Dilantin	ng/L	140	133	7	**5%**	ND	BDL	------	**------**	ND	BDL	------	**------**	1
12	Estradiol 17B	ng/L	<5	BDL	------	**------**	ND	BDL	------	**------**	ND	BDL	------	**------**	1
13	Estrone	ng/L	<3.9	BDL	------	**------**	ND	BDL	------	**------**	ND	BDL	------	**------**	2
14	Fluoexetine	ng/L	31	27.1	4	**13%**	ND	BDL	------	**------**	ND	BDL	------	**------**	2
15	Gemfibrizol	ng/L	52	42.6	9	**20%**	ND	BDL	------	**------**	ND	BDL	------	**------**	1
16	Ibuprofen	ng/L	-	BDL	------	**------**	ND	BDL	------	**------**	ND	BDL	------	**------**	1
17	Ketoprofen	ng/L	17	5	12	**109%**	ND	BDL	------	**------**	ND	BDL	------	**------**	2
18	Meprobamate	ng/L	160	285	125	**56%**	ND	BDL	------	**------**	ND	BDL	------	**------**	3
19	Methylparaben	ng/L	-	BDL	------	**------**	ND	BDL	------	**------**	ND	BDL	------	**------**	1
20	Naproxen	ng/L	8.5	12.8	4	**40%**	ND	BDL	------	**------**	ND	BDL	------	**------**	1
21	Primidone	ng/L	97	112	15	**14%**	ND	BDL	------	**------**	ND	BDL	------	**------**	1
22	Progesterone	ng/L	-	BDL	------	**------**	ND	BDL	------	**------**	ND	BDL	------	**------**	1
23	Propylparaben	ng/L	-	BDL	------	**------**	ND	BDL	------	**------**	ND	BDL	------	**------**	1
24	Sucralose	ng/L	48000	-	------	**------**	ND	-	------	**------**	ND	-	------	**------**	4
25	Sulfamethoxazole	ng/L	870	1130	260	**26%**	2.8	1.28	152%	**75%**	ND	BDL	------	**------**	3
26	TCEP	ng/L	270	451	181	**50%**	ND	BDL	------	**------**	<10	BDL	------	**------**	1
27	TCPP	ng/L	2300	357	1943	**146%**	ND	BDL	------	**------**	ND	BDL	------	**------**	4
28	TDCPP	ng/L	780	178	602	**126%**	ND	BDL	------	**------**	<100	BDL	------	**------**	3
29	Testosterone	ng/L	-	BDL	------	**------**	ND	BDL	------	**------**	ND	BDL	------	**------**	1
30	Triclosan	ng/L	28	36.8	9	**27%**	ND	BDL	------	**------**	ND	BDL	------	**------**	2
31	Trimethoprim	ng/L	280	298	18	**6%**	ND	BDL	------	**------**	ND	BDL	------	**------**	1

Note: Assigned QC Assessment Categories: 1 =comparison of lab results for the given compound showed consistent agreement (i.e. RPD's < 40% or ND); 2 = comparison of lab results for the given compound showed consistent agreement for some results and discrepancies for others; possibly due to inhomogeneity in the samples and / or sample contamination. 3=comparison of lab results for the given compound showed consistent disagreement possibly due to systematic differences between laboratory analysis procedures 4) Results could not be compared due to insufficient data. 3. The potential for systematic analytical differences was evaluated by having CSM participate in a project for SAWPA that involved a total of 5 labs. Memorandum from Dr. Andy Eaton.

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eurofins | Eaton Analytical

Jennifer Thompson, PE
CDM-Smith
1925 Palomar Oaks Way, Suite 300
Carlsbad, CA 92008

September 10, 2012

Dear Ms. Thompson;

As part of the San Diego AWP Facility testing program, MWH Labs (now Eurofins Eaton Analytical, Inc.) tested a target list of ninety two (92) constituents of emerging concern (CEC) including those used in pesticides, herbicides, and pharmaceuticals and personal care products (PPCP) representing a wide variety of physical and chemical properties. Analysis were conducted monthly for the initial 4 months of testing on samples collected throughout the purification processes including tertiary effluent prior to chlorination, RO feed, RO permeate and UV/AOP product water and imported raw aqueduct water. Though 92 constituents were initially targeted results were only provided for 90 constituents due to poor precision on two constituents (Azithromycin and TCPP). Analysis of this many compounds in a single method requires optimization of the column and instrumentation to get consistent resolution. Azithromycin and TCPP were both added to the method after it was optimized for the other analytes however, the chromatographic performance for these compounds was determined to be inadequate to generate quantitative data and therefore removed from the target list.

Following the initial 4 months of testing a subset of constituents were selected for additional sampling due to their consistent presence in the RO feed, making them candidates to serve as performance indicators for the RO and/or UV/AOP. The subset of compounds also included CECs identified by the State Board Science Advisory Panel (SAP) prioritized for monitoring based on toxicological relevance and those identified as viable performance indicators along with surrogate parameters for surface spreading and direct injection of recycled water for groundwater recharge operations.

Overall the results of the CEC testing, including QC samples, showed the number and concentration of constituents detected at each sample location to be consistent and the overall data set is considered to be of high quality in terms of consistency, accuracy, and reproducibility. In nearly every case, where there were detections in the RO feed, there were significant decreases through the RO and into the UV/AOP influent and UV/AOP product. Of the 545 individual CEC compound measurements (i.e. 90 constituents tested monthly X 4 months + 37 constituents tested weekly X 4 weeks + 1 quarterly sampling event) for the UV/AOP product water generated during the testing period, only 5 results were reported above the associated reporting limit (RL). The results of these individual detections are summarized below, along with the concentrations measured in the RO feed and RO permeate at the same time. Additional information as well as scientific interpretation of the results for each constituent is also provided below.

Sample Date	Compound	RL (ng/L)	RO feed (ng/L)	RO permeate (ng/L)	UV/AOP product (ng/L)
9/14/11	Triclosan	10	37	34	19
9/14/11	Iohexal	10	8700	<10	19
9/14/11	Acesulfame-k	20	29000	65	50
2/1/12	Triclosan	10	74	13	17
2/15/12	Acesulfame-k	20	44000	<20	31

- **Triclosan** is used as a synthetic broad-spectrum antimicrobial agent. Triclosan is used in a variety of consumer products, such as antimicrobial hand soaps, toothpaste, and over-the-counter drugs. It also functions as a material preservative in adhesives, fabrics, vinyl, plastics (toys, toothbrushes), polyethylene, polyurethane, polypropylene, floor wax emulsions, textiles (footwear, clothing), caulking compounds, sealants, rubber, carpeting, and a wide variety of other products. While MWH Labs has not historically seen extensive issues with method blank or field blank contamination for this compound, there have been sporadic cases where it has shown up unexpectedly, which is most likely due to ambient field or lab contamination. Although it was not possible to identify specific sources of triclosan in the laboratory, the lab did determine that blanks were somewhat higher than normal on the days with two of the positive hits. It is worth noting that the SAP recommended using an RL of 50 ng/L for compliance monitoring because of the ubiquitous occurrence of triclosan. In the WateResearch Foundation (WaterRF) sponsored Project 4167, triclosan was one of only 6 compounds (out of 22) with false positive rates of >10% with RLs that ranged from 1 to 20 ng/L. In that project, MWH was not one of the labs that had false positives for triclosan, and there was also no issue with either field blanks or method blanks on another large wastewater effluent project conducted in June of 2011 and again in June of 2012. However the high blanks on several of the days associated with hits make these hits suspect.

- **Acesulfame-k** is a widely used artificial sweetener. Ace-K is used in a variety of consumables, including baked goods, soft drinks, sports drinks, chewable and liquid medications, and other foods. Ace-K was present at very high levels in the RO Feed (6400 ng/L to 48,000 ng/L). Thus the detections of 18-65 ng/L in the permeate represent an RO rejection rate exceeding 99.5%. If one also considers the other sample events where it was not detected, the rejection rate is likely even higher. The expected analytical precision of Ace-K at these levels is +/-50% (e.g. ~10 ng/L), so the values in the AOP product are very similar to those in the RO. Buerge (2009) had suggested in Germany that Ace-K was an ideal tracer of wastewater presence in groundwaters in part because of the high source concentrations and also due to its conservative behavior and lack of reactivity. Eurofins Eaton Analytical has analyzed over 2,000 samples for Ace-K (Eaton, WateReuse 2012) and found that in the U.S. concentrations in wastewater effluents are somewhat more variable than sucralose (proposed by the SAP as an indicator compound) but generally of the same order of magnitude in wastewater effluent concentration. The increased analytical sensitivity for this compound compared to sucralose makes it more likely to be detected even with high rejection rates.

- **Iohexal** This compound is used widely as an X-ray contrasting agent in a variety of hospital radiological tests, such as coronary angiographs. It is used much more frequently than iopromide, which was suggested by the SAP as a good performance indicator compound. Ioxhexal was only detected in 1 of 9 purified water samples, even though the typical RO feed water had between 5,000 and 40,000 ng/L. On the day that it was detected in the AOP product water, the RO permeate and a blind duplicate of the RO permeate had trace level detects below the RL of 10 ng/L. This suggests that the positive value in the AOP was likely impacted by analytical imprecision at that level. There is no stable isotope analog available for iohexal so it is potentially subject to signal enhancement or suppression, although there should be minimal matrix impact in RO permeate or AOP product. Again the very high influent values suggest that the removal efficiency, even if there were iohexal in the AOP product is greater than 99%.

During the testing program, RL's were adjusted for three CECs as described below.

DEET – The RL for this compound was originally 2 ng/L however, because the RL for this compound is subject to change based on concentrations detected in blanks in a given analysis batch, the RL was increased to 10 ng/L for all samples to ensure consistency and the ability to compare data.

Oxolinic Acid – The RL for this compound was originally 5 ng/L, however because this compound does not have a reliable secondary isotope for quantification, and is prone to baseline noise, increasing uncertainty in quantitation) the RL for all samples was increased to 10 ng/L.

Theobromine – The RL for this compound was originally 5 ng/L, however, because this compound does not have a reliable secondary isotope for quantification and is sensitive to matrix impacts on the signal response, the RL for all samples was increased to 10 ng/L.

As part of the overall testing program, split samples of CECs collected at various sampling locations were also analyzed by Colorado School of Mines. Comparison of results of MWH Labs and CSM Labs showed overall good agreement between results however there were some results with higher than expected discrepancies (i.e. relative percent difference > 50%). In order to investigate the potential cause of these discrepancies several steps were taken as discussed below.

- **Exchange of Standards** Both labs reviewed their raw data and exchanged and analyzed standards prepared by each other for compounds analyzed for the project. Of the standards analyzed, results were in close agreement for both labs, generally within 20%. This included those compounds where there were significant differences between the labs. CSM did determine that their sensitivity for acetaminophen might not be as good as initially through. This suggested that the cause of any discrepancy was not due to obvious calibration differences, but there could be some impact from method sensitivity.

- **Investigation of Sample Volume –** Some of the discrepancies between the lab results were associated with possible sample contamination**.** Because the labs used two different sample volumes (MWH Labs = 40 mL; CSM = 1000 mL) an investigation was undertaken to determine if the smaller sample volume was more prone to sample contamination. Results of the investigation targeting DEET and triclosan showed no conclusive evidence that sample volume impacted detections, although one round of initial testing did suggest that smaller sample volumes were more likely to be impacted by any ambient field contamination.

- **Third Part Study Participation -** In tandem with the San Diego AWP Facility testing, both MWH Labs and and CSM participated in a multi lab study conducted on behalf of the Santa Ana Watershed Project Authority (SAWPA). This study is now in its third year of sampling over twenty wastewater dischargers to the SAWPA watershed. For purposes of the San Diego IPR project however, the more important part of the study is the QC samples that are an integral part of it. Each laboratory analyzes two blind samples prepared by Environmental Resources Associates (ERA) for a set of 11 SAWPA designated contaminants of emerging concern (CECs) and also analyzes a split sample of water from the Santa Ana River collected below Prado dam (representative of a receiving water) for whatever CECs they can report with their analytical method. In 2010 and 2011, only 4 laboratories were involved in the study, but in 2012, SAWPA agreed to let CSM also analyze the ERA samples and the Prado Dam sample as a way of evaluating any systematic bias between MWH Labs and CSM that might explain some of the discrepancies in the San Diego results. Also note that the Prado Dam sample included a field blank. Detailed results from this study, including tables comparing lab performance, are available from SAWPA in their annual report on CECs (2012 report still in preparation).

  For the ERA sample, results generally agreed well among all four labs with only a few exceptions. One of these was acetaminophen, where CSM had unusually low recovery on a low level spike sample. In the San Diego split samples there were three compounds: Acetaminophen, DEET, and sulfamethoxazole, that had significant differences on one or more of the split samples. Thus the low bias from CSM may at least partially explain the San Diego differences, although one PT sample is insufficient to demonstrate a systematic issue and could instead indicate a one-time error. Since acetaminophen was not detected by either lab in the Prado Dam sample, it is not possible to determine if there was also a matrix issue. Results for DEET and Sulfamethoxazole generally agreed amongst all labs. This indicates that there are no obvious differences in analytical methods in clean matrices such as proficiency testing samples or river water, but because CSM did not test any of the effluent samples from the SAWPA project we cannot use these data to determine if there are possible method differences on more complex matrices such as the RO feed water.

Based on the investigation measures described above it seems that the most likely cause for the differences in results between MWH and CSM on some of the San Diego splits may well be sample inhomogeneity for the RO feedwater (S6), where there are solids present that might impact either the analytical methods themselves or the representativeness of the split itself.

There is no obvious explanation for the differences at purified water sites as both labs have demonstrated the ability to produce accurate results. It is worth noting that PPCP studies occasionally have apparent outliers on individual samples, particularly when measurements are near the reporting limit. This is likely because measurements are being made in the low ng/L level, where there are a myriad of potential sources for lab or field contamination. One of the reasons the SAP recommended reporting limits as high as 50 ng/L for triclosan was just that reason.

If you have any questions about these data do not hesitate to contact me.

Sincerely yours,

Andrew Eaton

Andrew Eaton, PhD
Vice President/Technical Director

Appendix C

Technical Memorandum: Summary of Third Party Data Validation of AWP Facility Quarterly Sampling Event Results.

· T E C H N I C A L M E M O R A N D U M

To:	Anthony Van	**Date:**	**7**/31/12
From:	Jay DeCarolis, PE	**CC:**	Marsi Steirer Bill Pearce

Subject: Summary of AWPF Third Party Data Validation of Quarterly Sampling Event Number 1 Results

Background.
Per the QA/QC plan outlined in the Final T&M Plan third-party validation was performed on the water quality data produced from WECK Laboratories, Inc. (WECK) and MWH Laboratories, Inc. (MWH) for samples collected during the first Quarterly sampling event conducted on 8/24/11. The purpose of the validation was to determine the data quality and review laboratory procedures in order to identify possible procedural alterations to be implemented for subsequent sampling events.

Data validation was performed was on results from samples collected from the UV/AOP product water (S10). These included original samples analyzed by WECK and split samples analyzed by MWH along with blind duplicate samples analyzed by WECK labs only. The specific fractions analyzed by each lab are provided in Appendix A and Appendix B, respectively.

Benefits of Third Party Validation

Third party validation is beneficial whenever analytical data may be subject to intense scrutiny that could result in the accuracy of the reported data being challenged in a court of law. The USEPA issued guidance documents1,2 detailing analytical data evaluation and review processes for inorganic and organic data produced under the EPA Contract Lab Program (CLP). The CLP supports a major portion of the sample analysis needs of the EPA Superfund Program. Due to the potential for legal challenges, samples submitted under this program must be analyzed in conformance with specified analytical protocols and the assembled data package must go through a technical quality assurance review (validation) prepared by an independent third party. In 1986, the Director of the Office of Emergency and Remedial Response proposed several levels of data validation.

Commercial third party specialists performing water quality data validation utilize the guidance issued under the EPA CLP program. Level IV review is the most rigorous and is characterized by quality assurance / quality control (QA/QC) protocols and documentation resulting in a complete qualitative and quantitative analysis of the

[1] www.epa.gov/superfund/programs/clp/download.fgorg.pdf
[2] www.epa.gov/superfund/programs/clp/download/fginor.pdf

analytical data3. Data that fulfills the requirements of this level of third party validation fulfills the minimum data quality standards needed to allow the data to be used for its intended objective.

Selection and Credentials of Third Party Validation Firm

Many commercial firms are available to perform third party validations. Laboratory Data Consultants, Inc. (LDC) was selected to review the City's water quality data because they fulfill the following criteria:

- located locally in Carlsbad, CA
- disadvantaged business, 8(a) certified under Small Business Administration
- staffing capacity to meet rapid turn-around-time request
- previous experience validating WECK & MWH data
- wealth of prior water/wastewater laboratory experience in California firm
- subcontractor for EPA, Army Corps, AFCEE, Navy, DOE, DOD, and private consultants.

Protocols.
Laboratory Data Consultants, Inc. (LDC) performed all data validation analysis under EPA Level IV guidelines. Level IV review is the most rigorous and is characterized by QA/QC protocols and documentation resulting in a complete qualitative and quantitative analysis of the analytical data. Data that fulfills the requirements of this level of third party validation fulfills the minimum data quality standards needed to allow the data to be used for its intended objective. The analyses were validated using the following documents applicable to each method

- USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008.
- USEPA, CLP National Functional Guidelines for Inorganic Superfund Data Review, January 2010.
- USEPA, CLP National Functional Guidelines for Polychlorinated Dioxins / Dibenzofurans Data Review, Review, September 2005.
- Multiple Agency Radiological Laboratory Analytical Protocols (MARLAP) Manual, July 2004.

Summary of Results
The third party validation process confirmed that the majority of the data met the strict analytical standards of the USEPA CLP. Given the large number of parameters and control statistics analyzed, it is always likely that a handful of parameters will not quite fulfill all of the validation criteria. Since split samples were collected for analysis by each of the laboratories, this summary section only calls out the sample

[3] EPA 540/G 87/003A, Data Quality Objectives For Remedial Response Activities, March 1987)

parameter results that ended up being flagged and qualified for both laboratories or were flagged and only analyzed by one of the laboratories. Flagging of data is performed to denote lack of fulfillment with one or more of the CLP review criteria that could impact data detection or quantization. Flags are classified as P (protocol) or A (advisory) to indicate whether the flag is due to a laboratory deviation from a specified protocol or is of technical advisory nature. Flagged data is qualified to provide information on how the finding impacted the results. The following are definitions of the data qualifiers:

U Indicates the compound or analyte was analyzed for but not detected at or above the stated limit.

J Indicates an estimated value.

R Quality control indicates the data is not usable.

NJ Presumptive evidence of presence of the compound at an estimated quantity.

UJ Indicates the compound or analyte was analyzed for but not detected. The sample detection limit is an estimated value.

None Indicates the data was not significantly impacted by the finding, therefore qualification was not required.

All of the exceptions for either laboratory are detailed in the subsequent section. The project team contacted each laboratory to discuss the findings of the data validation and requested that any necessary procedural changes be implemented for analysis conducted In future sampling events.

Presentation and Interpretation of Third Party Validation Findings

WECK analyzed samples two sample sets utilizing 45 analytical methods as detailed in **Table A-1.** MWH analyzed samples from one sample location utilizing 56 analytical methods as detailed in **Table A-2**. Brief summaries of the items reviewed for each analytical methodology and description of the samples not fully meeting the analytical method requirements are provided below.

EPA Method 524.2 (Volatiles)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Instrument performance check met
4. Initial calibration performed with required standard concentrations

5. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
6. Method blanks contained no volatile contaminants
7. Surrogate spikes were within acceptable surrogate recoveries
8. Laboratory control samples (LCS) were within acceptable percent recoveries
9. Internal standards were within QC limits
10. Target compound identification were within validation criteria
11. Compound quantification and Reporting Limits were within validation criteria
12. System performance was acceptable
13. Overall assessment data
14. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The two (2) samples fulfilled most of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008.

The exceptions include:

- **Method Blanks –** No volatile contaminants were detected in the method blanks with the exception of bromodichloromethane (BDCM). As a result, the reported concentrations of BDCM were flagged as not detected at or above the stated values.
- **Laboratory Control Samples (LCS) –** All LCS's were within QC limits with the exception of dichlorofluoromethane. As a result the reported concentrations were flagged as estimates.

MWH Laboratories

The sample fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. No sample data was qualified.

EPA SRL 524.2 M (1,2,3 Trichloropropane)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations

4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no volatile contaminants
6. Laboratory control samples (LCS) were within acceptable percent recoveries
7. Internal standards were within QC limits
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The two (2) samples fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. No sample data was qualified

EPA 625 (Semi-volatiles)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Instrument performance check met
4. Initial calibration performed with required standard concentrations
5. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
6. Method blanks contained no volatile contaminants
7. Surrogate spikes were within acceptable surrogate recoveries
8. Laboratory control samples (LCS) were within acceptable percent recoveries
9. Internal standards were within QC limits
10. Target compound identification were within validation criteria
11. Compound quantification and Reporting Limits were within validation criteria
12. System performance was acceptable
13. Overall assessment data
14. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The two (2) samples fulfilled most of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. The only exception was that the continuing calibration differences (%D) for the following compounds: **hexachlorocyclopentadiene, ideno (1,2,3 –cd) pyrene, dibenzoa (a,h) anthracene, and benzo (g,h,i) perylene** were above the acceptable value of 20%. Therefore, all reported results for these compounds were flagged as estimated values (all detects) or with estimated detection limits (all non detects).

MWH Laboratories

The sample fulfilled most of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008.

The exceptions include:

- **Continuing Calibration –** All continued calibration was performed at the required frequencies. However, the difference (%D) for one compound (benzidine) was greater than 20% on two occasions. Therefore, the result for this parameter was flagged with an estimated detection limit.
- **Laboratory Control Samples (LCS) –** All LCS's were within QC limits with the exception of one compound (**benzidine**). Therefore, the result for this parameter was flagged with an estimated detection limit.

EPA 525.2 (Semi-volatiles)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Instrument performance check met
4. Initial calibration performed with required standard concentrations
5. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
6. Method blanks contained no volatile contaminants
7. Surrogate spikes were within acceptable surrogate recoveries
8. Laboratory control samples (LCS) were within acceptable percent recoveries
9. Internal standards were within QC limits

10. Target compound identification were within validation criteria
11. Compound quantification and Reporting Limits were within validation criteria
12. System performance was acceptable
13. Overall assessment data
14. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The two (2) samples fulfilled most of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. The only exception was that the acceptable percent recovery (%R) and relative percent difference (RPD), respectively for LCS's of two compounds were not met. The compounds included **disulfoton** and **diazinon**. Therefore, all reported results for these compounds were flagged as estimated values (all detects) or with estimated detection limits (all non detects).

MWH Laboratories

The sample fulfilled most of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008.
The exception follows:

- **Continuing Calibration –** All continued calibration was performed at the required frequencies. However, the values of the difference (%D) between calibrations for three compounds (**aldrin, endrin aldehyde and permitrin)** were greater than 30% on one occasion. Therefore, all reported results for these compounds were flagged as estimated values (all detects) or with estimated detection limits (all non-detects).

EPA SW 486 Method 8270M (1,4 Dioxane)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Instrument performance check met
4. Initial calibration performed with required standard concentrations
5. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
6. Method blanks contained no trace of the target compound

7. Laboratory control samples (LCS) were within acceptable percent recoveries
8. Internal standards were within QC limits
9. Target compound identification were within validation criteria
10. Compound quantification and Reporting Limits were within validation criteria
11. System performance was acceptable
12. Overall assessment data
13. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The S10 sample fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. The Blind Duplicate sample also fulfilled all of the stated requirements within the exception that one of the internal standards **(1,4 Dioxane-d8)** was outside the QC requirements. Therefore, the reported result for this sample location had to be flagged with an estimated detection limit.

MWH Laboratories

This analysis was not performed by the MWH Laboratories. Instead 1,4 dioxane was analyzed using EPA Method 522.

EPA 522 (1,4 Dioxane)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Instrument performance check met
4. Initial calibration performed with required standard concentrations
5. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
6. Method blanks contained no trace of the target compound
7. Laboratory control samples (LCS) were within acceptable percent recoveries
8. Internal standards were within QC limits
9. Target compound identification were within validation criteria
10. Compound quantification and Reporting Limits were within validation criteria
11. System performance was acceptable
12. Overall assessment data
13. Field duplicate relative percent difference for detected compounds

WECK Laboratories

This analysis was not performed by the WECK Laboratories. Instead 1,4 dioxane was analyzed using EPA SW 486 Method 8270M.

MWH Laboratories

The sample fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. No sample data was qualified.

EPA 508 (Chlorinated Pesticides and PCBs)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Instrument performance check met
4. Initial calibration performed with required standard concentrations
5. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
6. Method blanks contained no trace of the target compound(s)
7. Laboratory control samples (LCS) were within acceptable percent recoveries
8. Internal standards were within QC limits
9. Target compound identification were within validation criteria
10. Compound quantification and Reporting Limits were within validation criteria
11. System performance was acceptable
12. Overall assessment data
13. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The two (2) samples fulfilled most of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008.

The exceptions include:

- **Continuing Calibration –** All continued calibration was performed at the required frequencies. However, the values of the difference (%D) between calibrations for two compounds (**alpha-BHC, hexachlorocyclopentadiene)** were greater than 20% and results for both sample locations were flagged as

estimated values (all detects) or with estimated detection limits (all non-detects).

- **Surrogate Spikes** – The recovery (%R) of surrogate spikes for all compounds were within the QC limits for the S10 sample. However, the %R for the surrogate compound **decachlorobipheny**l was just outside the QC limits making it necessary to flag results as estimates.

MWH Laboratories

This analysis was not performed by the MWH Laboratories. Instead chlorinated pesticides and PCBs were analyzed using EPA Method 508 and 608.

EPA 505&608 (Chlorinated Pesticides and PCBs)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Instrument performance check met
4. Initial calibration performed with required standard concentrations
5. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
6. Method blanks contained no trace of the target compound(s)
7. Laboratory control samples (LCS) were within acceptable percent recoveries
8. Internal standards were within QC limits
9. Target compound identification were within validation criteria
10. Compound quantification and Reporting Limits were within validation criteria
11. System performance was acceptable
12. Overall assessment data
13. Field duplicate relative percent difference for detected compounds

WECK Laboratories

This analysis was not performed by the WECK Laboratories. Instead chlorinated pesticides and PCBs were analyzed using EPA Method 508.

MWH Laboratories

The sample fulfilled most of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008.
The exception follows:

- **Initial Calibration** – Relative standard deviations associated with the initial calibration of the column for all required compounds were less than or equal to 10% with the exception of **delta-BHC and 4,4 DDT**. . Therefore, all reported results for these compounds were flagged as estimated values (all detects) or with estimated detection limits (all non-detects).

EPA 200.7, 200.8, and 245.1 (Metals)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Instrument performance check met
4. Initial calibration performed with required standard concentrations
5. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
6. Method blanks contained no trace of the target compound(s)
7. Matrix spikes %R and RPD were within QC limits
8. Laboratory control samples (LCS) were within acceptable percent recoveries
9. Internal standards were within QC limits
10. Target compound identification were within validation criteria
11. Compound quantification and Reporting Limits were within validation criteria
12. System performance was acceptable
13. Overall assessment data
14. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The two samples fulfilled most of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. The first exception was the detection of **aluminum and mercury** in the S10 sample method blank where concentrations in the samples were detected at values less than 5 X the concentration measured in the method blank. The second exception was the detection of **mercury** in the Blind duplicate sample method blank where concentrations in the samples were detected at values less than 5 X the concentration measured in the method blank. For both occurrences results were flagged as being analyzed but not detected at or above the stated limit.

MWH Laboratories

The sample fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. No sample data was qualified.

EPA 515.3 / 515.4 (Herbicides)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Matrix spikes %R and RPD were within QC limits
7. Duplicate samples analyses were reviewed for each matrix as applicable to assess if QC limits were met
8. Laboratory control samples (LCS) were within acceptable percent recoveries
9. Internal standards were within QC limits
10. Target compound identification were within validation criteria
11. Compound quantification and Reporting Limits were within validation criteria
12. System performance was acceptable
13. Overall assessment data
14. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The two samples fulfilled most of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. No sample data was qualified.

MWH Laboratories

The sample fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. No sample data was qualified.

SM 2320 B (Alkalinity)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Laboratory control samples (LCS) were within acceptable percent recoveries
7. Internal standards were within QC limits
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The two samples fulfilled most of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. The exceptions were the detection of alkalinity and bicarbonate alkalinity in both the S10 and Blind Duplicate samples method blanks where concentrations in the sample were detected at concentration less than 5 X the concentration measured in the method blank. Therefore these results had to be flagged as being analyzed but not detected at or above the stated limit.

MWH Laboratories

The sample fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. No sample data was qualified.

EPA 100.2 (Asbestos)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations

4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Laboratory control samples (LCS) were within acceptable percent recoveries
7. Internal standards were within QC limits
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The samples fulfilled all of the review requirements of the modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
No sample data was qualified.

MWH Laboratories

The sample fulfilled all of the review requirements of the modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
No sample data was qualified.

EPA 326.0 / 317.0 (Bromate)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Laboratory control samples (LCS) were within acceptable percent recoveries
7. Internal standards were within QC limits
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable

11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

Bromate analysis was performed using EPA 326.0. The samples fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. No sample data was qualified.

MWH Laboratories

Bromate analysis was performed using EPA 317.0. The sample fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. No sample data was qualified.

EPA 300.1 (Chlorate and Chlorite)
Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Laboratory control samples (LCS) were within acceptable percent recoveries
7. Internal standards were within QC limits
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The samples fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. No sample data was qualified.

MWH Laboratories

Chlorate analysis of the sample using EPA 300.1 fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. No sample data was qualified. MWH Laboratories analyzed chlorite using EPA Method 300.0.

EPA 300.0 (Chloride, Chlorite, Nitrate, Nitrite, Fluoride, Sulfate)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Laboratory control samples (LCS) were within acceptable percent recoveries
7. Internal standards were within QC limits
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

WECK Laboratories used EPA 300.0 to analyze chloride, fluoride and sulfate. The two samples fulfilled most of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. The only exception was the detection of fluoride in the S10 sample method blank where concentrations in the sample were detected at concentration less than 5 X the concentration measured in the method blank. Therefore these result had to be flagged as being analyzed but not detected at or above the stated limit.

MWH Laboratories

MWH Laboratories used EPA 300.0 to analyze chloride, chlorite, nitrate, nitrite and sulfate. The sample fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. No sample data was qualified.

SM 2120 B (Color)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Laboratory control samples (LCS) were within acceptable percent recoveries
7. Internal standards were within QC limits
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The samples fulfilled all of the review requirements of the modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
No sample data was qualified.

MWH Laboratories

The sample fulfilled all of the review requirements of the modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
No sample data was qualified.

SM 2150 B (Conductivity)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Laboratory control samples (LCS) were within acceptable percent recoveries
7. Internal standards were within QC limits
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The samples fulfilled all of the review requirements of the modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
No sample data was qualified.

MWH Laboratories

The sample fulfilled all of the review requirements of the modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
No sample data was qualified.

EPA 335.4 / SM 4500 CN-F (Total Cyanide)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Laboratory control samples (LCS) were within acceptable percent recoveries
7. Internal standards were within QC limits
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The samples fulfilled all of the review requirements of the modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
No sample data was qualified.

MWH Laboratories

The sample fulfilled all of the review requirements of the modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
No sample data was qualified.

Calculation for Hardness, Total Nitrogen, Total Anions, Total Cations)

EPA 218.6 (Hexavalent Chromium)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Laboratory control samples (LCS) were within acceptable percent recoveries
7. Internal standards were within QC limits
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The samples fulfilled all of the review requirements of the modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
No sample data was qualified.

MWH Laboratories

The sample fulfilled all of the review requirements of the modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
No sample data was qualified.

SM 2330 B (Langlier Index)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Laboratory control samples (LCS) were within acceptable percent recoveries
7. Internal standards were within QC limits
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The samples fulfilled all of the review requirements of the modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
No sample data was qualified.

MWH Laboratories

The sample fulfilled all of the review requirements of the modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
No sample data was qualified.

EPA 353.2 (Nitrate, Nitrite as Nitrogen, Nitrate/Nitrite as Nitrogen)
Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Laboratory control samples (LCS) were within acceptable percent recoveries
7. Internal standards were within QC limits
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The samples fulfilled all of the review requirements of the modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
No sample data was qualified.
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MWH Laboratories

MWH Laboratories used EPA 300.0 to analyze nitrate and nitrite.

EPA 140.1 / SM 2150 B (Odor)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Laboratory control samples (LCS) were within acceptable percent recoveries
7. Internal standards were within QC limits
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

Odor analysis was performed using EPA 140.1. The samples fulfilled all of the review requirements of the modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010). No sample data was qualified.

MWH Laboratories

Odor analysis was performed using SM-2150 B. The sample fulfilled all of the review requirements of the modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010). No sample data was qualified.

EPA 314.0 (Perchlorate)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Laboratory control samples (LCS) were within acceptable percent recoveries
7. Internal standards were within QC limits
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The samples fulfilled all of the review requirements of the modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
No sample data was qualified.

MWH Laboratories

The sample fulfilled all of the review requirements of the modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
No sample data was qualified.

SM 4500 B (pH)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Laboratory control samples (LCS) were within acceptable percent recoveries
7. Internal standards were within QC limits
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The samples fulfilled all of the review requirements of the modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
No sample data was qualified.

MWH Laboratories

The sample fulfilled all of the review requirements of the modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
No sample data was qualified.

EPA 365.1 (Total Phosphorus)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Laboratory control samples (LCS) were within acceptable percent recoveries
7. Internal standards were within QC limits
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The samples fulfilled most of the review requirements of the modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
The only exception was the detection of phosphorus in the Blind Duplicate sample method blank where concentrations in the sample were detected at concentration less than 5 X the concentration measured in the method blank. Therefore these result had to be flagged as being analyzed but not detected at or above the stated limit.

MWH Laboratories

The sample fulfilled all of the review requirements of the modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
No sample data was qualified.

SM 5540 C / EPA 425.1 (Surfactants)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Laboratory control samples (LCS) were within acceptable percent recoveries
7. Internal standards were within QC limits
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

Surfactant analysis was performed using SM 5540C. The samples fulfilled all of the review requirements of the modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010). No sample data was qualified.

MWH Laboratories

Surfactant analysis was performed using SM 5540C & EPA 425.1. The sample fulfilled all of the review requirements of the modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010). No sample data was qualified.
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SM 2540 C / EPA 160.1 (Total Dissolved Solids)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Laboratory control samples (LCS) were within acceptable percent recoveries
7. Internal standards were within QC limits
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The samples fulfilled all of the review requirements of the modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
No sample data was qualified.

MWH Laboratories

The sample fulfilled all of the review requirements of the modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
No sample data was qualified.

SM 5310 C / EPA 415.3 (Total Organic Carbon)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Laboratory control samples (LCS) were within acceptable percent recoveries
7. Internal standards were within QC limits
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The samples fulfilled all of the review requirements of the modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
No sample data was qualified.

MWH Laboratories

The samples fulfilled all of the review requirements of the modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
No sample data was qualified.

EPA 351.2 (Total Kjeldahl Nitrogen)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Laboratory control samples (LCS) were within acceptable percent recoveries
7. Internal standards were within QC limits
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The samples fulfilled all of the review requirements of the modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
No sample data was qualified.

MWH Laboratories

The samples fulfilled all of the review requirements of the modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
No sample data was qualified.

EPA 180.1 (Turbidity)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Laboratory control samples (LCS) were within acceptable percent recoveries
7. Internal standards were within QC limits
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The samples fulfilled all of the review requirements of the modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
No sample data was qualified.

MWH Laboratories

The samples fulfilled all of the review requirements of the modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
No sample data was qualified

EPA 504.1 (1,2 Dibromoethane, 1,2-Dibromo-3-chloropropane)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Laboratory control samples (LCS) were within acceptable percent recoveries
7. Internal standards were within QC limits
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The samples fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. No sample data was qualified.

MWH Laboratories

The sample fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. No sample data was qualified.

EPA SW 836 Method 1613B (2,3,7,8-TCDD)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. HRGC/HRMS Instrument Performance Checked at required frequency
4. Initial calibration performed with required standard concentrations
5. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
6. Method blanks contained no trace of the target compound(s)
7. Laboratory control samples (LCS) were within acceptable percent recoveries
8. Internal standards were within QC limits
9. Target compound identification were within validation criteria
10. Compound quantification and Reporting Limits were within validation criteria
11. System performance was acceptable
12. Overall assessment data
13. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The samples fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Polychlorinated 2, 3, 7, 8-TCDD Data Review, (September 2005). No sample data was qualified.

MWH Laboratories

The sample fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Polychlorinated 2, 3, 7, 8-TCDD Data Review, (September 2005). No sample data was qualified.

EPA 900.0 (Gross Alpha and Beta Radioactivity)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Laboratory control samples (LCS) were within acceptable percent recoveries
7. All minimum detectable activities met required detection limits.
8. Internal standards were within QC limits
9. Target compound identification were within validation criteria
10. Compound quantification and Reporting Limits were within validation criteria
11. System performance was acceptable
12. Overall assessment data
13. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The samples fulfilled all of the review requirements of the Multi Agency Radiological Laboratory Analytical Protocols (MARLAP) Manual (July 2004) and a modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
. No sample data was qualified.

MWH Laboratories

The sample fulfilled all of the review requirements of the Multi Agency Radiological Laboratory Analytical Protocols (MARLAP) Manual (July 2004) and a modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
No sample data was qualified.

EPA 903.0 (Radium 226)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Laboratory control samples (LCS) were within acceptable percent recoveries
7. All minimum detectable activities met required detection limits.
8. Sample result verifications were acceptable
9. System performance was acceptable
10. Overall assessment data
11. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The samples fulfilled all of the review requirements of the Multi Agency Radiological Laboratory Analytical Protocols (MARLAP) Manual (July 2004) and a modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
No sample data was qualified.

MWH Laboratories

The sample fulfilled most of the review requirements of the Multi Agency Radiological Laboratory Analytical Protocols (MARLAP) Manual (July 2004) and a modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
The only exception was that the acceptable percent recovery (%R) and relative percent difference (RPD), respectively for LCS was not met. Therefore, the reported result for this parameter was flagged with an estimated detection limit.

EPA Ra-05 / EPA 904.0 (Radium 228)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Laboratory control samples (LCS) were within acceptable percent recoveries
7. All carrier recoveries were within validation criteria.
8. All minimum detectable activities met required detection limits.
9. Sample result verifications were acceptable
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

WECK analyzed Radium 228 using EPA Method Ra-05. The samples fulfilled all of the review requirements of the Multi Agency Radiological Laboratory Analytical Protocols (MARLAP) Manual (July 2004) and a modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010). No sample data was qualified.

MWH Laboratories

MWH analyzed Radium 228 using EPA Method 904.0. The sample fulfilled all of the review requirements of the Multi Agency Radiological Laboratory Analytical Protocols (MARLAP) Manual (July 2004) and a modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010). No sample data was qualified.

EPA 906.0 (Tritium)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Laboratory control samples (LCS) were within acceptable percent recoveries
7. All carrier recoveries were within validation criteria.
8. All minimum detectable activities met required detection limits.
9. Sample result verifications were acceptable
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The samples fulfilled most of the review requirements of the Multi Agency Radiological Laboratory Analytical Protocols (MARLAP) Manual (July 2004) and a modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
The only exception was that the acceptable percent recovery (%R) and relative percent difference (RPD), respectively for the LCS was not met. Therefore, the reported results were flagged to indicate the isotope was analyzed but not detected and the detection limit is estimated.

MWH Laboratories

The sample fulfilled all of the review requirements of the Multi Agency Radiological Laboratory Analytical Protocols (MARLAP) Manual (July 2004) and a modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
No sample data was qualified.

EPA 901.1 (Gamma Spectroscopy)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Laboratory control samples (LCS) were within acceptable percent recoveries
7. All carrier recoveries were within validation criteria.
8. All minimum detectable activities met required detection limits.
9. Sample result verifications were acceptable
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The samples fulfilled all of the review requirements of the Multi Agency Radiological Laboratory Analytical Protocols (MARLAP) Manual (July 2004) and a modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).

MWH Laboratories

MWH Laboratories did not perform this analysis.

EPA SW 846 Method 8330 (Explosives)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Surrogate recoveries were added to samples and blanks as required by the method.
7. Laboratory control samples (LCS) were within acceptable percent recoveries
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The samples fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. No sample data was qualified.

MWH Laboratories

MWH Laboratories analyzed explosives using LCMS.

LCMS (Explosives)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Surrogate recoveries were added to samples and blanks as required by the method.
7. Laboratory control samples (LCS) were within acceptable percent recoveries
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

WECK Laboratories analyzed explosives using EPA SW 846 Method 8330.

MWH Laboratories

The sample fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. No sample data was qualified.

EPA SW 846 Method 8015 B / 8270C (Ethylene Glycol)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Surrogate recoveries were added to samples and blanks as required by the method.
7. Laboratory control samples (LCS) were within acceptable percent recoveries
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

WECK Laboratories analyzed Ethylene Glycol using EPA SW 846 Method 8015B. The samples fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. No sample data was qualified.

MWH Laboratories

MWH Laboratories analyzed Ethylene Glycol using EPA SW 846 Method 8270C. The sample fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. No sample data was qualified.

EPA 552.2 / 6251B (Haloacetic Acids)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Surrogate recoveries were added to samples and blanks as required by the method.
7. Laboratory control samples (LCS) were within acceptable percent recoveries
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

WECK Laboratories analyzed Haloacetic Acids using EPA Method 552.2. The samples fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. No sample data was qualified.

MWH Laboratories

MWH Laboratories analyzed Haloacetic Acids using EPA Method 6251 B. The sample fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. No sample data was qualified.

EPA 905.0 (Strontium-90)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Laboratory control samples (LCS) were within acceptable percent recoveries
7. All carrier recoveries were within validation criteria.
8. All minimum detectable activities met required detection limits.
9. Sample result verifications were acceptable
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The samples fulfilled most of the review requirements of the Multi Agency Radiological Laboratory Analytical Protocols (MARLAP) Manual (July 2004) and a modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
The only exception was that the acceptable percent recovery (%R) and relative percent difference (RPD), respectively for the LCS's were not met. Therefore, the reported results were flagged to indicate the isotope was analyzed but not detected and the detection limit is estimated.

MWH Laboratories

The sample fulfilled all of the review requirements of the Multi Agency Radiological Laboratory Analytical Protocols (MARLAP) Manual (July 2004) and a modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).
No sample data was qualified.

EPA 556 (Aldehydes)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Surrogate recoveries were added to samples and blanks as required by the method.
7. Laboratory control samples (LCS) were within acceptable percent recoveries
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The samples fulfilled most of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008.
The only exception was the detection of acetaldehyde in both the S10 and Blind Duplicate sample method blank where concentrations in the sample were detected at concentration less than 5 X the concentration measured in the method blank. Therefore, the reported result had to be flagged and was modified as being analyzed but not detected at or above 2.0 ug/L.

MWH Laboratories

The sample fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. No sample data was qualified.

EPA 521 (Nitrosamines)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Surrogate recoveries were added to samples and blanks as required by the method.
7. Laboratory control samples (LCS) were within acceptable percent recoveries
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The samples fulfilled most of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008.
The only exception was the detection of N-nitrosdimethylamine (NDMA) in the S10 sample method blank where the concentration in the sample was detected at a concentration less than 5 X the concentration measured in the method blank. Therefore the reported result had to be flagged and modified as being analyzed but not detected at or above 2.0 ug/L.

MWH Laboratories

The sample fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. No sample data was qualified.

EPA 531.1 / 531.2 (Carbamate & Urea Pesticides)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Surrogate recoveries were added to samples and blanks as required by the method.
7. Laboratory control samples (LCS) were within acceptable percent recoveries
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

WECK Laboratories analyzed Carbamate & Urea pesticides using EPA Method 531.1. The samples fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. No sample data was qualified.

MWH Laboratories

MWH Laboratories analyzed Carbamate & Urea pesticides using EPA Method 531.2. The sample fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. No sample data was qualified.

EPA 549.2 (Diquat)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Surrogate recoveries were added to samples and blanks as required by the method.
7. Laboratory control samples (LCS) were within acceptable percent recoveries
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The samples fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. No sample data was qualified.

MWH Laboratories

The sample fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. No sample data was qualified.

EPA 547 (Glyphosphate)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Surrogate recoveries were added to samples and blanks as required by the method.
7. Laboratory control samples (LCS) were within acceptable percent recoveries
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The samples fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. No sample data was qualified.

MWH Laboratories

The sample fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. No sample data was qualified.

EPA 548.1 (Endothall)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained no trace of the target compound(s)
6. Surrogate recoveries were added to samples and blanks as required by the method.
7. Laboratory control samples (LCS) were within acceptable percent recoveries
8. Target compound identification were within validation criteria
9. Compound quantification and Reporting Limits were within validation criteria
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

The samples fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. No sample data was qualified.

MWH Laboratories

The sample fulfilled all of the review requirements in the USEPA, Contract Laboratory Program (CLP) National Functional Guidelines for Superfund Organic Methods Data Review, June 2008. No sample data was qualified.

EPA 901.1 (Gamma Emitting Radionuclides / Cesium 137)

Data review verified the following items:

1. Technical holding time requirements met
2. Cooler temperature requirements met
3. Initial calibration performed with required standard concentrations
4. Continuing calibration (CC) was performed at the required frequency and the difference between the initial and repeated calibrations were within QC limits.
5. Method blanks contained less than the minimum detectable activity (MDA)
6. Laboratory control samples (LCS) were within acceptable percent recoveries
7. All carrier recoveries were within validation criteria.
8. All minimum detectable activities met required detection limits.
9. Sample result verifications were acceptable
10. System performance was acceptable
11. Overall assessment data
12. Field duplicate relative percent difference for detected compounds

WECK Laboratories

WECK lab utilized Eberline Services to analyze for gamma emitting radionuclides using EPA 901.1. The samples fulfilled all of the review requirements of the Multi Agency Radiological Laboratory Analytical Protocols (MARLAP) Manual (July 2004) and a modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).

MWH Laboratories

MWH lab utilized GEL Laboratories to analyze for Cesium 137 using EPA 901.1. The samples fulfilled all of the review requirements of the Multi Agency Radiological Laboratory Analytical Protocols (MARLAP) Manual (July 2004) and a modified outline of the USEPA Contract Laboratory Program, National Functional Guidelines for Inorganic Superfund Review (January 2010).

Table A-1: Sample Analyses Performed by WECK Laboratories, Inc.

Sample Location	Collection Date	Method
UV/AOP Product Water (S10) Blind Duplicate (S10)	8/24/2011	EPA 524.2 (Volatiles) EPA SRL 524.2 M (1,2,3 Trichloropropane) EPA 625 (Semi-volatiles) EPA 525.2 (Semi-volatiles) EPA SW 486 Method 8270M (1,4 Dioxane) EPA 508 (Chlorinated Pesticides and PCBs) EPA 200.7, 200.8, and 245.1 (Metals) EPA 515.3 (Herbicides) SM 2320 B (Alkalinity) EPA 100.2 (Asbestos) EPA 326.0 (Bromate) EPA 300.1 (Chlorate and Chlorite) EPA 300 (Chloride, Fluoride and Sulfate) SM 2120 B (Color) SM 2150 B (Conductivity) EPA 335.4 (Total Cyanide,) Calculation for Hardness, Total Nitrogen, Total Anions, Total Cations) EPA 218.6 (Hexavalent Chromium) SM 2330 B (Langlier Index) EPA 353.2 (Nitrate, Nitrite as Nitrogen, Nitrate/Nitrite as Nitrogen) EPA 140.1 (Odor) EPA 314.0 (Perchlorate) SM 4500 B (pH) EPA 365.1 (Total Phosphorus) SM 5540 C (Surfactants) SM 2540 C (Total Dissolved Solids) SM 5310 C (Total Organic Carbon) EPA 351.2 (Total Kjeldahl Nitrogen) EPA 180.1 (Turbidity) EPA 504.1 (1,2 Dibromoethane, 1,2-Dibromo-3-chloropropane) EPA SW 836 Method 1613B (2,3,7,8-TCDD) EPA 900.0 (Gross Alpha and Beta Radioactivity) EPA 903.0 (Radium 226) Method Ra-05 (Radium 228) EPA 906.0 (Tritium)

Table A-1: Sample Analyses Performed by WECK Laboratories, Inc. (cont'd)

Sample Location	Collection Date	Method
UV/AOP Product Water (S10) Blind Duplicate (S10)	8/24/2011	EPA 901.1 (Gamma Spectroscopy) EPA SW 846 Method 8330 (Explosives) EPA SW 846 Method 8015 B (Ethylene Glycol) EPA 552.2 (Haloacetic Acids) EPA 905.0 (Strontium-90) EPA 556 (Aldehydes) EPA 521 (Nitrosamines) EPA 531.1 (Carbamate & Urea Pesticides) EPA 549.2 (Diquat) EPA 547 (Glyphosphate) EPA 548.1 (Endothall)

Table A-2: Sample Analyses Performed by MWH Laboratories, Inc.

Sample Location	Collection Date	Method
UV/AOP Product Water (S10)	8/24/2011	EPA 524.3 (Volatiles) EPA SRL 524.2 M (1,2,3 Trichloropropane) EPA 524.2 (Volatiles) EPA 524.2 using Selected Ion Monitoring (t-Butyl Alcohol) EPA 624 (Volatiles) EPA 624 (2-Chloroethylvinyl ether) EPA 625 (Semi-volatiles) EPA 525.2 (Semi-volatiles) EPA 522 (1,4 Dioxane) EPA SW 846 Method 8270 C (Ethylene Glycol) EPA 505 (Chlorinated Pesticides and PCBs) EPA 608 (Chlorinated Pesticides and PCBs) EPA 200.7, 200.8, and 245.1 (Metals) EPA 515.4 (Herbicides) SM 2320 B (Alkalinity) EPA 100.2 (Asbestos) EPA 317.0 (Bromate) EPA 300.1 (Chlorate) EPA 300 (Chloride, Chlorite, Nitrate, Nitrite, and Sulfate) SM 9223 (Coliform SM 2120 B (Color) SM 2150 B (Conductivity) SM 4500 CN-F (Cyanide) SM 4500 C02-D (Free Carbon Dioxide) SM 2340B (Hardness) EPA 218.6 (Dissolved Hexavalent Chromium) SM 2330 B (Langlier Index & pH) Calculation Method Nitrate, Nitrite/Nitrate, Total Nitrogen) EPA 2150B (Odor) EPA 314.0 (Perchlorate) SM 4500-PE & EPA 365.1 (Total Phosphorus and Phosphorus) SM 5540 C & EPA 425.1 (Surfactants) EPA 160.1 & SM 2540 C (Total Dissolved Solids) SM 5310 C & EPA 415.3 (Total Organic Carbon) EPA 351.2 (Total Kjeldahl Nitrogen) SM 1030 E (Total Anions, Total Cations, and Cation/Anion Difference)

Table A-2: Sample Analyses Performed by MWH Laboratories, Inc. (cont'd)

Sample Location	Collection Date	Method
UV/AOP Product Water (S10)	8/24/2011	EPA 180.1 (Turbidity) Calculation Method (Aggressiveness Index) SM 4500F-C (Fluoride) EPA 551.1 (Dibromochloropropane & Ethylene Dibromide) EPA SW 836 Method 1613B (2,3,7,8-TCDD) EPA 900.0 (Gross Alpha and Beta Radioactivity) EPA 903.0 (Radium 226) EPA 904.0 (Radium 228) EPA 906.0 (Tritium) LCMS (Explosives: 2,4,6-Trinitrotoluene, HMX and RDX) SM 6251 B (Haloacetic Acids) EPA 905.0 (Strontium-90) EPA 902 & SM 7500-IB (Iodine-131) EPA 556 (Acetaldehyde & Formaldehyde) LC-MS-MS (Hydrazines) EPA 521 (Nitrosoamines) EPA 531.2 (Carbamate & Urea Pesticides) EPA 549.2 (Diquat & Paraquat) EPA 547 (Glyphosphate) EPA 548.1 (Endothall) EPA 901.1 (Cesium 137) EPA 537 (Perfluorinated Chemicals) EPA 539 (Hormones) DX_ABI_NEG & POS (Pharmaceutical and Personal Care Products and Endocrine Disrupting Compounds)

Appendix D

Expert Report: In review of Data for City of San Diego AWP Facility prepared by Shane Snyder, PhD

EXPERT REPORT

OF

SHANE A. SNYDER, Ph.D.

In review of data for City of San Diego AWPF provided by CDM-Smith / MWH consultants

13th October 2012

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13th October 2012

1.0 INTRODUCTION

During a telephone discussion with CDM-Smith/MWH (consultant team) including Jennifer Thompson, Greg Wetterau and James DeCarolis, I became aware of detectable substances in the finished water of the AWPF in San Diego. I have discussed some of these "anomalies" previously with the consultant team; however, on the 21st of June call (taken by me in Singapore) I became aware of additional information relevant to the project. On the 24th of July, the consultant team provided me data and a specific list of issues to be addressed in my expert report. The data I reviewed in preparing my report is included in the Quarterly Testing Report No. 4 (Q4 Testing Report) as referenced in subsequent sections of this report.

The consultant team specifically asked me to provide expert opinions on:

1. The statistical significance of the detection of certain unregulated contaminants in product water and likelihood of being true occurrence values rather than false positives (Type 1 error),

2. Comparison of the results of the unregulated detected contaminants compounds in product water to those occurrences reported in the blanks of other studies (i.e., USGS),

3. Public health relevance of occurrence of the unregulated contaminants at the concentrations reported in product water,

4. Compare/contrast the analytical values provided by the three laboratories involved in the study,

5. Opinion on role of sample volume on method report limits between MWH Labs and Colorado School of Mines.

Data has been provided to me indicated the presence of said unregulated contaminants in advanced treated water. I understand that my evaluation includes those data provided along with peer-reviewed data from other studies and my expert opinion.

While I have been asked to provide opinions regarding sampling techniques, quality assurance, quality control, and representativeness of analytical measurements related to the detections reported, it is important to state upfront that I have had no direct (hands on) experience with the sampling that took place in San Diego. Therefore, my expert opinion is based on the facts provided to me and limits the scope of my expert opinion. In order to develop my expert opinion, I have relied upon water quality monitoring data by the consultant team, peer-reviewed published literature, federal and state government documents, electronic media, and my own academic and professional experience.

1.1 QUALIFICATIONS

A current curriculum vitae (CV) containing publications and research projects is provided in Attachment A. I am the Vice-President and Director of Total Environmental Solutions, Inc. (TES), in Boulder City, Nevada. I am also a Professor of Chemical and Environmental Engineering at the University of Arizona and the Co-Director of the Arizona Laboratory for Emerging Contaminants also at the University of Arizona. I have conducted environmental research for more than 15 years and have acted as an environmental consultant for over a decade. My career has focused on understanding the occurrence, fate, and transport of contaminants in water. I am the Principal Investigator for several projects related to emerging contaminants in water and serve on several expert panels and committees related to water quality in the United States (US). I was a member of the recent National Academy of Science's National Research Council expert panel on water reuse. I have served on two US EPA advisory committees on endocrine disrupting chemicals and was a member of two US EPA expert panels for the Contaminant Candidate List 3. I have conducted extensive research related to trace contaminants in water supplies and have authored or co-authored over 100 manuscripts, reports, and book chapters during my career. I am a well-established expert on contaminant occurrence, treatment, and distribution in municipal drinking and waste water. In 2011 alone, I delivered more than a dozen invited presentations in five countries. The US Senate Committee on Environment and Public Works invited me to testify in April of 2008 as one of six national experts on the occurrence and relevance of trace pharmaceuticals in US drinking water. I have provided briefings for the US Congress three additional times. I was appointed twice to the California State Water Resources Control Board's Blue Ribbon Panels on emerging water quality issues.

Prior to my current employment, I was the Research and Development Project Manager for the Southern Nevada Water Authority (SNWA) in Las Vegas, Nevada from 2000 through 2010. The SNWA provides public water services for nearly 2,000,000 permanent residents and up to 40,000,000 visitors per year. My primary role at SNWA is to lead a group of researchers to determine occurrence and treatment efficacy of emerging environmental contaminants. The SNWA relies on both surface and groundwater to supply water within Clark County, Nevada. With over ten years of experience at the SNWA, I became proficient in the issues surrounding the federal and state regulations that govern the supply, treatment, and delivery of municipal water.

For the purposes of this report, I am acting solely on behalf of TES.

1.1.1 **Academic Credentials**

I have received the following degrees from accredited colleges and universities:

1. Bachelor of Arts (B.A.) degree in Chemistry with a minor in Medical Biology from Thiel College in Greenville, Pennsylvania

2. Doctor of Philosophy (Ph.D.) in Zoology and Environmental Toxicology from Michigan State University in East Lansing, Michigan

2.0 BACKGROUND AND SUMMARY

Water Quality Constituents and Influences

Water inherently contains a variety of organic, inorganic, and biological constituents. In fact, pure water, being two hydrogen atoms covalently bonded to an oxygen atom, does not naturally exist as a liquid on earth. All water contains some degree of dissolved and solid materials that comprise the complex aqueous mixture. In fact, all water systems will endogenously contain various salts, elements, and organic constituents. Beyond endogenous/natural constituents, a diversity of contaminants, including pharmaceuticals, have been reported in drinking water (Benotti, Trenholm et al. 2009), municipal wastewater (Nelson, Do et al. 2011), and in septic systems (Conn, Barber et al. 2006). Fortunately, essentially all public water systems in the United States regularly monitor water quality and perform extensive maintenance procedures to ensure regulatory compliance and reliability.

Accuracy and Precision of Water Quality Data

In environmental monitoring, there are seven key steps (Figure 1) to consider, namely: problem definition, sample program design, field sampling, sample preparation, chemical analysis, data analysis, and reporting (Batley 1999). If these seven steps are not considered, data collected may lead to erroneous conclusions. Problem definition involves defining the purpose of the monitoring program and questions to be answered by the acquired data. For San Diego, this is most likely a question of is the advanced treatment process being piloted tested robust and reliable for the production of exemplary water quality. Sample program design involves establishment of a testing plan that allows the problem definition to be adequately addressed. This will involve consideration of diurnal, spacial, and temporal variability as well as providing the necessary statistical power to demonstrate trends and to have confidence in representativeness of data to estimate the true population. Of critical importance are field sampling protocols and blanks. How a sample is collected and stored can have a dramatic impact on the resulting data. Blanks provide a measure of knowledge as to the trueness of an analytical measurement. For environmental measurements, field blanks, method blanks, and instruments blanks are of paramount importance. For aqueous sampling, a field blank requires the transporting ultrapure, previously characterized, water to the field site and passing this water through all sampling devices and collecting in a sample bottle exactly in the same way that an actual sample is collected and handled, and ultimate analyzed. A method blank evaluates the cleanliness of the analytical procedure and thus involves ultrapure water processed in the laboratory in exactly the same manner as a sample. The final type of blank that is critical for environmental analysis is an instrument blank, which involves the analysis of a blank matrix (water or solvent depending on analysis) which provides a measure of instrument cleanliness. These are just three types of blanks that should be included in any environmental

sampling event. Failure to include these types of blanks will draw the resulting data into serious question. For instance, the issue of blanks is paramount when analyzing for ubiquitous substances such as bis(2-ethylhexyl)phthalate (DEHP). As a ubiquitous contaminant in laboratory and field sampling settings, DEHP sampling and analysis requires that the amount of DEHP contributed by sampling equipment, laboratory facilities, and other routes of contamination be accurately accounted for through blanks (Connelly ; Tienpont, David et al. 2005; Fankhauser-Noti and Grob 2007). The use of plastics and polymers, for instance the plastic bucket and polymeric tubing must be avoided when sampling for trace levels of DEHP in water. The issue with personal care products is similar in that people handling aqueous samples should avoid using products such as sunscreen, antimicrobial soaps, and insect repellent.

In 2002, the USGS published one of the most impactful reports on pharmaceuticals in US water systems (Kolpin, Furlong et al. 2002). However, later review of this report indicated that many of the steroid hormone data were at concentrations that were far higher than any other studies in the world. For instance, Kolpin purported a maximum ethynylestradiol (birthcontrol) concentration of 831 ng/L, yet another study from the USA published earlier showed a maximum concentration of just 0.759 ng/L. Later, the USGS issued an errata on their website (http://toxics.usgs.gov/regional/est_errata.html) lowering the maximum concentration by one order of magnitude. Regardless, the corrections were not made to the published article and the US EPA used those data in the development of the CCL3 and later the UCMR3. Had it not been for the faulty USGS data used by the EPA in the dossier for the CCL3, it is highly unlikely that steroid hormones would have made the CCL3 and perhaps would not have also appeared on the UMCR3. In addition, the USGS provided no QA/QC data within Kolpin 2002, yet on the USGS website it is obvious that there were problems in achieving clean blanks. For instance, the USGS reports that acetaminophen occurred in 59% of all blanks in the Kolpin study, while diethyl phthalate occurred at concentrations up to 74,000 ng/L. Thus these sage examples shows how inaccurate analytical data can influence public policy.

Acesulfame K

Acesulfame is an artificial sweetener with the "K" standing for potassium. Acesulfame K is around 200x sweeter than sucrose (table sugar) and is often blended with other artificial sweeteners which has been reported to have a synergistic effect on the sweetness. It is a bit unique compared to other artificial sweeteners as it is stable under elevated temperatures and can be used in baking. Acesulfame K is approved as a food additive in the US, Europe, and other countries, thus, health relevance at ng/L in water is assumed to be *de minimis*.

According to Table 41 of the Q4 Testing Report , Acesulfame K was detected two times in the UV-AOP product. On the 15th of February 2012, Acesulfame K demonstrated a concentration of 31 ng/L, yet, was undetectable (<20 ng/L) in the RO permeate. My guess is that the sample was miss-labeled and switched with the post-RO sample, since in all other events, the post-RO sample had between 30-40 ng/L. These post-RO values for Acesulfame K are expected, as rejection of organic constituents should not exceed the

rejection for TDS. In other words, 99% rejection of Acesulfame K would still result in detectable concentrations considering the feed concentration. Acesulfame K also was detected in product water on 9/14/2011 at 50 ng/L as shown in Table 36 of the Q4 Testing Report. In this sampling event, Acesulfame K was present at 65 ng/L in the RO permeate, this the 50 ng/L in the UV-AOP effluent would indicate a low degree of oxidation. Indeed, Acesulfame K is only moderately removed by UV-AOP, which would be relatively consistent with this finding. However, as mentioned above, in all other samples Acesulfame K is removed to less than detection. However, the 65 ng/L RO permeate is one of the higher feed concentrations entering the UV-AOP. Thus, there is no clear reason for the detection in the product water, but it is not entirely surprising to me.

Bromochloromethane (BCM)

Bromochloromethane was used in fire extinguishers (Halon 1011), but has not been widely used since the 1960's. Passage through RO is expected due to low molecular weight and neutral charge. The US EPA has calculated a reference dose for bromochloromethane of 0.01 mg/kg-day, thus for a 70 Kg human drinking 2L of water per day, an estimated drinking water equivalent level (DWEL) would be around 35 ug/L. As shown in Table 45 of the Q4 Testing Report, the maximum concentration of BCM reported in the purified water was 0.25 ug/L, which is >100 X lower than the DWEL. Considering the detected concentration of BCM is two orders of magnitude lower than the DWEL calculated from an EPA reference dose, I would not expect any relevance to public health from this concentration.

IOHEXAL

Iohexal is an iodinated contrast media applied intravenously before certain medical procedures. Since it is approved for intravenous application in high-doses, it is not a highly toxic agent and not likely to have any meaningful health relevance at ng/L. However, recent studies have shown that iohexal can contribute to iodinated disinfection byproducts when oxidized during water treatment. The detection of iohexal at 19 ng/L in the product water on the 14th of September (Table 36 of the Q4 Testing Report) seems to be an analytical artifact. There is no detection of iohexal in the RO permeate that feeds the UV-AOP reactor, yet it is detectable post UV-AOP. I do not believe this is accurate and I am strongly of the opinion that this singe detection is an artifact and can be discarded due to lack of detection in the RO permeate and lack of other detections in UV-AOP product water.

Triclosan

Triclosan is a commonly used anti-microbial agent that is used in a variety of household and personal care products. For instance, triclosan is approved as an additive for toothpaste at %triclosan by product weight. Obviously triclosan is not considered to be relevant to human health at nanograms when it is approved as an additive in toothpaste in milligrams. Additionally, triclosan is often used in hand soaps also at percent by weight,

thus, hand washing provides another significant source to humans. These common uses also lead to higher propensity in blanks. In the USGS study by Kolpin in 2002, triclosan was detected in blanks up to 560 ng/L. Triclosan has been shown to be highly rejected by RO and extremely susceptible to UV oxidation (Snyder, Adham et al. 2006; Snyder, Wert et al. 2007). Thus, the two detections of triclosan (sample date 9/14/11 = 19 ng/L and sample date 2/1/12 = 17 ug/L) in UV-AOP product water are highly unlikely due to rejection by RO and oxidation by UV-AOP. Moreover, triclosan is very common in laboratory blanks. At the laboratory at SNWA, we have established a reporting limit of 50 ng/L due to challenges of achieving consistently clean blanks below 30 ng/L.

Formaldehyde

Formaldehyde is a naturally occurring compound that is a gas at room temperature. Formaldehyde also is formed during oxidative processes and is considered the last transformation product of carboneous molecules before mineralization to carbon dioxide. Because it is volatile and relatively soluble in water, it is difficult to remove during water treatment. It will pass through RO membranes to some extent and is formed by UV and ozone AOPs (Trenholm, Rosario-Ortiz et al. 2008). At other reuse facilities using UV-AOP, I have observed formation of formaldehyde, at times with concentrations exceeding 100 ug/L. Thus, I am not surprised to see formaldehyde in the produce water here. On the contrary, if formaldehyde were not observed, it would indicate either over or under dosing of the UV-AOP system. However, I find the analytical data provided to be concerning since one laboratory differs from another by one order of magnitude. From the information provided, it appears both laboratories used the same method (EPA 556) and that both laboratories achieved spiked recoveries well within the acceptable range. Therefore, I can find no plausible explanation for the large discrepancy between the two laboratories. Regardless, formaldehyde is not considered to be highly toxic to human health by ingestion. The US EPA (IRIS) determined the NOAEL in rats to be 82 mg/kg-day, which equates to 5.7 g/day for an adult. Even if the uncertainty factor would be 1000, this equates to levels far above those levels detectable in product water here, regardless of laboratory providing analysis.

OPINION OF ROLE OF SAMPLE VOLUME ON METHOD REPORTING LIMITS AND BLANKS BETWEEN MWH LABS AND COLORADO SCHOOL OF MINES LAB.

I was asked to provide expert opinion regarding the impact of a 40 mL sample volume versus 1 L sample volume in the laboratories performing analyses for this study. In theory, the sample volume is critical depending on instrument sensitivity, operating conditions, and instrument/method blanks. In other words, one cannot judge a methods reporting limits or robustness simply on sample volume. Indeed, on-line solid-phase extraction methods have allowed trace organic analysis in very low volumes of water (Trenholm, Vanderford et al. 2009). In the cases here, I do not have sufficient information to thoroughly evaluate the two methods in dispute. However, I do believe the MWH method using 40 mL is an on-line SPE method. Again, we can assume that the concentration of analytes in water samples are the sample regardless of sample volume.

However, in analytical chemistry, the mass injected on-column is usually the most critical parameter in the method sensitivity on a given instrument. Thus, on-line SPE can accomplish a similar on-column mass by "injecting" the complete mass extracted in a small water volume while a 1 L sample would be extracted conventionally off-line, then usually 5-50 uL injected out of the resulting 1 mL extract. Thus, the 1000x concentration factor with off-line SPE actually results in a relatively small mass injected since only a few uL of the 1 mL extract are actually used. Thus, MRLs involve more than just the sample volume. In terms of blanks; however, there can be large differences between on-line and off-line SPE methods. For instance, we recently discovered that bisphenol A cannot reliably be analyzed using off-line SPE since the SPE cartridges are made of plastic that results in significant blank contamination. This contamination is not observed with on-line SPE since no plastic cartridges are used. On the contrary, if there are any issues with instrument blanks, such as carry over, solvent contamination, or leaching from instrument parts, the concentration calculated to the field blanks will be exaggerated. This is because the instrument reports a mass. This mass is then back calculated to the injection volume and later to the volume of water. Therefore, a systematic issue with blanks within the instrument system will calculate to a much higher concentration in a lower sample volume as compared to a large sample volume. Thus, instrumental blanks are even more important with on-line SPE techniques.

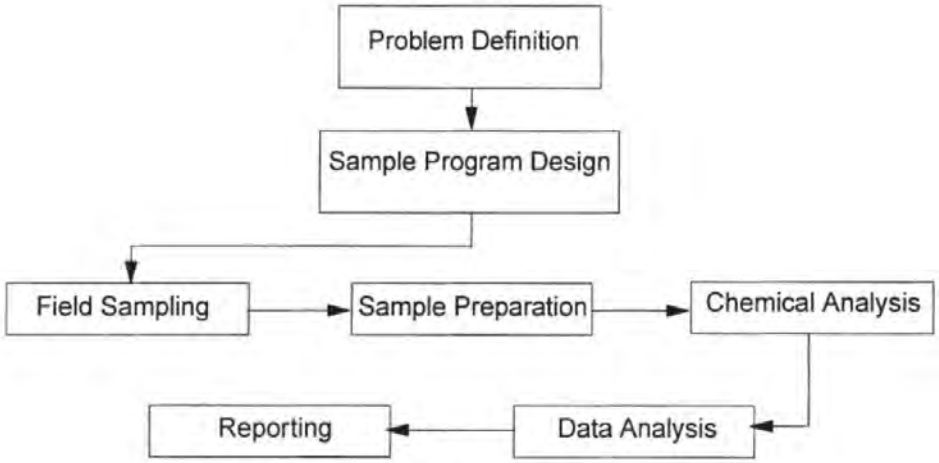

Figure 1. Seven Key Steps in Environmental Monitoring (from Batley, G. E. (1999). "Quality assurance in environmental monitoring." Marine Pollution Bulletin 39(1-12): 23-31.)

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Tienpont, B., F. David, et al. (2005). "Pitfalls and solutions for the trace determination of phthalates in water samples." Chromatographia **61**(7-8): 365-370.

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Education

1994-2000 **Michigan State University, East Lansing, Michigan**
Doctorate of Philosophy
Environmental Toxicology and Zoology
Dissertation Title: ***Instrumental and Bioanalytical Measures of Endocrine Disruptors in Water***
Advisor: Dr. John P. Giesy (Distinguished Professor)

1990-1994 **Thiel College, Greenville, Pennsylvania**
Department of Chemistry
Bachelor of Arts: *Magna Cum Laude*
Major: Chemistry
Minor: Medical Biology

Funded Research Projects

2011-2013 **Co-Principal Investigator – WateReuse Research Foundation:** "Development of Bio-Analytical Techniques to Assess the Potential Human Health Impacts of Recycled Water" – Project# 10-07

2010-2011 **Principal Investigator – WateReuse Research Foundation:** "Use of UV and Fluorescence Spectra as Surrogate Measures for Contaminant Oxidation and Disinfection in the Ozone/H2O2 Advanced Oxidation Process" – Project# 09-10

2010-2011 **Co-Principal Investigator – WateReuse Research Foundation:** "Effect of Prior Knowledge of Unplanned Potable Reuse on the Acceptance of Planned Potable Reuse" – Project# 09-01

2009-2011 **Principal Investigator – WateReuse Research Foundation: "**Use of Ozone in Water Reclamation for Contaminant Oxidation" – Project# 08-05

2009-2011 **Co-Principal Investigator – Water Environment Research Foundation:** "Trace Organic Compounds Removal during Wastewater Treatment – Categorizing Wastewater Treatment Processes by their Efficacy in Reduction of a Suite of Indicator TOrCs" – Project# CEC4R08

2009-2011 **Principal Investigator (with Brett Vanderford – SNWA Research Chemist) – Water Research Foundation:** "Evaluation of Analytical Methods for EDCs and PPCPs via Interlaboratory Comparison" – Project# 4167

2009-2011 **Principal Investigator (with Benjamin Stanford – SNWA Post-Doctoral Researcher) – WateReuse Foundation:** "Pilot-Scale Oxidative Technologies for Reducing Fouling Potential in Water Reuse and Drinking Water Treatment Membrane Systems" – Project# 08-008

2008-2009 **Principal Investigator – American Water Works Association/American Water Works Association Research Foundation:** "Hypochlorite – An Assessment of Factors That Influence the Formation of Perchlorate and Other Contaminants" – Project# 712/4147

2008-2010 **Principal Investigator – American Water Works Association Research Foundation:** "Role of bromamines on disinfection byproduct formation and impact on application of chloramination and

ozonation" – Project# 4159

2007-2009 **Principal Investigator – WateReuse Foundation:** "Comparisons of Chemical Composition of Reclaimed and Conventional Waters" Project# 06-006

2007-2008 **Principal Investigator – WateReuse Foundation:** "Identifying Hormonally Active Compounds, Pharmaceutical Ingredients, and Personal Care Product Ingredients of Most Health Concern From Their Potential Presence in Water Intended for Indirect Potable Reuse" Project# 05-005

2007-2009 **Principal Investigator (with Fernando Rosario – SNWA Post-Doctoral Researcher) – WateReuse Foundation:** "Optimization of Advanced Water Treatment Processes for Water Reuse" Project# 06-012

2006-2009 **Co-Principal Investigator – WateReuse Foundation:** "Development of Surrogates To Determine The Efficacy Of Groundwater Recharge Systems For The Removal Of Trace Organic Chemicals" Project# 05-004

2007-2009 **Co-Principal Investigator – American Water Works Association Research Foundation:** "Low Dose Risks from Bromate: The Relationship between Drinking Water Concentrations and the Actual Dose to Susceptible Organs in Rats and Humans" Project#4042

2005-2007 **Co-Principal Investigator – WateReuse Foundation:** "Reaction Rates and Mechanisms of Advanced Oxidation Processes for Water Reuse" Project# 04-017

2005-2006 **Principal Investigator – American Water Works Association Research Foundation:** "Comprehensive Utility Guide for Endocrine Disruptors and Pharmaceuticals in Drinking Water" Project# 3033

2004-2006 **Principal Investigator – American Water Works Association Research Foundation and WateReuse Foundation:** "Toxicological Relevance of EDC and Pharmaceuticals in Drinking Water" AwwaRF # 3085 & WRF 04-003

2004-2006 **Co-Principal Investigator – WateReuse Foundation:** *Colorado School of Mines as PI* "Development of Indicators and Surrogates for Chemical Contaminant Removal during Wastewater Treatment and Reclamation" Project# WRF-03-014

2004-2006 **Co-Principal Investigator – WateReuse Foundation:** *Carollo Engineers as PI* "Reclaimed Water Aquifer Storage and Recovery: Potential Changes in Water Quality" Project# WRF-03-009

2004-2006 **Co-Principal Investigator – Water Environment Research Foundation:** *Colorado School of Mines as PI.* "Contributions of Household Chemicals to Sewage and their Relevance to Municipal Wastewater Systems and the Environment" Project# 03-CTS-21UR

2002-2005 **Principal Investigator - American Water Works Association Research Foundation:** "Evaluation of Conventional and Advanced Treatment Processes to Remove Endocrine Disruptors and Pharmaceutically Active Compounds" Project #2758

2001-2004 **Principal Investigator - Strategic Environmental Research and Development Program (for Department of Defense):** "Toxicological Impact of Ammonium Perchlorate on Fish" Project# 1222

1998-2000 **Principal Investigator - Southern Nevada Water Authority/U.S. Bureau of Reclamation/National Park Service:** "Toxicity Identification and Evaluation of Xenobiotic Compounds in Lake Mead, Nevada"

1998-2000 **Principal Author - Chemical Manufacturers Association:** "Identification and Quantitation of Alkylphenols from Fish Tissues"

1997 **Principal Author - Las Vegas Valley Water District:** "Screening of Drinking Water for Possible Endocrine Disrupting Compounds"

1997 **Principal Author - Chemical Manufacturers Association:** Instrument grant for alkylphenol analyses

Recent Volunteer Efforts

2008-2011	**National Academy of Science – National Research Council**: Member of Water Reuse expert panel
2010-Present	**WateReuse Association:** Member of the Board of Directors
2009-2010	**National Association of Clean Water Agencies and Association of Metropolitan Water Agencies**: Co-chair of expert panel to author ***Pharmaceuticals in the Water Environment***
2008-2011	**Water Research Foundation**: Member of EDC Strategic Initiative Expert Panel
2008-2011	**American Water Works Association:** Appointed Trustee of the Water Science & Research Division
2008-Present	**WateReuse Research Foundation:** Research Advisory Council (RAC) member
2008-2010	**United Nations University & Gwangju Institute of Science and Technology:** Science Advisory Committee member.
2008-2009	**American Water Works Association**: Chair of the Planning Committee for the Organic Contaminants Research Symposium – Austin Texas February 2009
2006	**Expert Panel Member:** US EPA Contaminant Candidate List Classification Process Meeting
2004-2006	**Federal Advisory Committee Member:** Endocrine Disruptor Methods Validation Advisory Committee (EDMVAC)
2004-Present	**American Water Works Association:** Source Water Protection Committee – (Vice-Chair 2004-2006)
2002-Present	**American Water Works Association:** Organic Contaminants Research Committee – (Chair 2005-2008)
2002-2005	**Henderson Blue Ribbon Commission:** Member of special committee to promote educational excellence in Southern Nevada
2001-2004	**National Advisory Council for Environmental Policy and Technology:** Member of the US EPA Federal Advisory Committee "*Endocrine Disruptor Methods Validation Subcommittee* (EDMVS)"
2000-2001	**American Water Works Association:** Endocrine Disruptor & the Water Industry Symposium planning committee

Employment Experience

2010-Present	**University of Arizona – Professor of Chemical and Environmental Engineering.** Provide leadership and teaching in the areas of water treatment, contaminant fate and transport, and public/environmental health implications of water pollution.
2010-Present	**Arizona Laboratory for Emerging Contaminants (ALEC) – Co-Director.** State-of-the-art analytical facility at University of Arizona with a focus on identification and quantification of emerging contaminants, such as pharmaceutical, endocrine disrupting compounds, and nanoparticles.
2000-2010	**Research and Development – Project Manager.** Southern Nevada Water Authority, Las Vegas, Nevada. Develop and manage diversity of drinking and wastewater projects related to emerging contaminants, conventional and advanced treatment technologies, and modern analytical method development. Achieve external research funding to support team of chemists, engineers, graduate students, and post-doctoral researchers.
1998 – Present	**Owner/Consultant.** Total Environmental Solutions Inc., Boulder City, Nevada. Provide professional consultation, expert witness services, and build teams of experts capable of solving a diversity of challenging environmental issues.
1994-2000	**Graduate Student.** Michigan State University, East Lansing, Michigan. Department of Zoology

	and Institute of Environmental Toxicology. Developed novel analytical and bioanalytical approaches to identify and quantitate endocrine disrupting compounds and pharmaceuticals in the aquatic environment.
Summer 1995	**Research Internship.** Bayer Corp., Biotechnology Division, Leverkuesen, Germany. Synthesized and analyzed DNA and PNA strains for pharmaceutical discovery. Utilized DNA/PNA synthesizers and sequences. Purified strains using HPLC and verified molecular weights using Time of Flight Mass Spectrometry.
Summer 1994	**Research Internship.** Bayer Corp., New Martinsville, West Virginia. Developed spectral library using newly developed open-path FTIR instrumentation used to monitor potential leaks at industrial sites.

Additional Relevant Experience

2011-Present	**Chair.** National Water Research Institute. Expert Panel on Water Reuse in Tucson, Arizona
2011-2015	**Visiting Professor.** National University of Singapore – National Environmental Research Institute.
2010-Present	**Science Advisory Panel Member.** King Abdullah University of Science and Technology, Saudi Arabia.
2010-Present	**Science Advisory Panel Member.** Southern California Coastal Water Research Program. *Constituents of Emerging Concern in Coastal and Marine Ecosystems*
2010-Present	**Adjunct Professor.** Environmental Science & Engineering, Gwangju Institute of Science and Technology, South Korea
2009-2010	**Science Advisory Panel Member.** California Water Resources Control Board. *Constituents/Contaminants of Emerging Concern in Recycled Water*
2009	**Effective Media Communications.** Professional training for communicating with news media. *The Ammerman Experience.* Houston, Texas
2009	**Advanced Presentations Training.** Professional training in presentation of data in public forums
2008-Present	**Fellow.** University of California, Santa Cruz. Center for Integrated Water Research
2007-2008	**West Basin Water District Expert Panel**. Provide expert advice regarding water quality and technology issues related to water reuse operations at West Basin, California
2006-2011	**Pepsi Corporation Water Quality Advisory Council.** Provide expert advice and scientific opinion regarding global water quality and treatment technology issues
2000 – 2010	**Adjunct Faculty.** University of Nevada, Las Vegas. Act as a committee member for various graduate research programs. Aid in research efforts of faculty and students. Instruct classes and serve as a visiting lecturer
2000 – 2007	**Adjunct Faculty.** State College of Southern Nevada, Las Vegas, Nevada. Instruct undergraduate science classes. Work with other faculty on local environmental issues
1997 – Present	**Peer Reviewer.** Peer reviewer for several journals including: *Analytical Chemistry, Environmental Science and Technology, Water Research, Journal of the American Water Works Association, Chemosphere, and others*
2000 & 2008	**Invited Speaker.** National Public Radio (NPR) recorded in Las Vegas, Nevada. Interview regarding pharmaceuticals and personal care products in Lake Mead, Nevada

Invited Presentations and Seminars (Previous Years Available on Request)

December 2011	**Las Vegas, Nevada –** Invited speaker at Agilent Technologies Annual Meeting
December 2011	**Flagstaff, Arizona –** Invited speaker and panel member for public meeting on water reuse
November 2011	**Genoa, Italy –** Invited speaker for symposium on EDCs in water supplies
November 2011	**Santa Clara, California –** Invited seminar for Agilent Technologies

November 2011	**Phoenix, Arizona –** Invited speaker for Water Quality Technology Conference (WQTC) – reuse special session
October 2011	**Phoenix, Arizona –** Invited speaker for Western Coalition of Arid States (WESTCAS)
September 2011	**Barcelona, Spain** – Invited keynote presentation at International Water Association Water Reclamation and Reuse Conference
August 2011	**Dallas, Texas** – Invited presentation for EPA Region 9 Workshop
July 2011	**Singapore** – Invited presentation at the Singapore International Water Week
June 2011	**Amsterdam Netherlands** – IWA Leading Edge Technology meeting – Invited Keynote on Water Reuse and Emerging Water Quality Issues
May 2011	**Beijing China –** Peking University – Invited Presentation on Water Reuse
May 2011	**Beijing China –** Tsinghua University – Invited Plenary Presentation at Symposium EDCs, PPCPs, and DBPs in Water
April 2011	**Cambridge MA –** Harvard University – Invited Presentation at Symposium on R&D and Technology for Water
February 2011	**Northridge CA –** University of California, Northridge – Invited Presentation on PPCPs iN Water Supplies: Sustainable Solutions
November 2010	**Raleigh NC –** US EPA Research Triangle Park – Invited Presentation on Emerging Contaminants and Water Reuse
September 2010	**Washington DC –** Congressional Briefing on Pharmaceuticals in the Environment
July 2010	**Singapore – Singapore International Water Week.** Invited Session Chair and Speaker
June 2010	**Holderness, NH –** Gordon Research Conference: Water – Invited Presentation regarding Water Reuse and Emerging Water Quality Challenges
May 2010	**Racine, WI –** Wingspread Meeting on Environmental Estrogens – Invited Panelist
May 2010	**Cape Cod, MA –** Waquoit Bay Reserve – Invited Presentation regarding Emerging Contaminants in Septic Systems and Groundwater
March 2010	**Boston, MA** – Tufts University – Invited Presentation for the National Academy of Engineering
November 2009	**Gwangju, S. Korea –** United Nations University – Science Advisory Board
November 2009	**Boston, MA –** Harvard School of Public Health – Invited Presentation on DBPs
October 2009	**Princeton, NJ** – FASTRAC Meeting – Invited Presentation
September 2009	**Brisbane, Australia –** International Water Association WRRS – Invited Keynote
September 2009	**Tokyo, Japan –** International Ozone Association – Invited Keynote
August 2009	**Washington, DC** – ACS National Conference – Invited Keynote
August 2009	**Mount Holyeoke, MA** – Gordon Research Conference on Disinfection Byproducts
June 2009	**Singapore –** IWA Leading Edge Technology Meeting – Invited Keynote
June 2009	**San Francisco, CA –** IWA Micropol Meeting – Invited Keynote Presentation
June 2009	**Toronto, Canada –** Ontario Ministry of the Environment – Invited Presentation
May 2009	**Boise, ID –** Idaho Water Reuse Symposium – Invited Presentation
May 2009	**Salem, OR –** Pacific Northwest Awwa meeting – Invited Presentation
April 2009	**Costa Mesa, CA –** So. Cal. Coastal Water Research Program – Invited Presentation
March 2009	**Boston, MA –** Harvard University's School of Public Health – Invited Seminar

March 2009	**Washington, DC –** US Senate – Invited Briefing
March 2009	**New York, NY –** Hazen & Sawyer – Invited Seminar
March 2009	**San Diego, CA –** Association of Environmental Health Sciences – Invited Keynote
March 2009	**Las Vegas, NV –** US/Japan Joint Water Conference – Invited Presentation
February 2009	**Washington DC –** US House of Representatives – Invited Briefing
February 2009	**Phoenix, Arizona –** Arizona Water Association – Invited Seminar
February 2009	**Austin, Texas** – Awwa Emerging Contaminant Symposium – Conference Chair
January 2009	**Delft, The Netherlands –** Vakantiecursus in Drinkwatervoorziening – Invited Presentation
January 2009	**Greenville, South Carolina –** Southeastern Regional Water Technology Transfer Conference – Invited Presentation
November 2008	**East Lansing, Michigan** – Michigan State University – Invited Seminar
November 2008	**Cincinnati, Ohio –** Water Quality Technology Conference – Invited Presentation
October 2008	**Monterey, California** – WateReuse Foundation – Invited Presentation on agricultural water reuse
October 2008	**Gwangju, S. Korea** – United Nations University – Science Advisory Board Meeting
September 2008	**Tucson, Arizona** – University of Arizona – Invited Seminar
August 2008	**Orlando, Florida** – International Ozone Association – Invited Plenary Presentation
June 2008	**Singapore –** Invited delegate for World Water Leaders Summit
March 2008	**Long Beach, California –** California Water Environment Association – Invited Presentation
March 2008	**Cork, Ireland –** Invited presentation on emerging water quality issues
March 2008	**Zurich, Switzerland –** Invited Seminar for EAWAG on emerging contaminants
March 2008	**Lyon, France –** Invited speaker for EU NORMAN meeting on bioassay techniques
February 2008	**Mumbai, India –** Invited expert panel member for Pepsi Corporation FEMA meeting
December 2007	**University of California, Berkeley** – Invited Seminar for Department of Engineering
November 2007	**Canberra, Australia**: EDC/PPCPs in Australia – Invited Keynote Presentation
November 2007	**Brisbane, Australia** – Invited Seminar for Queensland Water
November 2007	**Gwangju, South Korea** – Invited Presentation at Opening of National Desalination Program (SeaHERO)
October 2007	**Costa Mesa, California**: National Groundwater Association – Keynote Presentation
October 2007	**Seattle, Washington**: Association of Metropolitan Water Agencies – Invited Presentation
September 2007	**University of Massachusetts, Amherst** – Invited Seminar in Water Sustainability Lecture Series
September 2007	**Tampa, Florida**: WateReuse Association – Invited Panelist in Closing Plenary Session
August 2007	**Los Angeles, California**: International Ozone Association – Invited Keynote Presentation
August 2007	**Carson City, Nevada**: Nevada Water Resources Association – Invited Keynote Presentation
August 2007	**Water Environment Federation** – Webcast on Emerging Issues – Invited Presentation
July 2007	**Flagstaff, Arizona**: Arizona Water Reuse Association – Invited Presentation
July 2007	**Los Angeles, California**: California Urban Water Association – Invited Seminar
May 2007	**Sacramento, California**: California EPA DTSC – Invited Presentation
May 2007	**Tampa, Florida**: World Environmental & Water Resources Congress – Keynote Presentation
April 2007	**Santa Rosa, California** – Invited Seminar for the Public Utilities Board

April 2007	**Greensboro, North Carolina** – Syngenta's Distinguished Speaker Series
April 2007	**Athens, Georgia**: Society for Environmental Toxicology and Chemistry – Invited Lecturer
February 2007	**Sacramento, California**: California DHS Meeting – Invited Seminar
February 2007	**New York, New York**: AwwaRF/KIWA CEO Conference – Invited Presentation
January 2007	**Okinawa, Japan**: Japanese-U.S. Conference on Water Quality and Wastewater Control – Invited Presentation

Publications

114.	2011	Stanford BD, Pisarenko AN, Holbrook RD, **Snyder SA.** *Preozonation Effects on the Reduction of Reverse Osmosis Membrane Fouling in Water Reuse.* Ozone: Science & Engineering. **33**(5):379-388.
113.	2011	Holbrook RD, Motabar D, Quinones O, Stanford BD, **Snyder SA**. *Titanium distribution in a swimming pool - The case for dissolution*. Geochimica et Cosmochimica Acta. **74**(12): A410-A410.
112.	2011	Gerrity D, Gamage S, Holady JC, Mawhinney DB, Quinones O, Trenholm RA, **Snyder SA.** *Pilot-scale evaluation of ozone and biological activated carbon for trace organic contaminant mitigation and disinfection.* Water Research 45(5):2155-2165.
111.	2011	Laws BV, Dickenson ERV, Johnson TA, **Snyder SA**, Drewes JE. *Attenuation of contaminants of emerging concern during surface-spreading aquifer recharge*. Science of the Total Environment. 409:1087-1094.
110.	2011	Gerrity D and **Snyder SA.** *Review of Ozone for Water Reuse Applications: Toxicity, Regulations, and Trace Organic Contaminant Oxidation.* Ozone Science and Engineering. 33:253-266.
109.	2011	Mawhinney DB, Young RB, Vanderford BJ, Borch T, **Snyder SA**. *The Artificial Sweetener Sucralose in U.S. Drinking Water Systems.* Environmental Science and Technology. *In press*
108.	2011	Sarp S, Stanford B, **Snyder SA**, Cho J. *Ozone oxidation of desalinated seawater, with respect to optimized control of boron and bromate.* Desalination and Water Treatment. 27:308-312.
107.	2011	Gerrity D, Trenholm RA, **Snyder SA**. *Temporal variations in pharmaceuticals and illicit drugs in wastewater during a major sporting event.* Water Research. 45(17):5399-5411.
106.	2011	Gerrity D and **Snyder SA**. *The Economic Value of Water in Metropolitan Areas of the United States*. Water Policy. 13:443-458.
105.	2011	Vanderford BJ, Mawhinney DB, Trenholm RA, Zeigler-Holady JC, **Snyder SA**. *Assessment of sample preservation techniques for pharmaceuticals, personal care products, and steroids in surface and drinking water.* Analytical and Bioanalytical Chemistry. 339:2227-2234.
104.	2011	Stanford BD, Pisarenko AN, **Snyder SA**, Gordon G. *Perchlorate, bromate, and chlorate in hypochlorite solutions: guidelines for utilities*. Journal of the American Water Works Association. 103(6):71-83.
103.	2011	Dickenson ERV, **Snyder SA,** Sedlak DL, Drewes JE. *Indicator Compounds for Assessment of Wastewater Effluent Contributions to Flow and Water Quality.* Water Research 45:1199-1212.
102.	2010	Makris KC and **Snyder SA.** *Screening of pharmaceuticals and endocrine disrupting compounds in water supplies of Cyprus*. Water Science & Technology 62.11:2720-2728.
101.	2010	Bruce GM, Pleus RC, **Snyder SA.** *Toxicological Relevance of Pharmaceuticals in Drinking Water*. Environmental Science & Technology. 41(14):5619-5626.
100.	2010	Stanford BD, Trenholm RA, Holady JC, Vanderford BJ, **Snyder SA**. *Estrogenic Activity of US Drinking Waters: A Relative Exposure Comparison*. Journal of the American Water Works Association. 110(11):55-65.
99.	2010	Stanford BD, Benotti MJ, **Snyder SA**. *"Impact of Endocrine Disruptors on the Water Industry"* In Endocrine Toxicology. J.T. Stevens and J.C. Eldridge (Editors). In Press.
98.	2010	Gerrity D, Benotti MJ, Reckhow DA, **Snyder SA**. *Pharmaceuticals and Potential Endocrine*

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4. 1999 Khim JS, Villeneuve DL, Kannan K, Lee KT, **Snyder SA**, Koh CH, Giesy JP. *Akylphenols, Polycyclic Aromatic Hydrocarbons (PAHs), and Organochlorines in Sediment from Lake Shihwa, Korea: Instrumental and Bioanalytical Characterization*. Environmental Toxicology and Chemistry 18(11):2424-2432.

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Deposition, Testimony, and Briefings

2010 *United States House of Representatives – Science and Technology Committee.* Invited briefing entitled "*Pharmaceuticals in Our Water: Concerns and Responses.*" Sponsored by the American Chemical Society

2009	*United States Senate – Committee on Environment and Public Works.* Invited briefing entitled *"Pharmaceuticals and Endocrine Disruptors in US Drinking Water: Occurrence, Treatment, & Relevance."* Sponsored by the Water Research Foundation.
2009	*Richard A. Rowe, et al. vs. E.I. du Pont de Nemours.* US District Court – District of New Jersey.
2009	*United States House of Representatives.* Invited briefing entitled *"Pharmaceuticals in Drinking Water."* Sponsored by the Water Research Foundation.
2009	*William R. Rhodes, et al. vs. E.I. du Pont de Nemours.* US District Court – Southern District of West Virginia.
2008	*United States Senate – Committee on Environment and Public Works.* Invited testimony at hearing entitled *"Pharmaceuticals in the Nation's Water: Assessing Potential Risks and Actions to Address the Issue."*
2005	*Jayne Palmisano and Richard Palmisano vs. Olin Corporation and Standard Fusee Corporation.* US District Court – San Jose California.

Professional Affiliations

2003 - Present	Water Environment Federation
2000 – Present	American Water Works Association
2000 – Present	International Ozone Association
2000 – Present	International Water Association
1997 – Present	American Association for the Advancement of Science
1996 – Present	Sigma Xi
1995 – Present	Society of Environmental Toxicology and Chemistry
1991 – Present	American Chemical Society

Students Mentored

2011-Current	**Shimin Wu – University of Arizona** – Current enrolled in Ph.D. program.
2011-Current	**Christopher Deason – University of Arizona** – Currently enrolled in M.Sc. program.
2011-Current	**Xu Li – University of Arizona** – Currently enrolled in Ph.D. program.
2010-Current	**Tarun Anumol - University of Arizona –** Currently enrolled in Ph.D. program.
2010-Current	**Darryl Jones – University of Arizona –** Currently enrolled in Ph.D. program.
2010	**Sujanie Gamage – University of Nevada, Las Vegas** – Currently enrolled in Ph.D. program in Vern Hodge's research group.
2010	**Dongxu Yan – University of Arizona** – Currently enrolled in Ph.D. program in Wendell Ella's research group.
2009	**Ludwig Kim – Texas A&M University** – Currently enrolled in Ph.D. program in Robin Autenreith's research group.
2009-2010	**Robert Young – Colorado State University** – Currently enrolled in Ph.D. program in Thomas Borch's research group.
2008-2009	**Sarper Sarp – Gwangju Institute of Science & Technology, Korea** – Currently enrolled in Ph.D. program in Jaeweon Cho's research group.
2008-2009	**Aleks Pisarenko – Miami University of Ohio** – Currently enrolled in Ph.D. program in Gilbert Pacey's research group.
2008-2010	**Susanna Blunt – University of Nevada, Las Vegas & Desert Research Institute** – Currently enrolled in M.S. program in Duane Mosher's research group.
2008-2009	**Deborah Dryer – University of Washington** - Currently enrolled in Ph.D. program in Gregory Korshin's research group.

2007-2008	**Seungyun Baik – State University of New York, Buffalo –** Currently enrolled in Ph.D. program in Diana Aga's research group.
2006-2008	**Mei Xin – University of Nevada, Reno –** Ph.D. granted in 2008; currently employed by Norit Carbon, Dallas Texas.
2005-2010	**Christy Meza – University of Nevada, Las Vegas** – Undergraduate research intern, B.S. awarded in 2008.
2005-2009	**Elaine Go – University of Nevada, Las Vegas** – Undergraduate research intern, B.S. expected in 2009.
2004-2006	**Fernando Rosario-Ortiz – University of California, Los Angeles –** D.Env. granted in 2006..
2003-2006	**Yixin Wei – University of Nevada, Las Vegas** – Ph.D. granted in 2006.
2000-2004	**Elisa Nemr – University of Nevada, Las Vegas** – M.S. granted in 2004**.**

Post-Doctoral Researchers Mentored

2010-Current	**Ai Jia** – Ph.D. from Peking University, China, with Professor Jianying Hu.
2010-2012	**Bradley Clarke** – Ph.D. from RMIT, Australia, with Professor Judy Blackbeard.
2010-Current	**Sylvain Merel –** Ph.D. from University of Rennes, France, with Professor Oliver Thomas
2009-2010	**Aleks Pisarenko** – Ph.D. from Miami University of Ohio with Professor Gilbert Gordon.
2008-2010	**Daniel Gerrity –** Ph.D. from Arizona State University with Professors John Crittenden and Morteza Abbaszadegan as advisors.
2008-2010	**Yongui Tan –** Ph.D. from Rensselaer Polytechnic Institute with Professor James Kilduff as primary advisor.
2007-2009	**Benjamin Stanford –** Ph.D. from University of North Carolina, Chapel Hill with Professor Howard Weinberg as primary advisor. Currently employed as Director of R&D, Hazen and Sawyer, New York.
2007-2009	**Mark Benotti –** Ph.D. from State University of New York, Stoney Brook with Professor Bruce Brownawell as primary advisor. Currently employed as private consultant.
2006-2008	**Fernando Rosario-Ortiz –** D.Env. from University of California, Los Angeles with Professor Mel Suffet as primary advisor. Currently employed as Assistant Professor at the University of Colorado, Boulder.
2005-2007	**Hongxia Lei –** Ph.D. from University of Illinois with Professor Benito J. Mariñas as primary advisor. Currently employed by Golden State Water, California.

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Quarterly Testing Report No. 4

Appendix C

Full-Scale Reservoir Augmentation Capacity Analysis Technical Memorandum

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Technical Memorandum

City of San Diego Water Purification Demonstration Project
Task 2 Conveyance Pipeline Concept Design Report

Subject:	**Full-scale Reservoir Augmentation Capacity Analysis**
Prepared For:	Amy Dorman and Anthony Van, Public Utilities Department
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1 Purpose

The purpose of this Technical Memorandum (TM) is to determine an optimal capacity for a proposed full scale Advanced Water Purification project being served by excess recycled water from the North City Water Reclamation Plant (NCWRP). For the purpose of this analysis, optimum capacity is the capacity that adheres to the regulatory strategy developed as part of the Water Purification Demonstration Project (WPDP) while minimizing annual cost. This analysis does not consider the wastewater-related benefit of maximizing diversion from the Point Loma Wastewater Treatment Plant, which will also need to be considered when making a final decision on sizing the full-scale project. Based on the results of this TM, and the findings of the Recycled Water Study (to be completed in 2012), the City of San Diego (City) will choose a preliminary capacity for both the advanced water purification facility (AWPF) and the conveyance system, consisting of purified water pump station and conveyance pipeline to San Vicente Reservoir (SVR). This preliminary capacity will be the basis for facilities layout and cost estimation.

2 Findings

The following are findings for the AWPF and conveyance system facilities.

2.1 AWPF

This analysis was performed using two different wastewater plant flow concepts and an optimal AWPF capacity was determined for each concept. The first flow concept assumes available flow to the AWPF is comprised of tertiary effluent after subtracting utility water and recycled water demand and assuming tertiary filter and membrane filter (MF) backwash is wasted to Point Loma Wastewater Treatment Plant. The second flow concept assumes tertiary filter and MF backwash is recycled to the head of the NCWRP plant, thereby increasing available flow to the AWPF.

*Without returning Backwash Flows:*The results of this analysis determined an apparent optimal AWPF capacity when not recycling the backwash waters from tertiary or MF of 14 million gallons per day (mgd) for the full-scale project, yielding 14,270 AFY of purified water. The size of the AWPF is limited by the NCWRP capacity and the amount of water available after serving the recycled water demands. The AWPF plant capacity can be as high as 18 mgd with a product water yield of 15,730 AFY based on the projected recycled water demands and assumptions used in this analysis.

*With returning Backwash Flows:*An increase in AWPF production could be achieved if tertiary filter backwash and MF backwash is recycled to the front of the NCWRP rather than wasted to Point Loma Wastewater Treatment Plant. Under this operation, an optimal AWPF capacity of 18 mgd for a full-scale project would yield approximately 16,876 AFY of purified water. To maximize yield, the AWPF capacity could be up to 20 MGD. However the projected available flows to the AWPF after satisfying the recycled water demands would result in operation at 19 mgd for three months and operation at 20 mgd for one month out of the year.

Recycling of these flows is currently not part of the demonstration testing at NCWRP. The potential impacts to NCWRP and AWPF treatment processes are not anticipated to impact to the overall process but may have a slight increase in nitrogen as the return flows include chloraminated waters. The return flows could have an impact to the NCWRP operations however. Thus the point of re-entry and challenges to the operations as well as nitrogen limits should be evaluated further during the next phase of the project.

The cost analysis in Section 9 is presented for both flow scenarios: 1) assuming tertiary filter and MF backwash is not recycled to the head of the plant, and 2) assuming tertiary filter and MF backwash is recycled to the front of NCWRP.

2.2 Pump Station

Capacity will be sized to convey purified water from the AWPF to the SVR, and is directly dependent upon the AWPF capacity. To provide flexibility for future changes to planning decisions and flow projections; the footprint, power requirements, equipment space should be sized to house the number of pumps required to convey the maximum potential product water flow. This would allow the City to potentially increase the station capacity in stages without paying significant capital costs with each increase.

2.3 Pipeline

At the City's request, the pipeline diameter in this analysis was sized for the ultimate conveyance flow from the AWPF. The optimum product water that can be produced is projected to be approximately 18 mgd. Based on discussions with the City, the conveyance pipeline will be sized for the ultimate condition to avoid construction of a parallel pipeline to accommodate a phased capacity approach. Using City design guidelines and assumed flow projections, a 30-inch pipe was determined to be an appropriate diameter for ultimate condition in 2030. A 30-inch pipeline would have a velocity of approximately 5.7 ft/s, which is higher than the goal of 5 ft/s. Note that the energy analysis will confirm the pipeline diameter. The following economic analyses use a 30-inch conveyance pipeline size regardless of the AWPF capacity. This pipe size provides flexibility to address the range of flows under consideration while maintaining relatively low energy costs for pumping. Pipe diameter should be re-assessed as part of an energy/capital cost analysis under the conceptual design report when flow and pipeline alignment are more defined.

3 Sources of Information

In the City of San Diego Water Reuse Study (March 2006), approximately 10,500 acre-ft per year (AFY) was identified as being offset via a 16 mgd AWPF. The latest Recycled Water Study increased this recycled water use to 16,800 AFY. In addition to these studies, the WPDP team met with NCWRP staff to gain insight into current operations in order to verify the results of these previous studies.

The conveyance facilities used in this analysis are based on previous studies prepared for the City. The conveyance pipeline alignment is based on the South Corridor alignment that traverses along SR-52. This was originally identified in the *1996 Repurification Project Report, Volume 3 - Repurified Water Conveyance System* (1996 Project Report). The study recommended a 42-inch pipeline to carry up to 27 mgd of purified water to the SVR and suggested two potential alignments, Sycamore Canyon or Mast Boulevard Alignments. The Mast Boulevard alignment was selected and refined with the intent to progress to 30% design in the *1997 Repurified Water Conveyance System Technical Memorandum Final, Pipeline Alignment - Mast Boulevard* (30% Design Report). Additional studies including geotechnical investigation, corrosivity reports, transient analysis, environmental assessment, and preliminary construction cost estimates were prepared for the proposed alignment. The 27-mgd design flow and single pump station concept initially proposed in the 1996 Project Report were retained and included in the 30% Design Report.

For the purpose of this TM, the proposed Mast Boulevard South Corridor alignment that is approximately 28-miles in length (5 miles of which is already built) and the single pump station concept at the AWPF will be used in developing the life cycle costs for the conveyance facilities. An optimum AWPF flow rate will be determined in this evaluation, and associated conveyance facility sizes (pipeline diameter and pump station capacity) will be updated and used for capital and operations and maintenance costs.

The following is a list of previous studies referenced in this TM:

1. *Repurification Project Report, Volume 3 - Repurified Water Conveyance System, April 2006* (1996 Project Report) prepared by Montgomery Watson and Woodward-Clyde.

2. *Repurified Water Conveyance System (RWCS) Technical Memorandum (Final), Pipeline Alignment - Mast Boulevard, May 1997* (30% Design Report) prepared by Boyle Engineering Corporation.

3. *City of San Diego Water Reuse Study, Final Draft Report, March 2006* prepared by PBS&J.

4. *City of San Diego Water Reuse Study, Cost Analysis, Technical Memorandum 7 (September 2005)* prepared by PBS&J.

5. *City of San Diego* Recycled Water Study, prepared by Brown and Caldwell.

4 Project Components

The project components that will be analyzed in this TM include the AWPF, pump station facility at the AWPF to pump purified water to the San Vicente Reservoir, and the conveyance pipeline. Preliminary sizes and life cycle costs were determined for each of the components at varying capacities and flow rates. Costs developed for this analysis are intended for comparison purposes; not for the City's budgeting of capital improvement program for construction costs. The dechlorination facility (included in the 1990's evaluations), discharge structure, bike path improvements, and surge control facilities are not included in this analysis.

5 Methodology

The methodology employed for this analysis included the following activities:

- Preliminarily size pipeline and pump station for varying AWPF capacities
- Account for monthly irrigation demands in flows available for AWPF
- Determine life cycled costs for proposed facilities
- Conduct cost analysis to illustrate optimum capacity (yielding lowest unit cost per acre-ft)
- Use analysis to provide City with options and tradeoffs (cost implications of maximizing yield)

The optimal capacity analysis included an economic evaluation and a seasonal flow balance evaluation. The economic evaluation involved a comparison of the total project life cycle cost on an annual unit cost per acre-foot basis for AWPF capacities from 1 to 20 mgd and associated conveyance facilities. These project costs were further evaluated on an incremental basis to determine the increased cost of purified water produced by increasing the AWPF capacity by 1 mgd. This analysis was performed to identify when there is a diminishing return with increasing AWPF capacity. As the facility capacity increases it is oversized for a longer span of time throughout the year, particularly during the summer months when less flow is available to the plant due to irrigation demands. Therefore, there will be a breakpoint where the gain in product water yield starts to decrease with increasing incremental cost.

The seasonal flow balance evaluation involved balancing available flows to the AWPF capacity. This analysis was performed to strike a balance between having a plant sized for available flow once peak summer irrigation demands are met resulting in less product water to Point Loma Wastewater Treatment Plant during off peak demands and a facility that is oversized and unable to be fully utilized for many months. The ideal capacity is believed to be slightly larger or in excess of what is needed during peak demands but not too large such that a portion of the asset is rarely used. For this flow balance analysis, the

balanced AWPF capacity is assumed to be achieved when the excess recycled water to the facility is the same as the deficit in available recycled water for the year.

6 Projected Flows to the AWPF and Recommended Capacity

The amount of purified water that may be produced by the proposed AWPF is estimated by deducting the waste streams and recycled water demands from the projected wastewater inflow of 30 mgd for the year 2030. It is assumed that the NCWRP's design capacity would remain at 30 mgd during that time. At the outset of this TM, the planning year is 2030. The flow projections, plant capacity and recycled water demands are consistent with the Recycled Water Study. The flows that impact the product water volume are identified as follows:

- Sludge waste
- Filter Backwash
- Utility Water
- Recycled Water Demands from the Distribution System
- MF/ RO Waste

In addition, the ultimate yield of the project will be impacted by the AWPF on-line factor. The calculations for the Projected Flows based on Max Month Recycled Water Demands can be found in **Appendix A.**

6.1 Sludge

Sludge waste is comprised of primary sludge, secondary sludge and scum. Its concentration averages approximately 4,000 mg/L of total solids. Approximately 1.4 mgd of sludge is estimated to be removed from the NCWRP influent flow and pumped to the Metro Biosolids Center (MBC). This is based on actual plant data and recommended value provided by Lynn Chou (former Senior Civil Engineer who oversaw the daily plant operation at NCWRP).

6.2 Filter Backwash

Filter backwash at the NCWRP is estimated by assuming 0.2 mgd per backwash per day for 10 mgd of tertiary flow (or 2, according to Lynn Chou. To project for 28.6 mgd of tertiary flow, triple the backwash flow for an estimated 0.6 mgd of flow lost due to filter backwash.

Utility water for processing cooling, sealant, and wash down will flow to the plant drain and is approximately 0.8 mgd. An additional 0.5 mgd is used for on-site irrigation. The total utility water demand is approximate 1.3 mgd. However, this is already included in recycled water demand from the distribution system described below.

6.3 Recycled Water Demands

Recycled water demands from the distribution system that are primarily for irrigation purposes are seasonal. According to the latest Recycled Water Study, the average annual recycled demand projected between the years 2015 and 2030 is 9.1 mgd. Monthly factors that correlate the average annual demand to the average monthly demand are provided in **Table 1** and depicted in **Figure 1**.

As previously mentioned, the projected recycled water demand includes utility water at NCWRP. Since utility water flows to the plant drain are not seasonal, they are not subject to the monthly peaking factors and are subtracted before the monthly factors are applied.

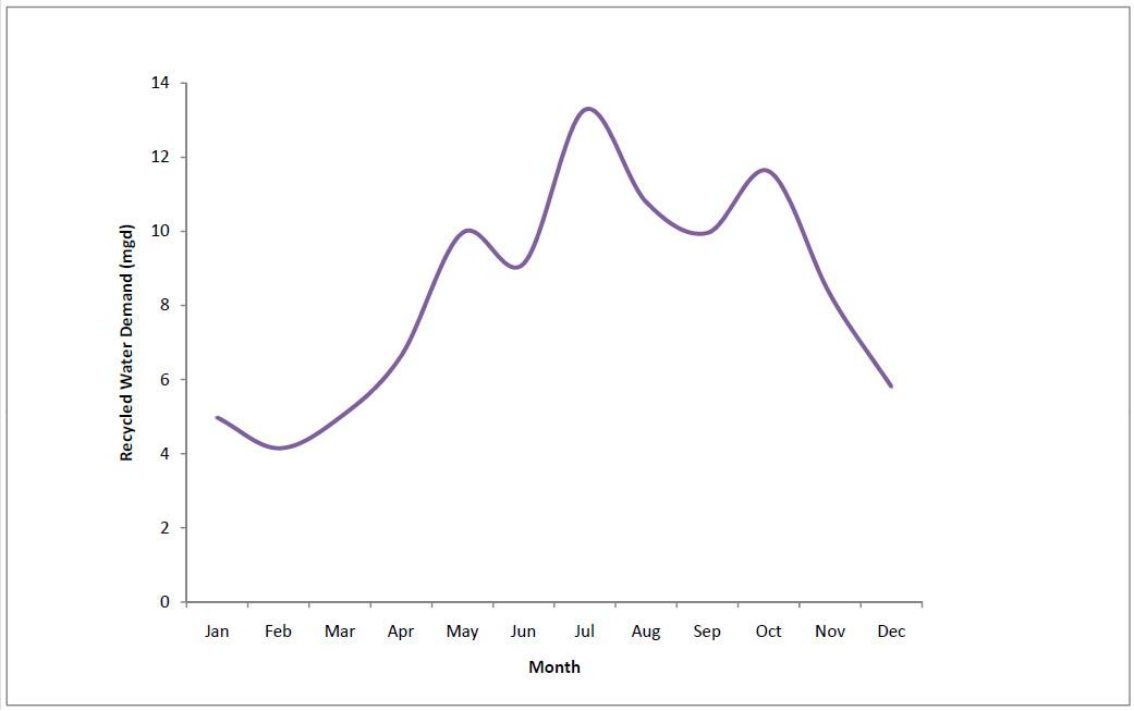
Table 1: Average Daily Recycled Water (RW) Demands by Month

Month	Avg Annual RW Demand (mgd)	Utility Water without Irrigation (mgd)	Irrigation RW Demands (mgd)	NCWRP RW Monthly Factor	Avg Daily Irrigation Demand by Month (mgd)
Jan	9.1	0.8	8.3	0.6	5.0
Feb	9.1	0.8	8.3	0.5	4.2
Mar	9.1	0.8	8.3	0.6	5.0
Apr	9.1	0.8	8.3	0.8	6.6
May	9.1	0.8	8.3	1.2	10.0
Jun	9.1	0.8	8.3	1.1	9.1
Jul	9.1	0.8	8.3	1.6	13.2
Aug	9.1	0.8	8.3	1.3	10.8
Sep	9.1	0.8	8.3	1.2	10.0
Oct	9.1	0.8	8.3	1.4	11.6
Nov	9.1	0.8	8.3	1.0	8.3
Dec	9.1	0.8	8.3	0.7	5.8

Note: NCWRP Recycled Water Monthly Factor obtained from Amy Dorman via email of Wed, June 8, 2011, 2:48:33PM. City referenced from latest Recycled Water Study.

After factoring in the above waste streams and recycled water demands, the remaining tertiary flow is available for the AWPF.

Figure 1: Average Daily Recycled Water Demands Curve



6.4 MF/ RO Waste

The available water will undergo membrane filtration (either micro- or ultra-filtration), and reverse osmosis (RO) at the AWPF. Each of these treatment processes will generate waste streams that would be

transported to the Point Loma Waste Water Treatment Plant. Recycling of backwash, also referred to as washwater, flows from MF is considered under this study as a potential scenario. The Independent Advisory Panel (IAP) discouraged recycling these flows, as expressed at the June 6, 2011 full IAP meeting.

Approximately 21.8% of the available flow supplying the AWPF is assumed to be wasted if MF backwash flows are not recycled. This waste percentage is consistent with the demonstration project currently underway at the NCWRP and represents 92% recovery for MF and 85% recovery for RO. Based on information collected from other AWPFs in southern California this is a reasonable assumption. The Los Angeles Water Replenishment District operates the Leo Van der Lans AWPF which has a biological treatment strategy that is closest to how the NCWRP operates utilizing nitrification and denitrification and operates with an overall 80% recovery.

6.5 On-line AWPF Operation

The AWPF is anticipated to operate continuously throughout the year. However, shutdown of the facility for maintenance and repairs for the AWPF throughout the year could occasionally interrupt or stop operation. An on-line percentage of 95% is assumed and factored into the amount of purified water produced annually when determining the unit cost per acre-foot of yield. In estimating the on-line percentage for the City, the operation of the Orange County Water District's (OCWD's) Ground Water Replenishment System in Fountain Valley, CA was investigated. The groundwater replenishment system treats secondary effluent and operates with 92% of the rated capacity on-line each year. Diurnal flow conditions limit the operation of the facility. OCWD anticipates increasing its on-line operation to 95% with the construction of equalization basins to attenuate the flow fluctuations. Since the NCWRP is equipped with flow equalization, an on-line percentage of 95% is assumed. This on-line operation is also used to estimate the pump station power usage for the year. The pump station is assumed to operate 24 hours per day, seven days a week with the exception of the annual shutdown resulting in an operation of approximately 347 days out of the year.

Figure 2 shows a schematic of the projected 2030 wastewater flow progression from the NCWRP through the AWPF to the final purified water product, and **Figure 3** shows a schematic of the flow progression with recycling of tertiary filter and MF backwash to the front of the plant. Example calculations of the estimated purified water product based on the apparent optimum AWPF capacity of 18 mgd with tertiary filter and MF backwash flows recycled to the front of the plant are provided as **Appendix A.**

Figure 2: Flow Progression from NCWRP to AWPF Purified Water Product (no recycle flows)

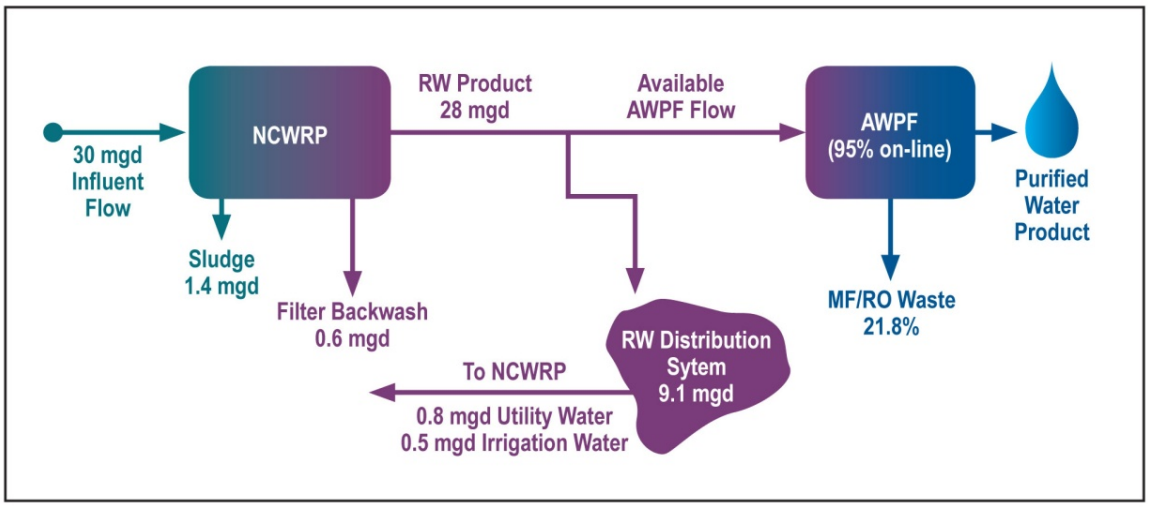
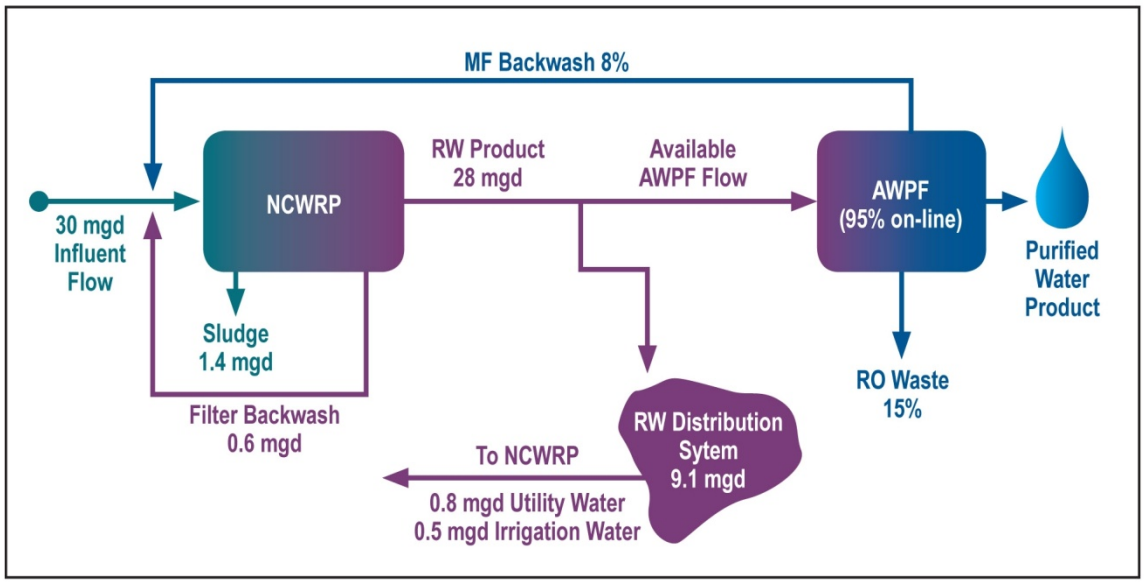


Figure 3: Flow Progression from NCWRP to AWPF Purified Water Product (with tertiary and MF backwash recycle)



7 Preliminary Design Criteria for Sizing Conveyance System

The design criteria and assumptions used in this analysis to preliminarily size the project components and determine the optimal AWPF capacity is provided in **Table 2**.

Table 2: Preliminary Facility Design Criteria

Facility	Criteria	Reference
Pipeline	Max Velocity = 5 ft/s Min Diameter = 8-inch Minor Losses = 10% of Friction Losses Hazen-Williams Coefficient = 135	*City of San Diego Water Department Capital Improvements Program Guidelines and Standards, Book 2*, November 2002 (City Guidelines and Standards).
Pump Station	Capacity = APWF Product Water Flow	Planned operation of AWPF at capacity
APWF	MF/ /RO Waste = 21.8% (8% MF Waste and 15% RO Waste) Online Factor = 95%	Based on Water Purification Demonstration Project performed by CDM Based on OCWD's Ground Water Replenishment System

For the purposes of this analysis, the 1996 Project Report recommendation of a single pump station at the AWPF to pump all of the purified water flows to the SVR will be used.

As previously mentioned, the selected pipeline alignment for this analysis is the South Corridor Mast Boulevard Alignment. The alignment is approximately 28-miles in length (5 miles of which is built) and extends from the AWPF to the SVR. The proposed alignment for this cost analysis assumes that the pipeline will connect to the existing recycled waterline that extends from the NCWRP to the MBC. The point of connection for the proposed conveyance pipeline would be to the existing 36-inch recycled water line at MBC. This would eliminate the construction of approximately 5 miles of pipeline.

8 Preliminary Project Life Cycle Costs

To help select the optimal capacity, preliminary costs in 2011 dollars have been developed. While these costs are not to be considered the programmatic costs, they are useful in comparing the relative and incremental costs or a given yield. The preliminary costs for the project components in this analysis were determined using the following cost assumptions summarized in **Table 3**. Sources for these assumptions include the 2005 Water Reuse Study, latest Recycled Water Study, data provided by the City, and assumed values based on typical industry standards.

Table 3: Facility Cost Assumptions

Facility	Cost Assumptions	Source
Capital Cost Pipeline	$20/in-dia/ft	Planning level unit cost includes some limited tunneling
Pump Station	PS Cost [1]= (440,000*(Q_{cfs})^0.75 * (H_{ft}/300)^0.66)	*Water Reuse Study, Cost Analysis, Technical Memorandum 7 (September 2005)*
AWPF	MF: $1,410,000/mgd RO: $1,750,000/mgd AOP: $310,000/mgd	Provided by City and rounded to nearest $10,000
O&M Cost Pipeline	1% of Construction Cost[2]	*Water Reuse Study, Cost Analysis, Technical Memorandum 7 (September 2005)*
Pump Station	2.5% of Construction Cost[2]	*Water Reuse Study, Cost Analysis, Technical Memorandum 7 (September 2005)*
	Pump Hrs per Day = 24 hrs	Assumed
	Days per Year = 95% of 365 days = 347 days	Based on AWPF on-line factor
	Wire to Water Pumping Efficiency = 75%	Assumed
	Energy Cost = $0.15/kWh	Assumed
AWPF	MF/RO/AOP: $600,000/mgd	Latest Recycled Water Study and rounded to nearest $10,000
Soft Costs		
Life Cycle	50 years	Apply to all facilities. Provided by City
Interest Rate	6%	*Water Reuse Study, Cost Analysis, Technical Memorandum 7 (September 2005)*
Contingency	40%	Provided by City
Engineering/Admin	20%	Provided by City
Environmental Doc	20%	Provided by City
Land Acquisition	4%	Provided by City
Construction Mgmt	10%	Provided by City

Notes:

1. The original pump station capital cost equation from *Water Reuse Study, Cost Analysis, Technical Memorandum 7 (September 2005)* included 30% administrative & engineering fees and 20% construction management fees. These were removed as soft costs provided by the City would be factored in later.
2. Pump station and pipeline O&M Costs is percentage of construction cost with 40% soft cost contingency factored into construction cost.

3. AWPF O&M costs for microfiltration, reverse osmosis, and advanced oxidation process provided by City was compared to OCSD's AWPF that produces 49 mgd of product water. OCWD in November 2008 had operating costs of $573k/mgd which includes $10k/mgd of OCSD credits. The difference of $17k/mgd can be attributed to data being 3 years ago and economies of scale.

9 Cost Analysis

As part of the cost analysis, the total project cost was estimated for varying AWPF capacities to determine an optimal unit cost per acre-foot of purified water produced annually. This analysis was done first assuming tertiary filter and MF backwash flows are wasted to Point Loma Wastewater Treatment Plant (Section 9.1), and next assuming tertiary filter and MF backwash flows are recycled to the head of the NCWRP (Section 9.2).

9.1 Cost Analysis Assuming No Recycle Flows

Table 4 summarizes the unit costs for the preliminarily sized pump station, ultimate conveyance pipeline diameter of 30-inch, and purified product water yield for AWPF capacities varying from 0 to 20 mgd. A complete detailed cost breakdown showing costs for each project component is provided as **Appendix B**.

Table 4: Purified Water Yields and Project Unit Costs by AWPF Capacity (no recycle flows)

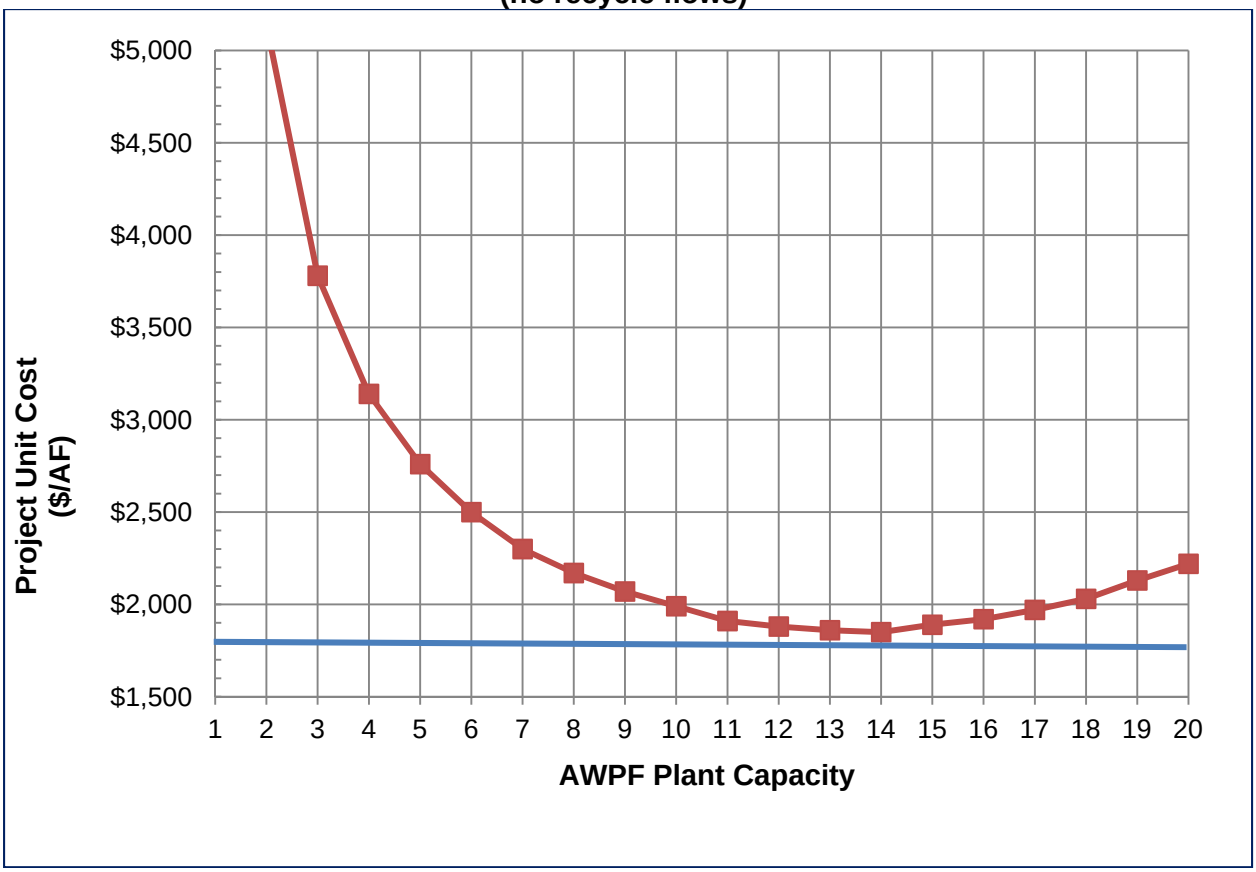
AWPF Plant Capacity (mgd)	Projected AWPF Product Water Yield (95% on-line) (AFY)	Conveyance Pipe Diameter (in)	Pump Flow (gpm)	TDH (ft)	Pump Power (Hp)	Unit Cost ($/AFY)
1	1,070	30	700	450	110	$8,970
2	2,130	30	1,400	450	220	$5,140
3	3,210	30	2,100	460	330	$3,780
4	4,270	30	2,800	460	440	$3,140
5	5,330	30	3,500	470	560	$2,760
6	6,400	30	4,200	480	680	$2,500
7	7,460	30	4,900	500	830	$2,300
8	8,530	30	5,600	510	970	$2,170
9	9,590	30	6,300	530	1130	$2,070
10	10,650	30	7,000	550	1300	$1,990
11	11,710	30	7,700	560	1460	$1,910
12	12,680	30	8,400	590	1670	$1,880
13	13,570	30	9,100	610	1870	$1,860
14	**14,270**	**30**	**9,800**	**630**	**2080**	**$1,850**
15	14,800	30	10,500	660	2340	$1,890
16	15,240	30	11,200	680	2570	$1,920
17	15,580	30	11,900	710	2850	$1,970
18	15,740	30	12,500	740	3120	$2,030
19	15,740	30	13,200	770	3430	$2,130
20	15,740	30	13,900	810	3800	$2,220

Notes:
1. Pipeline diameter sizes are based on a maximum velocity of 5 feet per second per *City of San Diego CIP Guidelines and Standards* for transmission mains less than 60-inch in diameter.
2. Estimated Projected AWPF Water Yield includes the 5% off-line factor.

Based on the unit cost per acre-foot cost analysis, Table 4 and **Figure 4** illustrate the apparent optimal price point is at an AWPF capacity of 14 mgd with an estimated unit cost of $1,850 per acre-feet of purified water produced annually. However, this analysis is based on the projected recycled water demands for 2030 (which may vary over the next 19 years) and concept level costs. Because of the potential variations in the assumptions, an optimum range would be reasonable as the differences in unit costs are within a narrow margin. Therefore, AWPF feed rates within the lower and flatter segment of the curve (from 11 to 16 mgd) are within an optimal range with 14 mgd estimated as having the lowest unit cost per acre-foot of product water yield. This range provides the City some flexibility in capturing the flows when the irrigation demands are less, thus avoiding lost product water to Point Loma Wastewater Treatment Plant.

Per the City's request, a separate analysis was performed assuming an ultimate 36-inch pipe diameter would be constructed. Similar to evaluating the economic analysis with a constant 30-inch pipe, this was performed to determine the cost implications the pipe capital cost would have on the project unit cost, as well as the overall project costs. The results of this analysis are included in **Appendix C**.

Figure 4: Project Unit Cost by AWPF Plant Capacity for 30-inch Pipe (no recycle flows)

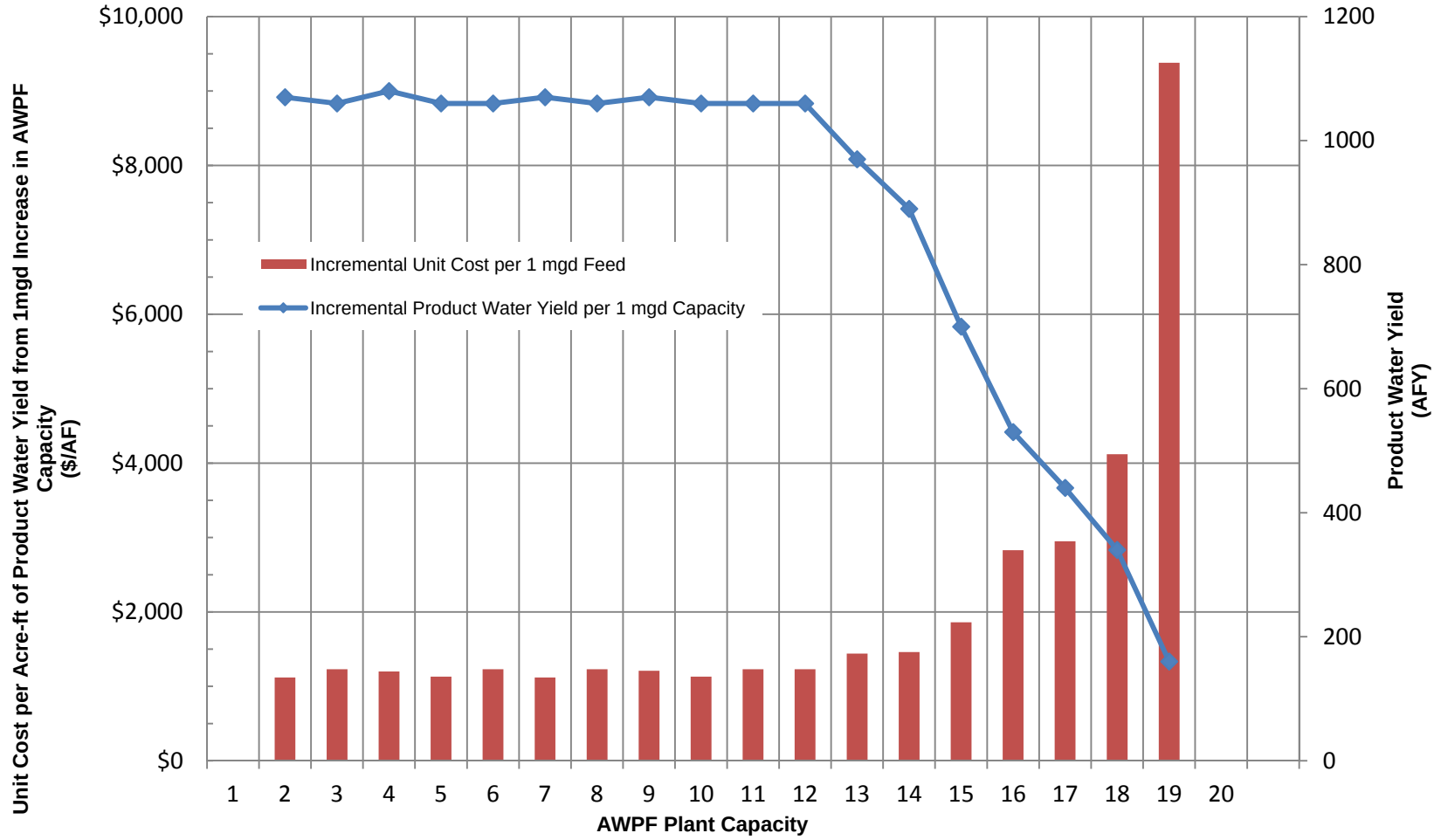


Another way to analyze the capacity is to look at the incremental costs for each additional 1 mgd of flow. **Table 5** below shows the incremental product water yield and total project costs for each additional increase in 1-mgd of AWPF feed rate. The incremental cost per 1mgd of capacity starts to increase at an increasing rate at 14 mgd and above.

Figure 5 shows the purified water yield for each additional 1 mgd of AWPF feed along with the "incremental" unit cost per acre-foot. The amount of product water yield from the AWPF begins to decrease for feed rates greater than 14 mgd because seasonal recycled water demands impact the amount of tertiary water available for advanced treatment. As the AWPF capacity increases, the product water yield diminishes because the facility is oversized for longer periods of time during the summer months when available tertiary flows to the purification facility are lowest. This incremental unit cost should not be confused with the overall project unit cost where annualized project costs are divided by the average annual purified water yield.

Based on the incremental unit cost analysis, the product water yield starts to decline for AWPF capacities that are greater than 11 mgd. Even for capacities from 12 to 14 mgd, it appears that the incremental costs are relatively comparable in cost despite the decline in product water yield. An AWPF capacity of 14 mgd is the breakpoint where the benefit to cost ratio starts to decline more dramatically.

Figure 5: Incremental Unit Cost of Purified Water Yield Per 1 MGD Increase of AWPF Capacity (no recycle flows)



NOTE: THE ABOVE UNIT COSTS ARE INCREMENTAL. THEY SHOULD NOT BE COMPARED TO TOTAL PROJECT UNIT COSTS OR SDCWA YR 2030 PROJECTED IMPORTED WATER COSTS OF $2000/AF. PRODUCT WATER YIELD ASSUMES AWPF IS 95% ON-LINE ANNUALLY.

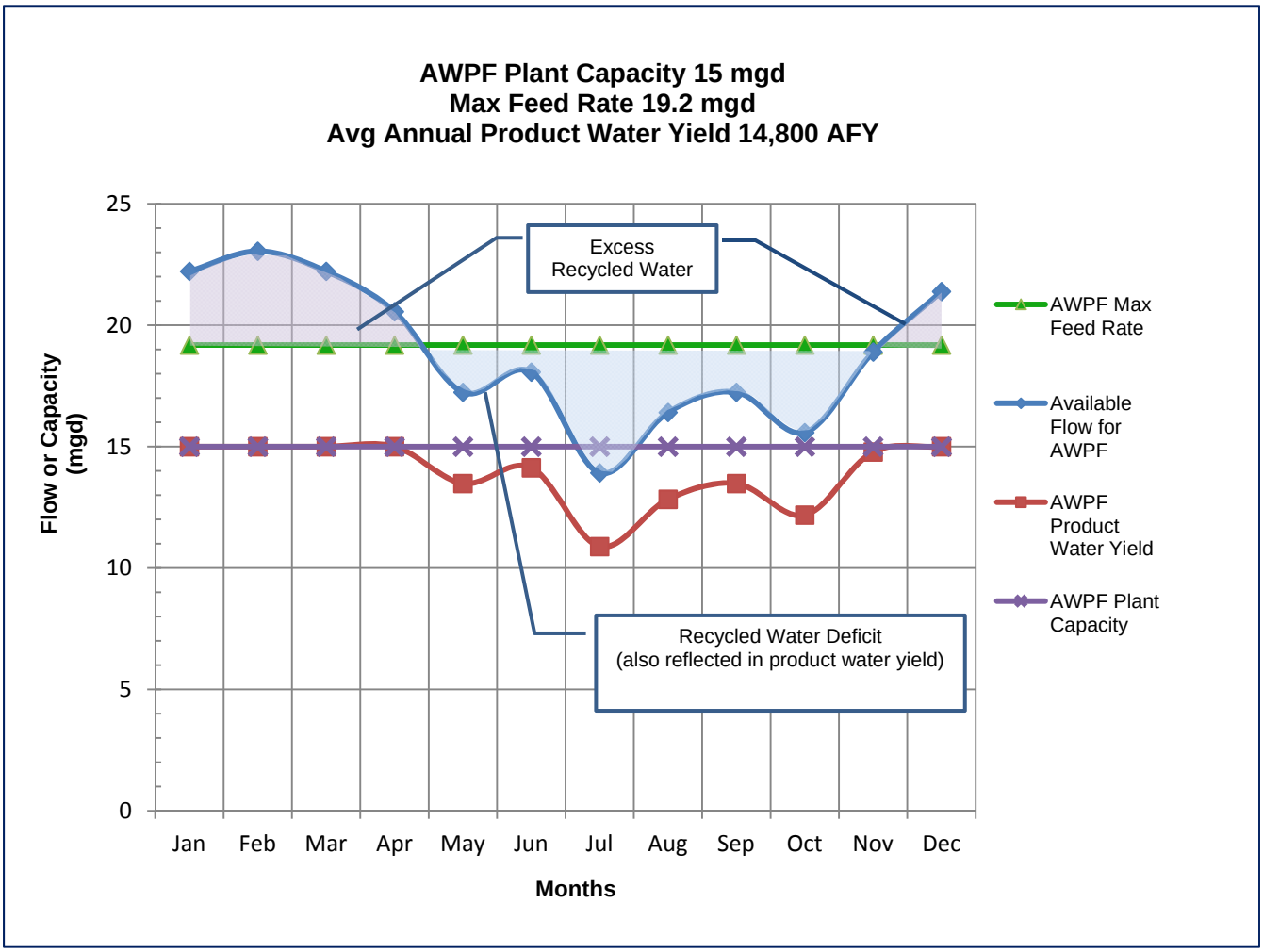
Table 5: Incremental Unit Cost by AWPF Capacity (no recycle flows)

AWPF Capacity (mgd)	Conveyance Pipe Diameter (in)	AWPF Product Water Yield (95% on-line) (AFY)	Incremental AWPF Capacity (AFY)	Incremental Capital Cost ($)	Incremental Annual O&M Cost ($)	Incremental Total Annual Cost ($)	Incremental Unit Cost ($/AF)
1	30	1,070	1,070	$8,300,000	$600,000	$1,200,000	$1,120
2	30	2,130	1,060	$7,900,000	$700,000	$1,300,000	$1,230
3	30	3,210	1,080	$7,900,000	$600,000	$1,300,000	$1,200
4	30	4,270	1,060	$7,800,000	$700,000	$1,200,000	$1,130
5	30	5,330	1,060	$7,800,000	$700,000	$1,300,000	$1,230
6	30	6,400	1,070	$7,800,000	$600,000	$1,200,000	$1,120
7	30	7,460	1,060	$7,800,000	$600,000	$1,300,000	$1,230
8	30	8,530	1,070	$7,800,000	$700,000	$1,300,000	$1,210
9	30	9,590	1,060	$7,900,000	$600,000	$1,200,000	$1,130
10	30	10,650	1,060	$7,800,000	$600,000	$1,300,000	$1,230
11	30	11,710	1,060	$7,800,000	$600,000	$1,300,000	$1,230
12	30	12,680	970	$8,000,000	$700,000	$1,400,000	$1,440
13	30	13,570	890	$7,900,000	$700,000	$1,300,000	$1,460
14	**30**	**14,270**	**700**	**$7,900,000**	**$600,000**	**$1,300,000**	**$1,860**
15	30	14,800	530	$8,000,000	$700,000	$1,500,000	$2,830
16	30	15,240	440	$7,900,000	$600,000	$1,300,000	$2,950
17	30	15,580	340	$8,100,000	$600,000	$1,400,000	$4,120
18	30	15,740	160	$8,000,000	$700,000	$1,500,000	$9,380
19	30	15,740	0	$8,100,000	$600,000	$1,400,000	---
20	30	15,740	0	$8,200,000	$700,000	$1,500,000	---

Note: The above flow data and costs are based on 30-inch pipe.

From an economic analysis, the optimum value appears to occur from an AWPF capacity of 14 mgd which produces a projected product yield of 14,270 AFY at a required feed flow of 17.9 mgd. Although it would treat less recycled water during the winter months than the balanced scenario, it would potentially operate at its design capacity for 9 months out of a given year depending upon recycled water demands.

Figure 6: Flow Balance Analysis
(no recycle flows)



9.2 Cost Analysis with Tertiary/MF Recycle Flows

Table 6 summarizes the unit costs for the preliminarily sized pump station, ultimate conveyance pipeline diameter of 30-inch, and purified product water yield for AWPF capacities varying from 0 to 20 mgd assuming tertiary filter and MF backwash flows are recycled to the front of the NCWRP. Recycling flows to the front of the plant will increase flow to the AWPF, increasing monthly yield when plant capacity exceeds the flow available. A complete detailed cost breakdown showing costs for each project component is provided as **Appendix B**.

Table 6: Purified Water Yields and Project Unit Costs by AWPF Capacity (with tertiary and MF backwash recycle)

AWPF Plant Capacity (mgd)	Projected AWPF Product Water Yield (95% on-line) (AFY)	Conveyance Pipe Diameter (in)	Pump Flow (gpm)	TDH (ft)	Pump Power (Hp)	Unit Cost ($/AFY)
1	1,070	30	700	450	110	$8,970
2	2,130	30	1,400	450	220	$5,140
3	3,210	30	2,100	460	330	$3,780
4	4,270	30	2,800	460	440	$3,140
5	5,330	30	3,500	470	560	$2,760
6	6,400	30	4,200	480	680	$2,500
7	7,460	30	4,900	500	830	$2,300
8	8,530	30	5,600	510	970	$2,170
9	9,590	30	6,300	530	1130	$2,070
10	10,650	30	7,000	550	1300	$1,990
11	11,720	30	7,700	560	1460	$1,910
12	12,780	30	8,400	590	1670	$1,870
13	13,770	30	9,100	610	1870	$1,820
14	14,700	30	9,800	630	2080	$1,800
15	15,510	30	10,500	660	2340	$1,800
16	16,100	30	11,200	680	2570	$1,820
17	16,570	30	11,900	710	2850	$1,850
18	**16,990**	**30**	**12,500**	**740**	**3120**	**$1,900**
19	17,290	30	13,200	770	3430	$1,940
20	17,370	30	13,900	810	3800	$2,030

Notes:

3. Pipeline diameter sizes are based on a maximum velocity of 5 feet per second per *City of San Diego CIP Guidelines and Standards* for transmission mains less than 60-inch in diameter.
4. Estimated Projected AWPF Water Yield includes the 5% off-line factor.

Based on the unit cost per acre-foot cost analysis, **Table 6** and **Figure 7,** AWPF feed rates within the lower and flatter segment of the curve (from 11 to 18 mgd) are within an optimal range with 14 to 15 mgd estimated as having the lowest unit cost per acre-foot of product water yield. This is because at 14 to 15 MGD the plant would operate at full capacity nearly year round. However, at a capacity of approximately 18 MGD, the City would be able to meet the stated IPR goals.

Figure 7: Project Unit Cost by AWPF Plant Capacity for 30-inch Pipeline (with tertiary and MF backwash recycle)

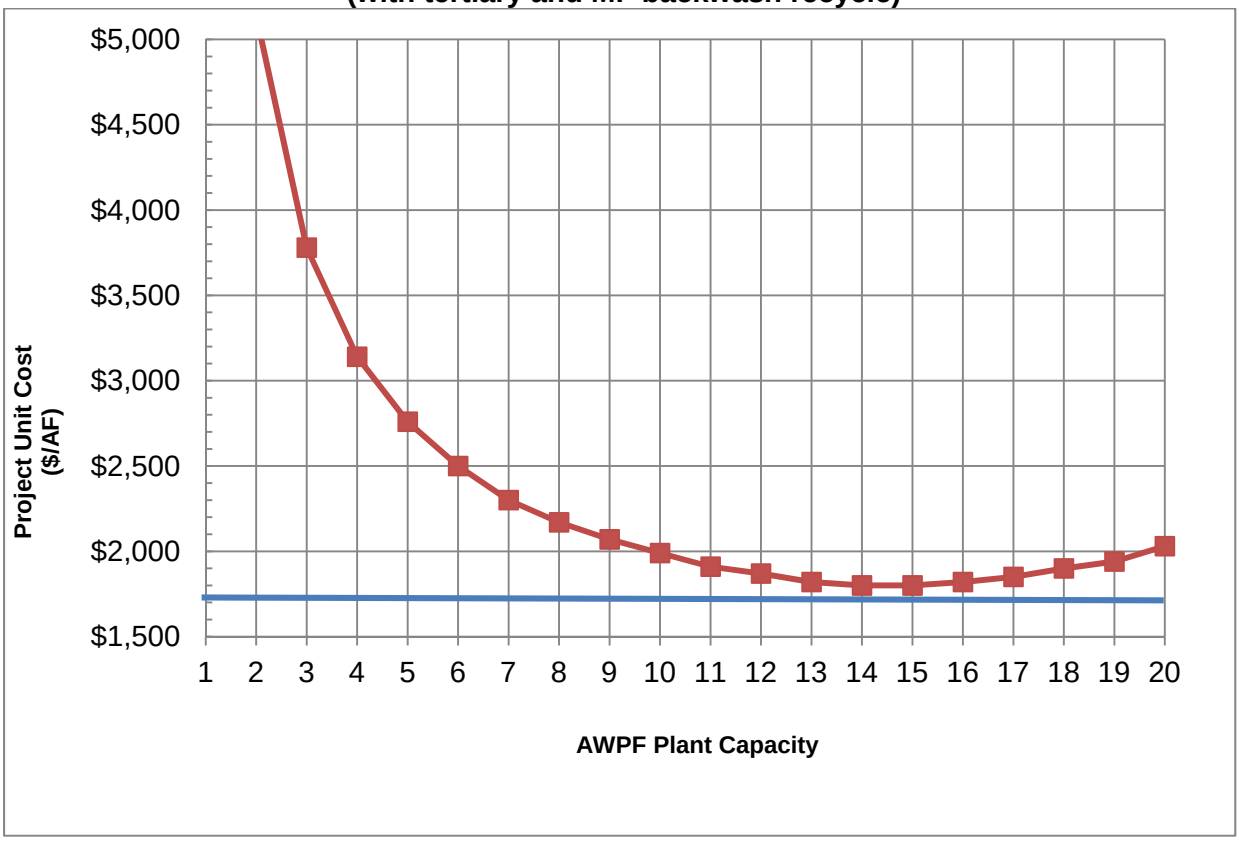
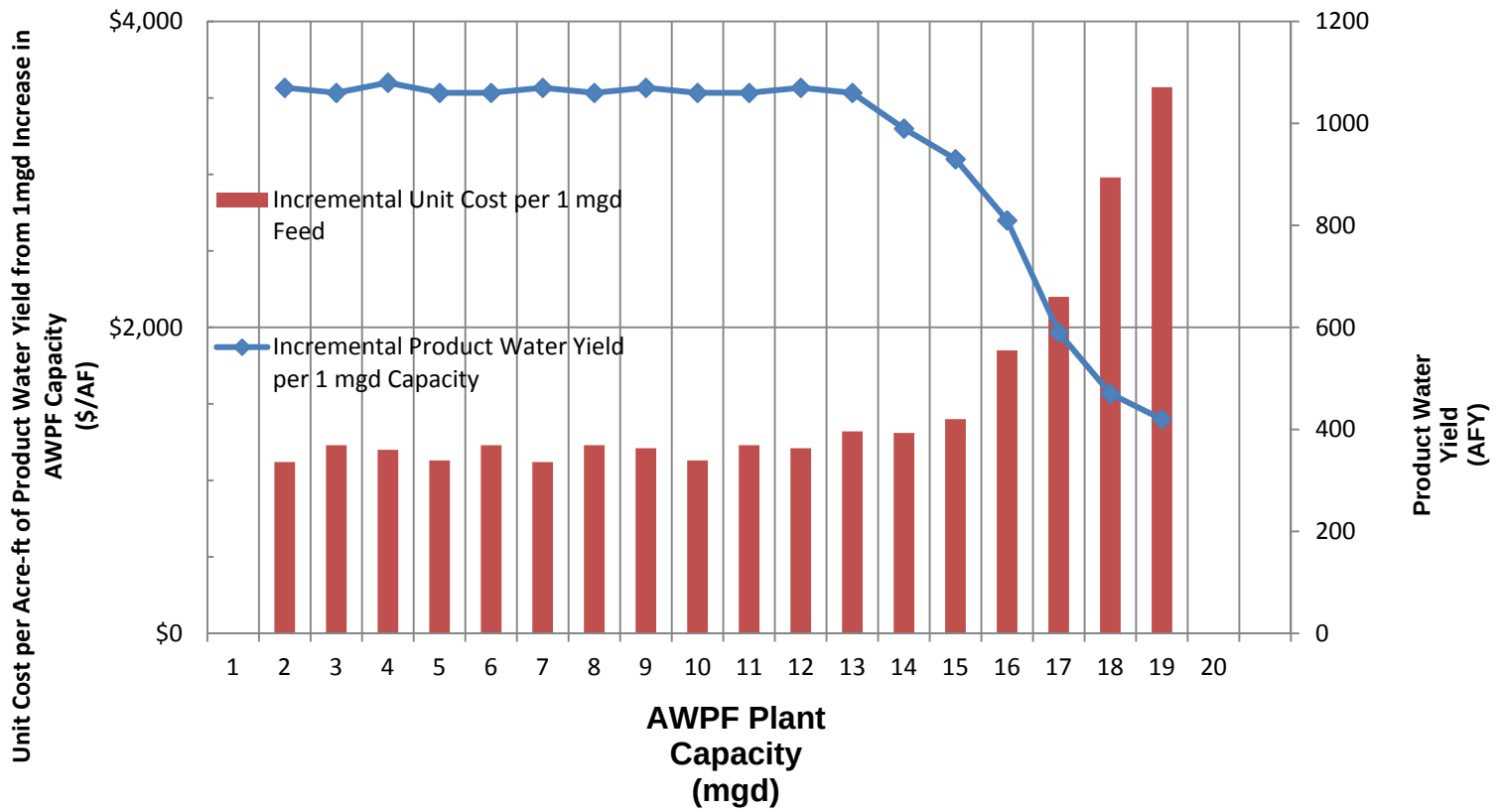


Table 7 shows the incremental product water yield and total project costs for each additional increase in 1-mgd of AWPF feed rate with recycle flows. The incremental cost per 1 mgd of capacity starts to increase at an increasing rate at 16 mgd and above.

Figure 8 shows the purified water yield for each additional 1 mgd of AWPF feed along with the "incremental" unit cost per acre-foot. The amount of product water yield from the AWPF begins to decrease for feed rates greater than 14 mgd because seasonal recycled water demands impact the amount of tertiary water available for advanced treatment. As the AWPF capacity increases, the product water yield diminishes because the facility is oversized for longer periods of time during the summer months when available tertiary flows to the purification facility are lowest.

Figure 8: Incremental Unit Cost and Purified Water Yield per 1 MGD Increase of AWPF Capacity (with tertiary and MF backwash recycle)



NOTE: THE ABOVE UNIT COSTS ARE INCREMENTAL. THEY SHOULD NOT BE COMPARED TO TOTAL PROJECT UNIT COSTS OR SDCWA YR 2030 PROJECTED IMPORTED WATER COSTS OF $2000/AF. PRODUCT WATER YIELD ASSUMES AWPF IS 95% ON-LINE ANNUALLY.

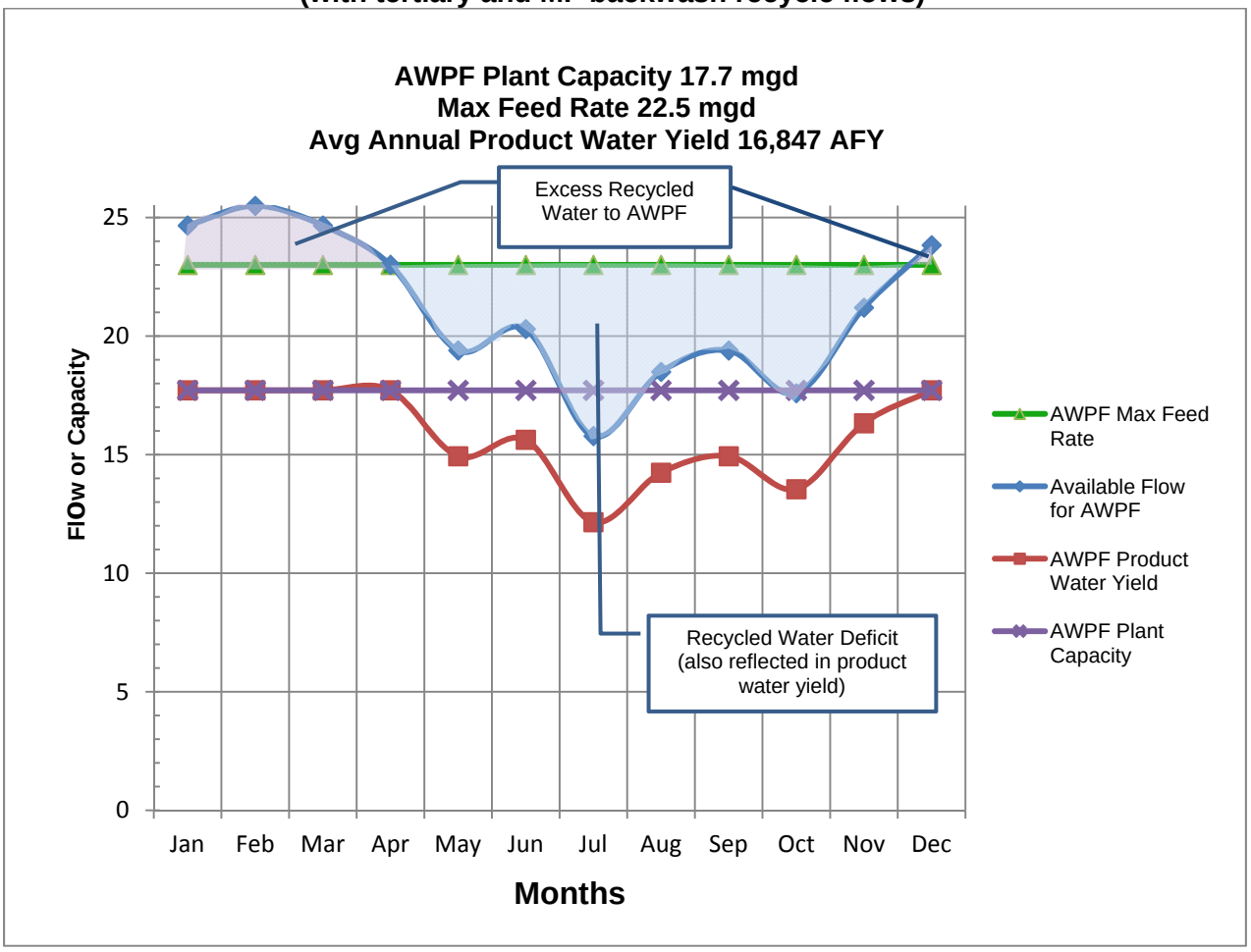
Table 7: Incremental Unit Cost by AWPF Capacity (with tertiary and MF backwash recycle)

AWPF Capacity (mgd)	Conveyance Pipe Diameter (in)	AWPF Product Water Yield (95% on-line) (AFY)	Incremental AWPF Capacity (AFY)	Incremental Capital Cost ($)	Incremental Annual O&M Cost ($)	Incremental Total Annual Cost ($)	Incremental Unit Cost ($/AF)
1	30	1,070	1,070	$8,300,000	$600,000	$1,200,000	$1,120
2	30	2,130	1,060	$7,900,000	$700,000	$1,300,000	$1,230
3	30	3,210	1,080	$7,900,000	$600,000	$1,300,000	$1,200
4	30	4,270	1,060	$7,800,000	$700,000	$1,200,000	$1,130
5	30	5,330	1,060	$7,800,000	$700,000	$1,300,000	$1,230
6	30	6,400	1,070	$7,800,000	$600,000	$1,200,000	$1,120
7	30	7,460	1,060	$7,800,000	$600,000	$1,300,000	$1,230
8	30	8,530	1,070	$7,800,000	$700,000	$1,300,000	$1,210
9	30	9,590	1,060	$7,900,000	$600,000	$1,200,000	$1,130
10	30	10,650	1,060	$7,800,000	$600,000	$1,300,000	$1,230
11	30	11,720	1,070	$7,800,000	$600,000	$1,300,000	$1,210
12	30	12,780	1,060	$8,000,000	$700,000	$1,400,000	$1,320
13	30	13,770	990	$7,900,000	$700,000	$1,300,000	$1,310
14	30	14,700	930	$7,900,000	$600,000	$1,300,000	$1,400
15	30	15,510	810	$8,000,000	$700,000	$1,500,000	$1,850
16	30	16,100	590	$7,900,000	$600,000	$1,300,000	$2,200
17	30	16,570	470	$8,100,000	$600,000	$1,400,000	$2,980
18	**30**	**16,990**	**420**	**$8,000,000**	**$700,000**	**$1,500,000**	**$3,570**
19	30	17,290		$8,100,000	$600,000	$1,400,000	
20	30	17,370		$8,200,000	$700,000	$1,500,000	

Note: The above flow data and costs are based on 30-inch pipe.

Calculations of treatment capacity and AWPF yield show that a 17.7 MGD plant can meet the City's goal of 16,800 AFY IPR reuse. **Figure 9** shows the amount of recycled water above and below the AWPF capacity by month for a 17.7 MGD AWPF, including excess recycled water available to the AWPF and deficit recycled water (excess AWPF capacity). For approximately 7 months out of the year, the flow available is less than required for the plant to run at full capacity. However, this is the minimum size plant that would meet the City's IPR goals.

Figure 9: Flow Balance Analysis
(with tertiary and MF backwash recycle flows)



10 Conclusion

As discussed earlier, flows available to the AWPF vary by season throughout the year. After on-site and irrigation demands are met, the maximum month available flow would be 25 mgd with recycling tertiary filter and MF backwash flows. Without recycling the tertiary filter and MF backwash flows the AWPF and pumping facilities should be sized for 14 mgd of capacity initially and 18 mgd for ultimate. **Table 8** summarizes the project costs by component and highlights the two recommended AWPF capacities. However, an increase in AWPF production could be achieved if tertiary filter backwash and membrane filtration (MF) backwash is recycled back to the front of the plant rather than wasted to Point Loma Wastewater Treatment Plant. If this scenario is implemented, an optimal AWPF capacity of 18 mgd for a full-scale project would yield approximately 16,876 AFY of purified water, which meets the City's goal of maximizing reuse. **Table 9** summarizes the project costs by component and highlights the recommended AWPF capacity.

Recycling of these flows is not part of the current operations at the NCWRP or at the pilot demonstration tests facility. The NCWRP plant staff believes that they can process more flow than the rated capacity but is actually operating well below the rated capacity and does not have a track record of performance above 30 mgd. In the future and with recycling the tertiary and MF backwash flows, the NCWRP could see flows greater than 10% above the rated capacity on a continuous basis. Note that this analysis did not evaluate the hydraulics or process design capabilities and limitations. The MF backwash water contains chloramines and thus would add more nitrogen back into the NCWRP from recycling this water. While the load may be relatively small, total nitrogen is a key regulatory parameter for reservoir augmentation. Therefore, potential water quality impacts and mitigation measures should be evaluated in the next phase of the design. In addition, recycling of these flows would deliver more flow to the front of the NCWRP, and potential impacts to NCWRP operations, including available process capacity must be evaluated.

Table 8: Project Cost Summary by AWPF Capacity
(no recycle flows)

AWPF Capacity (mgd)	AWPF Product Water Yield (95% online) (AFY)	Construction Costs Total ($)	Soft Costs Total ($)	Capital Costs				Annualized Capital Costs Total ($)	Annualized O&M Costs Total ($)	Total Annualized Cost Total ($)	Annual Unit Cost Total ($/AF)
				AWPF ($)	Pipeline ($)	Pump Station ($)	Total ($)				
1	1,070	$65,100,000	$61,200,000	$7,220,000	$118,000,000	$1,032,000	$126,300,000	$8,100,000	$1,500,000	$9,600,000	$8,970
2	2,130	$69,200,000	$65,100,000	$14,430,000	$118,000,000	$1,734,000	$134,200,000	$8,600,000	$2,200,000	$10,900,000	$5,140
3	3,210	$73,300,000	$68,900,000	$21,650,000	$118,000,000	$2,386,000	$142,100,000	$9,100,000	$2,800,000	$12,200,000	$3,780
4	4,270	$77,300,000	$72,700,000	$28,860,000	$118,000,000	$2,960,000	$149,900,000	$9,600,000	$3,500,000	$13,400,000	$3,140
5	5,330	$81,300,000	$76,400,000	$36,080,000	$118,000,000	$3,550,000	$157,700,000	$10,000,000	$4,200,000	$14,700,000	$2,760
6	6,400	$85,300,000	$80,200,000	$43,290,000	$118,000,000	$4,128,000	$165,500,000	$10,500,000	$4,800,000	$15,900,000	$2,500
7	7,460	$89,400,000	$84,000,000	$50,510,000	$118,000,000	$4,761,000	$173,300,000	$11,000,000	$5,400,000	$17,200,000	$2,300
8	8,530	$93,400,000	$87,800,000	$57,720,000	$118,000,000	$5,331,000	$181,100,000	$11,500,000	$6,100,000	$18,500,000	$2,170
9	9,590	$97,400,000	$91,600,000	$64,930,000	$118,000,000	$5,973,000	$189,000,000	$12,000,000	$6,700,000	$19,700,000	$2,070
10	10,650	$101,500,000	$95,400,000	$72,150,000	$118,000,000	$6,623,000	$196,800,000	$12,500,000	$7,300,000	$21,000,000	$1,990
11	11,710	$105,500,000	$99,200,000	$79,360,000	$118,000,000	$7,199,000	$204,600,000	$13,000,000	$7,900,000	$22,300,000	$1,910
12	12,680	$109,600,000	$103,000,000	$86,580,000	$118,000,000	$7,954,000	$212,600,000	$13,500,000	$8,600,000	$23,700,000	$1,880
13	13,570	$113,700,000	$106,900,000	$93,790,000	$118,000,000	$8,635,000	$220,500,000	$14,000,000	$9,300,000	$25,000,000	$1,860
14	**14,270**	**$117,800,000**	**$110,700,000**	**$101,010,000**	**$118,000,000**	**$9,324,000**	**$228,400,000**	**$14,500,000**	**$9,900,000**	**$26,300,000**	**$1,850**
15	14,800	$121,900,000	$114,600,000	$108,220,000	$118,000,000	$10,125,000	$236,400,000	$15,000,000	$10,600,000	$27,800,000	$1,890
16	15,240	$126,000,000	$118,400,000	$115,440,000	$118,000,000	$10,839,000	$244,300,000	$15,500,000	$11,200,000	$29,100,000	$1,920
17	15,580	$130,100,000	$122,300,000	$122,650,000	$118,000,000	$11,671,000	$252,400,000	$16,100,000	$11,800,000	$30,500,000	$1,970
18	**15,740**	**$134,300,000**	**$126,200,000**	**$129,870,000**	**$118,000,000**	**$12,521,000**	**$260,400,000**	**$16,600,000**	**$12,500,000**	**$32,000,000**	**$2,030**
19	15,740	$138,400,000	$130,100,000	$137,080,000	$118,000,000	$13,384,000	$268,500,000	$17,100,000	$13,100,000	$33,400,000	$2,130
20	15,740	$142,700,000	$134,100,000	$144,290,000	$118,000,000	$14,381,000	$276,700,000	$17,600,000	$13,800,000	$34,900,000	$2,220

Table 9: Project Cost Summary by AWPF Capacity (with tertiary and MF backwash recycle)

AWPF Capacity (mgd)	AWPF Product Water Yield (95% online) (AFY)	Construction Costs Total ($)	Soft Costs Total ($)	Capital Costs				Annualized Capital Costs Total ($)	Annualized O&M Costs Total ($)	Total Annualized Cost Total ($)	Annual Unit Cost Total ($/AF)
				AWPF ($)	Pipeline ($)	Pump Station ($)	Total ($)				
1	1,070	$65,100,000	$61,200,000	$7,220,000	$118,000,000	$1,032,000	$126,300,000	$8,100,000	$1,500,000	$9,600,000	$8,970
2	2,130	$69,200,000	$65,100,000	$14,430,000	$118,000,000	$1,734,000	$134,200,000	$8,600,000	$2,200,000	$10,900,000	$5,140
3	3,210	$73,300,000	$68,900,000	$21,650,000	$118,000,000	$2,386,000	$142,100,000	$9,100,000	$2,800,000	$12,200,000	$3,780
4	4,270	$77,300,000	$72,700,000	$28,860,000	$118,000,000	$2,960,000	$149,900,000	$9,600,000	$3,500,000	$13,400,000	$3,140
5	5,330	$81,300,000	$76,400,000	$36,080,000	$118,000,000	$3,550,000	$157,700,000	$10,000,000	$4,200,000	$14,700,000	$2,760
6	6,400	$85,300,000	$80,200,000	$43,290,000	$118,000,000	$4,128,000	$165,500,000	$10,500,000	$4,800,000	$15,900,000	$2,500
7	7,460	$89,400,000	$84,000,000	$50,510,000	$118,000,000	$4,761,000	$173,300,000	$11,000,000	$5,400,000	$17,200,000	$2,300
8	8,530	$93,400,000	$87,800,000	$57,720,000	$118,000,000	$5,331,000	$181,100,000	$11,500,000	$6,100,000	$18,500,000	$2,170
9	9,590	$97,400,000	$91,600,000	$64,930,000	$118,000,000	$5,973,000	$189,000,000	$12,000,000	$6,700,000	$19,700,000	$2,070
10	10,650	$101,500,000	$95,400,000	$72,150,000	$118,000,000	$6,623,000	$196,800,000	$12,500,000	$7,300,000	$21,000,000	$1,990
11	11,720	$105,500,000	$99,200,000	$79,360,000	$118,000,000	$7,199,000	$204,600,000	$13,000,000	$7,900,000	$22,300,000	$1,910
12	12,780	$109,600,000	$103,000,000	$86,580,000	$118,000,000	$7,954,000	$212,600,000	$13,500,000	$8,600,000	$23,700,000	$1,870
13	13,770	$113,700,000	$106,900,000	$93,790,000	$118,000,000	$8,635,000	$220,500,000	$14,000,000	$9,300,000	$25,000,000	$1,820
14	14,700	**$117,800,000**	**$110,700,000**	**$101,010,000**	**$118,000,000**	**$9,324,000**	**$228,400,000**	**$14,500,000**	**$9,900,000**	**$26,300,000**	$1,800
15	15,510	$121,900,000	$114,600,000	$108,220,000	$118,000,000	$10,125,000	$236,400,000	$15,000,000	$10,600,000	$27,800,000	$1,800
16	16,100	$126,000,000	$118,400,000	$115,440,000	$118,000,000	$10,839,000	$244,300,000	$15,500,000	$11,200,000	$29,100,000	$1,820
17	16,570	$130,100,000	$122,300,000	$122,650,000	$118,000,000	$11,671,000	$252,400,000	$16,100,000	$11,800,000	$30,500,000	$1,850
18	16,990	**$134,300,000**	**$126,200,000**	**$129,870,000**	**$118,000,000**	**$12,521,000**	**$260,400,000**	**$16,600,000**	**$12,500,000**	**$32,000,000**	$1,900
19	17,290	$138,400,000	$130,100,000	$137,080,000	$118,000,000	$13,384,000	$268,500,000	$17,100,000	$13,100,000	$33,400,000	$1,940
20	17,370	$142,700,000	$134,100,000	$144,290,000	$118,000,000	$14,381,000	$276,700,000	$17,600,000	$13,800,000	$34,900,000	$2,030

APPENDIX A

City of San Diego IPR/PMPO

Concept Design Report - Conveyance System

Table: Projected Flows Based on Max Month RW Demands and Fixed AWPF Capacity

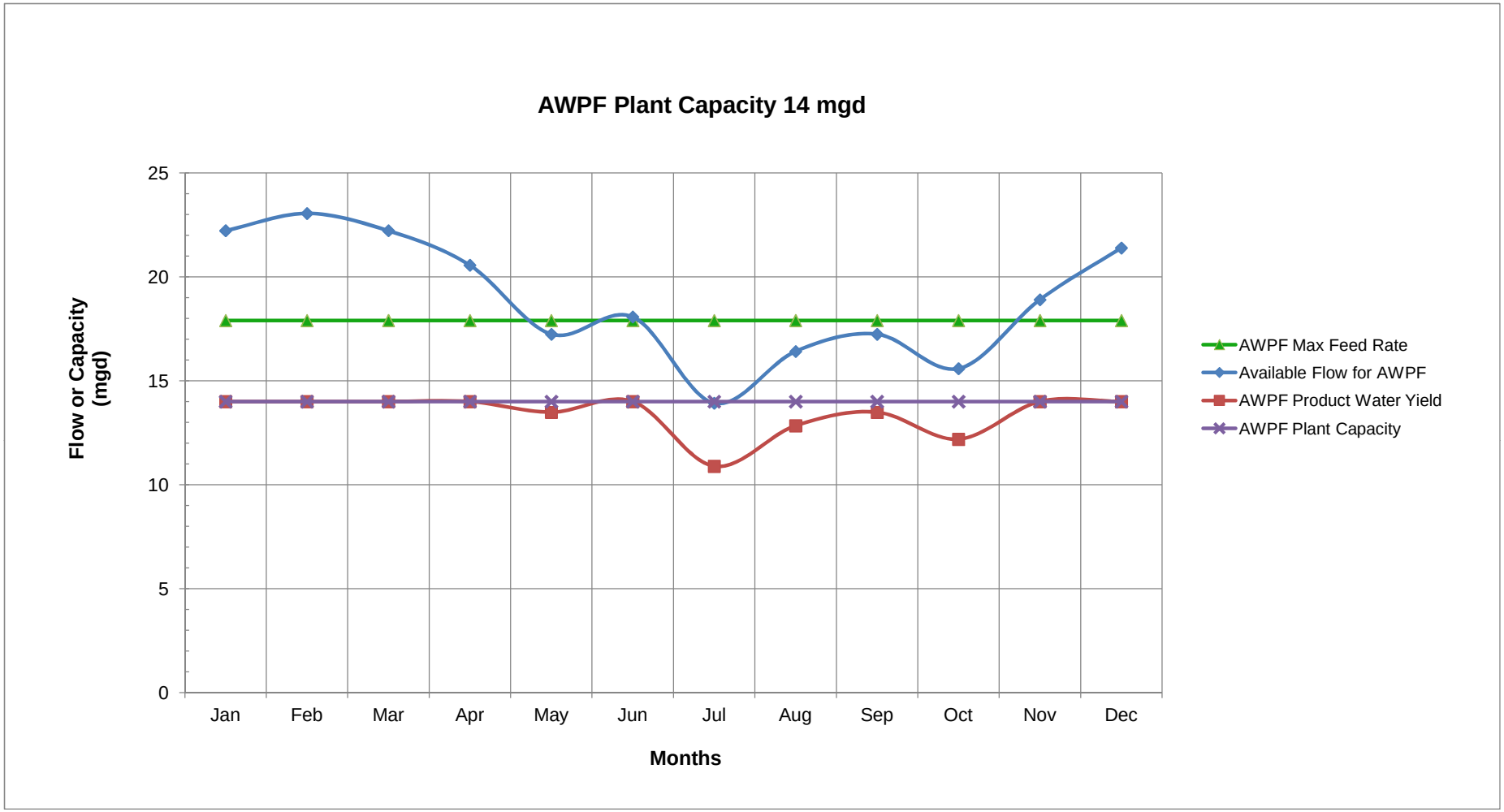
Month	NCWRP Capacity (mgd)	Sludge (mgd)	Available for Tertiary Flow (mgd)	Tertiary Filter Backwash (mgd)	Tertiary Flow Product (mgd)	Utility Water (mgd)	RW Demand by Month (mgd)	Available Flow for AWPF (mgd)	AWPF Feed Rate (mgd)	AWPF Waste Streams (mgd)	AWPF Product Yield (mgd)	Total Flow to PLWWTP (mgd)	AWPF Max Feed Rate (mgd)	Excess RW (mgd)	RW Deficit Capacity (mgd)
Jan	30	1.4	28.6	0.6	28.00	0.80	4.98	22.22	17.90	3.90	14.00	9.62	17.90	4.32	0
Feb	30	1.4	28.6	0.6	28.00	0.80	4.15	23.05	17.90	3.90	14.00	10.45	17.90	5.15	0
Mar	30	1.4	28.6	0.6	28.00	0.80	4.98	22.22	17.90	3.90	14.00	9.62	17.90	4.32	0
Apr	30	1.4	28.6	0.6	28.00	0.80	6.64	20.56	17.90	3.90	14.00	7.96	17.90	2.66	0
May	30	1.4	28.6	**0.6**	28.00	0.80	9.96	17.24	17.24	3.76	13.48	5.16	17.90	0	0.66
Jun	30	1.4	28.6	0.6	28.00	0.80	9.13	18.07	17.90	3.90	14.00	5.47	17.90	0.17	0
Jul	30	1.4	28.6	0.6	28.00	0.80	13.28	13.92	13.92	3.03	10.89	4.43	17.90	0	3.98
Aug	30	1.4	28.6	0.6	28.00	0.80	10.79	16.41	16.41	3.58	12.83	4.98	17.90	0	1.49
Sep	30	1.4	28.6	0.6	28.00	0.80	9.96	17.24	17.24	3.76	13.48	5.16	17.90	0	0.66
Oct	30	1.4	28.6	0.6	28.00	0.80	11.62	15.58	15.58	3.40	12.18	4.80	17.90	0	2.32
Nov	30	1.4	28.6	0.6	28.00	0.80	8.30	18.90	17.90	3.90	14.00	6.30	17.90	1	0.00
Dec	30	1.4	28.6	0.6	28.00	0.80	5.81	21.39	17.90	3.90	14.00	8.79	17.90	3.49	0
														21.11	9.11
Volume (MG/Yr)							3030	6899	6256	1364	4893	2517		633	273
Volume (AFY)								21,172	19,202	4,186	15,016	7,725		1,944	839
AWPF Annual Offline Percentage				5%					**960**	**209**	**751**	**386**		97	42
Adjusted Volume (AFY)								21,172	18,241	3,977	14,265	7,339		1,846	797
Adjusted Avg Annual Flow (mgd)							**8.30**	**18.90**	**16.3**	**3.5**	**12.7**	**6.6**		**1.6**	**0.7**

NCWRF RW Produced	30 mgd
Sludge	1.4 mgd
Filter Backwash	0.6 mgd
MF/RO Waste	21.8%
Utility Water	0.80 mgd

Max	14.00
Min	10.89

AWPF Max Feed Rate	17.90 mgd

AWPF Capacity	14 mgd


AWPF Plant Capacity 14 mgd
Flow or Capacity (mgd)
25
20
15
10
5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
AWPF Max Feed Rate
Available Flow for AWPF
AWPF Product Water Yield
AWPF Plant Capacity

City of San Diego IPR/PMPO
Concept Design Report - Conveyance System

Table: Projected Flows Based on Max Month RW Demands and Fixed AWPF Capacity (EDR Brine to PL)

Month	Raw WW Influent (mgd)	Tertiary Filter Backwash Return (mgd)	MF Backwash Return (mgd)	Total NCWRP Primary/ Secondary Influent (mgd)	Sludge sent to MBC (mgd)	Secondary Effluent (mgd)	Tertiary Filter Backwash (mgd)	Tertiary Product (mgd)	Utility Water (mgd)	EDR Feed (mgd)	EDR Product (Based on demands for RW, UW and TF BW water) (mgd)	EDR Brine (mgd)	RW Demand by Month (mgd)	Available Flow After NPR Demand (mgd)	Projected Flow to AWPF (mgd)	AWPF MF Backwash Water (mgd)	AWPF Brine (mgd)	AWPF Product Water Yield (mgd)	Total Flow to PLWWTP (Brine flows and surplus water)
Jan	30	0.6	1.61	32.21	1.4	30.81	0.6	30.21	0.80	2.48	2.11	0.37	4.98	24.06	23.00	1.61	3.2	18.2	4.88
Feb	30	0.6	1.61	32.21	1.4	30.81	0.6	30.21	0.80	2.15	1.83	0.32	4.15	24.94	23.00	1.61	3.2	18.2	5.71
Mar	30	0.6	1.61	32.21	1.4	30.81	0.6	30.21	0.80	2.48	2.11	0.37	4.98	24.06	23.00	1.61	3.2	18.2	4.88
Apr	30	0.6	1.56	32.16	1.4	30.76	0.6	30.16	0.80	3.12	2.65	0.47	6.64	22.25	22.26	1.56	3.1	17.6	3.81
May	30	0.6	1.29	31.89	1.4	30.49	0.6	29.89	0.80	4.41	3.75	0.66	9.96	18.47	18.48	1.29	2.6	14.6	3.43
Jun	30	0.6	1.36	31.96	1.4	30.56	0.6	29.96	0.80	4.09	3.47	0.61	9.13	19.42	19.42	1.36	2.7	15.4	3.53
Jul	30	0.6	1.03	31.63	1.4	30.23	0.6	29.63	0.80	5.70	4.84	0.85	13.28	14.69	14.70	1.03	2.1	11.6	3.06
Aug	30	0.6	1.23	31.83	1.4	30.43	0.6	29.83	0.80	4.73	4.02	0.71	10.79	17.53	17.53	1.23	2.4	13.9	3.34
Sep	30	0.6	1.29	31.89	1.4	30.49	0.6	29.89	0.80	4.41	3.75	0.66	9.96	18.47	18.48	1.29	2.6	14.6	3.43
Oct	30	0.6	1.16	31.76	1.4	30.36	0.6	29.76	0.80	5.05	4.30	0.76	11.62	16.58	16.59	1.16	2.3	13.1	3.25
Nov	30	0.6	1.43	32.03	1.4	30.63	0.6	30.03	0.80	3.77	3.20	0.56	8.30	20.36	20.36	1.43	2.8	16.1	3.62
Dec	30	0.6	1.61	32.21	1.4	30.81	0.6	30.21	0.80	2.80	2.38	0.42	5.81	23.18	23.00	1.61	3.2	18.2	4.05

	AWPF Max Feed Rate (mgd)	Surplus Water after NPR and AWPF Demands (mgd)	AWPF Capacity Not Used (mgd)
Jan	23.00	1.06	0
Feb	23.00	1.94	0
Mar	23.00	1.06	0
Apr	23.00	0	0.75
May	23.00	0	4.53
Jun	23.00	0	3.58
Jul	23.00	0	8.31
Aug	23.00	0	5.47
Sep	23.00	0	4.53
Oct	23.00	0	6.42
Nov	23.00	0	2.64
Dec	23.00	0.18	0
		4.23	36.23

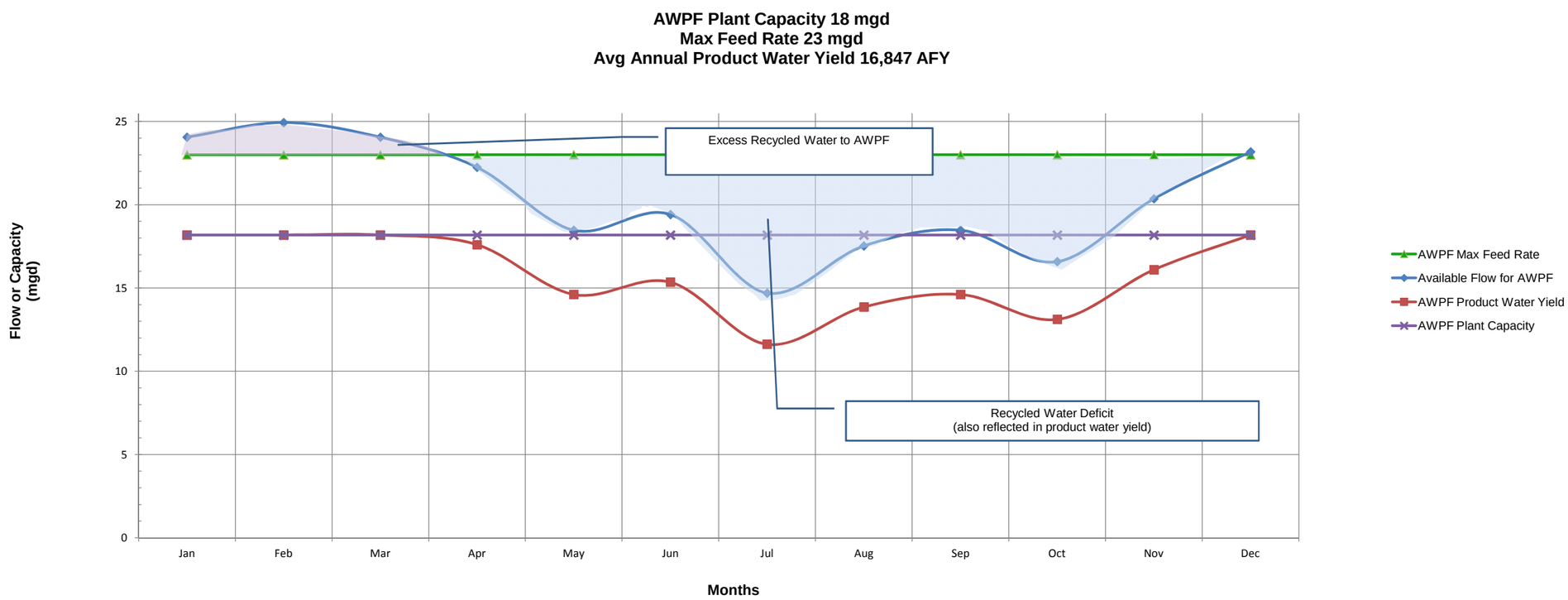
Annual Volume (MG)		10950		5766	129	1102	Annual Volume (MG)
Annual Volume (AF)		33,605		17,697	395	3,382	Annual Volume (AF)
AWPF Annual Offline Percentage	5%			885	20	169	AWPF Annual Offline Percentage
Adjusted Annual Volume (AF)				16,813	375	3,213	Adjusted Annual Volume (AF)
Adjusted Avg Annual AWPF Product Water Yield (mgd)		30.00		**15.01**	**0.34**	**2.87**	**Adjusted Avg Annual RW Flows (mgd)**
					122.340199		

	NCWRF RW Produced	30 mgd
1.57500	Sludge	1.4 mgd
0.07	Filter Backwash (Recycled)	0.6 mgd
	RO Waste	15%
	MF Backwash Recycled	7.0%
	Utility Water (excludes 0.5 mgd irr wtr)	0.80 mgd

Max Monthly Yield	18.2
Min Monthly Yield	11.6

AWPF Max Feed Rate	23.0 mgd

AWPF Capacity	18 mgd


AWPF Plant Capacity 18 mgd
Max Feed Rate 23 mgd
Avg Annual Product Water Yield 16,847 AFY
Flow or Capacity (mgd)
25
20
15
10
5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
Excess Recycled Water to AWPF
Recycled Water Deficit
(also reflected in product water yield)
AWPF Max Feed Rate
Available Flow for AWPF
AWPF Product Water Yield
AWPF Plant Capacity

APPENDIX B

APPENDIX B

City of San Diego WPDP

Detailed Cost Breakdown of Project Costs
(Constant 30-inch Conveyance Pipe)

AWPF Capacity (mgd)	Estimated AWPF Product Water Yield (AFY)	AWPF Product Wtr Yield, 95% On-line (AFY)	Adjusted Pipe Dia (in)	Pump Flow Rate (gpm)	Pump TDH (ft)	Pump Power (Hp)	Construction Costs				Soft Costs			
							AWPF ($)	Pipeline ($)	Pump Station ($)	Total ($)	AWPF ($)	Pipeline ($)	Pump Station ($)	Total ($)
1	1,120	1,070	30	700	450	110	$3,719,000	$60,840,000	$532,000	$65,100,000	$3,495,860	$57,189,600	$500,080	$61,200,000
2	2,240	2,130	30	1,400	450	220	$7,438,000	$60,840,000	$894,000	$69,200,000	$6,991,720	$57,189,600	$840,360	$65,100,000
3	3,370	3,210	30	2,100	460	330	$11,156,000	$60,840,000	$1,230,000	$73,300,000	$10,486,640	$57,189,600	$1,156,200	$68,900,000
4	4,490	4,270	30	2,800	460	440	$14,875,000	$60,840,000	$1,526,000	$77,300,000	$13,982,500	$57,189,600	$1,434,440	$72,700,000
5	5,610	5,330	30	3,500	470	560	$18,594,000	$60,840,000	$1,830,000	$81,300,000	$17,478,360	$57,189,600	$1,720,200	$76,400,000
6	6,730	6,400	30	4,200	480	680	$22,313,000	$60,840,000	$2,128,000	$85,300,000	$20,974,220	$57,189,600	$2,000,320	$80,200,000
7	7,850	7,460	30	4,900	500	830	$26,032,000	$60,840,000	$2,454,000	$89,400,000	$24,470,080	$57,189,600	$2,306,760	$84,000,000
8	8,970	8,530	30	5,600	510	970	$29,751,000	$60,840,000	$2,748,000	$93,400,000	$27,965,940	$57,189,600	$2,583,120	$87,800,000
9	10,090	9,590	30	6,300	530	1,130	$33,469,000	$60,840,000	$3,079,000	$97,400,000	$31,460,860	$57,189,600	$2,894,260	$91,600,000
10	11,210	10,650	30	7,000	550	1,300	$37,188,000	$60,840,000	$3,414,000	$101,500,000	$34,956,720	$57,189,600	$3,209,160	$95,400,000
11	12,320	11,710	30	7,700	560	1,460	$40,907,000	$60,840,000	$3,711,000	$105,500,000	$38,452,580	$57,189,600	$3,488,340	$99,200,000
12	13,340	12,680	30	8,400	590	1,670	$44,626,000	$60,840,000	$4,100,000	$109,600,000	$41,948,440	$57,189,600	$3,854,000	$103,000,000
13	14,280	13,570	30	9,100	610	1,870	$48,345,000	$60,840,000	$4,451,000	$113,700,000	$45,444,300	$57,189,600	$4,183,940	$106,900,000
14	15,020	14,270	30	9,800	630	2,080	$52,064,000	$60,840,000	$4,806,000	$117,800,000	$48,940,160	$57,189,600	$4,517,640	$110,700,000
15	15,570	14,800	30	10,500	660	2,340	$55,782,000	$60,840,000	$5,219,000	$121,900,000	$52,435,080	$57,189,600	$4,905,860	$114,600,000
16	16,040	15,240	30	11,200	680	2,570	$59,501,000	$60,840,000	$5,587,000	$126,000,000	$55,930,940	$57,189,600	$5,251,780	$118,400,000
17	16,400	15,580	30	11,900	710	2,850	$63,220,000	$60,840,000	$6,016,000	$130,100,000	$59,426,800	$57,189,600	$5,655,040	$122,300,000
18	16,560	15,740	30	12,500	740	3,120	$66,939,000	$60,840,000	$6,454,000	$134,300,000	$62,922,660	$57,189,600	$6,066,760	$126,200,000
19	16,560	15,740	30	13,200	770	3,430	$70,658,000	$60,840,000	$6,899,000	$138,400,000	$66,418,520	$57,189,600	$6,485,060	$130,100,000
20	16,560	15,740	30	13,900	810	3,800	$74,376,000	$60,840,000	$7,413,000	$142,700,000	$69,913,440	$57,189,600	$6,968,220	$134,100,000

APPENDIX B

City of San Diego WPDP

Detailed Cost Breakdown of Project Costs
(Constant 30-inch Conveyance Pipe)

AWPF Capacity (mgd)	Estimated AWPF Product Water Yield (AFY)	AWPF Product Wtr Yield, 95% On-line (AFY)	Adjusted Pipe Dia (in)	Pump Flow Rate (gpm)	Pump TDH (ft)	Capital Costs				Annualized Capital Costs			
						AWPF ($)	Pipeline ($)	Pump Station ($)	Total ($)	AWPF ($)	Pipeline ($)	Pump Station ($)	Total ($)
1	1,120	1,070	30	700	450	$7,220,000	$118,000,000	$1,032,000	$126,300,000	$458,000	$7,486,000	$65,000	$8,100,000
2	2,240	2,130	30	1,400	450	$14,430,000	$118,000,000	$1,734,000	$134,200,000	$916,000	$7,486,000	$110,000	$8,600,000
3	3,370	3,210	30	2,100	460	$21,650,000	$118,000,000	$2,386,000	$142,100,000	$1,374,000	$7,486,000	$151,000	$9,100,000
4	4,490	4,270	30	2,800	460	$28,860,000	$118,000,000	$2,960,000	$149,900,000	$1,831,000	$7,486,000	$188,000	$9,600,000
5	5,610	5,330	30	3,500	470	$36,080,000	$118,000,000	$3,550,000	$157,700,000	$2,289,000	$7,486,000	$225,000	$10,000,000
6	6,730	6,400	30	4,200	480	$43,290,000	$118,000,000	$4,128,000	$165,500,000	$2,747,000	$7,486,000	$262,000	$10,500,000
7	7,850	7,460	30	4,900	500	$50,510,000	$118,000,000	$4,761,000	$173,300,000	$3,205,000	$7,486,000	$302,000	$11,000,000
8	8,970	8,530	30	5,600	510	$57,720,000	$118,000,000	$5,331,000	$181,100,000	$3,662,000	$7,486,000	$338,000	$11,500,000
9	10,090	9,590	30	6,300	530	$64,930,000	$118,000,000	$5,973,000	$189,000,000	$4,119,000	$7,486,000	$379,000	$12,000,000
10	11,210	10,650	30	7,000	550	$72,150,000	$118,000,000	$6,623,000	$196,800,000	$4,578,000	$7,486,000	$420,000	$12,500,000
11	12,320	11,710	30	7,700	560	$79,360,000	$118,000,000	$7,199,000	$204,600,000	$5,035,000	$7,486,000	$457,000	$13,000,000
12	13,340	12,680	30	8,400	590	$86,580,000	$118,000,000	$7,954,000	$212,600,000	$5,493,000	$7,486,000	$505,000	$13,500,000
13	14,280	13,570	30	9,100	610	$93,790,000	$118,000,000	$8,635,000	$220,500,000	$5,950,000	$7,486,000	$548,000	$14,000,000
14	15,020	14,270	30	9,800	630	$101,010,000	$118,000,000	$9,324,000	$228,400,000	$6,409,000	$7,486,000	$592,000	$14,500,000
15	15,570	14,800	30	10,500	660	$108,220,000	$118,000,000	$10,125,000	$236,400,000	$6,866,000	$7,486,000	$642,000	$15,000,000
16	16,040	15,240	30	11,200	680	$115,440,000	$118,000,000	$10,839,000	$244,300,000	$7,324,000	$7,486,000	$688,000	$15,500,000
17	16,400	15,580	30	11,900	710	$122,650,000	$118,000,000	$11,671,000	$252,400,000	$7,781,000	$7,486,000	$740,000	$16,100,000
18	16,560	15,740	30	12,500	740	$129,870,000	$118,000,000	$12,521,000	$260,400,000	$8,240,000	$7,486,000	$794,000	$16,600,000
19	16,560	15,740	30	13,200	770	$137,080,000	$118,000,000	$13,384,000	$268,500,000	$8,697,000	$7,486,000	$849,000	$17,100,000
20	16,560	15,740	30	13,900	810	$144,290,000	$118,000,000	$14,381,000	$276,700,000	$9,154,000	$7,486,000	$912,000	$17,600,000

APPENDIX B

City of San Diego WPDP

Detailed Cost Breakdown of Project Costs
(Constant 30-inch Conveyance Pipe)

AWPF Capacity (mgd)	Estimated AWPF Product Water Yield (AFY)	AWPF Product Wtr Yield, 95% On-line (AFY)	Adjusted Pipe Dia (in)	Pump Flow Rate (gpm)	Pump TDH (ft)	Annualized O&M Costs				Total Annualized Cost			
						AWPF ($)	Pipeline ($)	Pump Station ($)	Total ($)	AWPF ($)	Pipeline ($)	Pump Station ($)	Total ($)
1	1,120	1,070	30	700	450	$600,000	$851,760	$18,620	$1,500,000	$1,058,000	$8,337,760	$186,070	$9,600,000
2	2,240	2,130	30	1,400	450	$1,300,000	$851,760	$31,290	$2,200,000	$2,216,000	$8,337,760	$346,040	$10,900,000
3	3,370	3,210	30	2,100	460	$1,900,000	$851,760	$43,050	$2,800,000	$3,274,000	$8,337,760	$501,250	$12,200,000
4	4,490	4,270	30	2,800	460	$2,500,000	$851,760	$53,410	$3,500,000	$4,331,000	$8,337,760	$650,910	$13,400,000
5	5,610	5,330	30	3,500	470	$3,200,000	$851,760	$64,050	$4,200,000	$5,489,000	$8,337,760	$810,300	$14,700,000
6	6,730	6,400	30	4,200	480	$3,800,000	$851,760	$74,480	$4,800,000	$6,547,000	$8,337,760	$969,330	$15,900,000
7	7,850	7,460	30	4,900	500	$4,400,000	$851,760	$85,890	$5,400,000	$7,605,000	$8,337,760	$1,160,390	$17,200,000
8	8,970	8,530	30	5,600	510	$5,100,000	$851,760	$96,180	$6,100,000	$8,762,000	$8,337,760	$1,337,030	$18,500,000
9	10,090	9,590	30	6,300	530	$5,700,000	$851,760	$107,765	$6,700,000	$9,819,000	$8,337,760	$1,538,565	$19,700,000
10	11,210	10,650	30	7,000	550	$6,300,000	$851,760	$119,490	$7,300,000	$10,878,000	$8,337,760	$1,749,390	$21,000,000
11	12,320	11,710	30	7,700	560	$6,900,000	$851,760	$129,885	$7,900,000	$11,935,000	$8,337,760	$1,945,735	$22,300,000
12	13,340	12,680	30	8,400	590	$7,600,000	$851,760	$143,500	$8,600,000	$13,093,000	$8,337,760	$2,202,800	$23,700,000
13	14,280	13,570	30	9,100	610	$8,200,000	$851,760	$155,785	$9,300,000	$14,150,000	$8,337,760	$2,444,235	$25,000,000
14	15,020	14,270	30	9,800	630	$8,800,000	$851,760	$168,210	$9,900,000	$15,209,000	$8,337,760	$2,696,110	$26,300,000
15	15,570	14,800	30	10,500	660	$9,500,000	$851,760	$182,665	$10,600,000	$16,366,000	$8,337,760	$3,002,515	$27,800,000
16	16,040	15,240	30	11,200	680	$10,100,000	$851,760	$195,545	$11,200,000	$17,424,000	$8,337,760	$3,275,595	$29,100,000
17	16,400	15,580	30	11,900	710	$10,700,000	$851,760	$210,560	$11,800,000	$18,481,000	$8,337,760	$3,603,160	$30,500,000
18	16,560	15,740	30	12,500	740	$11,400,000	$851,760	$225,890	$12,500,000	$19,640,000	$8,337,760	$3,923,740	$32,000,000
19	16,560	15,740	30	13,200	770	$12,000,000	$851,760	$241,465	$13,100,000	$20,697,000	$8,337,760	$4,282,915	$33,400,000
20	16,560	15,740	30	13,900	810	$12,600,000	$851,760	$259,455	$13,800,000	$21,754,000	$8,337,760	$4,708,305	$34,900,000

APPENDIX B

City of San Diego WPDP

Detailed Cost Breakdown of Project Costs
(Constant 30-inch Conveyance Pipe)

AWPF Capacity (mgd)	Estimated AWPF Product Water Yield (AFY)	AWPF Product Wtr Yield, 95% On-line (AFY)	Adjusted Pipe Dia (in)	Pump Flow Rate (gpm)	Pump TDH (ft)	Annual Unit Cost			
						AWPF ($/AF)	Pipeline ($/AF)	Pump Station ($/AF)	Total ($/AF)
1	1,120	1,070	30	700	450	$990	$7,800	$180	$8,970
2	2,240	2,130	30	1,400	450	$1,050	$3,920	$170	$5,140
3	3,370	3,210	30	2,100	460	$1,020	$2,600	$160	$3,780
4	4,490	4,270	30	2,800	460	$1,020	$1,960	$160	$3,140
5	5,610	5,330	30	3,500	470	$1,030	$1,570	$160	$2,760
6	6,730	6,400	30	4,200	480	$1,030	$1,310	$160	$2,500
7	7,850	7,460	30	4,900	500	$1,020	$1,120	$160	$2,300
8	8,970	8,530	30	5,600	510	$1,030	$980	$160	$2,170
9	10,090	9,590	30	6,300	530	$1,030	$870	$170	$2,070
10	11,210	10,650	30	7,000	550	$1,030	$790	$170	$1,990
11	12,320	11,710	30	7,700	560	$1,020	$720	$170	$1,910
12	13,340	12,680	30	8,400	590	$1,040	$660	$180	$1,880
13	14,280	13,570	30	9,100	610	$1,050	$620	$190	$1,860
14	15,020	14,270	30	9,800	630	$1,070	$590	$190	$1,850
15	15,570	14,800	30	10,500	660	$1,110	$570	$210	$1,890
16	16,040	15,240	30	11,200	680	$1,150	$550	$220	$1,920
17	16,400	15,580	30	11,900	710	$1,190	$540	$240	$1,970
18	16,560	15,740	30	12,500	740	$1,250	$530	$250	$2,030
19	16,560	15,740	30	13,200	770	$1,320	$530	$280	$2,130
20	16,560	15,740	30	13,900	810	$1,390	$530	$300	$2,220

APPENDIX B

City of San Diego WPDP

Detailed Cost Breakdown of Project Costs
(Constant 30-inch Conveyance Pipe)
(with tertiary and MF backwash recycle)

AWPF Capacity (mgd)	Estimated AWPF Product Water Yield (AFY)	AWPF Product Wtr Yield, 95% On-line (AFY)	Adjusted Pipe Dia (in)	Pump Flow Rate (gpm)	Pump TDH (ft)	Pump Power (Hp)	Construction Costs				Soft Costs			
							AWPF ($)	Pipeline ($)	Pump Station ($)	Total ($)	AWPF ($)	Pipeline ($)	Pump Station ($)	Total ($)
1	1,120	1,070	30	700	450	110	$3,719,000	$60,840,000	$532,000	$65,100,000	$3,495,860	$57,189,600	$500,080	$61,200,000
2	2,240	2,130	30	1,400	450	220	$7,438,000	$60,840,000	$894,000	$69,200,000	$6,991,720	$57,189,600	$840,360	$65,100,000
3	3,370	3,210	30	2,100	460	330	$11,156,000	$60,840,000	$1,230,000	$73,300,000	$10,486,640	$57,189,600	$1,156,200	$68,900,000
4	4,490	4,270	30	2,800	460	440	$14,875,000	$60,840,000	$1,526,000	$77,300,000	$13,982,500	$57,189,600	$1,434,440	$72,700,000
5	5,610	5,330	30	3,500	470	560	$18,594,000	$60,840,000	$1,830,000	$81,300,000	$17,478,360	$57,189,600	$1,720,200	$76,400,000
6	6,730	6,400	30	4,200	480	680	$22,313,000	$60,840,000	$2,128,000	$85,300,000	$20,974,220	$57,189,600	$2,000,320	$80,200,000
7	7,850	7,460	30	4,900	500	830	$26,032,000	$60,840,000	$2,454,000	$89,400,000	$24,470,080	$57,189,600	$2,306,760	$84,000,000
8	8,970	8,530	30	5,600	510	970	$29,751,000	$60,840,000	$2,748,000	$93,400,000	$27,965,940	$57,189,600	$2,583,120	$87,800,000
9	10,090	9,590	30	6,300	530	1,130	$33,469,000	$60,840,000	$3,079,000	$97,400,000	$31,460,860	$57,189,600	$2,894,260	$91,600,000
10	11,210	10,650	30	7,000	550	1,300	$37,188,000	$60,840,000	$3,414,000	$101,500,000	$34,956,720	$57,189,600	$3,209,160	$95,400,000
11	12,330	11,720	30	7,700	560	1,460	$40,907,000	$60,840,000	$3,711,000	$105,500,000	$38,452,580	$57,189,600	$3,488,340	$99,200,000
12	13,450	12,780	30	8,400	590	1,670	$44,626,000	$60,840,000	$4,100,000	$109,600,000	$41,948,440	$57,189,600	$3,854,000	$103,000,000
13	14,490	13,770	30	9,100	610	1,870	$48,345,000	$60,840,000	$4,451,000	$113,700,000	$45,444,300	$57,189,600	$4,183,940	$106,900,000
14	15,470	14,700	30	9,800	630	2,080	$52,064,000	$60,840,000	$4,806,000	$117,800,000	$48,940,160	$57,189,600	$4,517,640	$110,700,000
15	16,320	15,510	30	10,500	660	2,340	$55,782,000	$60,840,000	$5,219,000	$121,900,000	$52,435,080	$57,189,600	$4,905,860	$114,600,000
16	16,940	16,100	30	11,200	680	2,570	$59,501,000	$60,840,000	$5,587,000	$126,000,000	$55,930,940	$57,189,600	$5,251,780	$118,400,000
17	17,440	16,570	30	11,900	710	2,850	$63,220,000	$60,840,000	$6,016,000	$130,100,000	$59,426,800	$57,189,600	$5,655,040	$122,300,000
18	17,880	16,990	30	12,500	740	3,120	$66,939,000	$60,840,000	$6,454,000	$134,300,000	$62,922,660	$57,189,600	$6,066,760	$126,200,000
19	18,190	17,290	30	13,200	770	3,430	$70,658,000	$60,840,000	$6,899,000	$138,400,000	$66,418,520	$57,189,600	$6,485,060	$130,100,000
20	18,280	17,370	30	13,900	810	3,800	$74,376,000	$60,840,000	$7,413,000	$142,700,000	$69,913,440	$57,189,600	$6,968,220	$134,100,000

APPENDIX B

City of San Diego WPDP

Detailed Cost Breakdown of Project Costs
(Constant 30-inch Conveyance Pipe)
(with tertiary and MF backwash recycle)

AWPF Capacity (mgd)	Estimated AWPF Product Water Yield (AFY)	AWPF Product Wtr Yield, 95% On-line (AFY)	Adjusted Pipe Dia (in)	Pump Flow Rate (gpm)	Pump TDH (ft)	Capital Costs				Annualized Capital Costs			
						AWPF ($)	Pipeline ($)	Pump Station ($)	Total ($)	AWPF ($)	Pipeline ($)	Pump Station ($)	Total ($)
1	1,120	1,070	30	700	450	$7,220,000	$118,000,000	$1,032,000	$126,300,000	$458,000	$7,486,000	$65,000	$8,100,000
2	2,240	2,130	30	1,400	450	$14,430,000	$118,000,000	$1,734,000	$134,200,000	$916,000	$7,486,000	$110,000	$8,600,000
3	3,370	3,210	30	2,100	460	$21,650,000	$118,000,000	$2,386,000	$142,100,000	$1,374,000	$7,486,000	$151,000	$9,100,000
4	4,490	4,270	30	2,800	460	$28,860,000	$118,000,000	$2,960,000	$149,900,000	$1,831,000	$7,486,000	$188,000	$9,600,000
5	5,610	5,330	30	3,500	470	$36,080,000	$118,000,000	$3,550,000	$157,700,000	$2,289,000	$7,486,000	$225,000	$10,000,000
6	6,730	6,400	30	4,200	480	$43,290,000	$118,000,000	$4,128,000	$165,500,000	$2,747,000	$7,486,000	$262,000	$10,500,000
7	7,850	7,460	30	4,900	500	$50,510,000	$118,000,000	$4,761,000	$173,300,000	$3,205,000	$7,486,000	$302,000	$11,000,000
8	8,970	8,530	30	5,600	510	$57,720,000	$118,000,000	$5,331,000	$181,100,000	$3,662,000	$7,486,000	$338,000	$11,500,000
9	10,090	9,590	30	6,300	530	$64,930,000	$118,000,000	$5,973,000	$189,000,000	$4,119,000	$7,486,000	$379,000	$12,000,000
10	11,210	10,650	30	7,000	550	$72,150,000	$118,000,000	$6,623,000	$196,800,000	$4,578,000	$7,486,000	$420,000	$12,500,000
11	12,330	11,720	30	7,700	560	$79,360,000	$118,000,000	$7,199,000	$204,600,000	$5,035,000	$7,486,000	$457,000	$13,000,000
12	13,450	12,780	30	8,400	590	$86,580,000	$118,000,000	$7,954,000	$212,600,000	$5,493,000	$7,486,000	$505,000	$13,500,000
13	14,490	13,770	30	9,100	610	$93,790,000	$118,000,000	$8,635,000	$220,500,000	$5,950,000	$7,486,000	$548,000	$14,000,000
14	15,470	14,700	30	9,800	630	$101,010,000	$118,000,000	$9,324,000	$228,400,000	$6,409,000	$7,486,000	$592,000	$14,500,000
15	16,320	15,510	30	10,500	660	$108,220,000	$118,000,000	$10,125,000	$236,400,000	$6,866,000	$7,486,000	$642,000	$15,000,000
16	16,940	16,100	30	11,200	680	$115,440,000	$118,000,000	$10,839,000	$244,300,000	$7,324,000	$7,486,000	$688,000	$15,500,000
17	17,440	16,570	30	11,900	710	$122,650,000	$118,000,000	$11,671,000	$252,400,000	$7,781,000	$7,486,000	$740,000	$16,100,000
18	17,880	16,990	30	12,500	740	$129,870,000	$118,000,000	$12,521,000	$260,400,000	$8,240,000	$7,486,000	$794,000	$16,600,000
19	18,190	17,290	30	13,200	770	$137,080,000	$118,000,000	$13,384,000	$268,500,000	$8,697,000	$7,486,000	$849,000	$17,100,000
20	18,280	17,370	30	13,900	810	$144,290,000	$118,000,000	$14,381,000	$276,700,000	$9,154,000	$7,486,000	$912,000	$17,600,000

APPENDIX B

City of San Diego WPDP

Detailed Cost Breakdown of Project Costs
(Constant 30-inch Conveyance Pipe)
(with tertiary and MF backwash recycle)

AWPF Capacity (mgd)	Estimated AWPF Product Water Yield (AFY)	AWPF Product Wtr Yield, 95% On-line (AFY)	Adjusted Pipe Dia (in)	Pump Flow Rate (gpm)	Pump TDH (ft)	Annualized O&M Costs				Total Annualized Cost			
						AWPF ($)	Pipeline ($)	Pump Station ($)	Total ($)	AWPF ($)	Pipeline ($)	Pump Station ($)	Total ($)
1	1,120	1,070	30	700	450	$600,000	$851,760	$18,620	$1,500,000	$1,058,000	$8,337,760	$186,070	$9,600,000
2	2,240	2,130	30	1,400	450	$1,300,000	$851,760	$31,290	$2,200,000	$2,216,000	$8,337,760	$346,040	$10,900,000
3	3,370	3,210	30	2,100	460	$1,900,000	$851,760	$43,050	$2,800,000	$3,274,000	$8,337,760	$501,250	$12,200,000
4	4,490	4,270	30	2,800	460	$2,500,000	$851,760	$53,410	$3,500,000	$4,331,000	$8,337,760	$650,910	$13,400,000
5	5,610	5,330	30	3,500	470	$3,200,000	$851,760	$64,050	$4,200,000	$5,489,000	$8,337,760	$810,300	$14,700,000
6	6,730	6,400	30	4,200	480	$3,800,000	$851,760	$74,480	$4,800,000	$6,547,000	$8,337,760	$969,330	$15,900,000
7	7,850	7,460	30	4,900	500	$4,400,000	$851,760	$85,890	$5,400,000	$7,605,000	$8,337,760	$1,160,390	$17,200,000
8	8,970	8,530	30	5,600	510	$5,100,000	$851,760	$96,180	$6,100,000	$8,762,000	$8,337,760	$1,337,030	$18,500,000
9	10,090	9,590	30	6,300	530	$5,700,000	$851,760	$107,765	$6,700,000	$9,819,000	$8,337,760	$1,538,565	$19,700,000
10	11,210	10,650	30	7,000	550	$6,300,000	$851,760	$119,490	$7,300,000	$10,878,000	$8,337,760	$1,749,390	$21,000,000
11	12,330	11,720	30	7,700	560	$6,900,000	$851,760	$129,885	$7,900,000	$11,935,000	$8,337,760	$1,945,735	$22,300,000
12	13,450	12,780	30	8,400	590	$7,600,000	$851,760	$143,500	$8,600,000	$13,093,000	$8,337,760	$2,202,800	$23,700,000
13	14,490	13,770	30	9,100	610	$8,200,000	$851,760	$155,785	$9,300,000	$14,150,000	$8,337,760	$2,444,235	$25,000,000
14	15,470	14,700	30	9,800	630	$8,800,000	$851,760	$168,210	$9,900,000	$15,209,000	$8,337,760	$2,696,110	$26,300,000
15	16,320	15,510	30	10,500	660	$9,500,000	$851,760	$182,665	$10,600,000	$16,366,000	$8,337,760	$3,002,515	$27,800,000
16	16,940	16,100	30	11,200	680	$10,100,000	$851,760	$195,545	$11,200,000	$17,424,000	$8,337,760	$3,275,595	$29,100,000
17	17,440	16,570	30	11,900	710	$10,700,000	$851,760	$210,560	$11,800,000	$18,481,000	$8,337,760	$3,603,160	$30,500,000
18	17,880	16,990	30	12,500	740	$11,400,000	$851,760	$225,890	$12,500,000	$19,640,000	$8,337,760	$3,923,740	$32,000,000
19	18,190	17,290	30	13,200	770	$12,000,000	$851,760	$241,465	$13,100,000	$20,697,000	$8,337,760	$4,282,915	$33,400,000
20	18,280	17,370	30	13,900	810	$12,600,000	$851,760	$259,455	$13,800,000	$21,754,000	$8,337,760	$4,708,305	$34,900,000

APPENDIX B

City of San Diego WPDP

Detailed Cost Breakdown of Project Costs
(Constant 30-inch Conveyance Pipe)
(with tertiary and MF backwash recycle)

AWPF Capacity (mgd)	Estimated AWPF Product Water Yield (AFY)	AWPF Product Wtr Yield, 95% On-line (AFY)	Adjusted Pipe Dia (in)	Pump Flow Rate (gpm)	Pump TDH (ft)	Annual Unit Cost			
						AWPF ($/AF)	Pipeline ($/AF)	Pump Station ($/AF)	Total ($/AF)
1	1,120	1,070	30	700	450	$990	$7,800	$180	$8,970
2	2,240	2,130	30	1,400	450	$1,050	$3,920	$170	$5,140
3	3,370	3,210	30	2,100	460	$1,020	$2,600	$160	$3,780
4	4,490	4,270	30	2,800	460	$1,020	$1,960	$160	$3,140
5	5,610	5,330	30	3,500	470	$1,030	$1,570	$160	$2,760
6	6,730	6,400	30	4,200	480	$1,030	$1,310	$160	$2,500
7	7,850	7,460	30	4,900	500	$1,020	$1,120	$160	$2,300
8	8,970	8,530	30	5,600	510	$1,030	$980	$160	$2,170
9	10,090	9,590	30	6,300	530	$1,030	$870	$170	$2,070
10	11,210	10,650	30	7,000	550	$1,030	$790	$170	$1,990
11	12,330	11,720	30	7,700	560	$1,020	$720	$170	$1,910
12	13,450	12,780	30	8,400	590	$1,030	$660	$180	$1,870
13	14,490	13,770	30	9,100	610	$1,030	$610	$180	$1,820
14	15,470	14,700	30	9,800	630	$1,040	$570	$190	$1,800
15	16,320	15,510	30	10,500	660	$1,060	$540	$200	$1,800
16	16,940	16,100	30	11,200	680	$1,090	$520	$210	$1,820
17	17,440	16,570	30	11,900	710	$1,120	$510	$220	$1,850
18	17,880	16,990	30	12,500	740	$1,160	$500	$240	$1,900
19	18,190	17,290	30	13,200	770	$1,200	$490	$250	$1,940
20	18,280	17,370	30	13,900	810	$1,260	$490	$280	$2,030

APPENDIX C

APPENDIX C

City of San Diego WPDP

Detailed Cost Breakdown of Project Costs
(Constant 36-inch Conveyance Pipe)

AWPF Capacity (mgd)	Estimated AWPF Product Water Yield (AFY)	AWPF Product Wtr Yield, 95% On-line (AFY)	Adjusted Pipe Dia (in)	Pump Flow Rate (gpm)	Pump TDH (ft)	Pump Power (Hp)	Construction Costs				Soft Costs			
							AWPF ($)	Pipeline ($)	Pump Station ($)	Total ($)	AWPF ($)	Pipeline ($)	Pump Station ($)	Total ($)
1	1,120	1,070	36	700	450	110	$3,719,000	$73,008,000	$532,000	$77,300,000	$3,495,860	$68,627,520	$500,080	$72,700,000
2	2,240	2,130	36	1,400	450	220	$7,438,000	$73,008,000	$894,000	$81,400,000	$6,991,720	$68,627,520	$840,360	$76,500,000
3	3,370	3,210	36	2,100	450	320	$11,156,000	$73,008,000	$1,212,000	$85,400,000	$10,486,640	$68,627,520	$1,139,280	$80,300,000
4	4,490	4,270	36	2,800	450	430	$14,875,000	$73,008,000	$1,504,000	$89,400,000	$13,982,500	$68,627,520	$1,413,760	$84,100,000
5	5,610	5,330	36	3,500	460	550	$18,594,000	$73,008,000	$1,804,000	$93,500,000	$17,478,360	$68,627,520	$1,695,760	$87,900,000
6	6,730	6,400	36	4,200	460	660	$22,313,000	$73,008,000	$2,069,000	$97,400,000	$20,974,220	$68,627,520	$1,944,860	$91,600,000
7	7,850	7,460	36	4,900	470	780	$26,032,000	$73,008,000	$2,355,000	$101,400,000	$24,470,080	$68,627,520	$2,213,700	$95,400,000
8	8,970	8,530	36	5,600	470	890	$29,751,000	$73,008,000	$2,603,000	$105,400,000	$27,965,940	$68,627,520	$2,446,820	$99,100,000
9	10,090	9,590	36	6,300	480	1,020	$33,469,000	$73,008,000	$2,884,000	$109,400,000	$31,460,860	$68,627,520	$2,710,960	$102,800,000
10	11,210	10,650	36	7,000	490	1,160	$37,188,000	$73,008,000	$3,164,000	$113,400,000	$34,956,720	$68,627,520	$2,974,160	$106,600,000
11	12,320	11,710	36	7,700	490	1,280	$40,907,000	$73,008,000	$3,398,000	$117,400,000	$38,452,580	$68,627,520	$3,194,120	$110,300,000
12	13,340	12,680	36	8,400	500	1,420	$44,626,000	$73,008,000	$3,676,000	$121,400,000	$41,948,440	$68,627,520	$3,455,440	$114,100,000
13	14,280	13,570	36	9,100	510	1,570	$48,345,000	$73,008,000	$3,955,000	$125,400,000	$45,444,300	$68,627,520	$3,717,700	$117,800,000
14	15,020	14,270	36	9,800	520	1,720	$52,064,000	$73,008,000	$4,235,000	$129,400,000	$48,940,160	$68,627,520	$3,980,900	$121,600,000
15	15,570	14,800	36	10,500	530	1,880	$55,782,000	$73,008,000	$4,516,000	$133,400,000	$52,435,080	$68,627,520	$4,245,040	$125,400,000
16	16,040	15,240	36	11,200	540	2,040	$59,501,000	$73,008,000	$4,799,000	$137,400,000	$55,930,940	$68,627,520	$4,511,060	$129,100,000
17	16,400	15,580	36	11,900	560	2,250	$63,220,000	$73,008,000	$5,144,000	$141,400,000	$59,426,800	$68,627,520	$4,835,360	$132,900,000
18	16,560	15,740	36	12,500	570	2,400	$66,939,000	$73,008,000	$5,432,000	$145,400,000	$62,922,660	$68,627,520	$5,106,080	$136,700,000
19	16,560	15,740	36	13,200	580	2,580	$70,658,000	$73,008,000	$5,722,000	$149,400,000	$66,418,520	$68,627,520	$5,378,680	$140,500,000
20	16,560	15,740	36	13,900	590	2,770	$74,376,000	$73,008,000	$6,014,000	$153,400,000	$69,913,440	$68,627,520	$5,653,160	$144,200,000

APPENDIX C

City of San Diego WPDP

Detailed Cost Breakdown of Project Costs
(Constant 36-inch Conveyance Pipe)

AWPF Capacity (mgd)	Estimated AWPF Product Water Yield (AFY)	AWPF Product Wtr Yield, 95% On-line (AFY)	Adjusted Pipe Dia (in)	Pump Flow Rate (gpm)	Pump TDH (ft)	Capital Costs				Annualized Capital Costs			
						AWPF ($)	Pipeline ($)	Pump Station ($)	Total ($)	AWPF ($)	Pipeline ($)	Pump Station ($)	Total ($)
1	1,120	1,070	36	700	450	$7,220,000	$141,600,000	$1,032,000	$149,900,000	$458,000	$8,984,000	$65,000	$9,600,000
2	2,240	2,130	36	1,400	450	$14,430,000	$141,600,000	$1,734,000	$157,800,000	$916,000	$8,984,000	$110,000	$10,100,000
3	3,370	3,210	36	2,100	450	$21,650,000	$141,600,000	$2,351,000	$165,700,000	$1,374,000	$8,984,000	$149,000	$10,600,000
4	4,490	4,270	36	2,800	450	$28,860,000	$141,600,000	$2,918,000	$173,400,000	$1,831,000	$8,984,000	$185,000	$11,000,000
5	5,610	5,330	36	3,500	460	$36,080,000	$141,600,000	$3,500,000	$181,200,000	$2,289,000	$8,984,000	$222,000	$11,500,000
6	6,730	6,400	36	4,200	460	$43,290,000	$141,600,000	$4,014,000	$189,000,000	$2,747,000	$8,984,000	$255,000	$12,000,000
7	7,850	7,460	36	4,900	470	$50,510,000	$141,600,000	$4,569,000	$196,700,000	$3,205,000	$8,984,000	$290,000	$12,500,000
8	8,970	8,530	36	5,600	470	$57,720,000	$141,600,000	$5,050,000	$204,400,000	$3,662,000	$8,984,000	$320,000	$13,000,000
9	10,090	9,590	36	6,300	480	$64,930,000	$141,600,000	$5,595,000	$212,200,000	$4,119,000	$8,984,000	$355,000	$13,500,000
10	11,210	10,650	36	7,000	490	$72,150,000	$141,600,000	$6,138,000	$219,900,000	$4,578,000	$8,984,000	$389,000	$14,000,000
11	12,320	11,710	36	7,700	490	$79,360,000	$141,600,000	$6,592,000	$227,600,000	$5,035,000	$8,984,000	$418,000	$14,500,000
12	13,340	12,680	36	8,400	500	$86,580,000	$141,600,000	$7,131,000	$235,400,000	$5,493,000	$8,984,000	$452,000	$15,000,000
13	14,280	13,570	36	9,100	510	$93,790,000	$141,600,000	$7,673,000	$243,100,000	$5,950,000	$8,984,000	$487,000	$15,500,000
14	15,020	14,270	36	9,800	520	$101,010,000	$141,600,000	$8,216,000	$250,900,000	$6,409,000	$8,984,000	$521,000	$16,000,000
15	15,570	14,800	36	10,500	530	$108,220,000	$141,600,000	$8,761,000	$258,600,000	$6,866,000	$8,984,000	$556,000	$16,500,000
16	16,040	15,240	36	11,200	540	$115,440,000	$141,600,000	$9,310,000	$266,400,000	$7,324,000	$8,984,000	$591,000	$16,900,000
17	16,400	15,580	36	11,900	560	$122,650,000	$141,600,000	$9,979,000	$274,300,000	$7,781,000	$8,984,000	$633,000	$17,400,000
18	16,560	15,740	36	12,500	570	$129,870,000	$141,600,000	$10,538,000	$282,100,000	$8,240,000	$8,984,000	$669,000	$17,900,000
19	16,560	15,740	36	13,200	580	$137,080,000	$141,600,000	$11,101,000	$289,800,000	$8,697,000	$8,984,000	$704,000	$18,400,000
20	16,560	15,740	36	13,900	590	$144,290,000	$141,600,000	$11,667,000	$297,600,000	$9,154,000	$8,984,000	$740,000	$18,900,000

APPENDIX C

City of San Diego WPDP

Detailed Cost Breakdown of Project Costs
(Constant 36-inch Conveyance Pipe)

AWPF Capacity (mgd)	Estimated AWPF Product Water Yield (AFY)	AWPF Product Wtr Yield, 95% On-line (AFY)	Adjusted Pipe Dia (in)	Pump Flow Rate (gpm)	Pump TDH (ft)	Annualized O&M Costs				Total Annualized Cost			
						AWPF ($)	Pipeline ($)	Pump Station ($)	Total ($)	AWPF ($)	Pipeline ($)	Pump Station ($)	Total ($)
1	1,120	1,070	36	700	450	$600,000	$1,022,112	$18,620	$1,700,000	$1,058,000	$10,006,112	$186,070	$11,300,000
2	2,240	2,130	36	1,400	450	$1,300,000	$1,022,112	$31,290	$2,400,000	$2,216,000	$10,006,112	$346,040	$12,600,000
3	3,370	3,210	36	2,100	450	$1,900,000	$1,022,112	$42,420	$3,000,000	$3,274,000	$10,006,112	$489,320	$13,800,000
4	4,490	4,270	36	2,800	450	$2,500,000	$1,022,112	$52,640	$3,600,000	$4,331,000	$10,006,112	$637,840	$15,000,000
5	5,610	5,330	36	3,500	460	$3,200,000	$1,022,112	$63,140	$4,300,000	$5,489,000	$10,006,112	$797,090	$16,300,000
6	6,730	6,400	36	4,200	460	$3,800,000	$1,022,112	$72,415	$4,900,000	$6,547,000	$10,006,112	$941,665	$17,500,000
7	7,850	7,460	36	4,900	470	$4,400,000	$1,022,112	$82,425	$5,600,000	$7,605,000	$10,006,112	$1,098,425	$18,800,000
8	8,970	8,530	36	5,600	470	$5,100,000	$1,022,112	$91,105	$6,300,000	$8,762,000	$10,006,112	$1,239,405	$20,100,000
9	10,090	9,590	36	6,300	480	$5,700,000	$1,022,112	$100,940	$6,900,000	$9,819,000	$10,006,112	$1,405,290	$21,300,000
10	11,210	10,650	36	7,000	490	$6,300,000	$1,022,112	$110,740	$7,500,000	$10,878,000	$10,006,112	$1,579,440	$22,500,000
11	12,320	11,710	36	7,700	490	$6,900,000	$1,022,112	$118,930	$8,100,000	$11,935,000	$10,006,112	$1,728,230	$23,700,000
12	13,340	12,680	36	8,400	500	$7,600,000	$1,022,112	$128,660	$8,800,000	$13,093,000	$10,006,112	$1,902,310	$25,100,000
13	14,280	13,570	36	9,100	510	$8,200,000	$1,022,112	$138,425	$9,400,000	$14,150,000	$10,006,112	$2,086,725	$26,300,000
14	15,020	14,270	36	9,800	520	$8,800,000	$1,022,112	$148,225	$10,000,000	$15,209,000	$10,006,112	$2,270,025	$27,500,000
15	15,570	14,800	36	10,500	530	$9,500,000	$1,022,112	$158,060	$10,700,000	$16,366,000	$10,006,112	$2,463,810	$28,900,000
16	16,040	15,240	36	11,200	540	$10,100,000	$1,022,112	$167,965	$11,300,000	$17,424,000	$10,006,112	$2,657,665	$30,100,000
17	16,400	15,580	36	11,900	560	$10,700,000	$1,022,112	$180,040	$12,000,000	$18,481,000	$10,006,112	$2,907,190	$31,400,000
18	16,560	15,740	36	12,500	570	$11,400,000	$1,022,112	$190,120	$12,700,000	$19,640,000	$10,006,112	$3,092,920	$32,800,000
19	16,560	15,740	36	13,200	580	$12,000,000	$1,022,112	$200,270	$13,300,000	$20,697,000	$10,006,112	$3,305,620	$34,100,000
20	16,560	15,740	36	13,900	590	$12,600,000	$1,022,112	$210,490	$13,900,000	$21,754,000	$10,006,112	$3,528,690	$35,300,000

APPENDIX C

City of San Diego WPDP

Detailed Cost Breakdown of Project Costs
(Constant 36-inch Conveyance Pipe)

AWPF Capacity (mgd)	Estimated AWPF Product Water Yield (AFY)	AWPF Product Wtr Yield, 95% On-line (AFY)	Adjusted Pipe Dia (in)	Pump Flow Rate (gpm)	Pump TDH (ft)	Annual Unit Cost			
						AWPF ($/AF)	Pipeline ($/AF)	Pump Station ($/AF)	Total ($/AF)
1	1,120	1,070	36	700	450	$990	$9,360	$180	$10,530
2	2,240	2,130	36	1,400	450	$1,050	$4,700	$170	$5,920
3	3,370	3,210	36	2,100	450	$1,020	$3,120	$160	$4,300
4	4,490	4,270	36	2,800	450	$1,020	$2,350	$150	$3,520
5	5,610	5,330	36	3,500	460	$1,030	$1,880	$150	$3,060
6	6,730	6,400	36	4,200	460	$1,030	$1,570	$150	$2,750
7	7,850	7,460	36	4,900	470	$1,020	$1,350	$150	$2,520
8	8,970	8,530	36	5,600	470	$1,030	$1,180	$150	$2,360
9	10,090	9,590	36	6,300	480	$1,030	$1,050	$150	$2,230
10	11,210	10,650	36	7,000	490	$1,030	$940	$150	$2,120
11	12,320	11,710	36	7,700	490	$1,020	$860	$150	$2,030
12	13,340	12,680	36	8,400	500	$1,040	$790	$160	$1,990
13	14,280	13,570	36	9,100	510	$1,050	$740	$160	$1,950
14	15,020	14,270	36	9,800	520	$1,070	$710	$160	$1,940
15	15,570	14,800	36	10,500	530	$1,110	$680	$170	$1,960
16	16,040	15,240	36	11,200	540	$1,150	$660	$180	$1,990
17	16,400	15,580	36	11,900	560	$1,190	$650	$190	$2,030
18	16,560	15,740	36	12,500	570	$1,250	$640	$200	$2,090
19	16,560	15,740	36	13,200	580	$1,320	$640	$220	$2,180
20	16,560	15,740	36	13,900	590	$1,390	$640	$230	$2,260

Appendix D

Estimated Construction Cost Process Area Breakdown

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FULL SCALE FACILITY
City Of San Diego
Opinion of Probable Construction Cost- Feb 2012

Project name	2012-02-001-IPR-Full
Labor rate table	RS CA LA 2011
Equipment rate table	00 12 Equip BOF
Notes	This is an Opinion of Probable Construction Cost only, as defined by the documents provided at the level of design for a preliminary design report. CDM Smith has no control over the cost of labor, materials, equipment, or services furnished, over schedules, over contractor's methods of determining prices, competitive bidding (at least 3 each - both prime bidders and major subcontractors), market conditions or negotiating terms. CDM Smith does not guarantee that this opinion will not vary from actual cost, or contractor's bids. There are not any costs provided for: Change Orders, Finance or Funding Costs, Legal Fees, Land Acquisition or temporary/permanent Easements, Operations, or any other costs associated with this project that are not specifically part of the bidding contractor's proposed scope. Assumptions: Site is assumed as relitively flat and 5 foot of over excavation & backfill is included for site prep. Construction duration is assumed to be 30 months based on the concept design provided. Escalation is exculed and the owner is to add this cost to the overall capitol budget for a complet project budget for project funding No rock excavation is required. Only nominal dewatering is needed. No consideration for contaminated soils or hazardous materials (e.g. asbestos, lead) Based on a 40 hour work week with no overtime. Electric Utility line extensions/service drops not estimated.
Report format	Sorted by 'Area/95CSI Sctn/Element' 'Detail' summary Combine items

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Equip Amount	Sub Amount	Direct Cost Total	Capital Cost
0010.0010 AWPF INFLUENT PUMP STATION								
11210 Water Supply & Treatment Pumps								
11210.2670 Influent Pumps	4.00 ea	433.201	29,853	510,000	11,960		555,205	869,913
11210 Water Supply & Treatment Pumps		433.201	29,853	510,000	11,960		555,205	869,913
15060 Hangers & Supports								
15220.2670 Pump Discharge Piping	64.00 lf	25.200	1,716	1,600			3,316	5,077
15060 Hangers & Supports		25.200	1,716	1,600			3,316	5,077
15110 Valves								
15220.2670 Pump Discharge Piping	64.00 lf	74.284	5,059	166,844			171,903	269,667
15110 Valves		74.284	5,059	166,844			171,903	269,667
15220 Steel Pipe								
15220.2670 Pump Discharge Piping	64.00 lf	398.114	27,096	47,066	2,185		76,387	117,904
15220.2671 Pump Discharge Piping Header	72.00 lf	73.694	4,761	39,051	1,451	149	45,456	71,030
15220 Steel Pipe		471.808	31,857	86,117	3,636	149	121,843	188,935
0010.0010 AWPF INFLUENT PUMP STATION	**1.00 LS**	**1,004.492**	**68,485**	**764,561**	**15,596**	**149**	**852,266**	**1,333,591**
0010.0010A AWPF INFLUENT PUMP STATION STRUCTURE ONLY								
02250 Excavation Support & Protection								
02250.2605 Shoring	5,940.00 sf	1,379.811	80,576	76,329	48,106	8,250	213,261	328,149
02250 Excavation Support & Protection		1,379.811	80,576	76,329	48,106	8,250	213,261	328,149
02300 Earthwork								
02300.2600 Structural Excavation & Backfill	3,706.60 cy	449.815	23,925	1,185	32,665	442	58,217	89,571
02300 Earthwork		449.815	23,925	1,185	32,665	442	58,217	89,571
03212 Concrete Walls								
03212.2670 Concrete Walls @ Pump Wet Well	207.00 cy	1,748.291	108,302	70,080	3,120	3,381	185,286	282,430
03212 Concrete Walls		1,748.291	108,302	70,080	3,120	3,381	185,286	282,430
03310 Concrete Slab on Grade								
03310.2670 Concrete Slab On Grade Base Pump Vault Slab	168.00 cy	563.617	35,969	38,569	311	659	75,835	116,298
03310 Concrete Slab on Grade		563.617	35,969	38,569	311	659	75,835	116,298
03314 Concrete Elevated Slabs								
03314.2670 Concrete Elevated Deck over pump Vault	80.00 cy	885.222	53,472	28,599	2,115	560	84,902	129,194
03314 Concrete Elevated Slabs		885.222	53,472	28,599	2,115	560	84,902	129,194
03410 Precast Concrete								
03410.2670 Exterior Walls	111.50 cy	428.127	27,740	29,544	130	781	58,412	89,556
03410 Precast Concrete		428.127	27,740	29,544	130	781	58,412	89,556
03412 Concrete Equipment Pabs/Curbs/Fill								
03412.2670 Pump Pads	5.33 cy	89.384	5,673	2,006	18	105	7,811	11,824
03412.2671 MCC/ VFD Equipment Pads	10.67 cy	136.817	8,641	3,809	35	209	12,715	19,289
03412 Concrete Equipment Pabs/Curbs/Fill		226.200	14,313	5,815	53	314	20,526	31,113
03470 Walls								
03410.2670 Exterior Walls	111.50 cy	428.127	27,740	29,544	130	781	58,412	89,556
03470.2606 Wall Texture	3,696.00 sf			31,416			31,416	49,355
03470 Walls		428.127	27,740	60,960	130	781	89,828	138,910
04000 Masonry								
04000.2610 Interior Partition Walls	1,012.00 sf					28,336	28,336	42,320
04000 Masonry						28,336	28,336	42,320
05210 Steel Joist								
05210.2605 Building Roof Framing	2,160.00 sf	8.280	572	3,630	247		4,448	6,944
05210 Steel Joist		8.280	572	3,630	247		4,448	6,944
05300 Steel Deck								
05300.2605 Roof Deck	2,160.00 sf	64.800	4,473	12,960	1,930		19,363	30,073
05300 Steel Deck		64.800	4,473	12,960	1,930		19,363	30,073
07000 Thermal & Moisture Protection								

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Equip Amount	Sub Amount	Direct Cost Total	Capital Cost
07000.2605 EPDM Roofing	22.00 sq	95.040	6,423	9,720			16,143	24,862
07000 Thermal & Moisture Protection		95.040	6,423	9,720			16,143	24,862
08000 Doors & Windows								
08000.2605 Exterior Doors & Windows	1.00 ls	63.132	3,585	10,792		17,280	31,658	48,117
08000 Doors & Windows		63.132	3,585	10,792		17,280	31,658	48,117
15300 Fire Protection								
15300.2605 Fire Protection Allowance	1.00 allw					20,520	20,520	30,647
15300 Fire Protection						20,520	20,520	30,647
15400 Plumbing								
15400.2605 Plumbing Allowance	1.00 allw					14,040	14,040	20,969
15400 Plumbing						14,040	14,040	20,969
15500 HVAC								
15500.2605 HVAC Allowance	1.00 allw					54,000	54,000	80,649
15500 HVAC						54,000	54,000	80,649
0010.0010A AWPF INFLUENT PUMP STATION STRUCTURE ONLY	**2,160.00 SF**	**6,340.462**	**387,090**	**348,184**	**88,806**	**149,343**	**974,776**	**1,489,800**
0010.0020 SITE CIVIL/ YARD PIPING								
02300 Earthwork								
02300.2620 Mass Excavation & Grading	45,510.00 c y	3,753.782	226,992		243,134		470,126	720,977
02300 Earthwork		3,753.782	226,992		243,134		470,126	720,977
02510 Water Distribution								
02510.2600 Open Cut Tunnel For Road Crossing	240.00 lf	918.112	51,561	264,547	39,989	12,100	368,197	573,503
02510.2605 MFB Piping	3,500.00 lf	3,891.029	258,810	181,155	32,943	4,260	477,168	729,243
02510.2610 TE Piping	2,500.00 lf	3,713.482	248,151	206,862	16,396	3,038	474,447	725,890
02510.2615 ROC Piping	3,100.00 lf	3,620.171	241,083	205,376	29,105	3,764	479,328	734,048
02510.2620 MFP Piping	120.00 lf	202.731	13,624	87,617	839	178	102,308	159,655
02510.2625 ROF Piping	20.00 lf	72.628	4,901	41,593	361	74	46,978	73,417
02510.2630 ROP Piping	30.00 lf	74.696	5,027	44,764	210	46	50,047	78,230
02510.2635 FW Piping from AOP to FW Pump Station	72.00 lf	93.914	6,273	16,261	538	107	23,254	36,038
02510.2640 FW Piping to Outside of Plant	960.00 lf	852.399	55,688	181,185	7,952	1,425	246,587	382,962
02510.2645 Small Bore Piping Allowance	4,500.00 lf		157,500	112,500	67,500		337,500	518,006
02510 Water Distribution		13,439.163	1,042,618	1,341,861	195,832	24,992	2,605,813	4,010,993
02600 Drainage & Containment								
02600.2605 Storm Drainage Measures Allowance	1.00 allw	798.788	47,532	73,574	11,892	1,271	135,115	208,484
02600 Drainage & Containment		798.788	47,532	73,574	11,892	1,271	135,115	208,484
02700 Pavements & Surfaces								
02700.2605 Paving & Surface Allowances	1.00 allw	233.176	13,087	201,655	8,904	19,937	243,583	380,109
02700 Pavements & Surfaces		233.176	13,087	201,655	8,904	19,937	243,583	380,109
02800 Site Improvements								
02800.2600 Landscaping Allowance	1.00 allw					350,000	350,000	522,725
02800 Site Improvements						350,000	350,000	522,725
0010.0020 SITE CIVIL/ YARD PIPING	**1.00 LS**	**18,224.909**	**1,330,230**	**1,617,090**	**459,763**	**396,200**	**3,804,637**	**5,843,287**
0020.0010 OPERATIONS, MAINTENANCE & ADMINISTRATION BLDG								
A Conceptual Buildings								
A-01111 Admin Building Allowance	1.00 allw	10,789.701	752,974	307,025			1,059,999	1,606,902
A Conceptual Buildings		10,789.701	752,974	307,025			1,059,999	1,606,902
0020.0010 OPERATIONS, MAINTENANCE & ADMINISTRATION BLDG	**5,300.00 SF**	**10,789.701**	**752,974**	**307,025**			**1,059,999**	**1,606,902**
0080.0005 MEMBRANE FILTRATION BREAK TANK & RO TRANSFER PUMP STATION								
11200 Water Treatment Equipment								
11200.2630 RO Transfer Pumps	5.00 ea	269.000	18,594	930,394	4,157		953,144	1,495,949
11200 Water Treatment Equipment		269.000	18,594	930,394	4,157		953,144	1,495,949
11228 Filter Membrane Systems								

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Equip Amount	Sub Amount	Direct Cost Total	Capital Cost
11228.2620 Cartridge Filter Pre RO	8.00 ea	189.000	12,893	302,209	2,771		317,874	498,381
11228 Filter Membrane Systems		189.000	12,893	302,209	2,771		317,874	498,381
15110 Valves								
15220.26101 Break Tank Feed Piping	36.00 lf	19.700	1,335	3,651			4,986	7,729
15220.26102 Break Tank Discharge Piping	65.00 lf	19.700	1,335	3,651			4,986	7,729
15220.26107 24" Pump Discharge Header	65.00 lf	75.020	5,109	38,430			43,539	68,003
15221.2619 14" Filter Connections	28.00 lf	59.680	4,064	13,724			17,788	27,630
15110 Valves		174.101	11,842	59,456			71,298	111,091
15120 Pipe Specialties								
15220.26101 Break Tank Feed Piping	36.00 lf	6.811	464	573			1,037	1,593
15220.26102 Break Tank Discharge Piping	65.00 lf	6.811	464	573			1,037	1,593
15120 Pipe Specialties		13.622	928	1,146			2,074	3,186
15220 Steel Pipe								
15220.26101 Break Tank Feed Piping	36.00 lf	69.342	4,722	11,775	881		17,398	26,967
15220.26102 Break Tank Discharge Piping	65.00 lf	84.395	5,753	10,115	1,573		17,461	26,985
15220.26105 14" Pump Branch Connections to Pump Cans	30.00 lf	35.800	2,438	6,767			9,205	14,272
15220.26106 14" Pump Discharge Piping	60.00 lf	120.750	8,269	20,947	4,249		33,522	52,022
15220.26107 24" Pump Discharge Header	65.00 lf	56.590	3,880	20,683	2,126		26,728	41,689
15220 Steel Pipe		366.877	25,062	70,286	8,830		104,314	161,935
15221 Stainless Steel Pipe								
15221.2619 14" Filter Connections	54.00 lf	64.996	4,426	36,894			41,320	64,571
15221.2650 16" Filter Discharge Connections	96.00 lf	137.840	9,402	105,264	2,080		116,961	183,016
15221.2651 24" Discharge Header	65.00 lf	72.750	4,970	89,065	2,080		96,437	151,117
15221 Stainless Steel Pipe		275.586	18,797	231,223	4,160		254,718	398,705
0080.0005 MEMBRANE FILTRATION BREAK TANK & RO TRANSFER PUMP STATION	**21.20 MGD**	**1,288.185**	**88,117**	**1,594,713**	**19,917**		**1,703,422**	**2,669,246**
0080.0005A MEMBRANE FILTRATION BREAK TANK & RO TRANSFER PUMP STATION STRUCTURE ON								
02300 Earthwork								
02300.2610 Structural Excavation & backfill	2,652.00 cy	299.752	16,139	4,507	21,050	1,682	43,378	66,766
02300 Earthwork		299.752	16,139	4,507	21,050	1,682	43,378	66,766
03212 Concrete Walls								
03212.2620 Concrete Walls Break Tank	260.67 cy	1,990.262	123,368	85,903	3,788	6,940	220,611	336,481
03212 Concrete Walls		1,990.262	123,368	85,903	3,788	6,940	220,611	336,481
03310 Concrete Slab on Grade								
03310.226344 Strainer Pad	12.50 cy	61.875	3,899	2,192	41	2,046	8,428	12,779
03310.2605 Building Base Slab	79.19 cy	280.167	17,630	18,853	131	925	37,737	57,847
03310.2650 Concrete Slab On Grade Break Tank	138.89 cy	482.802	30,676	32,837	259	880	64,923	99,548
03310 Concrete Slab on Grade		824.845	52,205	53,882	432	3,851	111,087	170,174
03314 Concrete Elevated Slabs								
03314.2605 Concrete Elevated Deck @ Break Tank	100.15 cy	1,103.105	66,787	36,851	2,599	571	107,043	162,944
03314 Concrete Elevated Slabs		1,103.105	66,787	36,851	2,599	571	107,043	162,944
03412 Concrete Equipment Pabs/Curbs/Fill								
03412.226008 Pipe Supports-Spread Footing	12.80 cy	143.191	8,551	2,685	79		11,315	17,114
03412.226020 Pipe Supports	8.00 cy	82.601	5,013	2,113	43	1,877	9,045	13,676
03412 Concrete Equipment Pabs/Curbs/Fill		225.792	13,564	4,798	122	1,877	20,361	30,790
03470 Walls								
03470.2605 Exterior Walls	87.04 cy	270.530	17,397	20,216	29	497	38,343	58,850
03470.2606 Wall Texture				50,036			50,036	78,606
03470 Walls		270.530	17,397	70,252	29	497	88,379	137,456
05210 Steel Joist								
05210.2605 Building Roof Framing	4,500.00 sf	51.960	3,587	22,051	1,548		27,186	42,431

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Equip Amount	Sub Amount	Direct Cost Total	Capital Cost
05210 Steel Joist		51.960	3,587	22,051	1,548		27,186	42,431
05300 Steel Deck								
05300.2605 Roof Deck	4,500.00 sf	134.730	9,300	26,957	4,014		40,270	62,544
05300 Steel Deck		134.730	9,300	26,957	4,014		40,270	62,544
07000 Thermal & Moisture Protection								
07000.2605 EPDM Roofing	45.00 sq	197.730	13,362	20,217			33,580	51,718
07000 Thermal & Moisture Protection		197.730	13,362	20,217			33,580	51,718
08000 Doors & Windows								
08000.2605 Exterior Doors & Windows	1.00 ls	57.808	3,226	11,023		8,626	22,875	35,018
08000 Doors & Windows		57.808	3,226	11,023		8,626	22,875	35,018
15300 Fire Protection								
15300.2605 Fire Protection Allowance	1.00 allw					42,681	42,681	63,745
15300 Fire Protection						42,681	42,681	63,745
15400 Plumbing								
15400.2605 Plumbing Allowance	1.00 allw					29,203	29,203	43,615
15400 Plumbing						29,203	29,203	43,615
15500 HVAC								
15500.2605 HVAC Allowance	1.00 allw					112,319	112,319	167,749
15500 HVAC						112,319	112,319	167,749
0080.0005A MEMBRANE FILTRATION BREAK TANK & RO TRANSFER PUMP STATION STRUCTURE ON	**4,500.00 SF**	**5,156.513**	**318,936**	**336,439**	**33,581**	**208,248**	**898,973**	**1,371,430**
0080.0006 CHEMICAL STORAGE AREA #1 (PRETREATMENT)								
11210 Water Supply & Treatment Pumps								
60 Chem System Sodium Bisulfite	2.00 ea	11.250	745	15,723	208		16,676	26,140
61 Chem System Ammonium Hydroxide	4.00 ea	25.663	1,680	38,758	261		40,699	63,807
62 Chem System Antiscalent	4.00 ea	20.530	1,350	31,978	261		33,588	52,663
64 Chem System Sufuric Acid	4.00 ea	30.330	1,958	40,723	261		42,941	67,309
65 Chem System Sodium Hypochlorite	4.00 ea	27.663	1,803	63,466	261		65,529	102,807
11210 Water Supply & Treatment Pumps		115.437	7,535	190,648	1,251		199,434	312,726
11240 Chemical/Disinfection Equipment								
41 Water Softener	1.00 ea	19.000	1,276	17,232	79	950	19,537	30,521
11240 Chemical/Disinfection Equipment		19.000	1,276	17,232	79	950	19,537	30,521
13200 Tanks								
61 Chem System Ammonium Hydroxide	2.00 ea	97.714	6,616	44,088	1,583		52,288	81,631
62 Chem System Antiscalent	2.00 ea	97.714	6,616	15,170	1,583		23,369	36,200
64 Chem System Sufuric Acid	3.00 ea	188.286	12,750	181,732	4,453		198,935	311,539
65 Chem System Sodium Hypochlorite	2.00 ea	120.571	8,173	26,088	1,583		35,844	55,678
13200 Tanks		504.285	34,155	267,078	9,204		310,436	485,048
15060 Hangers & Supports								
CPVC80 Sch 80 CPVC Pipe & Fittings	780.00 lf	68.266	4,649	9,185			13,834	21,373
PVC80 Sch 80 PVC Pipe & Fittings	320.00 lf	13.333	908	2,200			3,108	4,812
15060 Hangers & Supports		81.600	5,557	11,385			16,942	26,185
15110 Valves								
ALOYBV Alloy 20 Ball Valves	8.00 ea	21.059	1,682	20,000			21,682	33,933
CPVCBFV CPVC Butterfly Valves	6.00 ea	8.206	656	2,688			3,343	5,202
CPVCBV CPVC Ball Valves	15.00 ea	13.257	1,059	854			1,913	2,923
CPVCDV CPVC Diaphragm Valves	4.00 ea	5.228	418	3,680			4,098	6,405
PVCBFV PVC Butterfly Valves	6.00 ea	15.206	1,215	2,405			3,619	5,592
PVCCV PVC Check Valves	2.00 ea	1.074	86	1,104			1,190	1,862
15110 Valves		64.029	5,115	30,730			35,845	55,916
15120 Pipe Specialties								

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Equip Amount	Sub Amount	Direct Cost Total	Capital Cost
CPVC80 Sch 80 CPVC Pipe & Fittings	780.00 lf	8.307	570	1,350			1,920	2,972
PVC80 Sch 80 PVC Pipe & Fittings	320.00 lf	6.487	442	1,452			1,894	2,941
15120 Pipe Specialties		14.793	1,011	2,802			3,813	5,912
15240 Plastic Pipe								
CPVC80 Sch 80 CPVC Pipe & Fittings	780.00 lf	93.204	6,347	23,078	3		29,428	45,739
PVC80 Sch 80 PVC Pipe & Fittings	320.00 lf	62.637	4,265	6,718	1		10,985	16,926
15240 Plastic Pipe		155.841	10,612	29,796	4		40,413	62,666
0080.0006 CHEMICAL STORAGE AREA #1 (PRETREATMENT)	**1.00 LS**	**954.985**	**65,262**	**549,670**	**10,538**	**950**	**626,420**	**978,974**
0080.0006a CHEMICAL STOREAGE AREA #1 (PRETREATMENT) STRUCTURE ONLY								
02300 Earthwork								
02310.100 Site Earthwork	1,134.00 cy					39,690	39,690	59,277
02300 Earthwork						39,690	39,690	59,277
02600 Drainage & Containment								
CT Chemical Trench	1.00 ls	23.993	1,512		1,575		3,086	4,732
CT - MH Chemical Trench - Manholes	4.00 ea	10.332	619	6,000	676		7,295	11,413
02600 Drainage & Containment		34.326	2,131	6,000	2,251		10,382	16,144
03000 Concrete								
03210.100 Reinforcing Steel	77.60 tn	1,254.830	91,002	70,667	960		162,629	248,437
03300.2602 Chemical Building Slabs/Walls/Foundations	664.68 cy	3,350.435	201,452	109,949	1,260	9,643	322,304	489,979
03000 Concrete		4,605.265	292,454	180,617	2,219	9,643	484,933	738,417
04000 Masonry								
04400.2600 Chemical Partition Walls	1,088.00 sf					34,816	34,816	51,998
04000 Masonry						34,816	34,816	51,998
06000 Wood								
FRP - Rail FRP Railing	578.00 lf	72.013	4,595	43,350	106		48,051	75,132
FRP Stairs FRP Stairs	312.00 sf	52.633	3,359	35,040	175		38,573	60,339
06000 Wood		124.646	7,954	78,390	280		86,624	135,470
10000 Specialties								
10520.000 Fire Protection Specialty	6.00 ea	9.000	612	2,100			2,712	4,212
10000 Specialties		9.000	612	2,100			2,712	4,212
13000 Special Construction								
MC Metal Canopy	5,550.00 sf					249,750	249,750	373,002
13000 Special Construction						249,750	249,750	373,002
0080.0006a CHEMICAL STOREAGE AREA #1 (PRETREATMENT) STRUCTURE ONLY	**5,550.00 SF**	**4,773.236**	**303,150**	**267,107**	**4,751**	**333,899**	**908,906**	**1,378,520**
0080.0010 MEMBRANE FILTRATION FACILITY								
01190 Manufacture Spare Parts & start-up Services								
01190.2600 Start-up Services & Spare Parts	1.00 ls			9,150			9,150	14,374
01190 Manufacture Spare Parts & start-up Services				9,150			9,150	14,374
11210 Water Supply & Treatment Pumps								
11228.2612 MF CIP Pumps	2.00 ea	73.006	5,061				5,061	7,559
11228.2630 MF Citric Acid Transfer Pump	1.00 ea	41.669	2,868	12,559			15,427	24,014
11228.2631 MF Sodium Hydroxide Transfer Pump	1.00 ea	41.669	2,868	12,559			15,427	24,014
11228.2632 Sodium Hypochlorite Transfer Pump	1.00 ea	41.669	2,868	12,559			15,427	24,014
11210 Water Supply & Treatment Pumps		198.013	13,666	37,677			51,343	79,601
11228 Filter Membrane Systems								
11228.2600 Pall Membrane System	21.20 mgd	4,592.067	313,458	9,384,000	54,692		9,752,149	15,296,333
11228.2603 MF Plant Air Equipment	1.00 ea	233.057	16,191				16,191	24,181
11228.2604 MF Reverse Flush Pumps	4.00 ea	146.012	10,123				10,123	15,118
11228.2606 MF Feed Pumps	4.00 ea	1,111.938	77,531	1,143,904			1,221,435	1,912,866
11228.2610 MF EFM Pumps	2.00 ea	73.006	5,061				5,061	7,559

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Equip Amount	Sub Amount	Direct Cost Total	Capital Cost
11228 Filter Membrane Systems		6,156.080	422,363	10,527,904	54,692		11,004,959	17,256,057
11300 Fluid Waste Treatement & Disposal								
11300.2600 Submersable Pump Discharge	2.00 ea	81.430	5,581	15,984	7,781		29,345	45,669
11300.2601 Submersable Pump Circulation	2.00 ea	81.430	5,581	8,884	7,781		22,245	34,515
11300 Fluid Waste Treatement & Disposal		162.860	11,161	24,868	15,561		51,591	80,184
13200 Tanks								
13200.2600 MF Reverse Filtration Tank	2.00 ea	70.857	4,812		1,237		6,049	9,131
13200.2601 MF CIP Tank	2.00 ea	70.857	4,812	36,614	1,237		42,663	66,651
13200.2603 MF EFM Tank	1.00 ea	26.179	1,788	16,599	619		19,005	29,719
13200.2604 Citric Acid Dedicated Tote	2.00 ea	8.000	547	16,000	173		16,720	26,225
13200.2605 Sodium Hydroxide Dedicated Tote	2.00 ea	8.000	547	16,000	173		16,720	26,225
13200.2606 Sodium Hypochlorite Storage Tank	2.00 ea	70.857	4,812	29,828	1,237		35,878	55,991
13200 Tanks		254.750	17,318	115,041	4,676		137,036	213,941
15051 Mechanical Welding								
15051.2600 Weld Rig For Make-up Joints	1.00 ls					177,600	177,600	265,246
15051 Mechanical Welding						177,600	177,600	265,246
15060 Hangers & Supports								
15220.26001 42" Manifold For Strainer Feed	100.00 lf	60.000	4,086	7,700			11,786	18,199
15220.2612 24" MFF Supply Piping	210.00 lf	12.000	817	7,500			8,317	13,003
15220.2613 14" MFF Suction Piping	100.00 lf	18.000	1,226	4,200			5,426	8,429
15220.2614 MF Feed Pump Discharge	50.00 lf	36.000	2,451	4,200			6,651	10,259
15220.2616 24" MFE Manifold Piping	120.00 lf	96.000	6,537	53,292			59,829	93,484
15220.2618 MFF Piping @Strainers	40.00 lf	66.150	4,505	3,150			7,655	11,676
15240.2610 6" MCR/EFMR Piping From MF to CIP Area	120.00 lf	2.667	182	560			742	1,151
15240.2611 MCF/EFMF Feed Piping From MF area to CIP area	120.00 lf	2.500	170	560			730	1,134
15240.2615 10" PVC RF Feed Pipe from MF System to CIP Area	70.00 lf	30.000	2,043	2,224			4,267	6,545
15240.2618 16" MFBWW Piping	330.00 lf	24.000	1,634	14,880			16,514	25,817
15240.2625 RF Tank Feed to RF Pumps	90.00 lf	27.000	1,839	1,230			3,069	4,678
15240.2626 RF Pump Discharge Piping	70.00 lf	24.000	1,634	980			2,614	3,980
15240.2627 ROP Piping Acid CIPTank	60.00 lf	5.000	340	1,315			1,656	2,575
15240.2631 ROP Piping Caustic	60.00 lf	5.000	340	1,315			1,656	2,575
15240.2633 SCH Piping To Caustic Tank	120.00 lf	10.000	681	2,458			3,139	4,879
15240.2634 SH Piping to Caustic Tank	120.00 lf	10.000	681	2,458			3,139	4,879
15240.2638 Citric Acid Feed to Acid Tank	120.00 lf	10.000	681	2,458			3,139	4,879
15240.2639 NaOCL Feed to EFM tank	120.00 lf	10.000	681	2,458			3,139	4,879
15240.2640 ROP Piping to EFM Tank	60.00 lf	5.000	340	1,315			1,656	2,575
15240.2644 MCR/EFMR Pump Feed/ Discharge	80.00 lf	19.775	1,347	800			2,147	3,268
15240.2645 Citric Acid From Tote to Transfer Pump	40.00 lf	2.400	163	125			288	440
15240.2646 Citric Acid transfer Pump Discharge	40.00 lf	1.680	114	175			289	446
15240.2647 Sodium Hydroxide From Tote to Transfer Pump	40.00 lf	2.400	163	125			288	440
15240.2648 Sodium Hydroxide From Transfer Pump	80.00 lf	1.680	114	175			289	446
15240.2649 Sodium Hypochlorite Storage From tank to Pump	40.00 lf	2.400	163	125			288	440
15240.2650 3" Tank Feed Piping	60.00 lf	2.400	163	1,315			1,479	2,310
15240.2651 m Hypochlorite From transfer Pump	40.00 lf	1.680	114	175			289	446
15240.2652 Citric Acid Waste Tank Discharge	30.00 lf	10.150	691	318			1,010	1,532
15240.2653 SH Dosing Influent	20.00 lf	10.150	691	318			1,010	1,532
15240.2654 Circ Pump Piping	20.00 lf	8.960	610	287			897	1,361
15060 Hangers & Supports		516.992	35,206	118,192			153,397	238,259
15110 Valves								
15220.2612 24" MFF Supply Piping	210.00 lf	87.360	5,949	31,882			37,831	58,971
15220.2613 14" MFF Suction Piping	72.00 lf	68.400	4,658	64,800			69,458	108,757

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Equip Amount	Sub Amount	Direct Cost Total	Capital Cost
15220.2614 MF Feed Pump Discharge	36.00 lf	106.800	7,273	55,057			62,330	97,357
15220.2617 6" MFE Piping to RF tank	30.00 lf	5.520	376	9,400			9,776	15,329
15220.2618 MFF Piping @Strainers	40.00 lf	137.480	9,362	39,640			49,002	76,256
15221.2600 EF Suction Piping	40.00 lf	70.080	4,772	35,926			40,698	63,567
15224.2605 PA Piping	270.00 lf	74.820	5,095	6,482			11,577	17,793
15224.2606 1" Control Air Piping	270.00 lf	10.660	726	4,503			5,229	8,158
15224.2607 PA Piping Tank & Compressor Piping	70.00 lf	41.680	2,838	8,226			11,064	17,162
15240.2611 MCF/EFMF Feed Piping From MF area to CIP area	120.00 lf	14.220	968	13,440			14,408	22,560
15240.2619 MFE/OF Piping	40.00 lf	5.520	376	356			732	1,121
15240.2620 LI Tank Pipe Reverse Filtration Tank	20.00 lf	2.660	181	133			314	479
15240.2621 LI tank Piping Acid CIP tank	20.00 lf	2.660	181	133			314	479
15240.2622 LI tank Piping Caustic CIP Tank	20.00 lf	2.660	181	133			314	479
15240.2623 LI Piping MF EFM Tank	20.00 lf	2.660	181	133			314	479
15240.2624 LI Piping NaOCL Tank	20.00 lf	2.660	181	964			1,145	1,785
15240.2625 RF Tank Feed to RF Pumps	60.00 lf	43.080	2,934	8,284			11,218	17,396
15240.2626 RF Pump Discharge Piping	70.00 lf	52.691	3,588	32,580			36,168	56,542
15240.2627 ROP Piping Acid CIPTank	60.00 lf	5.824	397	5,172			5,569	8,718
15240.2628 MCW/OF Piping From Acid CIP	50.00 lf	4.634	316	700			1,016	1,571
15240.2629 MCR Piping From Acid Tank	120.00 lf	41.664	2,837	18,848			21,685	33,848
15240.2630 MCF PipingFrom Acid feed Pump	100.00 lf	43.204	2,942	16,944			19,886	31,013
15240.2631 ROP Piping Caustic	60.00 lf	5.824	397	5,172			5,569	8,718
15240.2633 SCH Piping To Caustic Tank	120.00 lf	2.618	178	1,560			1,738	2,717
15240.2634 SH Piping to Caustic Tank	120.00 lf	2.618	178	1,560			1,738	2,717
15240.2635 MCR Piping From Caustic Tank	40.00 lf	5.208	355	2,356			2,711	4,231
15240.2636 MCF Piping From Caustic Tank to Feed Pump	60.00 lf	10.416	709	5,424			6,133	9,580
15240.2637 MCF Piping From caustic Feed Pump to System	60.00 lf	6.748	460	2,452			2,912	4,538
15240.2638 Citric Acid Feed to Acid Tank	120.00 lf	2.618	178	1,560			1,738	2,717
15240.2639 NaOCL Feed to EFM tank	120.00 lf	2.618	178	1,560			1,738	2,717
15240.2640 ROP Piping to EFM Tank	60.00 lf	5.824	397	5,928			6,325	9,905
15240.2641 MCW/OF Piping EFM Tank	40.00 lf	4.634	316	700			1,016	1,571
15240.2642 EFMF Piping From Tank Through Pumps	160.00 lf	29.120	1,983	7,972			9,955	15,486
15240.2643 EFMR Piping From EFM tank	40.00 lf	5.208	355	2,356			2,711	4,231
15240.2644 MCR/EFMR Pump Feed/ Discharge	80.00 lf	11.956	814	3,344			4,158	6,470
15240.2645 Citric Acid From Tote to Transfer Pump	40.00 lf	8.988	612	2,570			3,182	4,952
15240.2646 Citric Acid transfer Pump Discharge	40.00 lf	6.252	426	2,000			2,426	3,778
15240.2647 Sodium Hydroxide From Tote to Transfer Pump	40.00 lf	31.066	2,116	7,540			9,656	15,006
15240.2648 Sodium Hydroxide From Transfer Pump	80.00 lf	8.052	548	4,650			5,198	8,124
15240.2649 Sodium Hypochlorite Storage From tank to Pump	40.00 lf	10.472	713	3,000			3,713	5,778
15240.2650 3" Tank Feed Piping	60.00 lf	20.818	1,418	14,540			15,958	24,960
15240.2651 m Hypochlorite From transfer Pump	40.00 lf	3.852	262	1,300			1,562	2,434
15240.2652 Citric Acid Waste Tank Discharge	30.00 lf	3.766	256	217			473	724
15240.2653 SH Dosing Influent	20.00 lf	1.498	102	149			251	386
15240.2654 Circ Pump Piping	20.00 lf	5.698	388	441			829	1,272
15240.2655 3" BW Discharge	40.00 lf	7.154	487	1,658			2,145	3,332
15110 Valves		1,029.963	70,137	433,743			503,881	786,161
15120 Pipe Specialties								
15120.2001 Instrument Valves	93.00 ea	31.568	2,150	6,636			8,785	13,635
15120.2600 24" Static Mixer MF Influent	2.00 ea	44.927	3,059	37,204			40,263	63,017
15120.2601 Strainers	8.00 ea	20.000	1,362	20,580			21,942	34,365
15120.2602 Auto Strainers MF System	8.00 ea	116.661	7,927	627,442	4,157		639,525	1,004,080
15120.2620 Flex Couplings for Plastic Pipe	41.00 ea			2,379			2,379	3,738

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Equip Amount	Sub Amount	Direct Cost Total	Capital Cost
15220.2612 24" MFF Supply Piping	210.00 lf	39.000	2,656	7,035			9,691	15,018
15220.2613 14" MFF Suction Piping	72.00 lf	19.320	1,316	2,347			3,663	5,652
15220.2614 MF Feed Pump Discharge	36.00 lf	19.320	1,316	2,347			3,663	5,652
15220.2616 24" MFE Manifold Piping	120.00 lf	23.352	1,590	4,690			6,280	9,743
15220.2618 MFF Piping @Strainers	40.00 lf	81.732	5,566	10,201			15,767	24,339
15240.2625 RF Tank Feed to RF Pumps	60.00 lf	11.000	749	1,370			2,119	3,271
15240.2626 RF Pump Discharge Piping	70.00 lf	10.490	714	1,250			1,964	3,031
15240.2645 Citric Acid From Tote to Transfer Pump	40.00 lf	5.808	396	2,120			2,516	3,921
15240.2647 Sodium Hydroxide From Tote to Transfer Pump	40.00 lf	5.808	396	2,120			2,516	3,921
15120 Pipe Specialties		428.986	29,195	727,721	4,157		761,072	1,193,382
15220 Steel Pipe								
15220.26001 42" Manifold For Strainer Feed	100.00 lf	56.100	3,820	57,889			61,710	96,650
15220.2612 24" MFF Supply Piping	210.00 lf	261.300	17,794	91,975			109,768	171,067
15220.2613 14" MFF Suction Piping	72.00 lf	78.280	5,331	25,402			30,733	47,868
15220.2614 MF Feed Pump Discharge	36.00 lf	54.300	3,698	24,307			28,005	43,709
15220.2615 12" MFE Piping to Manifold	36.00 lf	51.000	3,473	14,324			17,797	27,690
15220.2616 24" MFE Manifold Piping	120.00 lf	66.000	4,494	38,839			43,333	67,728
15220.2617 6" MFE Piping to RF tank	30.00 lf	12.560	855	2,366			3,221	4,995
15220.2618 MFF Piping @Strainers	40.00 lf	289.800	19,735	86,533			106,268	165,417
15220 Steel Pipe		869.340	59,199	341,635			400,835	625,123
15221 Stainless Steel Pipe								
15221.2600 EF Suction Piping	40.00 lf	24.480	1,667	4,865			6,532	10,133
15221.2601 EF Discharge Pipe	80.00 lf	65.040	4,429	12,803			17,232	26,728
15221 Stainless Steel Pipe		89.520	6,096	17,668			23,764	36,861
15224 Copper Pipe								
15224.2605 PA Piping	270.00 lf	178.489	12,155	24,496			36,651	56,637
15224.2606 1" Control Air Piping	270.00 lf	86.973	5,923	2,714			8,637	13,109
15224.2607 PA Piping Tank & Compressor Piping	70.00 lf	92.174	6,277	8,137			14,414	22,158
15224 Copper Pipe		357.635	24,354	35,348			59,702	91,904
15240 Plastic Pipe								
15240.2610 6" MCR/EFMR Piping From MF to CIP Area	120.00 lf	19.600	1,335	4,031			5,366	8,326
15240.2611 MCF/EFMF Feed Piping From MF area to CIP area	120.00 lf	23.940	1,630	4,239			5,869	9,094
15240.2615 10" PVC RF Feed Pipe from MF System to CIP Area	70.00 lf	33.977	2,314	6,627			8,941	13,867
15240.2616 4" MF BWW Piping From MF to Backwash Main	120.00 lf	28.392	1,933	1,112			3,045	4,634
15240.2617 4" MFBWW Piping	100.00 lf	23.296	1,586	960			2,546	3,877
15240.2618 16" MFBWW Piping	220.00 lf	114.162	7,774	16,949			24,723	38,237
15240.2619 MFE/OF Piping	40.00 lf	19.894	1,355	1,430			2,784	4,269
15240.2620 LI Tank Pipe Reverse Filtration Tank	20.00 lf	4.293	292	92			384	581
15240.2621 LI tank Piping Acid CIP tank	20.00 lf	4.293	292	92			384	581
15240.2622 LI tank Piping Caustic CIP Tank	20.00 lf	4.293	292	92			384	581
15240.2623 LI Piping MF EFM Tank	20.00 lf	4.293	292	92			384	581
15240.2624 LI Piping NaOCL Tank	20.00 lf	4.293	292	92			384	581
15240.2625 RF Tank Feed to RF Pumps	60.00 lf	48.757	3,320	8,673			11,993	18,584
15240.2626 RF Pump Discharge Piping	70.00 lf	68.228	4,646	10,207			14,853	22,974
15240.2627 ROP Piping Acid CIPTank	60.00 lf	13.644	929	507			1,436	2,184
15240.2628 MCW/OF Piping From Acid CIP	50.00 lf	17.547	1,195	830			2,025	3,088
15240.2629 MCR Piping From Acid Tank	120.00 lf	55.029	3,747	4,949			8,696	13,371
15240.2630 MCF PipingFrom Acid feed Pump	100.00 lf	44.310	3,017	4,445			7,462	11,489
15240.2631 ROP Piping Caustic	60.00 lf	15.350	1,045	507			1,552	2,357
15240.2633 SCH Piping To Caustic Tank	120.00 lf	18.144	1,236	208			1,443	2,172
15240.2634 SH Piping to Caustic Tank	120.00 lf	9.072	618	208			826	1,249

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Equip Amount	Sub Amount	Direct Cost Total	Capital Cost
15240.2635 MCR Piping From Caustic Tank	40.00 lf	17.024	1,159	921			2,080	3,178
15240.2636 MCF Piping From Caustic Tank to Feed Pump	60.00 lf	23.240	1,583	1,481			3,064	4,690
15240.2637 MCF Piping From caustic Feed Pump to System	60.00 lf	31.209	2,125	2,497			4,623	7,097
15240.2638 Citric Acid Feed to Acid Tank	120.00 lf	9.072	618	208			826	1,249
15240.2639 NaOCL Feed to EFM tank	120.00 lf	9.072	618	208			826	1,249
15240.2640 ROP Piping to EFM Tank	60.00 lf	12.280	836	507			1,343	2,045
15240.2641 MCW/OF Piping EFM Tank	40.00 lf	15.512	1,056	819			1,876	2,865
15240.2642 EFMF Piping From Tank Through Pumps	160.00 lf	63.541	4,327	5,508			9,835	15,116
15240.2643 EFMR Piping From EFM tank	40.00 lf	15.232	1,037	781			1,818	2,776
15240.2644 MCR/EFMR Pump Feed/ Discharge	80.00 lf	18.113	1,233	1,570			2,804	4,309
15240.2645 Citric Acid From Tote to Transfer Pump	40.00 lf	4.396	299	95			394	596
15240.2646 Citric Acid transfer Pump Discharge	40.00 lf	6.370	434	171			605	917
15240.2647 Sodium Hydroxide From Tote to Transfer Pump	40.00 lf	4.396	299	94			394	596
15240.2648 Sodium Hydroxide From Transfer Pump	80.00 lf	8.442	575	230			805	1,221
15240.2649 Sodium Hypochlorite Storage From tank to Pump	40.00 lf	4.396	299	94			394	596
15240.2650 3" Tank Feed Piping	60.00 lf	22.724	1,547	1,105			2,652	4,047
15240.2651 m Hypochlorite From transfer Pump	40.00 lf	6.370	434	171			605	917
15240.2652 Citric Acid Waste Tank Discharge	30.00 lf	2.982	203	163			366	560
15240.2653 SH Dosing Influent	20.00 lf	2.562	174	138			313	478
15240.2654 Circ Pump Piping	20.00 lf	3.878	264	320			584	897
15240.2655 3" BW Discharge	40.00 lf	6.440	439	565			1,004	1,543
15240 Plastic Pipe		862.059	58,704	83,986			142,690	219,616
0080.0010 MEMBRANE FILTRATION FACILITY	**22.80 MGD**	**10,926.197**	**747,400**	**12,472,933**	**79,086**	**177,600**	**13,477,019**	**21,100,709**
0080.0010A MEMBRANE FILTRATION FACILITY STRUCTURE ONLY								
02300 Earthwork								
02300.2605 Structural Excavation & Backfill	4,307.10 cy	441.470	23,885		31,022		54,907	84,407
02300 Earthwork		441.470	23,885		31,022		54,907	84,407
03212 Concrete Walls								
03212.226001 Containment Curbs 18" high	12.13 cy	241.174	14,583	5,959	111	1,471	22,124	33,513
03212.226002 Pipe Trench Walls	62.79 cy	491.687	29,372	12,675	193	10,299	52,538	79,463
03212 Concrete Walls		732.861	43,955	18,634	304	11,770	74,663	112,976
03310 Concrete Slab on Grade								
03310.226004 Pipe Trench Floor	25.22 cy	115.409	6,996	5,036	128	5,738	18,602	28,237
03310.226006 Air Supply Pad	19.40 cy	73.967	4,382	3,369	63	4,904	13,224	20,055
03310.2605 Building Base Slab	847.81 cy	3,013.841	189,653	202,835	1,410	9,953	405,977	622,320
03310 Concrete Slab on Grade		3,203.217	201,032	211,239	1,600	20,595	437,803	670,612
03412 Concrete Equipment Pabs/Curbs/Fill								
03412.226002 Housekeeping pads - tanks/pumps	24.00 cy	136.429	7,951	3,502	57	3,961	15,953	24,139
03412.226006 Pipe Supports on MF Pad	8.00 cy	83.001	5,037	2,123	43	1,886	9,089	13,743
03412.226008 Pipe Supports-Spread Footing	12.80 cy	118.211	7,121	2,699	79		9,899	14,999
03412.226302 Strainer pad	16.00 cy	147.760	8,901	3,373	99		12,373	18,749
03412.226306 Pipe Supports - Strainer Header	40.00 cy	340.026	20,609	9,266	171	7,545	37,591	56,873
03412.226308 Pipe Supports - Strainer Feed Line	10.00 cy	85.008	5,152	2,317	43	1,886	9,398	14,218
03412 Concrete Equipment Pabs/Curbs/Fill		910.435	54,771	23,280	493	15,278	94,303	142,721
03470 Walls								
03470.2605 Exterior Walls	512.00 cy	1,599.159	102,836	119,500	174	2,936	226,653	347,874
03470.2606 Wall Texture	13,340.00 sf			113,765			113,765	178,724
03470 Walls		1,599.159	102,836	233,265	174	2,936	340,417	526,598
05210 Steel Joist								
05210.2605 Building Roof Framing	20,800.00 sf	203.523	14,049	97,449	6,063		117,561	183,599
05210 Steel Joist		203.523	14,049	97,449	6,063		117,561	183,599
05300 Steel Deck								

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Equip Amount	Sub Amount	Direct Cost Total	Capital Cost
05300.2605 Roof Deck	20,800.00 sf	625.248	43,159	125,212	18,626		186,998	290,428
05300 Steel Deck		625.248	43,159	125,212	18,626		186,998	290,428
07000 Thermal & Moisture Protection								
07000.2605 EPDM Roofing	208.00 sq	918.320	62,058	93,909			155,967	240,215
07000 Thermal & Moisture Protection		918.320	62,058	93,909			155,967	240,215
08000 Doors & Windows								
08000.2605 Exterior Doors & Windows	1.00 ls	215.607	12,382	37,099		52,011	101,493	154,454
08000 Doors & Windows		215.607	12,382	37,099		52,011	101,493	154,454
15300 Fire Protection								
15300.2605 Fire Protection Allowance	1.00 allw					260,859	260,859	389,593
15300 Fire Protection						260,859	260,859	389,593
15400 Plumbing								
15400.2605 Plumbing Allowance	1.00 allw					313,031	313,031	467,511
15400 Plumbing						313,031	313,031	467,511
15500 HVAC								
15500.2605 HVAC Allowance	1.00 allw					626,061	626,061	935,023
15500 HVAC						626,061	626,061	935,023
0080.0010A MEMBRANE FILTRATION FACILITY STRUCTURE ONLY	**20,800.00 SF**	**8,849.841**	**558,127**	**840,087**	**58,282**	**1,302,541**	**2,764,061**	**4,198,139**
0080.0030 REVERSE OSMOSIS FACILITY								
11200 Water Treatment Equipment								
11200.2610 RO Train Feed Pumps	5.00 ea	269.000	18,594	1,130,394	4,157		1,153,144	1,810,149
11200 Water Treatment Equipment		269.000	18,594	1,130,394	4,157		1,153,144	1,810,149
11201 Process Equipment N.O.C.								
11201.2605 Energy Recovery Turbines	5.00 ea	128.000	8,877	197,500			206,919	324,382
11201 Process Equipment N.O.C.		128.000	8,877	197,500			206,919	324,382
11210 Water Supply & Treatment Pumps								
11210.2610 RO Flush Pumps	3.00 ea	238.500	16,647	77,575	2,078		96,847	150,856
11210 Water Supply & Treatment Pumps		238.500	16,647	77,575	2,078		96,847	150,856
11228 Filter Membrane Systems								
11228.2650 RO Train 1	882.00 ea	601.700	41,881	1,490,715			1,532,596	2,404,462
11228.2651 RO Train 2	882.00 ea	601.700	41,881	1,490,715			1,532,596	2,404,462
11228.2652 RO Train 3	882.00 ea	601.700	41,881	1,490,715			1,532,596	2,404,462
11228.2653 RO Train 4	882.00 ea	601.700	41,881	1,490,715			1,532,596	2,404,462
11228.2654 RO Train 5	882.00 ea	601.700	41,881	1,490,715			1,532,596	2,404,462
11228 Filter Membrane Systems		3,008.500	209,403	7,453,575			7,662,978	12,022,309
13200 Tanks								
13200.2650 RO Flush Tanks	2.00 ea	70.857	4,812	105,676	1,237		111,725	175,148
13200.2655 CIP Tanks	2.00 ea	70.857	4,812	73,742	1,237		79,792	124,980
13200 Tanks		141.714	9,625	179,418	2,474		191,517	300,128
15060 Hangers & Supports								
15221.2621 RO Feed Pump Discharge Piping Train 1 Through 3	57.00 lf	16.380	1,115	4,977			6,093	9,485
15221.2622 RO Feed Pump Discharge Piping Train 4 & 5	38.00 lf	10.920	744	3,318			4,062	6,323
15221.2623 6" ROF Piping train 1 Through 3	24.00 lf	7.896	538	1,920			2,458	3,819
15221.2624 6" ROF Piping train 4 & 5	16.00 lf	5.264	358	1,280			1,638	2,546
15221.2625 8" ROF Piping train 1 Through 3	52.50 lf	7.896	538	1,920			2,458	3,819
15221.2626 8" ROF Piping train 4 & 5	35.00 lf	5.264	358	1,280			1,638	2,546
15221.2627 6" ROC Piping train 1 Though 3	57.00 lf	7.896	538	1,920			2,458	3,819
15221.2628 6" ROC Piping train 4 & 5	38.00 lf	5.264	358	1,280			1,638	2,546
15240.2659 1-1/2" D Line	190.00 lf	20.300	1,382	637			2,019	3,065
15240.2661 10" CF/CR Piping	720.00 lf	369.600	25,169	22,241			47,409	72,530
15240.2665 10" PVC ROP Header	216.00 lf	36.960	2,517	2,224			4,741	7,253

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Equip Amount	Sub Amount	Direct Cost Total	Capital Cost
15240.2670 4" ROP Drains	60.00 lf	25.725	1,752	820			2,572	3,904
15240.2671 12" PVC ROP	150.00 lf	85.680	5,835	3,825			9,660	14,723
15240.2672 4" PCR Piping	495.00 lf	58.800	4,004	1,874			5,878	8,924
15248.2600 16" FRP Pipe Header	350.00 lf	84.231	5,736	13,800			19,536	30,246
15248.2601 12" FRP Pipe to RO Feed Pump Header	140.00 lf	33.600	2,288	1,500			3,788	5,774
15248.2602 12" FRP Pipe to RO Feed Pump Branch Piping	440.00 lf	33.600	2,288	1,500			3,788	5,774
15248.2603 20" FRP ROP	75.00 lf	54.000	3,677	2,400			6,077	9,262
15060 Hangers & Supports		869.276	59,195	68,715			127,910	196,359
15110 Valves								
15221.2621 RO Feed Pump Discharge Piping Train 1 Through 3	57.00 lf	59.100	4,025	40,679			44,703	69,917
15221.2622 RO Feed Pump Discharge Piping Train 4 & 5	38.00 lf	39.400	2,683	27,119			29,802	46,611
15221.2627 6" ROC Piping train 1 Though 3	57.00 lf	17.400	1,185	58,150			59,335	93,123
15221.2628 6" ROC Piping train 4 & 5	38.00 lf	11.600	790	38,767			39,557	62,082
15240.2659 1-1/2" D Line	190.00 lf	11.340	772	342			1,114	1,690
15240.2661 10" CF/CR Piping	720.00 lf	15.480	1,054	3,433			4,487	6,968
15240.2662 6" CF/CR Piping	18.00 lf	18.780	1,279	74,254			75,533	118,564
15240.2663 6" CR Piping	18.00 lf	18.780	1,279	74,254			75,533	118,564
15240.2664 8" CR/CF Piping	18.00 lf	20.820	1,418	77,293			78,711	123,545
15240.2670 4" ROP Drains	60.00 lf	30.480	2,076	69,035			71,111	111,554
15240.2671 12" PVC ROP	150.00 lf	118.200	8,049	82,799			90,848	142,098
15240.2672 4" PCR Piping	495.00 lf	36.060	2,456	9,909			12,365	19,235
15248.2601 12" FRP Pipe to RO Feed Pump Header	140.00 lf	59.311	4,039	21,622			25,661	40,001
15248.2602 12" FRP Pipe to RO Feed Pump Branch Piping	440.00 lf	59.311	4,039	21,622			25,661	40,001
15110 Valves		516.063	35,142	599,280			634,422	993,954
15221 Stainless Steel Pipe								
15221.2621 RO Feed Pump Discharge Piping Train 1 Through 3	57.00 lf	71.881	4,895	107,967			112,862	176,926
15221.2622 RO Feed Pump Discharge Piping Train 4 & 5	38.00 lf	47.920	3,263	71,978			75,241	117,951
15221.2623 6" ROF Piping train 1 Through 3	24.00 lf	7.056	481	19,800			20,281	31,824
15221.2624 6" ROF Piping train 4 & 5	16.00 lf	4.704	320	13,200			13,521	21,216
15221.2625 8" ROF Piping train 1 Through 3	52.50 lf	19.268	1,312	15,966			17,278	27,043
15221.2626 8" ROF Piping train 4 & 5	35.00 lf	12.845	875	10,644			11,519	18,028
15221.2627 6" ROC Piping train 1 Though 3	57.00 lf	13.230	901	23,284			24,185	37,925
15221.2628 6" ROC Piping train 4 & 5	38.00 lf	8.820	601	15,523			16,123	25,283
15221 Stainless Steel Pipe		185.724	12,647	278,363			291,010	456,197
15240 Plastic Pipe								
15240.2659 1-1/2" D Line	190.00 lf	27.790	1,892	546			2,438	3,684
15240.2661 10" CF/CR Piping	720.00 lf	179.574	12,228	29,116			41,344	64,004
15240.2662 6" CF/CR Piping	18.00 lf	7.140	486	536			1,022	1,567
15240.2663 6" CR Piping	18.00 lf	7.140	486	1,136			1,622	2,510
15240.2664 8" CR/CF Piping	18.00 lf	20.280	1,381	1,034			2,415	3,687
15240.2665 10" PVC ROP Header	216.00 lf	151.803	10,337	26,347			36,685	56,831
15240.2666 6" PVC ROP Drops	36.00 lf	3.528	240	186			426	651
15240.2667 4" PVC ROP Drops	36.00 lf	2.520	172	101			272	414
15240.2668 6" PVC ROP Header	90.00 lf	29.783	2,028	2,190			4,218	6,469
15240.2669 3" ROP Header	90.00 lf	16.032	1,092	597			1,689	2,568
15240.2670 4" ROP Drains	60.00 lf	28.476	1,939	1,351			3,290	5,018
15240.2671 12" PVC ROP	150.00 lf	89.734	6,111	15,239			21,349	33,066
15240.2672 4" PCR Piping	495.00 lf	47.970	3,267	2,812			6,078	9,296
15240.2673 6" FW Piping	495.00 lf	75.296	5,127	4,677			9,804	15,005
15240 Plastic Pipe		687.066	46,787	85,865			132,652	204,771
15248 FRP Pipe								

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Equip Amount	Sub Amount	Direct Cost Total	Capital Cost
15248.2600 16" FRP Pipe Header	350.00 lf	503.113	34,260	95,829			130,090	201,716
15248.2601 12" FRP Pipe to RO Feed Pump Header	140.00 lf	395.877	26,958	108,706			135,664	211,039
15248.2602 12" FRP Pipe to RO Feed Pump Branch Piping	440.00 lf	578.799	39,415	158,498			197,912	307,866
15248.2603 20" FRP ROP	75.00 lf	105.692	7,197	59,158			66,356	103,687
15248 FRP Pipe		1,583.481	107,830	422,191			530,022	824,307
0080.0030 REVERSE OSMOSIS FACILITY	**21.20 MGD**	**7,627.323**	**524,749**	**10,492,875**	**8,709**		**11,027,421**	**17,283,411**
0080.0030A RO FACILITY STRUCTURE ONLY								
02300 Earthwork								
02300.2605 Structural Excavation & Backfill	4,307.00 cy	439.984	23,804		30,918		54,722	84,123
02300 Earthwork		439.984	23,804		30,918		54,722	84,123
03212 Concrete Walls								
03212.228102 Walls w/ 18" x 18" columns	216.00 cy	1,720.300	103,450	75,577	1,035	50,383	234,765	356,893
03212 Concrete Walls		1,720.300	103,450	75,577	1,035	50,383	234,765	356,893
03310 Concrete Slab on Grade								
03310.228102 Pipe Trench Base Slab	128.00 cy	269.885	16,245	16,782	253	36,095	71,936	108,955
03310.228104 RO Equipment Slabs @ TOW	128.00 cy	200.175	11,838	14,751	148	30,080	59,376	90,032
03310.2605 Building Base Slab	465.63 cy	1,650.620	103,868	111,079	772	5,451	222,335	340,816
03310 Concrete Slab on Grade		2,120.680	131,951	142,612	1,174	71,626	353,647	539,803
03470 Walls								
03470.2605 Exterior Walls	512.00 cy	1,593.858	102,495	119,105	173	2,926	225,902	346,721
03470.2606 Wall Texture	13,340.00 sf			113,388			113,388	178,133
03470 Walls		1,593.858	102,495	232,493	173	2,926	339,290	524,854
05210 Steel Joist								
05210.2605 Building Roof Framing	20,800.00 sf	202.867	14,003	97,126	6,043		117,173	182,994
05210 Steel Joist		202.867	14,003	97,126	6,043		117,173	182,994
05300 Steel Deck								
05300.2605 Roof Deck	20,800.00 sf	624.000	43,073	124,798	18,589		186,460	289,591
05300 Steel Deck		624.000	43,073	124,798	18,589		186,460	289,591
05505 Metal Fabrications								
05505.2710 Aluminum Grating	20,800.00 sf	1,176.661	81,049	158,372	18,799		258,220	399,382
05505 Metal Fabrications		1,176.661	81,049	158,372	18,799		258,220	399,382
07000 Thermal & Moisture Protection								
07000.2605 EPDM Roofing	208.00 sq	915.408	61,861	93,599			155,460	239,433
07000 Thermal & Moisture Protection		915.408	61,861	93,599			155,460	239,433
08000 Doors & Windows								
08000.2605 Exterior Doors & Windows	1.00 ls	214.889	12,341	36,977		51,839	101,157	153,943
08000 Doors & Windows		214.889	12,341	36,977		51,839	101,157	153,943
15300 Fire Protection								
15300.2605 Fire Protection Allowance	1.00 allw					197,597	197,597	295,111
15300 Fire Protection						197,597	197,597	295,111
15400 Plumbing								
15400.2605 Plumbing Allowance	1.00 allw					135,198	135,198	201,918
15400 Plumbing						135,198	135,198	201,918
15500 HVAC								
15500.2605 HVAC Allowance	1.00 allw					519,992	519,992	776,607
15500 HVAC						519,992	519,992	776,607
0080.0030A RO FACILITY STRUCTURE ONLY	**20,800.00 SF**	**9,008.647**	**574,028**	**961,554**	**76,730**	**1,029,560**	**2,653,680**	**4,044,653**
0090.0010 UV AOP FACILITY								
11240 Chemical/Disinfection Equipment								
11240.2620 UV System Trojen UVPhox	4.00 ea	279.000	18,466	4,374,080	3,117		4,395,664	6,904,157
11240 Chemical/Disinfection Equipment		279.000	18,466	4,374,080	3,117		4,395,664	6,904,157
13200 Tanks								

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Equip Amount	Sub Amount	Direct Cost Total	Capital Cost
13200.2660 Hydrogen Peroxide Storage	1.00 ea	32.000	2,187		2,771		4,958	7,619
13200 Tanks		32.000	2,187		2,771		4,958	7,619
15060 Hangers & Supports								
15221.2632 UV Reactor Outlet Piping	417.00 lf	121.500	8,274	22,950			31,224	48,411
15221.2633 UV Reactor Inlet Piping	117.00 lf	36.000	2,451	5,850			8,301	12,852
15221.2660 UV Reactor Inlet Header	110.00 lf	36.000	2,451	11,250			13,701	21,335
15240.26600 Hydrogen Peroxide Piping	120.00 lf	10.000	681	2,458			3,139	4,879
15060 Hangers & Supports		203.500	13,858	42,508			56,366	87,477
15110 Valves								
15221.2632 UV Reactor Outlet Piping	417.00 lf	82.710	5,632	89,262			94,894	148,642
15221.2633 UV Reactor Inlet Piping	117.00 lf	342.900	23,350	189,378			212,728	332,387
15240.26600 Hydrogen Peroxide Piping	120.00 lf	2.618	178	1,560			1,738	2,717
15110 Valves		428.228	29,161	280,200			309,361	483,746
15221 Stainless Steel Pipe								
15221.2632 UV Reactor Outlet Piping	417.00 lf	363.308	24,740	289,989			314,729	492,522
15221.2633 UV Reactor Inlet Piping	117.00 lf	396.351	26,990	343,888			370,878	580,558
15221.2660 UV Reactor Inlet Header	110.00 lf	201.354	13,743	288,224	4,160		306,126	479,859
15221 Stainless Steel Pipe		961.013	65,473	922,101	4,160		991,734	1,552,939
15240 Plastic Pipe								
15240.26600 Hydrogen Peroxide Piping	120.00 lf	9.072	618	208			826	1,249
15240 Plastic Pipe		9.072	618	208			826	1,249
0090.0010 UV AOP FACILITY	**18.00 MGD**	**1,912.813**	**129,762**	**5,619,097**	**10,048**		**5,758,908**	**9,037,187**
0090.0010A UV AOP SYSTEM STRUCTURE ONLY								
02300 Earthwork								
02310.100 Site Earthwork	1,995.00 cy					69,815	69,815	104,269
02300 Earthwork						69,815	69,815	104,269
03310 Concrete Slab on Grade								
03310.2605 Building Base Slab	107.41 cy	380.584	23,949	25,612	178	1,257	51,264	78,582
03310 Concrete Slab on Grade		380.584	23,949	25,612	178	1,257	51,264	78,582
03470 Walls								
03470.2605 Exterior Walls	113.28 cy	352.659	22,678	26,353	38	647	49,983	76,715
03470.2606 Wall Texture	6,329.00 sf			53,797			53,797	84,515
03470 Walls		352.659	22,678	80,149	38	647	103,779	161,230
05210 Steel Joist								
05210.2605 Building Roof Framing	4,800.00 sf	59.850	4,131	26,823	1,783		32,737	51,110
05210 Steel Joist		59.850	4,131	26,823	1,783		32,737	51,110
05300 Steel Deck								
05300.2605 Roof Deck	4,800.00 sf	144.000	9,940	28,800	4,290		43,030	66,829
05300 Steel Deck		144.000	9,940	28,800	4,290		43,030	66,829
07000 Thermal & Moisture Protection								
07000.2605 EPDM Roofing	48.00 sq	211.200	14,272	21,600			35,873	55,250
07000 Thermal & Moisture Protection		211.200	14,272	21,600			35,873	55,250
08000 Doors & Windows								
08000.2605 Exterior Doors & Windows	1.00 ls	63.133	3,585	10,792		17,280	31,658	48,117
08000 Doors & Windows		63.133	3,585	10,792		17,280	31,658	48,117
15300 Fire Protection								
15300.2605 Fire Protection Allowance	1.00 allw					45,600	45,600	68,104
15300 Fire Protection						45,600	45,600	68,104
15400 Plumbing								
15400.2605 Plumbing Allowance	1.00 allw					31,200	31,200	46,597
15400 Plumbing						31,200	31,200	46,597
15500 HVAC								

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Equip Amount	Sub Amount	Direct Cost Total	Capital Cost
15500.2605 HVAC Allowance	1.00 allw					120,000	120,000	179,220
15500 HVAC						120,000	120,000	179,220
0090.0010A UV AOP SYSTEM STRUCTURE ONLY	**4,800.00 SF**	**1,211.426**	**78,556**	**193,777**	**6,289**	**285,800**	**564,957**	**859,309**
0090.0020 CHEMICAL STORAGE AREA #2 (POST TREATMENT)								
11210 Water Supply & Treatment Pumps								
70 Chem System-Calcium Chloride	4.00 ea	25.663	1,680	51,395	261		53,336	83,660
71 Chem System- Sodium Hydroxide	4.00 ea	21.667	1,425	38,758	208		40,391	63,343
11210 Water Supply & Treatment Pumps		47.330	3,104	90,153	469		93,726	147,003
13200 Tanks								
70 Chem System-Calcium Chloride	4.00 ea	195.428	13,232	100,176	3,167		116,575	182,114
71 Chem System- Sodium Hydroxide	3.00 ea	146.572	9,924	49,332	2,375		61,631	96,054
13200 Tanks		342.000	23,156	149,508	5,542		178,206	278,168
15060 Hangers & Supports								
CPVC80 Sch 80 CPVC Pipe & Fittings	797.00 lf	53.800	3,664	7,062			10,726	16,566
PVC80 Sch 80 PVC Pipe & Fittings	265.00 lf	10.667	726	1,760			2,486	3,850
15060 Hangers & Supports		64.466	4,390	8,822			13,212	20,416
15110 Valves								
CPVCBFV CPVC Butterfly Valves	10.00 ea	13.677	1,093	5,088			6,180	9,625
CPVCBV CPVC Ball Valves	14.00 ea	12.191	974	774			1,748	2,670
CPVCDV CPVC Diaphragm Valves	4.00 ea	5.228	418	3,680			4,098	6,405
PVCBFV PVC Butterfly Valves	6.00 ea	15.206	1,215	2,405			3,619	5,592
PVCCV PVC Check Valves	2.00 ea	1.074	86	1,104			1,190	1,862
15110 Valves		47.375	3,785	13,050			16,835	26,154
15120 Pipe Specialties								
CPVC80 Sch 80 CPVC Pipe & Fittings	797.00 lf	6.895	473	1,121			1,593	2,467
PVC80 Sch 80 PVC Pipe & Fittings	265.00 lf	5.384	367	1,205			1,572	2,441
15120 Pipe Specialties		12.278	839	2,326			3,165	4,907
15240 Plastic Pipe								
CPVC80 Sch 80 CPVC Pipe & Fittings	797.00 lf	77.360	5,268	19,155	2		24,425	37,964
PVC80 Sch 80 PVC Pipe & Fittings	265.00 lf	51.989	3,540	5,576	1		9,117	14,049
15240 Plastic Pipe		129.348	8,808	24,731	3		33,542	52,013
0090.0020 CHEMICAL STORAGE AREA #2 (POST TREATMENT)	**1.00 LS**	**642.798**	**44,083**	**288,590**	**6,014**		**338,687**	**528,660**
0090.0020A CHEMICAL STORAGE AREA #2 (POST TREATMENT) STRUCTURE ONLY								
02300 Earthwork								
02310.100 Site Earthwork	1,394.82 cy					48,819	48,819	72,911
02300 Earthwork						48,819	48,819	72,911
02600 Drainage & Containment								
CT Chemical Trench	1.00 ls	29.511	1,859		1,937		3,796	5,820
CT - MH Chemical Trench - Manholes	5.00 ea	12.815	767	7,500	839		9,106	14,246
02600 Drainage & Containment		42.327	2,627	7,500	2,776		12,902	20,066
03000 Concrete								
03210.100 Reinforcing Steel	197.63 tn	1,543.423	111,931	86,920	1,180		200,031	305,574
03300.2602 Chemical Building Slabs/Walls/Foundations	817.56 cy	4,121.036	247,786	135,238	1,549	11,861	396,434	602,675
03000 Concrete		5,664.460	359,717	222,158	2,730	11,861	596,465	908,250
06000 Wood								
FRP - Rail FRP Railing	710.00 lf	88.576	5,652	53,321	130		59,102	92,412
FRP Stairs FRP Stairs	383.76 sf	64.739	4,132	43,099	215		47,445	74,217
06000 Wood		153.315	9,783	96,420	345		106,548	166,628
10000 Specialties								
10520.000 Fire Protection Specialty	6.00 ea	9.000	612	2,100			2,712	4,213
10000 Specialties		9.000	612	2,100			2,712	4,213
13000 Special Construction								

Spreadsheet Level	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Equip Amount	Sub Amount	Direct Cost Total	Capital Cost
MC Metal Canopy	5,250.00 sf					236,250	236,250	352,839
13000 Special Construction						236,250	236,250	352,839
0090.0020A CHEMICAL STORAGE AREA #2 (POST TREATMENT) STRUCTURE ONLY	**5,250.00 SF**	**5,869.102**	**372,739**	**328,177**	**5,850**	**296,929**	**1,003,696**	**1,524,906**

Estimate Totals

Description	Amount	Totals	Hours	Rate	
Labor	6,343,686		94,581 hrs		
Material	36,981,879				
Subcontract	4,181,218				
Equipment	883,961		13,139 hrs		
Other	27,082				
	48,417,826	**48,417,826**			
MOT Allowance	2,420,891			5.00 %	
Misc Metals Allowance	968,357			2.00 %	
Painting Allowance	968,357			2.00 %	
I&C Allowance	3,873,426			8.00 %	
Electrical Allowance	8,715,209			18.00 %	
Subtotal Allowance Cost	**16,946,240**	**65,364,066**			

Client Permits	653,641			1.00 %	
GC General Conditions	6.294.317			13.00 %	5.70%
Sales Tax (MEO)	2,936,701			7.75 %	
Subtotal Capital Cost	**9,884,659**	**75,248,725**			
Construction Contingency	22,574,618			30.00 %	
Subtotal Contingency	**22,574,618**	**97,823,343**			
Contractor Total OH&P	9,782,334			10.00 %	
Subtotal OH&P	**9,782,334**	**107,605,677**			
Bldr's Risk Insurance	215,211			0.20 %	
Gen Liab Insurance	1,076,057			1.00 %	
GC Bonds	1,614,085			1.50 %	
Subtotal Insurance & Bond	**2,905,353**	**110,511,030**			
Engineering & Pre-Construction					
Enviromental Documentation					
Construction Management					
Escalation to Mid Point Constr					
Escalation NOT INCLUDED					
Subtotal Escalation		**110,511,030**			
Total		***110,511,030***			

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Appendix E

Estimated O&M Cost Process Area Breakdown

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Client: **City of San Diego**	Job No.: **2072-78220**	Computed By:	**A.Goh**
Project: **IPR/RA Demonstration Project AWP Facility**			**4/9/2012**
	Checked By: **L. Voelz**	Date:	**Updated 6/7/2012**
			Updated 11/5/2012
Detail: **Full-Scale Facility O&M Costs - 15 mgd**	Date Checked: **6/7/2012**	Page No.:	**1 of 2**

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Power cost	0.12	$/kWh
Hours of operation per day	24	hours
Days of operation per year	365	days
AWP Facility Online Factor	95%	
Annual Average Flow	15	mgd

1) Equipment/Building Operations

#	Load	HP	kW	# Operating	Demand	Annual Power (kWh/yr)	Annual Cost ($/yr)
1	AWP Facility Influent Pumps	137	102	3	100%	2,548,536	$305,824
2	MF System Automatic Strainers	0.5	0	6	100%	18,650	$2,238
3	MF Backwash Pumps	30	22	2	22%	80,815	$9,698
4	MF System Blowers	50	37	1	22%	67,346	$8,081
5	MF System Air Compressors	15	11	1	100%	93,248	$11,190
6	MF CIP Recirculation/Drain Pumps	20	15	2	3.6%	8,856	$1,063
7	MF System CIP Tank Heaters	24	18	2	28%	85,363	$10,244
8	RO Booster Pumps	149	111	3	100%	2,777,506	$333,301
9	RO Feed Pumps	572	427	3	100%	10,665,622	$1,279,875
10	RO Energy Recovery (*accounted for in RO Feed Pumps*)				100%		
11	RO Flush Pumps	60	45	2	0.20%	1,480	$178
12	RO System CIP Recirculation Pumps	40	30	2	0.27%	1,363	$164
13	RO System CIP Tank Heaters	24	18	2	1.5%	4,378	$525
14	UV	116	86	3	71%	1,540,759	$184,891
15	Sodium Hypochlorite Feed Pump	0.5	0.37	3	100%	9,325	$1,119
16	Ammonium Hydroxide Feed pump	0.5	0.37	3	100%	9,325	$1,119
17	Sulfuric Acid Feed Pump	0.5	0.37	3	100%	9,325	$1,119
18	Antiscalant Feed Pump	0.5	0.37	3	100%	9,325	$1,119
19	Hydrogen Peroxide Feed Pump	0.5	0.37	3	100%	9,325	$1,119
20	Calcium Chloride Feed Pump	0.5	0.37	2	100%	6,294	$755
21	Caustic Soda Feed Pump	0.5	0.37	2	100%	6,294	$755
22	Sodium Hypochlorite Feed Pump MF MC	0.5	0.37	1	14%	421	$51
23	Sodium Hypochlorite Feed Pump MF CIP	0.5	0.37	1	0.9%	28	$3
24	Sodium Bisulfite Feed Pump MF CIP	0.5	0.37	1	0.9%	28	$3
25	Citric Acid Feed Pump for MF CIP	0.5	0.37	1	0.9%	28	$3
26	Caustic Soda Feed Pump MF CIP	0.5	0.37	1	0.9%	28	$3
27	Citric Acid Feed Pump RO CIP	0.5	0.37	1	0.09%	3	$0
28	Caustic Soda Feed Pump RO CIP	0.5	0.37	1	0.09%	3	$0
#	**Load**	**Area (SF)**	**Unit Power (kW/SF)**	**Total Power (kW)**	**Demand**	**Annual Power (kWh/yr)**	**Annual Cost ($/yr)**
29	Multiple Buildings	50,700	0.01	482	100%	4,008,291	$480,995
	Operations Subtotal					**21,961,962**	**$2,635,435**

Client: **City of San Diego**	Job No.: **2072-78220**	Computed By:	**A.Goh**
Project: **IPR Project/Reservoir Augmentation Demonstration Project AWP Project**	Checked By: **L. Voelz**	Date:	**4/9/2012 Updated 6/7/2012**
Detail: **Full-Scale Facility O&M Costs - 15 mgd**	Date Checked: **6/7/2012**	Page No.:	**1 of 2**

2) Chemical Usage Costs

#	Chemical	Dose (mg/L)	Usage (gal/day)	Usage (gal/yr)	Demand	Unit Cost ($/gal)	Annual Cost ($)
	Pre-/Post-Treatment						
1	Sodium Hypochlorite (Pre-treatment)	5.0	632	230,835	100%	0.66	$144,734
2	Ammonium Hydroxide	1.5	163	59,426	100%	1.39	$78,240
3	Sulfuric Acid	60.0	619	225,817	100%	1.39	$298,191
4	Antiscalant	4.0	59	21,468	100%	6.49	$132,359
5	Hydrogen Peroxide	5.0	126	46,002	100%	4.94	$215,893
6	Calcium Chloride	20.0	640	233,718	100%	0.53	$118,118
7	Caustic Soda	15.0	294	107,338	100%	2.35	$239,641
8	Sodium Hypochlorite (Membrane Cleaning)	1000.0		1,441		0.66	$951
9	Caustic Soda (Membrane Cleaning)	Varies		2,946		2.35	$6,923
10	Citric Acid (Membrane Cleaning)	Varies		8,974		10.55	$94,659
	Chemical Usage Subtotal						**$1,329,710**

*MF/RO CIP chemicals not included

3) Major Equipment Replacement Costs

#	Equipment	Units/ Modules	Unit Cost ($/unit)	Replacement (#/year)			Annual Cost ($)
1	MF Membrane Replacement(1)	1,084	$ 3,000.00	0.14			$441,167
2	Cartridge Filter Replacement(2)	6					$72,818
3	RO Element Replacement(2)	3					$245,759
4	UV Lamp Replacement(3)	1,296	$268.00	0.7			$225,474
5	UV Ballast Replacement(4)	648	$636.00	0.14			$55,932
	Major Equipment Replacement Subtotal						**$1,041,149**

(1) Assumes replacement every 7 years. Unit cost provided by MF manufacturer (Pall).
(2) Based on information from similar sized AWPF.
(3) Assumes 8200 hours of lamp operation per year. Per vendor (Trojan): 12,000 hours life per lamp. Unit cost provided UV manufacturer (Trojan)
(4) Assumes replacement every 7 years. Unit cost provided by UV manufacturer (Trojan).

4) Maintenance Cost

#	Item	Percentage	Equipment Cost				Annual Cost ($)
1	Maintenance Cost	1.7%	$82,883,273				$1,409,016
	Maintenance Cost Subtotal						**$1,409,016**

5) Other Costs

#	Item						Annual Cost ($)
1	Compliance Testing						$150,000
2	Security						$160,000
	Other Costs Subtotal						**$310,000**

6) Labor Costs

#	Personnel	#				Full Labor Cost ($)	Annual Labor Cost ($)
1	Associate Civil Engineer	0.5				$173,384.60	$86,692
2	Water Plant Operator	3				$136,749.18	$410,248
3	Water Operations Supervisor	2				$141,935.48	$283,871
4	Water Production Superintendent	0.5				$171,983.84	$85,992
5	Water Systems Technician II	2				$78,581.88	$157,164
6	Electrician	2				$104,177.17	$208,354
7	Laboratory Technician	0.5				$85,522.93	$42,761
8	Assistant Chemist	0.5				$110,646.90	$55,323
9	Clerical II/Receptionist	1				$62,865.50	$62,866
10	Outside Lab Sample/Special Testing Allowance	-				-	$25,000
	Labor Subtotal	12.00					**$1,418,271**

	Phase 1 Total Annual O&M Cost						**$8,143,581**

Client: **City of San Diego**	Job No.: **2072-78220**	Computed By: **A.Goh**
Project: **IPR/RA Demonstration Project AWP Facility**	Checked By: **L. Voelz**	Date: **4/9/2012**
Detail: **Full-Scale Facility Electrical Load List - 15 mgd**	Date Checked: **4/9/2012**	Page No.: **1 of 1**

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Phase 1														
							Loads							
#	Load	Volts	Phase	HP	KVA	kW	Total #	Operating	Standby	Operating Frequency	Demand	Current	VFD
	Major Process Equipment												
1	AWP Facility Influent Pumps	480	3	137		102	4	3	1	Continuous	100%		Yes
2	MF System Automatic Strainers	480	3	0.5		0.37	7	6	1	Continuous	100%		No
3	MF Backwash Pumps	480	3	30		22	3	2	1	1x30sec/30min/skid	22%		Yes
4	MF System Blowers	480	3	50		37	2	1	1	1x30sec/30min/skid	22%		Yes
5	MF System Air Compressors	480	3	15.0		11	2	1	1	Continuous	100%		No
6	MF CIP Recirculation/Drain Pumps	480	3	20		15	4	2	2	1x2hr/mo/skid	3.6%		Yes
7	MF System CIP Tank Heaters	480	3	24		18	3	2	1	1x16hr/mo/skid	28%		No
8	RO Booster Pumps	480	3	149		111	4	3	1	Continuous	100%		Yes
9	RO Feed Pumps	480	3	572		427	4	3	1	Continuous	100%		Yes
10	RO Energy Recovery	480	3	0		0	1	1	0	Continuous	100%		**Yes**
11	RO Flush Pumps	480	3	60		45	3	2	1	1 x 5min/wk/train	0.20%		Yes
12	RO System CIP Recirculation Pumps	480	3	40		30	3	2	1	2 x 3hr/yr/train	0.27%		Yes
13	RO System CIP Tank Heaters	480	3	24		18	3	2	1	2 x 16hr/yr/train	1.5%		No
14	UV	480	3	116		86	3	3	0	Continuous	100%		No
15	Finished Water Pumps					0				Continuous	100%		Yes
	Influent Pre-treatment Chemicals												
16	Sodium Hypochlorite Feed Pumps	115	1	0.5		0.37	4	3	1	Continuous	100%		Integral to Pump
17	Ammonium Hydroxide Feed Pumps	115	1	0.5		0.37	4	3	1	Continuous	100%		Integral to Pump
	RO Pre-treatment Chemicals												
18	Sulfuric Acid Feed Pumps	115	1	0.5		0.37	4	3	1	Continuous	100%		Integral to Pump
19	Antiscalant Feed Pumps	115	1	0.5		0.37	4	3	1	Continuous	100%		Integral to Pump
	AOP Chemicals												
21	Hydrogen Peroxide Feed Pumps	115	1	0.5		0.37	4	3	1	Continuous	100%		Integral to Pump
	Product Water Post-treatment Chemicals												
22	Calcium Chloride Feed Pumps	115	1	0.5		0.37	3	2	1	Continuous	100%		Integral to Pump
23	Caustic Soda Feed Pumps	115	1	0.5		0.37	3	2	1	Continuous	100%		Integral to Pump
	MF MC Chemicals												
25	Sodium Hypochlorite Feed Pumps for MF MC	115	1	0.5		0.37	1	1	0	1 x 15min/day/skid	14%		Integral to Pump
	MF CIP and Neutralization Chemicals												
26	Sodium Hypochlorite Feed Pumps for MF CIP	115	1	0.5		0.37	2	1	1	1 x 30min/mo/skid	0.9%		Integral to Pump
27	Sodium Bisulfite Feed Pumps for MF CIP Neutralization	115	1	0.5		0.37	2	1	1	1 x 30min/mo/skid	0.9%		Integral to Pump
28	Citric Acid Feed Pumps for MF CIP	115	1	0.5		0.37	2	1	1	1 x 30min/mo/skid	0.9%		Integral to Pump
29	Caustic Soda Feed Pumps for MF CIP Neutralization	115	1	0.5		0.37	2	1	1	1 x 30min/mo/skid	0.9%		Integral to Pump
	RO CIP and Neutralization Chemicals												
30	Citric Acid Feed Pumps for RO CIP/Neutralization	115	1	0.5		0.37	2	1	1	2 x 1hr/yr/train	0.09%		Integral to Pump
31	Caustic Soda Feed Pumps for RO CIP/Neutralization	115	1	0.5		0.37	2	1	1	2 x 1hr/yr/train	0.09%		Integral to Pump
	TOTAL			**4,545**		**3,395**							

Volts - Typically 120, 208, 240 or 480
Phase - 1 or 3 (Usually 3 phase for motors except for 120 V chemical metering pumps)
HP, KVA, KW - Only one of these columns would be filled out (typically HP for motors, KVA for transformers, KW for heaters)
Total # - Total number of that particular load (EG. 3 RO Feed Pumps)
Operating - Total number of that particular load that runs during normal operations (EG. 1 RO Feed Pump runs during normal operations)
Standby - The additional number of that particular load that can run during emergency operations (EG. 1 additional RO Feed Pump runs during emergency operations)
Demand (HP loads) - The amount of time a load runs. If a pump runs continuously, the number will be 100%. If a pump runs occasionally then the % of the day the pump will run.
Demand (kVA loads) - The percent loaded a transformer is based on panel schedules.
Current - This column will be filled out by the electrical engineer based on the data in the other columns.

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Appendix F

Demonstration Facility Power Consumption

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City of San Diego		Calc By:	E. You
Indirect Potable Reuse/Reservoir Augmentation Demonstration Project		Calc Date:	5/31/2012
Advanced Water Purification Facility		Checked By:	J. Thompson
Demonstration Facility Power Consumption - MF Control Panel Power Consumption		Checked Date:	6/7/2012

MF Control Panel Power Consumption

Power = Voltage*Current

I (current) =	5	amps	(MF control panel internal power, based on co)
V (current) =	120	volts	(Power source for MF control panel was 120 V)
W = I*V =	0.6	kW	
MF control panel power usage =	14.4	kW-hr/day	for 24 hour/day plant operation

City of San Diego
Indirect Potable Reuse/Reservoir Augmentation Demonstration Project
Advanced Water Purification Facility
Demonstration Facility Power Consumption - MF Compressor Power Consumption

Calc By: E. You
Calc Date: 5/31/2012
Checked By: J. Thompson
Checked Date: 6/7/2012

Summary of MF Compressor Runtime (hours) for One Week

(Received from Jay DeCarolis on 5/31/12)

Date / Time	MF Compressor Runtime (hour)	Compresor Runtime on day of reading (hour)	Plant Runtime on day of reading (hour)	
5/25/2012 6:29	3324.61	9.37	20.9	
5/26/2012 7:17	3333.98	11.47	24	
5/27/2012 10:04	3345.45	2.74	13	
5/28/2012 11:20	3348.19	18.7	24	
5/30/2012 7:02	3366.89	3.17	24	
5/30/2012 14:24	3370.06	7.12	24	
5/31/2012 7:20	3377.18		7.7	
Total		52.57	137.6	38%

Assume compressor and dryer operate 40% of time MF is online.

MF Air Dryer Power Consumption

W =	0.3	kW	(see vendor cutsheet)
T =	9.6	hrs/day for 24-hr plant operation	
W =	2.88	kW-hr/day	

City of San Diego
Indirect Potable Reuse/Reservoir Augmentation Demonstration Project
Advanced Water Purification Facility
Demonstration Facility Power Consumption - With MF/UF Feed Pumping Power Consumption Measured from EDR Feed Pump

		Power Monitor	Calculated	*Calculated*	*Calculated*	*Calculated*	Power Monitor	*Calculated*	*Calculated*	Power Monitor	Power Monitor	Power Monitor	*Calculated*	*Calculated*	*Calculated*	*Calculated*	Power Monitor	
		Total Daily Power Consumption (W-hr) (August 2011)																
Date	**Purified Water Flow (gpm)**	**MF Power Monitor (a)**	**MF Feed Pumping (b)**	**MF Control Panel (c)**	**MF Air Dryer (d)**	**Total MF (e) = (a)+(b)+(c)+(d)**	**UF Power Monitor (f)**	**UF Feed Pumping (g)**	**Total UF (h) = (f)+(g)**	**RO Train A Power Monitor (i)**	**RO Train B Power Monitor (j)**	**UV/AOP Power Monitor (k)**	**Ancillary Loads (l) = (p)-(o)**	**Total AWPF Processes Including MF/UF Feed Pumping (m) = (e)+(h)+(i)+(j)+(k)**	**Total AWPF Including MF/UF Feed Pumping (n) = (p)+(b)+(g)**	**Total AWPF Process without MF/UF Feed Pumping (o) = (m)-(b)-(g)**	**Total AWPF without MF/UF Feed Pumping (Main Power Monitor) (p)**	**Comments**
8/1/2011		69,382	483,747	14,400	2,880	570,409	177,175	468,854	646,029	154,749	785,020	275,289		2,431,496		1,478,895		RO A power meter reading low.
8/2/2011		71,411	483,747	14,400	2,880	572,438	174,969	468,854	643,823	270,270	820,177	273,271		2,579,979		1,627,378		RO A power meter reading low.
8/3/2011		62,367	483,747	14,400	2,880	563,394	164,713	468,854	633,567	207,498	642,896	214,921		2,262,276		1,309,675		RO A power meter reading low.
8/4/2011																		Offline for North City filter mudball chlorination
8/5/2011																		Offline for North City filter mudball chlorination
8/6/2011																		Offline for North City filter mudball chlorination
8/7/2011		3,197	20,156	600	120	24,073	105,975	468,854	574,829	0	0	21,600		620,502		131,492		RO systems offline.
8/8/2011		50,077	483,747	14,400	2,880	551,104	153,239	468,854	622,093	190,139	260,084	199,665		1,823,085		870,484		RO A power meter reading low.
8/9/2011		76,340	483,747	14,400	2,880	577,367	166,572	468,854	635,426	268,418	827,364	280,904		2,589,479		1,636,878		RO A power meter reading low.
8/10/2011		76,306	483,747	14,400	2,880	577,333	168,510	468,854	637,364	285,679	802,415	281,882		2,584,673		1,632,072		RO A power meter reading low.
8/11/2011		73,287	483,747	14,400	2,880	574,314	158,422	468,854	627,276	507,055	761,544	270,528		2,740,717		1,788,116		Electrician swapped 2 wires on RO A power meter.
8/12/2011		72,739	483,747	14,400	2,880	573,766	172,002	468,854	640,856	786,253	840,360	286,875		3,128,110		2,175,509		
8/13/2011		70,661	483,747	14,400	2,880	571,688	164,452	468,854	633,306	769,482	820,144	264,656		3,059,276		2,106,675		
8/14/2011		47,229	483,747	14,400	2,880	548,256	144,236	468,854	613,090	507,716	540,324	243,933		2,453,319		1,500,718		
8/15/2011		67,876	483,747	14,400	2,880	568,903	154,829	468,854	623,683	743,783	791,380	274,836		3,002,585		2,049,984		
8/16/2011		71,481	483,747	14,400	2,880	572,508	157,357	468,854	626,211	784,927	835,420	302,400		3,121,466		2,168,865		
8/17/2011		71,754	483,747	14,400	2,880	572,781	146,844	468,854	615,698	783,901	833,325	300,013		3,105,718		2,153,117		
8/18/2011		71,502	483,747	14,400	2,880	572,529	144,077	468,854	612,931	794,484	838,166	302,465		3,120,575		2,167,974		
8/19/2011																		Totals not recorded.
8/20/2011		29,478	483,747	14,400	2,880	530,505	124,587	468,854	593,441	290,233	309,204	109,878		1,833,261		880,660		
8/21/2011		17,433	483,747	14,400	2,880	518,460	118,133	468,854	586,987	173,358	160,102	67,017		1,505,924		553,323		
8/22/2011		50,326	483,747	14,400	2,880	551,353	133,286	468,854	602,140	551,012	569,555	208,435		2,482,495		1,529,894		
8/23/2011		74,411	483,747	14,400	2,880	575,438	148,203	468,854	617,057	811,023	829,978	301,956		3,135,452		2,182,851		
8/24/2011		72,283	483,747	14,400	2,880	573,310	154,231	468,854	623,085	805,821	856,534	302,195		3,160,945		2,208,344		
8/25/2011		72,297	483,747	14,400	2,880	573,324	149,646	468,854	618,500	806,455	858,888	310,680		3,167,847		2,215,246		
8/26/2011		58,773	483,747	14,400	2,880	559,800	148,074	468,854	616,928	647,053	675,318	244,696		2,743,795		1,791,194		
8/27/2011																		Totals not recorded.
8/28/2011		72,920	483,747	14,400	2,880	573,947	154,274	468,854	623,128	799,079	854,588	311,392		3,162,134		2,209,533		
8/29/2011		72,549	483,747	14,400	2,880	573,576	160,316	468,854	629,170	805,315	848,794	302,346		3,159,201		2,206,600		
8/30/2011		72,399	483,747	14,400	2,880	573,426	155,077	468,854	623,931	816,466	861,770	302,412		3,178,005		2,225,404		
8/31/2011		72,574	483,747	14,400	2,880	573,601	153,396	468,854	622,250	819,239	862,184	298,566		3,175,840		2,223,239		
TOTAL (kW-hr)		**1,621**	**12,114**	**361**	**72**	**14,168**	**3,953**	**12,190**	**16,143**	**14,379**	**18,086**	**6,553**		**69,328**		**45,024**		
AVERAGE (kW-hr/MG)		**122**	**913**	**27**	**5**	**1,067**	**287**	**885**	**1,171**	**1,150**	**1,447**	**262**		**2,773**		**1,801**		

City of San Diego
Indirect Potable Reuse/Reservoir Augmentation Demonstration Project
Advanced Water Purification Facility
Demonstration Facility Power Consumption - With MF/UF Feed Pumping Power Consumption Measured from EDR Feed Pump

		Power Monitor	Calculated	*Calculated*	*Calculated*	*Calculated*	Power Monitor	*Calculated*	*Calculated*	Power Monitor	Power Monitor	Power Monitor	*Calculated*	*Calculated*	*Calculated*	*Calculated*	Power Monitor	
		Total Daily Power Consumption (W-hr) (September 2011)																
Date	**Purified Water Flow (gpm)**	**MF Power Monitor (a)**	**MF Feed Pumping (b)**	**MF Control Panel (c)**	**MF Air Dryer (d)**	**Total MF (e) = (a)+(b)+(c)+(d)**	**UF Power Monitor (f)**	**UF Feed Pumping (g)**	**Total UF (h) = (f)+(g)**	**RO Train A Power Monitor (i)**	**RO Train B Power Monitor (j)**	**UV/AOP Power Monitor (k)**	**Ancillary Loads (l) = (p)-(o)**	**Total AWPF Processes Including MF/UF Feed Pumping (m) = (e)+(h)+(i)+(j)+(k)**	**Total AWPF Including MF/UF Feed Pumping (n) = (p)+(b)+(g)**	**Total AWPF Process without MF/UF Feed Pumping (o) = (m)-(b)-(g)**	**Total AWPF without MF/UF Feed Pumping (Main Power Monitor) (p)**	**Comments**
9/1/2011		71,884	483,747	14,400	2,880	572,911	150,591	468,854	619,445	822,969	849,608	268,390		3,133,323		2,180,722		
9/2/2011		66,237	483,747	14,400	2,880	567,264	141,659	468,854	610,513	741,020	755,582	237,032		2,911,411		1,958,810		
9/3/2011		53,834	483,747	14,400	2,880	554,861	137,444	468,854	606,298	591,336	612,258	184,835		2,549,588		1,596,987		
9/4/2011																		Totals not available.
9/5/2011		3,089	483,747	14,400	2,880	504,116	107,038	468,854	575,892	0	0	0		1,080,008		127,407		RO and UV/AOP offline.
9/6/2011		88,037	483,747	14,400	2,880	589,064	128,629	468,854	597,483	562,688	580,606	186,182		2,516,023		1,563,422		
9/7/2011		191,669	483,747	14,400	2,880	692,696	178,902	468,854	647,756	796,060	542,594	274,407		2,953,513		2,000,912		UF cleaning.
9/8/2011																		Blackout occurred at 3:30 p.m. Offline for weekend
9/9/2011																		Offline due to blackout
9/10/2011																		Offline due to blackout
9/11/2011		0					43,260	117,214	160,474	0	0	0		160,474		43,260		Offline due to blackout
9/12/2011		50,852	322,498	9,600	1,920	384,870	121,213	312,569	433,782	525,600	458,486	178,267		1,981,006		1,345,938		Back online at ~8 A.M.
9/13/2011		72,443	483,747	14,400	2,880	573,470	174,005	468,854	642,859	814,238	859,576	263,788		3,153,931		2,201,330		
9/14/2011		72,086	483,747	14,400	2,880	573,113	170,557	468,854	639,411	826,192	862,508	262,035		3,163,259		2,210,658		
9/15/2011		71,458	483,747	14,400	2,880	572,485	175,543	468,854	644,397	834,726	863,430	261,465		3,176,503		2,223,902		
9/16/2011		62,254	483,747	14,400	2,880	563,281	163,775	468,854	632,629	726,872	743,700	238,493		2,904,975		1,952,374		
9/17/2011		72,249	483,747	14,400	2,880	573,276	171,963	468,854	640,817	840,096	863,858	267,446		3,185,493		2,232,892		
9/18/2011		70,673	483,747	14,400	2,880	571,700	176,938	468,854	645,792	839,302	863,892	265,498		3,186,184		2,233,583		
9/19/2011	722.91	71,472	483,747	14,400	2,880	572,499	171,889	468,854	640,743	835,564	846,810	271,549		3,167,165		2,214,564		
9/20/2011	702.67	71,943	483,747	14,400	2,880	572,970	167,910	468,854	636,764	837,178	814,944	269,463		3,131,319		2,178,718		
9/21/2011	687.11	71,865	483,747	14,400	2,880	572,892	173,320	468,854	642,174	840,548	826,312	268,666		3,150,592		2,197,991		
9/22/2011	736.78	70,729	483,747	14,400	2,880	571,756	173,608	468,854	642,462	828,866	832,392	264,021		3,139,497		2,186,896		
9/23/2011	2.99																	Totals not available.
9/24/2011	687.83	71,068	483,747	14,400	2,880	572,095	194,134	468,854	662,988	838,174	811,920	201,340		3,086,517		2,133,916		
9/25/2011	709.57	70,878	483,747	14,400	2,880	571,905	195,343	468,854	664,197	832,254	804,412	4		2,872,772		1,920,171		UV/AOP offline.
9/26/2011	662.62	71,214	483,747	14,400	2,880	572,241	193,885	468,854	662,739	804,784	767,424	194,237		3,001,425		2,048,824		
9/27/2011	691.19	71,366	483,747	14,400	2,880	572,393	190,600	468,854	659,454	835,984	805,804	282,694		3,156,329		2,203,728		
9/28/2011	708.83	40,928	483,747	14,400	2,880	541,955	169,839	468,854	638,693	462,392	451,376	173,747		2,268,163		1,315,562		
9/29/2011	232.59	51,536	483,747	14,400	2,880	552,563	174,505	468,854	643,359	520,864	561,296	209,871		2,487,953		1,535,352		
9/30/2011	712.37	58,670	483,747	14,400	2,880	559,697	180,890	468,854	649,744	622,260	672,508	237,928		2,742,137		1,789,536		
TOTAL (kW-hr)		**1,668**	**11,449**	**341**	**68**	**13,526**	**4,027**	**11,213**	**15,241**	**17,180**	**17,051**	**5,261**		**68,260**		**45,597**		
AVERAGE (kW-hr/MG)		**133**	**913**	**27**	**5**	**1,078**	**318**	**885**	**1,202**	**1,516**	**1,505**	**243**		**3,150**		**2,104**		

City of San Diego
Indirect Potable Reuse/Reservoir Augmentation Demonstration Project
Advanced Water Purification Facility
Demonstration Facility Power Consumption - With MF/UF Feed Pumping Power Consumption Measured from EDR Feed Pump

		Power Monitor	Calculated	*Calculated*	*Calculated*	*Calculated*	Power Monitor	*Calculated*	*Calculated*	Power Monitor	Power Monitor	Power Monitor	*Calculated*	*Calculated*	*Calculated*	*Calculated*	Power Monitor	
		Total Daily Power Consumption (W-hr) (October 2011)																
Date	**Purified Water Flow (gpm)**	**MF Power Monitor (a)**	**MF Feed Pumping (b)**	**MF Control Panel (c)**	**MF Air Dryer (d)**	**Total MF (e) = (a)+(b)+(c)+(d)**	**UF Power Monitor (f)**	**UF Feed Pumping (g)**	**Total UF (h) = (f)+(g)**	**RO Train A Power Monitor (i)**	**RO Train B Power Monitor (j)**	**UV/AOP Power Monitor (k)**	**Ancillary Loads (l) = (p)-(o)**	**Total AWPF Processes Including MF/UF Feed Pumping (m) = (e)+(h)+(i)+(j)+(k)**	**Total AWPF Including MF/UF Feed Pumping (n) = (p)+(b)+(g)**	**Total AWPF Process without MF/UF Feed Pumping (o) = (m)-(b)-(g)**	**Total AWPF without MF/UF Feed Pumping (Main Power Monitor) (p)**	**Comments**
10/1/2011	733.37	71,720	483,747	14,400	2,880	572,747	172,270	468,854	641,124	816,800	849,632	300,201		3,180,504		2,227,903		
10/2/2011	697.21	71,950	483,747	14,400	2,880	572,977	174,610	468,854	643,464	813,808	846,920	337,770		3,214,939		2,262,338		
10/3/2011	712.21	71,260	483,747	14,400	2,880	572,287	181,130	468,854	649,984	810,744	844,152	331,570		3,208,737		2,256,136		
10/4/2011	721.33																	Totals not available.
10/5/2011	333.67	77,960	483,747	14,400	2,880	578,987	180,010	468,854	648,864	810,744	3,612	318,560		2,360,767		1,408,166		MF cleaning. RO B offline.
10/6/2011	382.43	163,170	0	0	0	163,170	179,870	468,854	648,724	823,136	607,880	306,130		2,549,040		2,080,186		RO B Cleaning.
10/7/2011	728.60	328,000	0	0	0	328,000	181,190	468,854	650,044	812,024	263,412	314,110		2,367,590		1,898,736		RO B Cleaning.
10/8/2011	330.84																	Totals not available.
10/9/2011	687.71	64,620	483,747	14,400	2,880	565,647	195,070	468,854	663,924	830,600	824,432	337,490		3,222,093		2,269,492		
10/10/2011	685.95	62,610	483,747	14,400	2,880	563,637	198,260	468,854	667,114	815,200	814,184	352,790		3,212,925		2,260,324		
10/11/2011	732.95	64,100	483,747	14,400	2,880	565,127	200,490	468,854	669,344	824,320	828,432	350,530		3,237,753		2,285,152		
10/12/2011	723.43	64,070	483,747	14,400	2,880	565,097	201,950	468,854	670,804	802,168	835,616	294,820		3,168,505		2,215,904		
10/13/2011	703.74	43,200	483,747	14,400	2,880	544,227	209,210	468,854	678,064	650,692	719,760	261,660		2,854,403		1,901,802		
10/14/2011	758.02	216,800	0	0	0	216,800	203,640	468,854	672,494	243,188	822,336	227,770		2,182,588		1,713,734		RO A Cleaning. (MF/RO A/UV offline)
10/15/2011	353.75	154,040	0	0	0	154,040	205,610	468,854	674,464	296,972	829,672	118,420		2,073,568		1,604,714		RO A Cleaning. (MF/RO A/UV offline)
10/16/2011	699.35	64,350	483,747	14,400	2,880	565,377	199,630	468,854	668,484	814,980	838,960	304,300		3,192,101		2,239,500		
10/17/2011	716.54	64,560	483,747	14,400	2,880	565,587	198,400	468,854	667,254	814,832	837,464	302,420		3,187,557		2,234,956		
10/18/2011	673.47	56,580	403,123	12,000	2,400	474,103	190,220	390,712	580,932	719,648	739,600	265,780		2,780,063		1,986,228		All systems offline for ~ 4 hours.
10/19/2011	680.00	63,840	483,747	14,400	2,880	564,867	200,870	468,854	669,724	822,300	844,800	302,340		3,204,031		2,251,430		
10/20/2011	716.40	63,440	483,747	14,400	2,880	564,467	200,650	468,854	669,504	823,960	846,064	303,800		3,207,795		2,255,194		
10/21/2011	658.21	54,270	423,279	12,600	2,520	492,669	185,450	410,247	595,697	674,788	700,952	276,240		2,740,346		1,906,820		All systems offline for ~ 3 hours.
10/22/2011	725.29	63,930	483,747	14,400	2,880	564,957	197,810	468,854	666,664	809,192	846,880	362,210		3,249,903		2,297,302		
10/23/2011	671.29	63,460	483,747	14,400	2,880	564,487	194,730	468,854	663,584	807,568	845,760	311,430		3,192,829		2,240,228		
10/24/2011	685.50	63,070	483,747	14,400	2,880	564,097	191,690	468,854	660,544	806,584	844,008	304,990		3,180,223		2,227,622		
10/25/2011	667.76	62,810	483,747	14,400	2,880	563,837	194,180	468,854	663,034	812,520	850,880	302,610		3,192,881		2,240,280		
10/26/2011	702.31	63,000	483,747	14,400	2,880	564,027	190,480	468,854	659,334	806,728	845,136	301,720		3,176,945		2,224,344		
10/27/2011	729.80	63,720	483,747	14,400	2,880	564,747	190,810	468,854	659,664	817,688	859,104	304,480		3,205,683		2,253,082		
10/28/2011	673.06	57,490	483,747	14,400	2,880	558,517	182,170	468,854	651,024	746,472	783,920	276,400		3,016,333		2,063,732		
10/29/2011	678.68	63,140	483,747	14,400	2,880	564,167	188,780	468,854	657,634	824,152	866,568	305,230		3,217,751		2,265,150		
10/30/2011	481.82	53,160	483,747	14,400	2,880	554,187	177,060	468,854	645,914	678,688	711,600	244,740		2,835,129		1,882,528		
10/31/2011	667.71	63,670	483,747	14,400	2,880	564,697	194,310	468,854	663,164	820,288	859,520	298,030		3,205,699		2,253,098		
TOTAL (kW-hr)		**2,438**	**11,953**	**356**	**71**	**14,818**	**5,561**	**13,460**	**19,021**	**21,951**	**22,211**	**8,619**		**86,619**		**61,206**		
AVERAGE (kW-hr/MG)		**186**	**913**	**27**	**5**	**1,132**	**365**	**885**	**1,250**	**1,644**	**1,663**	**323**		**3,243**		**2,292**		

City of San Diego
Indirect Potable Reuse/Reservoir Augmentation Demonstration Project
Advanced Water Purification Facility
Demonstration Facility Power Consumption - With MF/UF Feed Pumping Power Consumption Measured from EDR Feed Pump

		Power Monitor	Calculated	*Calculated*	*Calculated*	*Calculated*	Power Monitor	*Calculated*	*Calculated*	Power Monitor	Power Monitor	Power Monitor	*Calculated*	*Calculated*	*Calculated*	*Calculated*	Power Monitor	
		Total Daily Power Consumption (W-hr) (November 2011)																
Date	**Purified Water Flow (gpm)**	**MF Power Monitor (a)**	**MF Feed Pumping (b)**	**MF Control Panel (c)**	**MF Air Dryer (d)**	**Total MF (e) = (a)+(b)+(c)+(d)**	**UF Power Monitor (f)**	**UF Feed Pumping (g)**	**Total UF (h) = (f)+(g)**	**RO Train A Power Monitor (i)**	**RO Train B Power Monitor (j)**	**UV/AOP Power Monitor (k)**	**Ancillary Loads (l) = (p)-(o)**	**Total AWPF Processes Including MF/UF Feed Pumping (m) = (e)+(h)+(i)+(j)+(k)**	**Total AWPF Including MF/UF Feed Pumping (n) = (p)+(b)+(g)**	**Total AWPF Process without MF/UF Feed Pumping (o) = (m)-(b)-(g)**	**Total AWPF without MF/UF Feed Pumping (Main Power Monitor) (p)**	**Comments**
11/1/2011	718.37	63,260	483,747	14,400	2,880	564,287	199,080	468,854	667,934	826,400	865,336	333,772		3,257,729		2,305,128	NA	
11/2/2011	732.68	58,030	443,435	13,200	2,640	517,305	192,000	429,783	621,783	746,280	781,184	275,416		2,941,968		2,068,750	NA	All systems offline for ~2 hours.
11/3/2011	728.24	64,040	483,747	14,400	2,880	565,067	197,890	468,854	666,744	832,344	872,424	306,584		3,243,163		2,290,562	NA	
11/4/2011	712.08	44,060	322,498	9,600	1,920	378,078	171,680	312,569	484,249	567,168	593,936	212,868		2,236,300		1,601,232	NA	All systems offline for ~8 hours.
11/5/2011	23.93	35,850	483,747	14,400	2,880	536,878	140,795	468,854	609,650	498,769	548,883	181,349		2,375,528		1,422,927	NA	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
11/6/2011	688.19	62,360	483,747	14,400	2,880	563,387	196,160	468,854	665,014	847,048	886,792	313,860		3,276,101		2,323,500	NA	
11/7/2011	704.11	63,570	483,747	14,400	2,880	564,597	199,020	468,854	667,874	844,960	884,672	313,200		3,275,303		2,322,702	NA	
11/8/2011	677.76	63,170	483,747	14,400	2,880	564,197	202,120	468,854	670,974	855,552	897,256	311,212		3,299,191		2,346,590	NA	
11/9/2011	611.19	42,040	483,747	14,400	2,880	543,068	165,105	468,854	633,960	584,887	643,654	212,661		2,618,230		1,665,628	NA	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
11/10/2011	311.41	32,750	221,718	6,600	1,320	262,388	157,930	214,891	372,821	393,912	405,496	146,784		1,581,401		1,144,792	NA	All systems offline for ~13 hours.
11/11/2011	53.23	40,390	483,747	14,400	2,880	541,417	158,623	468,854	627,477	561,923	618,382	204,311		2,553,509		1,600,908	NA	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
11/12/2011	444.31	40,390	483,747	14,400	2,880	541,417	158,623	468,854	627,477	561,923	618,382	204,311		2,553,509		1,600,908	NA	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
11/13/2011	401.37	40,390	483,747	14,400	2,880	541,417	158,623	468,854	627,477	561,923	618,382	204,311		2,553,509		1,600,908	NA	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
11/14/2011	546.35	51,400	382,967	11,400	2,280	448,047	181,330	371,176	552,506	693,800	715,344	251,344		2,661,041		1,906,898	NA	All systems offline for ~5 hours.
11/15/2011	569.12	41,940	282,186	8,400	1,680	334,206	148,660	273,498	422,158	498,892	502,728	189,416		1,947,400		1,391,716	NA	All systems offline for ~10 hours.
11/16/2011	132.77	26,980	181,405	5,400	1,080	214,865	144,240	175,820	320,060	319,268	332,760	119,920		1,306,874		949,648	NA	All systems offline for ~15 hours.
11/17/2011	6.75	22,590	141,093	4,200	840	168,723	145,890	136,749	282,639	260,308	260,608	97,560		1,069,838		791,996	NA	All systems offline for ~17 hours.
11/18/2011	129.23	32,730	241,874	7,200	1,440	283,244	156,820	234,427	391,247	384,012	442,840	154,840	2,606,518	1,656,183	4,262,701	1,179,882	3,786,400	All systems offline for ~12 hours. Total AWPF Power Meter Installed.
11/19/2011	738.27	62,320	483,747	14,400	2,880	563,347	205,690	468,854	674,544	858,300	897,944	300,852	109,894	3,294,987	3,404,881	2,342,386	2,452,280	
11/20/2011	713.42	62,030	483,747	14,400	2,880	563,057	207,820	468,854	676,674	860,536	900,576	300,212	113,086	3,301,055	3,414,141	2,348,454	2,461,540	
11/21/2011	686.73	61,900	483,747	14,400	2,880	562,927	206,470	468,854	675,324	867,816	907,632	325,200	110,692	3,338,899	3,449,591	2,386,298	2,496,990	
11/22/2011	673.24	61,630	483,747	14,400	2,880	562,657	204,720	468,854	673,574	875,704	914,952	356,040	112,414	3,382,927	3,495,341	2,430,326	2,542,740	
11/23/2011	657.91	62,158	483,747	14,400	2,880	563,185	244,113	468,854	712,967	864,772	951,661	314,425	102,441	3,407,010	3,509,451	2,454,409	2,556,849	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
11/24/2011	687.66	61,730	483,747	14,400	2,880	562,757	203,850	468,854	672,704	870,944	911,264	436,920	114,302	3,454,589	3,568,891	2,501,988	2,616,290	
11/25/2011	674.87	61,560	483,747	14,400	2,880	562,587	207,110	468,854	675,964	863,920	904,248	432,752	110,340	3,439,471	3,549,811	2,486,870	2,597,210	
11/26/2011	660.51	60,890	483,747	14,400	2,880	561,917	202,060	468,854	670,914	875,064	914,760	434,248	113,748	3,456,903	3,570,651	2,504,302	2,618,050	
11/27/2011	669.91	61,430	483,747	14,400	2,880	562,457	207,050	468,854	675,904	868,504	909,288	434,740	116,648	3,450,893	3,567,541	2,498,292	2,614,940	
11/28/2011	672.47	61,620	483,747	14,400	2,880	562,647	211,570	468,854	680,424	869,200	909,864	361,280	114,566	3,383,415	3,497,981	2,430,814	2,545,380	
11/29/2011	651.35	61,350	483,747	14,400	2,880	562,377	217,290	468,854	686,144	875,540	916,688	299,892	113,610	3,340,641	3,454,251	2,388,040	2,501,650	
11/30/2011	709.50	61,410	483,747	14,400	2,880	562,437	200,170	468,854	669,024	875,704	914,832	298,068	109,796	3,320,065	3,429,861	2,367,464	2,477,260	
TOTAL (kW-hr)		**1,566**	**12,860**	**383**	**77**	**14,885**	**5,593**	**12,464**	**18,056**	**21,265**	**22,443**	**8,328**		**84,978**		**59,654**		
AVERAGE (kW-hr/MG)		**111**	**913**	**27**	**5**	**1,056**	**397**	**885**	**1,282**	**1,600**	**1,688**	**313**		**3,197**		**2,244**		

City of San Diego
Indirect Potable Reuse/Reservoir Augmentation Demonstration Project
Advanced Water Purification Facility
Demonstration Facility Power Consumption - With MF/UF Feed Pumping Power Consumption Measured from EDR Feed Pump

		Power Monitor	Calculated	*Calculated*	*Calculated*	*Calculated*	Power Monitor	*Calculated*	*Calculated*	Power Monitor	Power Monitor	Power Monitor	*Calculated*	*Calculated*	*Calculated*	*Calculated*	Power Monitor	
		Total Daily Power Consumption (W-hr) (December 2011)																
Date	**Purified Water Flow (gpm)**	**MF Power Monitor (a)**	**MF Feed Pumping (b)**	**MF Control Panel (c)**	**MF Air Dryer (d)**	**Total MF (e) = (a)+(b)+(c)+(d)**	**UF Power Monitor (f)**	**UF Feed Pumping (g)**	**Total UF (h) = (f)+(g)**	**RO Train A Power Monitor (i)**	**RO Train B Power Monitor (j)**	**UV/AOP Power Monitor (k)**	**Ancillary Loads (l) = (p)-(o)**	**Total AWPF Processes Including MF/UF Feed Pumping (m) = (e)+(h)+(i)+(j)+(k)**	**Total AWPF Including MF/UF Feed Pumping (n) = (p)+(b)+(g)**	**Total AWPF Process without MF/UF Feed Pumping (o) = (m)-(b)-(g)**	**Total AWPF without MF/UF Feed Pumping (Main Power Monitor) (p)**	**Comments**
12/1/2011	700.98	55,830	423,279	12,600	2,520	494,229	206,210	410,247	616,457	778,264	813,840	267,052	99,796	2,969,842	3,069,638	2,136,316	2,236,112	All systems offline for ~3 hours.
12/2/2011	736.18	61,100	483,747	14,400	2,880	562,127	213,390	468,854	682,244	884,864	922,928	302,068	98,906	3,354,231	3,453,137	2,401,630	2,500,536	
12/3/2011	659.63	61,030	483,747	14,400	2,880	562,057	223,180	468,854	692,034	801,808	838,088	275,480	102,278	3,169,467	3,271,745	2,216,866	2,319,144	RO Trains and UV offline for ~3 hours.
12/4/2011	734.79	61,360	483,747	14,400	2,880	562,387	202,450	468,854	671,304	884,432	925,496	304,252	105,798	3,347,871	3,453,669	2,395,270	2,501,068	
12/5/2011	657.36	59,890	483,747	14,400	2,880	560,917	188,950	390,712	579,662	741,376	901,856	294,760	101,808	3,078,571	3,180,379	2,204,112	2,305,920	UF and ROA offline for ~4 hours.
12/6/2011	685.86	60,770	483,747	14,400	2,880	561,797	201,290	468,854	670,144	869,408	932,992	301,568	104,412	3,335,909	3,440,321	2,383,308	2,487,720	
12/7/2011	687.67	60,740	483,747	14,400	2,880	561,767	190,510	468,854	659,364	833,504	937,712	301,208	100,138	3,293,555	3,393,693	2,340,954	2,441,092	
12/8/2011	696.77	57,720	463,591	13,800	2,760	537,871	189,320	449,319	638,639	832,880	890,296	285,392	103,032	3,185,078	3,288,110	2,272,168	2,375,200	All systems offline for ~1 hour.
12/9/2011	688.49	55,670	443,435	13,200	2,640	514,945	186,670	429,783	616,453	810,336	862,792	277,440	101,788	3,081,966	3,183,754	2,208,748	2,310,536	All systems offline for ~2 hours.
12/10/2011	684.62	61,210	483,747	14,400	2,880	562,237	217,020	468,854	685,874	883,824	943,168	302,728	107,154	3,377,831	3,484,985	2,425,230	2,532,384	
12/11/2011	723.24	60,970	483,747	14,400	2,880	561,997	217,970	468,854	686,824	883,656	941,936	302,272	105,284	3,376,685	3,481,969	2,424,084	2,529,368	
12/12/2011	700.65	60,530	483,747	14,400	2,880	561,557	210,410	468,854	679,264	872,808	930,560	298,128	109,516	3,342,317	3,451,833	2,389,716	2,499,232	
12/13/2011	694.04	62,050	483,747	14,400	2,880	563,077	212,540	468,854	681,394	887,680	943,360	302,292	87,638	3,377,803	3,465,441	2,425,202	2,512,840	
12/14/2011	703.49	61,420	483,747	14,400	2,880	562,447	207,080	468,854	675,934	892,152	946,424	304,612	107,728	3,381,569	3,489,297	2,428,968	2,536,696	
12/15/2011	697.67	61,090	483,747	14,400	2,880	562,117	197,880	468,854	666,734	890,200	939,256	301,088	104,926	3,359,395	3,464,321	2,406,794	2,511,720	
12/16/2011	571.53	51,480	403,123	12,000	2,400	469,003	190,080	390,712	580,792	726,960	769,512	246,752	100,680	2,793,019	2,893,699	1,999,184	2,099,864	All systems offline for ~4 hours.
12/17/2011	439.82	54,770	423,279	12,600	2,520	493,169	206,570	410,247	616,817	778,768	825,224	263,280	102,092	2,977,258	3,079,350	2,143,732	2,245,824	All systems offline for ~3 hours.
12/18/2011	692.05	61,240	483,747	14,400	2,880	562,267	216,410	468,854	685,264	890,968	946,408	303,608	109,430	3,388,515	3,497,945	2,435,914	2,545,344	
12/19/2011	719.79	61,960	483,747	14,400	2,880	562,987	213,990	468,854	682,844	891,232	946,616	303,672	110,322	3,387,351	3,497,673	2,434,750	2,545,072	
12/20/2011	662.09	43,490	342,654	10,200	2,040	398,384	185,170	332,105	517,275	619,712	657,592	211,568	96,532	2,404,531	2,501,063	1,729,772	1,826,304	All systems offline for ~7 hours.
12/21/2011	79.38	41,970	322,498	9,600	1,920	375,988	180,810	312,569	493,379	589,264	623,336	205,400	93,908	2,287,368	2,381,276	1,652,300	1,746,208	All systems offline for ~8 hours.
12/22/2011	679.24	63,130	483,747	14,400	2,880	564,157	211,690	468,854	680,544	888,896	943,952	306,792	110,676	3,384,341	3,495,017	2,431,740	2,542,416	
12/23/2011	312.87	49,620	382,967	11,400	2,280	446,267	165,550	371,176	536,726	705,440	746,528	241,656	94,198	2,676,617	2,770,815	1,922,474	2,016,672	All systems offline for ~5 hours.
12/24/2011	673.52	60,095	483,747	14,400	2,880	561,122	236,010	468,854	704,864	836,066	920,070	303,987	98,467	3,326,110	3,424,576	2,373,508	2,471,975	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
12/25/2011	684.25	61,820	483,747	14,400	2,880	562,847	196,540	468,854	665,394	892,312	946,744	305,200	102,096	3,372,497	3,474,593	2,419,896	2,521,992	
12/26/2011	703.81	61,030	483,747	14,400	2,880	562,057	200,860	468,854	669,714	899,616	949,472	303,092	105,306	3,383,951	3,489,257	2,431,350	2,536,656	
12/27/2011	670.02	61,420	483,747	14,400	2,880	562,447	193,100	468,854	661,954	902,928	950,336	303,492	102,228	3,381,157	3,483,385	2,428,556	2,530,784	
12/28/2011	686.76	60,800	483,747	14,400	2,880	561,827	193,660	468,854	662,514	909,304	952,520	303,328	110,044	3,389,493	3,499,537	2,436,892	2,546,936	
12/29/2011	663.57	60,868	483,747	14,400	2,880	561,896	239,048	468,854	707,902	846,831	931,917	307,901	99,957	3,356,447	3,456,404	2,403,846	2,503,803	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
12/30/2011	588.91	53,800	423,279	12,600	2,520	492,199	199,720	410,247	609,967	775,680	818,560	263,852	100,628	2,960,258	3,060,886	2,126,732	2,227,360	All systems offline for ~3 hours.
12/31/2011	720.68	61,900	483,747	14,400	2,880	562,927	243,100	468,854	711,954	861,184	947,712	313,120	101,944	3,396,897	3,498,841	2,444,296	2,546,240	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
TOTAL (kW-hr)		**1,811**	**14,271**	**425**	**85**	**16,591**	**6,337**	**13,753**	**20,090**	**25,762**	**27,547**	**8,907**	**3,179**	**98,898**	**102,077**	**70,874**	**74,053**	
AVERAGE (kW-hr/MG)		**116**	**913**	**27**	**5**	**1,061**	**408**	**885**	**1,292**	**1,764**	**1,876**	**305**	**109**	**3,386**	**3,495**	**2,427**	**2,535**	

City of San Diego
Indirect Potable Reuse/Reservoir Augmentation Demonstration Project
Advanced Water Purification Facility
Demonstration Facility Power Consumption - With MF/UF Feed Pumping Power Consumption Measured from EDR Feed Pump

		Power Monitor	Calculated	*Calculated*	*Calculated*	*Calculated*	Power Monitor	*Calculated*	*Calculated*	Power Monitor	Power Monitor	Power Monitor	*Calculated*	*Calculated*	*Calculated*	*Calculated*	Power Monitor	
		Total Daily Power Consumption (W-hr) (January 2012)																
Date	**Purified Water Flow (gpm)**	**MF Power Monitor (a)**	**MF Feed Pumping (b)**	**MF Control Panel (c)**	**MF Air Dryer (d)**	**Total MF (e) = (a)+(b)+(c)+(d)**	**UF Power Monitor (f)**	**UF Feed Pumping (g)**	**Total UF (h) = (f)+(g)**	**RO Train A Power Monitor (i)**	**RO Train B Power Monitor (j)**	**UV/AOP Power Monitor (k)**	**Ancillary Loads (l) = (p)-(o)**	**Total AWPF Processes Including MF/UF Feed Pumping (m) = (e)+(h)+(i)+(j)+(k)**	**Total AWPF Including MF/UF Feed Pumping (n) = (p)+(b)+(g)**	**Total AWPF Process without MF/UF Feed Pumping (o) = (m)-(b)-(g)**	**Total AWPF without MF/UF Feed Pumping (Main Power Monitor) (p)**	**Comments**
1/1/2012	685.48	61,330	483,747	14,400	2,880	562,357	210,870	468,854	679,724	895,440	948,720	306,432	110,640	3,392,673	3,503,313	2,440,072	2,550,712	
1/2/2012	689.21	61,290	483,747	14,400	2,880	562,317	210,870	468,854	679,724	896,248	949,424	305,388	110,956	3,393,101	3,504,057	2,440,500	2,551,456	
1/3/2012	673.73	61,390	483,747	14,400	2,880	562,417	213,840	468,854	682,694	877,672	937,760	301,620	113,430	3,362,163	3,475,593	2,409,562	2,522,992	
1/4/2012	698.29	61,700	483,747	14,400	2,880	562,727	216,520	468,854	685,374	892,608	947,888	303,592	114,060	3,392,189	3,506,249	2,439,588	2,553,648	
1/5/2012	683.36	61,120	483,747	14,400	2,880	562,147	212,100	468,854	680,954	895,768	950,368	304,776	117,444	3,394,013	3,511,457	2,441,412	2,558,856	
1/6/2012	707.14	51,820	382,967	11,400	2,280	448,467	194,900	371,176	566,076	731,960	772,304	257,224	103,224	2,776,031	2,879,255	2,021,888	2,125,112	All systems offline for ~5 hours.
1/7/2012	704.90	61,270	483,747	14,400	2,880	562,297	212,300	468,854	681,154	898,584	950,192	309,028	108,610	3,401,255	3,509,865	2,448,654	2,557,264	
1/8/2012	683.52	62,110	483,747	14,400	2,880	563,137	204,230	468,854	673,084	904,952	951,936	309,060	105,328	3,402,169	3,507,497	2,449,568	2,554,896	
1/9/2012	712.06	62,970	483,747	14,400	2,880	563,997	206,940	468,854	675,794	905,584	951,920	311,232	104,018	3,408,527	3,512,545	2,455,926	2,559,944	
1/10/2012	688.64	34,190	282,186	8,400	1,680	326,456	162,030	273,498	435,528	484,688	551,376	182,136	91,268	1,980,184	2,071,452	1,424,500	1,515,768	All systems offline for ~10 hours. Energy recovery device removed from RO Train A.
1/11/2012	7.12	6,440	483,747	14,400	2,880	507,467	113,400	468,854	582,254	9,816	8,816	11,760	54,080	1,120,113	1,174,193	167,512	221,592	Systems offline for ERD maintenance.
1/12/2012	0.00	39,350	302,342	9,000	1,800	352,492	173,412	293,034	466,446	569,488	576,752	193,640	97,878	2,158,818	2,256,696	1,563,442	1,661,320	All systems offline for ~9 hours.
1/13/2012	698.12	59,470	483,747	14,400	2,880	560,497	192,656	468,854	661,510	921,472	946,208	302,172	107,686	3,391,859	3,499,545	2,439,258	2,546,944	
1/14/2012	716.47	60,000	483,747	14,400	2,880	561,027	188,904	468,854	657,758	926,504	954,512	301,300	101,308	3,401,101	3,502,409	2,448,500	2,549,808	
1/15/2012	668.57	60,510	483,747	14,400	2,880	561,537	204,708	468,854	673,562	931,680	953,824	305,900	102,450	3,426,503	3,528,953	2,473,902	2,576,352	
1/16/2012	679.50	60,540	483,747	14,400	2,880	561,567	204,260	468,854	673,114	931,304	955,136	305,188	106,692	3,426,309	3,533,001	2,473,708	2,580,400	
1/17/2012	683.65	57,900	483,747	14,400	2,880	558,927	208,672	468,854	677,526	886,480	867,776	290,744	100,796	3,281,453	3,382,249	2,328,852	2,429,648	
1/18/2012	673.50	60,450	483,747	14,400	2,880	561,477	254,888	468,854	723,742	937,496	955,200	309,408	100,110	3,487,323	3,587,433	2,534,722	2,634,832	Positioner on UF feed valve controller replaced.
1/19/2012	724.74	60,530	483,747	14,400	2,880	561,557	267,432	468,854	736,286	939,224	955,184	311,592	103,606	3,503,843	3,607,449	2,551,242	2,654,848	
1/20/2012	722.54	18,620	382,967	11,400	2,280	415,267	245,968	371,176	617,144	733,080	747,696	246,976	127,596	2,760,163	2,887,759	2,006,020	2,133,616	All systems offline for ~5 hours.
1/21/2012	715.58	60,760	483,747	14,400	2,880	561,787	266,550	468,854	735,404	931,936	954,112	311,632	119,778	3,494,871	3,614,649	2,542,270	2,662,048	
1/22/2012	669.42	60,760	483,747	14,400	2,880	561,787	265,340	468,854	734,194	932,880	954,976	312,408	103,860	3,496,245	3,600,105	2,543,644	2,647,504	
1/23/2012	717.65	60,470	483,747	14,400	2,880	561,497	259,820	468,854	728,674	937,256	954,304	315,760	108,358	3,497,491	3,605,849	2,544,890	2,653,248	
1/24/2012	709.55	60,660	483,747	14,400	2,880	561,687	262,020	468,854	730,874	934,400	954,656	310,440	103,920	3,492,057	3,595,977	2,539,456	2,643,376	
1/25/2012	717.28	60,830	483,747	14,400	2,880	561,857	266,040	468,854	734,894	936,960	954,464	310,112	108,826	3,498,287	3,607,113	2,545,686	2,654,512	
1/26/2012	654.56	59,940	483,747	14,400	2,880	560,967	266,120	468,854	734,974	923,280	935,840	304,992	112,356	3,460,053	3,572,409	2,507,452	2,619,808	
1/27/2012	638.93	57,980	483,747	14,400	2,880	559,007	231,260	468,854	700,114	496,280	886,368	276,240	97,840	2,918,009	3,015,849	1,965,408	2,063,248	
1/28/2012	325.45	62,610	483,747	14,400	2,880	563,637	226,840	468,854	695,694	489,360	956,368	295,920	97,462	3,000,979	3,098,441	2,048,378	2,145,840	
1/29/2012	647.18	60,890	483,747	14,400	2,880	561,917	250,920	468,854	719,774	928,616	956,448	315,176	103,774	3,481,931	3,585,705	2,529,330	2,633,104	
1/30/2012	704.74	51,150	403,123	12,000	2,400	468,673	240,400	390,712	631,112	762,712	785,056	261,240	98,722	2,908,793	3,007,515	2,114,958	2,213,680	All systems offline for ~4 hours.
1/31/2012	674.16	61,400	483,747	14,400	2,880	562,427	267,348	468,854	736,202	928,240	958,528	314,384	110,388	3,499,781	3,610,169	2,547,180	2,657,568	
TOTAL (kW-hr)		**1,720**	**14,331**	**427**	**85**	**16,563**	**6,902**	**13,890**	**20,791**	**25,372**	**27,084**	**8,797**	**3,246**	**98,608**	**101,855**	**70,387**	**73,634**	
AVERAGE (kW-hr/MG)		**110**	**913**	**27**	**5**	**1,055**	**440**	**885**	**1,324**	**1,713**	**1,828**	**297**	**110**	**3,329**	**3,438**	**2,376**	**2,486**	

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Demonstration Facility Power Consumption - With MF/UF Feed Pumping Power Consumption Measured from EDR Feed Pump

		Power Monitor	Calculated	*Calculated*	*Calculated*	*Calculated*	Power Monitor	*Calculated*	*Calculated*	Power Monitor	Power Monitor	Power Monitor	*Calculated*	*Calculated*	*Calculated*	*Calculated*	Power Monitor	
		Total Daily Power Consumption (W-hr) (February 2012)																
Date	**Purified Water Flow (gpm)**	**MF Power Monitor (a)**	**MF Feed Pumping (b)**	**MF Control Panel (c)**	**MF Air Dryer (d)**	**Total MF (e) = (a)+(b)+(c)+(d)**	**UF Power Monitor (f)**	**UF Feed Pumping (g)**	**Total UF (h) = (f)+(g)**	**RO Train A Power Monitor (i)**	**RO Train B Power Monitor (j)**	**UV/AOP Power Monitor (k)**	**Ancillary Loads (l) = (p)-(o)**	**Total AWPF Processes Including MF/UF Feed Pumping (m) = (e)+(h)+(i)+(j)+(k)**	**Total AWPF Including MF/UF Feed Pumping (n) = (p)+(b)+(g)**	**Total AWPF Process without MF/UF Feed Pumping (o) = (m)-(b)-(g)**	**Total AWPF without MF/UF Feed Pumping (Main Power Monitor) (p)**	**Comments**
2/1/2012	750.29	60,190	483,747	14,400	2,880	561,217	266,864	468,854	735,718	928,600	957,712	312,388	108,902	3,495,635	3,604,537	2,543,034	2,651,936	
2/2/2012	723.27	60,270	483,747	14,400	2,880	561,297	263,280	468,854	732,134	928,904	956,528	315,240	101,490	3,494,103	3,595,593	2,541,502	2,642,992	
2/3/2012	762.94	54,520	483,747	14,400	2,880	555,547	254,416	468,854	723,270	823,528	849,328	280,628	98,588	3,232,301	3,330,889	2,279,700	2,378,288	
2/4/2012	680.75	60,868	483,747	14,400	2,880	561,896	239,048	468,854	707,902	846,831	931,917	307,901	99,957	3,356,447	3,456,404	2,403,846	2,503,803	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
2/5/2012	681.86	60,350	483,747	14,400	2,880	561,377	262,320	468,854	731,174	934,344	957,632	316,420	102,246	3,500,947	3,603,193	2,548,346	2,650,592	
2/6/2012	751.82	60,860	483,747	14,400	2,880	561,887	262,860	468,854	731,714	929,640	956,864	316,440	105,736	3,496,545	3,602,281	2,543,944	2,649,680	
2/7/2012	741.66	60,950	483,747	14,400	2,880	561,977	268,440	468,854	737,294	929,352	956,784	313,320	120,818	3,498,727	3,619,545	2,546,126	2,666,944	
2/8/2012	692.53	60,710	483,747	14,400	2,880	561,737	269,060	468,854	737,914	933,360	958,640	313,460	113,570	3,505,111	3,618,681	2,552,510	2,666,080	
2/9/2012	741.90	60,890	483,747	14,400	2,880	561,917	269,928	468,854	738,782	937,600	958,688	309,220	113,626	3,506,207	3,619,833	2,553,606	2,667,232	
2/10/2012	692.76	51,780	403,123	12,000	2,400	469,303	256,532	390,712	647,244	775,936	794,768	261,300	96,516	2,948,551	3,045,067	2,154,716	2,251,232	All systems offline for ~4 hours.
2/11/2012	712.89	61390	483,747	14,400	2,880	562,417	264612	468,854	733,466	936064	958000	317392	103,150	3,507,339	3,610,489	2,554,738	2657888	
2/12/2012	704.15	60790	483,747	14,400	2,880	561,817	264840	468,854	733,694	930496	956896	318028	104,662	3,500,931	3,605,593	2,548,330	2652992	
2/13/2012	688.73	60830	483,747	14,400	2,880	561,857	262928	468,854	731,782	928032	956208	317988	106,030	3,495,867	3,601,897	2,543,266	2649296	
2/14/2012	684.65	60410	483,747	14,400	2,880	561,437	267688	468,854	736,542	932080	956720	318532	104,490	3,505,311	3,609,801	2,552,710	2657200	
2/15/2012	677.95	60540	483,747	14,400	2,880	561,567	261852	468,854	730,706	931392	943600	311508	104,708	3,478,773	3,583,481	2,526,172	2630880	
2/16/2012	692.83	58030	483,747	14,400	2,880	559,057	260680	468,854	729,534	898768	909872	298160	101,434	3,395,391	3,496,825	2,442,790	2544224	
2/17/2012	684.41	59870	483,747	14,400	2,880	560,897	246440	468,854	715,294	747568	755584	249584	79,786	3,028,927	3,108,713	2,076,326	2156112	
2/18/2012	673.55	61100	483,747	14,400	2,880	562,127	266020	468,854	734,874	940368	954688	315560	104,408	3,507,617	3,612,025	2,555,016	2659424	
2/19/2012	693.96	61100	483,747	14,400	2,880	562,127	267780	468,854	736,634	938592	954832	320120	105,416	3,512,305	3,617,721	2,559,704	2665120	
2/20/2012	705.63	52490	483,747	14,400	2,880	553,517	251612	468,854	720,466	774320	809904	271856	96,346	3,130,063	3,226,409	2,177,462	2273808	
2/21/2012	676.50	61390	483,747	14,400	2,880	562,417	262056	468,854	730,910	862000	957728	318960	101,722	3,432,015	3,533,737	2,479,414	2581136	
2/22/2012	720.19	60550	483,747	14,400	2,880	561,577	258832	468,854	727,686	861552	958992	316652	113,118	3,426,459	3,539,577	2,473,858	2586976	
2/23/2012	723.71	60400	483,747	14,400	2,880	561,427	260840	468,854	729,694	847072	873648	290900	105,380	3,302,741	3,408,121	2,350,140	2455520	
2/24/2012	664.92	61620	483,747	14,400	2,880	562,647	261432	468,854	730,286	872352	955680	316760	107,292	3,437,725	3,545,017	2,485,124	2592416	
2/25/2012	721.22	61190	483,747	14,400	2,880	562,217	260268	468,854	729,122	872128	955264	316352	105,342	3,435,083	3,540,425	2,482,482	2587824	
2/26/2012	705.81	61320	483,747	14,400	2,880	562,347	259040	468,854	727,894	868592	952840	320344	105,864	3,432,017	3,537,881	2,479,416	2585280	
2/27/2012	680.39	61416	483,747	14,400	2,880	562,444	243759	468,854	712,613	788134	885108	320021	89,535	3,268,321	3,357,855	2,315,719	2405254	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
2/28/2012	678.96	60390	483,747	14,400	2,880	561,417	259536	468,854	728,390	867296	948624	315296	105,834	3,421,023	3,526,857	2,468,422	2574256	
2/29/2012	660.96	61250	483,747	14,400	2,880	562,277	261112	468,854	729,966	878144	957024	317632	105,366	3,445,043	3,550,409	2,492,442	2597808	
TOTAL (kW-hr)		**1,737**	**13,948**	**415**	**83**	**16,184**	**7,554**	**13,519**	**21,073**	**25,643**	**26,880**	**8,918**	**3,011**	**98,698**	**101,709**	**71,231**	**74,242**	
AVERAGE (kW-hr/MG)		**114**	**913**	**27**	**5**	**1,059**	**494**	**885**	**1,379**	**1,779**	**1,865**	**309**	**104**	**3,423**	**3,527**	**2,470**	**2,575**	

City of San Diego
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Demonstration Facility Power Consumption - With MF/UF Feed Pumping Power Consumption Measured from EDR Feed Pump

		Power Monitor	Calculated	*Calculated*	*Calculated*	*Calculated*	Power Monitor	*Calculated*	*Calculated*	Power Monitor	Power Monitor	Power Monitor	*Calculated*	*Calculated*	*Calculated*	*Calculated*	Power Monitor	
		Total Daily Power Consumption (W-hr) (March 2012)																
Date	**Purified Water Flow (gpm)**	**MF Power Monitor (a)**	**MF Feed Pumping (b)**	**MF Control Panel (c)**	**MF Air Dryer (d)**	**Total MF (e) = (a)+(b)+(c)+(d)**	**UF Power Monitor (f)**	**UF Feed Pumping (g)**	**Total UF (h) = (f)+(g)**	**RO Train A Power Monitor (i)**	**RO Train B Power Monitor (j)**	**UV/AOP Power Monitor (k)**	**Ancillary Loads (l) = (p)-(o)**	**Total AWPF Processes Including MF/UF Feed Pumping (m) = (e)+(h)+(i)+(j)+(k)**	**Total AWPF Including MF/UF Feed Pumping (n) = (p)+(b)+(g)**	**Total AWPF Process without MF/UF Feed Pumping (o) = (m)-(b)-(g)**	**Total AWPF without MF/UF Feed Pumping (Main Power Monitor) (p)**	**Comments**
3/1/2012	705.49	61,360	483,747	14,400	2,880	562,387	259,900	468,854	728,754	875,760	956,400	318,176	109,684	3,441,477	3,551,161	2,488,876	2,598,560	
3/2/2012	736.44	55,080	483,747	14,400	2,880	556,107	249,700	468,854	718,554	758,144	828,960	278,464	96,916	3,140,229	3,237,145	2,187,628	2,284,544	
3/3/2012	737.78	55,850	483,747	14,400	2,880	556,877	252,680	468,854	721,534	794,624	869,456	293,600	98,926	3,236,091	3,335,017	2,283,490	2,382,416	
3/4/2012	2.33	5,370	483,747	14,400	2,880	506,397	172,448	312,569	485,017	4,672	4,560	11,632	51,222	1,012,279	1,063,501	215,962	267,184	UF Critical alarm shut down plant (Bray air valve)
3/5/2012	2.63	32,940	483,747	14,400	2,880	533,967	199,532	371,176	570,708	414,061	456,848	15,728	224,459	1,991,313	2,215,772	1,136,389	1,360,848	
3/6/2012	761.64	61,210	483,747	14,400	2,880	562,237	241,612	468,854	710,466	844,544	899,632	315,536	104,314	3,332,415	3,436,729	2,379,814	2,484,128	
3/7/2012	657.01	49,930	483,747	14,400	2,880	550,957	226,948	468,854	695,802	670,400	738,000	250,872	91,562	2,906,031	2,997,593	1,953,430	2,044,992	
3/8/2012	690.75	61,740	483,747	14,400	2,880	562,767	239,300	468,854	708,154	866,112	952,640	322,672	101,760	3,412,345	3,514,105	2,459,744	2,561,504	
3/9/2012	746.76	56,410	483,747	14,400	2,880	557,437	236,740	468,854	705,594	776,480	858,944	287,360	100,258	3,185,815	3,286,073	2,233,214	2,333,472	
3/10/2012	688.76	61,820	483,747	14,400	2,880	562,847	246,132	468,854	714,986	851,368	948,416	313,560	107,728	3,391,177	3,498,905	2,438,576	2,546,304	
3/11/2012	695.63	61,580	483,747	14,400	2,880	562,607	244,640	468,854	713,494	851,360	948,496	318,648	106,732	3,394,605	3,501,337	2,442,004	2,548,736	
3/12/2012	667.07	61,990	483,747	14,400	2,880	563,017	244,760	468,854	713,614	844,560	948,816	318,400	106,050	3,388,407	3,494,457	2,435,806	2,541,856	
3/13/2012	686.46	62,100	483,747	14,400	2,880	563,127	244,868	468,854	713,722	848,800	948,160	309,296	104,760	3,383,105	3,487,865	2,430,504	2,535,264	
3/14/2012	738.25	61,900	483,747	14,400	2,880	562,927	245,740	468,854	714,594	848,480	949,376	309,992	106,700	3,385,369	3,492,069	2,432,768	2,539,468	
3/15/2012	705.61	62,130	483,747	14,400	2,880	563,157	244,940	468,854	713,794	846,576	948,432	313,048	104,906	3,385,007	3,489,913	2,432,406	2,537,312	
3/16/2012	717.17	61,500	483,747	14,400	2,880	562,527	245,280	468,854	714,134	843,552	948,960	313,328	104,020	3,382,501	3,486,521	2,429,900	2,533,920	
3/17/2012	681.82	62,010	483,747	14,400	2,880	563,037	243,300	468,854	712,154	844,192	946,080	313,504	103,874	3,378,967	3,482,841	2,426,366	2,530,240	
3/18/2012	696.55	61,680	483,747	14,400	2,880	562,707	243,760	468,854	712,614	853,632	948,928	316,272	101,616	3,394,153	3,495,769	2,441,552	2,543,168	
3/19/2012	737.05	61,750	483,747	14,400	2,880	562,777	242,700	468,854	711,554	854,640	948,352	315,488	102,510	3,392,811	3,495,321	2,440,210	2,542,720	
3/20/2012	654.64	60,470	483,747	14,400	2,880	561,497	240,360	468,854	709,214	851,952	937,152	307,568	103,554	3,367,383	3,470,937	2,414,782	2,518,336	
3/21/2012	740.29	61,900	483,747	14,400	2,880	562,927	243,100	468,854	711,954	861,184	947,712	313,120	101,944	3,396,897	3,498,841	2,444,296	2,546,240	
3/22/2012	646.07	342,470	483,747	14,400	2,880	843,497	204,528	390,712	595,240	857,712	481,664	288,640	120,026	3,066,753	3,186,779	2,192,294	2,312,320	UF cleaning.
3/23/2012	342.38	290,286	483,747	14,400	2,880	791,313	199,472	390,712	590,184	838,352	418,128	281,344	122,242	2,919,321	3,041,563	2,044,862	2,167,104	UF cleaning.
3/24/2012	666.30	61,870	483,747	14,400	2,880	562,897	244,072	468,854	712,926	863,200	951,312	316,248	104,450	3,406,583	3,511,033	2,453,982	2,558,432	
3/25/2012	667.90	62,270	483,747	14,400	2,880	563,297	240,536	468,854	709,390	862,176	951,456	314,352	102,874	3,400,671	3,503,545	2,448,070	2,550,944	
3/26/2012	641.09	61,270	483,747	14,400	2,880	562,297	243,652	468,854	712,506	861,856	950,256	317,288	103,150	3,404,203	3,507,353	2,451,602	2,554,752	
3/27/2012	638.37	58,050	483,747	14,400	2,880	559,077	239,012	468,854	707,866	832,736	935,792	297,136	96,602	3,332,607	3,429,209	2,380,006	2,476,608	
3/28/2012	658.41	52,700	483,747	14,400	2,880	553,727	244,640	468,854	713,494	871,072	1,024,640	314,856	114,428	3,477,789	3,592,217	2,525,188	2,639,616	
3/29/2012	691.55	52,310	483,747	14,400	2,880	553,337	243,768	468,854	712,622	870,432	1,019,616	319,552	113,522	3,475,559	3,589,081	2,522,958	2,636,480	
3/30/2012	737.82	56,210	483,747	14,400	2,880	557,237	233,552	468,854	702,406	779,840	914,912	286,456	98,470	3,240,851	3,339,321	2,288,250	2,386,720	
3/31/2012	703.09	59,140	483,747	14,400	2,880	560,167	240,368	468,854	709,222	863,152	1,024,384	304,200	98,932	3,461,125	3,560,057	2,508,524	2,607,456	
TOTAL (kW-hr)		**2,277**	**14,996**	**446**	**89**	**17,809**	**7,342**	**14,124**	**21,466**	**24,706**	**26,606**	**8,896**	**3,308**	**99,484**	**102,792**	**70,363**	**73,672**	
AVERAGE (kW-hr/MG)		**139**	**913**	**27**	**5**	**1,084**	**460**	**885**	**1,344**	**1,594**	**1,717**	**287**	**107**	**3,209**	**3,316**	**2,270**	**2,377**	

City of San Diego
Indirect Potable Reuse/Reservoir Augmentation Demonstration Project
Advanced Water Purification Facility
Demonstration Facility Power Consumption - With MF/UF Feed Pumping Power Consumption Measured from EDR Feed Pump

		Power Monitor	Calculated	*Calculated*	*Calculated*	*Calculated*	Power Monitor	*Calculated*	*Calculated*	Power Monitor	Power Monitor	Power Monitor	*Calculated*	*Calculated*	*Calculated*	*Calculated*	Power Monitor	
		Total Daily Power Consumption (W-hr) (April 2012)																
Date	**Purified Water Flow (gpm)**	**MF Power Monitor (a)**	**MF Feed Pumping (b)**	**MF Control Panel (c)**	**MF Air Dryer (d)**	**Total MF (e) = (a)+(b)+(c)+(d)**	**UF Power Monitor (f)**	**UF Feed Pumping (g)**	**Total UF (h) = (f)+(g)**	**RO Train A Power Monitor (i)**	**RO Train B Power Monitor (j)**	**UV/AOP Power Monitor (k)**	**Ancillary Loads (l) = (p)-(o)**	**Total AWPF Processes Including MF/UF Feed Pumping (m) = (e)+(h)+(i)+(j)+(k)**	**Total AWPF Including MF/UF Feed Pumping (n) = (p)+(b)+(g)**	**Total AWPF Process without MF/UF Feed Pumping (o) = (m)-(b)-(g)**	**Total AWPF without MF/UF Feed Pumping (Main Power Monitor) (p)**	**Comments**
4/1/2012	709.80	62,050	483,747	14,400	2,880	563,077	244,100	468,854	712,954	863,680	1,085,504	317,360	105,898	3,542,575	3,648,473	2,589,974	2,695,872	
4/2/2012	785.51	61,870	483,747	14,400	2,880	562,897	243,040	468,854	711,894	860,768	1,043,136	316,728	108,730	3,495,423	3,604,153	2,542,822	2,651,552	
4/3/2012	683.45	61,770	483,747	14,400	2,880	562,797	240,892	468,854	709,746	860,272	1,057,616	315,192	109,378	3,505,623	3,615,001	2,553,022	2,662,400	
4/4/2012	685.26	238,810	483,747	14,400	2,880	739,837	238,968	468,854	707,822	836,208	1,028,688	307,040	103,438	3,619,595	3,723,033	2,666,994	2,770,432	
4/5/2012	695.09	182,990	483,747	14,400	2,880	684,017	244,872	468,854	713,726	685,936	981,968	306,192	101,082	3,371,839	3,472,921	2,419,238	2,520,320	
4/6/2012	772.50	105,050	483,747	14,400	2,880	606,077	236,208	468,854	705,062	772,480	893,552	286,088	97,502	3,263,259	3,360,761	2,310,658	2,408,160	
4/7/2012	712.52	62,060	483,747	14,400	2,880	563,087	242,280	468,854	711,134	849,232	1,036,224	312,176	106,828	3,471,853	3,578,681	2,519,252	2,626,080	
4/8/2012	714.10	62,600	483,747	14,400	2,880	563,627	245,368	468,854	714,222	846,288	1,037,232	311,976	105,016	3,473,345	3,578,361	2,520,744	2,625,760	
4/9/2012	685.09	62,090	483,747	14,400	2,880	563,117	243,840	468,854	712,694	839,232	1,023,536	312,296	106,686	3,450,875	3,557,561	2,498,274	2,604,960	
4/10/2012	703.56	62,340	483,747	14,400	2,880	563,367	243,192	468,854	712,046	840,304	1,009,312	308,448	102,836	3,433,477	3,536,313	2,480,876	2,583,712	
4/11/2012	779.18	62,040	483,747	14,400	2,880	563,067	245,632	468,854	714,486	842,048	1,007,008	305,584	104,920	3,432,193	3,537,113	2,479,592	2,584,512	
4/12/2012	673.57	62,850	483,747	14,400	2,880	563,877	245,256	468,854	714,110	839,728	1,002,528	306,104	100,846	3,426,347	3,527,193	2,473,746	2,574,592	
4/13/2012	751.96	56,920	483,747	14,400	2,880	557,947	235,712	468,854	704,566	753,232	900,544	272,400	95,528	3,188,689	3,284,217	2,236,088	2,331,616	
4/14/2012	719.99	61,990	483,747	14,400	2,880	563,017	243,560	468,854	712,414	847,840	1,010,224	307,696	101,842	3,441,191	3,543,033	2,488,590	2,590,432	
4/15/2012	750.11	61,800	483,747	14,400	2,880	562,827	246,060	468,854	714,914	846,368	1,006,304	315,624	103,812	3,446,037	3,549,849	2,493,436	2,597,248	
4/16/2012	677.57	598,720	483,747	14,400	2,880	1,099,747	245,692	468,854	714,546	441,216	991,952	301,160	145,708	3,548,621	3,694,329	2,596,020	2,741,728	RO A offline for approximately 12 hours for cleaning; Extra power usage at MF due to heating CIP water
4/17/2012	384.99	462,370	483,747	14,400	2,880	963,397	244,200	468,854	713,054	286,368	990,336	303,840	131,670	3,256,995	3,388,665	2,304,394	2,436,064	RO A offline for approximately 15 hours for cleaning; Extra power usage at MF due to heating CIP water
4/18/2012	643.70	297,120	423,279	12,600	2,520	735,519	230,128	410,247	640,375	293,888	349,072	110,408	696,264	2,129,262	2,825,526	1,295,736	1,992,000	All systems offline for approx. 3 hours; RO B offline for approximately 16 hours for cleaning; Extra power usage at MF due to heating CIP water
4/19/2012	326.57	125,610	483,747	14,400	2,880	626,637	243,808	468,854	712,662	840,291	445,648	303,684	67,135	2,928,922	2,996,057	1,976,321	2,043,456	RO B offline for approximately 12 hours for cleaning; Extra power usage at MF due to heating CIP water. Power total for RO A not available, usage estimated based on runtime and typical power usage.
4/20/2012	685.96	55,680	423,279	12,600	2,520	494,079	234,452	410,247	644,699	735,254	832,384	283,008	60,038	2,989,424	3,049,462	2,155,898	2,215,936	All systems offline for approximately 3 hours. Power total for RO A not available, usage estimated based on runtime and typical power usage.
4/21/2012	708.89	61,880	483,747	14,400	2,880	562,907	243,932	468,854	712,786	840,291	939,776	319,488	45,545	3,375,248	3,420,793	2,422,647	2,468,192	Power total for RO A not available, usage estimated based on runtime and typical power usage.
4/22/2012	608.97	58,080	443,435	13,200	2,640	517,355	239,948	429,783	669,731	770,267	882,080	300,768	65,913	3,140,201	3,206,114	2,266,983	2,332,896	All systems offline for approximately 2 hours. Power total for RO A not available, usage estimated based on runtime and typical power usage.
4/23/2012	681.64	61,180	483,747	14,400	2,880	562,207	244,188	468,854	713,042	840,291	907,808	316,152	39,853	3,339,500	3,379,353	2,386,899	2,426,752	Power total for RO A not available, usage estimated based on runtime and typical power usage.
4/24/2012	562.18	56,560	423,279	12,600	2,520	494,959	233,512	410,247	643,759	735,254	779,120	275,896	55,322	2,928,988	2,984,310	2,095,462	2,150,784	All systems offline for approximately 3 hours. Power total for RO A not available, usage estimated based on runtime and typical power usage.
4/25/2012	656.22	62,030	483,747	14,400	2,880	563,057	243,392	468,854	712,246	778,624	874,640	302,256	98,482	3,230,823	3,329,305	2,278,222	2,376,704	Power total for RO A not available, usage estimated based on runtime and typical power usage.
4/26/2012	649.71	61,520	483,747	14,400	2,880	562,547	243,048	468,854	711,902	778,928	876,576	300,992	100,472	3,230,945	3,331,417	2,278,344	2,378,816	
4/27/2012	737.47	53,739	423,279	12,600	2,520	492,138	213,289	410,247	623,536	689,618	774,470	280,018	78,343	2,859,780	2,938,123	2,026,254	2,104,597	All systems offline for approximately 3 hours. Power totals not available. Usage estimated based on runtime and typical power usage.
4/28/2012	686.76	61,540	483,747	14,400	2,880	562,567	243,428	468,854	712,282	780,128	876,480	315,912	98,832	3,247,369	3,346,201	2,294,768	2,393,600	
4/29/2012	710.65	60,930	483,747	14,400	2,880	561,957	242,632	468,854	711,486	780,528	877,488	345,992	101,582	3,277,451	3,379,033	2,324,850	2,426,432	
4/30/2012	677.13	56,930	463,591	13,800	2,760	537,081	240,312	449,319	689,631	745,024	823,552	327,069	102,233	3,122,357	3,224,590	2,209,447	2,311,680	All systems offline for approximately 1 hour
TOTAL (kW-hr)		**3,401**	**14,210**	**423**	**85**	**18,119**	**7,225**	**13,773**	**20,998**	**22,720**	**27,345**	**8,988**	**3,442**	**98,168**	**101,610**	**70,186**	**73,627**	
AVERAGE (kW-hr/MG)		**218**	**913**	**27**	**5**	**1,164**	**464**	**885**	**1,349**	**1,608**	**1,894**	**306**	**117**	**3,342**	**3,459**	**2,389**	**2,506**	

City of San Diego
Indirect Potable Reuse/Reservoir Augmentation Demonstration Project
Advanced Water Purification Facility
Demonstration Facility Power Consumption - With MF/UF Feed Pumping Power Consumption Measured from EDR Feed Pump

		Power Monitor	Calculated	*Calculated*	*Calculated*	*Calculated*	Power Monitor	*Calculated*	*Calculated*	Power Monitor	Power Monitor	Power Monitor	*Calculated*	*Calculated*	*Calculated*	*Calculated*	Power Monitor	
		Total Daily Power Consumption (W-hr) (May 2012)																
Date	**Purified Water Flow (gpm)**	**MF Power Monitor (a)**	**MF Feed Pumping (b)**	**MF Control Panel (c)**	**MF Air Dryer (d)**	**Total MF (e) = (a)+(b)+(c)+(d)**	**UF Power Monitor (f)**	**UF Feed Pumping (g)**	**Total UF (h) = (f)+(g)**	**RO Train A Power Monitor (i)**	**RO Train B Power Monitor (j)**	**UV/AOP Power Monitor (k)**	**Ancillary Loads (l) = (p)-(o)**	**Total AWPF Processes Including MF/UF Feed Pumping (m) = (e)+(h)+(i)+(j)+(k)**	**Total AWPF Including MF/UF Feed Pumping (n) = (p)+(b)+(g)**	**Total AWPF Process without MF/UF Feed Pumping (o) = (m)-(b)-(g)**	**Total AWPF without MF/UF Feed Pumping (Main Power Monitor) (p)**	**Comments**
5/1/2012	691.82	61,470	483,747	14,400	2,880	562,497	244,000	468,854	712,854	775,296	874,272	318,192	100,978	3,243,111	3,344,089	2,290,510	2,391,488	
5/2/2012	696.28	61,360	483,747	14,400	2,880	562,387	242,880	468,854	711,734	777,760	879,024	359,032	100,872	3,289,937	3,390,809	2,337,336	2,438,208	
5/3/2012	693.84	61,380	483,747	14,400	2,880	562,407	244,888	468,854	713,742	773,072	874,992	357,496	100,108	3,281,709	3,381,817	2,329,108	2,429,216	
5/4/2012	745.35	56,910	443,435	13,200	2,640	516,185	237,040	429,783	666,823	686,048	794,784	314,104	95,210	2,977,944	3,073,154	2,104,726	2,199,936	All systems offline for approxmiately 2 hours
5/5/2012	720.72	60,830	483,747	14,400	2,880	561,857	243,480	468,854	712,334	771,648	875,664	293,872	98,890	3,215,375	3,314,265	2,262,774	2,361,664	
5/6/2012	735.24	61,460	483,747	14,400	2,880	562,487	245,480	468,854	714,334	772,912	879,472	290,848	99,268	3,220,053	3,319,321	2,267,452	2,366,720	
5/7/2012	698.04	35,826	282,186	8,400	1,680	328,092	142,193	273,498	415,691	459,745	516,313	186,679	52,229	1,906,520	1,958,749	1,350,836	1,403,065	All sytems offline for approximately 10 hours. Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
5/8/2012	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	All systems offline all day
5/9/2012	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	All systems offline all day
5/10/2012	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	All systems offline all day
5/11/2012	383.26	38,385	302,342	9,000	1,800	351,527	152,349	293,034	445,383	492,584	553,193	200,013	55,960	2,042,700	2,098,660	1,447,324	1,503,284	All systems offline for approximately 9 hours. Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
5/12/2012	688.36	62,740	483,747	14,400	2,880	563,767	198,680	468,854	667,534	766,224	872,080	296,536	100,060	3,166,141	3,266,201	2,213,540	2,313,600	
5/13/2012	738.32	62,110	483,747	14,400	2,880	563,137	198,380	468,854	667,234	764,800	873,264	295,544	99,150	3,163,979	3,263,129	2,211,378	2,310,528	
5/14/2012	700.96	61,930	483,747	14,400	2,880	562,957	197,780	468,854	666,634	759,328	871,808	295,680	99,170	3,156,407	3,255,577	2,203,806	2,302,976	
5/15/2012	680.77	62,560	483,747	14,400	2,880	563,587	192,988	468,854	661,842	762,288	876,864	296,528	100,036	3,161,109	3,261,145	2,208,508	2,308,544	
5/16/2012	694.54	62,900	483,747	14,400	2,880	563,927	193,944	468,854	662,798	762,416	873,760	293,104	101,556	3,156,005	3,257,561	2,203,404	2,304,960	
5/17/2012	667.47	55,960	483,747	14,400	2,880	556,987	190,600	468,854	659,454	719,248	789,808	264,656	95,856	2,990,153	3,086,009	2,037,552	2,133,408	
5/18/2012	688.49	55,824	483,747	14,400	2,880	556,851	172,125	468,854	640,979	676,644	775,462	260,130	88,187	2,910,067	2,998,253	1,957,465	2,045,652	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
5/19/2012	687.87	62,310	483,747	14,400	2,880	563,337	197,904	468,854	666,758	817,312	875,584	293,264	97,146	3,216,255	3,313,401	2,263,654	2,360,800	
5/20/2012	706.77	62,170	483,747	14,400	2,880	563,197	193,216	468,854	662,070	814,192	868,608	292,896	98,678	3,200,963	3,299,641	2,248,362	2,347,040	
5/21/2012	714.98	61,940	483,747	14,400	2,880	562,967	200,144	468,854	668,998	811,200	864,240	297,432	99,220	3,204,837	3,304,057	2,252,236	2,351,456	
5/22/2012	737.93	62,300	483,747	14,400	2,880	563,327	196,416	468,854	665,270	818,912	867,536	296,936	100,620	3,211,981	3,312,601	2,259,380	2,360,000	
5/23/2012	694.26	62,270	483,747	14,400	2,880	563,297	196,772	468,854	665,626	820,032	872,080	280,304	96,638	3,201,339	3,297,977	2,248,738	2,345,376	
5/24/2012	674.21	61,720	483,747	14,400	2,880	562,747	195,588	468,854	664,442	819,472	871,952	292,352	99,652	3,210,965	3,310,617	2,258,364	2,358,016	
5/25/2012	684.48	54,280	423,279	12,600	2,520	492,679	197,612	410,247	607,859	710,544	679,152	237,944	87,940	2,728,178	2,816,118	1,894,652	1,982,592	All systems offline for ~3 hours; ROB and UV offline for ~5 hours
5/26/2012	679.13		483,747	14,400	2,880	501,027		468,854	468,854				-17,280	969,881	952,601	17,280		
5/27/2012	376.72	35,810	262,030	7,800	1,560	307,200	180,680	253,963	434,643	442,816	479,568	164,312	82,878	1,828,538	1,911,416	1,312,546	1,395,424	All systems offline for ~11 hours
5/28/2012	49.76	50,058	382,967	11,400	2,280	446,705	154,347	371,176	525,523	606,756	695,367	233,262	80,894	2,507,613	2,588,507	1,753,470	1,834,364	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period. All systems offline ~ 5 hours.
5/29/2012	686.71	50,058	382,967	11,400	2,280	446,705	154,347	371,176	525,523	606,756	695,367	233,262	80,894	2,507,613	2,588,507	1,753,470	1,834,364	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period. All systems offline ~ 5 hours.
5/30/2012	682.85	231,900	483,747	14,400	2,880	732,927	188,780	468,854	657,634	786,720	872,080	306,656	99,208	3,356,017	3,455,225	2,403,416	2,502,624	Extra power usage on MF due to heating of water for UF CIP
5/31/2012	663.21	285,150	483,747	14,400	2,880	786,177	177,068	214,891	391,959	364,800	853,488	279,184	136,214	2,675,609	2,811,823	1,976,970	2,113,184	UF and ROA offline for ~13 hours due to UF cleaning; Extra power usage on MF due to heating of water for UF CIP
TOTAL (kW-hr)		**1,942**	**12,638**	**376**	**75**	**15,031**	**5,330**	**11,995**	**17,325**	**19,140**	**21,676**	**7,530**	**2,530**	**80,701**	**83,231**	**56,068**	**58,598**	
AVERAGE (kW-hr/MG)		**140**	**913**	**27**	**5**	**1,086**	**393**	**885**	**1,278**	**1,496**	**1,665**	**289**	**97**	**3,099**	**3,196**	**2,153**	**2,250**	

City of San Diego
Indirect Potable Reuse/Reservoir Augmentation Demonstration Project
Advanced Water Purification Facility
Demonstration Facility Power Consumption - With MF/UF Feed Pumping Power Consumption Measured from EDR Feed Pump

		Power Monitor	Calculated	*Calculated*	*Calculated*	*Calculated*	Power Monitor	*Calculated*	*Calculated*	Power Monitor	Power Monitor	Power Monitor	*Calculated*	*Calculated*	*Calculated*	*Calculated*	Power Monitor	
		Total Daily Power Consumption (W-hr) (June 2012)																
Date	**Purified Water Flow (gpm)**	**MF Power Monitor (a)**	**MF Feed Pumping (b)**	**MF Control Panel (c)**	**MF Air Dryer (d)**	**Total MF (e) = (a)+(b)+(c)+(d)**	**UF Power Monitor (f)**	**UF Feed Pumping (g)**	**Total UF (h) = (f)+(g)**	**RO Train A Power Monitor (i)**	**RO Train B Power Monitor (j)**	**UV/AOP Power Monitor (k)**	**Ancillary Loads (l) = (p)-(o)**	**Total AWPF Processes Including MF/UF Feed Pumping (m) = (e)+(h)+(i)+(j)+(k)**	**Total AWPF Including MF/UF Feed Pumping (n) = (p)+(b)+(g)**	**Total AWPF Process without MF/UF Feed Pumping (o) = (m)-(b)-(g)**	**Total AWPF without MF/UF Feed Pumping (Main Power Monitor) (p)**	**Comments**
6/1/2012	346.82	199,139	483,747	14,400	2,880	700,166	171,593	468,854	640,447	692,067	844,410	270,463	84,614	3,147,553	3,232,167	2,194,951	2,279,565	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
6/2/2012	685.87	61,680	483,747	14,400	2,880	562,707	195,472	468,854	664,326	789,280	882,624	306,784	98,816	3,205,721	3,304,537	2,253,120	2,351,936	
6/3/2012	707.57	61,660	483,747	14,400	2,880	562,687	192,328	468,854	661,182	784,432	888,944	307,104	105,532	3,204,349	3,309,881	2,251,748	2,357,280	
6/4/2012	694.28	62,040	483,747	14,400	2,880	563,067	191,472	468,854	660,326	780,416	887,264	306,912	93,976	3,197,985	3,291,961	2,245,384	2,339,360	
6/5/2012	695.82	61,440	483,747	14,400	2,880	562,467	192,840	468,854	661,694	780,752	924,640	306,632	99,264	3,236,185	3,335,449	2,283,584	2,382,848	
6/6/2012	693.39	225,440	483,747	14,400	2,880	726,467	194,256	468,854	663,110	783,472	955,936	306,184	98,072	3,435,169	3,533,241	2,482,568	2,580,640	Extra power usage on MF due to heating water for ROB CIP
6/7/2012	700.85	206,870	141,093	4,200	840	353,003	193,672	468,854	662,526	771,984	287,168	178,672	102,482	2,253,353	2,355,835	1,643,406	1,745,888	MF and ROB offline for ~17 hours, UV offline for ~9 hours; Extra power usage on MF due to heating water for ROB CIP
6/8/2012	365.15	94,873	201,561	6,000	1,200	303,634	81,749	195,356	277,105	329,711	402,290	128,852	41,344	1,441,593	1,482,937	1,044,675	1,086,019	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period. All systems offline ~ 14 hours.
6/9/2012	691.19	61,360	483,747	14,400	2,880	562,387	195,800	468,854	664,654	768,512	914,272	289,416	99,536	3,199,241	3,298,777	2,246,640	2,346,176	
6/10/2012	716.41	62,080	483,747	14,400	2,880	563,107	192,720	468,854	661,574	760,928	906,752	297,752	99,320	3,190,113	3,289,433	2,237,512	2,336,832	
6/11/2012	697.37	57,680	443,435	13,200	2,640	516,955	192,160	429,783	621,943	709,040	847,584	278,160	97,680	2,973,682	3,071,362	2,100,464	2,198,144	All systems offline for ~2 hours
6/12/2012	487.45	44,900	342,654	10,200	2,040	399,794	186,976	332,105	519,081	538,336	643,904	193,656	87,924	2,294,771	2,382,695	1,620,012	1,707,936	All systems offline for ~7 hours
6/13/2012	709.75	62,400	483,747	14,400	2,880	563,427	195,144	468,854	663,998	760,880	911,040	293,600	98,536	3,192,945	3,291,481	2,240,344	2,338,880	
6/14/2012	764.56	61,500	483,747	14,400	2,880	562,527	197,608	468,854	666,462	765,648	918,464	294,976	98,220	3,208,077	3,306,297	2,255,476	2,353,696	
6/15/2012	664.89	43,190	342,654	10,200	2,040	398,084	140,856	332,105	472,961	530,512	637,696	203,840	80,306	2,243,093	2,323,399	1,568,334	1,648,640	All systems offline for ~7 hours
6/16/2012	704.58	63,030	483,747	14,400	2,880	564,057	194,096	468,854	662,950	762,384	915,008	289,344	100,746	3,193,743	3,294,489	2,241,142	2,341,888	
6/17/2012	712.99	63,070	483,747	14,400	2,880	564,097	198,912	468,854	667,766	758,896	912,224	290,128	101,634	3,193,111	3,294,745	2,240,510	2,342,144	
6/18/2012	672.25	62,910	423,279	12,600	2,520	501,309	195,512	410,247	605,759	743,760	869,216	286,992	105,050	3,007,036	3,112,086	2,173,510	2,278,560	
6/19/2012	684.73	27,660	201,561	6,000	1,200	236,421	175,960	195,356	371,316	311,440	370,368	125,976	80,916	1,415,521	1,496,437	1,018,604	1,099,520	All systems offline for ~14 hours due to leak at chlorine pump
6/20/2012	487.38	44,850	282,186	8,400	1,680	337,116	185,944	273,498	459,442	540,592	639,200	212,632	94,734	2,188,982	2,283,716	1,633,298	1,728,032	All systems offline for ~7 hours due to leak at chlorine pump
6/21/2012	733.28	62,110	483,747	14,400	2,880	563,137	198,024	468,854	666,878	758,400	902,496	293,648	104,042	3,184,559	3,288,601	2,231,958	2,336,000	
6/22/2012	737.44	52,960	403,123	12,000	2,400	470,483	191,312	390,712	582,024	632,768	748,832	254,056	96,872	2,688,163	2,785,035	1,894,328	1,991,200	All systems offline for ~4 hours
6/23/2012	676.15	52,794	403,123	12,000	2,400	470,316	168,320	390,712	559,032	644,640	767,122	249,601	88,724	2,690,711	2,779,435	1,896,876	1,985,600	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period. All systems offline ~4 hours.
6/24/2012	2.64	4,710	0	0	0	4,710	161,752	0	161,752	4,320	3,904	11,736	68,170	186,422	254,592	186,422	254,592	All systems offline all day
6/25/2012	27.66	26,080	181,405	5,400	1,080	213,965	173,080	175,820	348,900	272,048	317,600	114,584	80,944	1,267,098	1,348,042	909,872	990,816	All systems offline for ~15 hours
6/26/2012	665.22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Power Outage plant shutdown
6/27/2012	685.98	61,690	483,747	14,400	2,880	562,717	195,016	468,854	663,870	754,192	888,736	299,000	102,966	3,168,515	3,271,481	2,215,914	2,318,880	
6/28/2012	694.48	61,270	483,747	14,400	2,880	562,297	196,408	468,854	665,262	753,328	888,032	298,856	100,058	3,167,775	3,267,833	2,215,174	2,315,232	
6/29/2012	715.90	53,739	423,279	12,600	2,520	492,138	172,266	410,247	582,514	660,731	778,878	262,122	87,795	2,776,382	2,864,178	1,942,856	2,030,651	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period. All systems offline ~3 hours for maintenance.
6/30/2012	686.19	53,739	423,279	12,600	2,520	492,138	172,266	410,247	582,514	660,731	778,878	262,122	87,795	2,776,382	2,864,178	1,942,856	2,030,651	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period. All systems offline ~3 hours for maintenance.
TOTAL (kW-hr)		**2,057**	**11,469**	**341**	**68**	**13,935**	**5,294**	**11,448**	**16,741**	**18,804**	**21,633**	**7,214**	**2,686**	**78,328**	**81,014**	**55,412**	**58,098**	
AVERAGE (kW-hr/MG)		**164**	**913**	**27**	**5**	**1,109**	**409**	**885**	**1,294**	**1,615**	**1,825**	**300**	**112**	**3,258**	**3,370**	**2,305**	**2,417**	

City of San Diego
Indirect Potable Reuse/Reservoir Augmentation Demonstration Project
Advanced Water Purification Facility
Demonstration Facility Power Consumption - With MF/UF Feed Pumping Power Consumption Measured from EDR Feed Pump

		Power Monitor	Calculated	*Calculated*	*Calculated*	*Calculated*	Power Monitor	*Calculated*	*Calculated*	Power Monitor	Power Monitor	Power Monitor	*Calculated*	*Calculated*	*Calculated*	*Calculated*	Power Monitor	
		Total Daily Power Consumption (W-hr) (July 2012)																
Date	**Purified Water Flow (gpm)**	**MF Power Monitor (a)**	**MF Feed Pumping (b)**	**MF Control Panel (c)**	**MF Air Dryer (d)**	**Total MF (e) = (a)+(b)+(c)+(d)**	**UF Power Monitor (f)**	**UF Feed Pumping (g)**	**Total UF (h) = (f)+(g)**	**RO Train A Power Monitor (i)**	**RO Train B Power Monitor (j)**	**UV/AOP Power Monitor (k)**	**Ancillary Loads (l) = (p)-(o)**	**Total AWPF Processes Including MF/UF Feed Pumping (m) = (e)+(h)+(i)+(j)+(k)**	**Total AWPF Including MF/UF Feed Pumping (n) = (p)+(b)+(g)**	**Total AWPF Process without MF/UF Feed Pumping (o) = (m)-(b)-(g)**	**Total AWPF without MF/UF Feed Pumping (Main Power Monitor) (p)**	**Comments**
7/1/2012	686.30	61,530	443,435	13,200	2,640	520,805	196,080	429,783	625,863	748,160	890,592	305,432	103,774	3,090,852	3,194,626	2,217,634	2,321,408	Shutdown for ~2hrs due to pump failure.
7/2/2012	683.71	61,110	483,747	14,400	2,880	562,137	201,600	468,854	670,454	745,968	887,264	303,472	104,778	3,169,295	3,274,073	2,216,694	2,321,472	
7/3/2012	626.00	56,419	443,435	13,200	2,640	515,694	180,859	429,783	610,642	693,690	817,729	275,197	92,209	2,912,952	3,005,161	2,039,734	2,131,943	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period. All systems offline ~2 hours.
7/4/2012	685.74	61,200	483,747	14,400	2,880	562,227	193,360	468,854	662,214	751,520	894,976	894,976	-	3,765,913	3,270,681	2,813,312	2,318,080	
7/5/2012	757.62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Plant shutdown due to pump failures & EDR exercises
7/6/2012		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Plant shutdown all weekend due to comm. Failures
7/7/2012		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Plant shutdown all weekend due to comm. Failures
7/8/2012		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Plant shutdown all weekend due to comm. Failures
7/9/2012		39,430	0	0	0	39,430	185,136	0	185,136	457,504	540,192	540,192	-	1,762,454	1,512,256	1,762,454	1,512,256	Plant shutdown all weekend due to comm. Failures
7/10/2012	742.63	55,610	483,747	14,400	2,880	556,637	193,720	468,854	662,574	665,296	774,976	774,976	-	3,434,459	3,029,017	2,481,858	2,076,416	
7/11/2012	714.10	61,120	483,747	14,400	2,880	562,147	197,656	468,854	666,510	738,112	861,312	296,784	103,768	3,124,865	3,228,633	2,172,264	2,276,032	
7/12/2012	761.65	61,480	483,747	14,400	2,880	562,507	196,784	468,854	665,638	739,328	866,816	294,720	104,936	3,129,009	3,233,945	2,176,408	2,281,344	
7/13/2012	682.49	56,229	483,747	14,400	2,880	557,256	179,975	468,854	648,830	676,177	792,775	269,546	94,497	2,944,584	3,039,081	1,991,982	2,086,479	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
7/14/2012	686.46	56,229	483,747	14,400	2,880	557,256	179,975	468,854	648,830	676,177	792,775	269,546	94,497	2,944,584	3,039,081	1,991,982	2,086,479	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
7/15/2012	685.26	60,740	483,747	14,400	2,880	561,767	198,480	468,854	667,334	736,368	858,240	293,688	100,804	3,117,397	3,218,201	2,164,796	2,265,600	
7/16/2012	673.47	60,350	483,747	14,400	2,880	561,377	197,352	468,854	666,206	738,448	860,032	292,096	99,210	3,118,159	3,217,369	2,165,558	2,264,768	
7/17/2012	717.20	61,350	483,747	14,400	2,880	562,377	196,960	468,854	665,814	746,112	870,400	294,984	99,506	3,139,687	3,239,193	2,187,086	2,286,592	
7/18/2012	738.82	60,480	483,747	14,400	2,880	561,507	193,464	468,854	662,318	748,800	874,368	296,856	104,688	3,143,849	3,248,537	2,191,248	2,295,936	
7/19/2012	673.81	55,550	483,747	14,400	2,880	556,577	189,304	468,854	658,158	675,040	786,144	268,320	101,418	2,944,239	3,045,657	1,991,638	2,093,056	
7/20/2012	727.18	60,900	483,747	14,400	2,880	561,927	193,320	468,854	662,174	743,360	865,920	294,632	102,156	3,128,013	3,230,169	2,175,412	2,277,568	
7/21/2012	684.05	60,900	483,747	14,400	2,880	561,927	193,320	468,854	662,174	743,360	865,920	294,632	102,156	3,128,013	3,230,169	2,175,412	2,277,568	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
7/22/2012	684.88	61,300	483,747	14,400	2,880	562,327	197,592	468,854	666,446	743,776	876,040	293,424	93,852	3,142,013	3,235,865	2,189,412	2,283,264	
7/23/2012	712.83	60,420	483,747	14,400	2,880	561,447	194,792	468,854	663,646	743,328	869,120	291,856	103,140	3,129,397	3,232,537	2,176,796	2,279,936	
7/24/2012	396.00	48,760	382,967	11,400	2,280	445,407	190,976	371,176	562,152	588,160	688,096	231,080	97,424	2,514,895	2,612,319	1,760,752	1,858,176	Plant shutdown ~5 hrs due to pump failure while operator not present
7/25/2012	658.36	60,700	483,747	14,400	2,880	561,727	194,464	468,854	663,318	745,968	878,144	294,824	99,884	3,143,981	3,243,865	2,191,380	2,291,264	
7/26/2012	682.36	60,480	483,747	14,400	2,880	561,507	198,288	468,854	667,142	742,096	871,552	295,184	101,328	3,137,481	3,238,809	2,184,880	2,286,208	
7/27/2012	674.07	56,448	483,747	14,400	2,880	557,475	185,069	468,854	653,923	692,623	813,449	275,505	93,421	2,992,975	3,086,396	2,040,373	2,133,794	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
7/28/2012	684.54	56,448	483,747	14,400	2,880	557,475	185,069	468,854	653,923	692,623	813,449	275,505	93,421	2,992,975	3,086,396	2,040,373	2,133,794	Power totals not available. Values estimated based on runtime and typical power usage for 24 hour period.
7/29/2012	684.37	60,620	483,747	14,400	2,880	561,647	196,928	468,854	665,782	737,920	863,840	293,712	99,908	3,122,901	3,222,809	2,170,300	2,270,208	
7/30/2012	652.18	60,270	483,747	14,400	2,880	561,297	198,392	468,854	667,246	735,520	862,400	291,488	100,058	3,117,951	3,218,009	2,165,350	2,265,408	
7/31/2012	724.27	60,780	483,747	14,400	2,880	561,807	201,760	468,854	670,614	734,832	861,920	289,488	99,668	3,118,661	3,218,329	2,166,060	2,265,728	
TOTAL (kW-hr)		**1,577**	**12,396**	**369**	**74**	**14,416**	**5,211**	**12,014**	**17,225**	**19,180**	**22,498**	**9,092**	**2,390**	**82,412**	**83,651**	**58,001**	**59,241**	
AVERAGE (kW-hr/MG)		**116**	**913**	**27**	**5**	**1,061**	**384**	**885**	**1,268**	**1,497**	**1,756**	**355**	**93**	**3,216**	**3,264**	**2,263**	**2,312**	

City of San Diego
Indirect Potable Reuse/Reservoir Augmentation Demonstration Project
Advanced Water Purification Facility
Demonstration Facility Power Consumption - With MF/UF Feed Pumping Power Consumption Measured from EDR Feed Pump

		Power Monitor	Calculated	*Calculated*	*Calculated*	*Calculated*	Power Monitor	*Calculated*	*Calculated*	Power Monitor	Power Monitor	Power Monitor	*Calculated*	*Calculated*	*Calculated*	*Calculated*	Power Monitor	
		Total Monthly Power Consumption (kW-hr/month)																
Date	**Purified Water Flow (gpm)**	**MF Power Monitor (a)**	**MF Feed Pumping (b)**	**MF Control Panel (c)**	**MF Air Dryer (d)**	**Total MF (e) = (a)+(b)+(c)+(d)**	**UF Power Monitor (f)**	**UF Feed Pumping (g)**	**Total UF (h) = (f)+(g)**	**RO Train A Power Monitor (i)**	**RO Train B Power Monitor (j)**	**UV/AOP Power Monitor (k)**	**Ancillary Loads (l) = (p)-(o)**	**Total AWPF Processes Including MF/UF Feed Pumping (m) = (e)+(h)+(i)+(j)+(k)**	**Total AWPF Including MF/UF Feed Pumping (n) = (p)+(b)+(g)**	**Total AWPF Process without MF/UF Feed Pumping (o) = (m)-(b)-(g)**	**Total AWPF without MF/UF Feed Pumping (Main Power Monitor) (p)**	**Comments**
Aug-11		1,621	12,114	361	72	14,168	3,953	12,190	16,143	14,379	18,086	6,553	0	69,328	0	45,024	0	
Sep-11		1,668	11,449	341	68	13,526	4,027	11,213	15,241	17,180	17,051	5,261	0	68,260	0	45,597	0	
Oct-11		2,438	11,953	356	71	14,818	5,561	13,460	19,021	21,951	22,211	8,619	0	86,619	0	61,206	0	
Nov-11		1,566	12,860	383	77	14,885	5,593	12,464	18,056	21,265	22,443	8,328	0	84,978	0	59,654	0	
Dec-11		1,811	14,271	425	85	16,591	6,337	13,753	20,090	25,762	27,547	8,907	3,179	98,898	102,077	70,874	74,053	
Jan-12		1,720	14,331	427	85	16,563	6,902	13,890	20,791	25,372	27,084	8,797	3,246	98,608	101,855	70,387	73,634	
Feb-12		1,737	13,948	415	83	16,184	7,554	13,519	21,073	25,643	26,880	8,918	3,011	98,698	101,709	71,231	74,242	
Mar-12		2,277	14,996	446	89	17,809	7,342	14,124	21,466	24,706	26,606	8,896	3,308	99,484	102,792	70,363	73,672	
Apr-12		3,401	14,210	423	85	18,119	7,225	13,773	20,998	22,720	27,345	8,988	3,442	98,168	101,610	70,186	73,627	
May-12		1,942	12,638	376	75	15,031	5,330	11,995	17,325	19,140	21,676	7,530	2,530	80,701	83,231	56,068	58,598	
Jun-12		2,057	11,469	341	68	13,935	5,294	11,448	16,741	18,804	21,633	7,214	2,686	78,328	81,014	55,412	58,098	
Jul-12		1,577	12,396	369	74	14,416	5,211	12,014	17,225	19,180	22,498	9,092	2,390	82,412	83,651	58,001	59,241	
TOTAL POWER (kW-hr)		**23,816**	**156,633**	**4,663**	**933**	**186,044**	**70,327**	**153,843**	**224,170**	**256,102**	**281,061**	**97,104**		**1,044,481**		**734,005**		
TOTAL FLOWS TREATED (gallons)		**171,609,583**	**171,609,583**	**171,609,583**	**171,609,583**	**171,609,583**	**173,906,250**	**173,906,250**	**173,906,250**	**161,187,500**	**162,020,833**	**323,708,333**	**323,708,333**	**323,708,333**	**323,708,333**	**323,708,333**	**323,708,333**	
AVERAGE (kW-hr/MG)		**139**	**913**	**27**	**5**	**1,084**	**404**	**885**	**1,289**	**1,589**	**1,735**	**300**		**3,227**		**2,267**		

		Average Power Consumption per Treated Flow (kW-hr/MG)																
Date	**Purified Water Flow (gpm)**	**MF Power Monitor (a)**	**MF Feed Pumping (b)**	**MF Control Panel (c)**	**MF Air Dryer (d)**	**Total MF (e) = (a)+(b)+(c)+(d)**	**UF Power Monitor (f)**	**UF Feed Pumping (g)**	**Total UF (h) = (f)+(g)**	**RO Train A Power Monitor (i)**	**RO Train B Power Monitor (j)**	**UV/AOP Power Monitor (k)**	**Ancillary Loads (l) = (p)-(o)**	**Total AWPF Processes Including MF/UF Feed Pumping (m) = (e)+(h)+(i)+(j)+(k)**	**Total AWPF Including MF/UF Feed Pumping (n) = (p)+(b)+(g)**	**Total AWPF Process without MF/UF Feed Pumping (o) = (m)-(b)-(g)**	**Total AWPF without MF/UF Feed Pumping (Main Power Monitor) (p)**	**Comments**
Aug-11		122	913	27	5	1,067	287	885	1,171	1,150	1,447	262	0	2,773	0	1,801	0	
Sep-11		133	913	27	5	1,078	318	885	1,202	1,516	1,505	243	0	3,150	0	2,104	0	
Oct-11		186	913	27	5	1,132	365	885	1,250	1,644	1,663	323	0	3,243	0	2,292	0	
Nov-11		111	913	27	5	1,056	397	885	1,282	1,600	1,688	313	0	3,197	0	2,244	0	
Dec-11		116	913	27	5	1,061	408	885	1,292	1,764	1,876	305	109	3,386	3,495	2,427	2,535	
Jan-12		110	913	27	5	1,055	440	885	1,324	1,713	1,828	297	110	3,329	3,438	2,376	2,486	
Feb-12		114	913	27	5	1,059	494	885	1,379	1,779	1,865	309	104	3,423	3,527	2,470	2,575	
Mar-12		139	913	27	5	1,084	460	885	1,344	1,594	1,717	287	107	3,209	3,316	2,270	2,377	
Apr-12		218	913	27	5	1,164	464	885	1,349	1,608	1,894	306	117	3,342	3,459	2,389	2,506	
May-12		140	913	27	5	1,086	393	885	1,278	1,496	1,665	289	97	3,099	3,196	2,153	2,250	
Jun-12		164	913	27	5	1,109	409	885	1,294	1,615	1,825	300	112	3,258	3,370	2,305	2,417	
Jul-12		116	913	27	5	1,061	384	885	1,268	1,497	1,756	355	93	3,216	3,264	2,263	2,312	
AVERAGE		**139**	**913**	**27**	**5**	**1,084**	**402**	**885**	**1,286**	**1,581**	**1,727**	**299**	**71**	**3,219**	**3,383**	**2,332**	**2,432**	

LIMNOLOGY AND RESERVOIR DETENTION STUDY OF SAN VICENTE RESERVOIR

INTRODUCTION AND CONTENTS

San Vicente Reservoir (SVR) is located near Lakeside, California, and is used as a source of drinking water supply by the City of San Diego (City), its owner and operator. The reservoir currently has a capacity of about 90,000 acre-feet. It is undergoing an expansion that will raise the dam 117 feet and increase the reservoir's storage capacity to 247,000 acre-feet at the spillway level. The City is considering an option to augment the SVR supply by bringing advanced treated recycled water (*i.e*., purified water) from an advanced water purification facility to SVR. This would be an Indirect Potable Reuse / Reservoir Augmentation (IPR/RA) project. The purified water would be blended with other water in the reservoir. The current project – the Water Purification Demonstration Project (Demonstration Project) – will not actually put any purified water into the reservoir; rather it will study and model the reservoir augmentation process.

A component of the Demonstration Project is the Limnology and Reservoir Detention Study of San Vicente Reservoir (Limnology Study). For the Limnology Study, Flow Science Incorporated (FSI) has employed a numerical three-dimensional water quality model that is used to evaluate hydrodynamic and water quality effects of using purified water to augment SVR. The Limnology Study consists of four technical memoranda or TMs:

- TM #1 – calibration of the model
  (*Reservoir Augmentation Demonstration Project: Limnology and Reservoir Detention Study of San Vicente Reservoir - Calibration of the Water Quality Model, May 1, 2012*)
- TM #2 – hydrodynamic modeling
  (*Water Purification Demonstration Project: Limnology and Reservoir Detention Study of San Vicente Reservoir - Hydrodynamic Modeling Study, May 1, 2012*)
- TM #3 – nutrients and algae modeling results
  (*Water Purification Demonstration Project: Limnology and Reservoir Detention Study of San Vicente Reservoir – Nutrient and Algae Modeling Results, May 1, 2012*)
- TM #4 – proposed water quality monitoring plan
  (*San Vicente Reservoir Proposed Water Quality Monitoring Program, July 10, 2012*)

Flow Science Incorporated (FSI) began by developing [i.e., customizing or tailoring] the three-dimensional water model to conditions at SVR. The model was calibrated using measured data from SVR. After the model was developed its results were compared to existing field data. The results of this analysis were documented in a Technical Memorandum (TM #1) submitted to the City in 2010 and finalized in May 2012 (FSI, 2012a). TM #1 has been peer-reviewed by the National Water Research Institute Independent Advisory Panel (IAP) that was assembled for the review of the City's Demonstration Project. After implementing suggestions proposed by the IAP, the model was deemed by IAP to be "an effective and robust tool, for 1) simulating

thermoclines and hydrodynamics of the San Vicente Reservoir; 2) assessing biological water quality for nutrients; 3) assessing options for the purified water inlet location" (NWRI, 2010).

Upon completion of the SVR model calibration and validation, FSI conducted simulations of purified water delivery to the expanded SVR under various projected future operating conditions using the calibrated and validated model. The simulation results and findings are presented in two separate Technical Memorandums. TM #2 summarizes the hydrodynamic aspects of the modeling results, focusing on density stratification, mixing, and dilution in the reservoir. TM #2 was submitted to the City on November 28, 2011 and finalized in May 2012 (FSI, 2012b). TM #3 focuses on the water quality aspects of the modeling results and findings, with emphasis on nutrients (phosphorus and nitrogen), dissolved oxygen (DO), and algal productivity, and was submitted to the City on February 24, 2012 and finalized in May 2012 (FSI, 2012c). Both TM#2 and TM#3 have been peer-reviewed by the IAP (NWRI, 2012 a, b).

If SVR is augmented by purified water in the future, the three-dimensional model developed for the Limnology Study is expected to provide a tool for evaluating various reservoir management options, assessing residence time and dilution of the purified water within SVR, determining optimal reservoir operations for maximizing water quality, and minimizing any potential short-circuiting between the inlet and outlet. It is expected that the model will be updated on a yearly basis using new data collected each year. In order to update the model and maintain it as a tool for assessing reservoir water quality and operations, data collection in the reservoir, as well as its inflows and outflows, will be needed. TM #4 provides an outline of a reservoir monitoring plan to obtain these necessary data and was submitted to the City on June 21, 2012 and finalized in July 2012 (FSI, 2012d). Another goal of the monitoring plan is to identify monitoring efforts that may be needed to enhance water treatability and address future water quality regulatory issues.

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Flow Science Incorporated (2012c). "Water Purification Demonstration Project: Limnology and Reservoir Detention Study of San Vicente Reservoir – Nutrient and Algae Modeling Results", FSI Project V094005, Pasadena, CA.

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National Water Research Institute (2012b). “Findings and Recommendations of the Limnology and Reservoir Subcommittee Meeting for the Reservoir Augmentation Demonstration Project’s ‘Limnology and Reservoir Detention Study of the San Vicente Reservoir’ ” Memorandum from NWRI Independent Advisory Panel for the City of San Diego’s Indirect Potable Reuse/Reservoir Augmentation Demonstration Project, April 24, 2012.

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Reservoir Augmentation Demonstration Project: Limnology and Reservoir Detention Study of San Vicente Reservoir - Calibration of the Water Quality Model

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May 01, 2012

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SUMMARY

San Vicente Reservoir (SVR) is located near Lakeside, California, and is used as a source of drinking water supply by the City of San Diego (City), its owner and operator. The reservoir currently has a capacity of about 90,000 acre-feet. San Vicente Reservoir is undergoing an enlargement that will raise the dam 117 feet and increase the reservoir's storage to 247,000 acre-feet at the spillway level (or 242,000 acre-feet at the maximum operation level).

A water reuse project, entitled Reservoir Augmentation, is being studied by the City. If implemented at full-scale, Reservoir Augmentation would bring advanced treated recycled water from the North City Water Reclamation Plant to SVR via a pipeline. The advanced treated recycled water would be blended with other water in the reservoir. The current project – the Reservoir Augmentation Demonstration Project – will not actually put any advanced treated recycled water into the reservoir; rather it will study and demonstrate the Reservoir Augmentation process. A component of the Reservoir Augmentation Demonstration Project (Demonstration Project) is the Limnology and Reservoir Detention Study of San Vicente Reservoir.

As part of the Limnology Study, the City has requested that Flow Science Incorporated (FSI) develop a three-dimensional water quality model that can accurately predict hydrodynamics and water quality of the existing and expanded SVR. It is anticipated that this model will be utilized to (1) establish residence time requirement for advanced treated recycled water in the reservoir and assess the short-circuiting of the advanced treated recycled water to the outlet structure; and (2) evaluate the effects of the advanced treated recycled water on water quality and eutrophication in the reservoir. This Technical Memorandum focuses on the development, calibration and validation of the three-dimensional water quality model for SVR.

Flow Science used two comprehensive and coupled three-dimensional computer models to simulate the hydrodynamics and water bio-chemistry of SVR. The models include a three-dimensional hydrodynamic module (Estuary Lake and Coastal Ocean Model, or ELCOM) and a water quality module (Computational Aquatic Ecosystem DYnamics Model, or CAEDYM). ELCOM simulates water velocities, temperatures, concentrations of salinity (*i.e.*, conductivity) and tracers; CAEDYM computes changes in dissolved oxygen (DO), nutrients, organic matter, pH and chlorophyll *a*. The coupled models are used to study the spatial and temporal relationships between physical, biological, and chemical variables in SVR.

The modeling domain includes the existing portion of the reservoir as well as the proposed expanded portion of the reservoir. A fine grid with a horizontal resolution of 50 × 50 m was used in the ELCOM calibration while a coarse grid with a horizontal resolution of 100 × 100 m was used in the CAEDYM calibration. This was necessitated by the large computer requirements and the desire to limit computation time to several

days per model run for a two-year simulation. A variable grid size was used in the vertical dimension with a grid size of 1.64 ft (0.5 m) near the surface, and expanding in size with depth. The calibration was conducted for the two-year period of 2006-2007. The input data required by the calibration were either based on measured data or derived from these data. ELCOM requires limited calibration effort in that the physical aspects of water movements in reservoirs are fairly well understood. The CAEDYM model was calibrated by adjusting some model bio-chemical parameters so that the simulation results best match measured field data.

The calibrated/validated ELCOM model shows good agreement with the measured data for both water temperature and conductivity. The calibration involved reconstruction of some meteorological data during periods where data were unavailable. It also involved an adjustment for the outlet port openings during the second half of 2007. As will be discussed in detail in the report, the City-specified field reports of the ports open during a portion of 2007 are at variance with the basic thermodynamics of the system. It is demonstrated later in this report that the open ports must have been at or above the thermocline level and not in the hypolimnion, as specified. In the future, it is recommended that outflow temperatures from SVR be recorded so that they can provide verification of the field record of port openings.

The onset and duration of thermal stratification as well as the deepening rate of the thermocline were predicted accurately by the model. Furthermore, the water conductivity, a measure of salinity, was well predicted by the model. It is noted that future modeling of the hydrodynamics at SVR would benefit from a full set of meteorological data gathered at SVR (the City stopped gathering on-site meteorological data in March 2007). An analysis presented herein shows that the meteorological data measured at the nearby California Irrigation Management Information System (CIMIS) station in Escondido differ in significant aspects from data gathered at SVR.

After the model was calibrated, a validation was performed to compare the model against the results of previous field studies. The field studies involved two separate episodes of tracer injection in the reservoir (winter 1995 and summer 1995). The field studies clearly showed the impacts of stratification (or lack thereof) on the mixing and dispersion of the tracer. The ELCOM model was capable of replicating the main features of the tracer study. Due to the nature of the tracer used in those studies (Lanthanum Chloride), a significant amount of tracer was lost due to coagulation/flocculation and subsequent settling. A simple coagulation/settling model was added to ELCOM. After the implementation of the coagulation/settling model, very good agreement between the model and the data was obtained. This validation provides strong verification and assurance that the model performance is accurate.

The calibration of the water quality model CAEDYM was carried out after the ELCOM calibration and verification process. The comparison between simulation results and measured in-reservoir field data involved water quality parameters including

dissolved oxygen (DO), pH, nutrients (nitrogen and phosphorus), chlorophyll *a* and Secchi depth. It is noted that some assumptions had to be made in order to calibrate the model. For example, assumptions on nutrient levels for the Aqueduct inflows during the "Bypassing Period" were needed to characterize nutrient loadings because there are only limited nutrient data available for the Aqueduct inflow.

The calibrated CAEDYM model shows overall good agreements with measured data. The simulated DO concentrations capture the major trends in the measured DO concentrations, including the onset, duration, and magnitude of periods of anoxia in the hypolimnion, the depth to the top of the anoxic (*i.e.,* "without oxygen") region, the DO decay rate in the spring in the hypolimnion, and the high surface DO concentrations in the spring (and sometimes fall) that are due to algae blooms. The simulated pH values closely match the measured data and are on average within 0.3 of the measured values. The calibrated model also replicates the major trends in the measured nutrient (phosphorus and nitrogen) concentrations. It is noted, however, that some of the field data are below the detection limit. The available in-reservoir chlorophyll *a* data were qualitatively measured using a fluorometer that has not been calibrated. The calibration of chlorophyll *a* had to be conducted indirectly through the calibration of Secchi depth. The final calibration run shows a fairly good agreement with the measured Secchi depths, indicating a fairly good calibration for chlorophyll *a*.

At this point, it is believed that the model calibration/validation is nearly complete. The calibrated/validated model will undergo peer review. After that, the model will be applied to the study of the expanded reservoir as well as the evaluation of the mixing of the advanced treated recycled water within the reservoir. The planned modification of Aqueduct release locations/facilities into the expanded SVR and outlet structure/port depths will be incorporated into the model.

Finally, it is noted that future evaluations of water quality at SVR would benefit from more frequent sampling of nutrients and chlorophyll *a* within the reservoir, lower nutrient detection limits, and an increased use of duplicate samples or periodic sampling audits. It is recommended that nutrient samples be collected more frequently for the inflows and within the water column. It is further recommended that the collection of chlorophyll *a* samples be resumed. Composite samples should be collected from the reservoir surface in order to analyze chlorophyll *a* concentrations in the laboratory. This would allow for calibration of the optical fluorometer data and improve the usefulness and interpretation of those data.

1. INTRODUCTION

1.1 BACKGROUND AND OBJECTIVES

San Vicente Reservoir (SVR) is located near Lakeside, California, and is used as a drinking water supply by the City of San Diego (City), its owner and operator (**Figure 1**). The reservoir currently has a capacity of about 90,000 acre-feet. San Vicente Reservoir is undergoing an enlargement that will raise the dam by 117 feet and increase the reservoir's storage to 247,000 acre-feet at the spillway level (or 242,000 acre-feet at the maximum operation level).

A water reuse project, entitled Reservoir Augmentation, is being studied by the City. If implemented at full-scale, Reservoir Augmentation would bring advanced treated recycled water from the North City Water Reclamation Plant to SVR via a pipeline. The City's Reservoir Augmentation program consists of three phases (Welch, 1997; City of San Diego, 2008).

- In Phase One, a comprehensive evaluation of all viable options to maximize the amount of water reuse in San Diego was undertaken. It included analysis and research on the health effects of reuse options, and included a public participation process. The Reuse Study's stakeholders identified Reservoir Augmentation at the City's San Vicente Reservoir to be the preferred reuse strategy.

- Phase Two is the Reservoir Augmentation Demonstration Project (Demonstration Project). The Demonstration Project will: (1) design, construct, operate, and test a demonstration-scale advanced water treatment (AWT) plant at the North City Water Reclamation Plant which will produce advanced treated recycled water; (2) conduct a limnology study of SVR to evaluate the water quality effects of bringing advanced treated recycled water into the reservoir, establish residence time and assess short-circuiting for advanced treated recycled water in the reservoir; (3) convene an Independent Advisory Panel (IAP) to provide independent expert oversight of the Demonstration Project; (4) define the State's regulatory requirements for the Reservoir Augmentation program; (5) perform an independent energy and economic analysis for the Reservoir Augmentation program; (6) and conduct a public outreach and education program regarding Reservoir Augmentation.

- If the Demonstration Project meets regulatory requirements and provides evidence of the viability of the Reservoir Augmentation process, the City could choose to proceed with Phase Three, the full-scale Reservoir Augmentation Project. Phase Three would create a new potable water supply for the City of San Diego and the region from advanced treated recycled water.

A component of the Demonstration Project is the Limnology and Reservoir Detention Study of San Vicente Reservoir (Limnology Study). As part of the Limnology Study, the City has requested that Flow Science Incorporated (FSI) develop a three-dimensional water quality model that can accurately predict hydrodynamics and water quality of the existing and expanded SVR. It is anticipated that this model will be utilized to (1) establish residence time requirement for advanced treated recycled water in the reservoir and assess the short-circuiting of the advanced treated recycled water to the outlet structure; and (2) evaluate the effects of the advanced treated recycled water on water quality and eutrophication in the reservoir.

This Technical Memorandum (TM) focuses on the development, calibration and validation of the three-dimensional water quality modeling for SVR. This work has been performed by Flow Science Incorporated (FSI) of Pasadena, California, under contract to the City of San Diego, California.

1.2 PREVIOUS STUDIES

FSI has previously performed various hydraulic and water quality modeling evaluations of SVR. The current work builds on these previous evaluations.

In the early 1990s, FSI conducted an analysis to evaluate the feasibility of introducing some highly-treated tertiary effluent into SVR (FSI, 1994). The study comprised one-dimensional reservoir modeling, a field study and data analysis. In 1995, the City conducted two field tracer studies in SVR that were completed in the winter and summer of 1995 (FSI, 1995). The work was used to enhance understanding of the water circulation patterns in the reservoir and help identify the fate and transport of the Aqueduct inflow. The results of that work have been used here to validate the three-dimensional water quality model developed in this study.

In 1997, FSI evaluated the hypolimnetic oxygen demand in SVR (FSI, 1997). As part of that project, FSI developed calibrated models of temperature and DO in SVR for 1992-1994 using the one-dimensional Dynamic Reservoir Simulation Model – Water Quality (DYRESM-WQ). In 2001, FSI revised the estimated hypolimnetic oxygen demand for SVR based on more extensive reservoir profiling data from 1992-2000. These data were used to develop recommendations for sizing a diffused oxygen input system and to develop performance specifications and design criteria for such a system (FSI, 2001).

In 2005, FSI developed a calibrated one-dimensional DYRESM-WQ model of temperature, conductivity (*i.e.,* salinity), and dissolved oxygen (DO) for SVR for the period 1999-2000 (FSI, 2005a). The model was then used to perform an assessment of water quality in the reservoir after the proposed dam raise and expansion. The purpose of the modeling work was to identify the effects of the reservoir expansion and new inlet and outlet facilities on water quality and possible design and management options for

maintaining or enhancing water quality. In particular, the focus of the work was on identifying the optimum elevations for the seven ports in the outlet tower that is being constructed as part of the dam-raise project. The work defined the port elevations so that the City and the Water Authority can selectively withdraw the best-available water in the reservoir at different lake elevations and for different operating conditions.

Most recently, in 2009, FSI re-calibrated the SVR one-dimensional DYRESM-WQ model developed in 2005 for the period 2006-2007 (FSI, 2009) using newly-obtained in-reservoir nutrient and chlorophyll *a* data that were either insufficient, or non-existent, for the previous calibration period (1999-2000). The calibrated DYRESM-WQ model was then used to evaluate water quality effects within the reservoir during dam construction drawdown conditions, when the water surface elevation levels (WSELs) in the reservoir would be reduced from around 620 ft to around 590 ft during the dam-raise construction.

The current project builds upon knowledge gained from the development of these models and analysis and the associated database of information on SVR.

1.3 TECHNICAL MEMORANDUM ORGANIZATION

This TM provides a detailed description of the three-dimensional water quality modeling performed for SVR. **Chapter 2** of the report provides details of the modeling approach and setup, including a description of the computer code used in the model and its required inputs. **Chapter 3** describes the calibration of the hydrodynamic part of the model, including details on the calibration setup and field data used for the calibration. Then, the calibration validation of the hydrodynamic part of the model (ELCOM) is presented in **Chapter 4**. **Chapter 5** provides details of the calibration of the water quality part of the model (CAEDYM). Conclusions and discussion are provided in **Chapter 6**.

2. MODELING APPROACH AND SETUP

2.1 ELCOM AND CAEDYM DESCRIPTION

FSI used comprehensive computer modeling to simulate the hydrodynamics and water quality for this study. The models used include a three-dimensional hydrodynamic module (Estuary Lake and Costal Ocean Model, or ELCOM) and a water quality module (Computational Aquatic Ecosystem DYnamics Model, or CAEDYM). ELCOM simulates water velocities, temperatures, concentrations of salinity (*i.e.*, conductivity) and tracers; CAEDYM computes changes in dissolved oxygen (DO), nutrients, organic matter, pH and chlorophyll *a*. By coupling these two modules, the models can be used to study the spatial and temporal relationships between physical, biological, and chemical variables in San Vicente Reservoir (see **Figure 2**[1]).

Both the ELCOM and CAEDYM models were developed at the Centre for Water Research at the University of Western Australia. They have been used in predicting water quality in many lakes and reservoirs throughout the world and a more detailed description of them is included in **Appendix A**.

Compared to the one-dimensional DYRESM-WQ model used in the previous studies of SVR, both ELCOM and CAEDYM are more advanced computer models that are capable of simulating sophisticated hydrodynamic and biogeochemical processes in three dimensions. More importantly, as three-dimensional models, they can track the horizontal and vertical movement of the advanced treated recycled water in the reservoir. Therefore, water quality effects induced by the advanced treated recycled water can be evaluated both temporally and spatially. By comparison, DYRESM-WQ is a one-dimensional model that focuses on identifying the vertical gradients in the reservoir.

ELCOM can run independently of CAEDYM to predict only reservoir hydrodynamics and parameters such as water velocities, temperatures and tracer concentrations. However, CAEDYM needs to be run coupled with ELCOM because it relies on ELCOM to provide the hydrodynamic "driver" to transport and mix the biological and chemical water quality parameters that are the essence of CAEDYM.

[1] Note that Figure 2 illustrates some processes that do not occur or are not modeled in SVR and are therefore not included in the modeling.

2.2 APPROACH

The approach to studying water quality effects of the advanced treated recycled water using a computer model consists of the following steps:

- Select an appropriate hydrodynamic and water quality computer models for the SVR model, which in this case are ELCOM and CAEDYM;
- Obtain and assemble existing data for calibration and validation of the SVR model;
- Set up the SVR model and associated input data files;
- Perform ELCOM simulations necessary to calibrate and validate the hydrodynamic part of the SVR model;
- Perform ELOCM-CAEDYM simulations necessary to calibrate the water quality part of the SVR model;
- Extend the model to the enlarged reservoir;
- Determine the future scenarios and associated input data;
- Apply the calibrated SVR model to different future scenarios and evaluate water quality changes induced by the Demonstration Project.

This report focuses on the first five steps, which involve the calibration and validation of the SVR water quality model.

2.3 MODEL SETUP

2.3.1 Model Domain and Grid

The model domains include the existing portion of the reservoir (WSEL = 650 ft) and the expanded portion of the reservoir (WSEL = 780 ft) (see **Figure 1**). However, the calibration/validation work discussed herein only considers the existing reservoir.

Bathymetry contour data for the reservoir were provided by the City with contour intervals varying from 2 ft to 10 ft, from which the model computational grid was created. The horizontal resolution of the grid for the ELCOM runs is 50 × 50 m (see **Figure 3**). The model grid was rotated 42 degrees counter-clockwise from North in order to align the major channels of the reservoir with the model grid axes to reduce numerical

errors. A two-year ELCOM simulation using this grid takes approximately 7 days on a fast personal computer. In order to control the run time for ELCOM-CAEDYM, a 100 × 100 m grid was used, as will be discussed in **Chapter 5**.

A variable grid size was used in the vertical dimension. A vertical grid size of 1.64 ft (0.5 m) was used near the top of the reservoir in order to provide a high resolution for resolving vertical stratification in the reservoir. Below this a stretched grid was used in order to decrease the number of cells needed and to improve computational efficiency. Each stretched cell is 6 percent larger in the vertical direction than the cell directly above it (i.e., stretch ratio or the ratio of grid sizes for adjacent cells = 1.06). This is possible because vertical gradients of water parameters such as temperature and conductivity within the hypolimnion tend to be small. The same vertical resolution was used for both ELCOM and ELCOM-CAEDYM.

2.3.2 Modeling Period

The period of 2006-2007 was chosen as the model calibration period for the following reasons:

- Measurements of daily Aqueduct inflow volumes began in late 2006;
- It had as dense a data set as other years since nutrient sampling began in 2003;
- Most data sets in this period have been evaluated, cleaned (by removing seemingly erroneous data), and verified in the most recent SVR study conducted by FSI (FSI, 2009) and are ready to use;
- Field data in 2007 showed faster rates of DO decay and smaller Secchi depths than in previous years, which provided a more conservative basis for the calibration.

2.3.3 Model Inputs

The input data required by the modeling include flow rates for inflows and outflows, inflow water quality, and meteorological forcing functions (rainfall, air temperature, wind speed and direction, relative humidity, solar influx) over the modeling period. The input data used in this study were either based on measured data or derived from these data. The sources and derivation of these data are discussed in more detail in the next three chapters.

3. ELCOM CALIBRATION

3.1 OVERVIEW

Model calibration is the process of adjusting some model parameters and sometimes correcting seemingly erroneous input data in an attempt to match the simulation results with measured field data. In this study, the calibration of the hydrodynamic model ELCOM was carried out first. The comparison between simulation results and measured in-reservoir field data involved the following parameters: water surface elevation (WSEL), water temperature and conductivity.

The in-reservoir field data were measured and provided by the City. **Appendix B** includes plots of the historical in-reservoir water temperature data since 1992 and conductivity data since 1999, as well WSEL data since 1990. During the calibration period (year 2006-2007), WSELs were measured daily while temperature and conductivity profiles were measured weekly. Most of these inputs were obtained by FSI for the recent study in 2009 (FSI, 2009).

3.2 ELCOM CALIBRATION SETUP

3.2.1 Computational Grid Setup and Initial Conditions

As described in **Chapter 2**, the model grid with a constant horizontal grid size of 50 × 50 m and a variable vertical grid size was used for ELCOM calibration (see **Figure 3**).

The initial reservoir temperature profile at the beginning of 2006 was based on in-reservoir measured data from Station A (near the outlet tower, see **Figure 1**) on January 3, 2006, as shown in **Appendix B**.

Since ELCOM requires salinity as an input, but only conductivity is generally measured in the reservoir and in the inflows, salinity values were estimated from the conductivity data. The in-reservoir salinity is estimated to be approximately equal to the total dissolved solids (TDS) concentration, and the TDS concentration and salinity can be estimated according to the following formula developed from comparisons of available measured TDS and conductivity data using a least squares best fit to a linear relation (FSI, 2009):

$$\text{TDS (mg/L)} = \text{Salinity (mg/L)} = 0.65 * \text{Conductivity } (\mu\text{S/cm}) \qquad \text{[Eqn. 1]}$$

As suggested in the previous SVR modeling study (FSI, 2009), conductivity data from January 9, 2006, were used for the initial conditions for the computation. The calibration was performed as one continuous two-year simulation,

3.2.2 Flow Rate Inputs

Three surface inflows were included in the model calibration. These include the First San Diego Aqueduct (Aqueduct), stream inflows (Runoff), and water transfers from Sutherland Reservoir. The Aqueduct consists of two pipelines that extend from the Metropolitan Water District of Southern California's (MWD's) Colorado River Aqueduct near San Jacinto, California, and terminate at the north-west corner of SVR (**Figure 1**). The Aqueduct inflow cascades down a steep, natural channel and enters the reservoir at the surface. Runoff enters the reservoir as a surface inflow through several tributaries, with San Vicente Creek being the dominant Runoff inflow. When water is transferred from Sutherland Reservoir, it enters San Vicente Reservoir at the north end of the reservoir via San Vicente Creek.

The only modeled outflow in the calibration is the withdrawal from the existing outlet tower located near the center of the upstream face of the dam (see **Figure 1**). It consists of a vertical outlet tower with six tiers, three of which can also be equipped with an optional 20 ft riser. The multiple tier elevations allow for selective withdrawal of the water at desired depths. A detailed discussion of modeled withdrawal elevations is included in **Section 3.2.5**.

Total monthly flow volumes for each of the three inflows and the outflow were provided by the City. In addition, daily Aqueduct inflow volumes were provided starting in November 2006, and daily outflow (draft) volumes were provided for the entire calibration period. During those times when daily Aqueduct inflow volumes were not available, the monthly inflow data were used for the average daily inflow volumes. The monthly inflow data were also used for the average daily inflow volumes for the Runoff and Sutherland Reservoir inflows. Note that the Runoff volumes are not measured directly; instead, they are determined from other known values based on a mass balance computation.

However, the calculated reservoir storage using the inflow/outflow rates provided by the City does not match the measured storage volumes and it varied by as much as 40 Million Gallon (MG) (about 0.2% of the total reservoir volume) from the measured volumes in June 2006 and April, May, and December 2007. Thus, as part of WSEL calibration, a correction was made to the Aqueduct inflow or outlet flows (depending upon whether additional inflows or outflows were needed to correct the storage) to improve the WSEL results. Details on the correction method can be found in the previous SVR model calibration study (FSI, 2009). A plot of the resulting inflow and outflow volumes used in the model calibration, as compared to the measured volumes, is included in **Figures 4** and **5**.

As shown, the Aqueduct comprises the major inflow source to SVR with maximum flow rates generally occurring in the winter and spring. Runoff inflows were much less

than the Aqueduct inflows during this period, with maximum Runoff occurring in the winter and spring. The controlled inflows from Sutherland Reservoir occurred in March, November, and December 2007.

3.2.3 Inflow Temperatures and Conductivity Inputs

Temperature and salinity of all inflows are the parameters required as inputs in the ELCOM calibration; but these data were not available at all times for all inflows. Therefore several assumptions and estimates were made when preparing these input files for the calibration. A brief description of these assumptions is provided below for each inflow and details can be found in the previous SVR model calibration study (FSI, 2009). **Appendix C** (see **Figures C-1** through **C-6**) includes plots of the measured data and input data used in the model calibration for each inflow.

Aqueduct Inflows

Discharges from Lake Skinner generally supply the Aqueduct. Therefore, since Aqueduct temperature and conductivity data are not measured at the inlet to SVR, data measured at the Lake Skinner outlet (located 80 miles upstream) were used to characterize the Aqueduct inflow for most of the 2006-2007 calibration period under the assumption that these parameters in the Aqueduct do not change significantly from the Lake Skinner discharge to SVR. These data at Lake Skinner were obtained directly from MWD and included approximately bi-weekly temperature and conductivity (and some TDS data).

During the period from approximately October 2006 through January 2007, about 80% of the water in the Aqueduct was being supplied directly from the San Diego Canal while the remaining water was supplied by Lake Skinner (verbal communication with Dr. Rich Losee of MWD on June 4, 2008). Based on limited data obtained from MWD for the San Diego Canal, temperature and conductivity (*i.e.*, salinity) values during the "Bypassing Period" are comparable to data measured at the Lake Skinner outflow, so the more dense Lake Skinner outflow data were used. The final temperature and conductivity input values for the Aqueduct inflow as well as all the measured data were presented in **Figures C-1** and **C-2**.

Runoff Inflows

Temperature and conductivity data for the local tributaries to SVR were obtained from the City and sampled as often as monthly since 2003. Data were measured in San Vicente Creek (SV Creek) - both upstream and downstream of the confluence with the Sutherland Reservoir inflow - and in Barona Creek, Aqueduct Creek, Kimball Creek, and Tool Road Creek. Due to the lack of data for other tributaries, data measured in SV Creek were used to estimate the model inputs for other tributaries.

The Runoff conductivity can vary significantly depending upon whether it is composed of a small or large rain event, and stream data are not collected frequently enough to characterize the complex relationship between conductivity and flow rate. However, stream conductivity generally decreases with increasing flow rates. As suggested in the previous SVR model calibration study (FSI, 2009), salinity values were reduced in February 2006, March 2006, December 2007 for possible sustained runoff events that were not captured by monthly sampling data (per statements made by City and Water Authority personnel during 9/23/08 conference call). Otherwise there is no conductivity drop as demonstrated in the measured conductivity profile data. The final temperature and conductivity input values for the runoff as well as all the measured data are presented in **Figures C-3** and **C-4**.

Sutherland Reservoir Inflows

Water from Sutherland Reservoir is intermittently released from the hypolimnion and travels through an approximately 12-mile pipeline before discharging into SV Creek about 4.5 miles upstream of SVR. During the calibration period, inflows from Sutherland Reservoir occurred in March 2006 and November-December 2007. In-reservoir temperature and conductivity data were obtained from the City for Sutherland Reservoir. The temperature and conductivity values of inflows from Sutherland Reservoir were in general assumed to be equal to the values from the in-reservoir profile data measured from within the hypolimnion near the elevation of the sole Sutherland outlet located at EL 1940 ft.

As suggested in the previous SVR model calibration study (FSI, 2009), inflow temperatures in March 2007 were adjusted in order to decrease the density of the inflow relative to San Vicente Reservoir so that the Sutherland Reservoir inflow would insert at the surface as indicated by conductivity profile data taken from San Vicente Reservoir. This correction may be related to the heating of the water while it travels between the two reservoirs. The final temperature and conductivity input values for the Sutherland reservoir inflow as well as all the measured data are presented in **Figures C-5** and **C-6**.

3.2.4 Meteorological Inputs

The meteorological inputs required for the model, which features a complete thermodynamic calculation, include measurements of solar radiation, air temperature, wind speed, wind direction, relative humidity, and rainfall. The meteorological data at SVR are only available from January 1, 2006, through December 11, 2006, and January 1, 2007, through March 15, 2007, which were measured every 10 minutes by the City at a monitoring station on Lowell Island within San Vicente Reservoir (see **Figure 1**).

Initially, the remaining meteorological data for 2006 and 2007 were filled by data obtained from the California Irrigation Management Information System (CIMIS). Hourly CIMIS data were measured at Station 153 in Escondido, California, which is the closest operational CIMIS station during the calibration period and is more than 10 miles from SVR (see **Figure 6**). The ELCOM calibration run using this composite data set shows that the simulated temperature profiles track closely to the measured value in 2006 when the meteorological data from the City were used, while the model overestimates thermocline depths in the summer of 2007 when the CIMIS data were mostly used (see **Figure 7**). Several attempts were made to adjust the CIMIS data based on an evaluation of the overlapping City and CIMIS data, but they all failed to accurately reproduce the measured thermocline depths in the summer of 2007. It was concluded that the CIMIS meteorological data do not represent meteorological conditions at SVR, even with the adjustments, probably because of distance between these two places and the complex terrain surrounding SVR. In particular, it is noted that the wind velocity can have a significant impact on lake mixing and the depth of the thermocline, and as a result, using wind speed from a remote location with different wind patterns can lead to erroneous modeling results.

Due to the inadequacy of using the meteorological data from Escondido, the approach used herein involved constructing a composite meteorological data set by filling in the missing 2007 meteorological data from SVR with the corresponding 2006 data gathered by the City. For an approximately three-week period in December 2006 and 2007, there were no meteorological data available from the City. This period was filled by using the CIMIS data from Escondido (see **Table 1)**. Using this composite data set, the simulation results show very good agreement between the simulated and measured water temperatures between April and June 2007, but the model results start to deviate from the measured data after July 2007 (see **Figure 8**). As described later, the deviation in the second half of 2007 can be attributed to issues other than meteorological data. As a result, this composite meteorological data set was used in all the calibration runs. Graphical plots of the final meteorological data inputs are included in **Appendix C** (see **Figures C-7** through **C-12**).

Table 1. Details on the Composite Meteorological Data Used in the Model

Period	Data Source	Measured Location
1/1/2006 – 12/11/2006	City	Lowell Island
12/12/2006-12/31/2006	CIMIS	Escondido
1/1/2007 – 3/15/2007	City	Lowell Island
3/16/2007 – 12/11/2007	Using data between 3/16/2006 – 12/11/2006 from the City	Lowell Island
12/12/2007 – 12/31/2007	Using data between 12/12/2006 – 12/31/2006 from CIMIS	Escondido

3.2.5 Outflow Port Openings

The existing reservoir outlet tower consists of six tiers, three of which are also equipped with an optional 20 ft riser. A summary of the available withdrawal elevations from the ports on the current tower is included in **Table 2**.

Table 2. Available Withdrawal Elevations on Existing Outlet Tower

Port	Withdrawal Elevation
1	493 ft
2	510 ft
2 w/ 20 ft riser	530 ft
3	540 ft
3 w/20 ft riser	560 ft
4	570 ft
4 w/20 ft riser	590 ft
5	600 ft
6	630 ft

Based on records obtained from the City, outflows were withdrawn from Port No. 3 with a 20-ft riser (560 ft EL) and Port No. 4 (570 ft EL) from January through mid-June 2006. From mid-June 2006 through mid-September 2007, outflows were withdrawn from Port No. 2 with a 20-ft riser (530 ft EL) and Port No. 3 (540 ft EL). Starting in mid-September 2007, outflow withdrawal switched back to Port No. 3 with a 20-ft riser (560 ft EL) and Port No. 4 (570 ft EL).

The ELCOM calibration run using the outflow port openings described above shows that simulated thermocline depths match well with measured data in 2006 and the first half of 2007, but it predicted much deeper thermocline levels than shown by the in-reservoir data from July 2007 onward (see **Figures 7** and **8**). Historical temperature data between 2000 and 2007 (**Figure 9**) reveal that the thermocline depth in the summer of 2007 resided around 20 ft below the surface and is much shallower than those in previous years. However, there is no evidence indicating that meteorological conditions in 2007 at SVR, which was believed to be not much different from previous years (verbal communication with Jeff Pasek of the City), could lead to such a shallow thermocline depth.

This initial finding led to a more careful examination of the effect of inflows and outflows on thermocline depths at SVR. In the summers of 2006 and 2007, the Aqueduct flow was the major inflow source at SVR and entered the reservoir at the surface. Temperatures for the Aqueduct inflow were between 20 and 28 ^{o}C between early June and later September in both 2006 and 2007 (see **Figure 10**). If the 18 ^{o}C isotherm (see **Figure 11**) is used to represent the thermocline, the Aqueduct inflow should reside above the defined thermocline, given that it enters the reservoir at the surface with a relatively high temperature. The City reported withdrawal levels during this period were below the observed thermocline. As a result, the increase in thickness of epilimnion (the layer above the thermocline) at SVR would be expected to be greater than the thickness of the layer formed by the Aqueduct inflow during the same period (making due allowance for evaporation losses). For 2006, the thermocline (defined as the 18 ^{o}C isotherm) is observed to deepen by about 9.5 ft between early June and early September. During the same period, the thickness of the layer formed by the Aqueduct inflow would be 2.6 ft and the evaporation loss is calculated to be about 2 ft. The net thermocline deepening in this time period due to external forcing (wind, heating and cooling, etc.) can be calculated using the following equation:

Deepening due to external forcing (m) = Net observed thermocline deepening (m)
- Deepening due to inflow insertion (m)
+ Loss due to withdrawal above thermocline (m)
+ Loss due to evaporation (m) [Eqn. 2]

From Eqn. 2, the deepening of the thermocline due to external forcing is estimated to be 8.9 ft, calculated as 9.5 less 2.6 plus 2 ft. However, for 2007, the thermocline (defined as the 18 ^{o}C isotherm) is observed to deepen by about 6.6 ft between early June and early September, while the thickness of the layer formed by the Aqueduct inflow is 11 ft. Applying Eqn. 2, the deepening of the thermocline due to external forcing in 2007 is therefore estimated to be -2.4 ft, which is a clearly unrealistic answer. If the mixing in

2007 is considered to actually have deepened the thermocline by the same amount as 2006 (*i.e.*, 8.9 ft which is a reasonable assumption[2]), then the thermocline depth would be 11.3 ft deeper than observed (calculated using Eqn. 2).

It is therefore apparent that the measured depth of the thermocline in the summer of 2007 is not reasonable unless some outflows were withdrawn from the epilimnion during this period[3] (about 11.3 ft worth of outflow). During this time period, the recorded outflows were from Port No. 2 with a 20-ft riser (530 ft EL) and Port No. 3 (540 ft EL), at a depth of 60 and 50 ft below the observed thermocline, respectively. The total water withdrawn from the reservoir during this time was 3,300 MG, corresponding to a reservoir layer of 11 ft (at the level of the thermocline). The only explanation of the above discrepancy is that the recorded open ports during this period were not correct, and that an approximately 11.3 ft thick layer of water was withdrawn at or above the thermocline level. It is noted that the recorded open ports show a switch to higher ports (Port No. 3 with a 20-ft riser at 560 ft EL and Port No. 4 at 570 ft EL) in mid-September 2007. However, these recorded open ports were too deep (both were below the thermocline) and the switch was too late to explain the above-mentioned discrepancy. To correct for the discrepancy it was considered in the model that the switch to the upper ports occurred earlier (in mid-June 2007) and the switch was to the shallower ports (Port No. 4 with a 20-ft riser at 590 ft EL and Port No. 5 at 600 ft EL) (see **Figure 12**), both of which were above the observed thermocline in the summer of 2007. The corresponding model results incorporating this change show good agreement in matching the measured data regarding thermocline depth (see **Figure 13**).

3.3 CALIBRATION RESULTS

3.3.1 Water Surface Elevation

Figure 14 shows the measured versus simulated water surface elevations for the calibration based on the flow data provided by the City. As shown, the simulated water surface elevations are generally within 1 ft of the measured WSELs.

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[2] We have conducted a few sensitivity test runs and the results indicated that reducing the wind speed by 30%, or decreasing sunlight penetration depth (due to higher algae concentrations) only reduced the thermocline deepening due to external forcing by 1-2 ft.

[3] It is noted here that the thermocline depth measurements were performed using three different instruments at different times, and all the instruments produced similar results, thus ruling out instrument error as a source of the discrepancy.

3.3.2 Temperature

Figure 15 shows a time series plot of the simulated versus measured temperatures for both 2006 and 2007 at the surface and bottom of the reservoir. **Figure 16** shows color contours of the simulated water temperatures in comparison to the measured data. In addition, comparisons of simulated and measured temperature profiles at selected dates are included in **Appendix C** (see **Figures C-13** through **C-15**). As presented, the simulated temperatures closely match the measured data and accurately predict the onset and duration of thermal stratification, as well as the depth of the thermocline.

A scatter plot of the measured and simulated temperature for years 2006 and 2007 is provided in **Figure 17**. The plot includes only surface and bottom temperature. In the plot, the 45-degree theoretical line with zero intercept represents what would be a "perfect" correlation between the simulated and measured data. Therefore, the nearer the plotted points are to the 45-degree line, the better is the simulation. The graph indicates a good calibration in temperature.

A statistical analysis of the calibration results versus the measured temperature produced the metrics presented in **Table 3**. These metrics quantitatively summarize the accuracy of the calibration results. For example, the computed Root Mean Square Errors (RMSE) indicate that the calibrated temperatures in 2006 are on average within 0.60 ^{o}C of the measured data, corresponding to 3.6% of the range in measured temperatures (relative RMSE = RMSE / $|T_{max} - T_{min}|$); and the calibrated temperatures in 2007 are on average within 1.03 ^{o}C of the measured data, corresponding to 6.2% of the range in measured temperatures. Mean error calculates the average of difference between the measured and simulated values. Thus, the model on average overestimates temperatures by 0.17 ^{o}C in 2006 and on average underestimates temperatures by 0.1 ^{o}C in 2007. These metrics indicate a good calibration.

Table 3. Temperature Calibration Metrics

PARAMETER	2006 RESULTS			2007 RESULTS		
	ROOT MEAN SQUARE ERROR (RMSE)	RELATIVE RMSE	MEAN ERROR	ROOT MEAN SQUARE ERROR (RMSE)	RELATIVE RMSE	MEAN ERROR
Surface and Bottom Temperature	0.60 °C	3.6 %	-0.17 °C	1.03 °C	6.2 %	0.1 °C

3.3.3 Conductivity

Figures 18 and **19** are comparison plots (time series and color contours, respectively) for the simulated and measured conductivities (*i.e.*, salinities). The simulated

conductivity data plotted in the figures are computed based on the in-reservoir relationships between conductivity, salinity, and TDS as given in Eqn. 1.

The resulting simulated conductivities capture the seasonal trends in both the surface and bottom conductivity values; the magnitudes of the simulated and measured conductivity data also track closely, particularly in 2006.

A scatter plot of the measured and simulated conductivity values for years 2006 and 2007 is provided in **Figure 20**. Statistical metrics are included in **Table 4**. The RMSE indicate that the calibrated conductivity values are on average within 15-30 μS/cm of the measured, corresponding to 10 – 20% of the range in measured conductivity. These indicate a good conductivity calibration for both years, especially given that an error of 30 μS/cm is common in field-measured conductivity (FSI, 2005b).

Table 4. Conductivity Calibration Metrics

PARAMETER	2006 RESULTS			2007 RESULTS		
	ROOT MEAN SQUARE ERROR (RMSE)	RELATIVE RMSE	MEAN ERROR	ROOT MEAN SQUARE ERROR (RMSE)	RELATIVE RMSE	MEAN ERROR
Surface and Bottom Conductivity	14.9 μS/cm	10.7 %	8.6 μS/cm	29.7 μS/cm	19.7 %	2.8 μS/cm

3.3.4 Animation of Aqueduct Tracer

An animation that shows transport and mixing of a conservative tracer injected into the Aqueduct inflow on July 1, 2006 is included in **Appendix D**. The tracer was added at a constant concentration of 100 to the Aqueduct inflow. The plan view plots the maximum value of the tracer concentrations for each vertical water column within the model domain. Two cross sections plot the tracer concentrations on the section connecting between Aqueduct inflow and the Dam and the section connecting between Kimball Arm and the Dam.

4. ELCOM VALIDATION

4.1 FIELD TRACER STUDIES

Model validation presented here involves simulating the periods of the tracer studies completed in 1995 using the previously-calibrated SVR model (**Chapter 3**). The ability of the calibrated model to reproduce observed field data in these tracer studies provides assurance of the predictive capability of the model.

Two tracer field studies were conducted by the City of San Diego in 1995: the winter study that was completed in January and February and the summer study that was completed between July and early September. In each study, a lanthanum (lanthanide) chloride solution was injected as a tracer into the Aqueduct inflow just before it enters the reservoir. Over the period of each study, tracer concentrations and other water quality parameters such as temperature, salinity and pH were measured at various reservoir stations (see **Figure 21**). **Table 5** presents a summary of information on field studies. A detailed description and analysis of the tracer studies can be found in the FSI report titled "San Vicente Water Reclamation Project: Results of Tracer Studies" (FSI, 1995).

Table 5. Summary of Information on Tracer Studies

Name	Injection Date	Injected Lanthanum Mass	Lake Condition	Sampling Period
Winter study	9:00 AM, 1/4/95-9:00 AM, 1/5/95	77.9 kg	Weak Stratification	1/6/95 – 2/7/95
Summer Study	10:00 AM, 7/24/95-10:00 AM, 7/25/95	154.5 kg	Strong Stratification	7/31/95 – 9/5/95

4.2 MODEL VALIDATION SETUP

4.2.1 Computational Grid and Model Inputs

The approach to setting up grid and input files for the model validation run is similar to that used in setting up the calibration run, except that 1995 data (inflows, outflow, meteorology) were used.

Since no meteorological data were collected at SVR in 1995, data at CIMIS Ramona Station (#98) were used as input in the validation run. Ramona Station is about 6 miles away from SVR. Note that the Ramona station was only in operation before 1999, and thus could not be used in the 2006/07 calibration to reconstruct missing meteorological data.

The winter validation run simulated a 45-day period starting on January 3, 1995 (1 day prior to the tracer injection) and ending on February 18, 1995. The initial conditions for the winter run were based on data measured at Station A on January 3, 1995.

The summer validation run simulated a 50-day period starting on July 21, 1995 (3 days prior to tracer injection) and ending on September 9, 1995. The initial conditions for the summer run were based on data measured at Station A on July 21, 1995.

4.2.2 Particle Settling

Both winter and summer tracer studies used lanthanum chloride as the tracer. Lanthanum, a coagulant used in the wastewater treatment, can bind with phosphate in water and form insoluble particles (Niquette, *et al.,* 2004, Recht, *et al*., 1970). After the particles are formed, they grow in size by attaching themselves to other large particles in the water (*i.e.,* "flocculation") and then settle within the water column and may deposit on the sediment. This lanthanum removal process by settling is evidenced in the exponential loss of total measured lanthanum mass in the reservoir over the time during the tracer studies (see **Figure 22**). For example, after 35 days from the initial injection of the lanthanum, there was about 15% of the lanthanum mass left in the water column for the winter tracer study (illustrated as red diamonds in **Figure 22**) and about 50% of the lanthanum remained in the water column in the summer tracer study (illustrated as green squares in **Figure 22**). These figures were obtained based on integrating the in-reservoir measured lanthanum concentration data at all stations. In contrast, after 35 days there would have been about 95% and 99% of the lanthanum left for the winter and summer studies, respectively, if the lanthanum were a conservative tracer (the contour plots for these runs are include in **Figures C-16** through **C-22** of **Appendix C**). This indicates that less than 5% of the lanthanum was withdrawn through outlets during the 35-day period and significant portion of the total injected lanthanum was lost through settling. It is also noted that the volume of water withdrawn from the reservoir during the winter and summer studies was approximately 4 and 10 % of the reservoir volume, respectively. Therefore, it is more appropriate to model lanthanum as particles that grow in size and settle rather than a conservative tracer.

Lanthanum chloride usually bonds with phosphate to form insoluble particles. In the winter study, most of injected lanthanum chloride was observed to reside close to the bottom of the reservoir, where phosphate is ample due to sediment release and lack of algae consumption at depth. In the summer study, most of lanthanum chloride resides in the epilimnion or at the level of the thermocline where phosphate level is low due to algae consumption. Therefore, more insoluble lanthanum phosphate particles are expected to form in the winter than in the summer. In addition, more large suspended particles in the reservoir were expected in the winter due to winter storms and runoff. These particles provide the medium to which lanthanum phosphate can attach.

Therefore, it is reasonable to apply different particle distributions and flocculation rates in the summer and winter simulations as described above.

In the validation run, the lanthanum coagulation/flocculation was modeled using a simplified representation as follows:

- Nine (9) different-sized particle groups (leading to different settling velocities) were used to represent the lanthanum in the reservoir. The settling velocity of each particle size group was calculated according to Stokes's Law, which suggests that the settling velocity increases in proportion to the square of the particle diameter. A summary of settling velocity for each particle size group is listed in **Table 6**.

- In the winter study, starting with the initial distribution among the particle size groups, it is assumed that 8% mass of each group particle moves to the next group with larger size daily (*i.e.*, a flocculation rate equal to 8% of mass / day). The simulated mass distributions of the particle groups on the sampling dates in the winter study are presented in **Figure 23**.

- In the summer study, two flocculation rates were used for each particle size group: 60% mass of each group has the flocculation rate of 0.9% of mass / day (*i.e.*, 0.9% mass of each group moves to the next group with larger size daily); and 40% mass of each group has the flocculation rate of 28% of mass / day (*i.e.*, 28% mass of each group moves to the next group with larger size daily). The simulated mass distributions of particle groups on the sampling dates in the summer study are presented in **Figure 23**. The use of different flocculation rates in summer and winter is discussed further below.

- These flocculation rates were selected mainly because they produce the best match to the rate of decrease in measured total lanthanum mass over the whole reservoir (see **Figure 24**).

Table 6. Settling Velocity for Simulated Particle Groups

Particle Size Group	Settling Velocity (m/day)
1	0.0
2	0.1
3	0.2
4	0.3
5	0.5
6	1.0
7	1.5
8	2.5
9	5.0

4.3 VALIDATION RESULTS

Figure 25 presents color contours of the simulated water temperature in comparison to the measured temperature data during the period of the winter tracer study. Note that the simulated temperature shows more diurnal fluctuations because the simulation results were plotted based on three-hour sampling, while the field data were measured once every few days. During the winter study, the reservoir was well-mixed initially and started to develop a weak stratification later. As presented, the simulated temperatures match well with the measured data and the model accurately predicts the onset and development of thermal stratification.

Figures 26 through **28** show color contours of measured and simulated lanthanum profiles in the winter tracer study along a continuous path joining Stations I, B, K, L, A, L, M, C, D, G, Q, and R as shown in **Figure 21**. The majority of the lanthanum stays close to the bottom of the reservoir and was rarely mixed to the surface (probably due to the settling of lanthanum and a weak stratification). This indicates that the Aqueduct inflows dove to the bottom of the reservoir in the winter after entering from the surface. (The inflow was slightly colder and therefore denser than the reservoir water during winter.) As presented, both the fate of the Aqueduct inflow and decrease of lanthanum concentrations over the time are well captured by the model.

Figures 29 through **33** are comparison plots of the simulated and measured temperatures and lanthanum concentrations for the summer tracer study. Due to the strong temperature stratification in the summer, the Aqueduct inflow, with its relatively higher temperature, stayed above the colder and denser water in the hypolimnion after entering at the surface as shown in the measured field data. Then, lanthanum started to settle as evidenced by the layer of lanthanum expanding vertically toward the bottom. Without the formation of lanthanum particles and subsequently settling, the lanthanum

would have mostly remained trapped at the thermocline and eventually mixed to the surface by wind (see **Figures C-16** through **C-22** of **Appendix C)**. Both the insertion level and settling were well captured by the model. The model was also able to accurately predict the horizontal extent of lanthanum plume in the reservoir.

The validation presented here introduced additional assumptions, such as particle distributions and flocculation rates other than those made in the calibration. However, both the particle distributions and flocculation rates were determined solely based on the measured decreasing mass of total lanthanum over the whole reservoir. The model was able to reproduce the three-dimensional details in measured lanthanum concentrations such as the insertion, horizontal extent and dilution of the plume, as well as the settling. This provides verification and confidence in the model performance.

5. CAEDYM CALIBRATION

5.1 OVERVIEW

The calibration of the water quality model CAEDYM was carried out after the ELCOM calibration was completed. The comparison between simulation results and measured in-reservoir field data involved the following water quality parameters: DO, pH, nutrients, chlorophyll *a* and Secchi depth.

The in-reservoir water quality data were obtained by the City and plots of these data are included in **Appendix B**. Secchi depths and DO profiles are measured weekly. Nutrients are measured monthly at the surface (*i.e.*, epilimnion) and 1 meter above the reservoir bottom (*i.e.*, within the hypolimnion). Surface grab samples of chlorophyll *a* were measured monthly through 2003 (**Figure B-21**); since 2004, chlorophyll *a* concentration profiles have been estimated using an optical fluorometer (**Figure B-11** through **B-15**). These in-reservoir data were used to specify the initial profile concentrations at the start of the calibration period as well as for comparison against the simulated results for CAEDYM calibration.

5.2 CAEDYM CALIBRATION SETUP

5.2.1 Computational Grid Setup and Initial Conditions

A grid with a horizontal resolution of 100 × 100 m as shown in **Figure** 34 (compared to the finer grid with a horizontal resolution of 50 × 50 m used in the ELCOM calibration) was used for the CAEDYM calibration in order to complete the two-year run in reasonable computation time (4 days on a fast PC). The vertical grid is the same as that in the ELCOM calibration. The ELCOM calibration run was conducted on both grids to evaluate any difference in the predicted hydrodynamic conditions. **Figure 35** shows a comparison of the predicted temperature profiles at Station A using the fine and coarse grids. **Figure 36** shows a time series of predicted surface and bottom conductivity using these two grids. The results indicate that using either the fine or coarse grids will result in almost the same predicted conductivity and very similar predicted temperature profiles. Therefore, it is appropriate to use the coarse grid in the CAEDYM calibration to provide both reasonable model run times as well as adequate model resolution.

The initial reservoir DO and pH concentrations at the beginning of 2006 were based on in-reservoir measured data from Station A (see **Figure 1**) on January 3, 2006, as shown in **Appendix B**. The initial conditions for nutrients were based on the first available measured data (*i.e.*, on January 26, 2006).

5.2.2 Inflow Water Quality Inputs

Water quality parameters such as pH, DO, nutrients and chlorophyll *a* of all inflows are required as inputs in the CAEDYM calibration; but these data were not measured at all times for all inflows. In the previous SVR modeling study (FSI, 2009), a lot of effort has been put into preparing and testing the input files for the water quality calibration based on several assumptions and estimates. These assumptions and estimates have been through peer review in the previous study and were adopted directly in this calibration. A brief description of these assumptions is provided below for each inflow and details can be found in the previous SVR model calibration study (FSI, 2009). **Appendix C** (see **Figures C-23** through **C-40**) includes plots of the measured data and input data used in the model calibration for each inflow.

Aqueduct Inflows

Similar to the ELCOM calibration, water quality data measured at the Lake Skinner outlet were used to characterize the Aqueduct inflow for most of the 2006-2007 calibration period. These data were obtained directly from MWD and included approximately bi-weekly total phosphate (TP), and nitrate for at least 2006-2007. Ortho-phosphate (OPO4, used interchangeably with soluble reactive phosphate, or SRP here) data were only available for 2001-2004, ammonia data were only available for 2000-2004, and total nitrogen (TN) data were not available at all. Assumptions made in developing the Aqueduct water quality input files (**Figures C-23** through **C-29**) are noted below:

- DO concentrations were assumed to be 100% saturated based on water temperature.
- Chlorophyll *a* concentrations were assumed to be 0 µg/L since releases from Lake Skinner are generally at depth.
- Concentrations of SRP were estimated as 40 percent of the TP concentrations based on comparisons of the limited OP data from 2001-2004 with the TP data.
- Ammonia concentrations were estimated as 20 percent of the nitrate concentrations based on comparisons of the limited ammonia data from 2000-2004 with the nitrate data.
- TN concentrations were estimated as 120 percent of the sum of the nitrate and ammonia concentrations

During the "Bypassing Period" (October 2006 through January 2007), about 80% of the water in the Aqueduct was being supplied directly from the San Diego Canal while

the remaining water was supplied by Lake Skinner. During this period, limited TP and nitrate, but not SRP, ammonia, and TN, data were obtained from MWD for the San Diego Canal. Assumptions made in developing the Aqueduct input data files during the Bypassing Period are noted below:

- DO concentrations were assumed to be 100 percent saturated based on water temperature.
- Chlorophyll *a* concentrations were assumed to be 0 µg/L.
- TP and nitrate concentrations measured at the San Diego Canal were used to represent those in the Aqueduct inflow. Concentrations of SRP were estimated as 40 percent of the TP concentrations. Ammonia concentrations were estimated as 20 percent of the nitrate concentrations. TN concentrations were estimated as 1.2 mg/L to reflect the fact that a majority of the water in the San Diego Canal at that time was from the State Water Project (SWP), and SWP water generally has high nutrient concentrations (verbal communication with Bill Taylor of MWD and Jeffery Pasek of the City).

Runoff Inflows

Water quality data for the local tributaries to SVR were obtained from the City and included DO, TP, OPO4, TN, nitrate, and ammonia data, measured as often as monthly since 2003. Similar to the ELCOM calibration, data measured in SV Creek were used to estimate the model inputs for other tributaries (**Figures C-30** through **C-36**).

Sutherland Reservoir Inflows

Due to the limited nutrient data available during the months in which the Sutherland Reservoir inflows occurred (**Figure C-37**), TP, SRP, and TN concentrations were estimated by computing the average concentrations from measurements taken within Sutherland Reservoir when destratified in the winter, a period when nutrients are generally not being quickly consumed. Nitrate data were all below the detection limit, so nitrate concentrations were estimated to be equal to the detection limit. Since ammonia concentration data were not collected, ammonia concentrations were estimated as 20% of the TN.

The pH, DO and chlorophyll *a* values of inflows from Sutherland Reservoir were assumed to be equal to the profile data measured within the hypolimnion near the elevation of the outlet (**Figures C-38** through **C-40**).

5.3 CALIBRATION RESULTS

5.3.1 Dissolved Oxygen

Comparison plots for the simulated and measured DO concentrations are provided in **Figures 37** and **38**. The measured data show that DO concentrations at the surface remained high throughout the years because of the supply of oxygen directly from the atmosphere by diffusion and because of oxygen produced by photosynthetic activity of algae at surface. At high rates of photosynthesis, oxygen production by algae exceeded the diffusion of oxygen out of the system and resulted in occasional oxygen supersaturation in the spring of 2006 and 2007. The DO at bottom was replenished through vertical mixing with the surface water with high DO concentrations during the reservoir destratified periods in the winter of 2006 and 2007. However, during the summer, strong stratification at SVR prevented such vertical mixing and DO at the bottom was quickly depleted by the decay of algae and other organic matter in the sediment (*i.e.*, Sediment Oxygen Demand or SOD). The water conditions in the hypolimnion became anoxic (*i.e.*, dissolved oxygen concentrations are 0 mg/L) in the spring and anoxia lasted through the fall for both years, until the reservoir became destratified in the winter.

The simulated DO concentrations capture the major trends in the measured DO concentrations, including the onset, duration, and magnitude of periods of anoxia in the hypolimnion, the depth to the top of the anoxic (*i.e.*, "without oxygen") region, and the high surface DO concentrations in the spring (and sometimes fall) that are due to algae blooms. A value of 1.5 $g/m^2/day$ was used for SOD in the calibration as it achieved the best match to the rate of decrease in DO measured at bottom during the stratified periods. This value is at the high end of the range of 0.1 – 1.75 $g/m^2/day$ for sediment oxygen demand measured at SVR in 2001 (Beutel, 2001), but is consistent with historic DO profile data (**Appendix B**) that show faster rates of DO decay at the bottom in 2006-2007 than in 2001 due to more algal productions in the reservoir evidenced by relatively smaller Secchi depths in 2006-2007.

A scatter plot of the measured and simulated DO concentrations for years 2006 and 2007 is provided in **Figure 39**. A statistical analysis of the calibration results versus the measured data produced the metrics presented in **Table 7**. The computed Root Mean Square Errors (RMSE) indicate that the calibrated DO concentrations are on average within 1.3 mg/L of the measured data, corresponding 7-9% of the range in measured DO concentrations. These indicate a good calibration for DO for both years.

Table 7. Dissolved Oxygen Calibration Metrics

PARAMETER	2006 RESULTS			2007 RESULTS		
	ROOT MEAN SQUARE ERROR (RMSE)	RELATIVE RMSE	MEAN ERROR	ROOT MEAN SQUARE ERROR (RMSE)	RELATIVE RMSE	MEAN ERROR
Surface and Bottom Dissolved Oxygen	1.26 mg/L	9.0 %	0.76 mg/L	1.03 mg/L	7.4 %	0.45 mg/L

5.3.2 pH

Figures 40 and **41** show comparison plots for the simulated and measured pH. The measured data show that pH increased in the spring and summer of each year when inorganic carbon was consumed by the photosynthetic activity of algae; pH values were reduced in the winter because of the release of CO_2 as a byproduct of algae respiration. The model accurately captures major trends in the measured pH and the simulated pH closely tracks measured data. It is noted in these figures that the measured surface pH on 11/5/07 and the measured bottom pH on 6/16/06, 4/23/07, 4/30/07, 7/16/07, 7/30/07, 11/5/07 and 11/19/07 are unusually low compared to other data. Thus, these data are considered as outliers and were excluded from the analysis described next. A scatter plot of the measured and simulated pH for years 2006 and 2007 is provided in **Figure 42**. A statistical analysis of the calibration results versus the measured data produced the metrics presented in **Table 8**. The computed Root Mean Square Errors (RMSE) indicates that the calibrated pH are on average within 0.3 of the measured data, corresponding to 10-15% of the range in measured pH values. These indicate a good pH calibration for both years, especially considering the small variation of pH during the two-year calibration period.

Table 8. pH Calibration Metrics

PARAMETER	2006 RESULTS			2007 RESULTS		
	ROOT MEAN SQUARE ERROR (RMSE)	RELATIVE RMSE	MEAN ERROR	ROOT MEAN SQUARE ERROR (RMSE)	RELATIVE RMSE	MEAN ERROR
Surface and Bottom pH	0.19	9.7 %	0.03	0.28	14.3 %	0.05

5.3.3 Nutrients

Figures 43 and 44 are plots of the simulated and measured SRP and TP concentrations, respectively. The measured surface SRP and TP data are usually below

the detection limits (*i.e.*, 0.008 and 0.08 mg/L P, respectively), and the bottom SRP and TP data are also below the detection limits in the winter and spring. Despite that, general trends in the measured phosphorus data can still be observed. At the surface, phosphorus levels were usually low due to consumption by algae. At the bottom, phosphorus concentrations were low at the beginning of 2006 when the reservoir was fully mixed. As the reservoir became stratified in the early spring of 2006, phosphorus concentrations started to increase due to the release of phosphorus from the sediment caused by anoxic conditions in the hypolimnion. However, after June 2006, phosphorus concentrations stayed relatively constant until the reservoir was fully mixed again in January 2007. This is due to the fact that the sediment release of phosphorus in spring probably exhausts the phosphorus storage in the sediments. In 2007, phosphorus concentrations increased slowly at the bottom through the year. As shown, the model captures these trends fairly well although the simulated bottom concentrations are slightly higher than the measured data.

Comparison plots of the simulated and measured ammonia, nitrate, and TN concentrations are provided in **Figures 45** through **47**, respectively. In these figures, ammonia concentrations are below the detection limit (*i.e.*, 0.04 mg/L N) at the surface throughout the year and at the bottom during the destratified period. The nitrate concentrations are below the detection limit (*i.e.*, 0.02 mg/L N) from about July through January of each year. The observed trends in measured ammonia data are similar to those in measured phosphorus data. However, the trends of nitrate concentrations at the bottom are the reverse of those in ammonia concentrations: nitrate concentrations are high when the reservoir is destratified and DO at bottom is high; nitrate concentrations decrease when the reservoir is stratified and DO at bottom is low. This is because ammonia in the sediment can convert to nitrate through a nitrification process if oxygen is present and, consequently, the sediment releases nitrate instead of ammonia. Once the bottom of the reservoir becomes anoxic, nitrate is depleted slowly by denitrification. As shown, the simulated ammonia and nitrate match the trends and magnitude of the measured data fairly well.

The simulated TN concentrations match the measured concentrations during the destratified periods and follow the general trends of the data, although the simulated TN concentrations are significantly lower than a few measured data points during the summer of 2006. These measured TN concentrations in the summer of 2006 are very high compared to those in summer of 2007. There are no evident sources of nitrogen that can explain such spikes.

5.3.4 Chlorophyll *a* and Secchi Depth

There are no measured chlorophyll *a* concentrations available in years 2006-2007 at SVR. Instead, chlorophyll *a* concentration profiles were estimated using an optical fluorometer and were provided by the City (**Figure B-11** through **B-15**). The optical

fluorometer measures fluorescence and, if calibrated, can make an estimate of relative chlorophyll *a* concentrations because algae fluoresce at characteristic wavelengths. Optical fluorometers can be used to collect profile measurements similar to a temperature or conductivity probe. Thus, they could provide more data (albeit of lower quality) more economically than could be obtained with grab samples and laboratory analysis. However, fluorometer readings can be corrupted by other particles present in the water column and indicate "false" algae blooms. For example, in SVR, the algae bloom that starts from August 2007 is probably a "false" algae bloom because the data show extremely high chlorophyll *a* concentrations (> 100 µg/L) at the depth below the thermocline but measured DO profiles show no evidence of high oxygen spikes/production at that depth to support the existence of such algae bloom (**Figure 48**). These high readings of fluorescence below the thermocline could, for example, be caused by the accumulation of surface algae and other particles at the thermocline due to settling flocculants such as manganese and iron hydroxides formed in the epilimnion. Manganese and iron hydroxides are insoluble under high DO conditions (*e.g.* in the epilimnion) and soluble under low DO conditions (*e.g.* in the hypolimnion). Therefore, if water is rich in manganese and iron hydroxides which are flocculants, they form flocs in the epilimninon under high DO conditions. These flocs catch algae and other particles as they settle at the thermocline, leading to concentrated algae and particles (thus high readings of fluorescence) at the thermocline. Similar processes involved in arsenic accumulation at the thermocline have been reported at Halls Brook Pond, Massachusetts (Ford, *et al.,* 2005 and 2006)

Since a fluorometer calibration had not been conducted at SVR, the simulated chlorophyll *a* concentrations by the SVR model were not compared directly against chlorophyll *a* data estimated using fluorometer data. Instead, the calibration of chlorophyll *a* was conducted through a "simulated" Secchi depth derived from a correlation between the simulated chlorophyll *a* concentrations and Secchi depth.

Secchi depth is a measure of the degree of transparency at the reservoir surface and, in a water body like SVR, is generally strongly correlated (for water with low inorganic turbidity) with chlorophyll *a* concentration since algae growth affects water clarity. Based on a study by Rast and Lee (1978) on various reservoirs, the following relationship was suggested:

$$\text{Log (Secchi Depth in m)} = -0.473 \text{ Log (Chlorophyll } a \text{ in } \mu\text{g/L)} + 0.803 \qquad \text{[Eqn. 4]}$$

Although CAEDYM does not simulate Secchi depth directly, the "simulated" Secchi depths can be derived from the simulated surface chlorophyll *a* concentrations using this formula. Therefore, a good calibration for Secchi depth can be translated into a good calibration for chlorophyll *a* concentrations.

The "simulated" Secchi depths are plotted against the measured Secchi depths in **Figure 49**. The measured Secchi depths are generally in the range of 3 to 5 m from

January through September 2006. However, between October and December 2006, the Secchi depths decreased significantly and remained low through June 2007. This period of small Secchi depth corresponds to the Bypassing Period when 80% of flow into the Aqueduct was coming directly from the San Diego Canal that has higher nutrient levels as discussed in **Section 5.2.2**. It is believed that the decrease in Secchi depth starting in October 2006 is predominantly due to chlorophyll *a* growth (verbal communication with Jeffery Pasek of the City) caused by a large influx of nutrient from the water in the San Diego Canal during the Bypassing Period.

The Secchi depth data in **Figure 49** suggest that the calibrated chlorophyll *a* concentrations during the Bypassing Period and through June 2007 are still a little lower than the data. But without more detailed information on the Aqueduct source water quality and direct chlorophyll *a* measurements, it was difficult to obtain a better correlation. A scatter plot of the measured and simulated Secchi depth for years 2006 and 2007 is provided in **Figure 50**. A statistical analysis of the calibration results versus the measured data produced the metrics presented in **Table 9**. The computed Root Mean Square Errors (RMSE) indicate that the calibrated Secchi depths are on average within 1.2 m of the measured data, corresponding to about 20% of the range in measured Secchi depth. These indicate a fairly good calibration for both Secchi depth and chlorophyll *a*, especially considering the unknown nutrient loadings during the Bypassing Period.

Table 9. Secchi Depth Calibration Metrics

PARAMETER	2006 RESULTS			2007 RESULTS		
	ROOT MEAN SQUARE ERROR (RMSE)	RELATIVE RMSE	MEAN ERROR	ROOT MEAN SQUARE ERROR (RMSE)	RELATIVE RMSE	MEAN ERROR
Secchi Depth	1.06 m	20.8 %	0.18 m	1.14 m	22.3 %	-0.87 m

6. CONCLUSIONS AND DISCUSSION

A three-dimensional water quality model has been applied, calibrated and verified for SVR. It is anticipated that this model will be used to study the dynamics, mixing, and residence time of advanced treated recycled water and its effects on eutrophication in the expanded SVR.

The modeling domain includes the existing portion of the reservoir as well as the proposed expanded portion of the reservoir. A fine grid with a horizontal resolution of 50 × 50 m was used in the ELCOM calibration while a coarse grid with a horizontal resolution of 100 × 100 m was used in the CAEDYM calibration. This was necessitated by the large computer requirements and the desire to limit computation time to several days per model run for a two-year simulation. A variable grid size was used in the vertical dimension with a grid size of 1.64 ft (0.5 m) near the surface, and expanding in size with depth. The calibration was conducted for the two-year period of 2006-2007. The input data required by the calibration were either based on measured data or derived from these data. ELCOM requires limited calibration effort in that the physical aspects of water movements in reservoirs are fairly well understood. The CAEDYM model was calibrated by adjusting some model bio-chemical parameters so that the simulation results best match measured field data.

The calibrated/validated ELCOM model shows good agreement with the measured data for both water temperature and conductivity. The calibration involved reconstruction of some meteorological data during periods where data were unavailable. It also involved an adjustment for the outlet port openings in the second half of 2007. As discussed in detail in the report, the City-specified field reports of the ports open during a portion of 2007 are at variance with the basic thermodynamics of the system. It is demonstrated later in this report that the open ports must have been at or above the thermocline level and not in the hypolimnion, as specified. In the future, it is recommended that outflow temperatures from SVR be recorded so that they can provide verification of the field record of port openings.

The onset and duration of thermal stratification as well as the deepening rate of the thermocline were predicted accurately by the model. Furthermore, the water conductivity, a measure of salinity, was well predicted by the model. It is noted that future modeling of the hydrodynamics at SVR would benefit from a full set of meteorological data gathered at SVR (the City stopped gathering on-site meteorological data in March 2007). An analysis presented herein shows that the meteorological data measured at the nearby California Irrigation Management Information System (CIMIS) station in Escondido differ in significant aspects from data gathered at SVR.

After the model was calibrated, a validation was performed to compare the model against the results of previous field studies. The field studies involved two separate episodes of tracer injection in the reservoir (winter 1995 and summer 1995). The field

studies clearly showed the impacts of stratification (or lack thereof) on the mixing and dispersion of the tracer. The ELCOM model was capable of replicating the main features of the tracer study. Due to the nature of the tracer used in those studies (Lanthanum Chloride), a significant amount of tracer was lost due to coagulation/flocculation and subsequent settling. A simple coagulation/settling model was added to ELCOM. After the implementation of the coagulation/settling model, very good agreement between the model and the data was obtained. This validation provides strong verification and assurance that the model performance is accurate.

The calibration of the water quality model CAEDYM was carried out after the ELCOM calibration and verification process. The comparison between simulation results and measured in-reservoir field data involved water quality parameters including dissolved oxygen (DO), pH, nutrients (nitrogen and phosphorus), chlorophyll *a* and Secchi depth. It is noted that some assumptions had to be made in order to calibrate the model. For example, assumptions on nutrient levels for the Aqueduct inflows during the "Bypassing Period" were needed to characterize nutrient loadings because there are only limited nutrient data available for the Aqueduct inflow.

The calibrated CAEDYM model shows overall good agreements with measured data. The simulated DO concentrations capture the major trends in the measured DO concentrations, including the onset, duration, and magnitude of periods of anoxia in the hypolimnion, the depth to the top of the anoxic (*i.e.*, "without oxygen") region, the DO decay rate in the spring in the hypolimnion, and the high surface DO concentrations in the spring (and sometimes fall) that are due to algae blooms. The simulated pH values closely match the measured data and are on average within 0.3 of the measured values. The calibrated model also replicates the major trends in the measured nutrient (phosphorus and nitrogen) concentrations. It is noted, however, that some of the field data are below the detection limit and real values of the nutrient concentrations on these days are unknown. The available in-reservoir chlorophyll *a* data were qualitatively measured using a fluorometer that has not been calibrated. The calibration of chlorophyll *a* had to be conducted indirectly through the calibration of Secchi depth. The final calibration run shows a fairly good agreement with the measured Secchi depths, indicating a fairly good calibration for chlorophyll *a*.

At this point, it is believed that the model calibration/validation is nearly complete. The calibrated/validated model will undergo peer review. After that, the model will be applied to the study of the expanded reservoir as well as the evaluation of the mixing of the advanced treated recycled water within the reservoir. The planned modification of Aqueduct release locations/facilities into the expanded SVR and outlet structure/port depths will be incorporated into the model.

Future evaluations and modeling of water quality at SVR would benefit from more frequent sampling of nutrients and chlorophyll *a* within the reservoir, also from lower nutrient detection limits, and an increased use of duplicate samples or periodic sampling

audits. It is recommended that nutrient samples be collected more frequently and at additional depths throughout the water column. This would increase the data resolution and reliability, improve understanding of the reservoir behavior, and allow for a more precise water quality calibration. It is further recommended that the collection of chlorophyll *a* samples be resumed. Composite samples should be collected from the reservoir surface in order to analyze chlorophyll *a* concentrations in the laboratory. This would allow for calibration of the optical fluorometer data and improve the usefulness and interpretation of that data. Finally, it is recommended that more frequent sampling of nutrients and other parameters be conducted for the inflows (especially the Runoff, and the Aqueduct inflow during bypassing conditions).

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FIGURES

San Vicente Reservoir

Plan View of Existing and Expanded Reservoir and Inflow/Outflow Locations

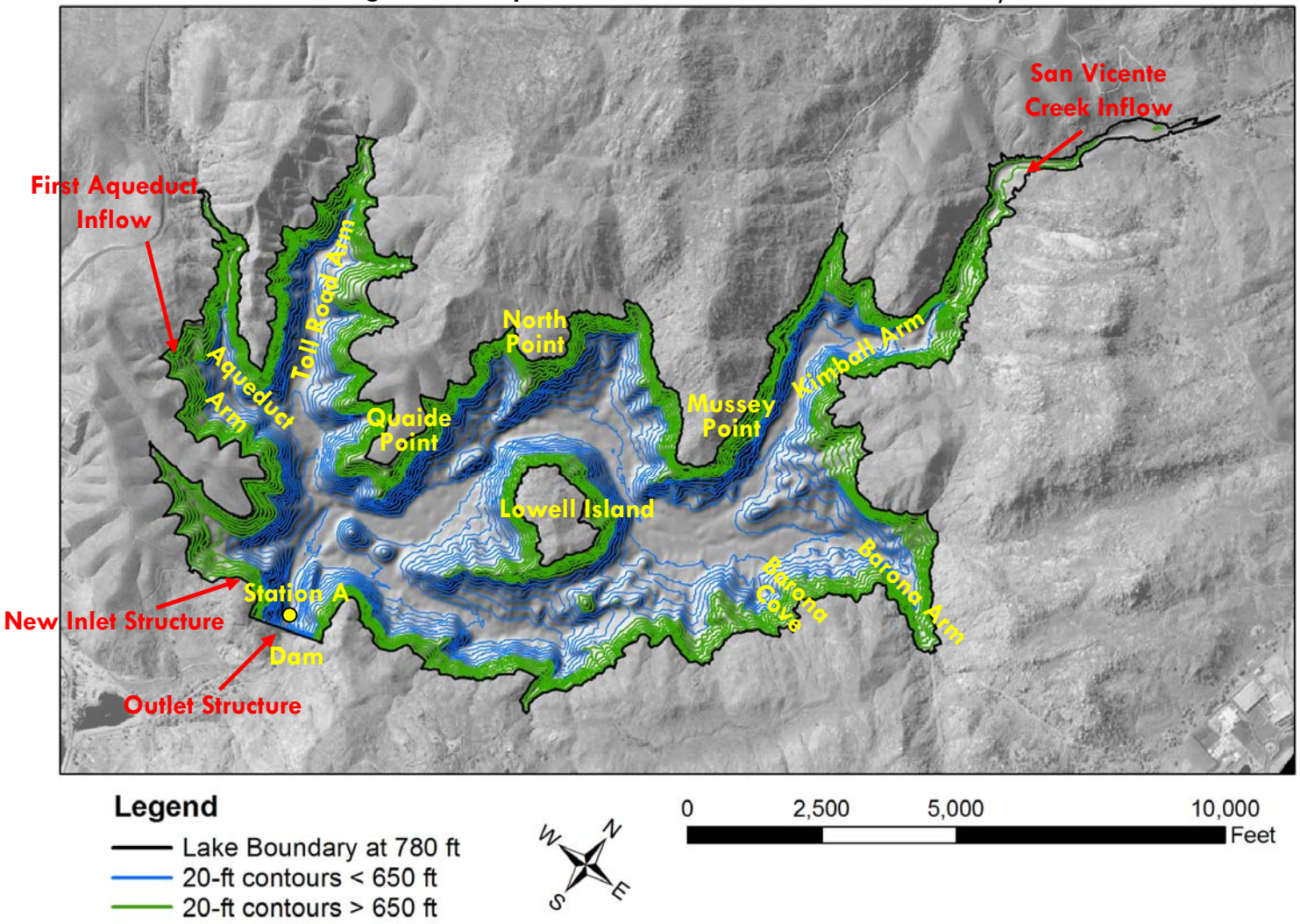

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Figure 1

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ELCOM-CAEDYM

Schematic of Processes Modeled in ELCOM-CAEDYM

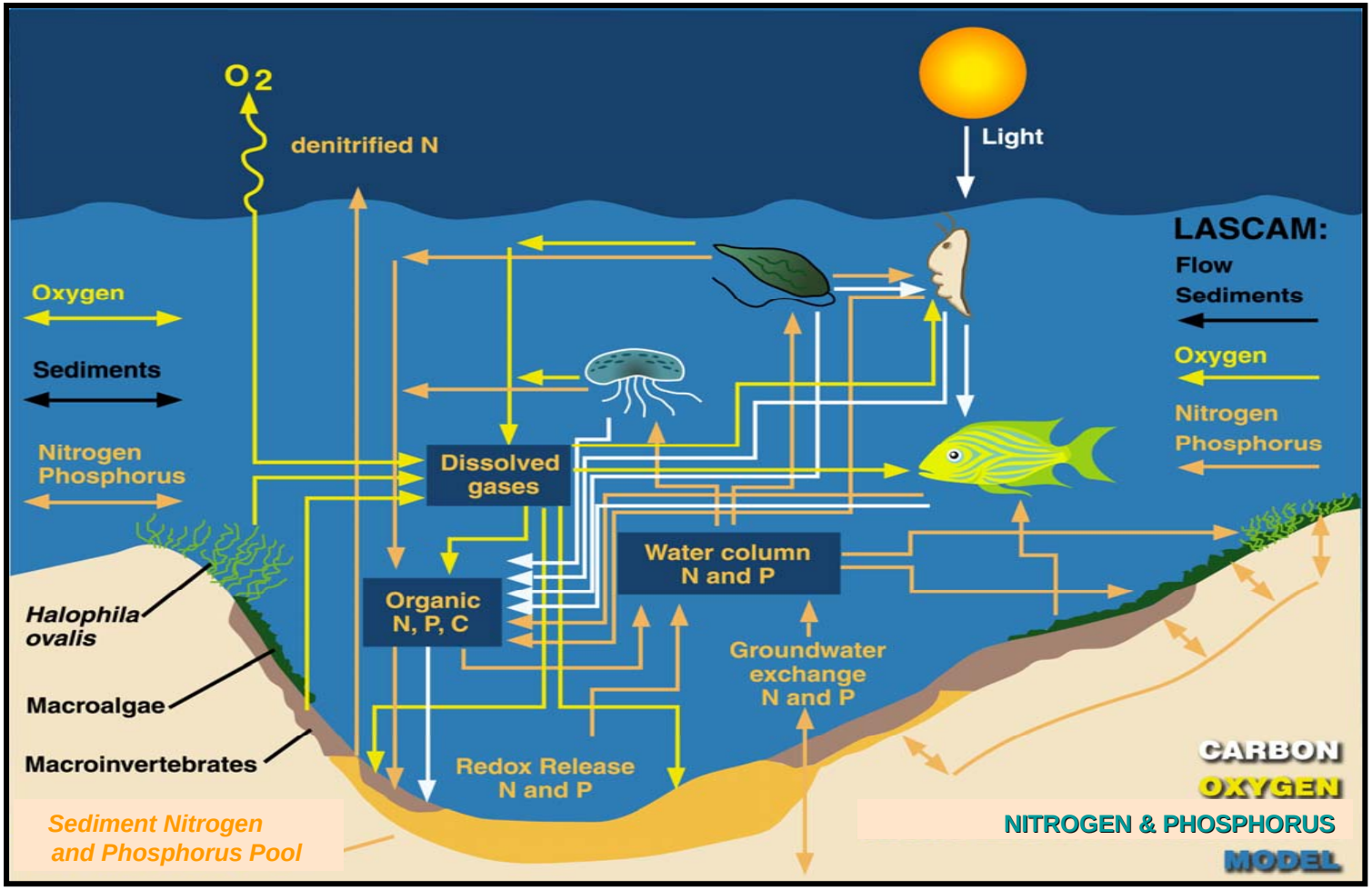

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Figure 2

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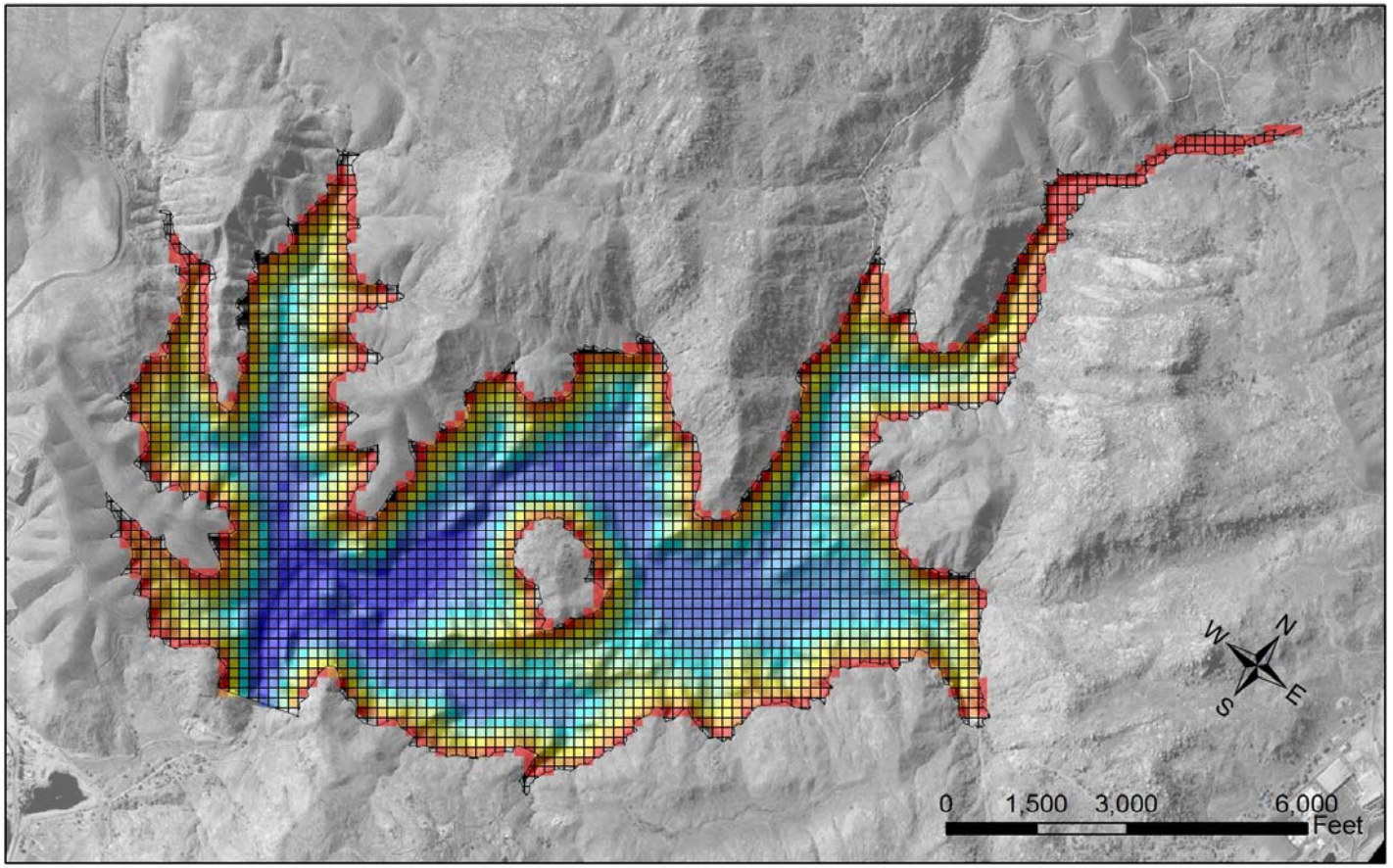
San Vicente Reservoir 50-m ELCOM Computational Grid



San Vicente
50-m ELCOM Grid

Legend

Lake Boundary at 780 ft

Elevation (ft)

480 - 510
511 - 540
541 - 569
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600 - 629
630 - 659
660 - 689
690 - 718
719 - 748
749 - 778

Figure 3

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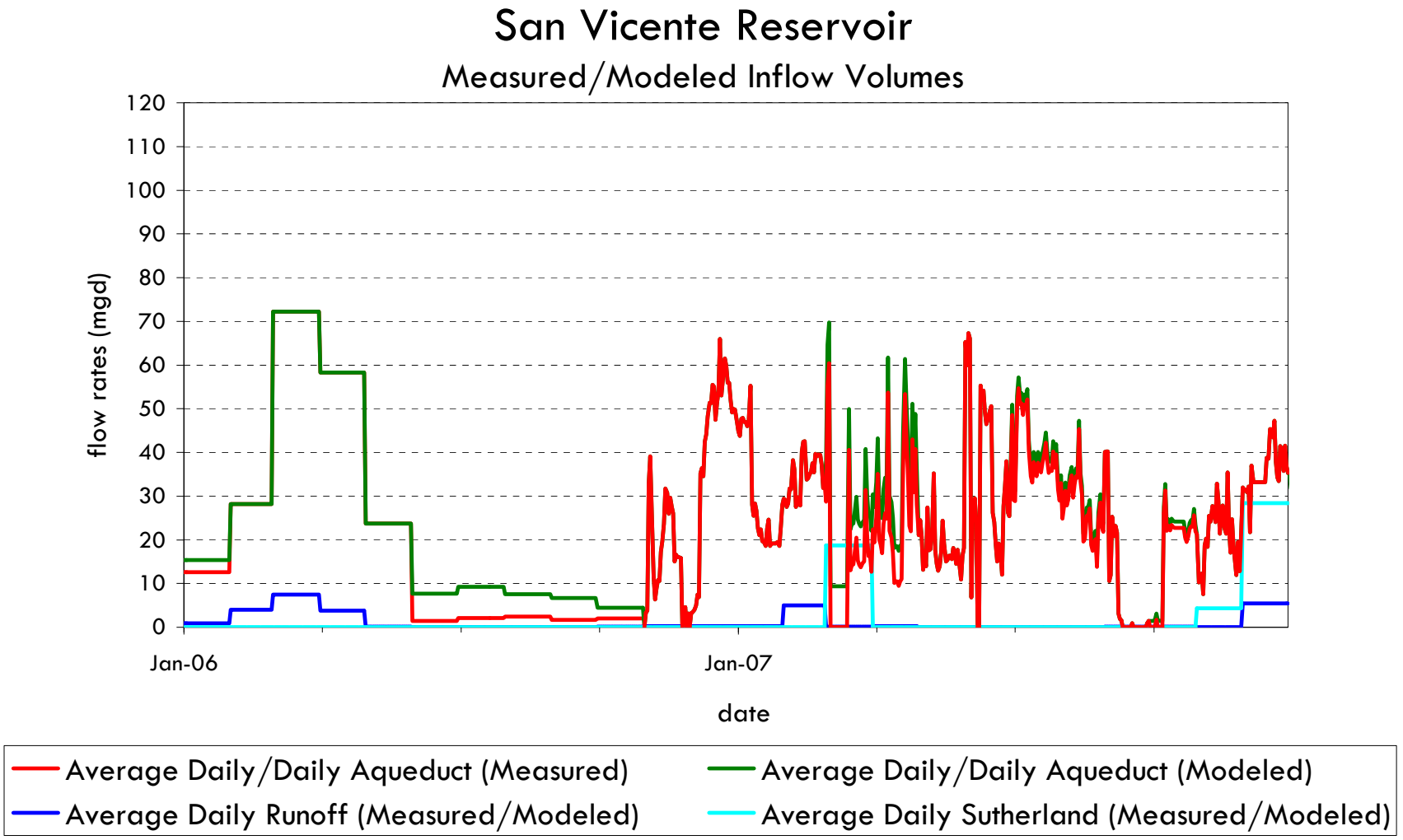

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Figure 4

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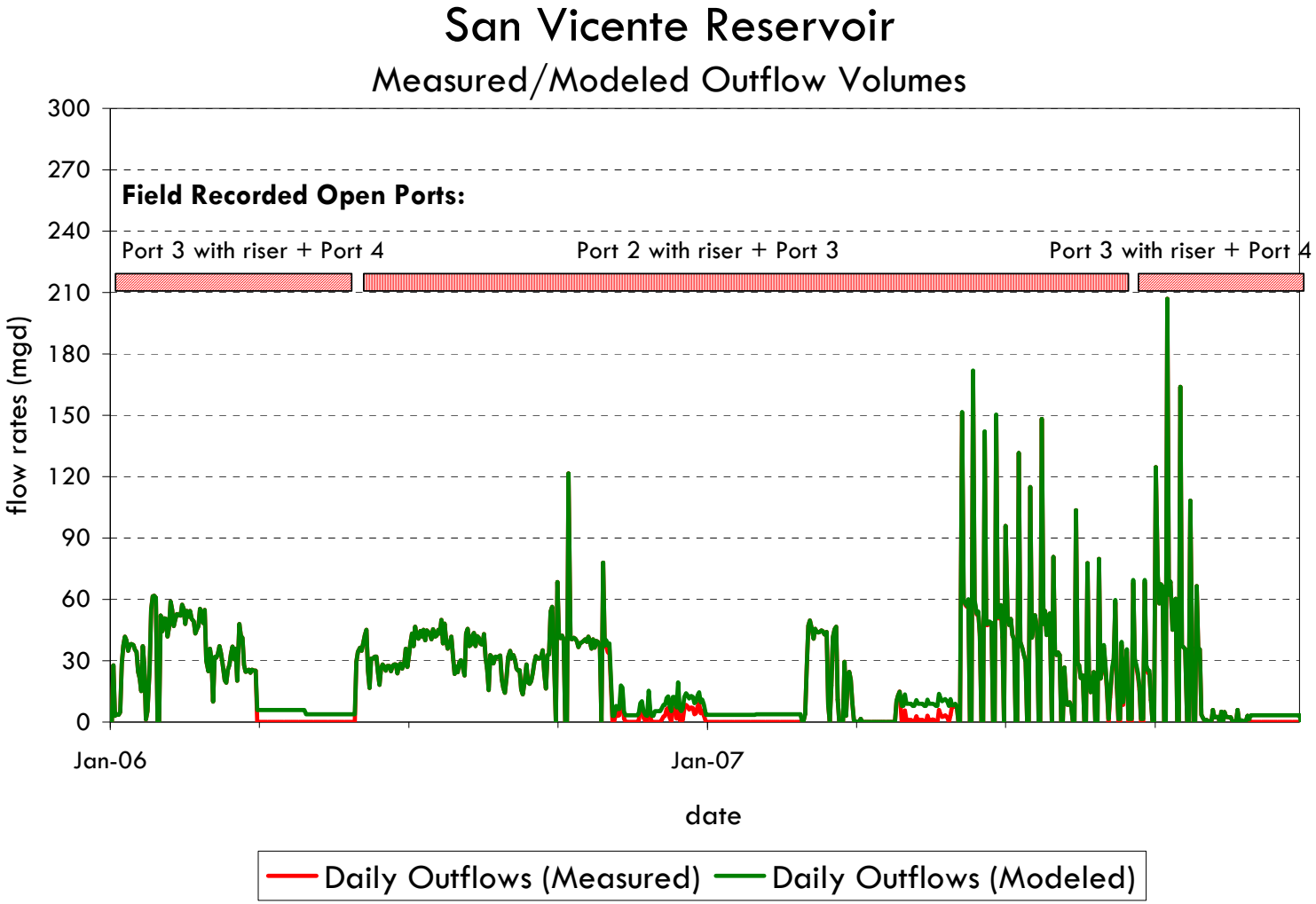

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Figure 5

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Map of Meteorological Stations

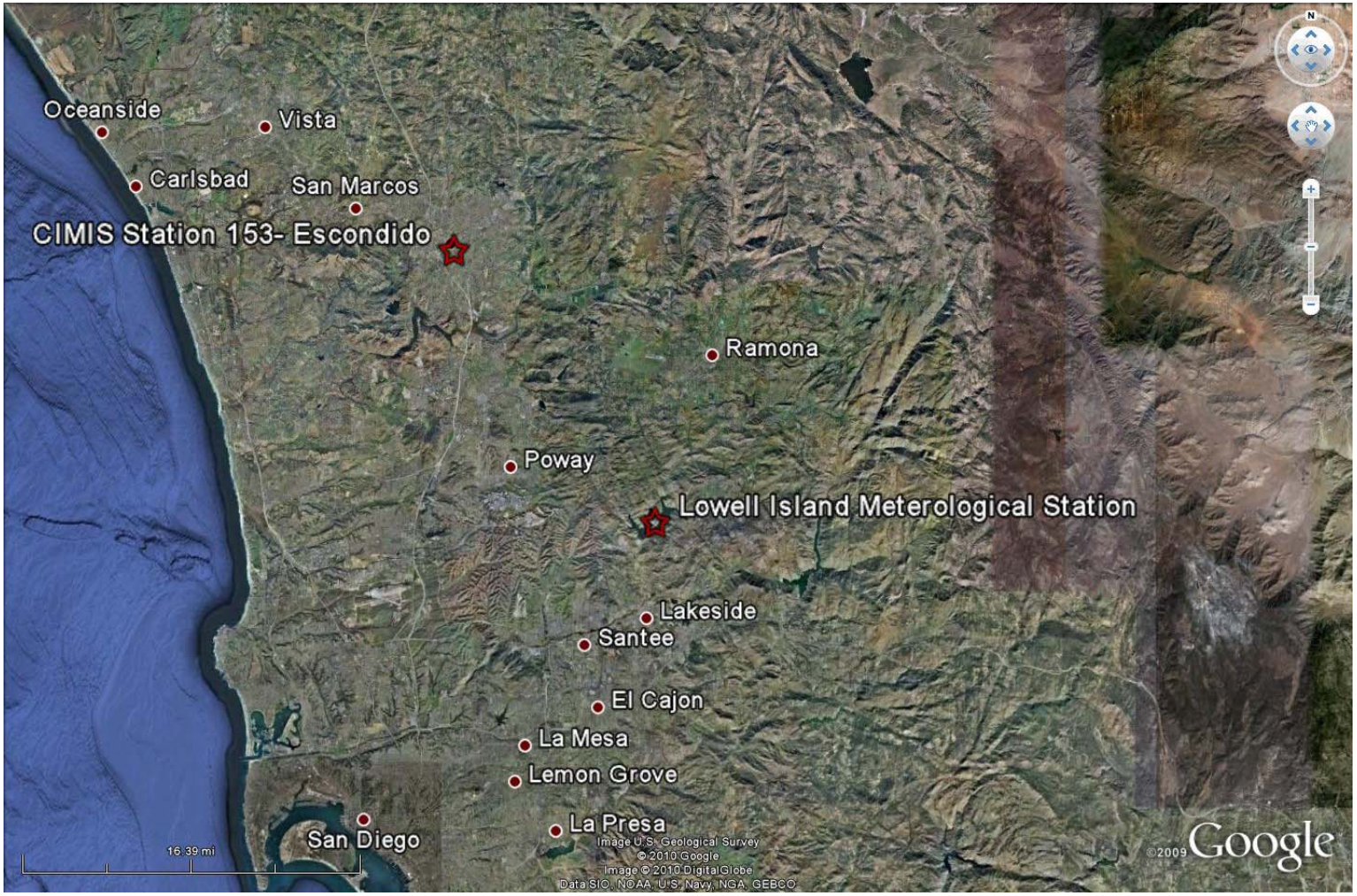

Figure 6

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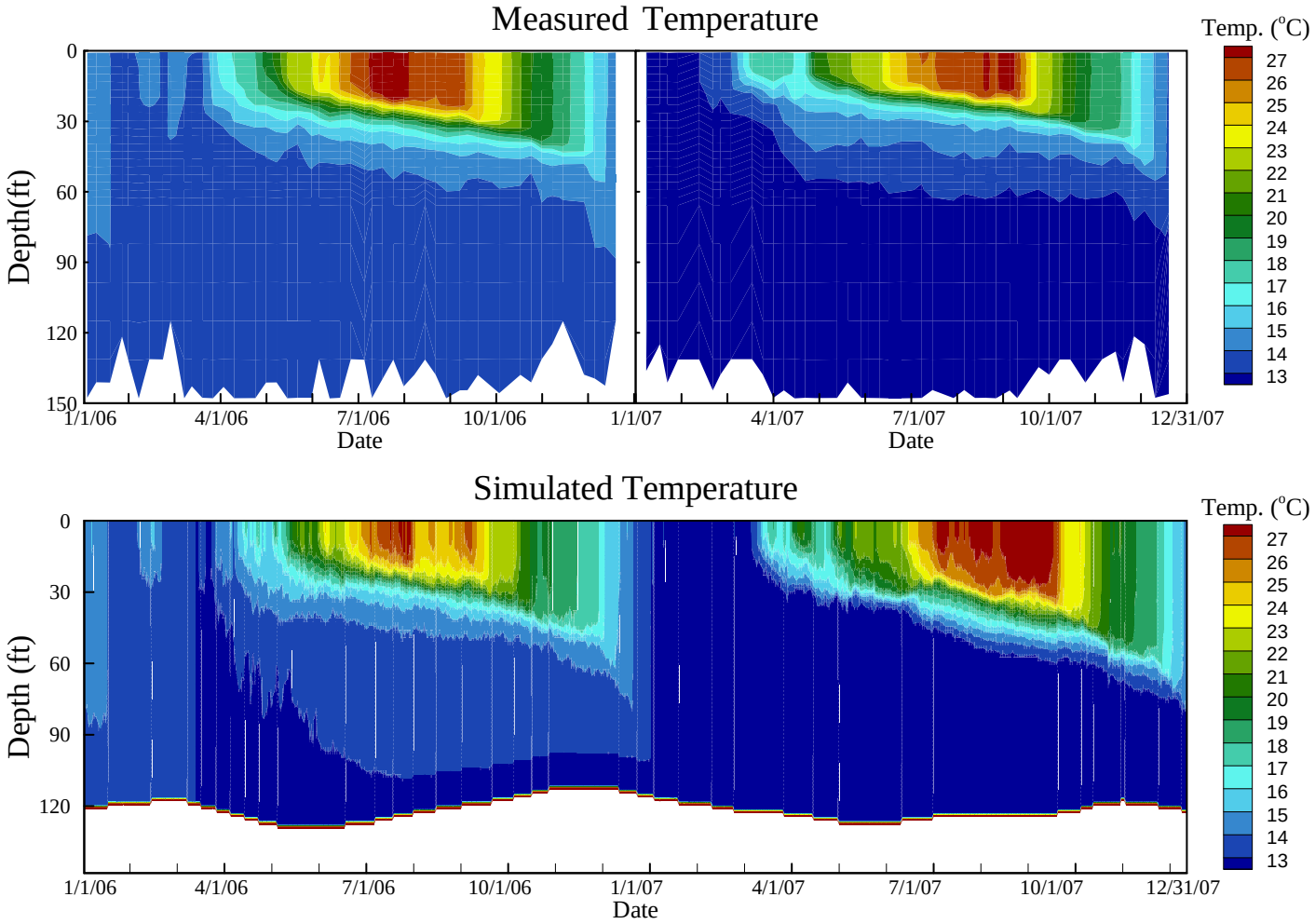
San Vicente Reservoir

Station A – Simulated Temperature Using CIMIS Meteorological Data After March 2007



Meteorological Data Source

Using the City Data at Lowell Island

Using CIMIS Data at Escondido

Figure 7

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San Vicente Reservoir - Station A Temperature Calibration

Impact of Using Different Meteorological Inputs

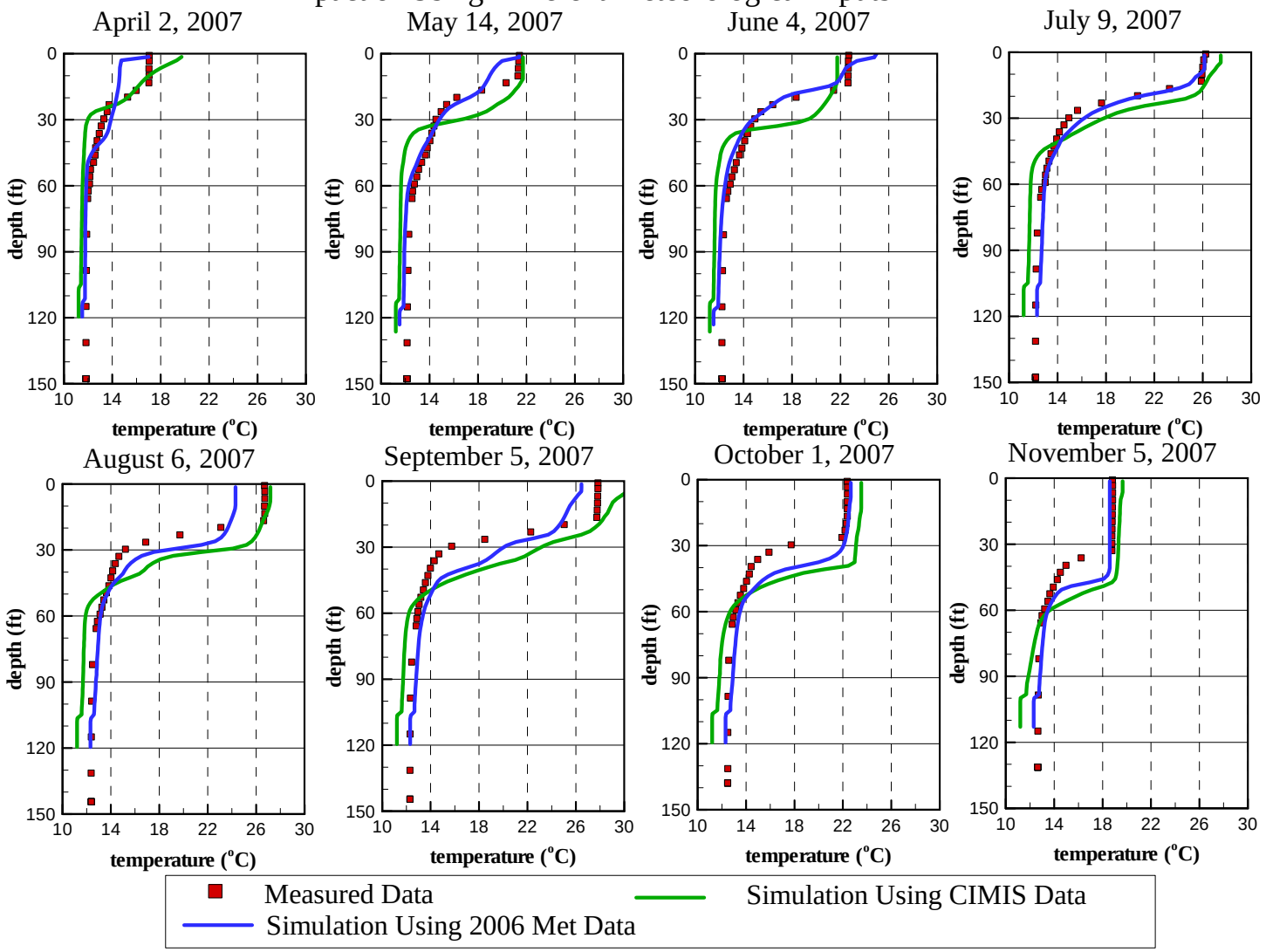

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Figure 8

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San Vicente Reservoir

Station A - Measured Temperature Contours (2000-2007)

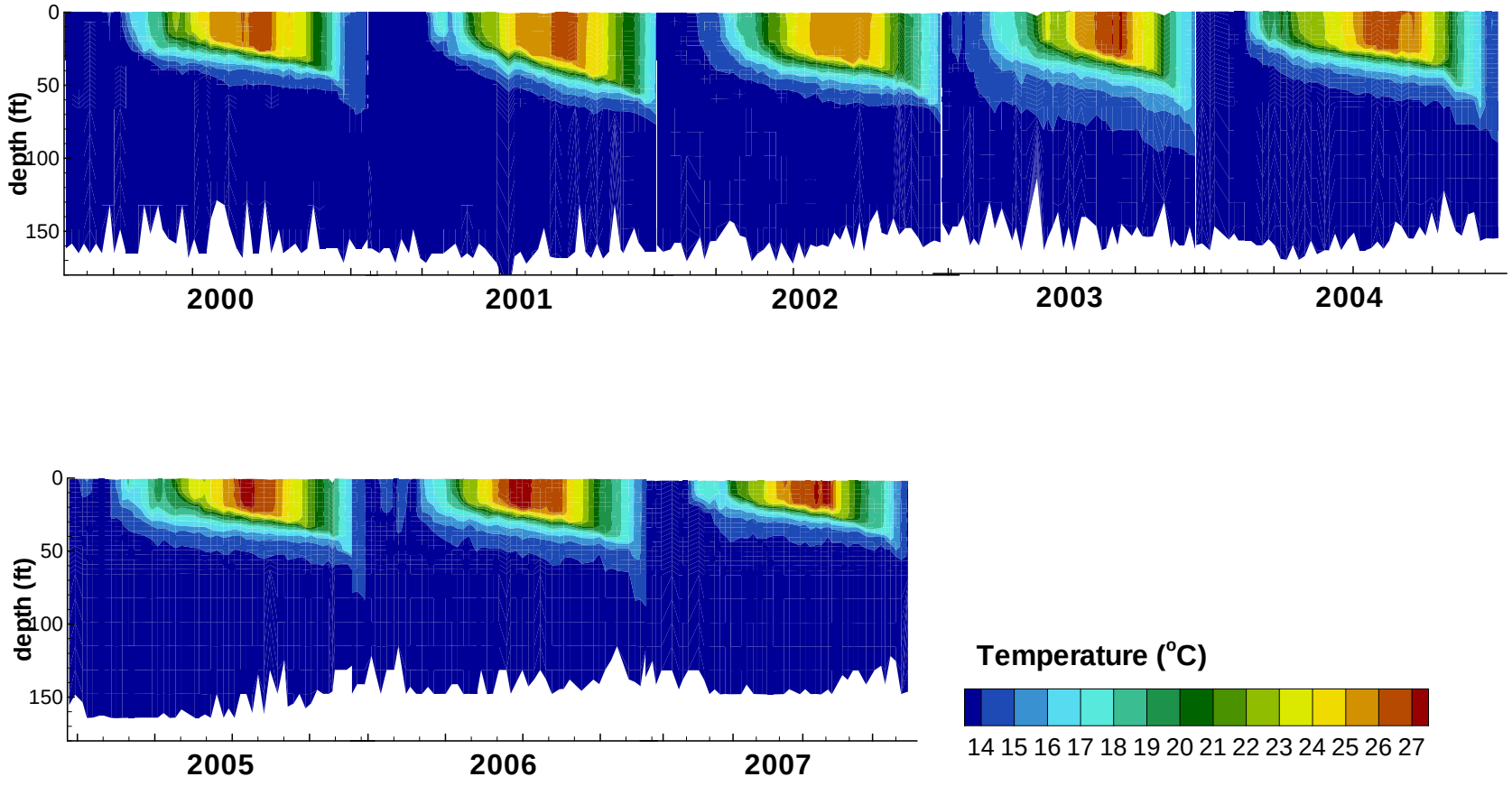

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Figure 9

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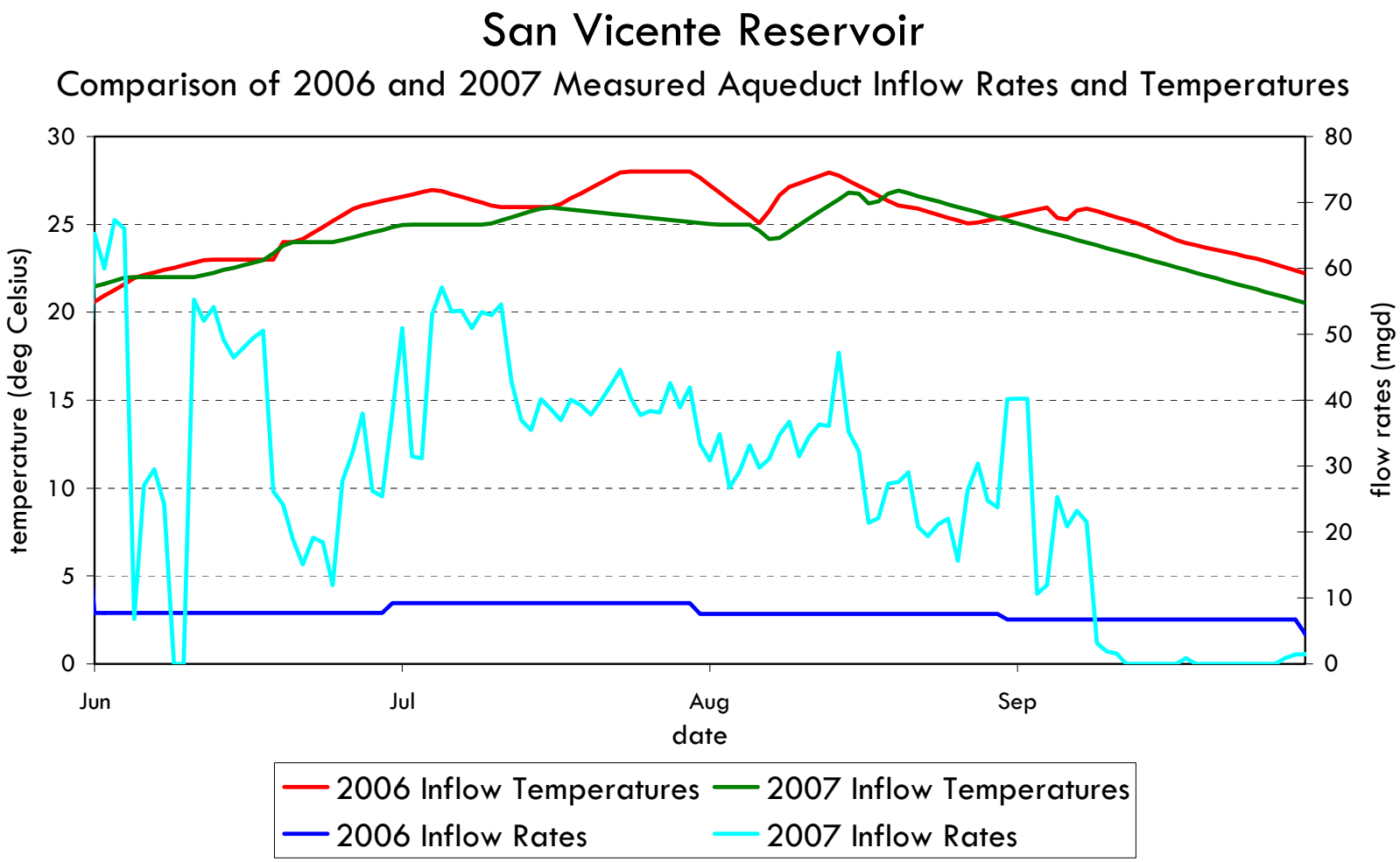

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Figure 10

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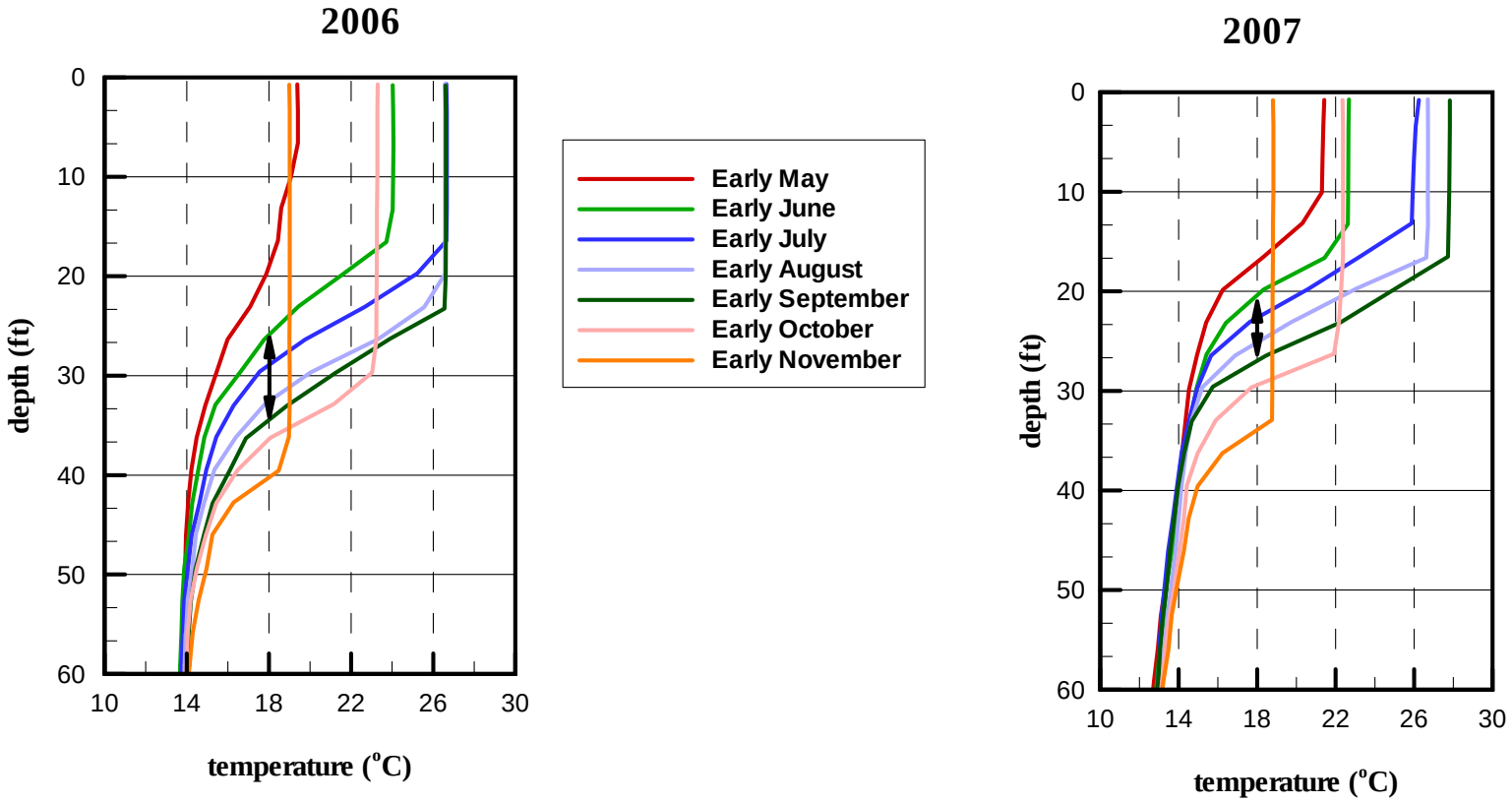
San Vicente Reservoir

Station A - 2006-2007 Measured Temperature Profiles



↔ Thermocline Deepening Between Early June and Early September

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Figure 11

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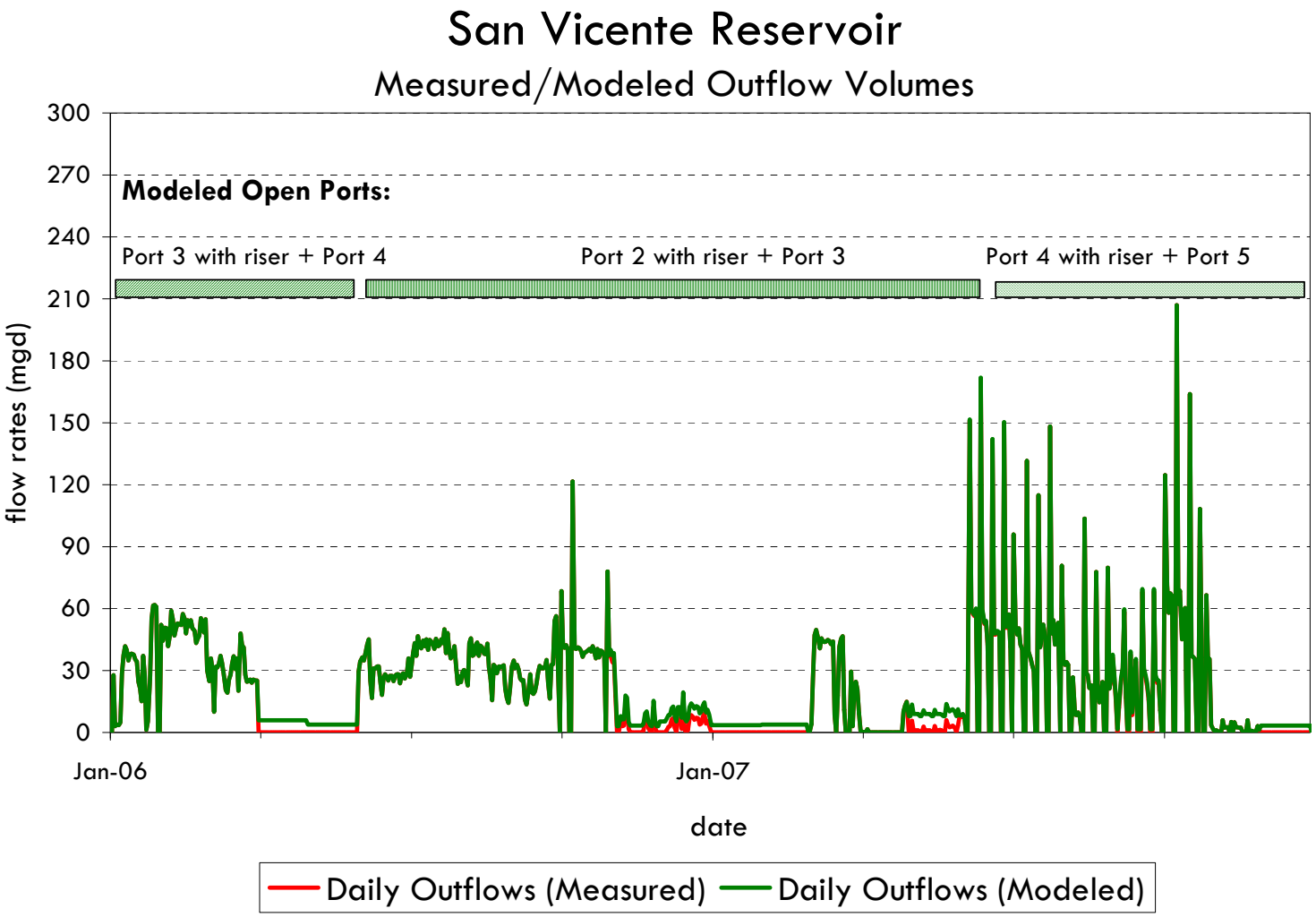

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Figure 12

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San Vicente Reservoir - Station A Temperature Calibration

Impact of Opening Different Outlet Ports

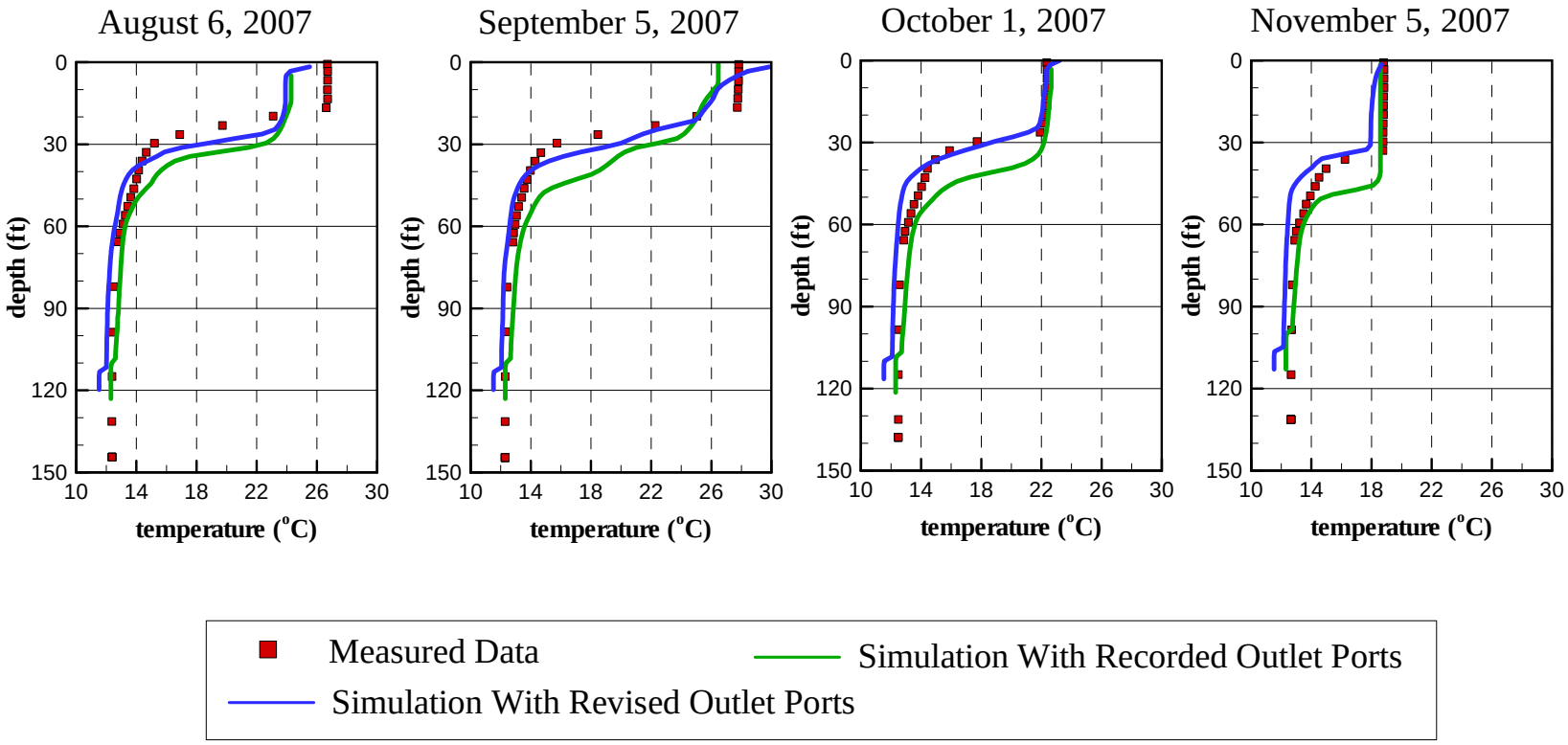

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Figure 13

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San Vicente Reservoir

Measured vs Simulated Water Surface Elevations

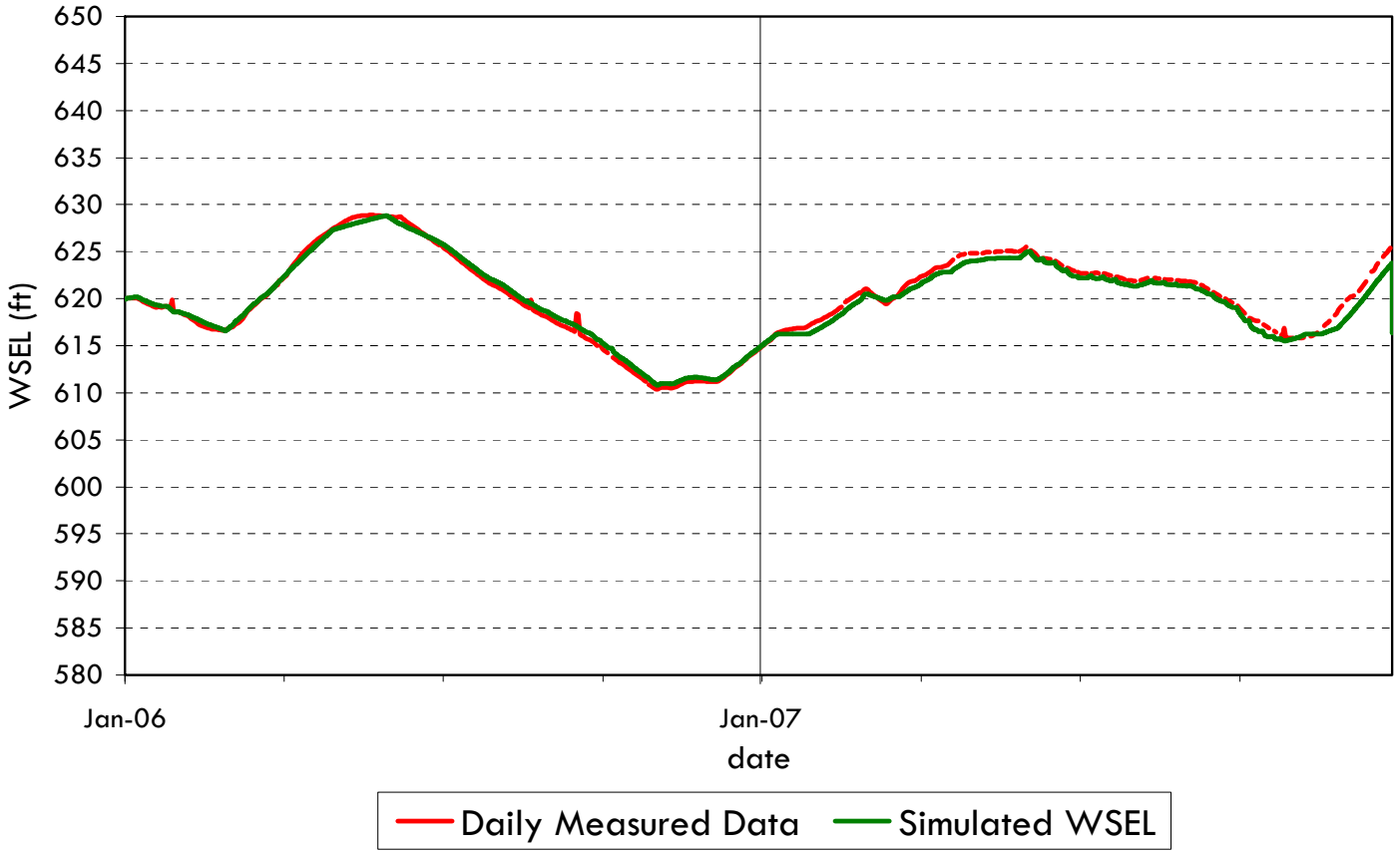

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Figure 14

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San Vicente Reservoir Station A - Water Temperature Calibration

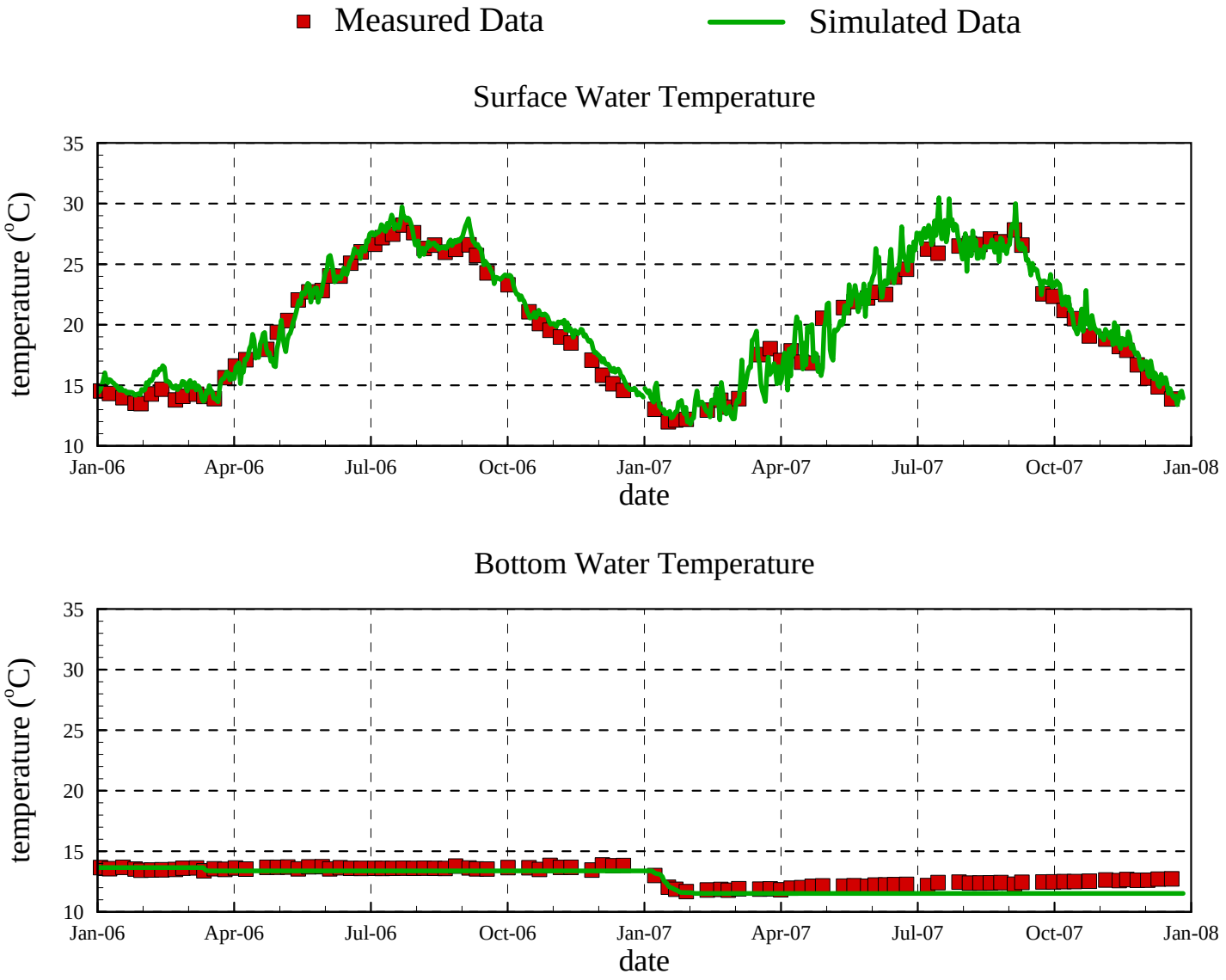

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Figure 15

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San Vicente Reservoir

Station A - Water Temperature Calibration

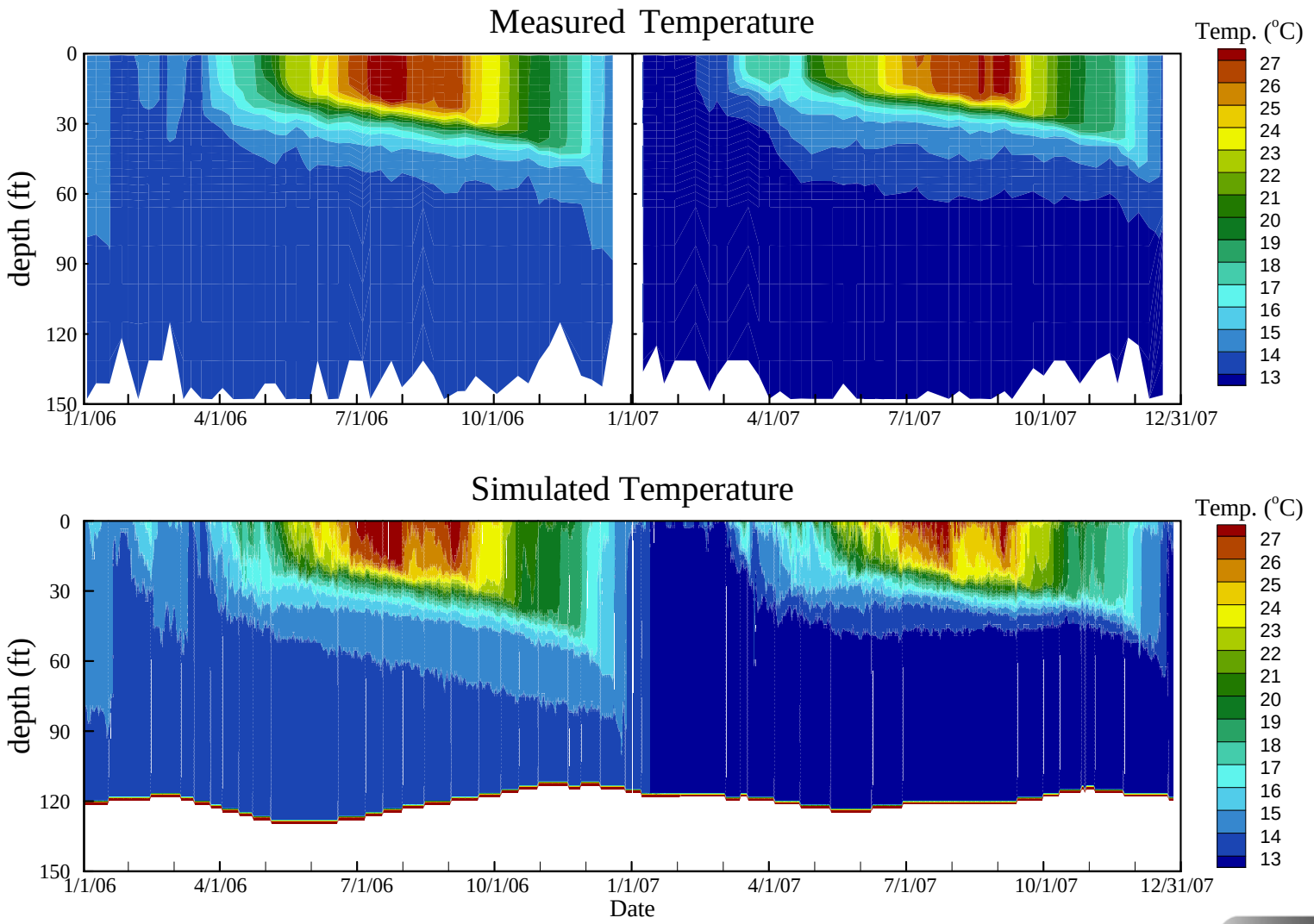

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Figure 16

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San Vicente Reservoir

Scatter Plot of Measured vs. Simulated Temperature

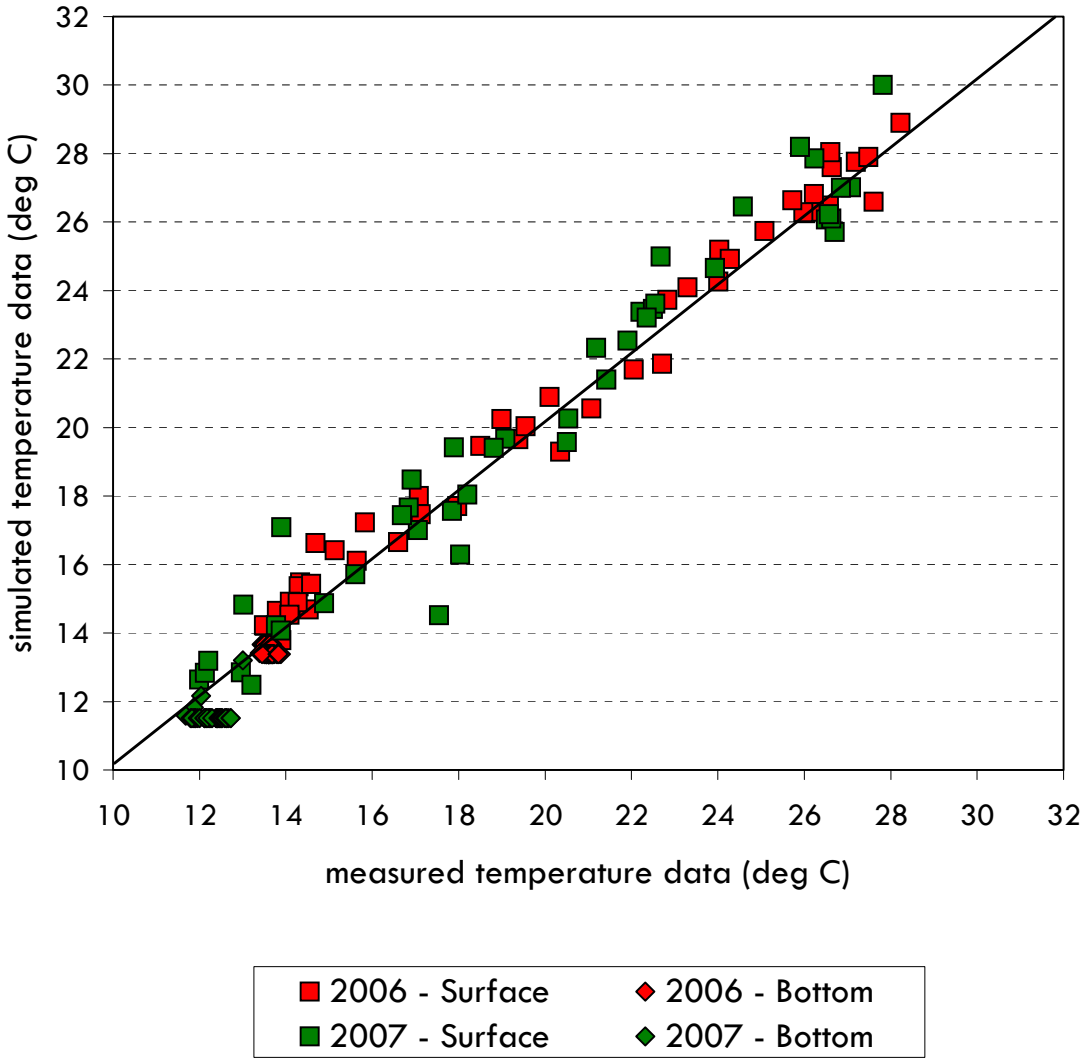

Figure 17

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San Vicente Reservoir Station A - Conductivity Calibration

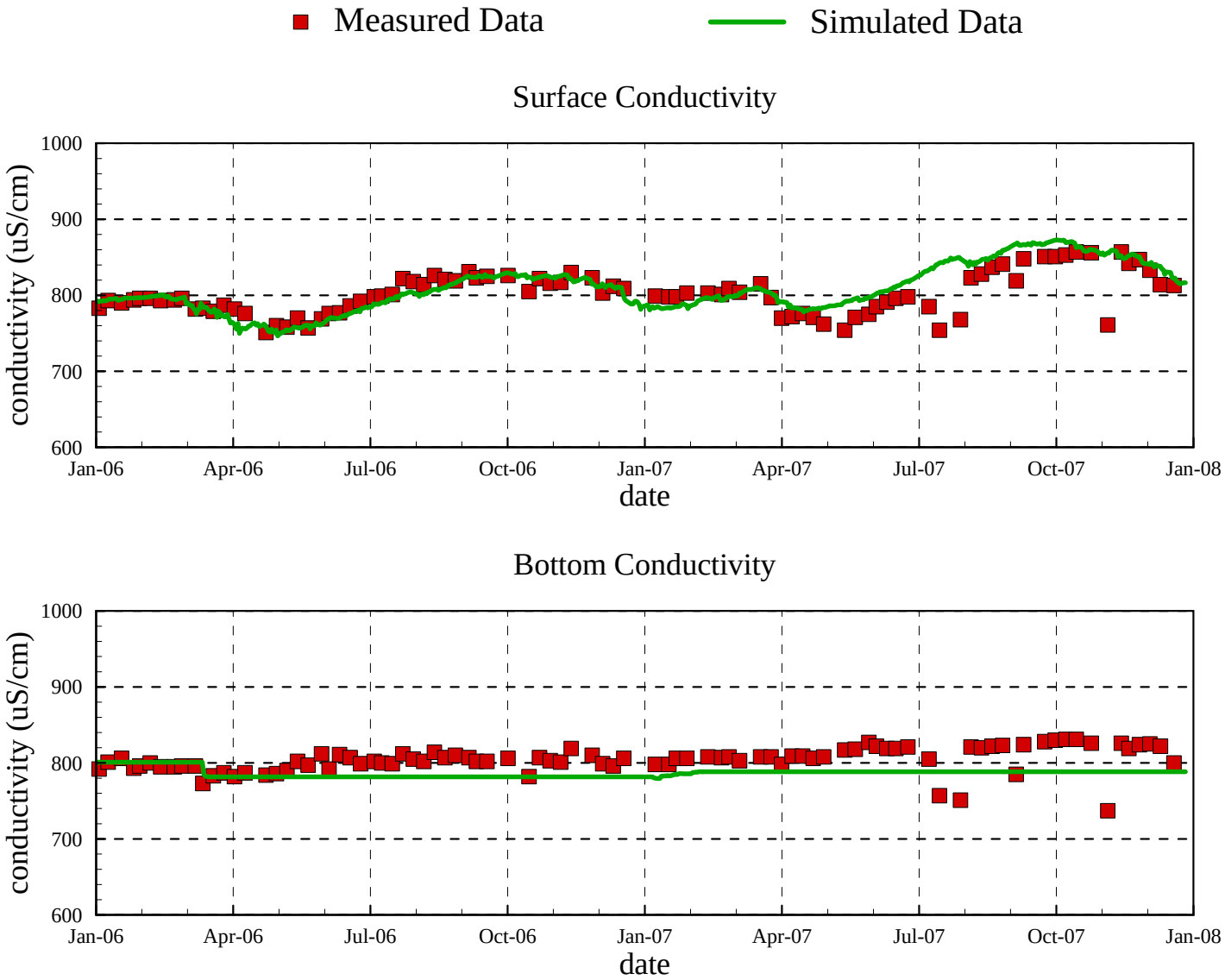

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Figure 18

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San Vicente Reservoir
Station A - Conductivity Calibration

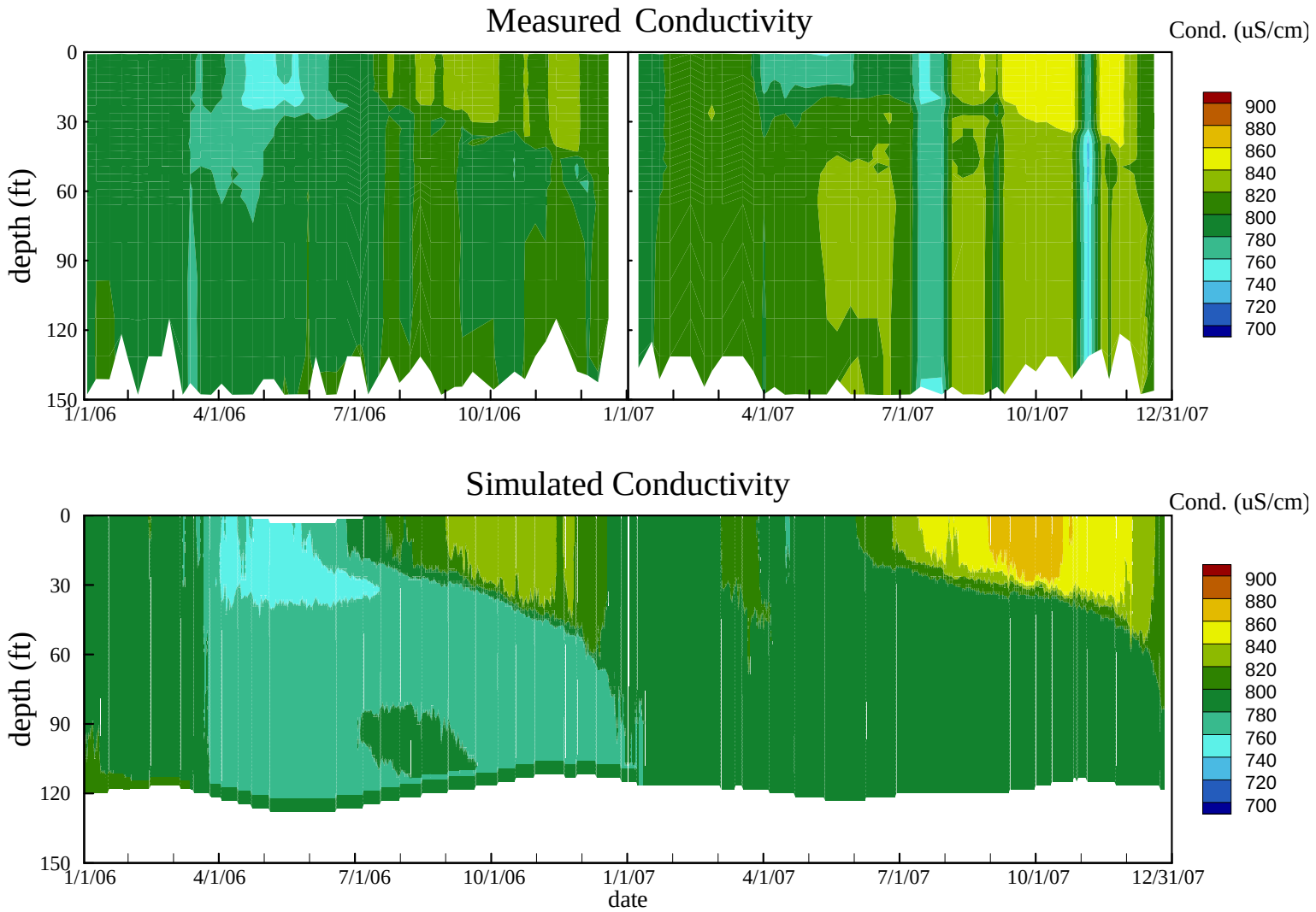

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Figure 19

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San Vicente Reservoir

Scatter Plot of Measured vs. Simulated Conductivity

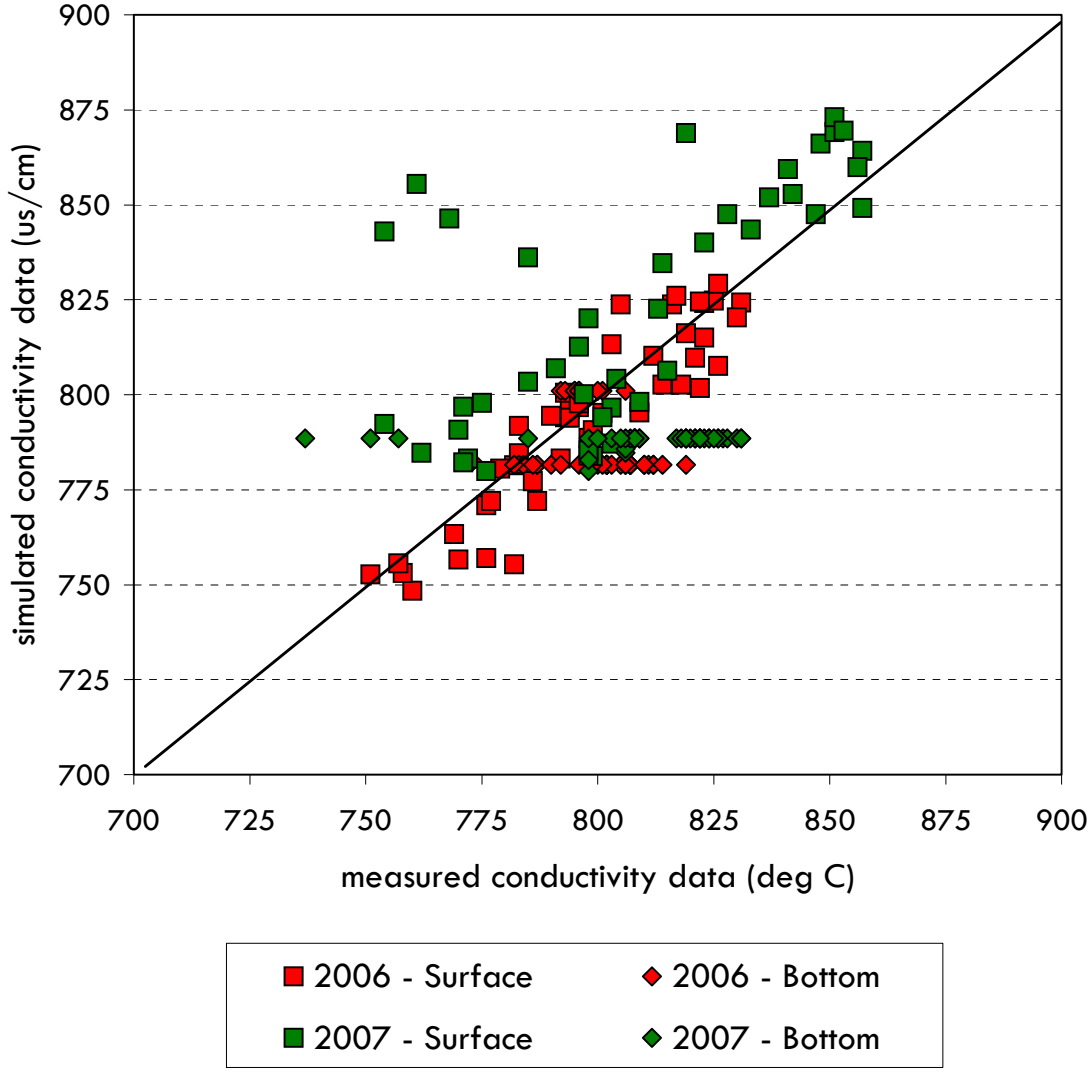

Figure 20

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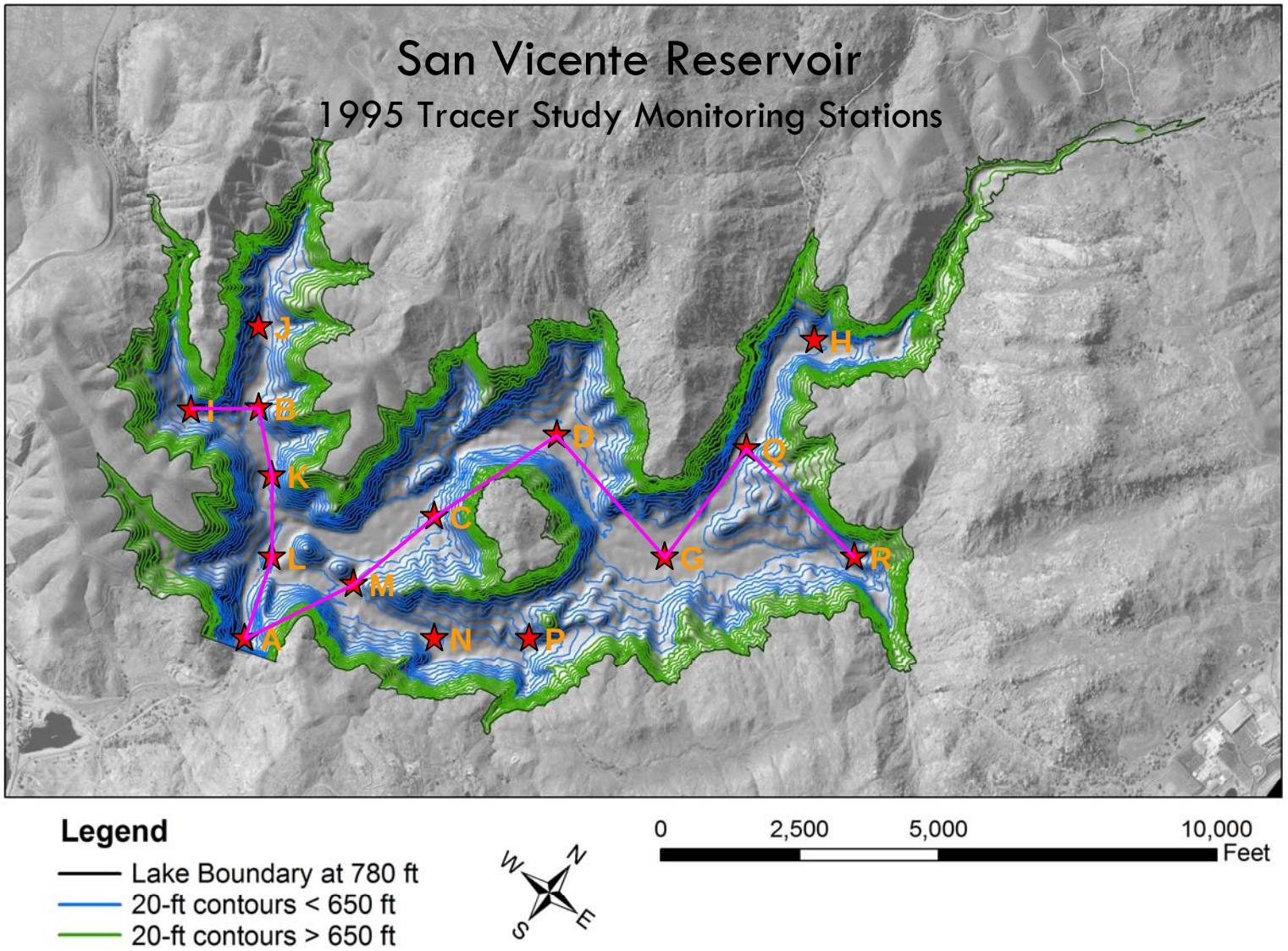

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Figure 21

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San Vicente Reservoir

1995 Tracer Studies - Percent of Total Initial Mass of Lanthanum in the Reservoir versus Time

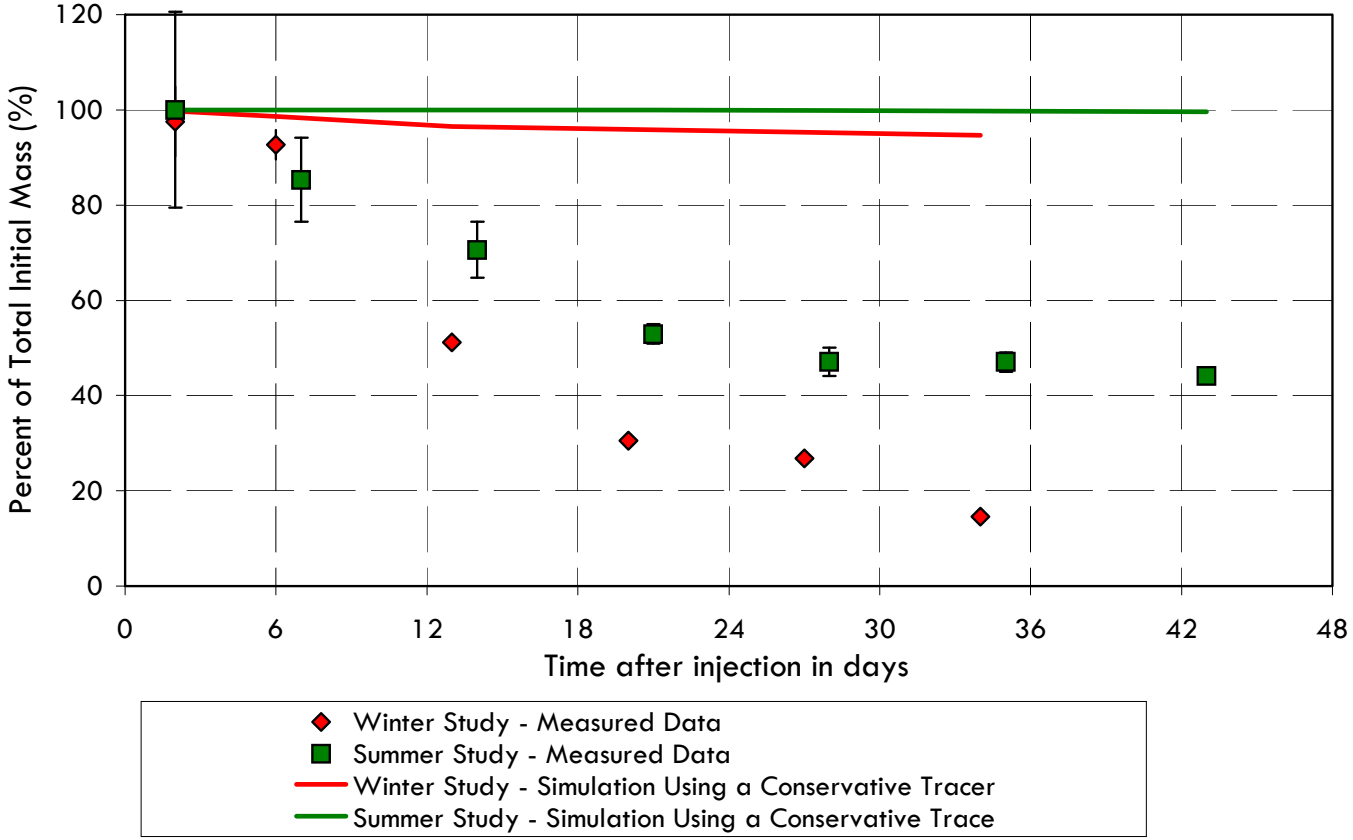

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Figure 22

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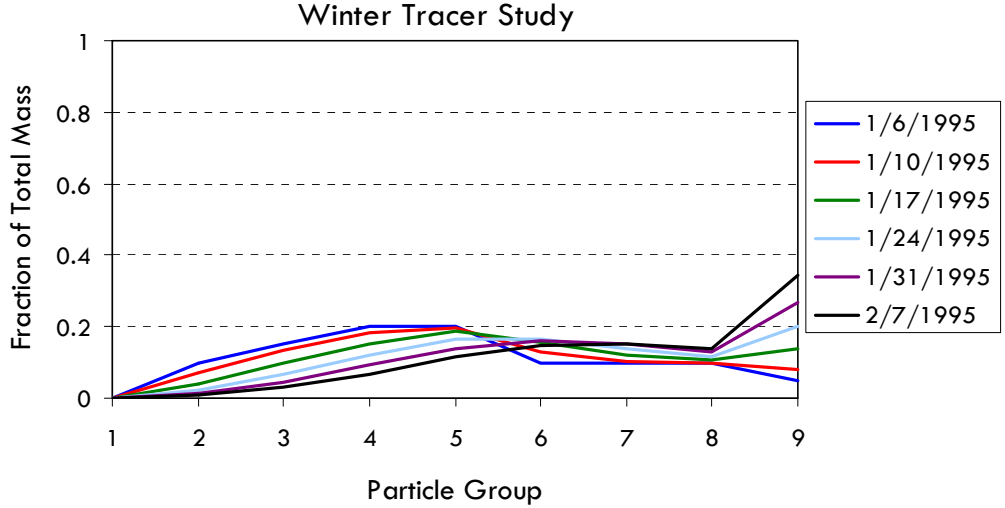
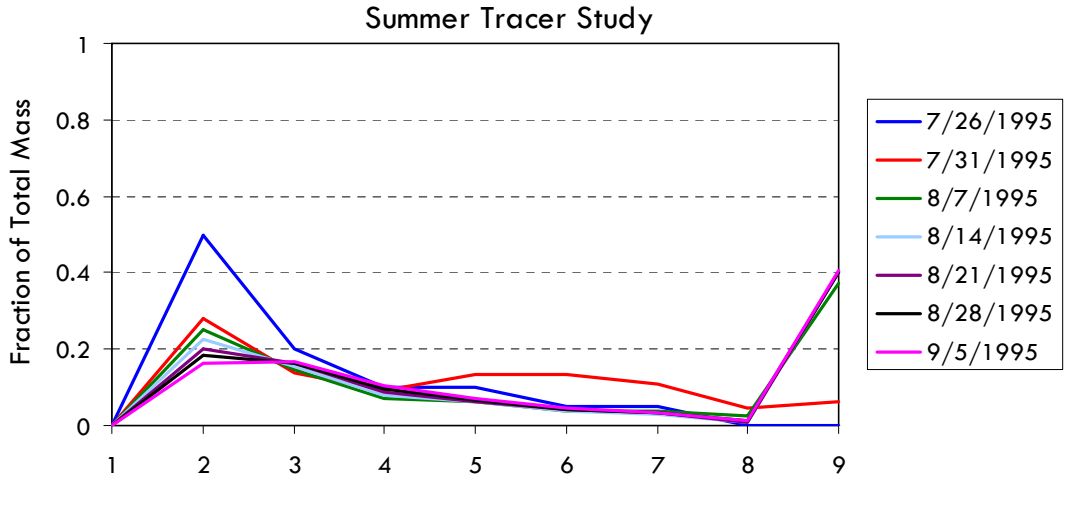
San Vicente Reservoir

1995 Tracer Studies – Simulated Mass Distribution of Particles





Particle Size: Small → Particle Group → **Large**

Settling Velocity: Low → **High**

Figure 23

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San Vicente Reservoir

1995 Tracer Studies - Percent of Total Initial Mass of Lanthanum in the Reservoir versus Time

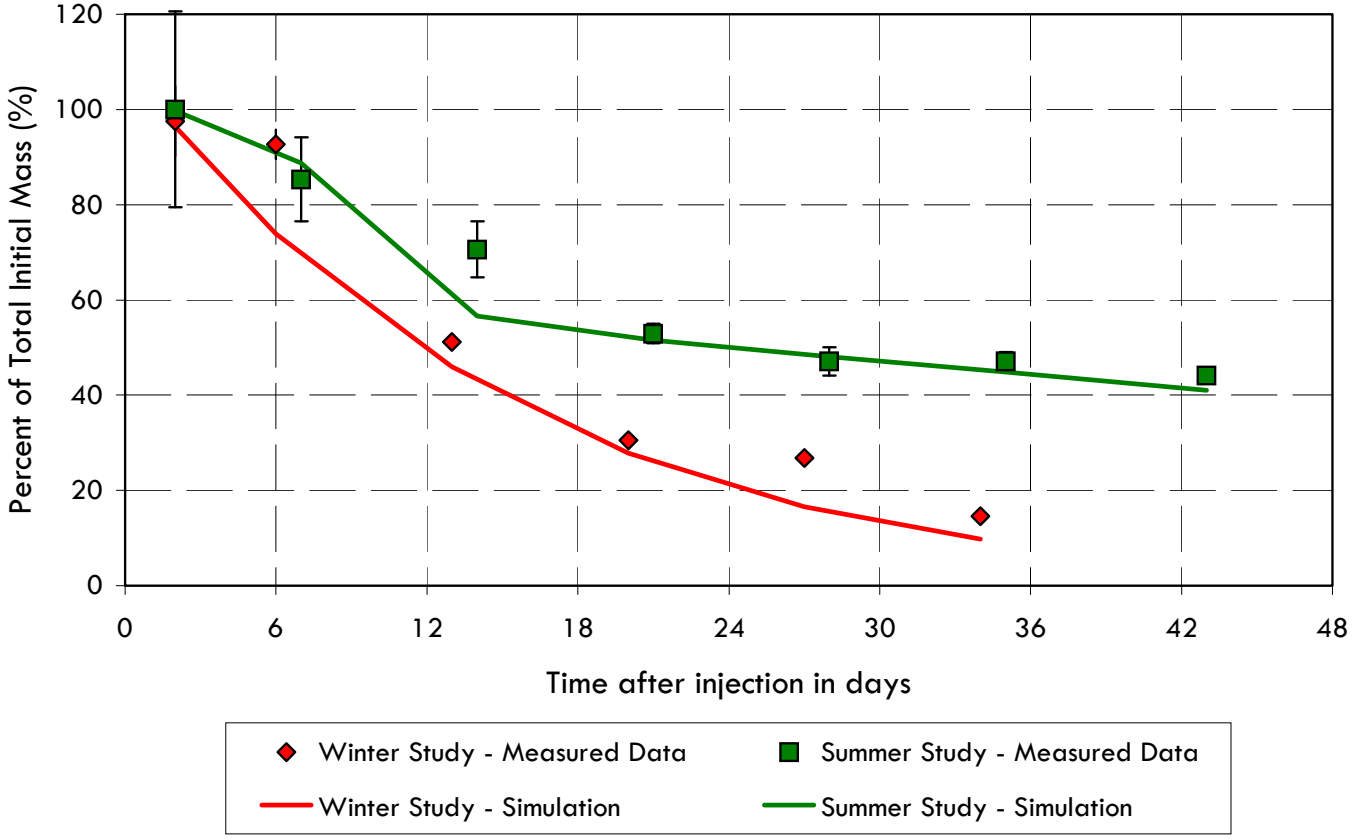

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Figure 24

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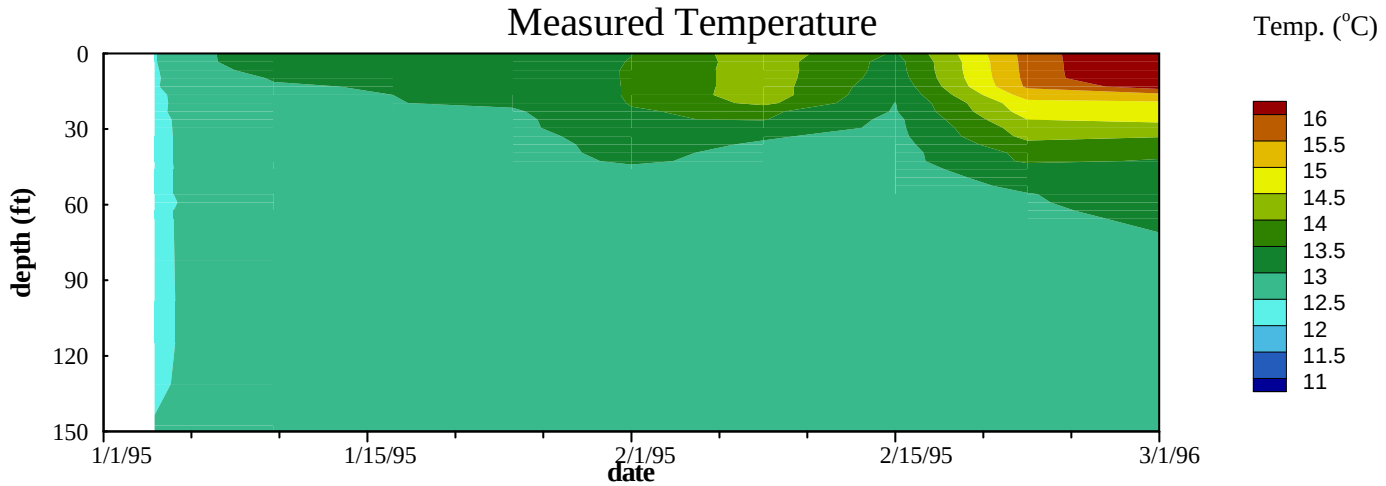
San Vicente Reservoir
Station A - Water Temperature in 1995 Winter Tracer Study



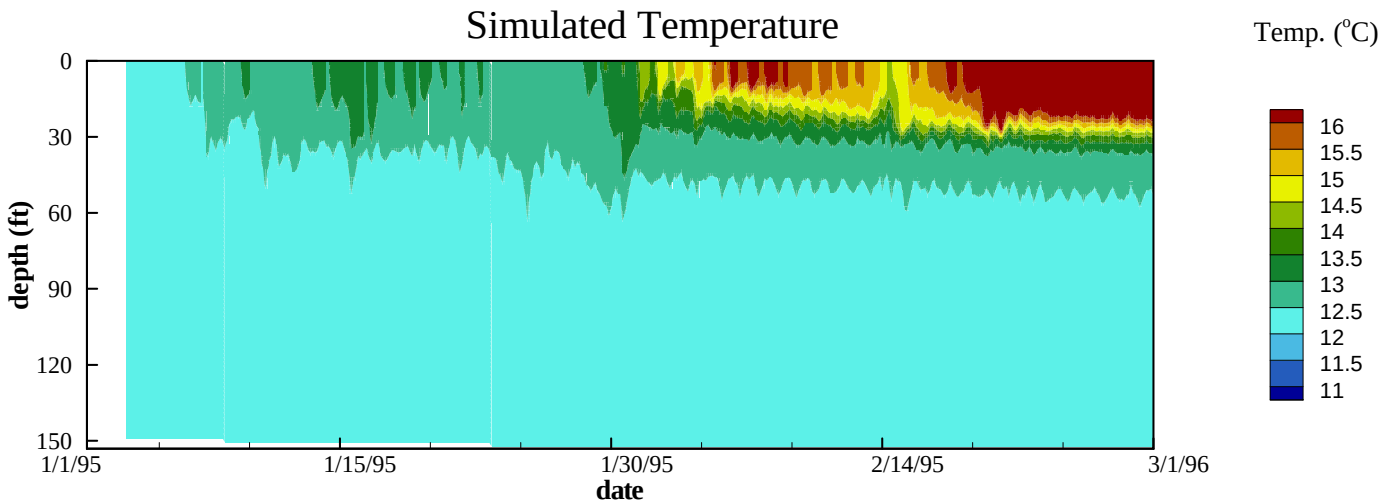


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Figure 25

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San Vicente Reservoir

1995 Tracer Winter Study – Measured versus Simulated Lanthanum Concentrations

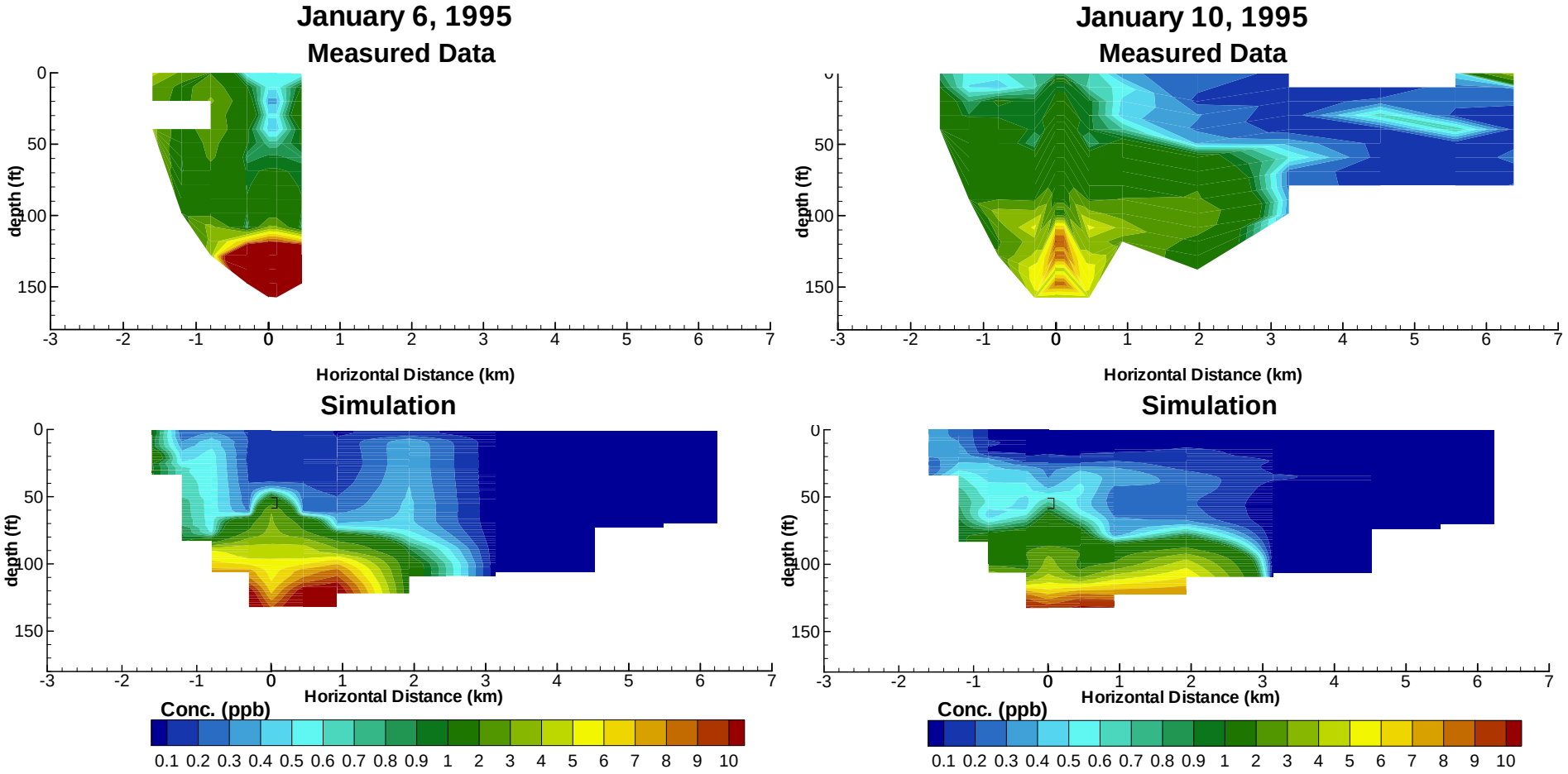

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Figure 26

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San Vicente Reservoir

1995 Winter Tracer Study – Measured versus Simulated Lanthanum Concentrations

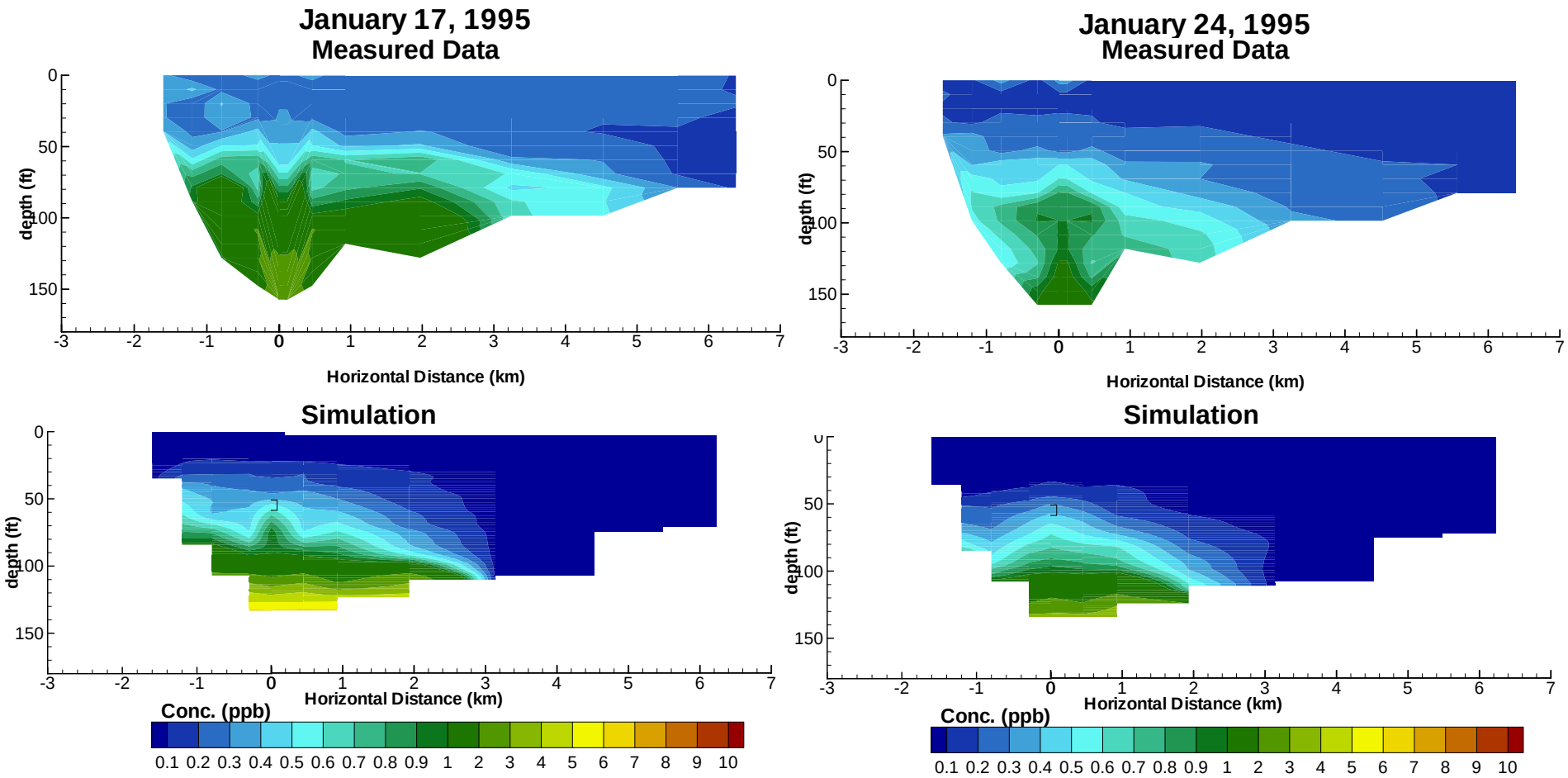

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Figure 27

FLOW SCIENCE®

San Vicente Reservoir

1995 Winter Tracer Study – Measured versus Simulated Lanthanum Concentrations

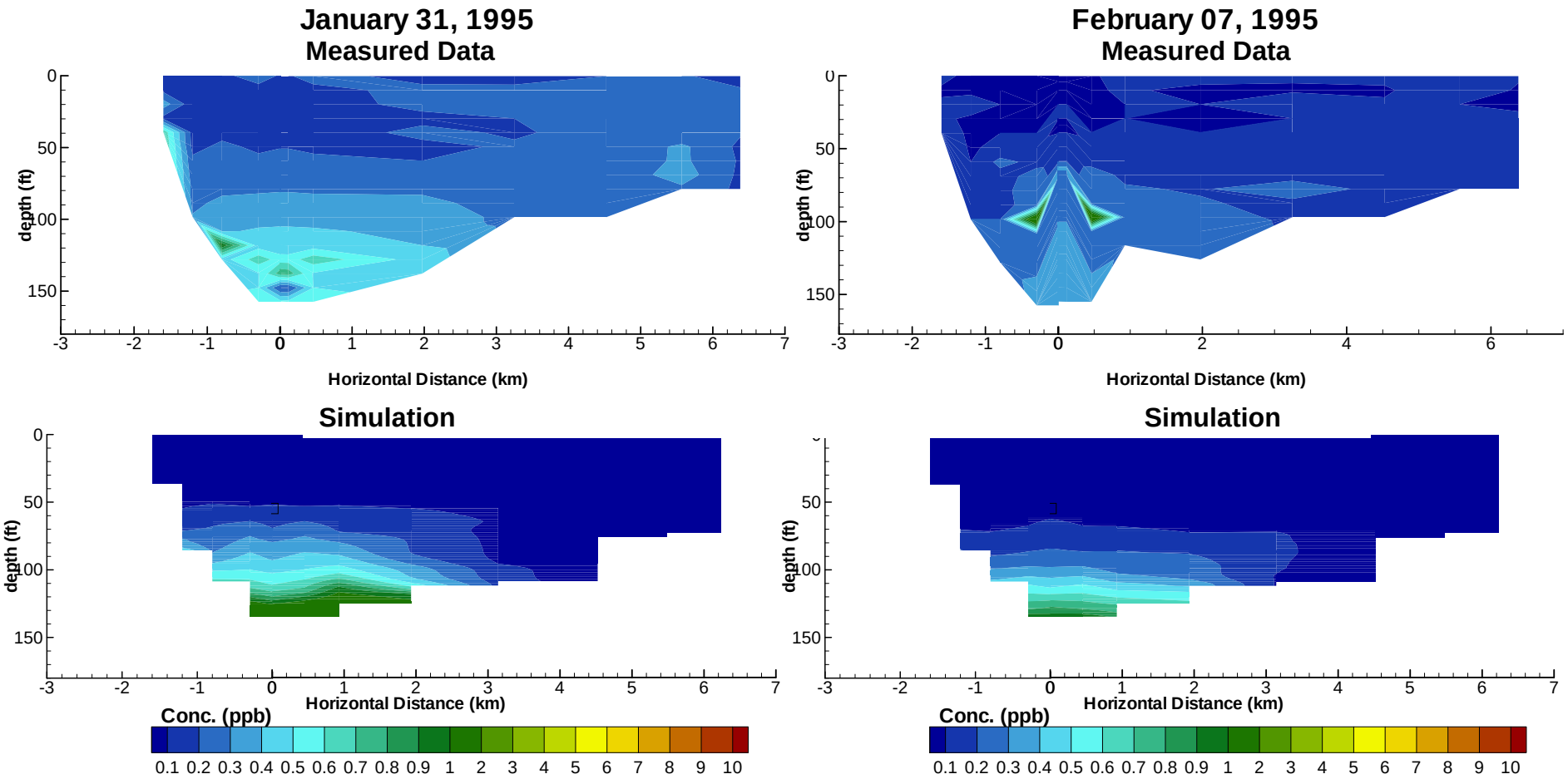

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Figure 28

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San Vicente Reservoir
Station A - Water Temperature Calibration

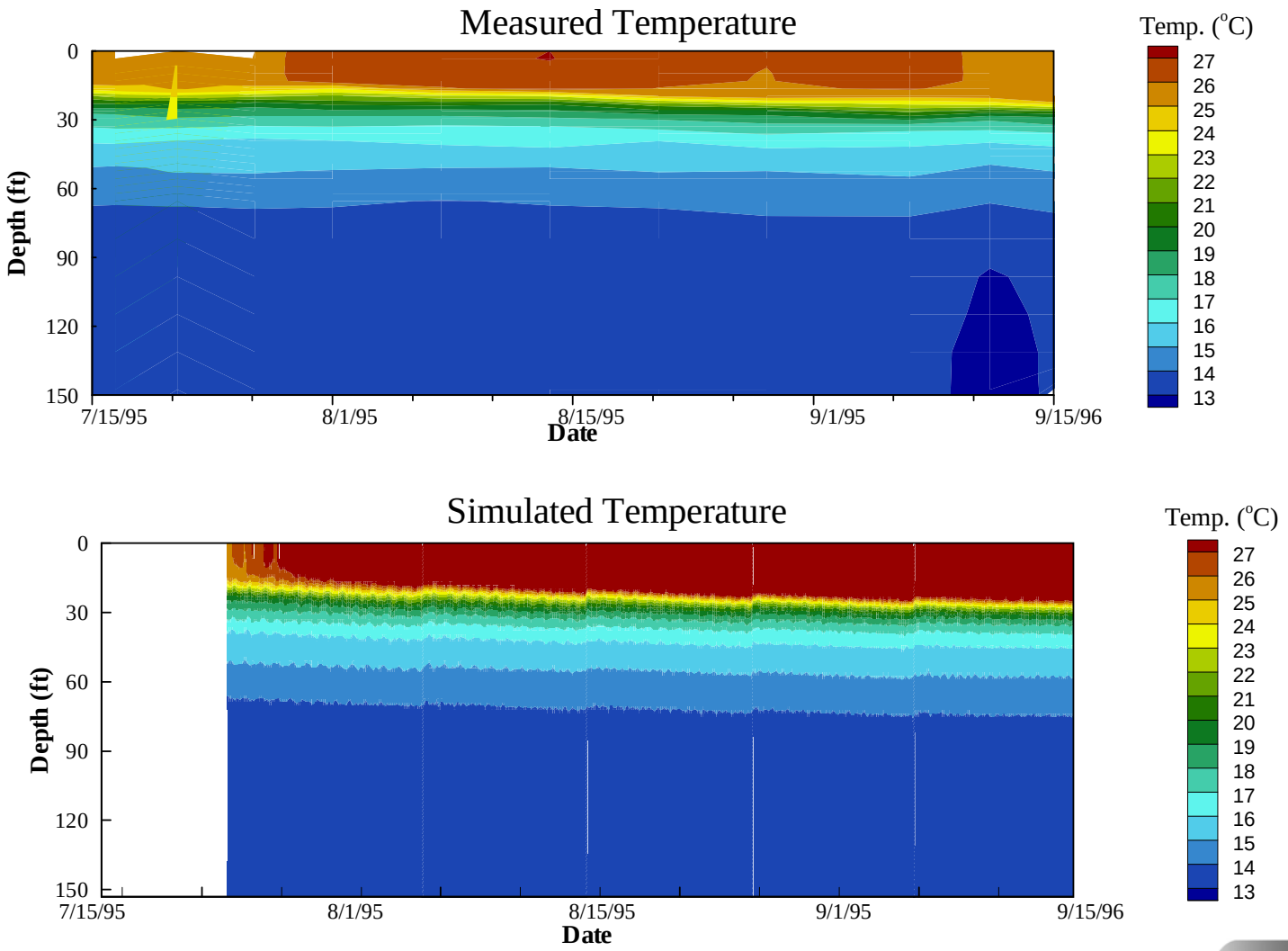

Figure 29

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San Vicente Reservoir

1995 Summer Tracer Study – Measured versus Simulated Lanthanum Concentrations

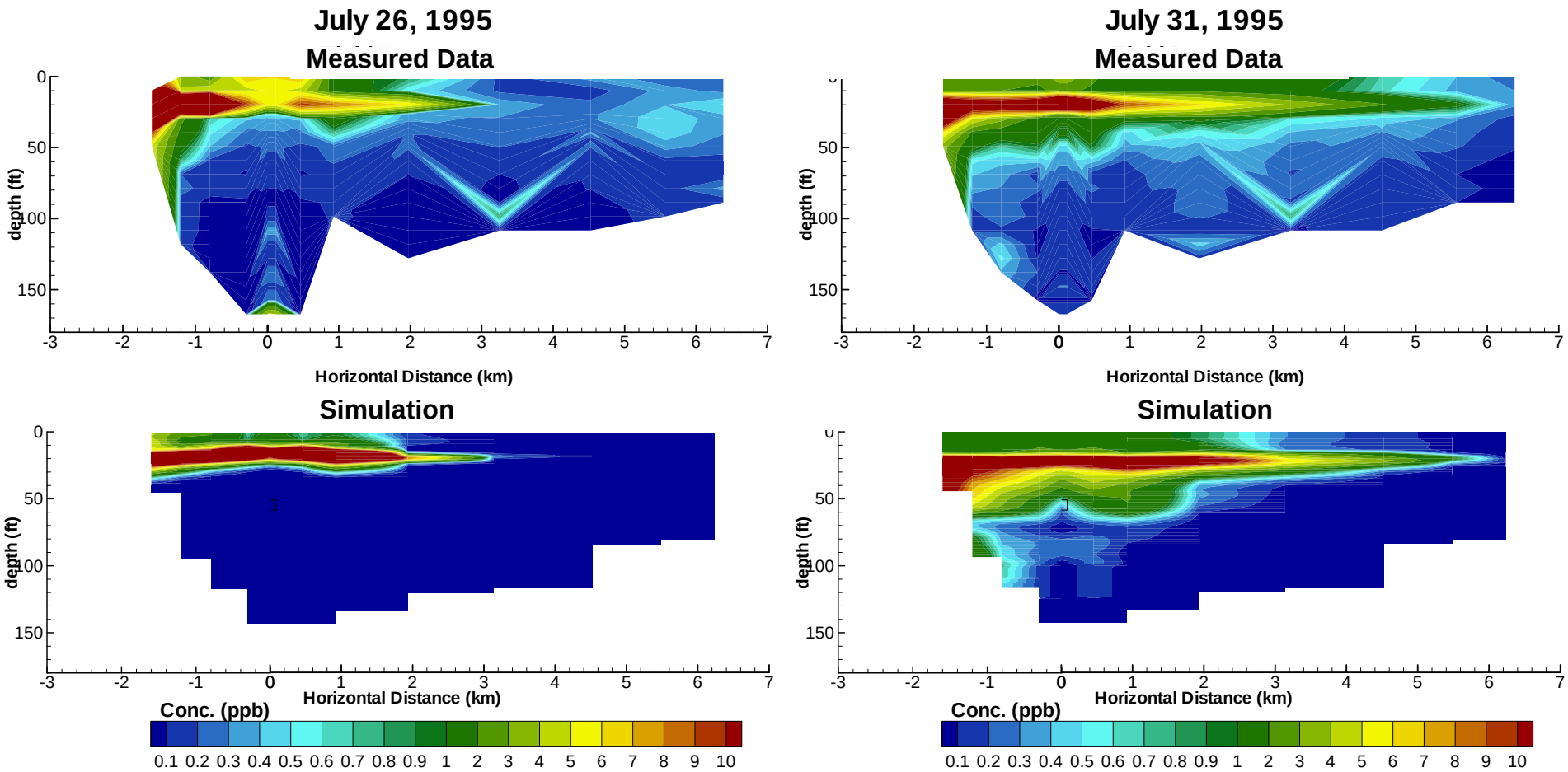

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Figure 30

FLOW SCIENCE®

San Vicente Reservoir

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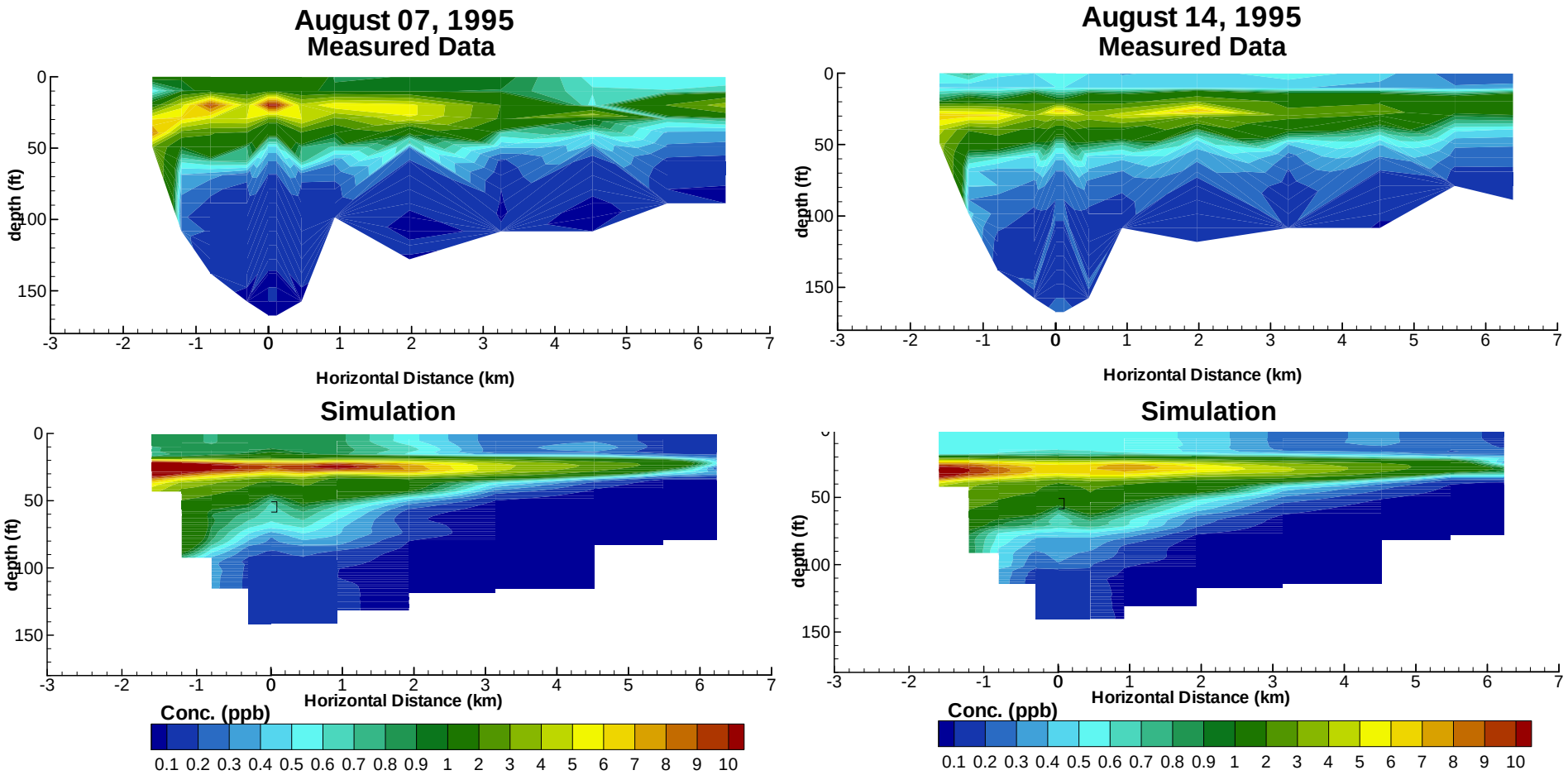

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Figure 31

FLOW SCIENCE®

San Vicente Reservoir

1995 Summer Tracer Study – Measured versus Simulated Lanthanum Concentrations

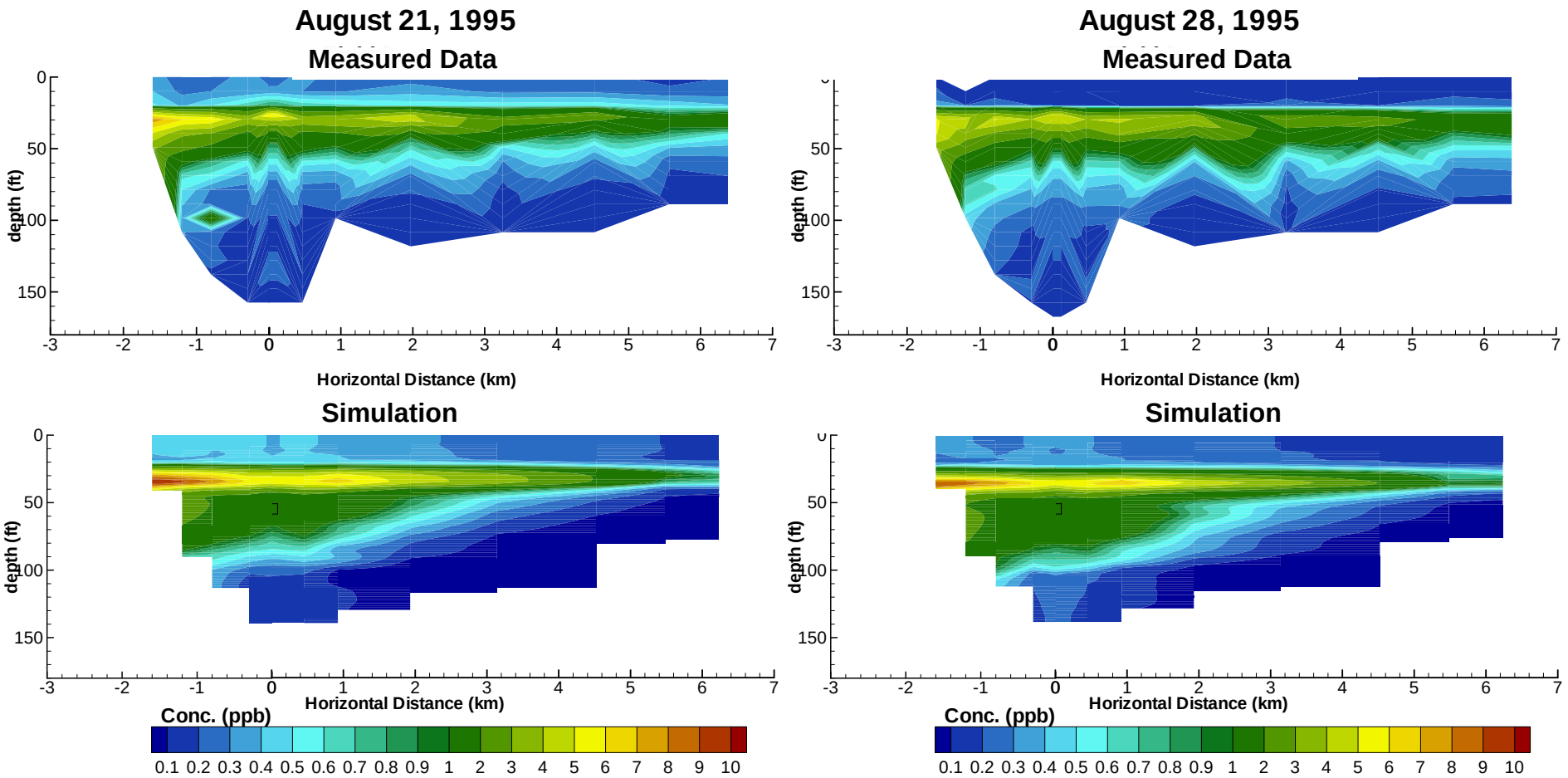

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Figure 32

FLOW SCIENCE®

San Vicente Reservoir

1995 Summer Tracer Study – Measured versus Simulated Lanthanum Concentrations

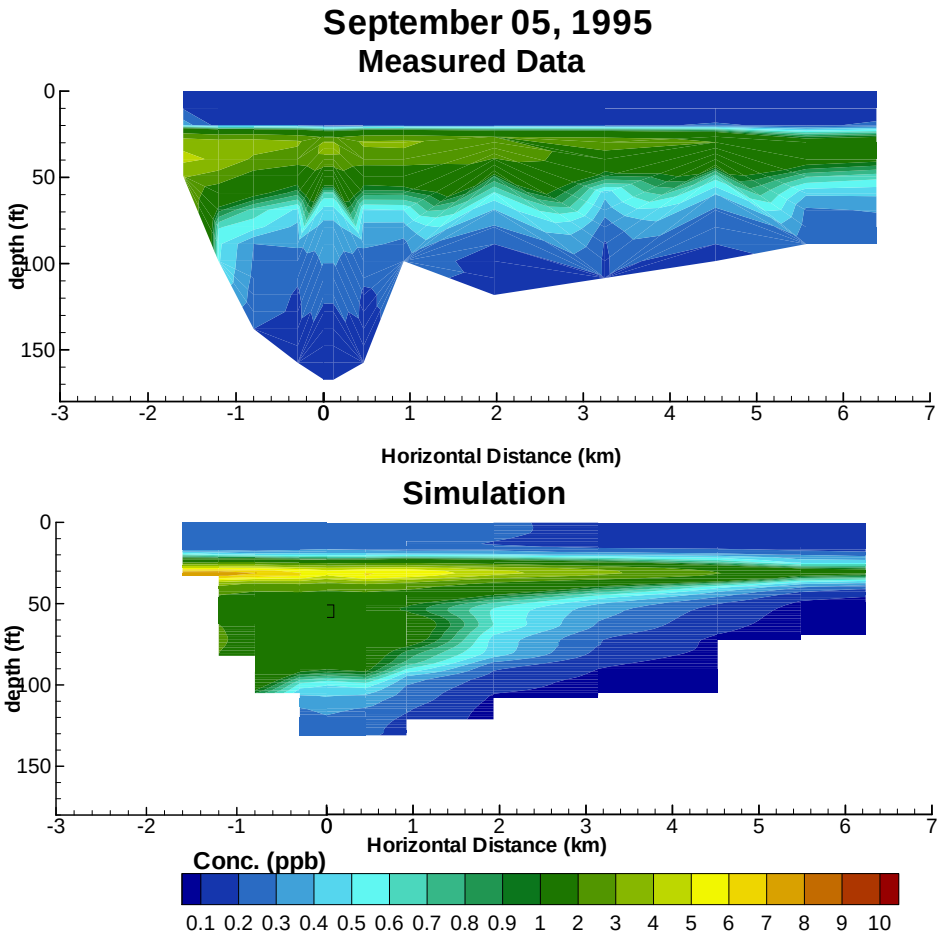

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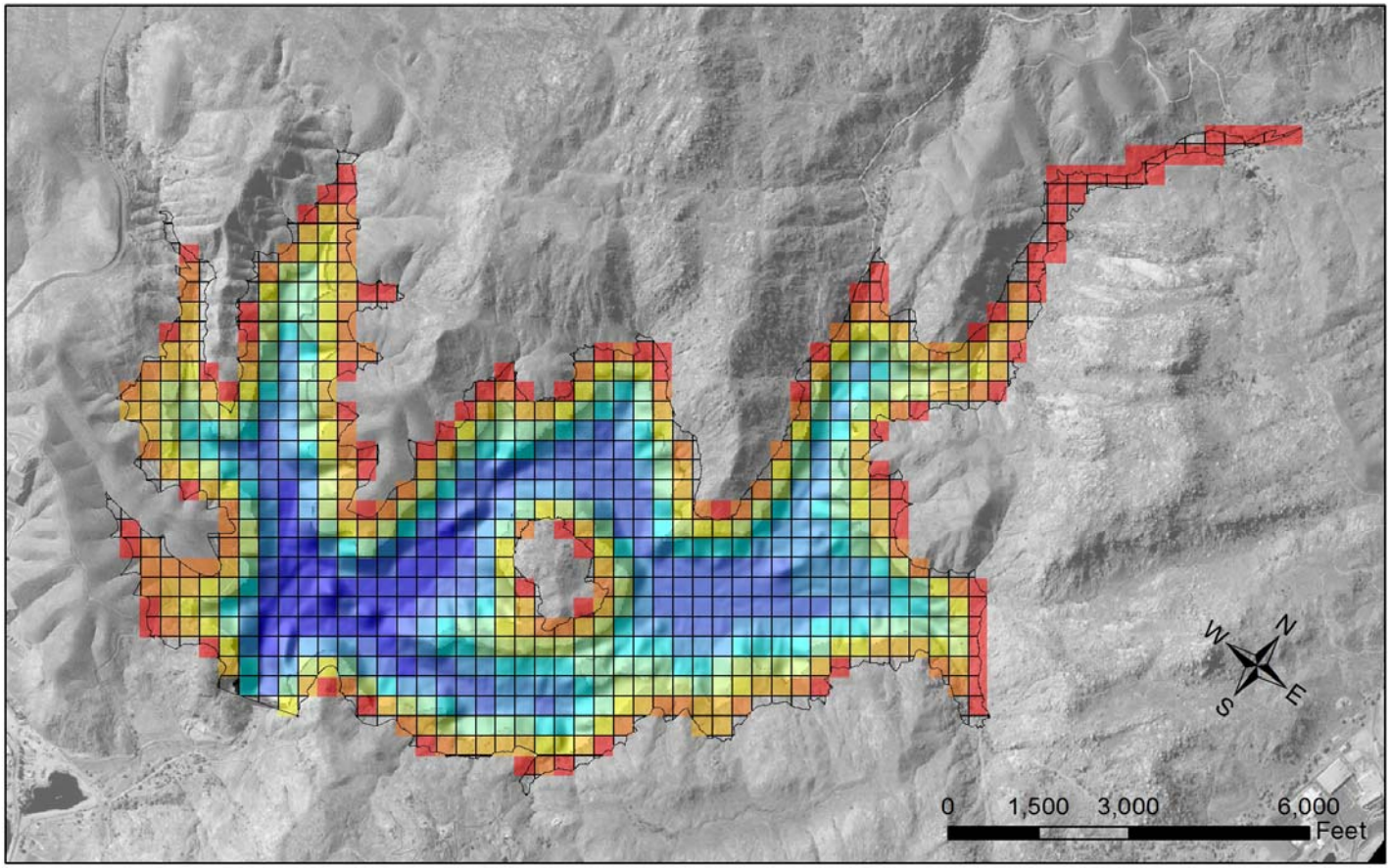
Figure 33

FLOW SCIENCE®

San Vicente Reservoir 100-m ELCOM-CAEDYM Computational Grid



San Vicente
100-m ELCOM Grid

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Lake Boundary at 780 ft

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Figure 34

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San Vicente Reservoir Station A - Water Temperature Simulation

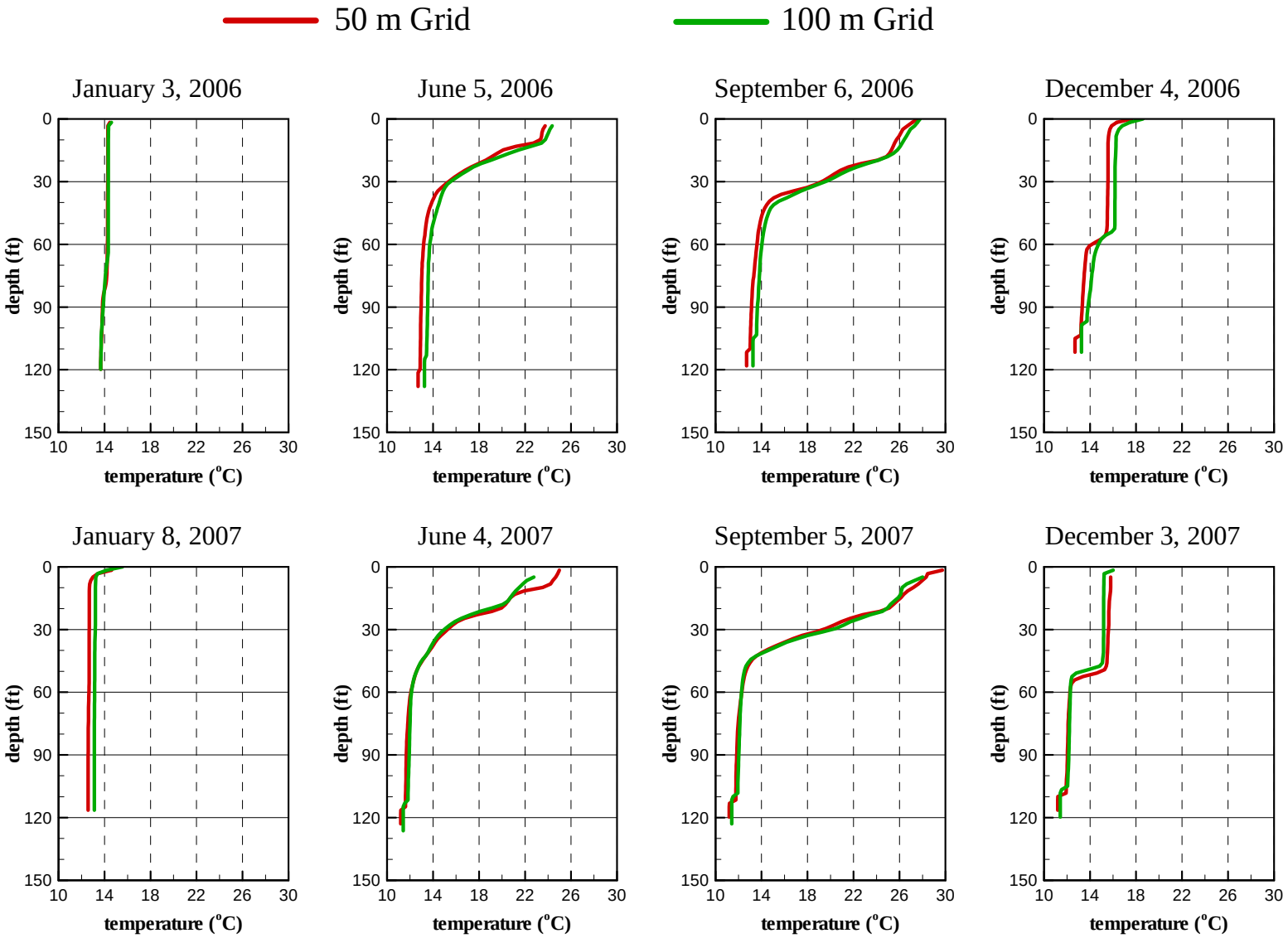

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Figure 35

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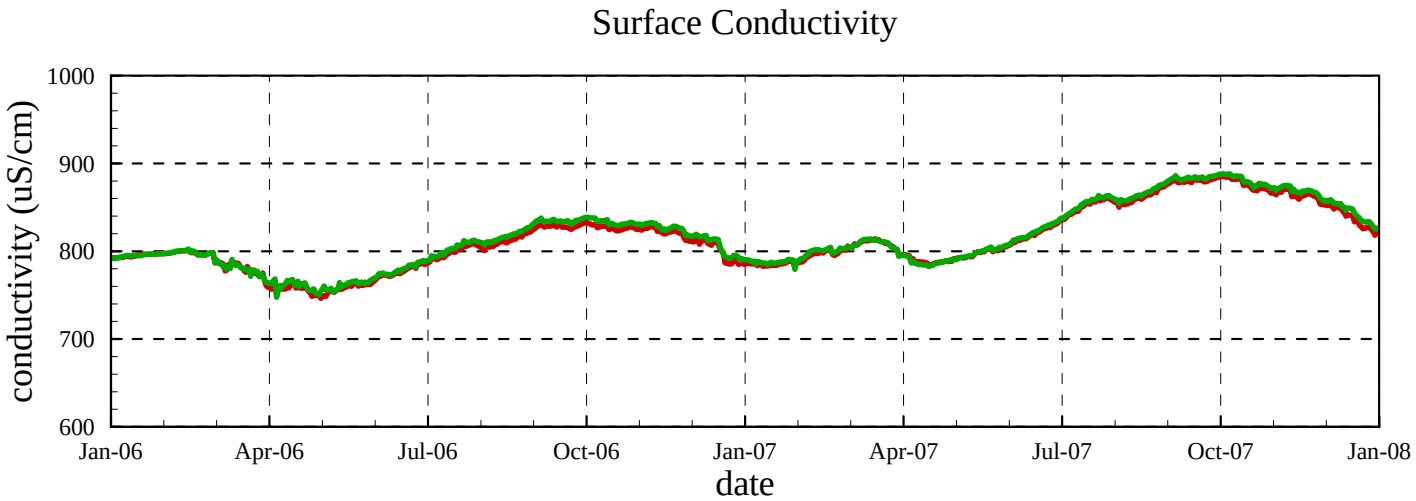
San Vicente Reservoir Station A - Conductivity Simulation

50 m Grid — 100 m Grid



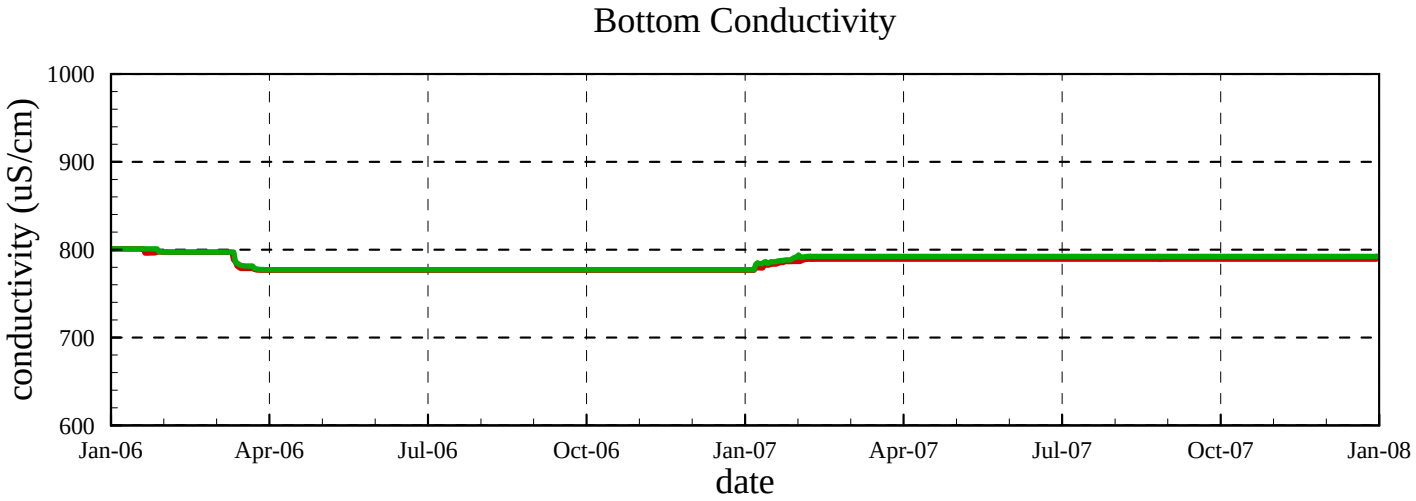


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Figure 36

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San Vicente Reservoir Station A - Dissolved Oxygen Calibration

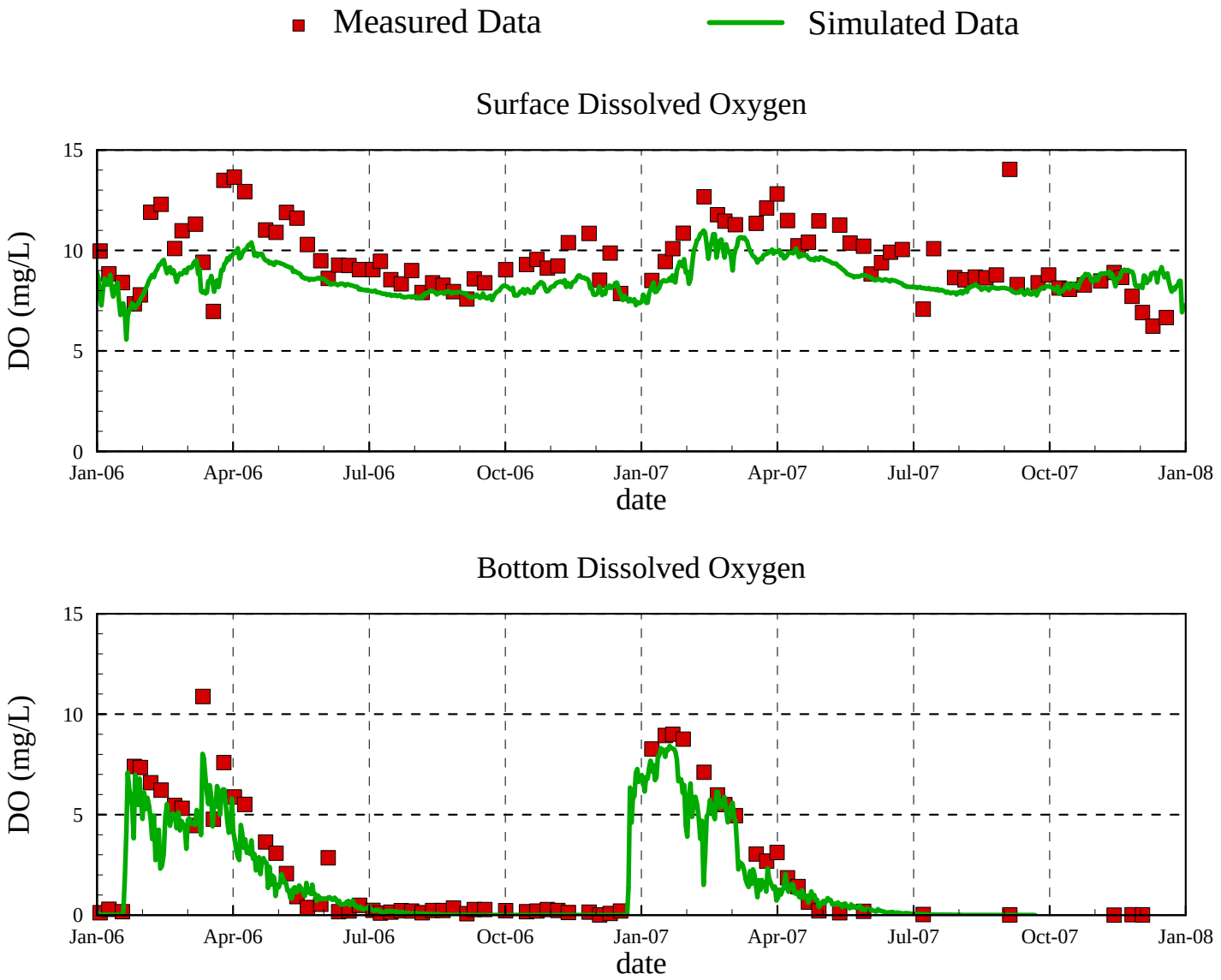

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Figure 37

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San Vicente Reservoir

Station A - Dissolved Oxygen Calibration

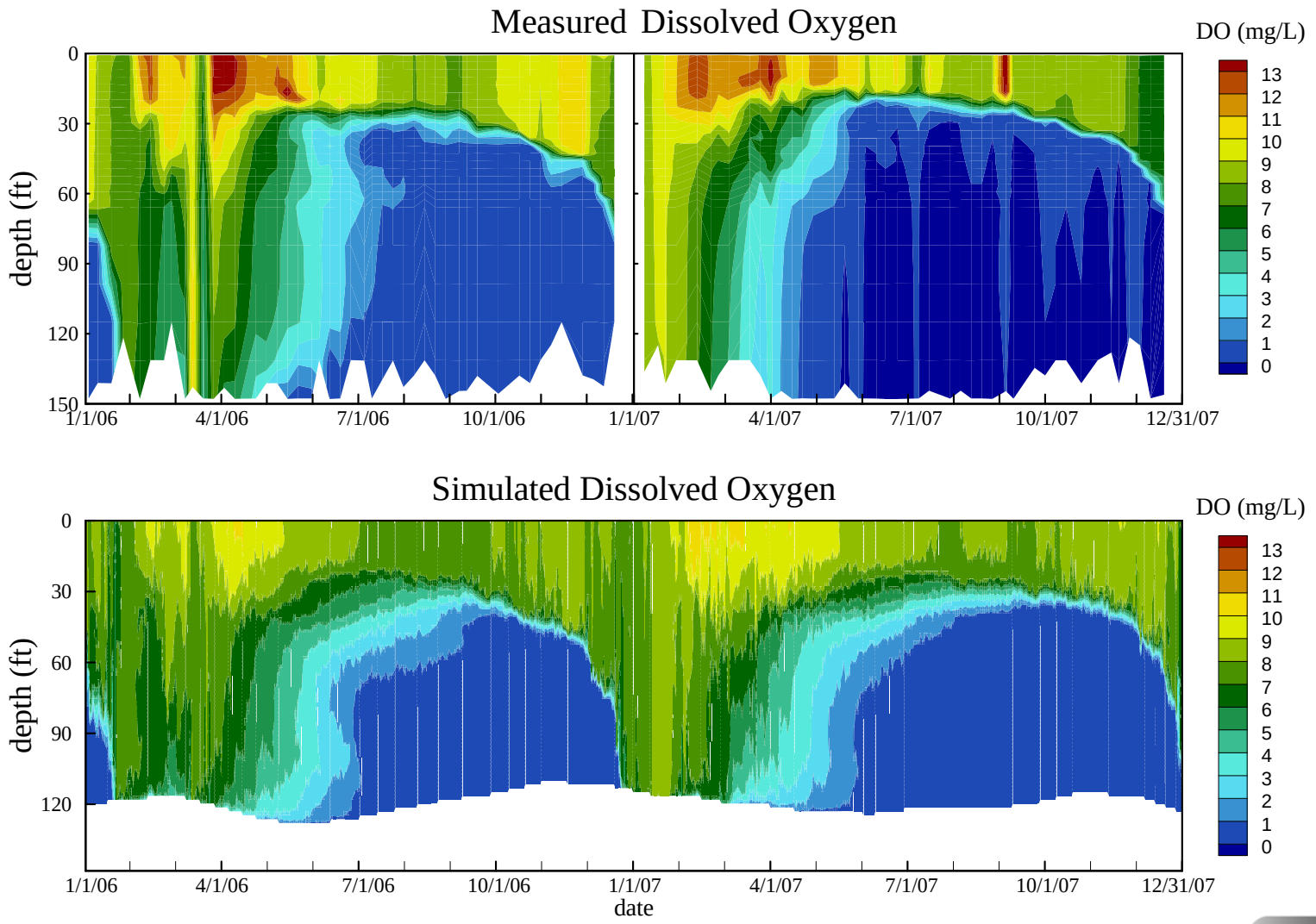

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Figure 38

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San Vicente Reservoir

Scatter Plot of Measured vs. Simulated Dissolved Oxygen

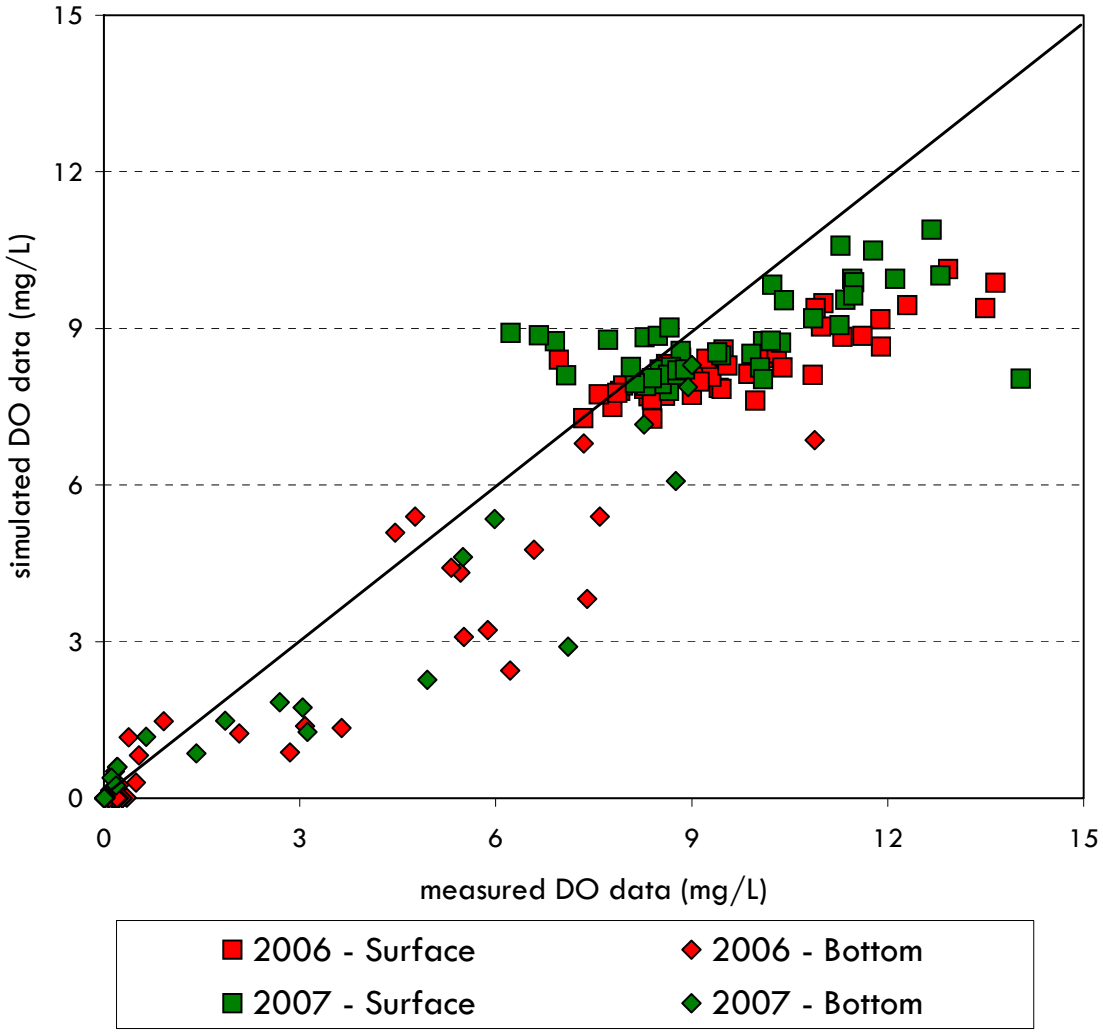

Figure 39

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San Vicente Reservoir Station A - pH Calibration

Measured Data — Simulated Data

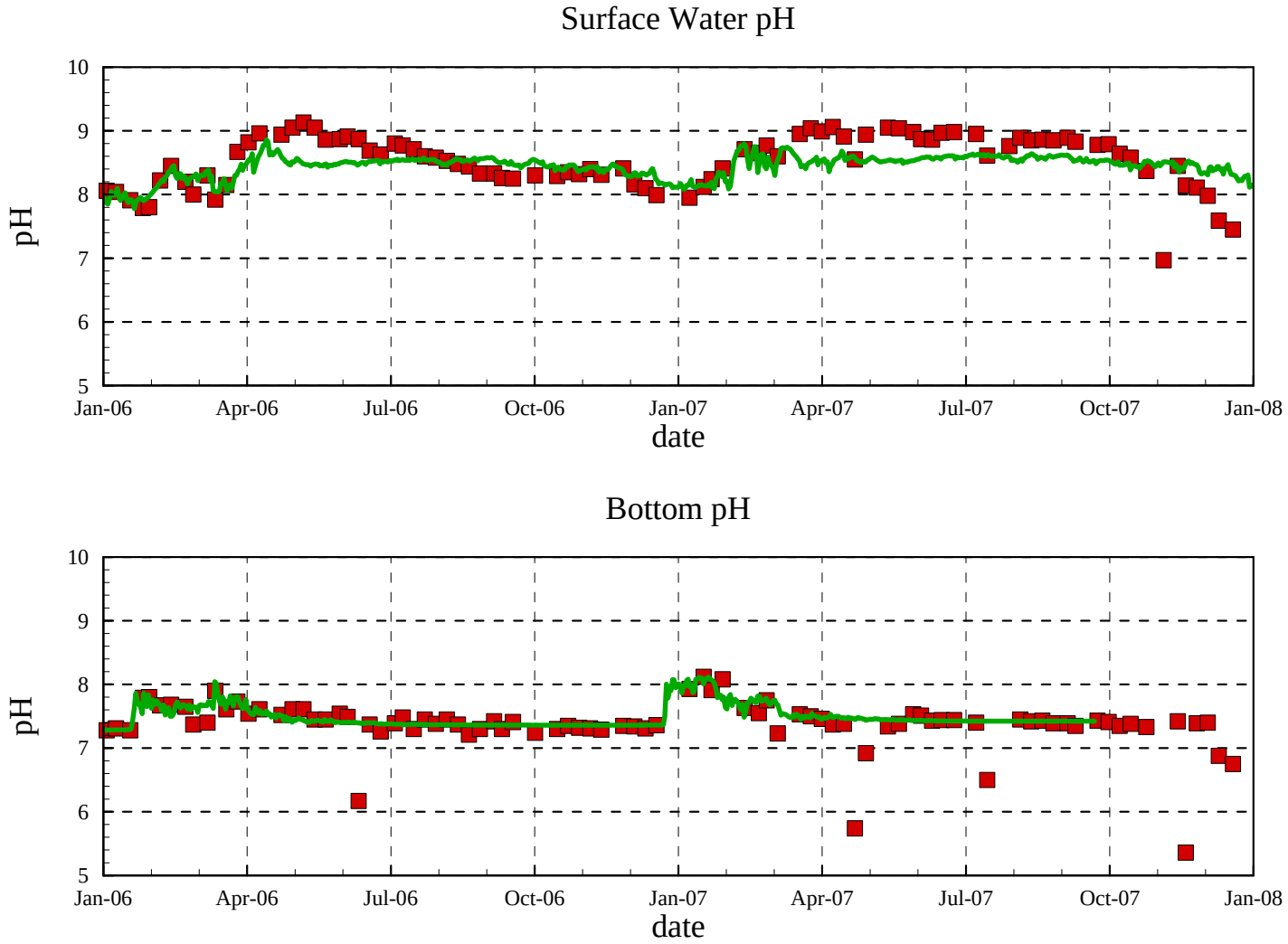

Figure 40

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San Vicente Reservoir

Station A - pH Calibration

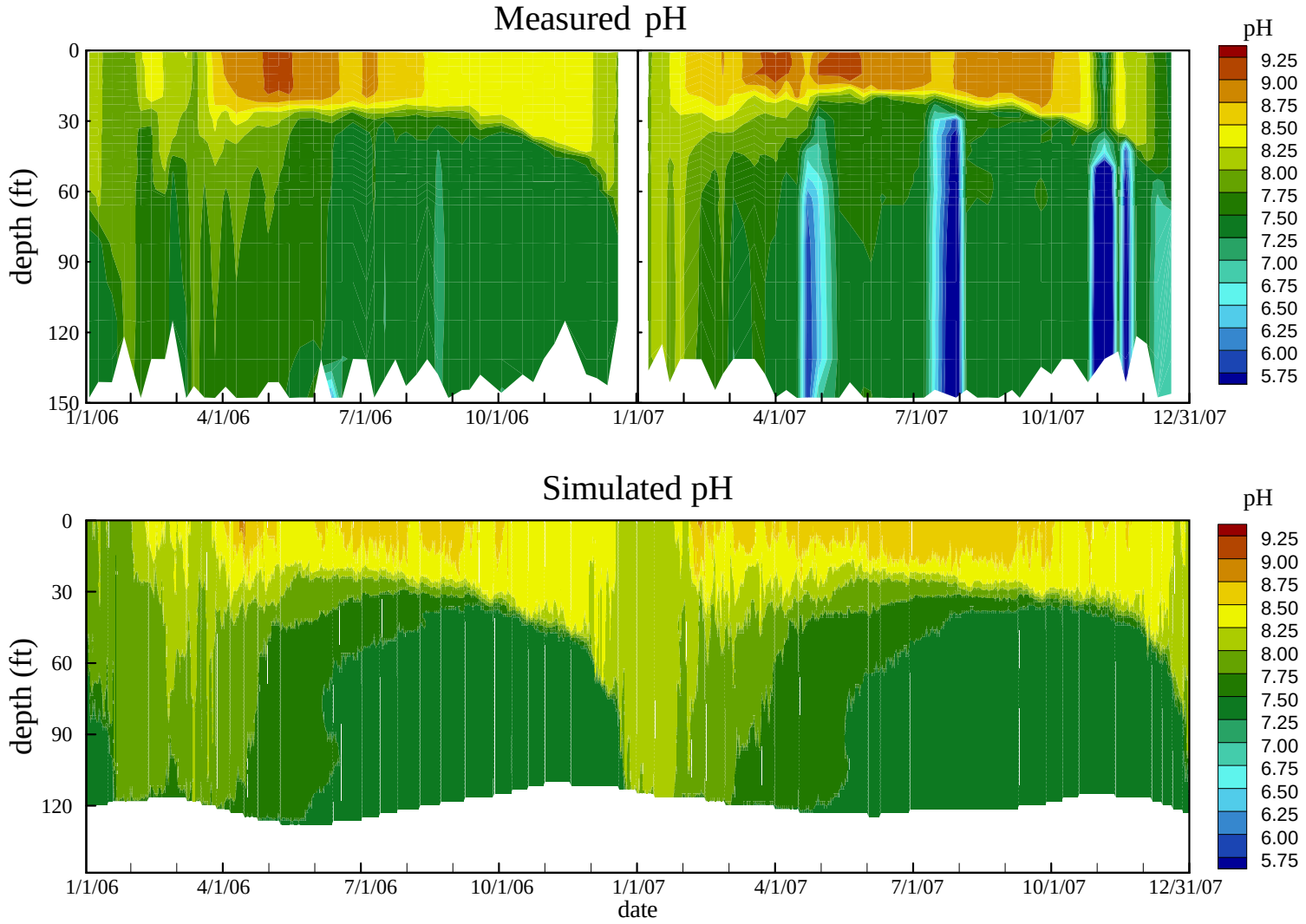

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Figure 41

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San Vicente Reservoir

Scatter Plot of Measured vs. Simulated pH

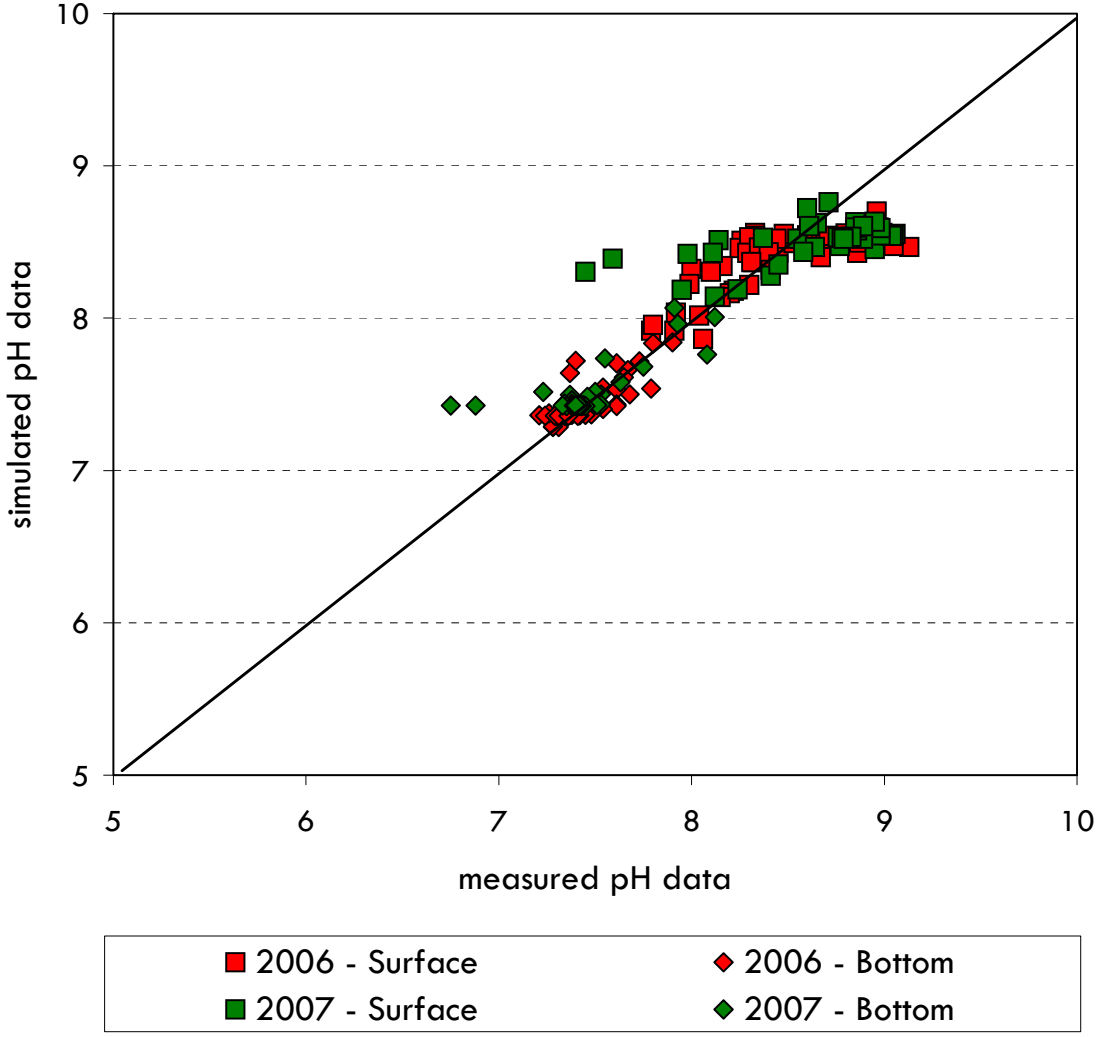

Figure 42

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San Vicente Reservoir Station A - Soluble Reactive Phosphorus

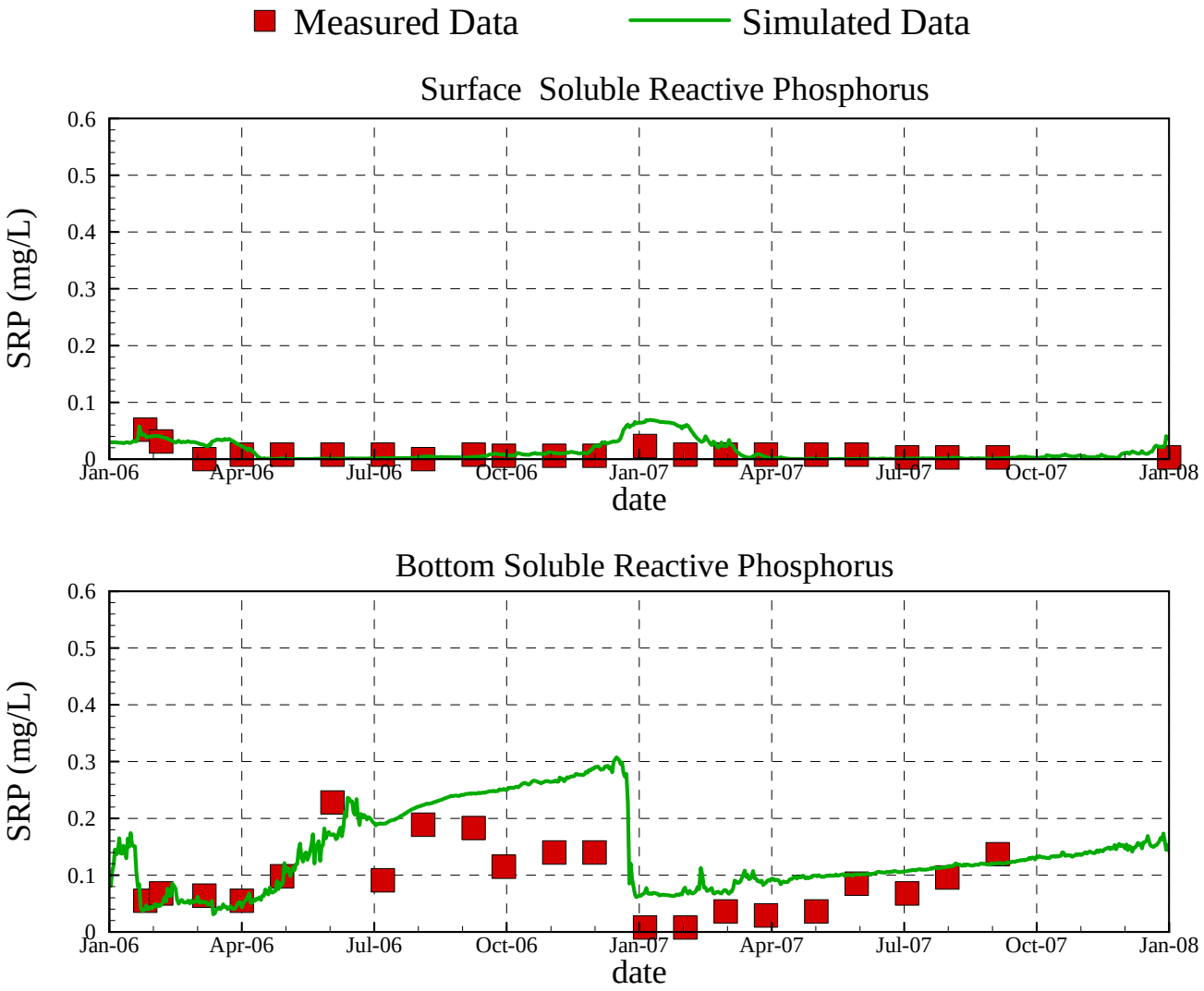

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Figure 43

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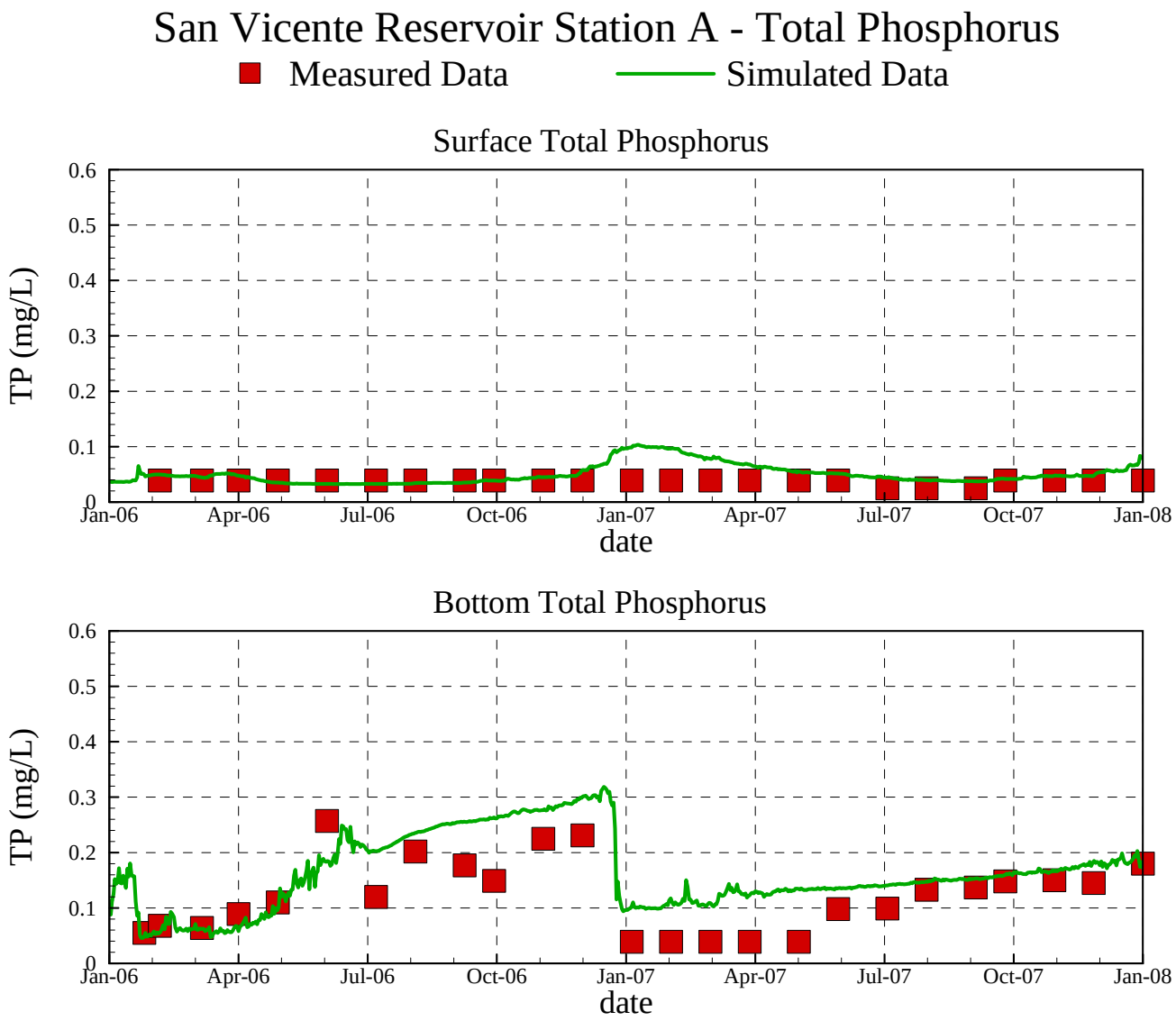

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Figure 44

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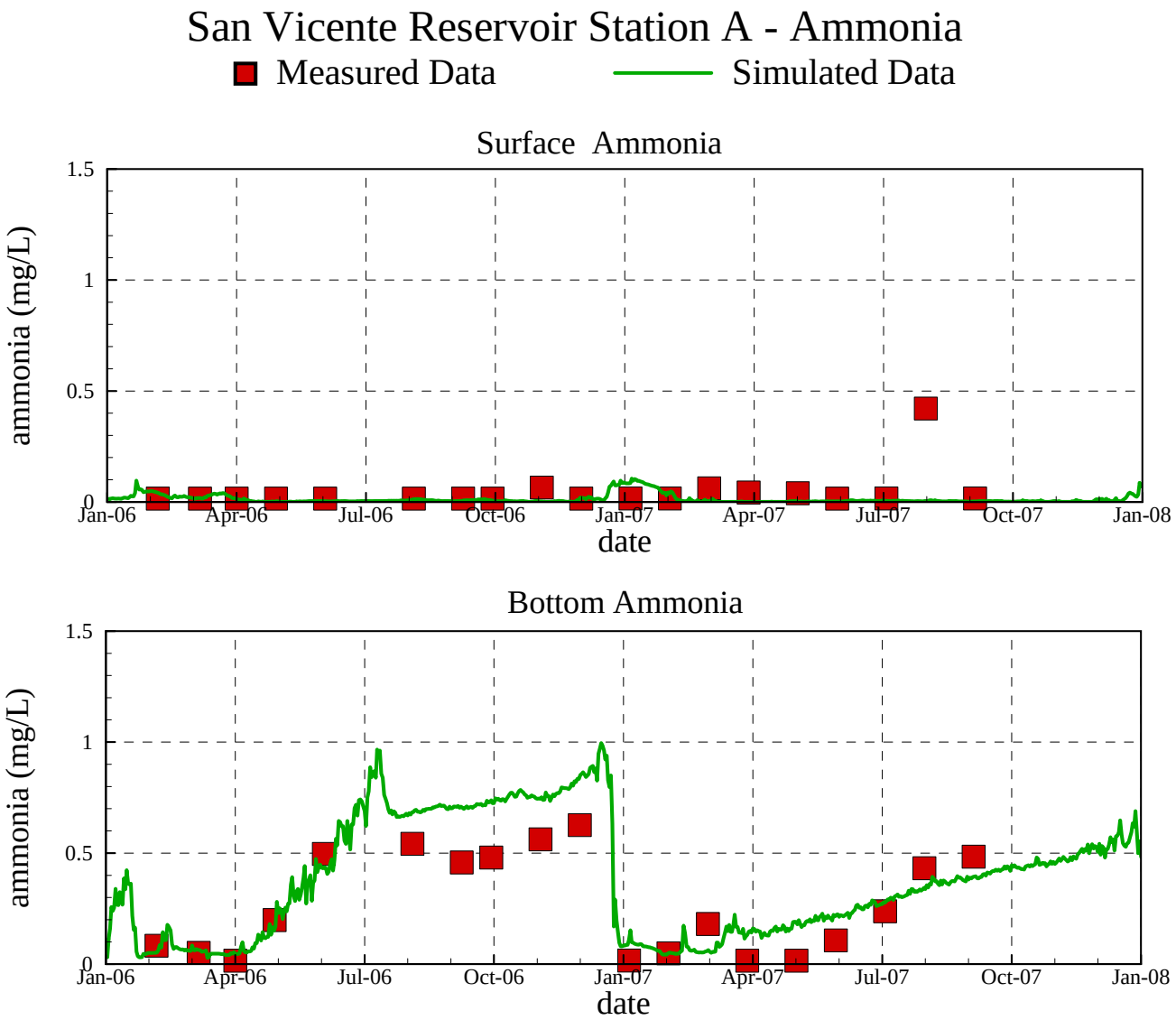

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Figure 45

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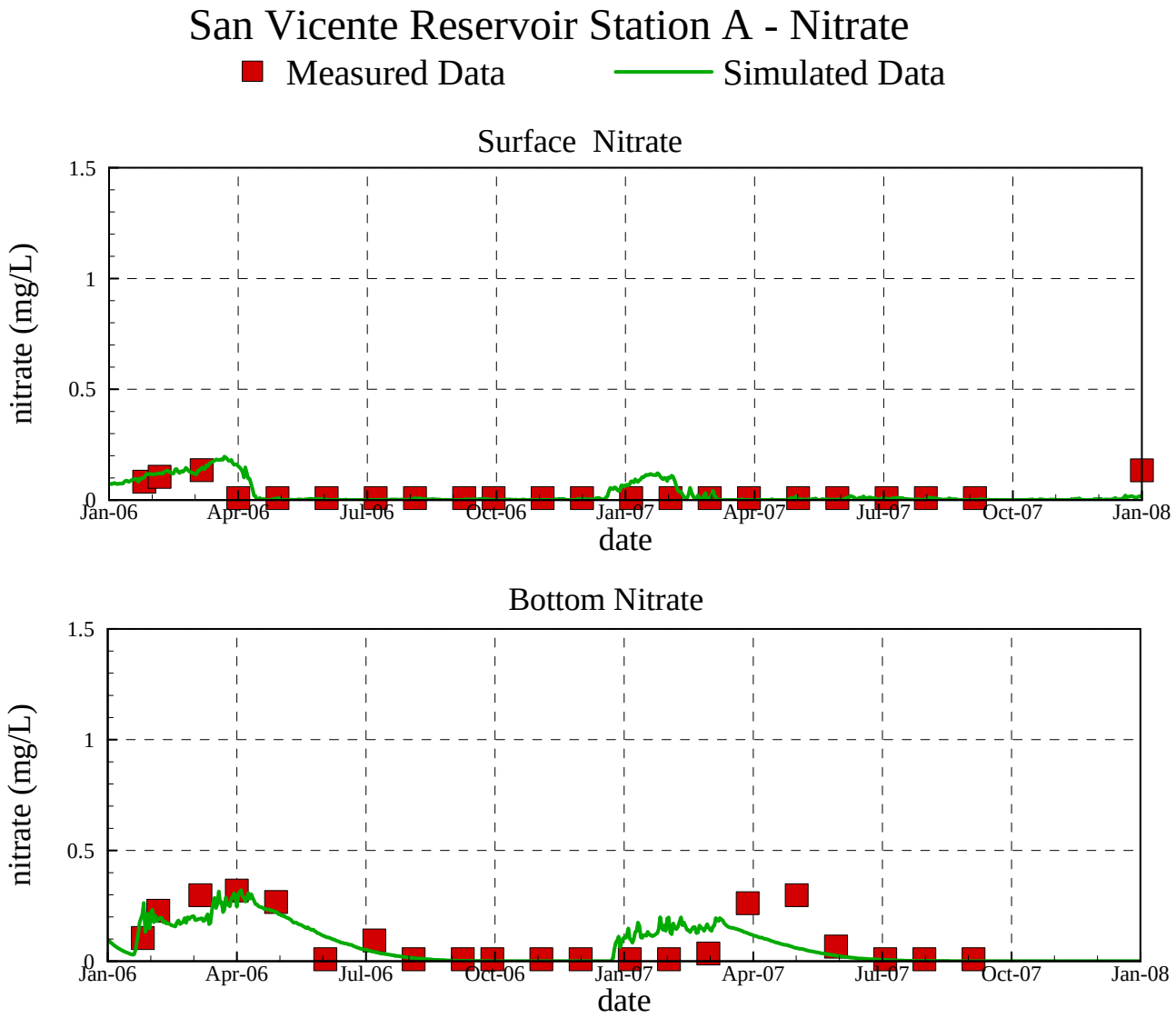

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Figure 46

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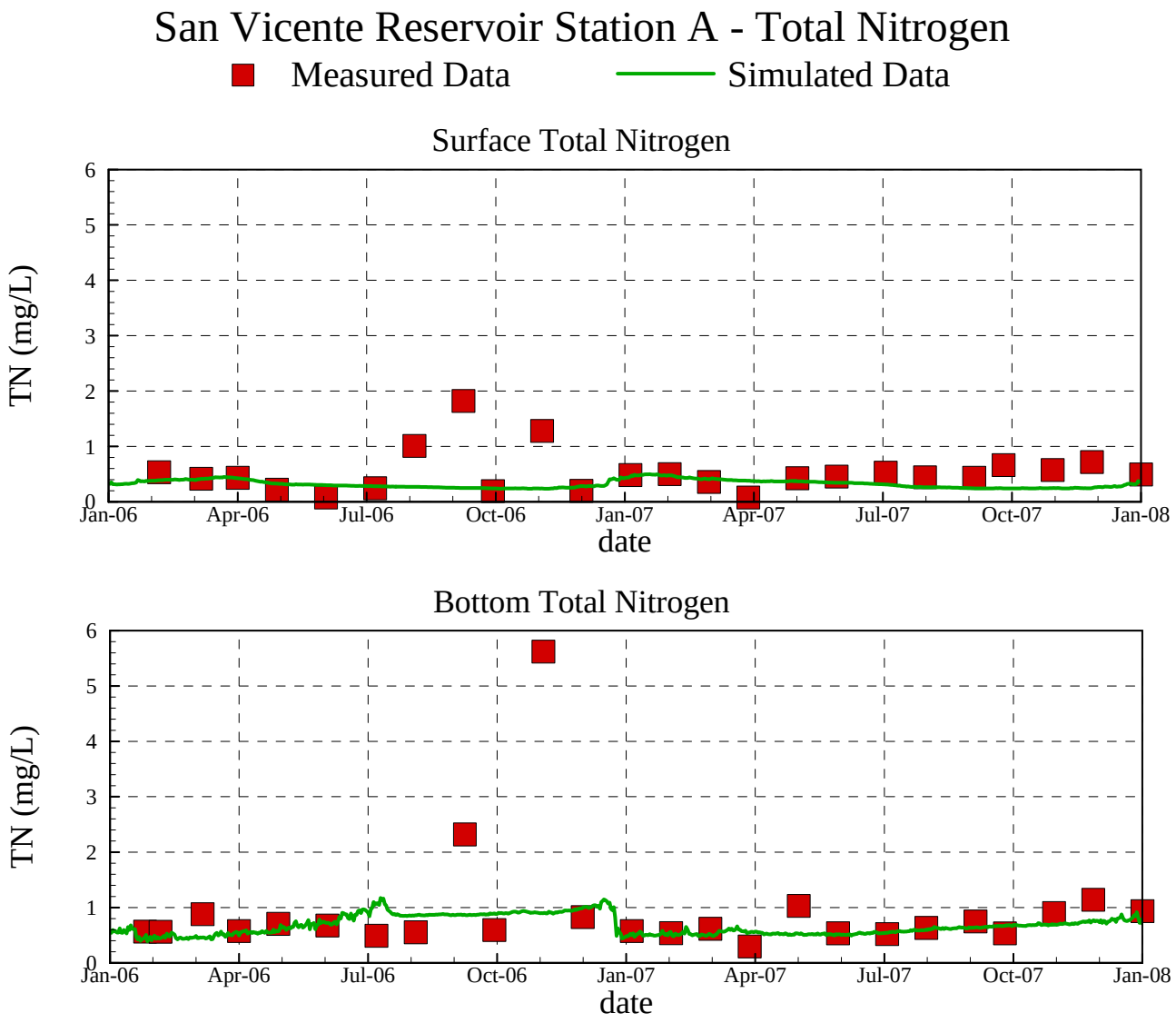

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Figure 47

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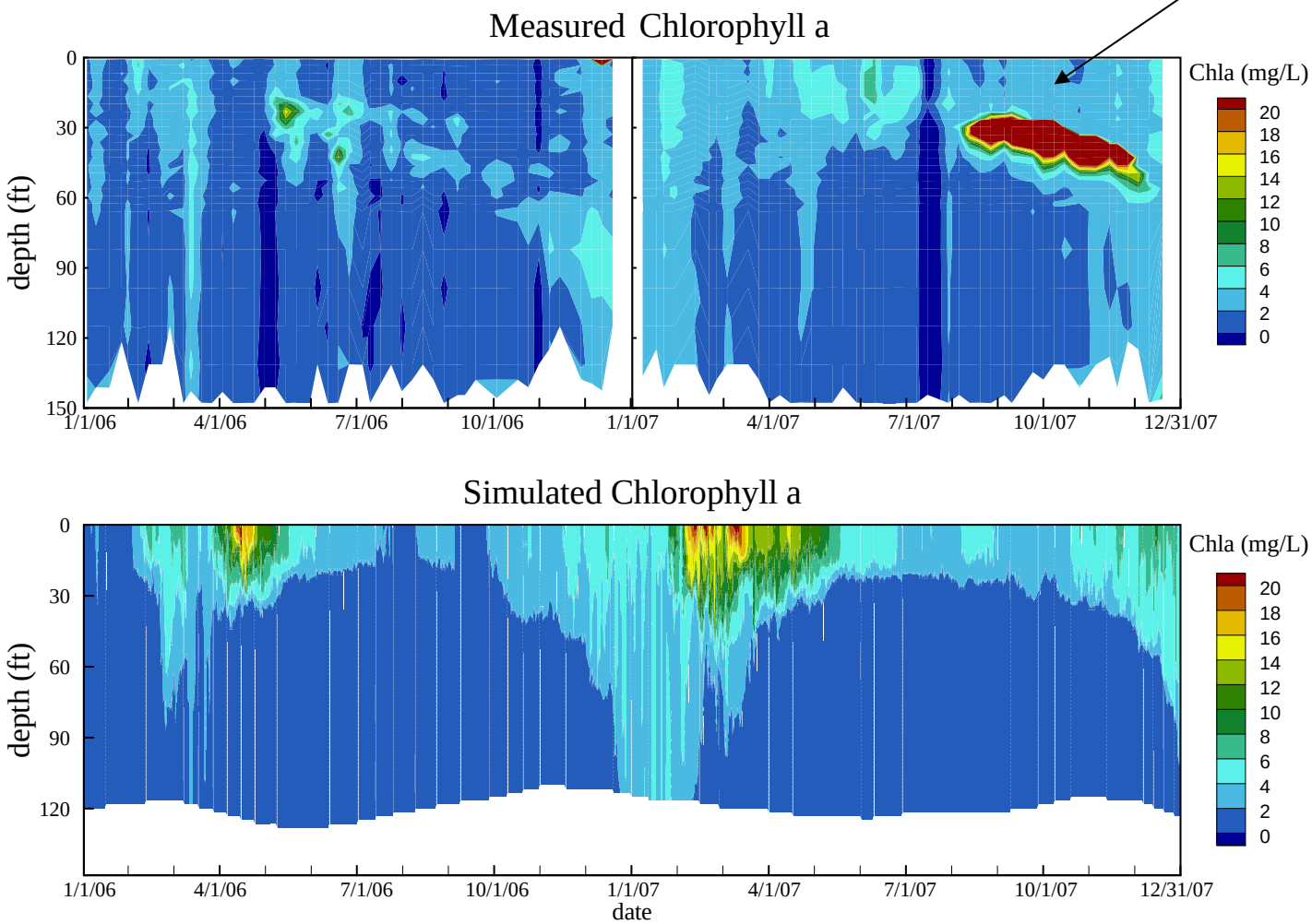
San Vicente Reservoir

Station A – Chlorophyll a Concentrations



Measured DO, chlorophyll a and temperature profiles on 9/24/2007

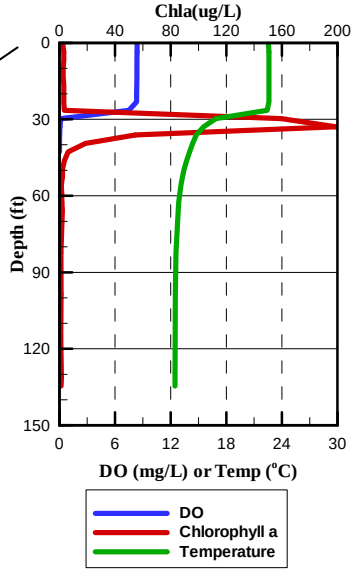


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Figure 48

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San Vicente Reservoir Station A - Secchi Depth Calibration

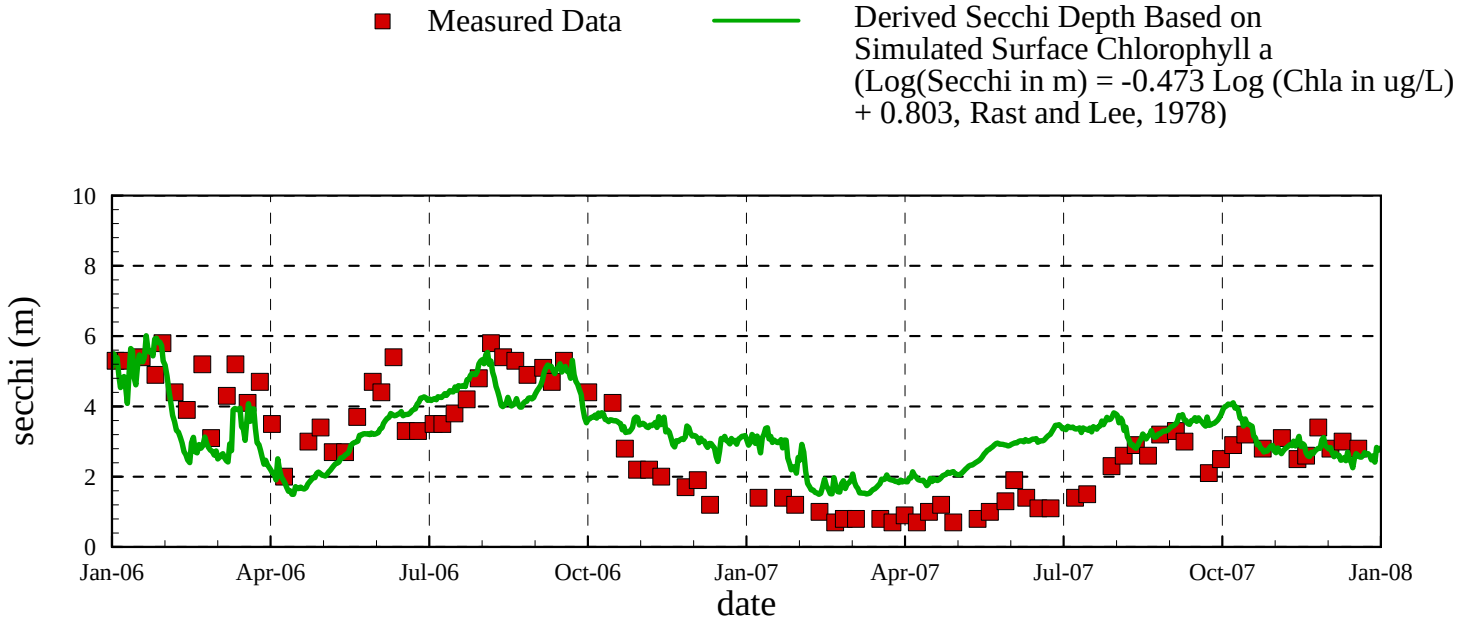

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Figure 49

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San Vicente Reservoir

Scatter Plot of Measured vs. Simulated Secchi Depth

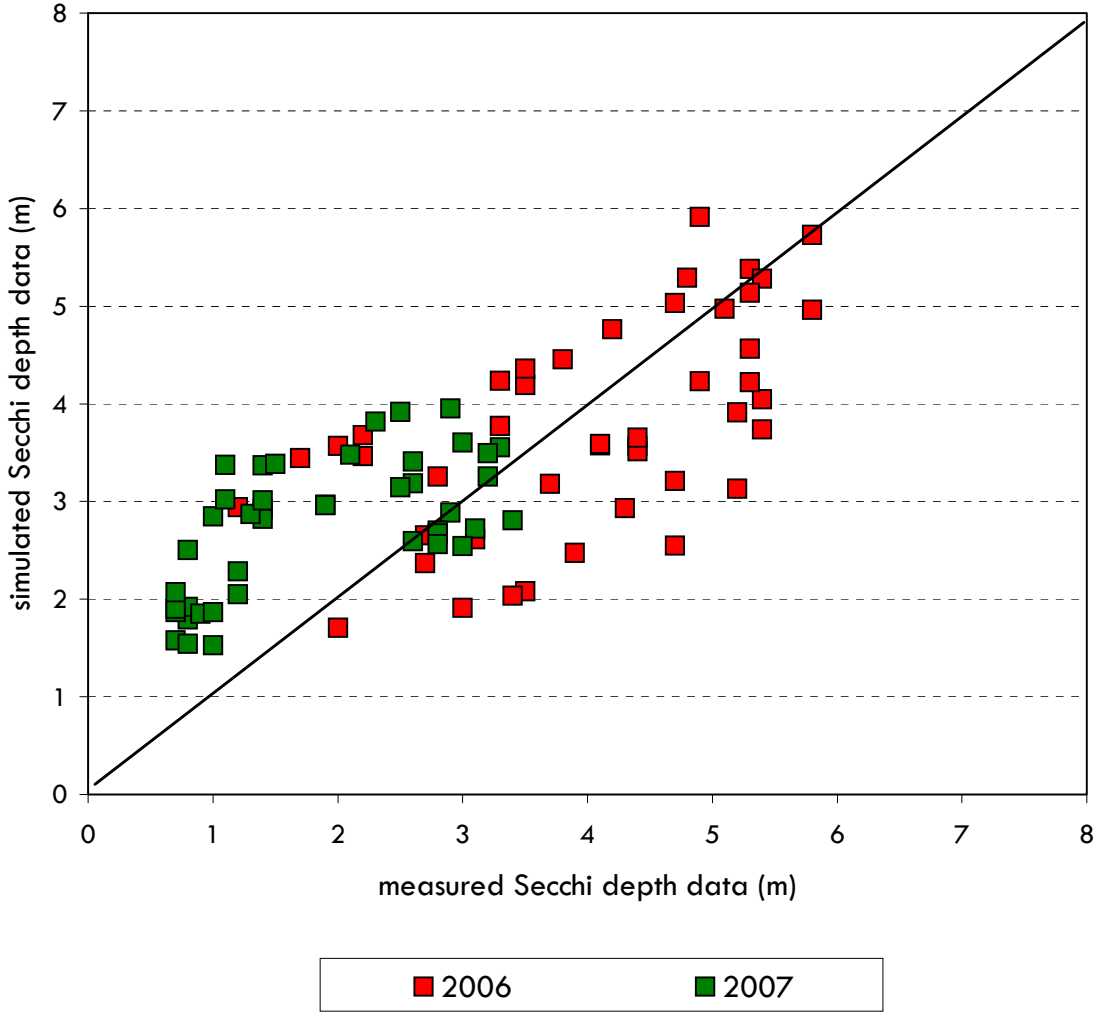

Figure 50

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APPENDIX A

DESCRIPTION OF ELCOM/CAEDYM MODELS AND EVIDENCE OF VALIDATION

DESCRIPTION OF ELCOM/CAEDYM MODELS AND EVIDENCE OF VALIDATION

1.0 INTRODUCTION

The coupling of biogeochemical and hydrodynamic processes in numerical simulations is a fundamental tool for research and engineering studies of water quality in coastal oceans, estuaries, lakes, and rivers. A modeling system for aquatic ecosystems has been developed that combines a three-dimensional hydrodynamic simulation method with a suite of water quality modules that compute interactions between biological organisms and the chemistry of their nutrient cycles. This integrated approach allows for the feedback and coupling between biogeochemical and hydrodynamic systems so that a complete representation of all appropriate processes can be included in an analysis. The hydrodynamic simulation code is the Estuary and Lake Computer Model (ELCOM) and the biogeochemical model is the Computational Aquatic Ecosystem Dynamics Model (CAEDYM).

The purpose of this document is to demonstrate that ELCOM and CAEDYM are accepted models that have been systematically tested and debugged, and then successfully validated in numerous applications. A history of the models is provided, followed by an outline of the general model methodology and evolution that emphasizes the basis of the ELCOM/ CAEDYM codes in previously validated models and research. Then the process of code development, testing, and validation of ELCOM/CAEDYM is detailed. Specific model applications are described to illustrate how the ELCOM/CAEDYM models have been applied to coastal oceans, estuaries, lakes, and rivers throughout the world and the results successfully validated against field data. Finally, a general description of the governing equations, numerical models, and processes used in the models is provided along with an extensive bibliography of supporting material.

A comprehensive description of the equations and methods used in the models is provided in the "The CWR Estuary and Lake Computer Model, User Guide" by Hodges (1999), "Estuary and Lake Computer Model, ELCOM Science Manual Code Version 1.5.0" by Hodges and Dallimore (2001), "Computational Aquatic Ecosystem Dynamics Model, CAEDYM: User Manual" (1999), and the "Computational Aquatic Ecosystem Dynamics Model (CAEDYM), An Ecological Water Quality Model Designed for Coupling with Hydrodynamic Drivers, Scientific Manual" by Hamilton and Herzfeld (1999).

2.0 MODEL HISTORY

The ELCOM/CAEDYM models were originally developed at the Centre for Water Research (CWR) at the University of Western Australia, although the hydrodynamics code ELCOM is an outgrowth of a hydrodynamic model developed earlier by Professor Vincenzo Casulli in Italy and now in use at Stanford University under the name TRIM-3D. The CAEDYM model was essentially developed at CWR as an outgrowth of earlier water quality modules used in the one-dimensional model, Dynamic Reservoir Simulation Model - Water Quality (DYRESM-WQ, Hamilton and Schladow, 1997).

The original ELCOM/CAEDYM models, as developed by CWR, were implemented in Fortran 90 (with F95 extensions) on a UNIX computer system platform. In 2001, the codes for both models were ported to a personal computer (PC) platform through an extensive recompiling and debugging effort by Flow Science Incorporated (Flow Science) in Pasadena, California.

3.0 MODEL METHODOLOGY

ELCOM is a three-dimensional numerical simulation code designed for practical numerical simulation of hydrodynamics and thermodynamics for inland and coastal waters. The code links seamlessly with the CAEDYM biogeochemical model undergoing continuous development at CWR, as shown graphically in **Figure 1**. The combination of the two codes provides three-dimensional simulation capability for examination of changes in water quality that arise from anthropogenic changes in either quality of inflows or reservoir operations.

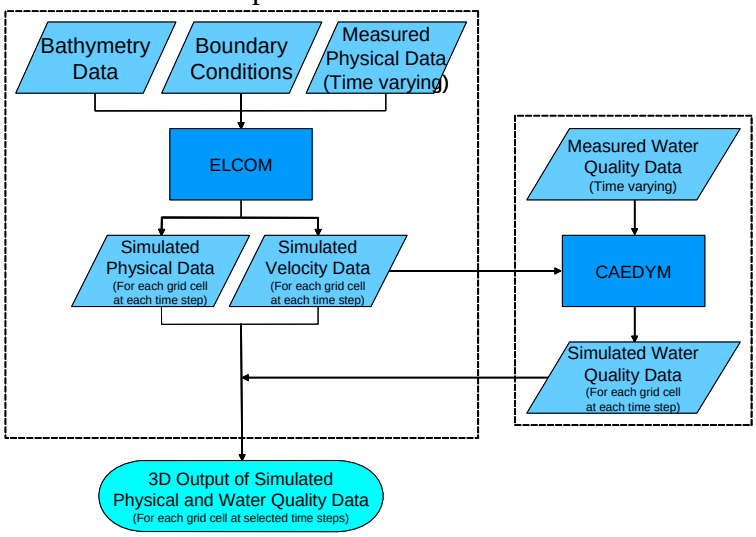

Figure 1 Flow chart showing the integration of the linked ELCOM/CAEDYM models.

The numerical method used in ELCOM is based on the TRIM-3D model scheme of Casulli and Cheng (1992) with adaptations made to improve accuracy, scalar conversion, numerical diffusion, and implementation of a mixed-layer model. The ELCOM model also extends the TRIM-3D scheme by including conservative advection of scalars. The unsteady Reynolds-averaged, Navier-Stokes equations, and the scalar transport equations serve as the basis of ELCOM. The pressure distribution is assumed hydrostatic and density changes do not impact the inertia of the fluid (the Boussinesq approximation), but are considered in the fluid body forces. There is an eddy-viscosity approximation for the horizontal turbulence correlations that represent the turbulent momentum transfer. Vertical momentum transfer is handled by a Richardson number-based diffusion coefficient. Since numerical diffusion generally dominates molecular processes, molecular diffusion in the vertical direction is neglected in ELCOM.

Both ELCOM and TRIM-3D are three-dimensional, computational fluid dynamics (CFD) models. CFD modeling is a validated and well-established approach to solving the equations of fluid motions in a variety of disciplines. Prior to the development of TRIM-3D, there were difficulties in modeling density stratified flows and such flows required special numerical methods. With TRIM-3D, Casulli and Cheng (1992) developed the first such successful method to model density-stratified flows, such as occur in the natural environment. Since then, TRIM-3D has been validated by numerous publications. ELCOM is based on the same proven method, but incorporates additional improvements as described above. Furthermore, the ELCOM model is based on governing equations and numerical algorithms that have been used in the past (e.g., in validated models such as TRIM-3D), and have been validated in refereed publications. For example:

- The hydrodynamic algorithms in ELCOM are based on the Euler-Lagrange method for advection of momentum with a conjugate gradient solution for the free-surface height (Casulli and Cheng, 1992).
- The free-surface evolution is governed by vertical integration of the continuity equation for incompressible flow applied to the kinematic boundary condition *(e.g.*, Kowalik and Murty, 1993).
- The numerical scheme is a semi-implicit solution of the hydrostatic Navier-Stokes equations with a quadratic Euler-Lagrange, or semi-Lagrangian (Staniforth and Côté, 1991).
- Passive and active scalars (*i.e.*, tracers, salinity, and temperature) are advected using a conservative ULTIMATE QUICKEST discretization (Leonard, 1991). The ULTIMATE QUICKEST approach has been implemented in two-dimensional format and demonstration of its effectiveness in estuarine flows has been documented by Lin and Falconer (1997).

- Heat exchange is governed by standard bulk transfer models found in the literature (*e.g.*, Amorocho and DeVries, 1980; Imberger and Patterson, 1981; Jacquet, 1983).
- The vertical mixing model is based on an approach derived from the mixing energy budgets used in one-dimensional lake modeling as presented in Imberger and Patterson (1981), Spigel *et al* (1986), and Imberger and Patterson (1990). Furthermore, Hodges presents a summary of validation using laboratory experiments of Stevens and Imberger (1996). This validation exercise demonstrates the ability of the mixed-layer model to capture the correct momentum input to the mixed-layer and reproduce the correct basin-scale dynamics, even while boundary-induced mixing is not directly modeled.
- The wind momentum model is based on a mixed-layer model combined with a model for the distribution of momentum over depth (Imberger and Patterson, 1990).

The numerical approach and momentum and free surface discretization used in ELCOM are defined in more detail in Hodges, Imberger, Saggio, and Winters (1999). Similarly, the water quality processes and methodology used in CAEDYM are described in more detail in Hamilton and Schladow (1997). Further technical details on ELCOM and CAEDYM are provided in Sections 5.0 and 6.0 below.

4.0 VALIDATION AND APPLICATION OF ELCOM/CAEDYM

Since initial model development, testing and validation of ELCOM and/or CAEDYM have been performed and numerous papers on model applications have been presented, written, and/or published as described in more detail below. In summary:

- ELCOM solves the full three-dimensional flow equations with small approximations.
- ELCOM/CAEDYM was developed, tested, and validated over a variety of test cases and systems by CWR.
- Papers on ELCOM/CAEDYM algorithms, methodology, and applications have been published in peer reviewed journals such as the *Journal of Geophysical Research*, the *Journal of Fluid Mechanics*, the *Journal of Hydraulic Engineering*, the *International Journal for Numerical Methods in Fluids*, and *Limnology and Oceanography*.
- ELCOM/CAEDYM was applied by Flow Science to Lake Mead, Nevada. As part of this application, mass balances were verified and results were presented to a model review panel over a two-year period. The model review panel, the National Park Service, the Bureau of Reclamation, the Southern Nevada Water Authority, and the Clean Water Coalition (a

consortium of water and wastewater operators in the Las Vegas, Nevada, region) all accepted the ELCOM/CAEDYM model use and validity.

- There are numerous applications of ELCOM/CAEDYM in the literature that compare the results to data, as summarized in Section 3.2.

The process of code development, testing, and validation of ELCOM/CAEDYM by CWR, and the ongoing validation and refinement of the codes through further application of the models are detailed in the following subsections. The major components of the development, testing, and validation process are summarized in **Figure 2**.

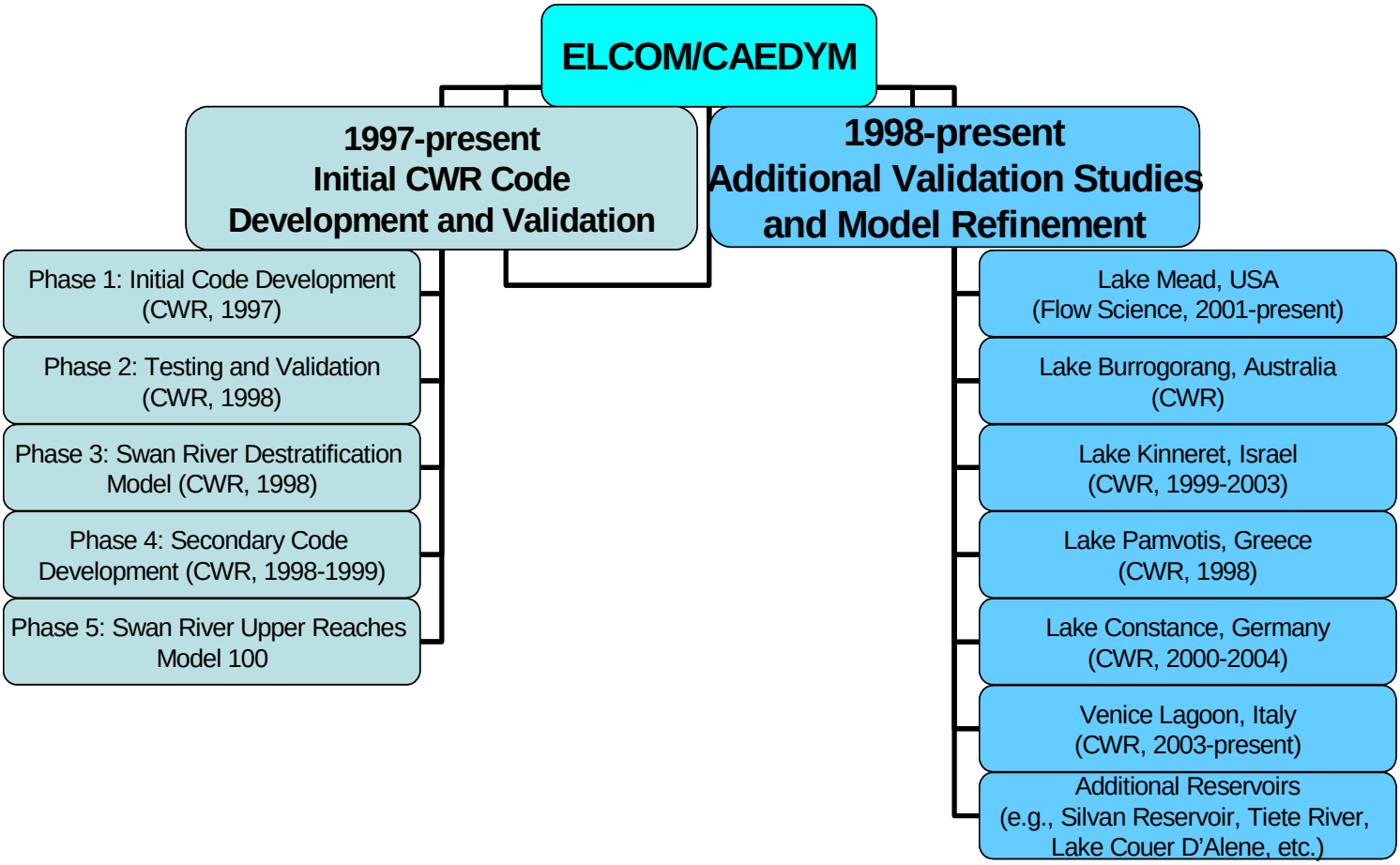

Figure 2 ELCOM/CAEDYM code development, testing, validation, and applications by CWR and Flow Science Incorporated.

4.1 CWR CODE DEVELOPMENT, TESTING, AND VALIDATION

Initial development of the code by CWR occurred from March through December 1997 (Phase 1), followed by a period of testing and validation from January through April 1998 (Phases 2 and 3). Secondary code development by CWR occurred from September 1998 through February 1999 (Phase 4). Testing and validation were performed over a variety of test cases and systems to ensure that all facets of the code were tested. In addition, Phase 5 modeling of the Swan River since 1998 has been used to gain a better understanding of the requirements and limitations of the model (Hodges *et al*, 1999).

4.1.1 Phase 1: Initial Code Development

The ELCOM code was initially conceived by CWR as a Fortran 90/95 adaptation of the TRIM-3D model of Casulli and Cheng (1992) in order to: 1) link directly to the CAEDYM water quality module developed concurrently at CWR and 2) provide a basis for future development in a modern programming language. Although written in Fortran 77, TRIM-3D is considered a state-of-the-art numerical model for estuarine applications using a semi-implicit discretization of the Reynolds-averaged hydrostatic Navier-Stokes equations and an Euler-Lagrange method for momentum and scalar transport.

During development of ELCOM, it became clear that additional improvements to the TRIM-3D algorithm were required for accurate solution of density-stratified flows in estuaries. After the basic numerical algorithms were written in Fortran 90, subroutine-by-subroutine debugging was performed to ensure that each subroutine produced the expected results. Debugging and testing of the entire model used a series of test cases that exercised the individual processes in simplified geometries. This included test cases for the functioning of the open boundary condition (tidal forcing), surface wave propagation, internal wave propagation, scalar transport, surface thermodynamics, density underflows, wind-driven circulations, and flooding/drying of shoreline grid cells. Shortcomings identified in the base numerical algorithms were addressed during secondary code development (Phase 4).

Towards the end of the initial code development, ELCOM/CAEDYM were coupled and test simulations were run to calibrate the ability of the models to work together on some simplified problems. Results showing the density-driven currents induced by phytoplankton shading were presented at the Second International Symposium on Ecology and Engineering (Hodges and Herzfeld, 1997). Further details of modeling of density-driven currents due to combinations of topographic effects and phytoplankton shading were presented at a joint meeting of the American Geophysical Union (AGU) and the American Society of Limnology and Oceanography (ASLO) by Hodges *et al*. (1998), and at a special seminar at Stanford University (Hodges 1998).

Additionally, presentations by Hamilton (1997), Herzfeld *et al*. (1997), and Herzfeld and Hamilton (1998) documented the concurrent development of the CAEDYM ecological model.

4.1.2 Phase 2: Testing and Validation

The simplified geometry tests of Phase I revealed deficiencies in the TRIM-3D algorithm including the inability of the TRIM-3D Euler-Lagrange method (ELM) to provide conservative transport of scalar concentrations (e.g., salinity and temperature). Thus, a variety of alternate scalar transport methods were tested, with the best performance being a flux-conservative implementation of the ULTIMATE filter applied to third-order QUICKEST discretization based on the work of Leonard (1991).

Model testing and validation against simple test cases was again undertaken. In addition, a simulation of a winter underflow event in Lake Burragorang in New South Wales, Australia, was performed to examine the ability of the model to capture a density underflow in complex topography in comparison to field data taken during the inflow event. These tests showed that the ability to model underflows is severely constrained by the cross-channel grid resolution.

4.1.3 Phase 3: Swan River Destratification Model

Phase 3 involved examining a linked ELCOM/CAEDYM destratification model of the Swan River system during a period of destratification in 1997 when intensive field monitoring had been conducted. The preliminary results of this work were presented at the Swan-Canning Estuary Conference (Hertzfeld *et al*, 1998). More comprehensive results were presented at the Western Australian Estuarine Research Foundation (WAERF) Community Forum (Imberger, 1998).

4.1.4 Phase 4: Secondary Code Development

In conducting the Phase 3 Swan River destratification modeling, it became clear to CWR that long-term modeling of the salt-wedge propagation would require a better model for mixing dynamics than presently existed. Thus, the availability of an extensive field data set for Lake Kinneret, Israel, led to its use as a test case for development of an improved mixing algorithm for stratified flows (Hodges *et al*, 1999).

A further problem appeared in the poor resolution of momentum terms using the linear ELM discretization (*i.e.*, as used in the original TRIM-3D method). Since the conservative ULTIMATE QUICKEST method (used for scalar transport, see Phase 1 above) does not lend itself to efficient use for discretization of momentum terms in a semi-implicit method, a quadratic ELM approach was developed for more accurate discretization of the velocities.

4.1.5 Phase 5: Swan River Upper Reaches Model

Phases 1-4 developed and refined the ELCOM code for accurate modeling of three-dimensional hydrodynamics where the physical domain is well resolved. Phase 5 is an ongoing process of model refinement that concentrates on developing a viable approach to modeling longer-term evolution hydrodynamics and water quality in the Swan River where fine-scale resolution of the domain is not practical. The Swan River application is also used for ongoing testing and calibration of the CAEDYM water quality module.

The Swan River estuary is located on the Swan Coastal Plain, Western Australia. It is subject to moderate to high nutrient loads associated with urban and agricultural runoff and suffered from *Microcystis aeruginosa* blooms in January 2000. In an effort to find a viable means of conducting seasonal to annual simulations of the Swan River that retain the fundamental along-river physics and the cross-channel variability in water quality parameters, CWR has developed and tested ELCOM/CAEDYM extensively. A progress report by Hodges *et al* (1999) indicates that ELCOM is capable of accurately reproducing the hydrodynamics of the Swan River over long time scales with a reasonable computational time.

Furthermore, studies conducted by Robson and Hamilton (2002) proved that ELCOM/CAEDYM accurately reproduced the unusual hydrodynamic circumstances that occurred in January 2000 after a record maximum rainfall, and predicted the magnitude and timing of the *Microcystis* bloom. These studies show that better identification and monitoring procedures for potentially harmful phytoplankton species could be established with ELCOM/CAEDYM and will assist in surveillance and warnings for the future.

4.2 MODEL APPLICATIONS

In addition to the initial code development, testing, and validation by CWR, numerous other applications of ELCOM/CAEDYM have been developed by CWR and validated against field data. Additionally, Flow Science has applied ELCOM/CAEDYM extensively at Lake Mead (USA) and validated the results against measured data. The results of numerous ELCOM/CAEDYM model applications are presented below.

4.2.1 Lake Mead (Nevada, USA)

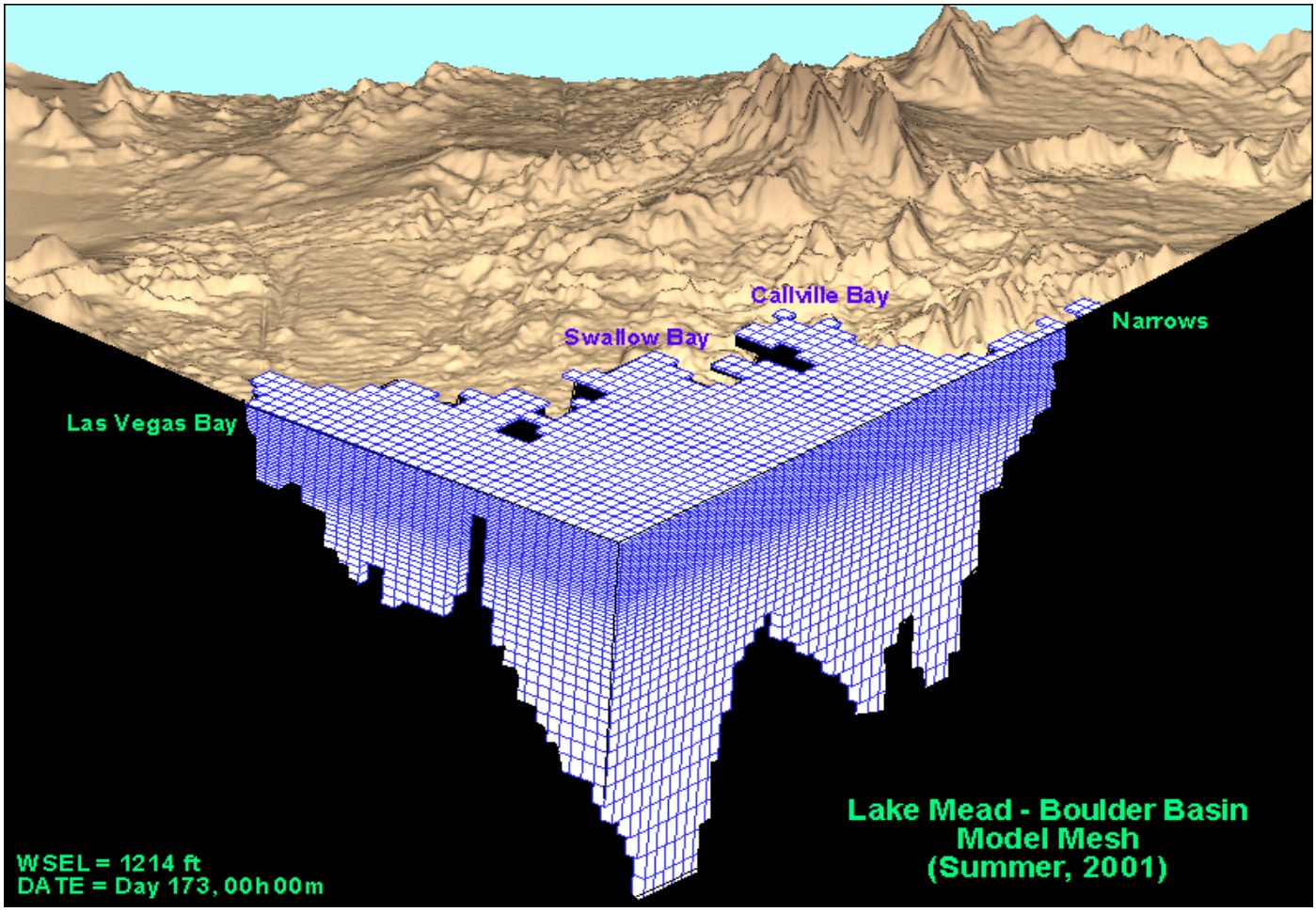

Figure 3 Model Grid for Lake Mead.

An ELCOM/CAEDYM model of Lake Mead near Las Vegas, Nevada, is being used to evaluate alternative discharge scenarios for inclusion in an Environmental Impact Statement (EIS) for the Clean Water Coalition (CWC), a consortium of water and wastewater operators in the Las Vegas region. **Figure 3** is a cut-away of the three-dimensional model grid used for Lake Mead, showing the varying grid spacing in the vertical direction. **Figure 4** is an example of the model output, showing the isopleths of a tracer plume within the reservoir for a sample case.

As part of the EIS process, a model review panel met monthly for two years to review the validation of the ELCOM/CAEDYM model, its calibration against field data, and its application. The modeling committee approved the use of the model.

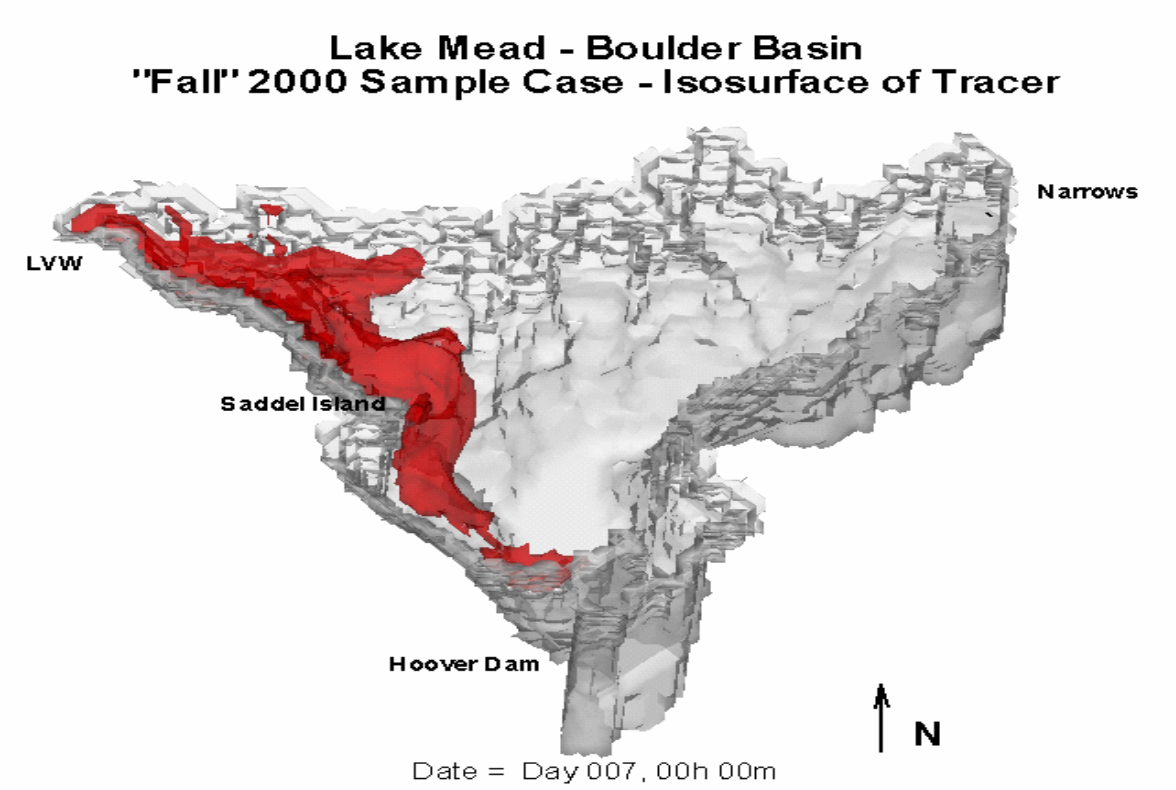

Figure 4 Lake Mead isopleths of tracer for a fall 2000 sample case.

Subsequently, a scientific Water Quality Advisory Panel concluded that the ELCOM/CAEDYM model was applicable and acceptable. The members of the Water Quality Advisory Panel were diverse and included Jean Marie Boyer, Ph.D., P.E. (Water Quality Specialist/Modeler, Hydrosphere), Chris Holdren, Ph.D., CLM (Limnologist, United States Bureau of Reclamation), Alex Horne, Ph.D. (Ecological Engineer, University of California Berkeley), and Dale Robertson, Ph.D. (Research Hydrologist, United States Geological Survey).

More specifically, the Water Quality Advisory Panel agreed on the following findings:

- The ELCOM/CAEDYM model is appropriate for the project.
- There are few three-dimensional models available for reservoirs. ELCOM is one of the best hydrodynamic models and has had good success in Lake Mead and other systems.
- The ELCOM model accurately simulates most physical processes.
- The algorithms used in CAEDYM are widely accepted (a biological consultant, Professor David Hamilton of The University of Waikato, New Zealand, has been retained to review the CAEDYM coefficients and algorithms).

The Lake Mead ELCOM/CAEDYM model was calibrated against four years of measured data for numerous physical and water quality parameters including temperature, salinity, conductivity, dissolved oxygen, pH, nutrients (nitrogen and phosphorus), chlorophyll *a*, perchlorate, chloride, sulfate, bromide, and total organic carbon. Detailed results of this calibration and the subsequent evaluation of alternative discharge scenarios will be made available in late 2005 in the CWC EIS that is currently being prepared for this project. An example of the calibration results for chlorophyll *a* for 2002 is presented in **Figure 5** below. In this figure, simulated concentrations are compared against field data measured in the lake by the United States Bureau of Reclamation (USBR) and the City of Las Vegas (COLV).

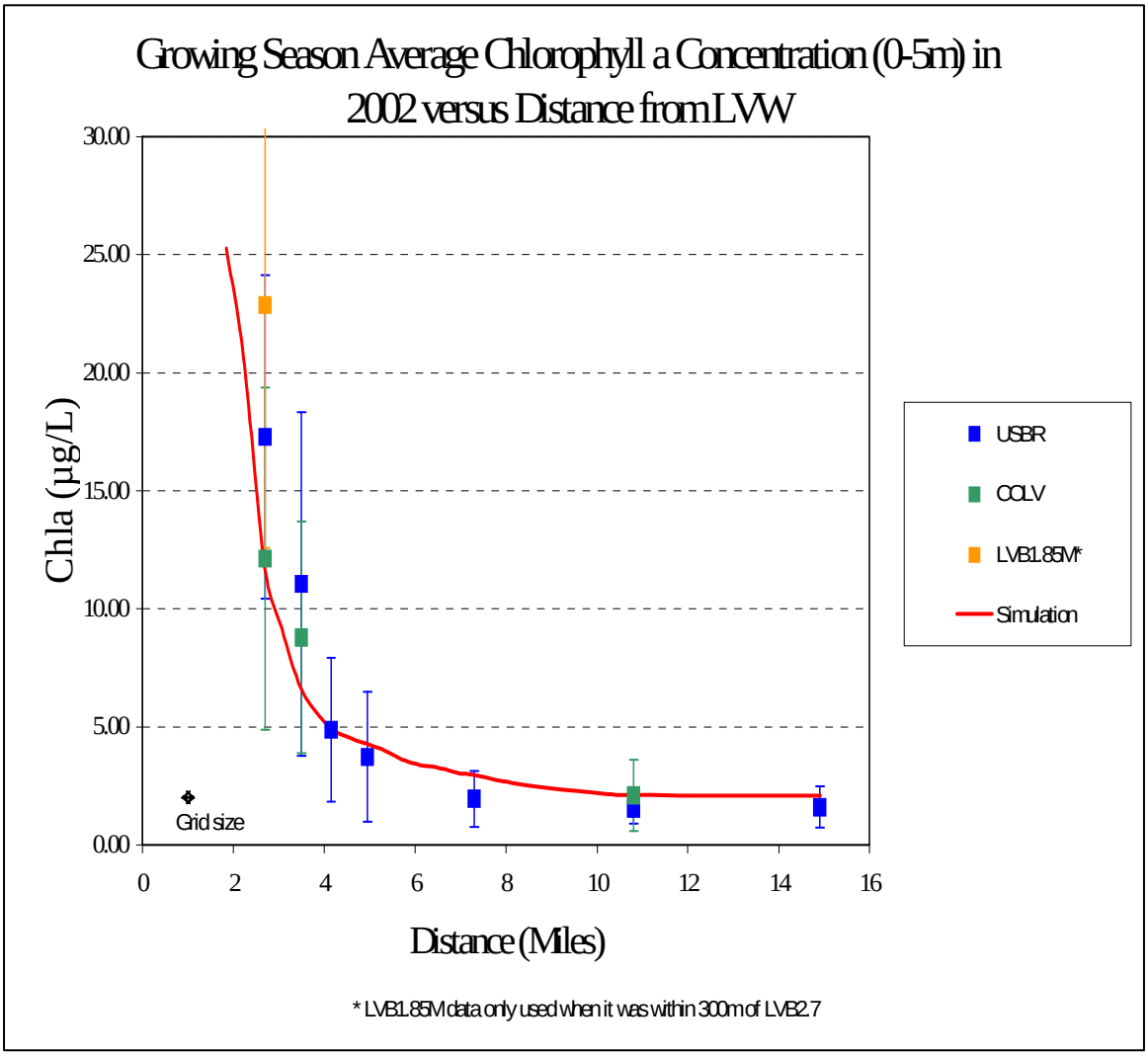

Figure 5 ELCOM/CAEDYM calibration results for chlorophyll a for 2002 as a function of distance from the inflow at Las Vegas Wash.

In addition to the good agreement between the model and field data and the acceptance of the model by the review committees, Flow Science also performed a mass balance on the model to ensure conservation of tracer materials. As a result of such tests and debugging, Flow Science and the CWR have made continuous improvements to the model as necessary including refinements to the ULTIMATE QUICKEST scheme and boundary cell representations.

4.2.2 Lake Burragorang (New South Wales, Australia)

ELCOM was applied and validated for Lake Burragorang in order to rapidly assess the potential impacts on water quality during an underflow event (CWR). Underflows usually occur during the winter when inflow water temperature is low compared to the reservoir. This causes the upheaval of hypolimnetic water at the dam wall, and as a result it transports nutrient rich waters into the euphotic zone.

The thermal dynamics during the underflow event were reproduced accurately by ELCOM for the case with idealized bathymetry data with coarse resolutions (straightened curves and rotating the lake in order to bypass the resolution problem), but not for the simulation with the complex, actual bathymetry. This is because the model tests showed that the ability to model underflows is severely constrained by the cross-channel grid resolution. When the cross-channel direction is poorly resolved at bends and curves, an underflow is unable to propagate downstream without a significant loss of momentum. Nevertheless, the simulations with the coarse idealized domain certainly can be used as aids and tools to visualize the behavior of reservoirs. Particularly, ELCOM was able to capture the traversal of the underflow down the length of Lake Burragorang and then had sufficient momentum to break against the wall causing the injection of underflow waters into the epilimnion near the dam. This simulated dynamic was in agreement with what was measured in the field.

4.2.3 Lake Kinneret (Israel)

ELCOM was applied to model basin-scale internal waves that are seen in Lake Kinneret, Israel, since understanding of basin-scale internal waves behaviors provide valuable information on mixing and transport of nutrients below the wind-mixed layer in stratified lakes. In studies done by Hodges *et al*. (1999) and Laval *et al* (2003), the ELCOM simulation results were compared with field data under summer stratification conditions to identify and illustrate the spatial structure of the lowest-mode basin-scale Kelvin and Poincare waves that provide the largest two peaks in the internal wave energy spectra. The results demonstrated that while ELCOM showed quantitative differences in the amplitude and steepness of the waves as well as in the wave phases, the basin-scale waves were resolved very well by ELCOM. In particular, the model captures the qualitative nature of the peaks and troughs in the thermocline and the depth of the wind-mixed layer at relatively coarse vertical grid resolutions (Hodges *et al*, 1999).

4.2.4 Lake Pamvotis (Greece)

ELCOM/CAEDYM was applied to Lake Pamvotis, a moderately sized (22 km^2), shallow (4 m average depth) lake located in northwest Greece. Since the lake has undergone eutrophication over the past 40 years, many efforts are directed at understanding the characteristics of the lake and developing watershed management and restoration plans.

Romero and Imberger (1999) simulated Lake Pamvotis over a one month period during May to June, 1998, and compared the simulated thermal and advective dynamics of the lake with data obtained from a series of field experiments. The simulation results over-predicted heating; however, diurnal fluctuations in thermal structures were similar to those measured. Since the meteorological site was sheltered from the winds, the wind data used in the simulation was believed to be too low, causing insufficient evaporative heat-loss and subsequent over-heating by ELCOM. An increase in the wind speed by a factor of three gave temperature profiles in agreement with the field data. Moreover, the study demonstrated that the model is capable of predicting the substantial diurnal variations in the intensity and direction of both vertical and horizontal velocities. Romero and Imberger were also able to illustrate the functionality of ELCOM when coupled to the water quality model, CAEDYM, and confirmed that the model could be used to evaluate the effect of various strategies to improve poor water quality in localized areas in the lake.

4.2.5 Lake Constance (Germany, Austria, Switzerland)

Appt (2000) and Appt *et al*. (2004) applied ELCOM to characterize the internal wave structures and motions in Lake Constance since internal waves are a key factor in understanding the transport mechanisms for chemical and biological processes in a stratified lake such as Lake Constance. Lake Constance is an important source of drinking water and a major tourism destination for its three surrounding countries of Germany, Austria, and Switzerland. Due to anthropogenic activities and climatic changes, Lake Constance water quality has deteriorated and its ecosystem has changed.

It was shown that ELCOM was able to reproduce the dominant internal wave and major hydrodynamic processes occurring in Lake Constance. For instance, three types of basin-scale waves were found to dominate the wave motion: the vertical mode-one Kelvin wave, the vertical mode-one Poincare waves, and a vertical mode-two Poincare wave. Moreover, an upwelling event was also reproduced by ELCOM suggesting that the width and length ratio of the basin, spatial variations in the wind, and Coriolis effects play critical roles in the details of the upwelling event. This on-going research has shown that ELCOM can be used as a tool to predict and understand hydrodynamics and water quality in lakes.

4.2.6 Venice Lagoon (Italy)

ELCOM/CAEDYM is being used to develop a hydrodynamic and sediment transport model of Venice Lagoon, Italy, since future gate closures at the mouth of the lagoon are likely to impact flushing patterns. This project is an integral part of the Venice Gate Projects in Italy that was launched in May 2003 to prevent flooding.

ELCOM was validated for the tidal amplitude and phase using the data obtained from 12 tidal stations located throughout the lagoon (Yeates, 2004). Remaining tasks include model validation of temperature, salinity, and velocity against measurements made in the major channels of the lagoon.

4.2.7 Silvan Reservoir (Australia)

ELCOM is currently being applied to reproduce the circulation patterns observed in Silvan Reservoir, Australia, during a field experiment that was conducted in March 2004 to determine the transport pathways in the lake. This experiment confirmed the upwelling behavior of the lake and the strong role of the inflows in creating hydraulic flows in the reservoir (Antenucci, 2004).

4.2.8 Billings and Barra Bonita Reservoirs (Brazil)

ELCOM/CAEDYM is being applied to Billings and Barra Bonita Reservoirs in Brazil. Billings Reservoir is an upstream reservoir that feeds Barra Bonita via the Tiete River. The objective of the project is to develop an integrated management tool for these reservoirs and river reaches for use in the future planning of water resource utilization in Sao Paulo, Brazil (Romero and Antenucci, 2004).

4.2.9 Lake Coeur D'Alene (Idaho, USA)

ELCOM/CAEDYM is being applied to investigate the trade-off between reducing heavy metal concentrations and a potential increase in eutrophication due to remediation procedures in Lake Coeur D'Alene, Idaho. In order to investigate heavy metal fate and transport, CAEDYM is being improved further to include heavy metals and a feedback loop to phytoplankton based on metal toxicity (Antenucci, 2004).

4.2.10 Lake Perris (California, USA)

ELCOM was applied to Lake Perris in order to compare the impacts of several recreational use strategies on measured fecal coliform concentrations at the outlet tower. The physical results of the simulation were validated against measured temperature and salinity data over a one-year period. The comparison of fecal coliform concentrations

against measured data was fair due to a lack of data describing the timing and magnitude of loading and the settling and re-suspension of fecal matter.

4.2.11 Other Applications

Other ELCOM/CAEDYM applications and development in on-going research at CWR include:

- Plume dynamics and horizontal dispersion (Marmion Marine Park, Australia).
- Inflow and pathogen dynamics (Helena, Myponga and Sugarloaf Reservoirs, Australia).
- Mixing and dissipation in stratified environments (Tone River, Japan, and Brownlee Reservoir, USA).
- Tidally forced estuaries and coastal lagoons (Marmion Marine Park and Barbamarco Lagoon, Italy).
- Three-dimensional circulation induced by wind and convective exchange (San Roque Reservoir, Argentina, and Prospect Reservoir, Australia).
- Sea-surface temperature fluctuation and horizontal circulation (Adriatic Sea).
- Response of bivalve mollusks to tidal forcing (Barbamarco Lagoon, Italy).
- Impacts of the additional withdrawals and brine discharge into the ocean from a proposed desalination facility co-located with an existing power plant in the City of Carlsbad (California, USA).

5.0 TECHNICAL DESCRIPTION OF ELCOM

As outlined above, ELCOM solves the unsteady, viscous Navier-Stokes equations for incompressible flow using the hydrostatic assumption for pressure. ELCOM can simulate the hydrodynamics and thermodynamics of a stratified system, including baroclinic effects, tidal forcing, wind stresses, heat budget, inflows, outflows, and transport of salt, heat and passive scalars. Through coupling with the CAEDYM water quality module, ELCOM can be used to simulate three-dimensional transport and interactions of flow physics, biology, and chemistry. The hydrodynamic algorithms in ELCOM are based upon the proven semi-Lagrangian method for advection of momentum with a conjugate-gradient solution for the free-surface height (Casulli and Cheng, 1992) and a conservative ULTIMATE QUICKEST transport of scalars (Leonard, 1991). This approach is advantageous for geophysical-scale simulations since the time step can be allowed to exceed the Courant-Friedrichs-Lewy (CFL) condition for the velocity without producing instability or requiring a fully-implicit discretization of the Navier-Stokes equations.

5.1 GOVERNING EQUATIONS

Significant governing equations and approaches used in ELCOM include:

- Three-dimensional simulation of hydrodynamics (unsteady Reynolds-averaged Navier-Stokes equations).
- Advection and diffusion of momentum, salinity, temperature, tracers, and water quality variables.
- Hydrostatic approximation for pressure.
- Boussinesq approximation for density effects.
- Surface thermodynamics module accounts for heat transfer across free surface.
- Wind stress applied at the free surface.
- Dirichlet boundary conditions on the bottom and sides.

5.2 NUMERICAL METHOD

Significant numerical methods used in ELCOM include:

- Finite-difference solution on staggered-mesh Cartesian grid.
- Implicit volume-conservative solution for free-surface position.
- Semi-Lagrangian advection of momentum allows time steps with CFL > 1.0.
- Conservative ULTIMATE QUICKEST advection of temperature, salinity, and tracers.
- User-selectable advection methods for water quality scalars using upwind, QUICKEST, or semi-Lagrangian to allow trade-offs between accuracy and computational speed.
- Solution mesh is uniform in horizontal directions but allows non-uniformity in vertical direction.

The implementation of the semi-Lagrangian method in Fortran 90 includes sparse-grid mapping of three-dimensional space into a single vector for fast operation using array-processing techniques. Only the computational cells that contain water are represented in the single vector so that memory usage is minimized. This allows Fortran 90 compiler parallelization and vectorization without platform-specific modification of the code. A future extension of ELCOM will include dynamic pressure effects to account for nonlinear dynamics of internal waves that may be lost due to the hydrostatic approximation.

Because the spatial scales in a turbulent geophysical flow may range from the order of millimeters to kilometers, it is presently impossible to conduct a Direct Navier-Stokes (DNS) solution of the equations of motion (*i.e.* an exact solution of the equations).

Application of a numerical grid and a discrete time step to a simulation of a geophysical domain is implicitly a filtering operation that limits the resolution of the equations. Numerical models (or closure schemes) are required to account for effects that cannot be resolved for a particular grid or time step. There are four areas of modeling in the flow physics: (l) turbulence and mixing, (2) heat budgets, (3) hydrodynamic boundary conditions, and (4) sediment transport.

5.3 TURBULENCE MODELING AND MIXING

ELCOM presently uses uniform fixed eddy viscosity as the turbulence closure scheme in the horizontal plane (in future versions a Smagorinsky 1963 closure scheme will be implemented to represent subgrid-scale turbulence effects as a function of the resolves large-scale strain-rates). These methods are the classic "eddy viscosity" turbulence closure. With the implementation of the Smagorinsky closure, future extensions will allow the eddy-viscosity to be computed on a local basis to allow improvements in modeling local turbulent events and flow effects of biological organisms (e.g., drag induced by macroalgae or seagrass).

In the present code, the user has the option to extend the eddy-viscosity approach to the vertical direction by setting different vertical eddy-viscosity coefficients for each grid layer. However, in a stratified system, this does not adequately account for vertical turbulent mixing that may be suppressed or enhanced by the stratification (depending on the stability of the density field and the magnitude of the shear stress). To model the effect of density stratification on turbulent mixing the CWR has developed a closure model based on computation of a local Richardson number to scale. The latter is generally smaller than the time step used in geophysical simulations, so the mixing is computed in a series of partial time steps. When the mixing time-scale is larger than the simulation time step, the mixing ratio is reduced to account for the inability to obtain mixing on very short time scales. This model has the advantage of computing consistent mixing effects without regard to the size of the simulation time-step (*i.e.* the model produces mixing between cells that is purely a function of the physics and not the numerical step size).

5.4 HEAT BUDGET

The heat balance at the surface is divided into short-wave (penetrative) radiation and a heat budget for surface heat transfer effects. The surface heat budget requires user input of the net loss or gain through conduction, convection, and long wave radiation in the first grid layer beneath the free surface. The short wave range is modeled using a user-prescribed input of solar radiation and an exponential decay with depth that is a function of a bulk extinction coefficient (a Beer's law formulation for radiation absorption). This coefficient is the sum of individual coefficients for the dissolved organics ("gilvin"), phytoplankton biomass concentration, suspended solids, and the

water itself. The extinction coefficients can either be computed in the water quality module (CAEDYM) or provided as separate user input.

5.5 HYDRODYNAMIC BOUNDARY CONDITIONS

The hydrodynamic solution requires that boundary conditions on the velocity must be specified at each boundary. There are six types of boundary conditions: (1) free surface, (2) open edge, (3) inflow-outflow, (4) no-slip, (5) free-slip, and (6) a Chezy-Manning boundary stress model (the latter is presently not fully implemented). For the free surface, the stress due to wind and waves is required. The user can either input the wind/wave stress directly, or use a model that relates the surface stress to the local wind speed and direction *via* a bulk aerodynamic drag coefficient. Open boundaries (e.g. tidal inflow boundaries for estuaries) require the user to supply the tidal signature to drive the surface elevation. Transport across open boundaries is modeled by enforcing a Dirichlet condition on the free-surface height and allowing the inflow to be computed from the barotropic gradient at the boundary. Inflow-outflow boundary conditions (e.g. river inflows) are Dirichlet conditions that specify the flow either at a particular boundary location *or inside the domain*. Allowing an inflow-outflow boundary condition to be specified for an interior position (*i.e.* as a source or sink) allows the model to be used for sewage outfalls or water outlets that may not be located on a land boundary. Land boundaries can be considered zero velocity (no-slip), zero-flux (free-slip) or, using a Chezy-Manning model, assigned a computed stress.

5.6 SEDIMENT TRANSPORT

While sediment transport is fundamentally an issue of flow physics, the algorithms for the sediment transport are more conveniently grouped with the water quality algorithms in CAEDYM. Settling of suspended particulate matter is computed using Stokes law to obtain settling velocities for the top and bottom of each affected grid cell. This allows the net settling flux in each cell to be computed. A two-layer sediment model has been developed that computes resuspension, deposition, flocculation, and consolidation of sediment based on (1) the shear stress at the water/sediment interface, (2) the type of sediment (cohesive/non-cohesive), and (3) the thickness of the sediment layer. Determination of the shear stress at the water/sediment interface requires the computation of bottom shear due to current, wind, and waves. A model has been developed to account for the effects of small-scale surface waves that cannot be resolved on a geophysical-scale grid. This model computes the theoretical wave height and period for small-scale surface waves from the wind velocity, water depth, and domain fetch. From these, the wavelength and orbital velocities are calculated. The wave-induced shear stress at the bottom boundary resulting from the wave orbital velocities is combined with a model for the current-induced shear stress to obtain the total bottom shear that effects sediment resuspension. The cohesiveness of the sediment determines the critical shear stresses that are necessary to resuspend or deposit the sediments. A model of

consolidation of the sediments is used to remove lower sediment layers from the maximum mass that may be resuspended.

6.0 TECHNICAL DESCRIPTION OF CAEDYM

CAEDYM is an outgrowth of previous CWR water quality modules in DYRESM-WQ and the Estuary Lake Model - Water Quality (ELMO-WQ) codes. CAEDYM is designed as a set of subroutine modules that can be directly coupled with one, two, or three-dimensional hydrodynamic "drivers", catchment surface hydrological models, or groundwater models. Additionally, it can be used in an uncoupled capacity with specification of velocity, temperature, and salinity distributions provided as input files rather than as part of a coupled computation. The user can specify the level of complexity in biogeochemical process representation so both simple and complex interactions can be studied. Direct coupling to a hydrodynamic driver (*e.g.* ELCOM) allows CAEDYM to operate on the same spatial and temporal scales as the hydrodynamics. This permits feedbacks from CAEDYM into ELCOM for water quality effects such as changes in light attenuation or effects of macroalgae accumulation on bottom currents. **Figure 6** shows an illustration of the interactions of modeled parameters in CAEDYM. Being an “N-P-Z” (nutrient-phytoplankton-zooplankton) model, CAEDYM can be used to assess eutrophication. Unlike the traditional general ecosystem model, CAEDYM serves as a species- or group-specific model (*i.e.* resolves various phytoplankton species). Furthermore, oxygen dynamics and several other state variables are included in CAEDYM.

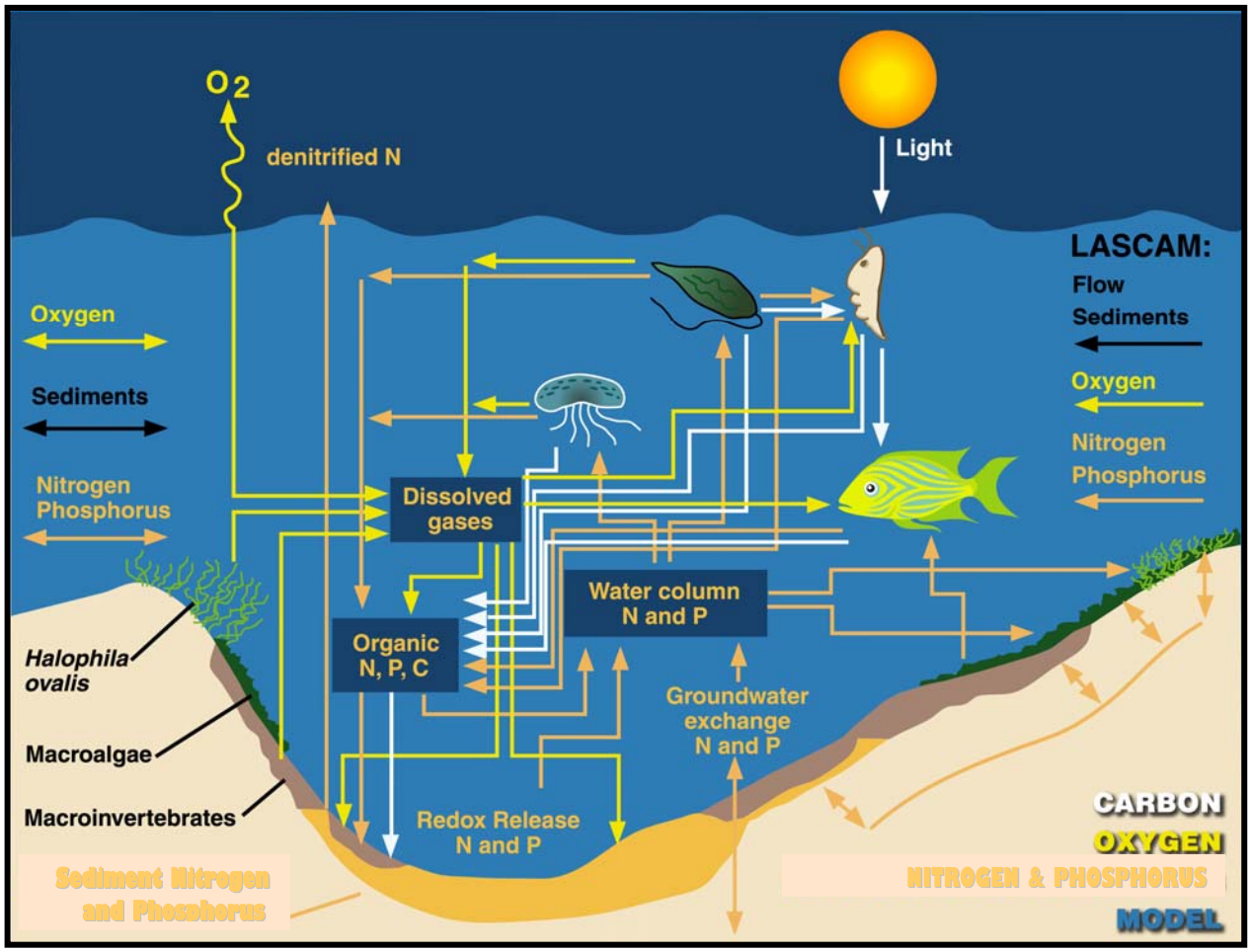

Illustration of interactions of modeled parameters in CAEDYM.

The representation of biogeochemical processes in ecological models has, historically, been treated in a simple manner. In fact, the pioneering work on modeling marine ecosystems (Riley *et al*, 1949; Steel, 1962) is still used as a template for many of the models that are currently used (Hamilton and Schladow, 1997). The level of sophistication and process representation included in CAEDYM is of a level hitherto unseen in any previous aquatic ecosystem model. This enables many different components of the system to be examined, as well as providing a better representation of the dynamic response of the ecology to major perturbations to the system (e.g. the response to various management strategies). **Figure 7** shows the major state variables included in the CAEDYM model. Using CAEDYM to aid in management decisions and

system understanding requires (1) a high level of process representation, (2) process interactions and species differentiation of several state variables, and (3) applicability over a spectrum of spatial and temporal scales. The spectrum of scales relates to the need for managers to assess the effects of temporary events, such as anoxia at specific locations, through to understanding long-term changes that may occur over seasons or years. There is considerable flexibility in the time step used for the ecological component. Long time steps (relative to the hydrodynamic advective scale) may be used to reduce the frequency of links to ELCOM when long-term (*i.e.* seasonal or annual) simulations are run.

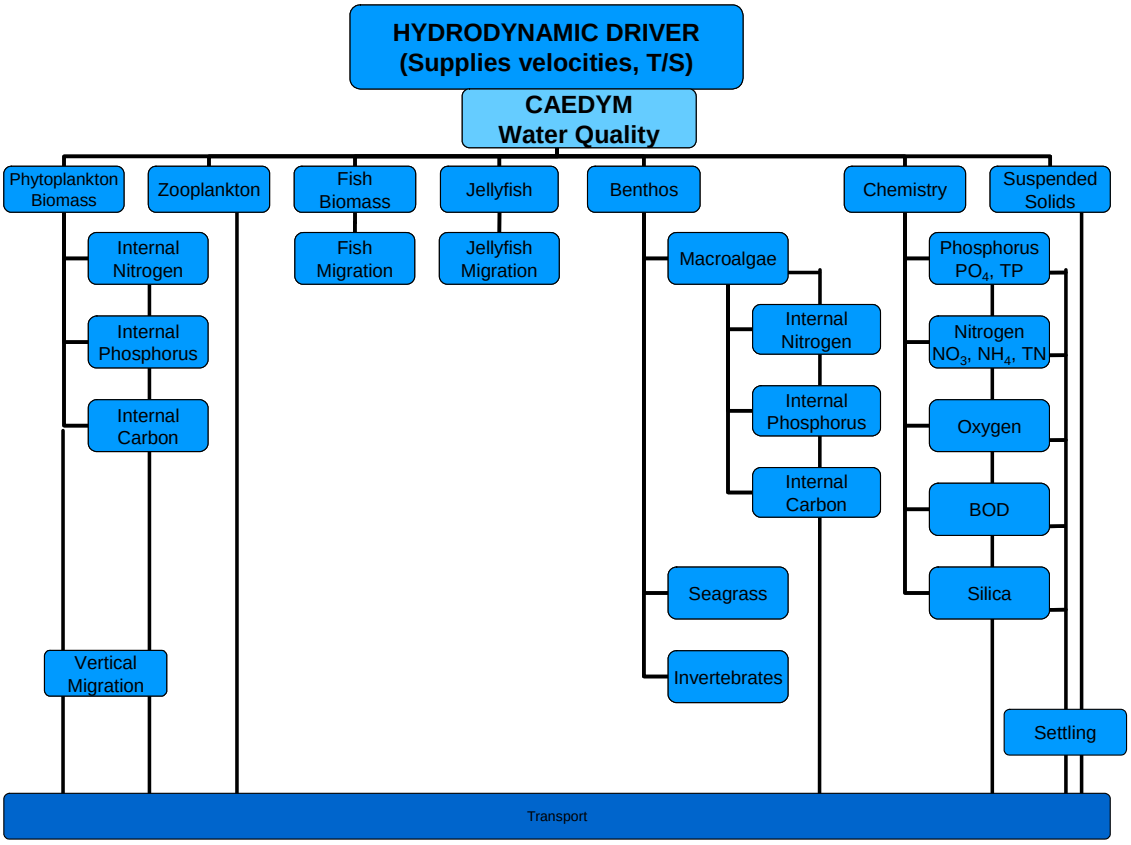

Figure 7 Major state variables included in the CAEDYM model.

6.1 BIOLOGICAL MODEL

The biological model used in CAEDYM consists of seven phytoplankton groups, five zooplankton groups, six fish groups, four macroalgae groups and three invertebrate groups, as well as models of seagrass and jellyfish. This set will be expanded as biological models are developed, tested, and calibrated to field data. There is flexibility for the user in choosing which species to include in a simulation. Vertical migration is simulated for motile and non-motile phytoplankton, and fish are migrated throughout the model domain according to a migration function based on their mortality. A weighted grazing function is included for zooplankton feeding on phytoplankton and fish feeding on zooplankton. The biomass grazed is related to both food availability and preference of the consumer for its food supply. Improved temperature, respiration and light limitation functions have been developed to represent the environmental response of the organisms. The benthic processes included a self-shading component and beach wrack function for macroalgae, sediment bioturbation and nutrient cycling by polychaetes, and effects of seagrass on sediment oxygen status.

In particular, the seven phytoplankton groups modeled are dinoflagellates, freshwater diatoms, marine/estuarine diatoms, freshwater cyanobacteria, marine estuarine cyanobacteria, chlorophytes, and cryptophytes. Phytoplankton biomass is represented in terms of chlorophyll *a*. Phytoplankton concentrations are affected by the following processes:

- Temperature growth function
- Light limitation
- Nutrient limitation by phosphorus and nitrogen (and when diatoms are considered, silica)
- Loss due to respiration, natural mortality, excretion, and grazing
- Salinity response
- Vertical migration and settling

6.2 NUTRIENTS, METALS, AND OXYGEN DYNAMICS

The transport and chemical cycling of nutrients is an important part of simulating the interaction of biological organisms in an ecosystem. CAEDYM includes as state variables the following:

- Nutrients (dissolved inorganic phosphorus, total phosphorus, total nitrogen, ammonium nitrate, and silica).
- Dissolved oxygen and biochemical oxygen demand.
- Metals (dissolved and particulate forms of iron and manganese).

- Suspended sediment (the particulate and colloidal fractions).
- pH

The model incorporates oxygen dynamics and nutrient cycling in both the sediments and water column. A sediment pool of organic detritus and inorganic sediments, both of which may be resuspended into the water column, is included. Redox-mediated release of dissolved nutrients is simulated from the sediments to the water column.

Processes included in the water and sediment oxygen dynamics include:

- Atmospheric exchange (Wanninkhof, 1992).
- Oxygen production and consumption through phytoplankton, macroalgae, and seagrass/macrophyte photosynthesis and respiration, respectively.
- Utilization of dissolved oxygen due to respiration of higher organisms such as zooplankton and fish and due to photosynthesis and respiration in jellyfish
- Water column consumption of oxygen during nitrification.
- Biochemical oxygen demand due to mineralization of organic matter in the water column and in the sediments.
- Oxygen flux from the water column to the sediments, sediment oxygen demand (SOD), as developed from Fick's law of diffusion.

The last two processes are used together with a sediment porosity and diffusion coefficient (Ullman and Aller, 1982) in order to define the depth of the toxic layer in the sediments.

Nutrient processes included in the sediment and water column dynamics include:

- Phytoplankton nutrient uptake, with provision for luxury storage of nutrients.
- Release of dissolved inorganic nutrients from phytoplankton excretion.
- Excretion of nutrients as fecal material by zooplankton.
- Nitrification and denitrification by bacterial mediated action.
- Generation of inorganic nutrients from organic detritus.
- Transfer of nutrients through the food chain (*e.g.* phytoplankton--zooplankton--fish).
- Uptake of nutrients by macroalgae and seagrasses.
- Adsorption/desorption of nutrients from inorganic suspended sediments.
- Sediment/water transfer of nutrients (*via* such processes as sediment resuspension, sedimentation, redox-mediated nutrient release, and bioturbation).

In essence, CAEDYM represents the type of interactive processes that occur amongst the ecological and chemical components in the aquatic ecosystem. As a broad generalization, one component of the system cannot be manipulated or changed within the model without affecting other components of the system. Similarly in nature, changing an integral component in the aquatic system will have wide-ranging and follow-on effects on many of the other system components. CAEDYM is designed to have the complexity and flexibility to be able to handle the continuum of responses that will be elicited as components of a system that are manipulated. Thus, the model represents a valuable tool to examine responses under changed conditions, as for example, when new approaches to managing an ecosystem are adopted.

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APPENDIX B

HISTORICAL RESERVOIR DATA

San Vicente Reservoir

Measured Water Surface Elevations

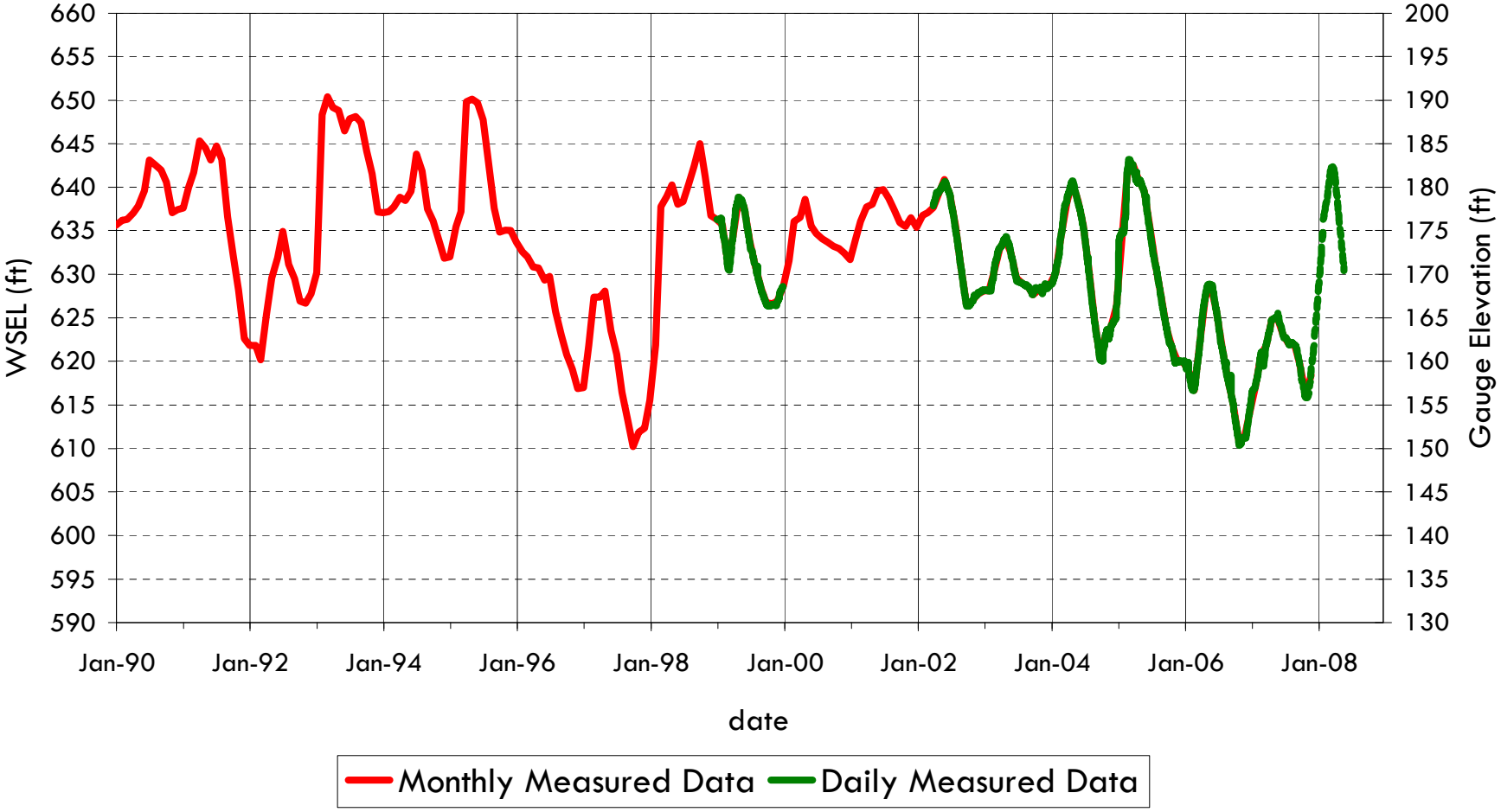

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Figure B-1

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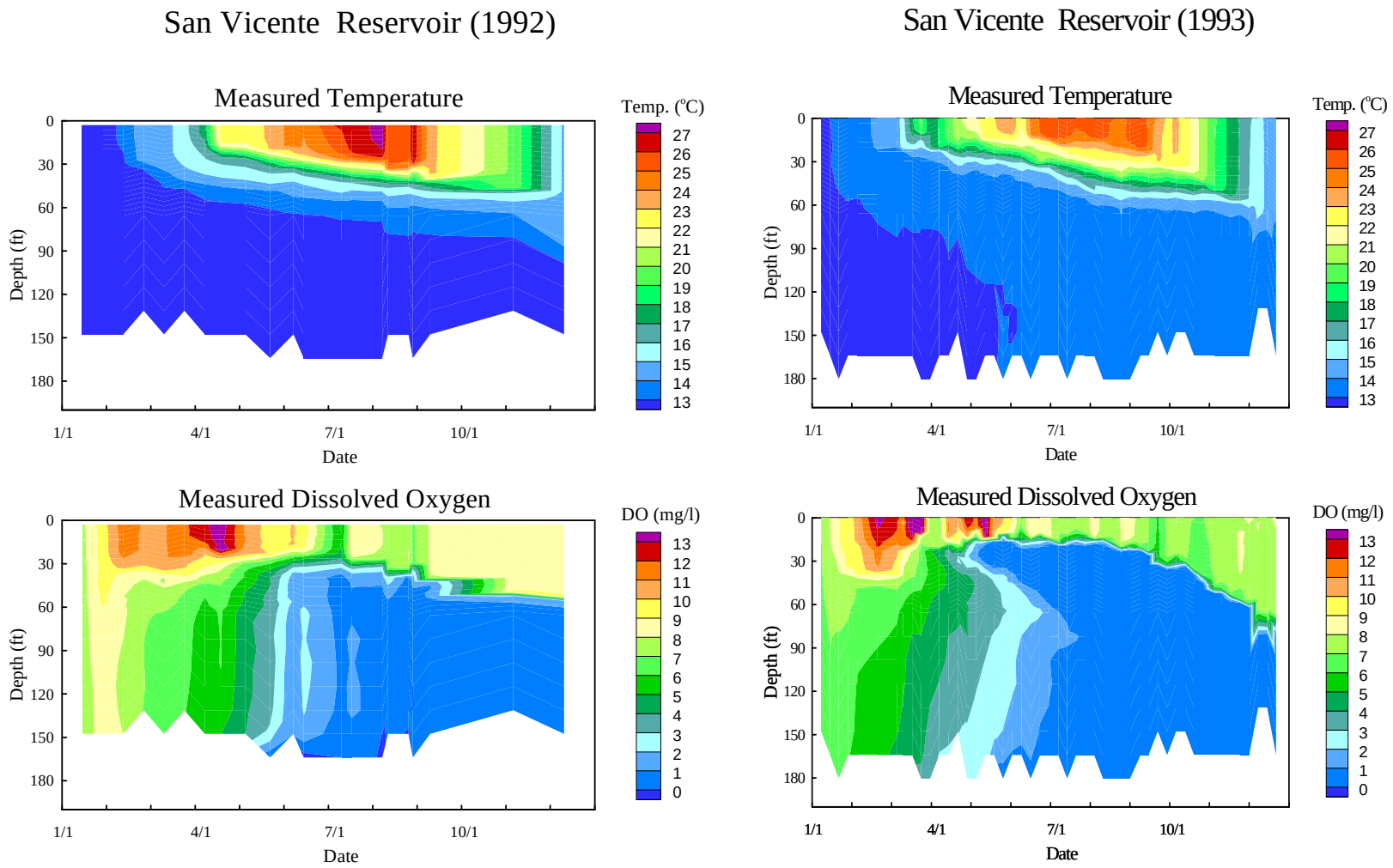

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Figure B-2

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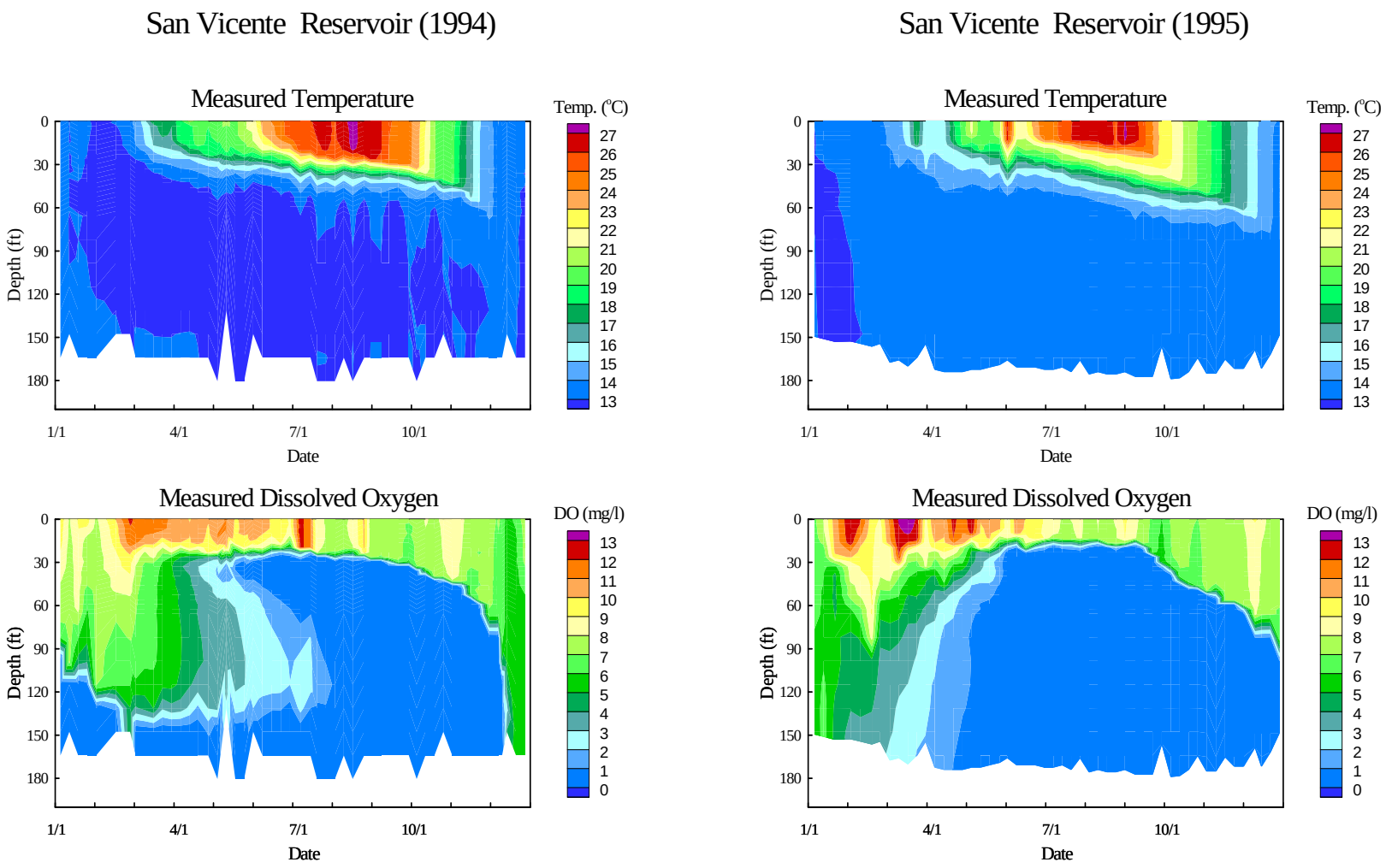

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Figure B-3

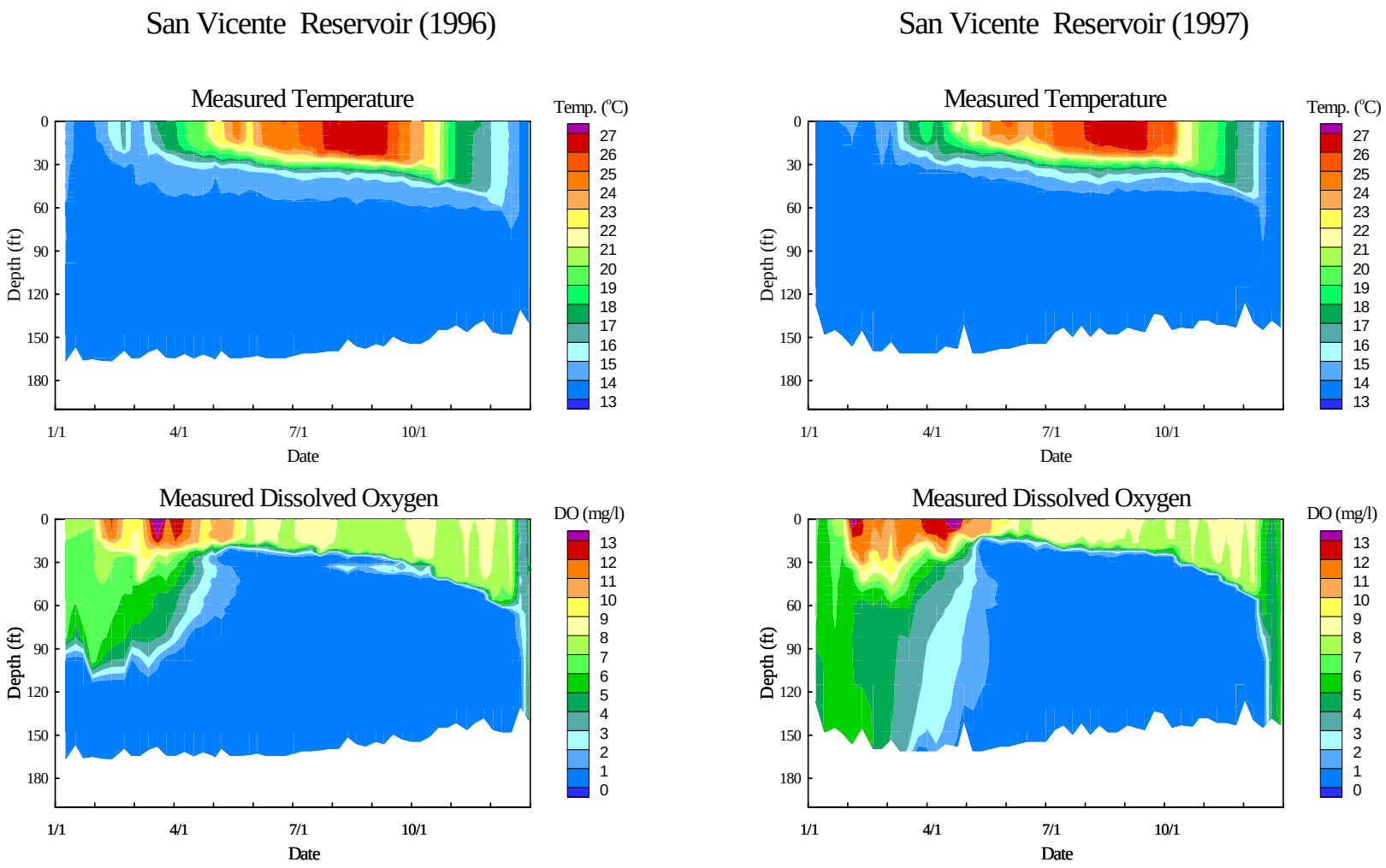

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Figure B-4

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San Vicente Reservoir (1998)

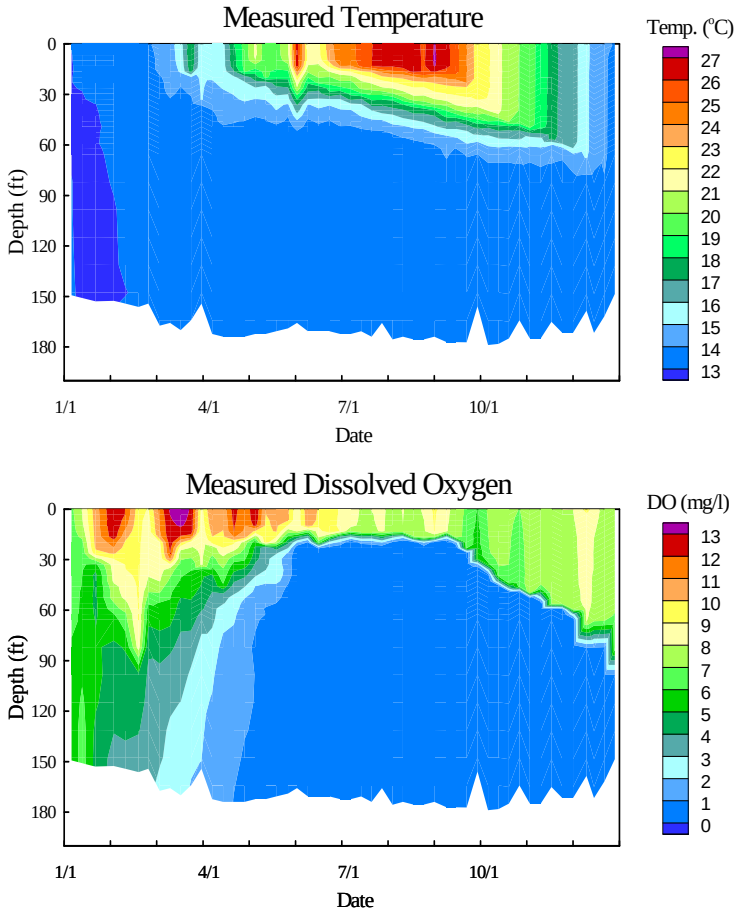

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Figure B-5

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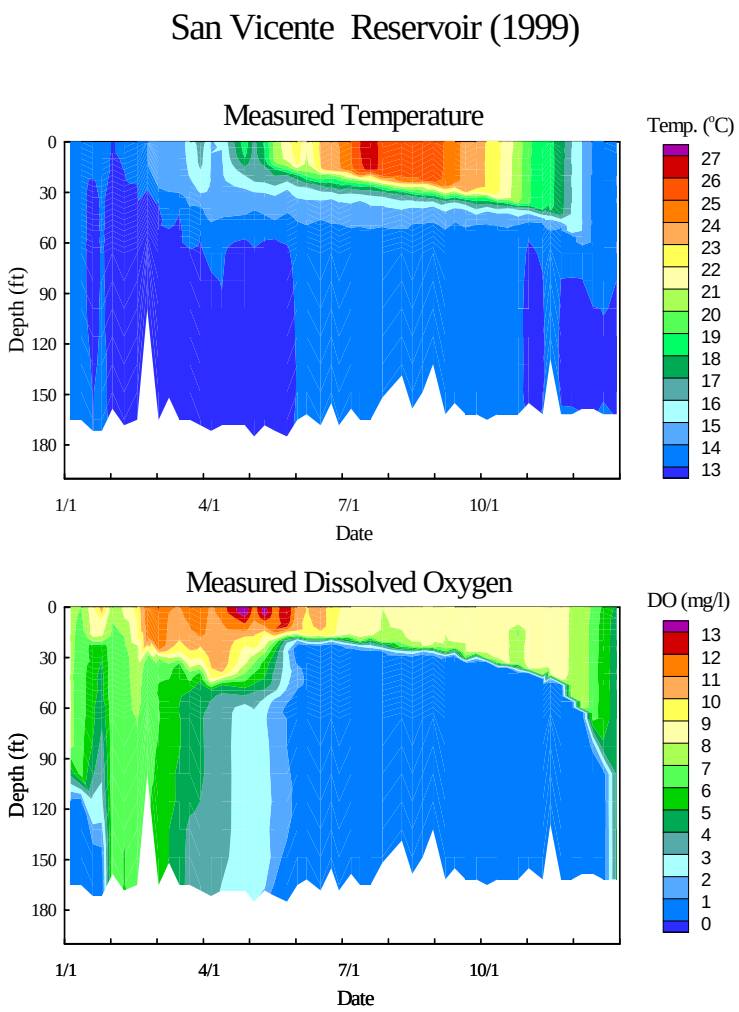

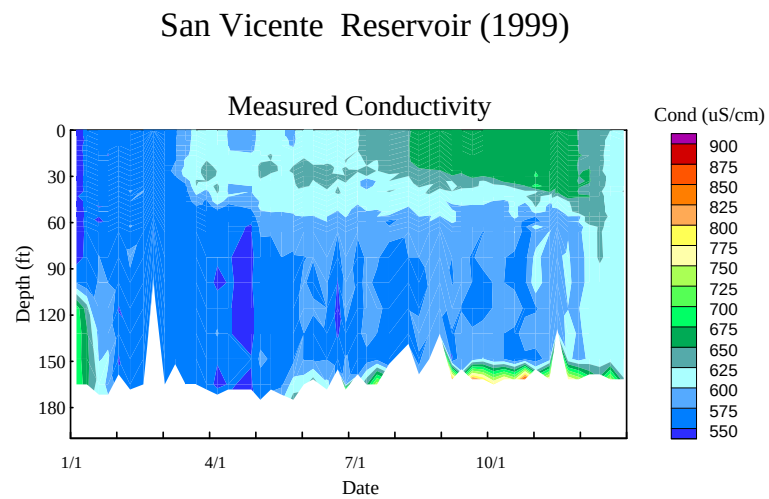

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Figure B-6

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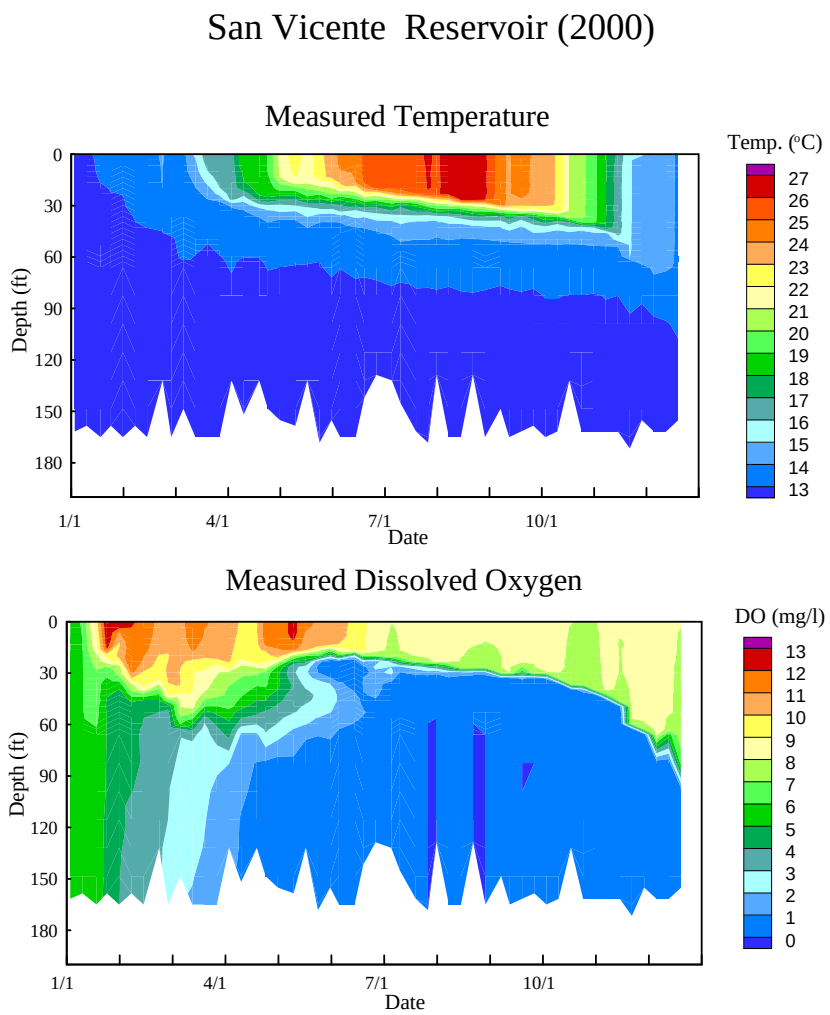

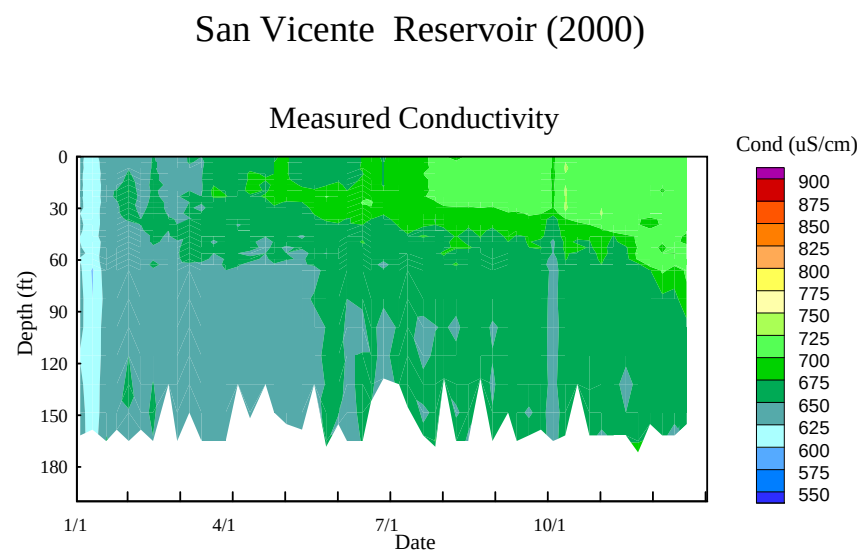

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Figure B-7

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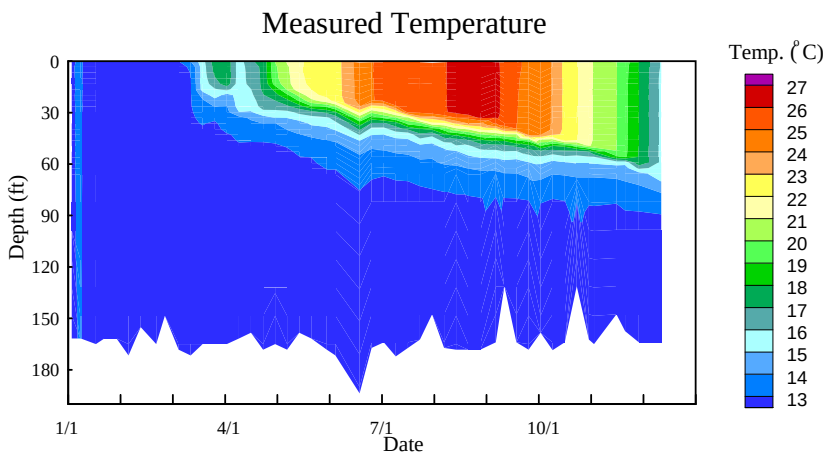
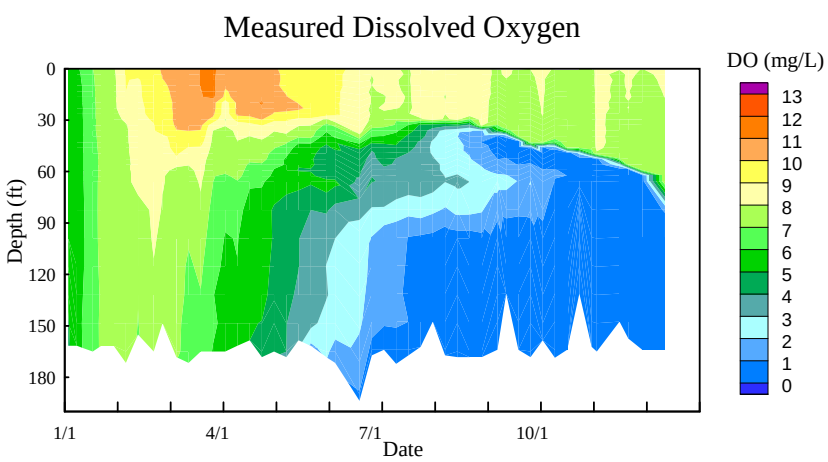
San Vicente Reservoir (2001)





San Vicente Reservoir (2001)

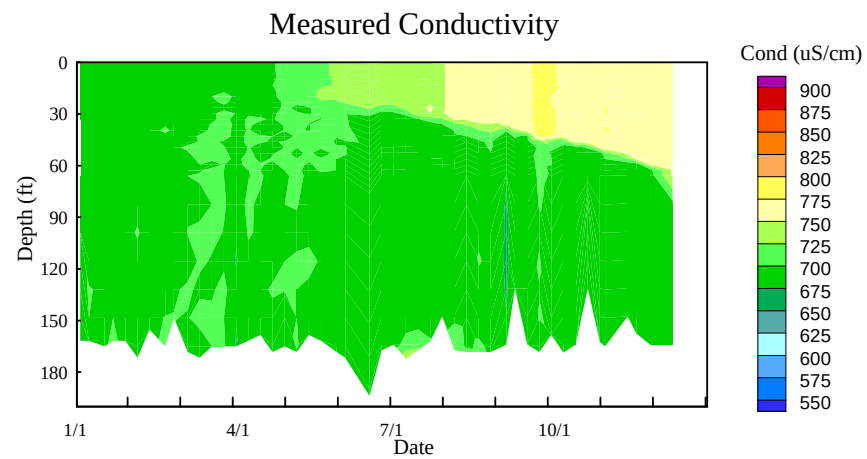


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Figure B-8

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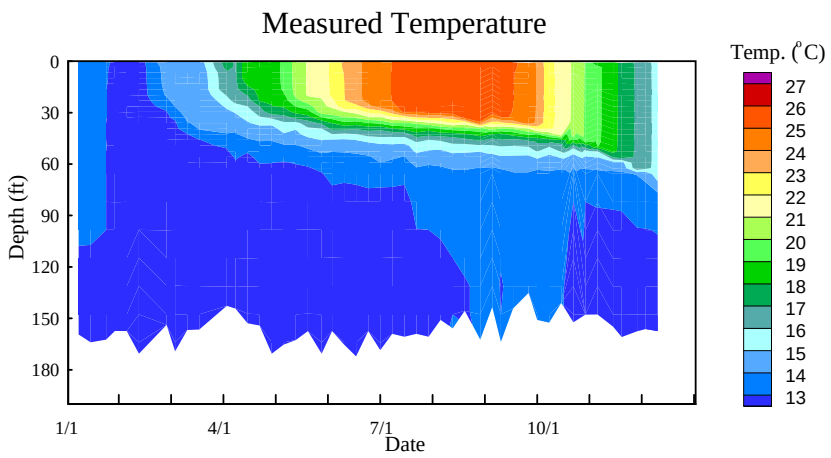
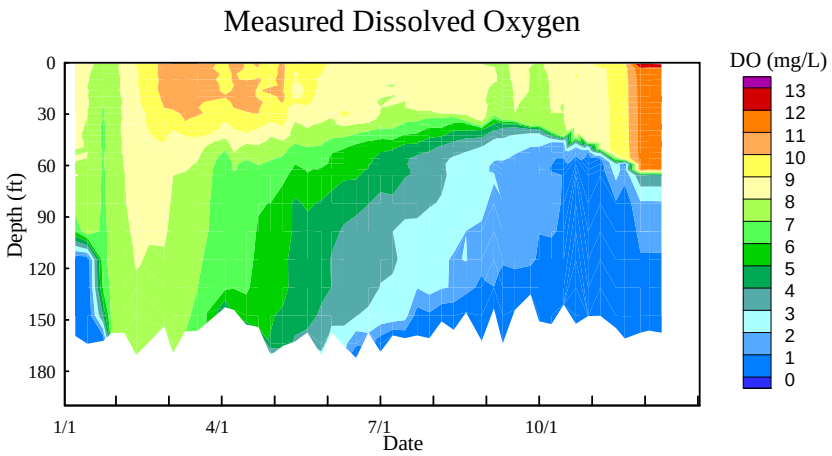
San Vicente Reservoir (2002)





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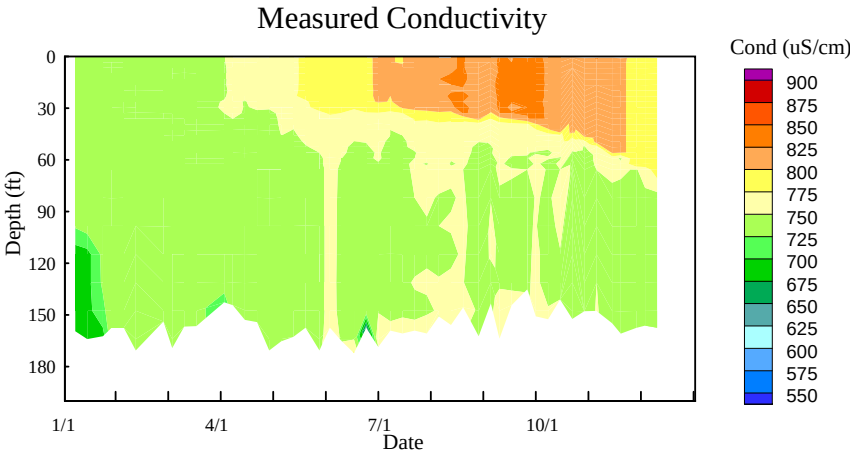

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Figure B-9

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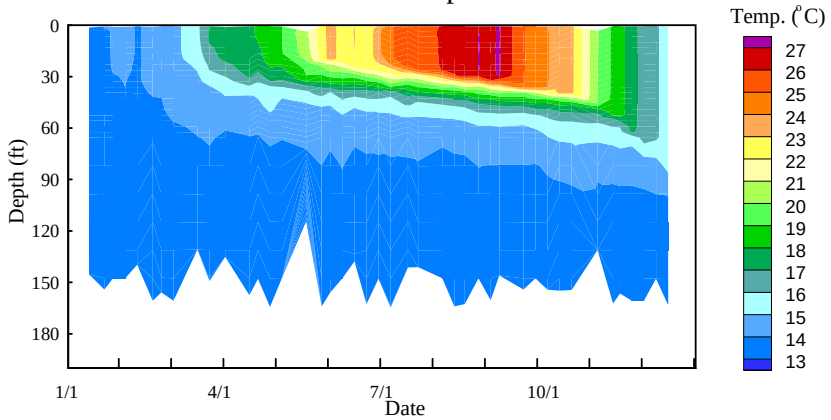
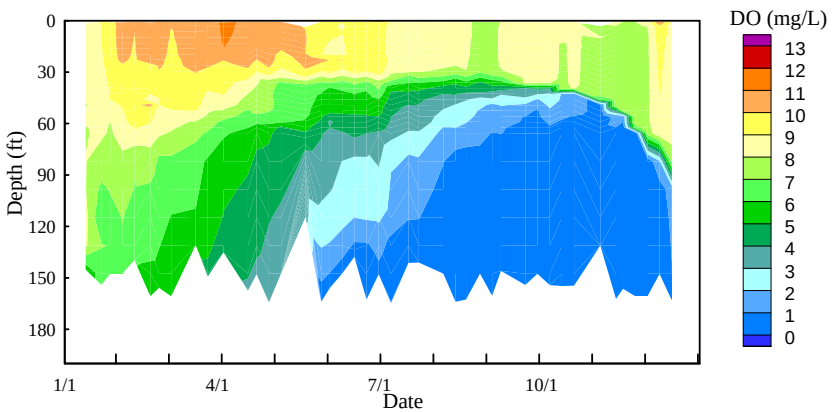
San Vicente Reservoir (2003)

Measured Temperature



Measured Dissolved Oxygen



San Vicente Reservoir (2003)

Measured Conductivity

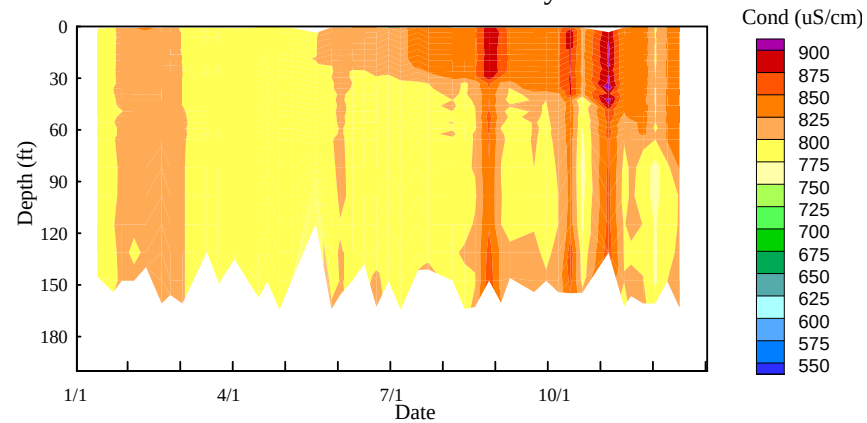


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Figure B-10

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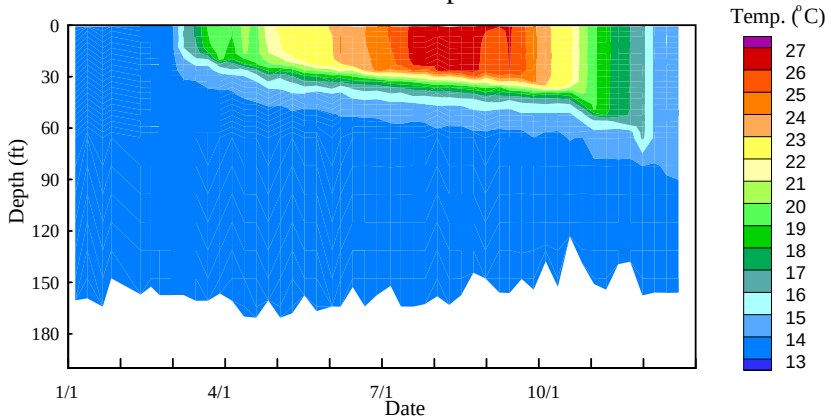
San Vicente Reservoir (2004)

Measured Temperature



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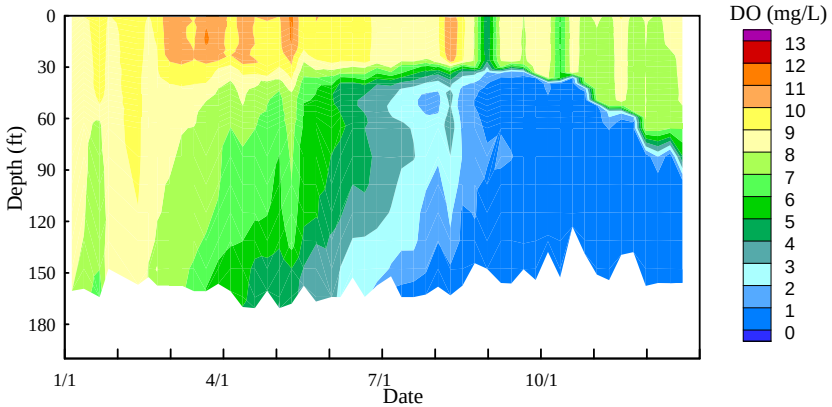
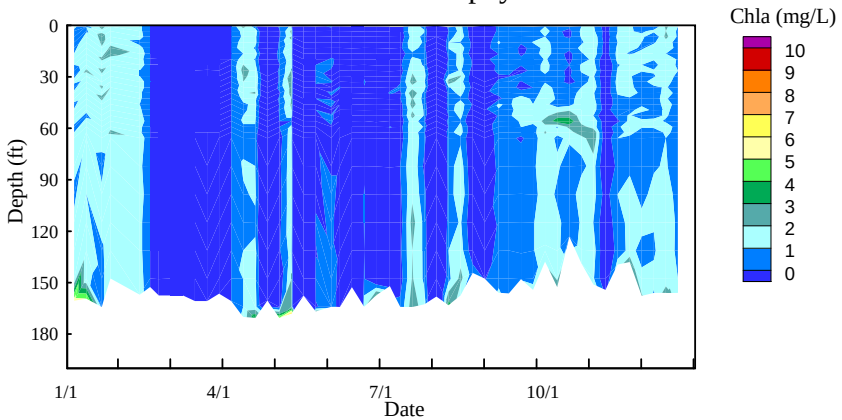


San Vicente Reservoir (2004)

Measured Chlorophyll a



Measured Conductivity

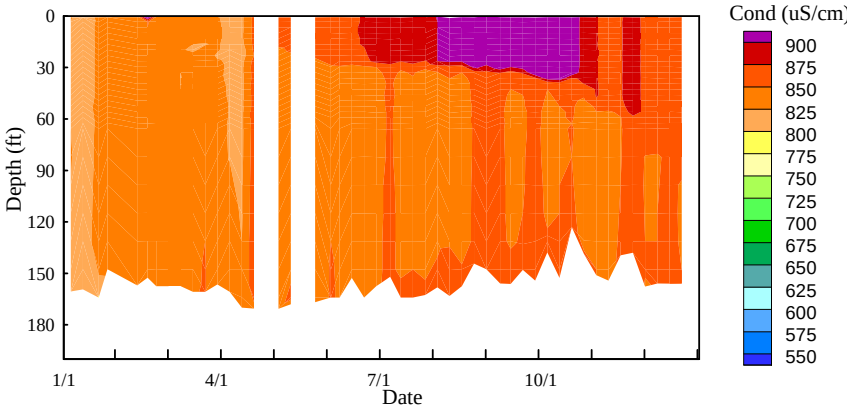


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Figure B-11

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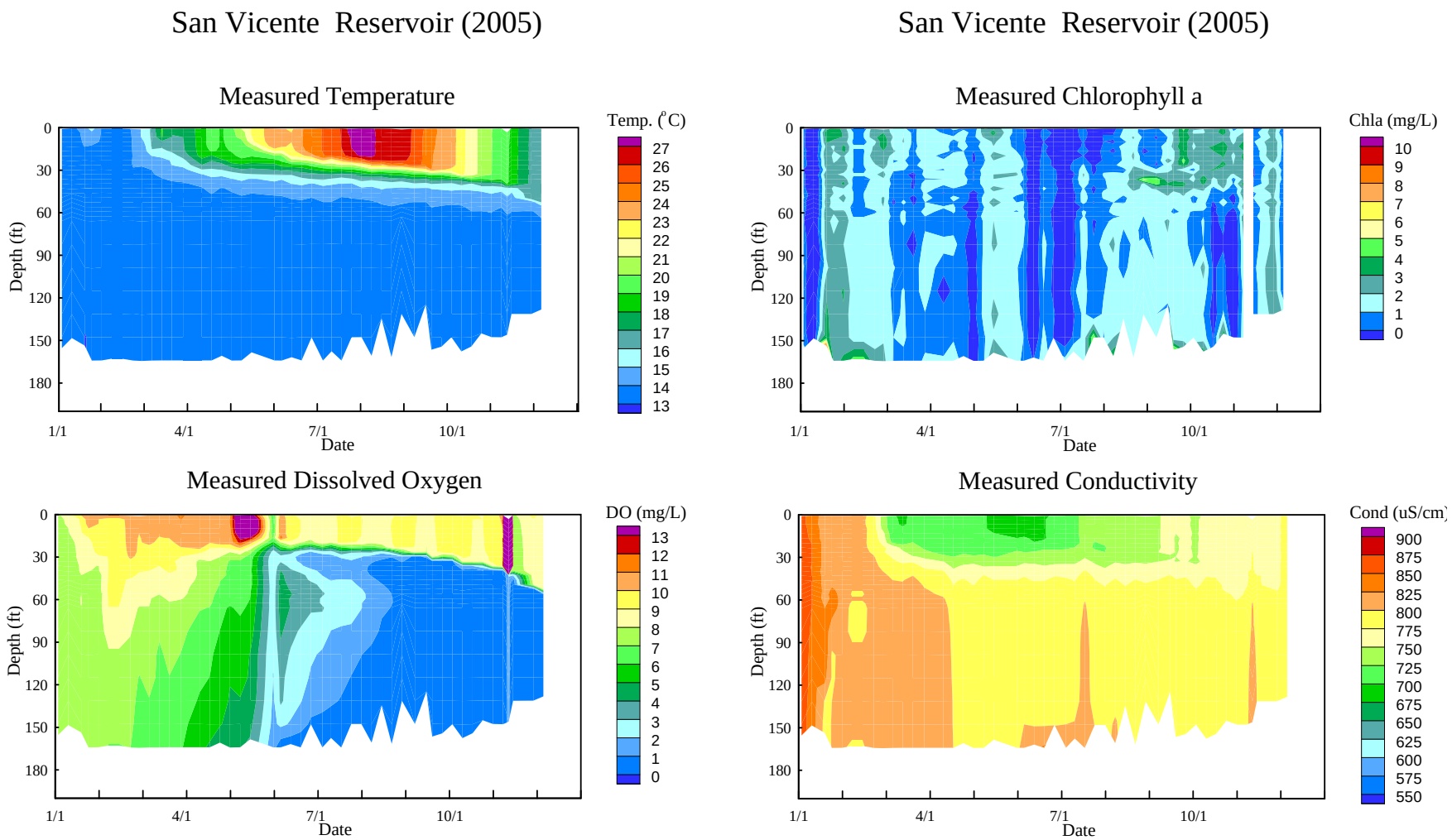

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Figure B-12

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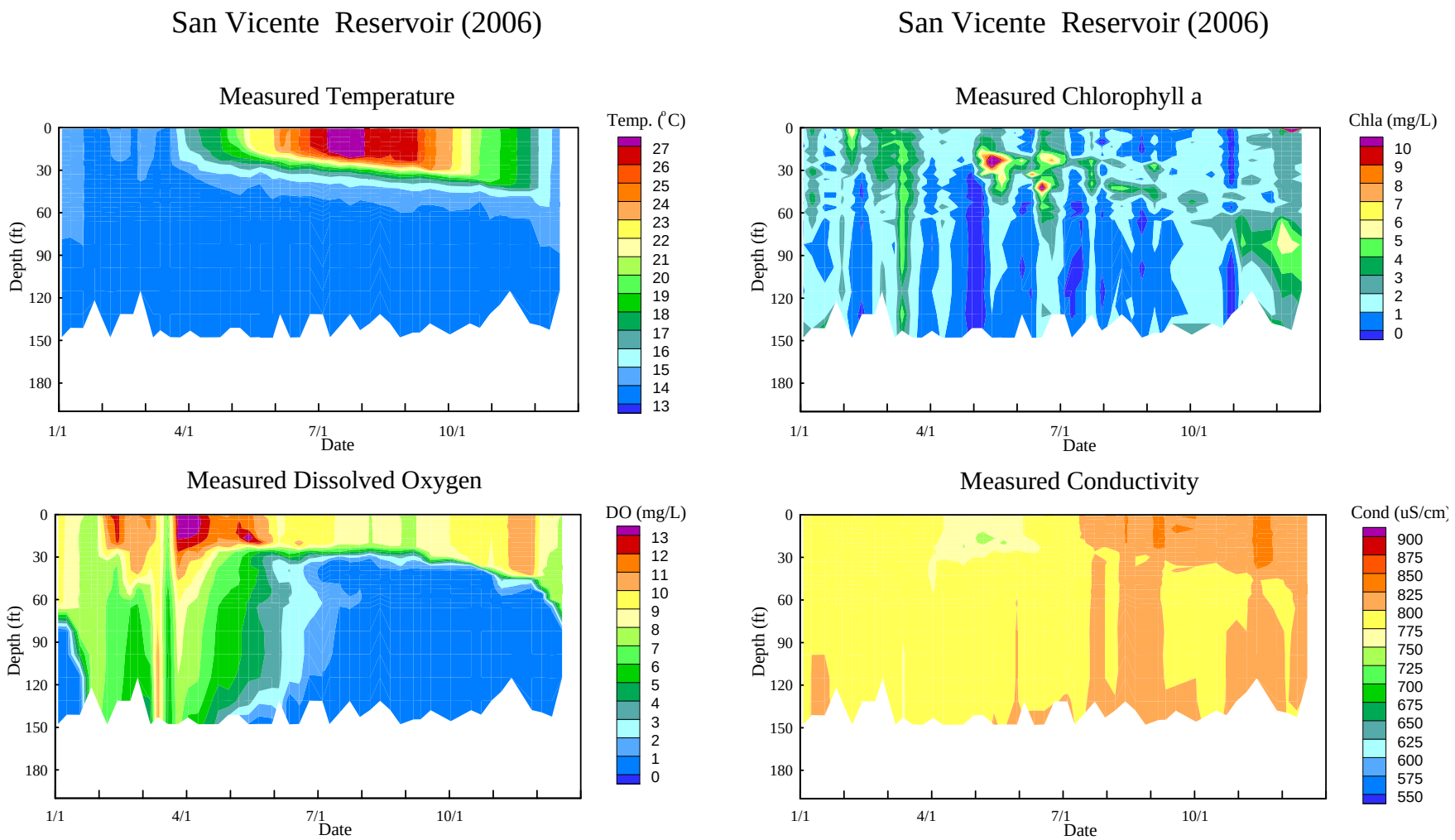

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Figure B-13

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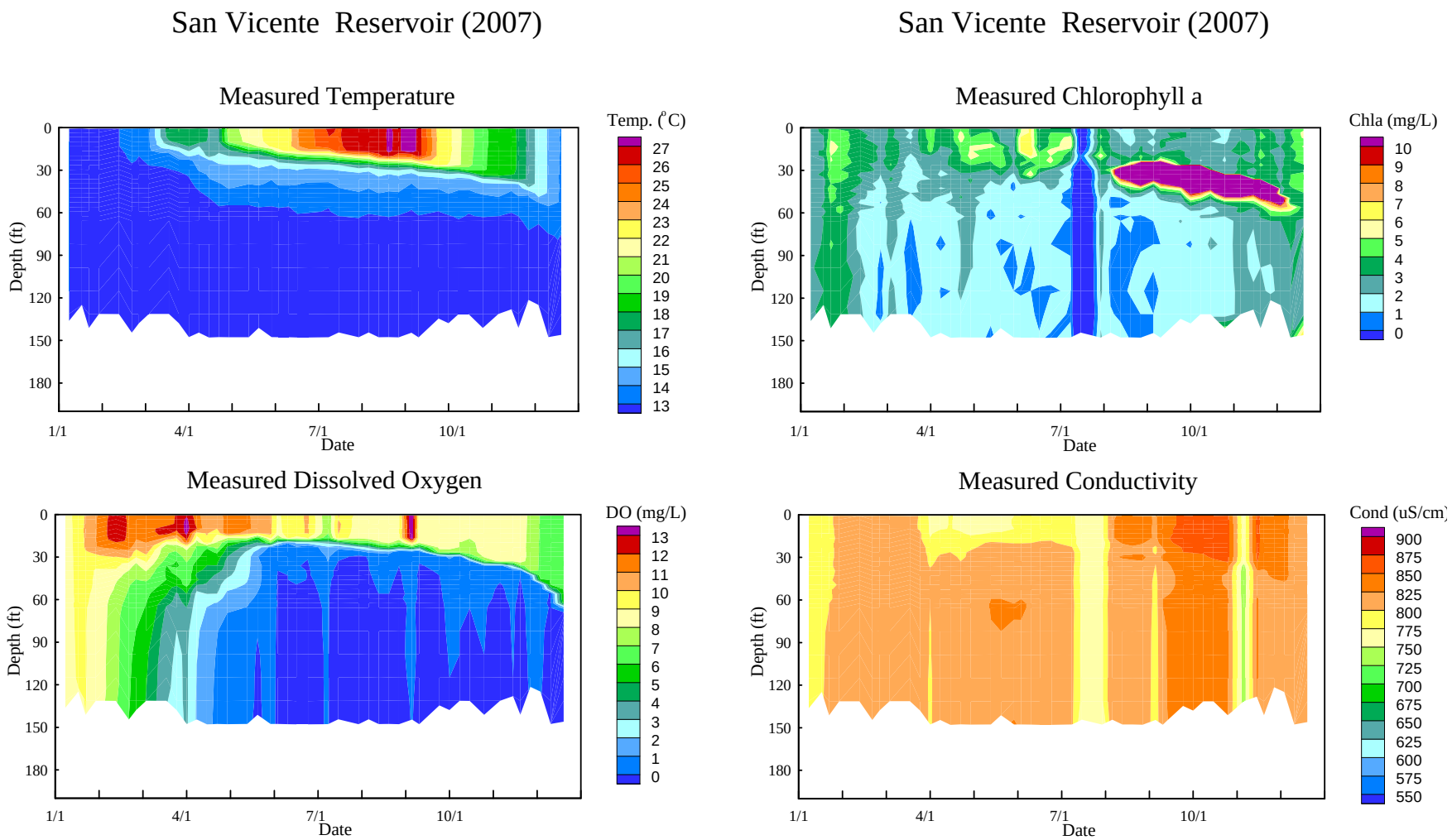

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Figure B-14

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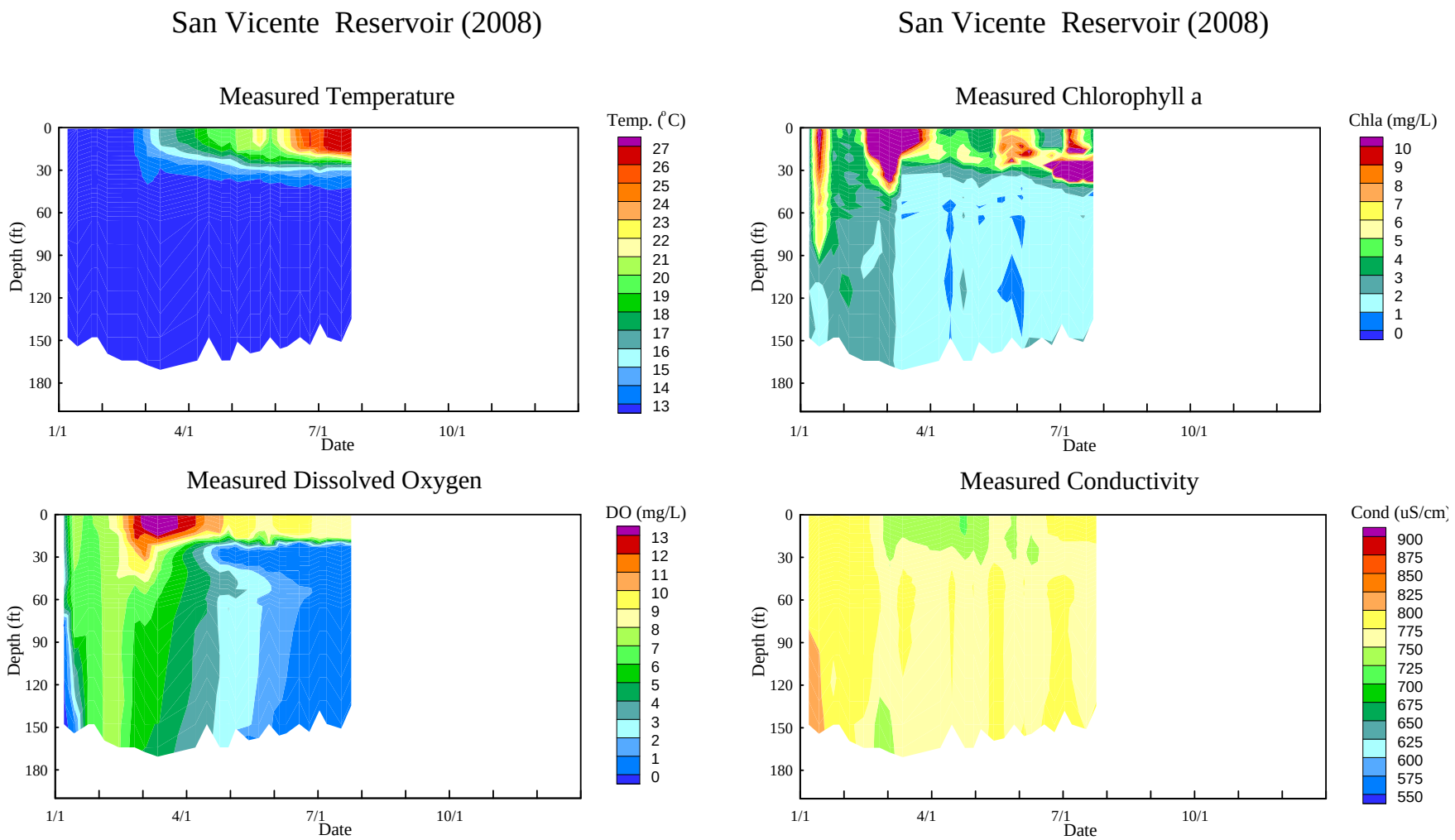

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Figure B-15

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San Vicente Reservoir

In Reservoir Total Phosphorus Data

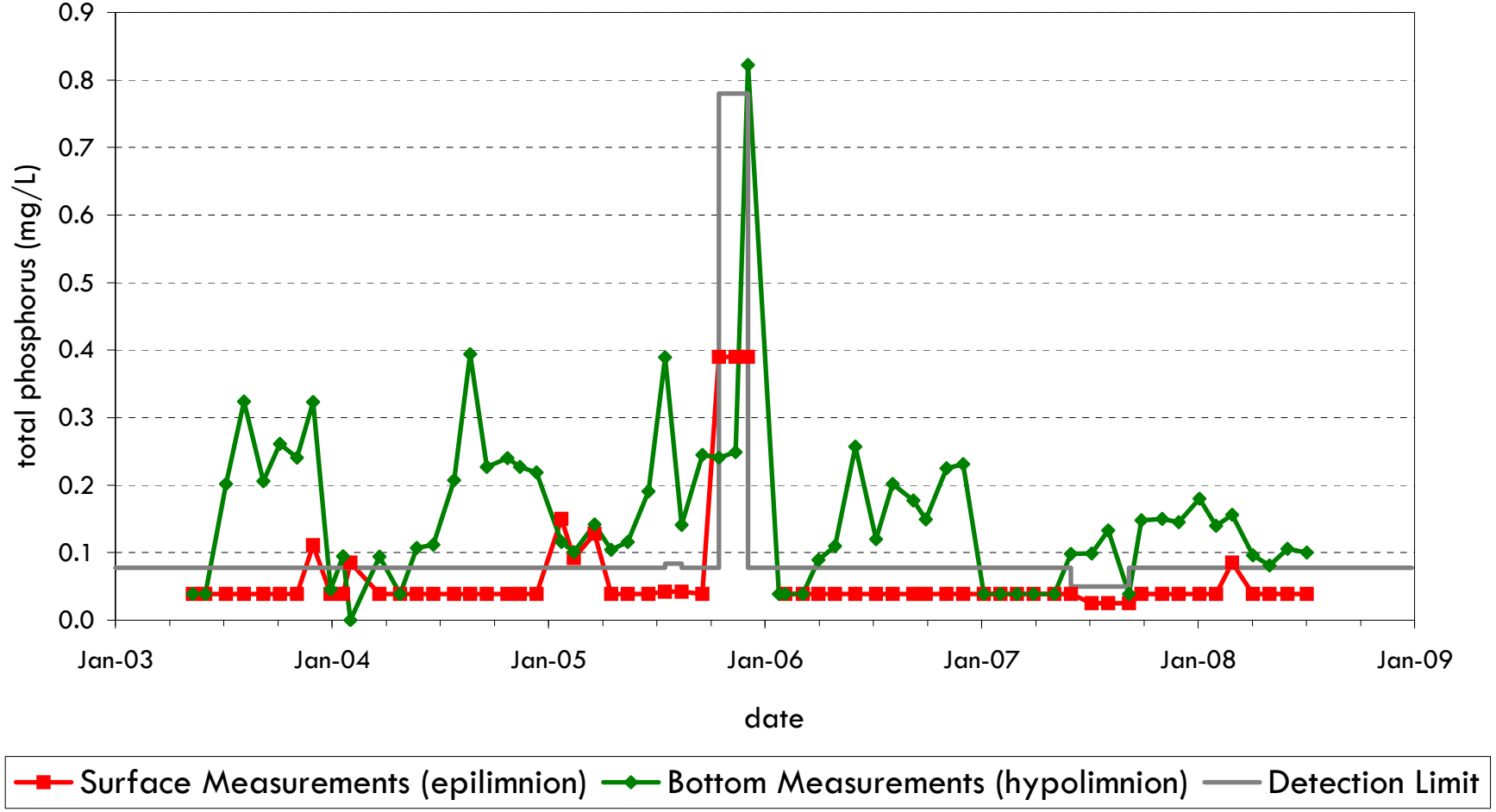

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Figure B-16

FLOW SCIENCE®

San Vicente Reservoir

In Reservoir Soluble Reactive Phosphorus Data

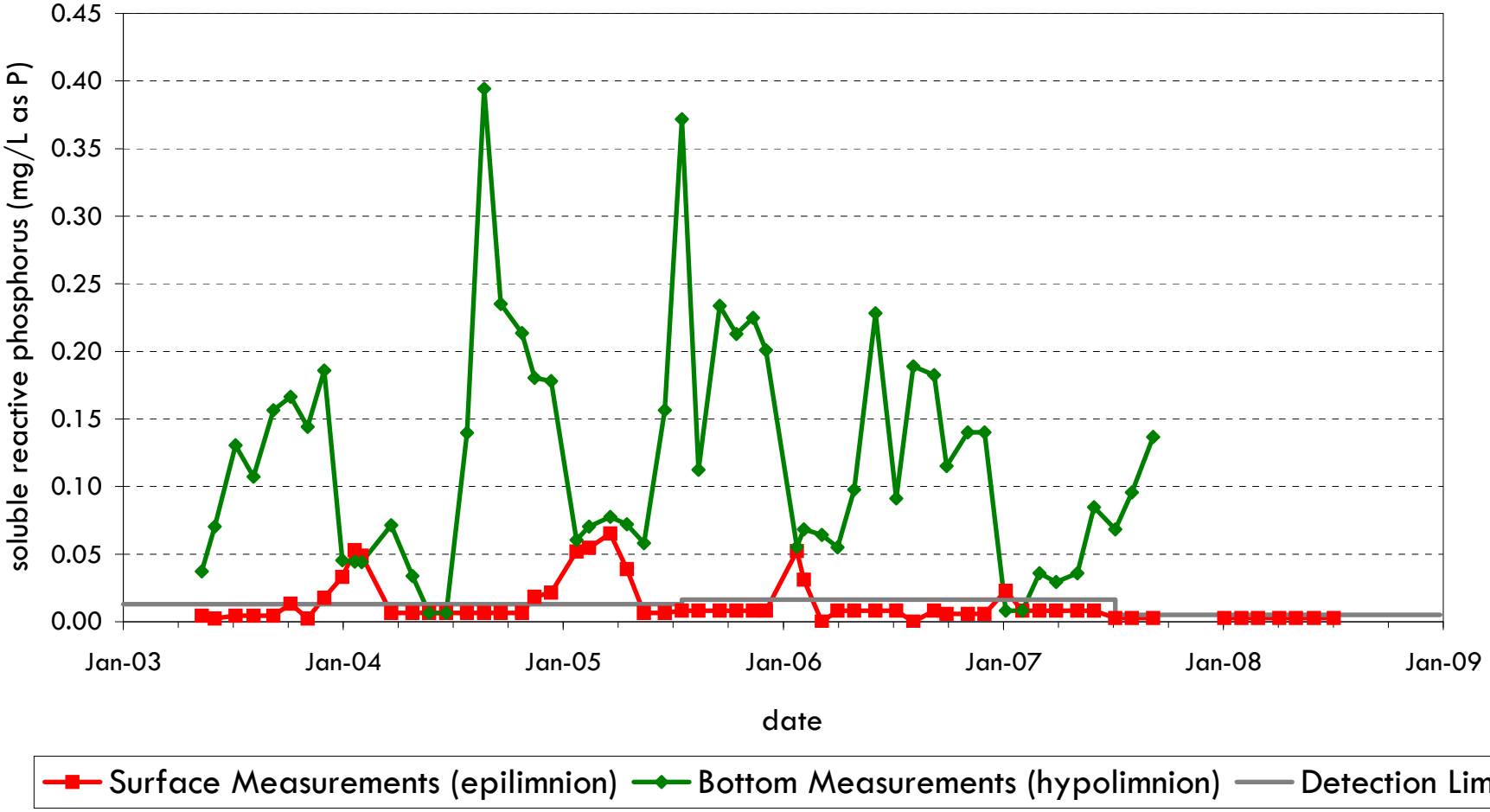

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Figure B-17

FLOW SCIENCE®

San Vicente Reservoir

In Reservoir Total Nitrogen Data

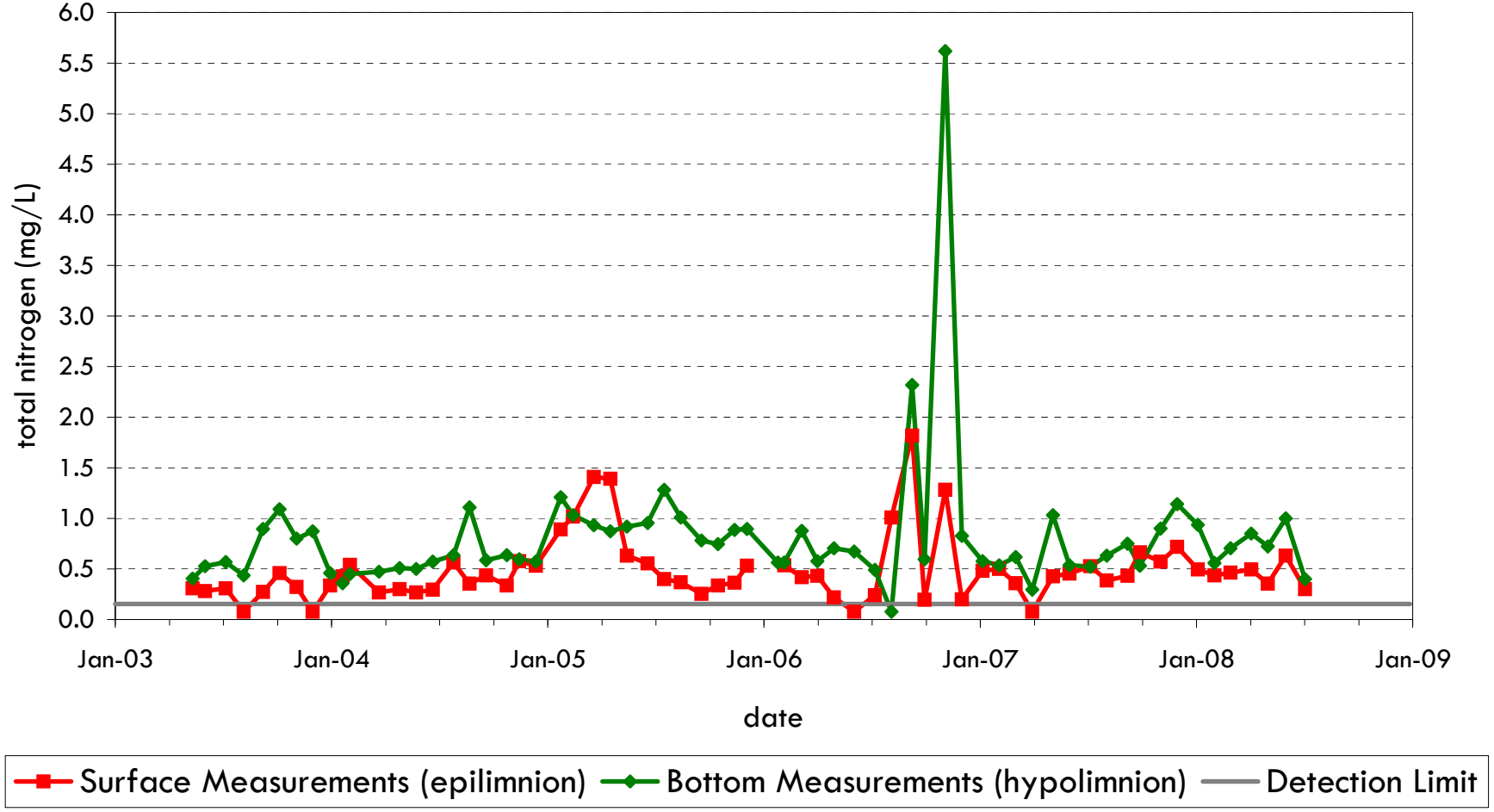

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Figure B-18

FLOW SCIENCE®

San Vicente Reservoir

In Reservoir Nitrate Data

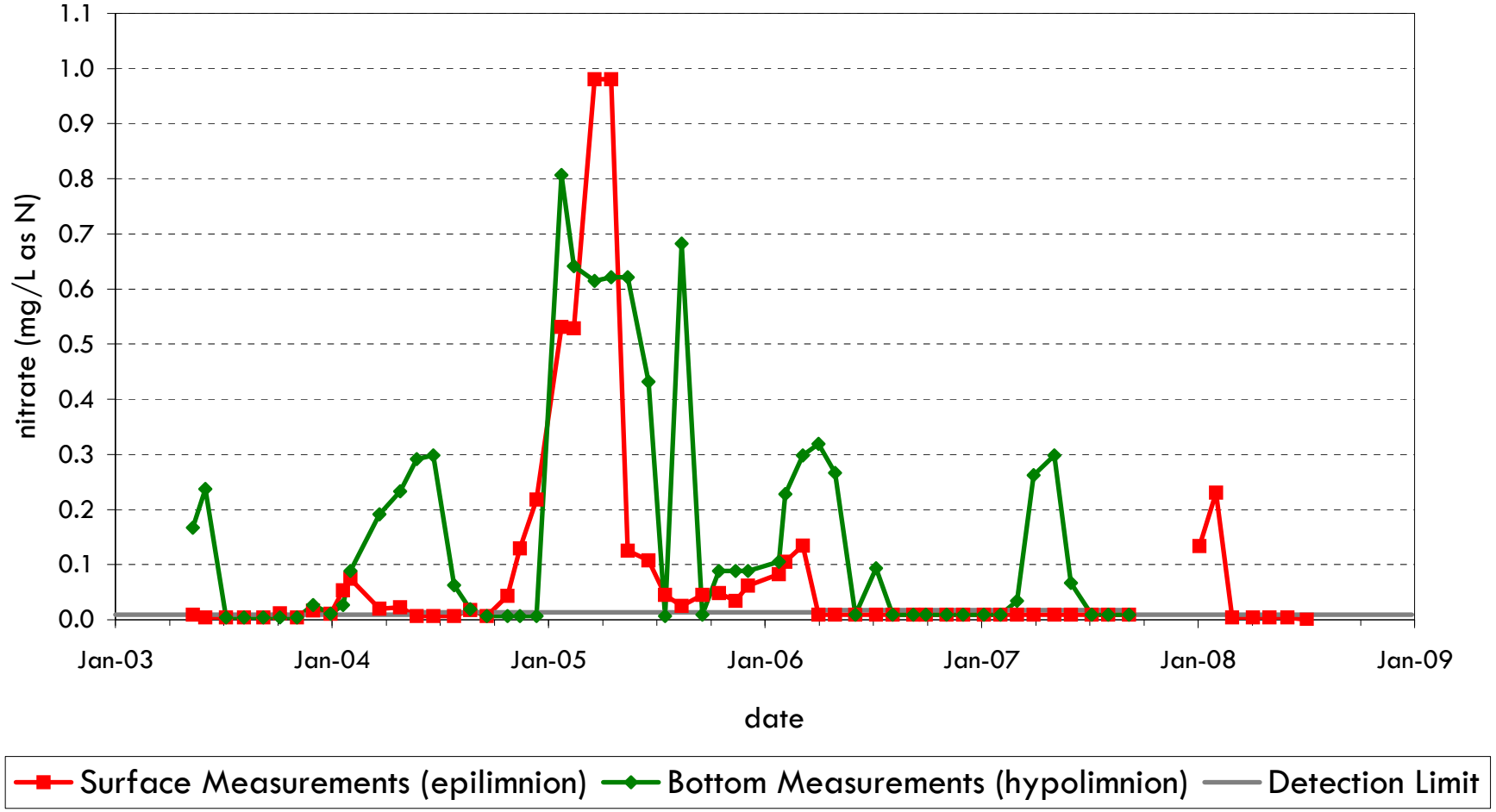

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Figure B-19

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San Vicente Reservoir

In Reservoir Ammonia Data

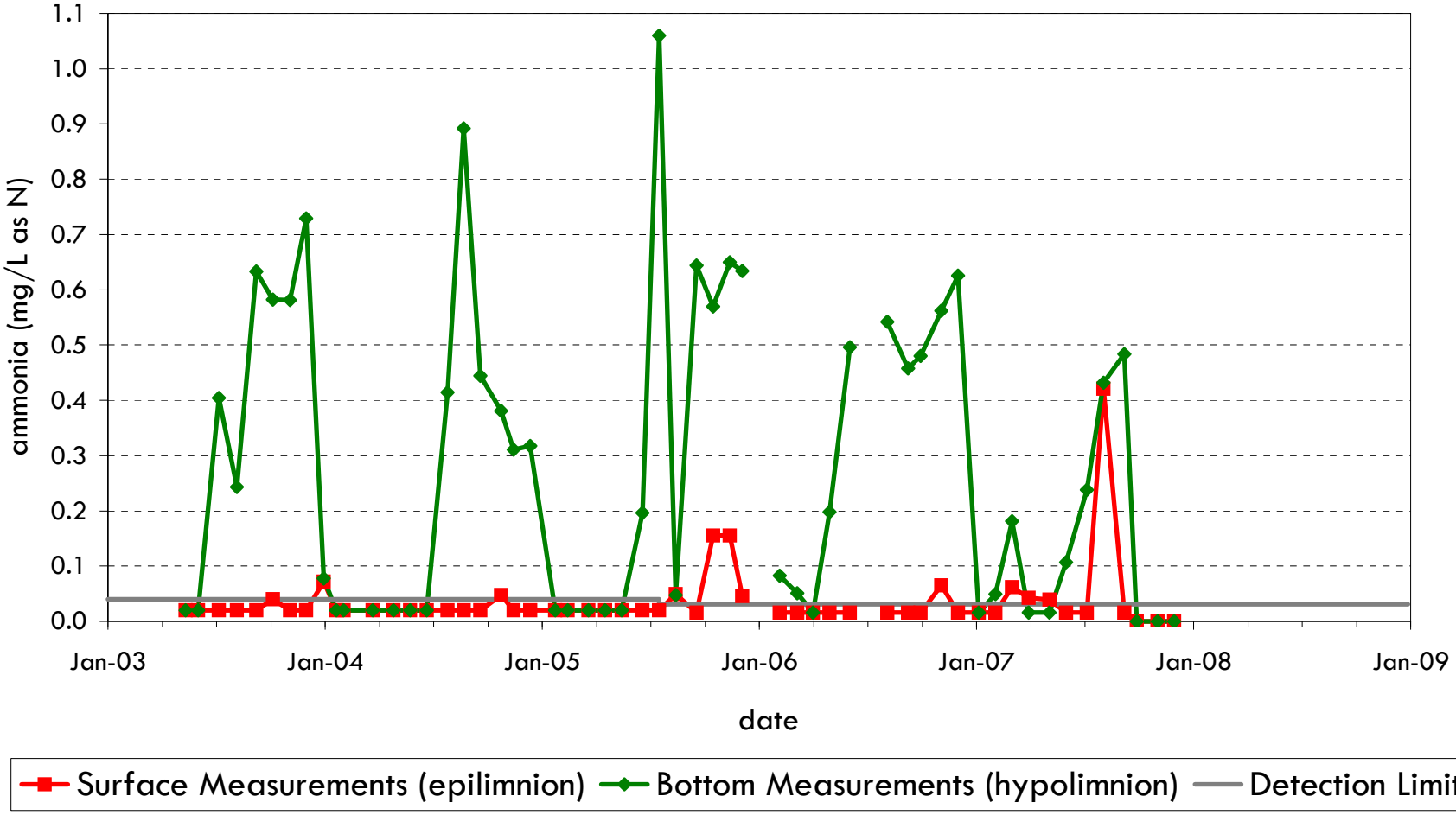

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Figure B-20

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San Vicente Reservoir

In Reservoir Chlorophyll a Data

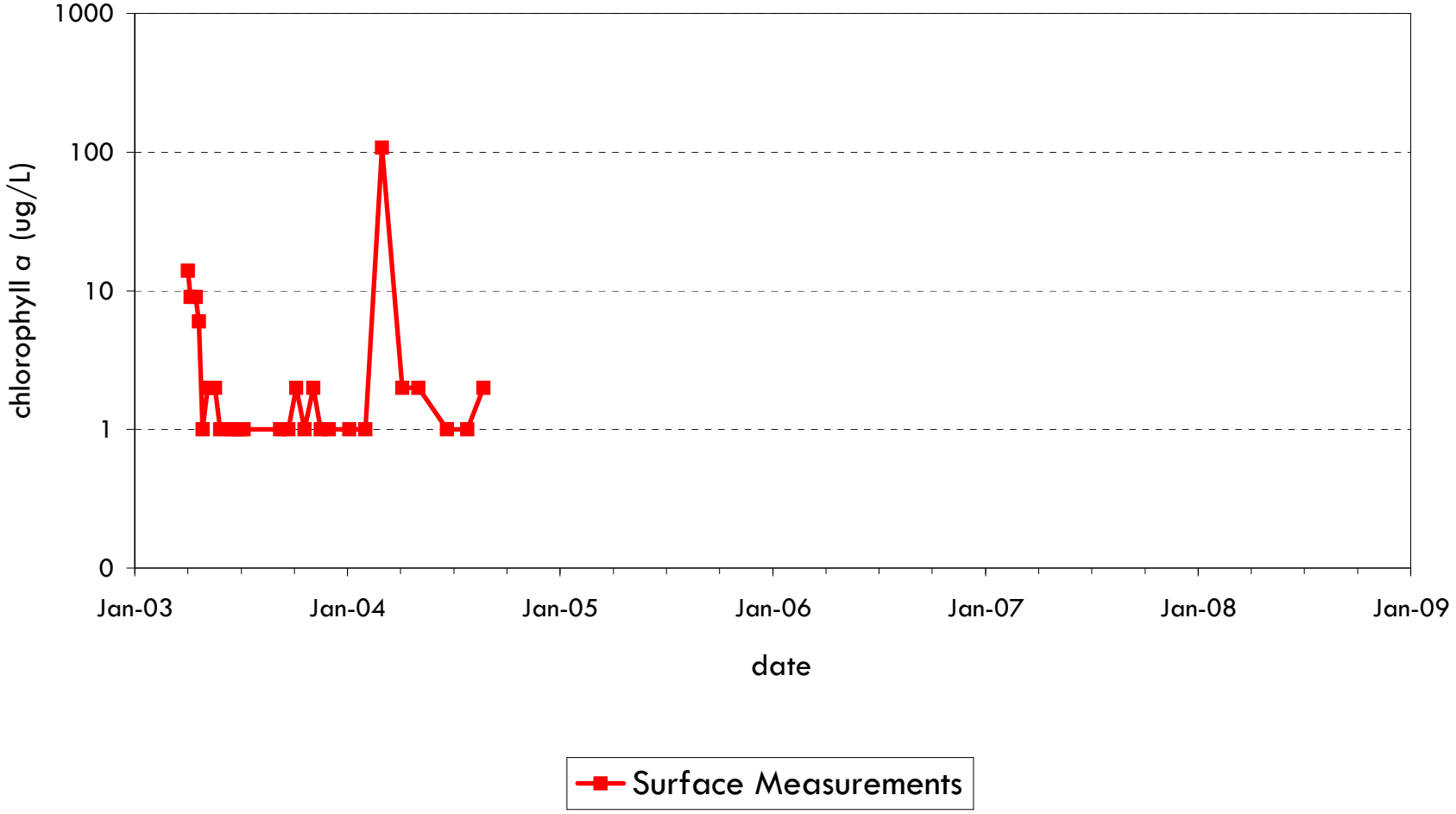

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Figure B-21

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San Vicente Reservoir

In Reservoir Transparency Data

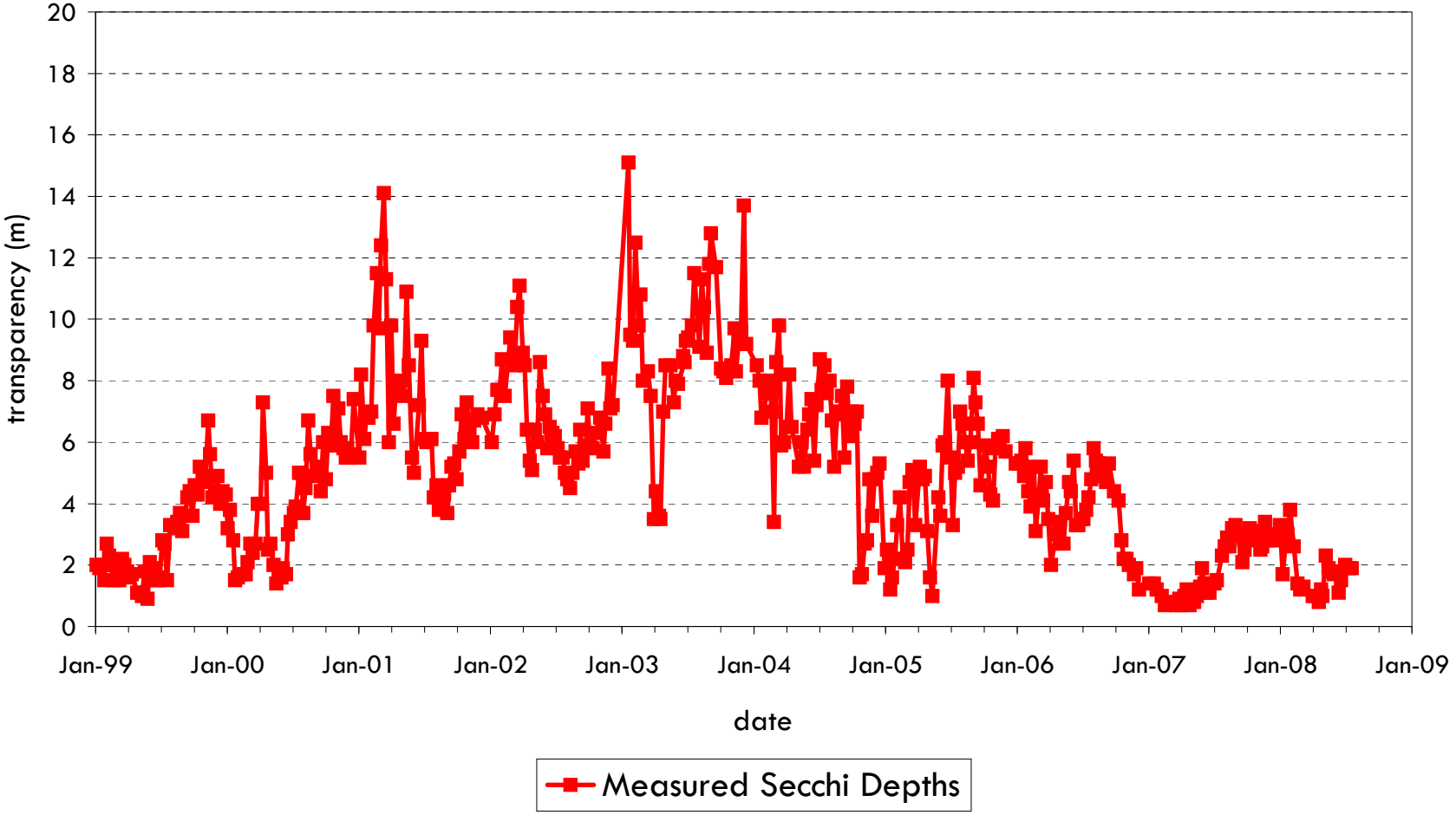

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Figure B-22

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APPENDIX C

INPUTS FOR CALIBRATION
CALIBRATION/VALIDATION RESULTS

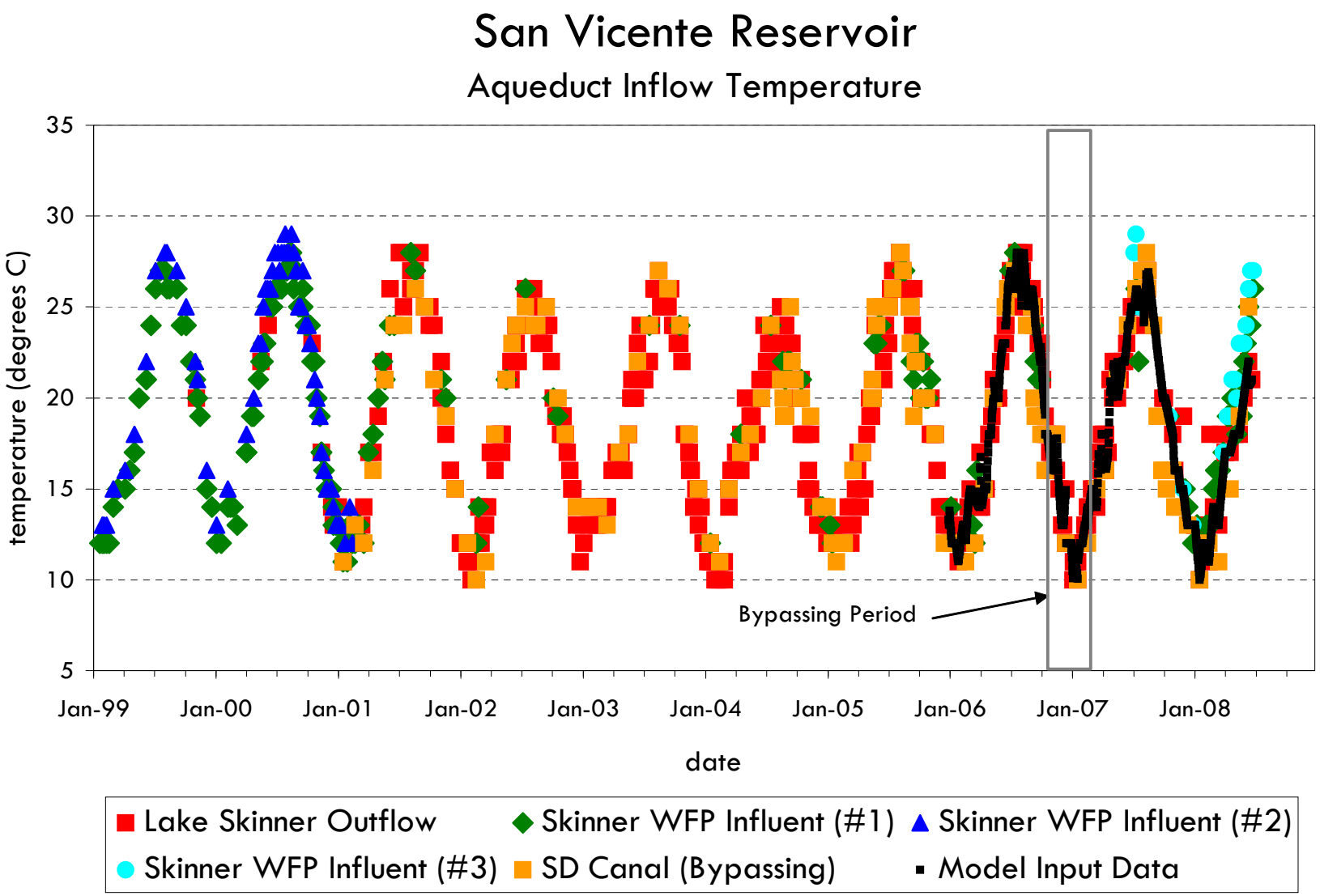

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Figure C-1

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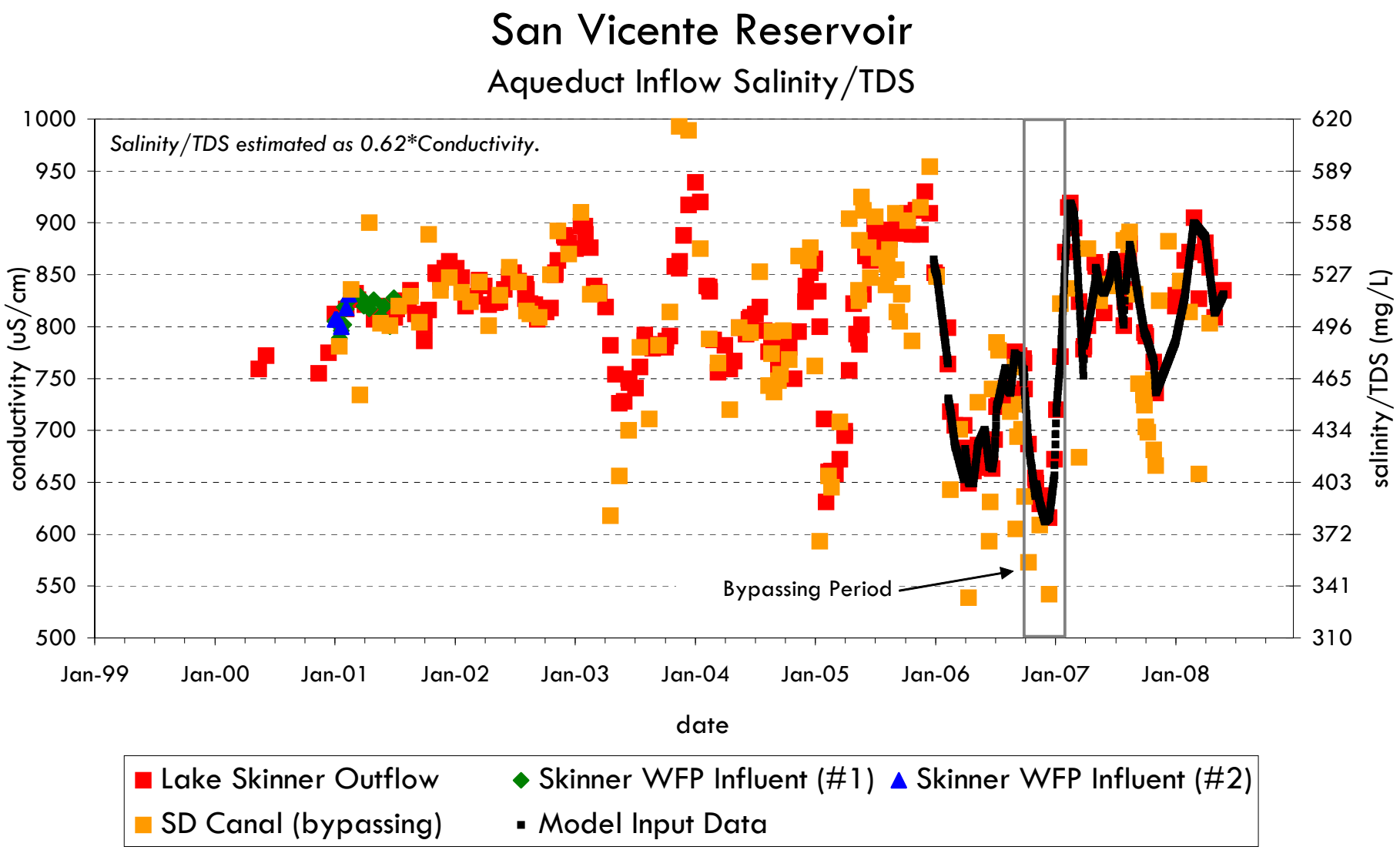

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Figure C-2

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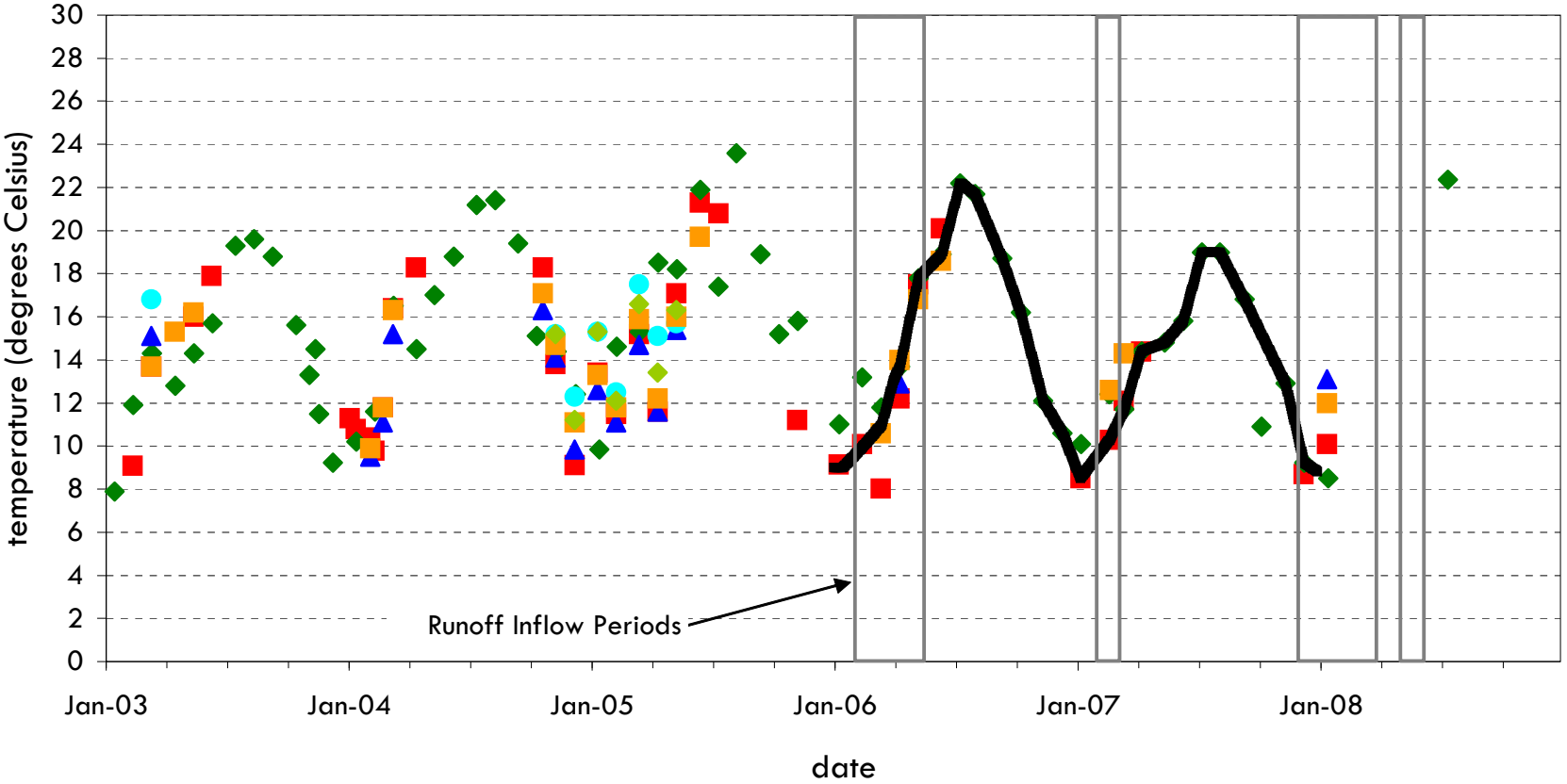
San Vicente Reservoir

Runoff Inflow Temperature



SV Creek (Blw Confluence) | SV Creek (Abv Confluence) | Barona Creek | Aqueduct Creek
Kimball Creek | Tool Road Creek | Model Input Data

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Figure C-3

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San Vicente Reservoir

Runoff Inflow Salinity/TDS

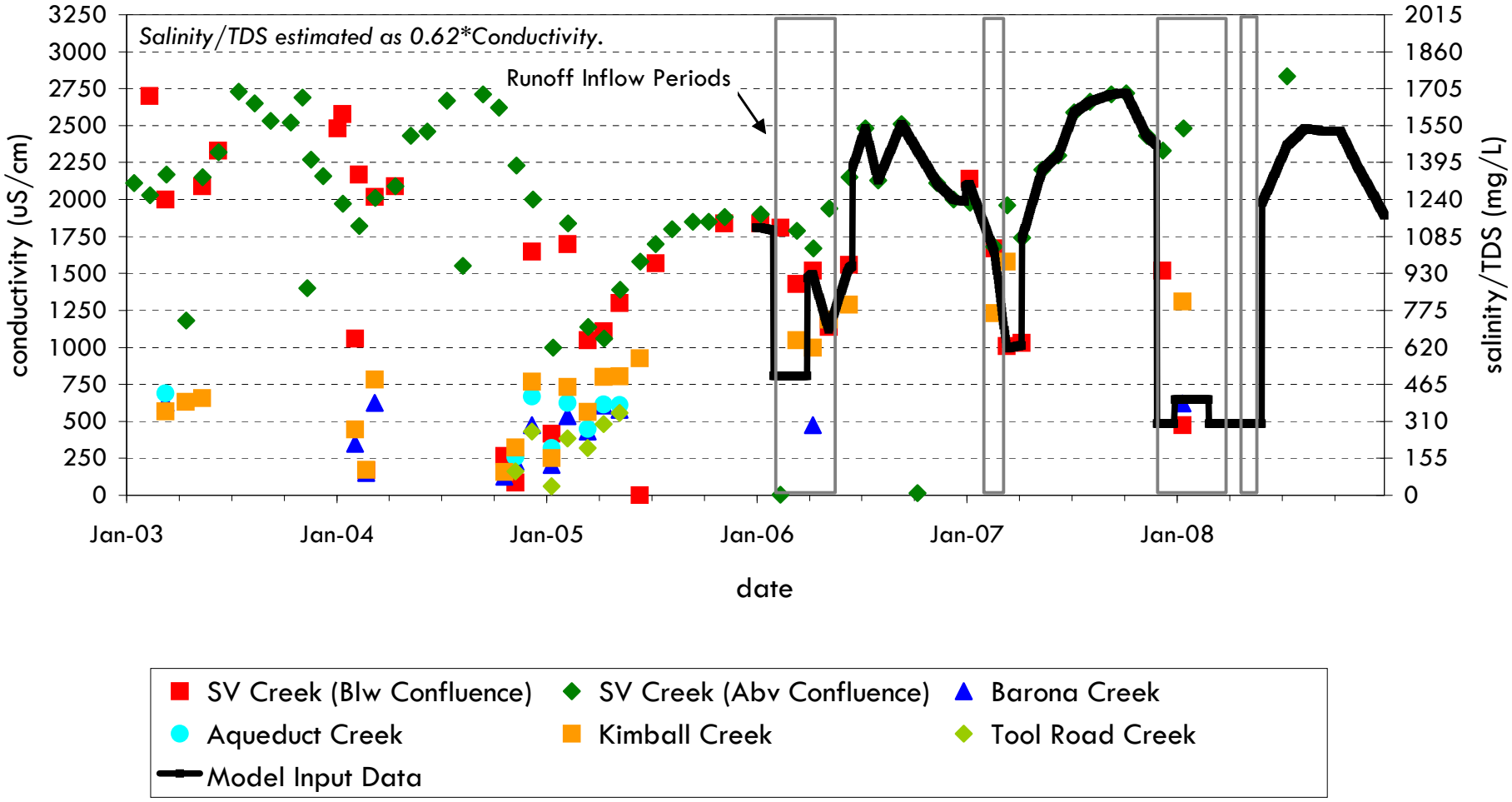

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Figure C-4

FLOW SCIENCE®

San Vicente Reservoir

Sutherland Reservoir Temperatures Near Outlet (El 1940 ft)

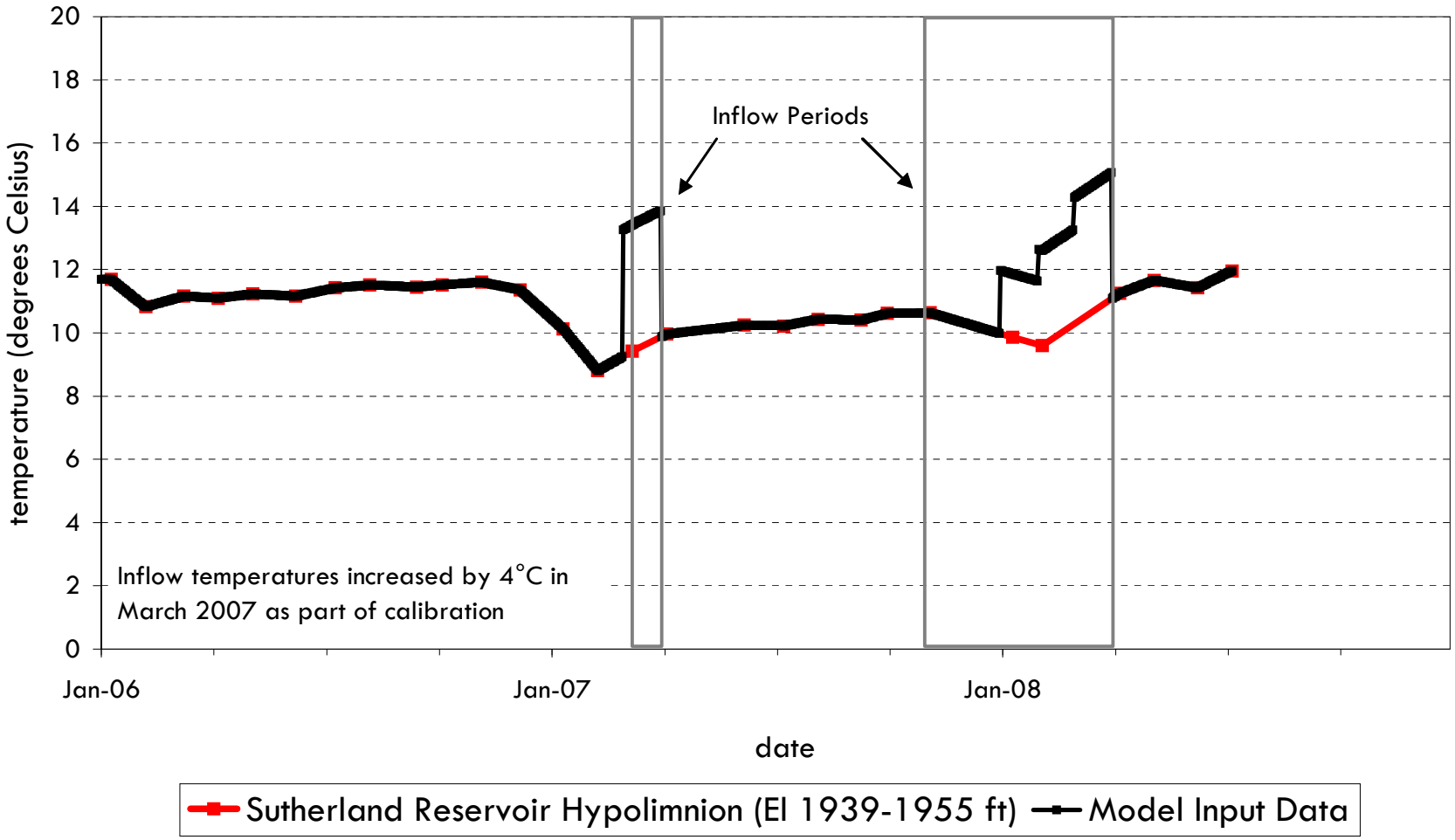

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Figure C-5

FLOW SCIENCE®

San Vicente Reservoir

Sutherland Reservoir Salinity/TDS Near Outlet (El 1940 ft)

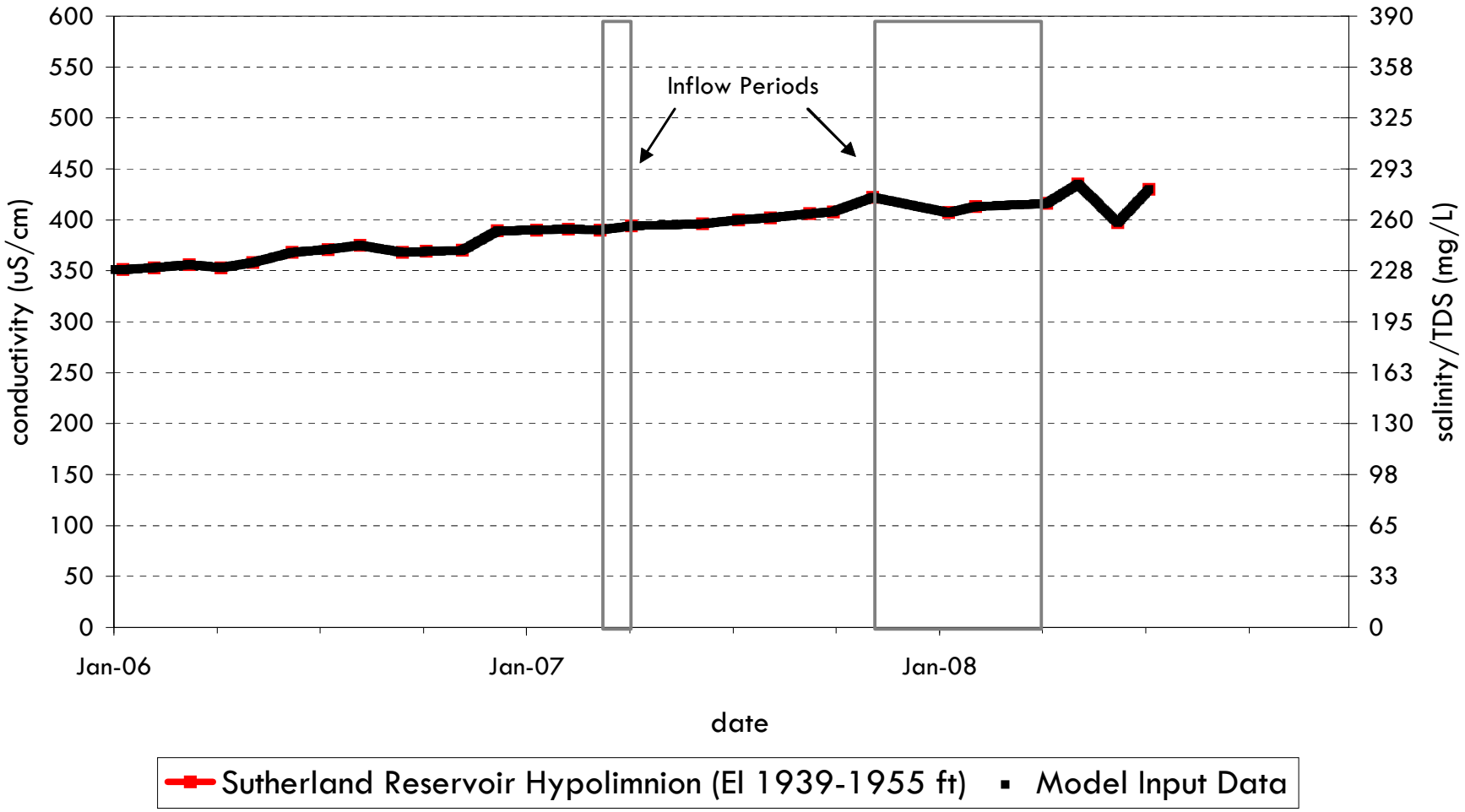

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Figure C-6

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San Vicente Reservoir

Input Meteorological Data - Solar Radiation

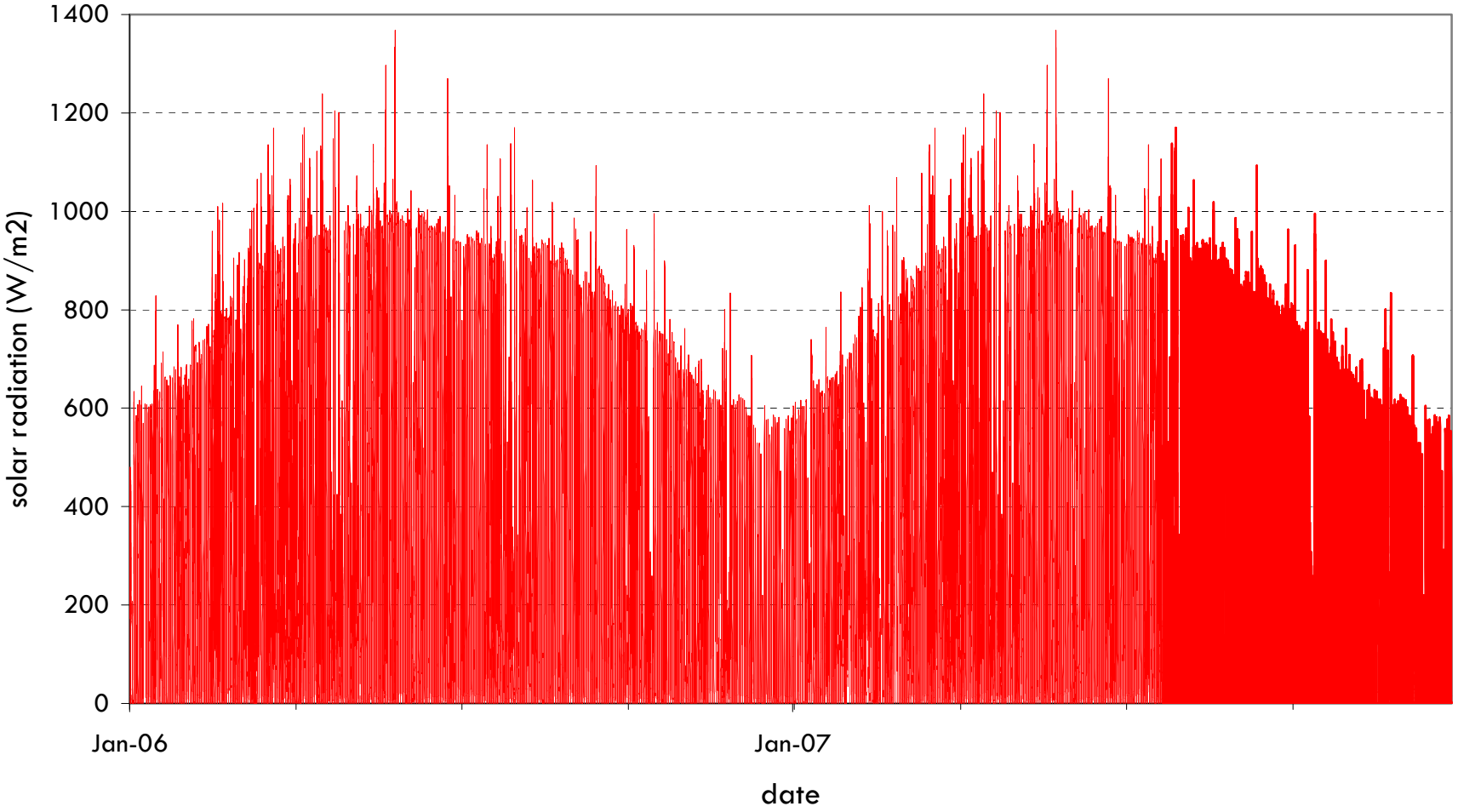

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Figure C-7

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San Vicente Reservoir

Input Meteorological Data - Air Temperature

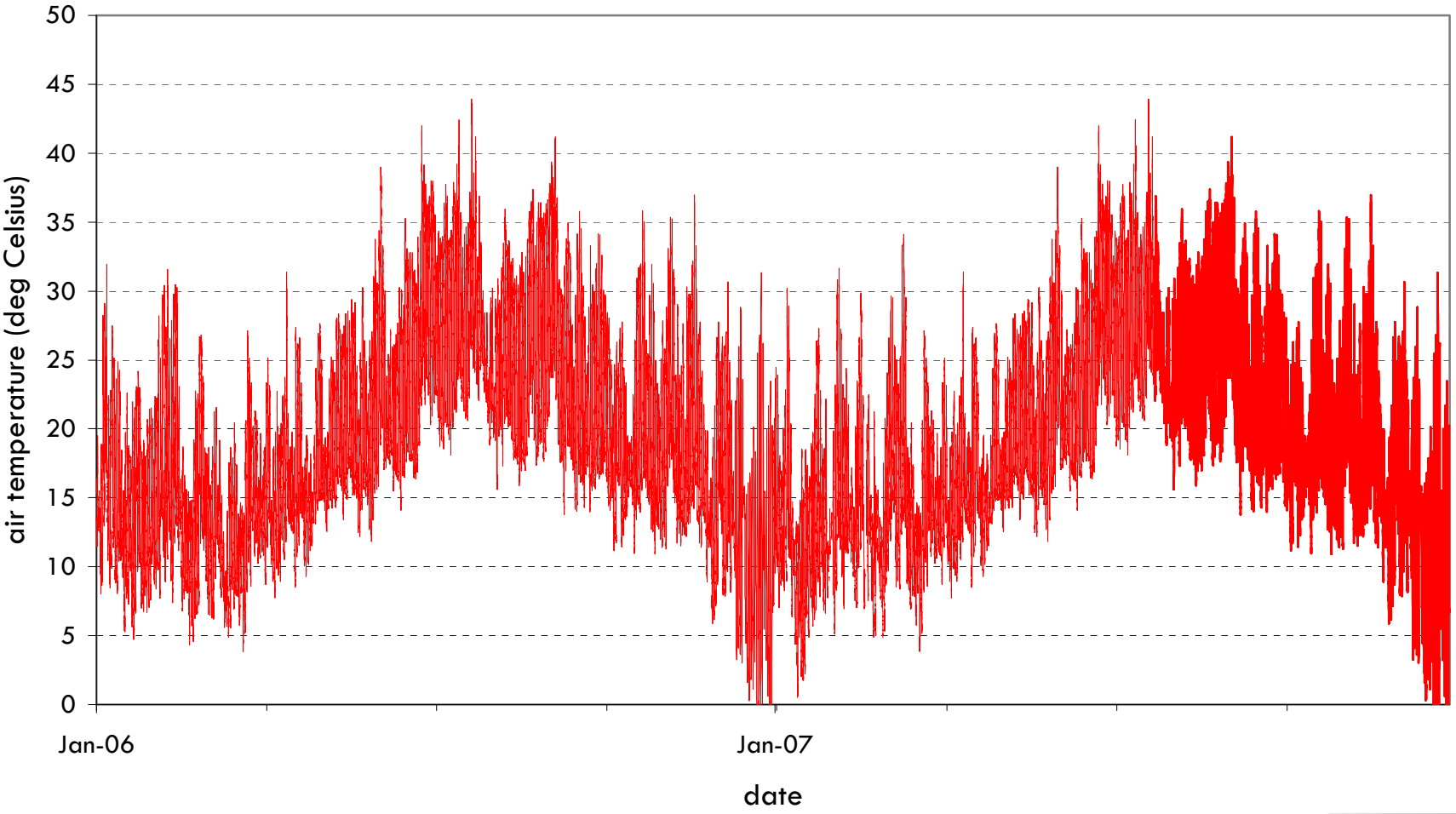

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Figure C-8

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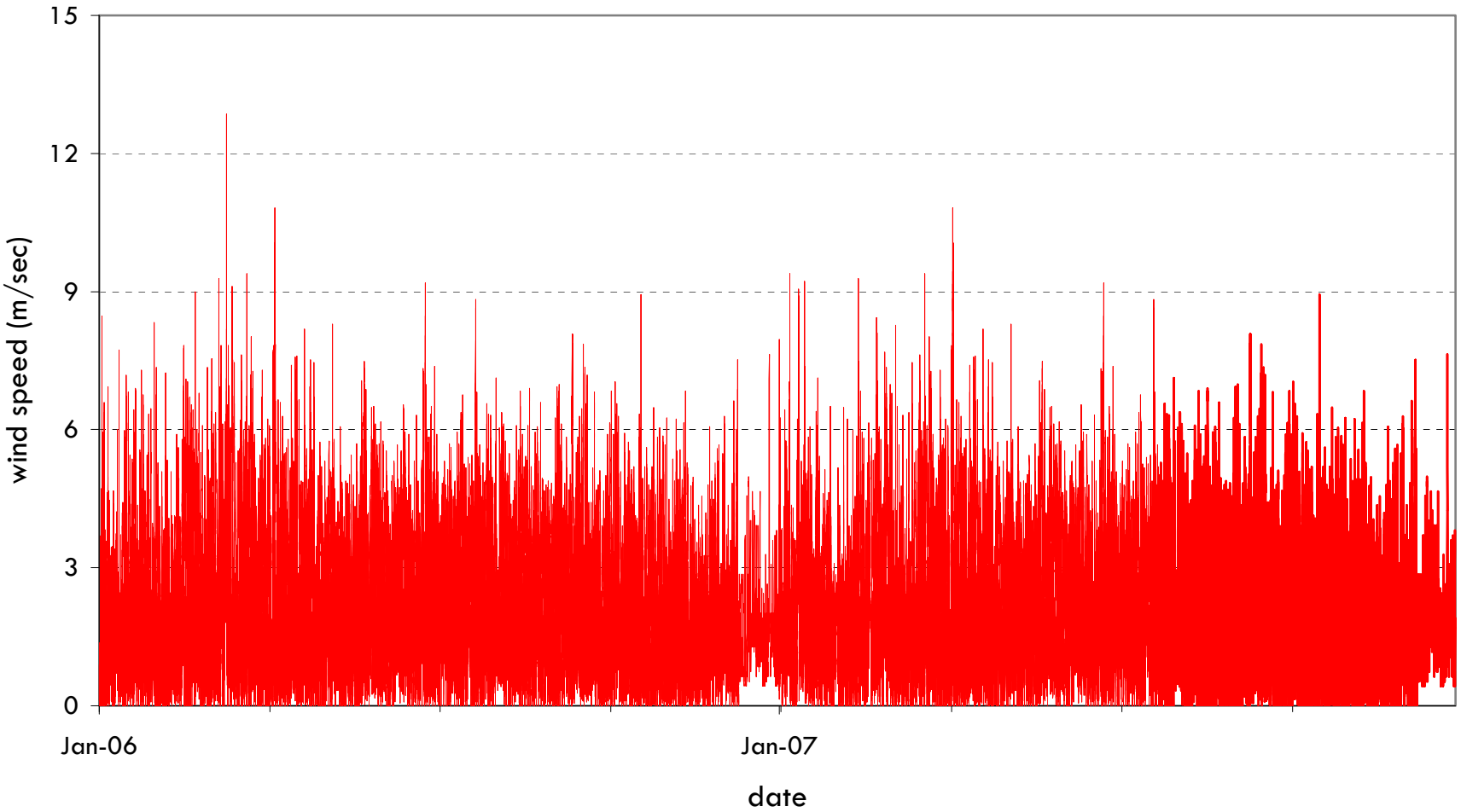
San Vicente Reservoir

Input Meteorological Data - Wind Speed



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May 01, 2012

Figure C-9

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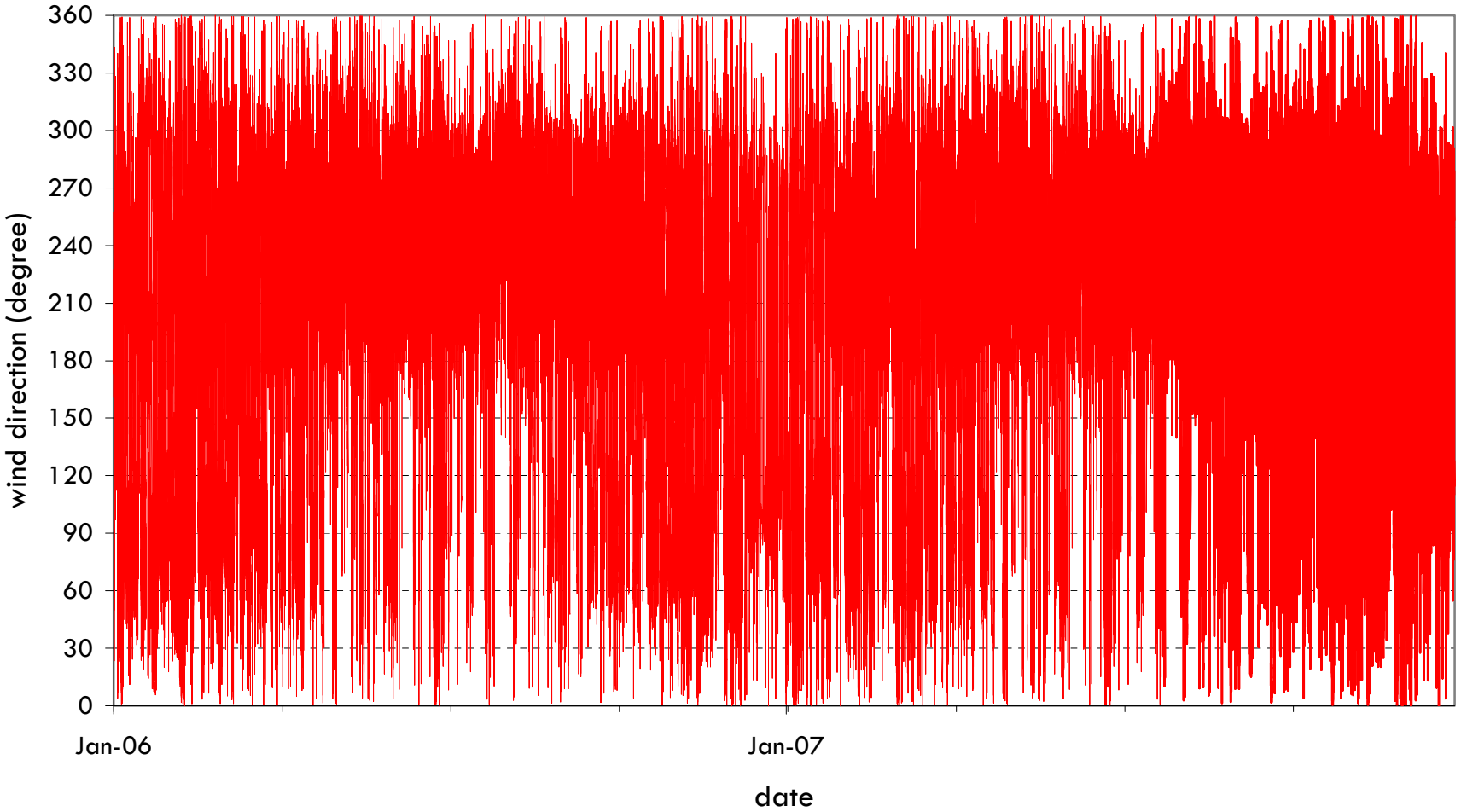
San Vicente Reservoir

Input Meteorological Data - Wind Direction



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May 01, 2012

Figure C-10

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San Vicente Reservoir

Input Meteorological Data - Relative Humidity

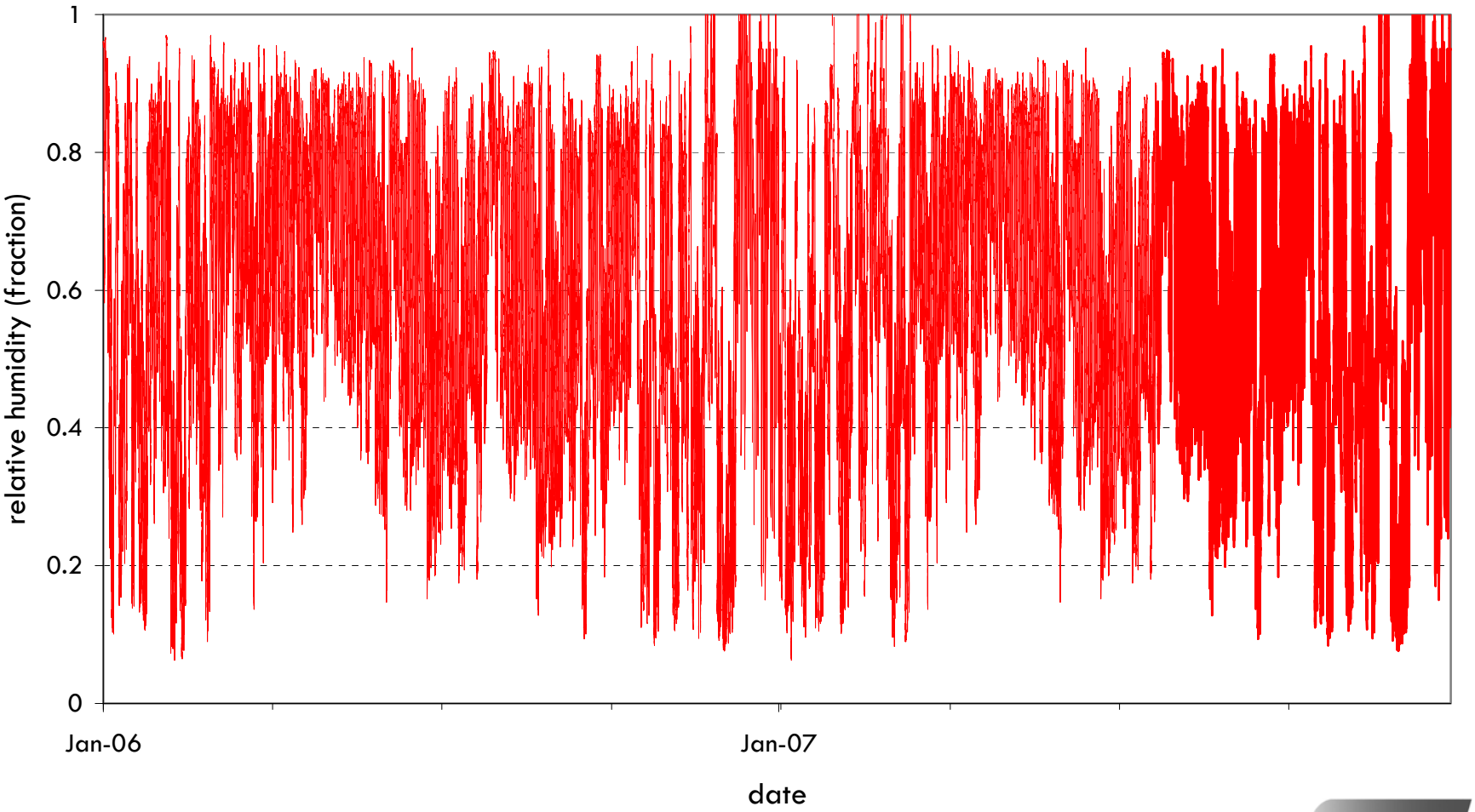

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Figure C-11

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San Vicente Reservoir

Input Meteorological Data - Precipitation Rate

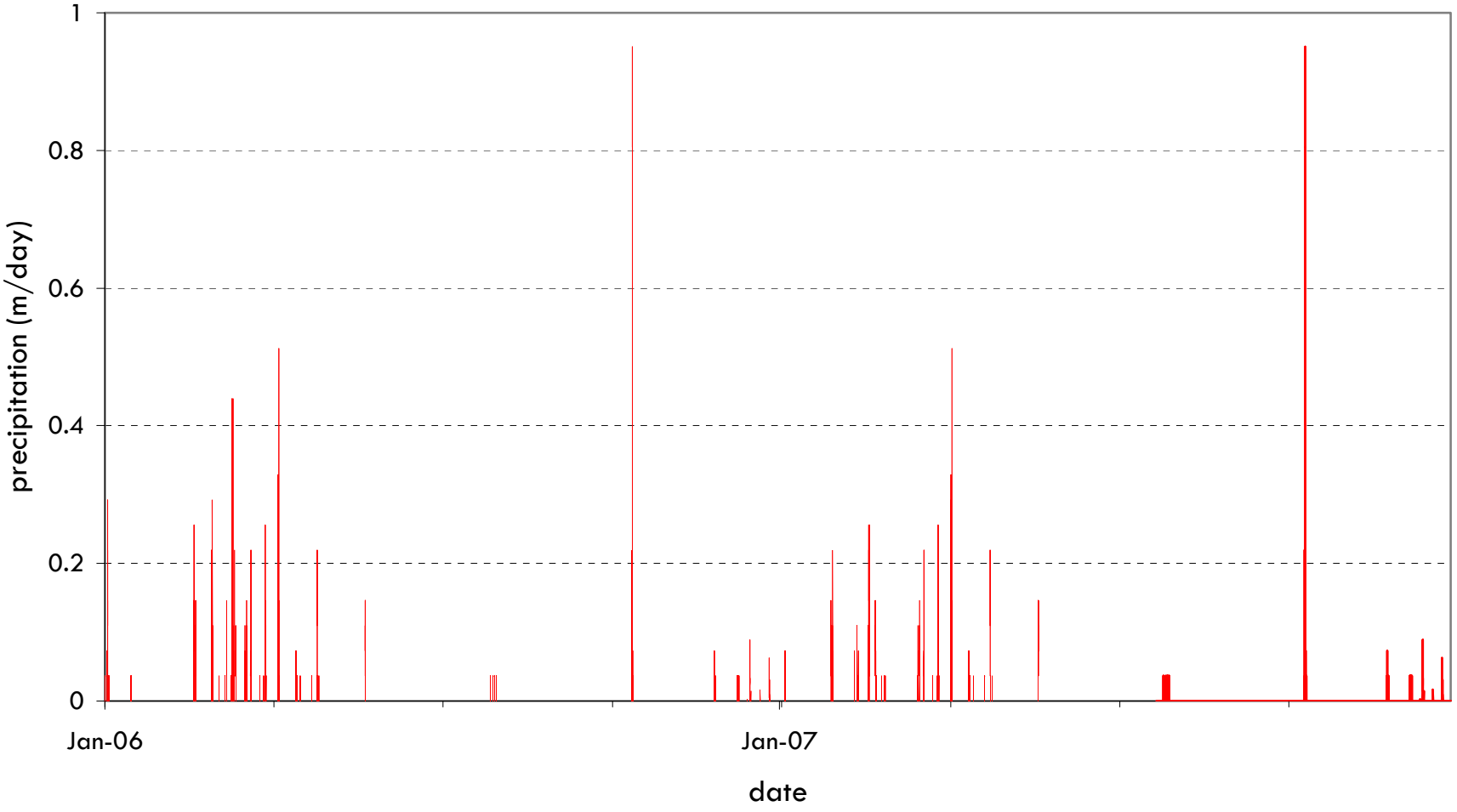

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Figure C-12

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San Vicente Reservoir Station A - Water Temperature Calibration

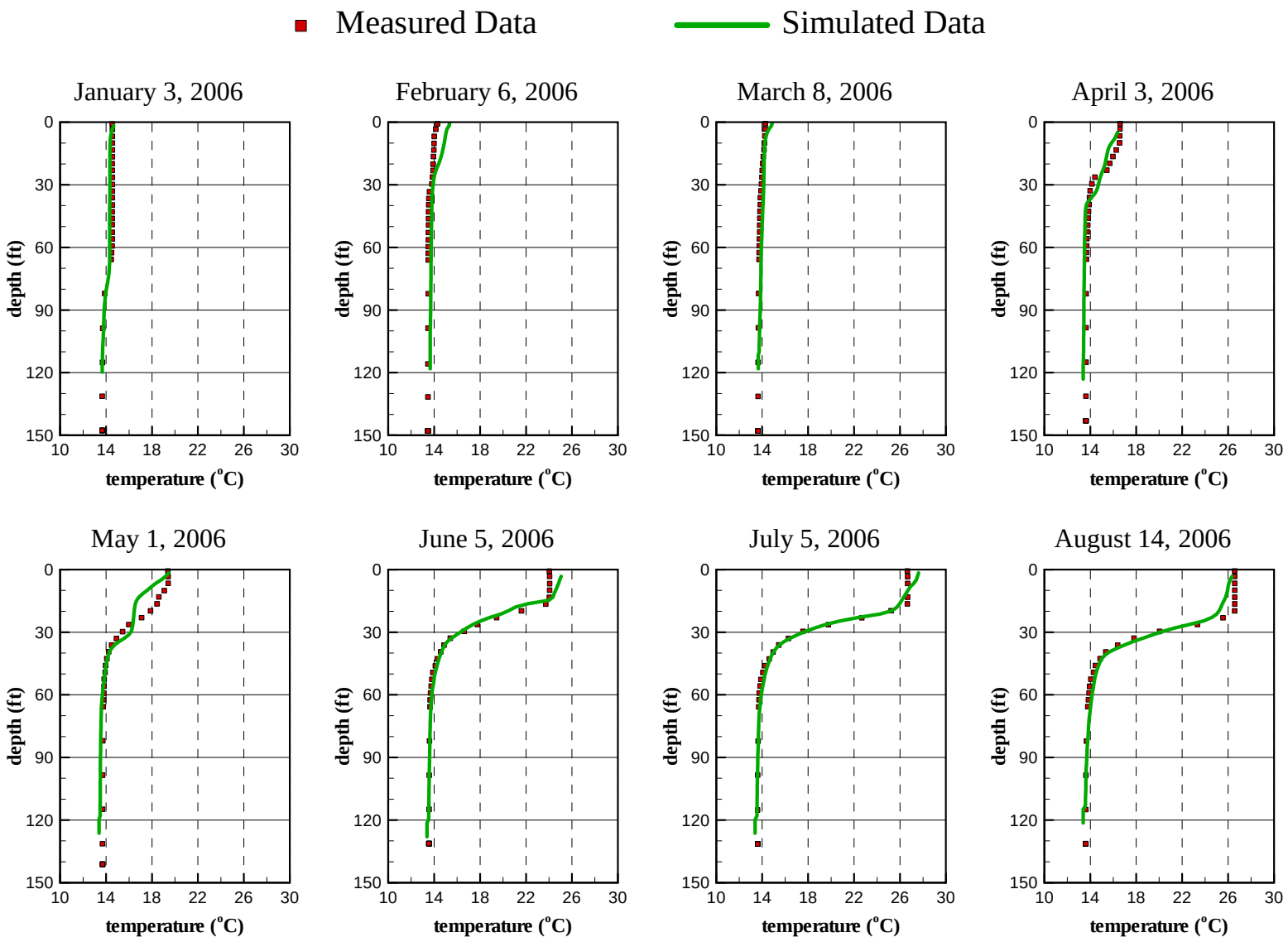

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Figure C-13

FLOW SCIENCE®

San Vicente Reservoir Station A - Water Temperature Calibration

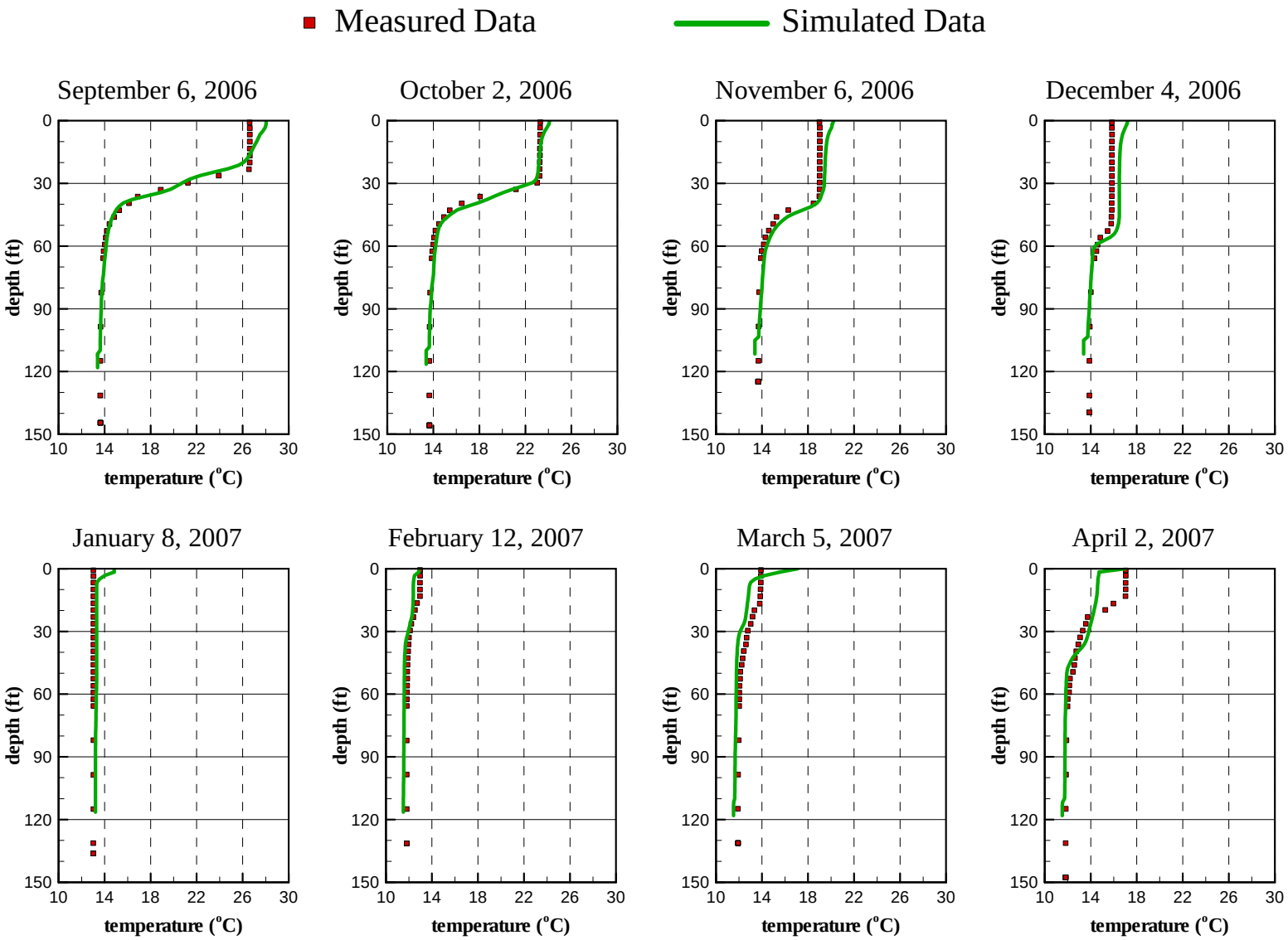

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Figure C-14

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San Vicente Reservoir Station A - Water Temperature Calibration

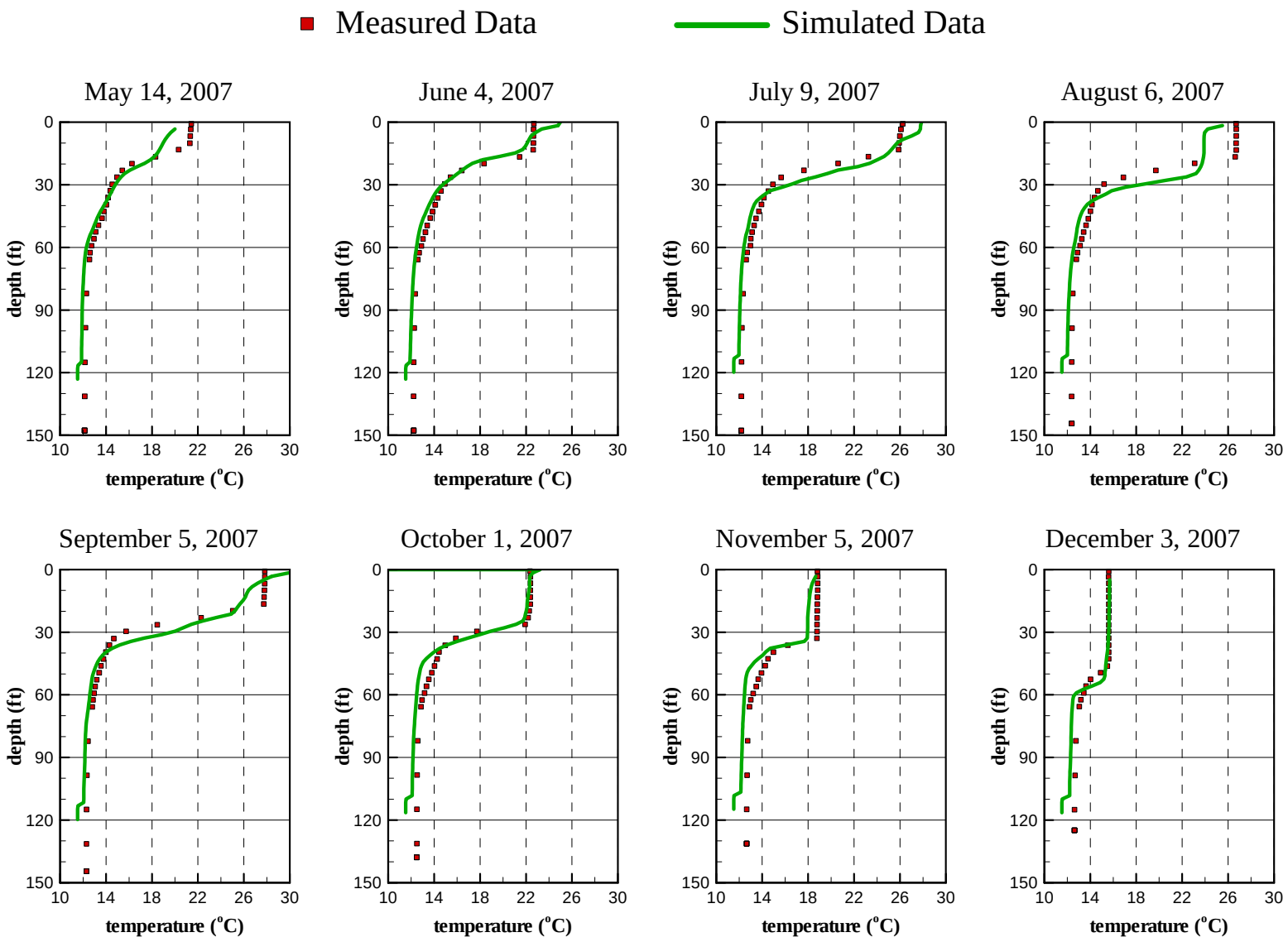

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Figure C-15

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San Vicente Reservoir

1995 Tracer Winter Study – Measured Tracer versus Simulated Conservative Tracer

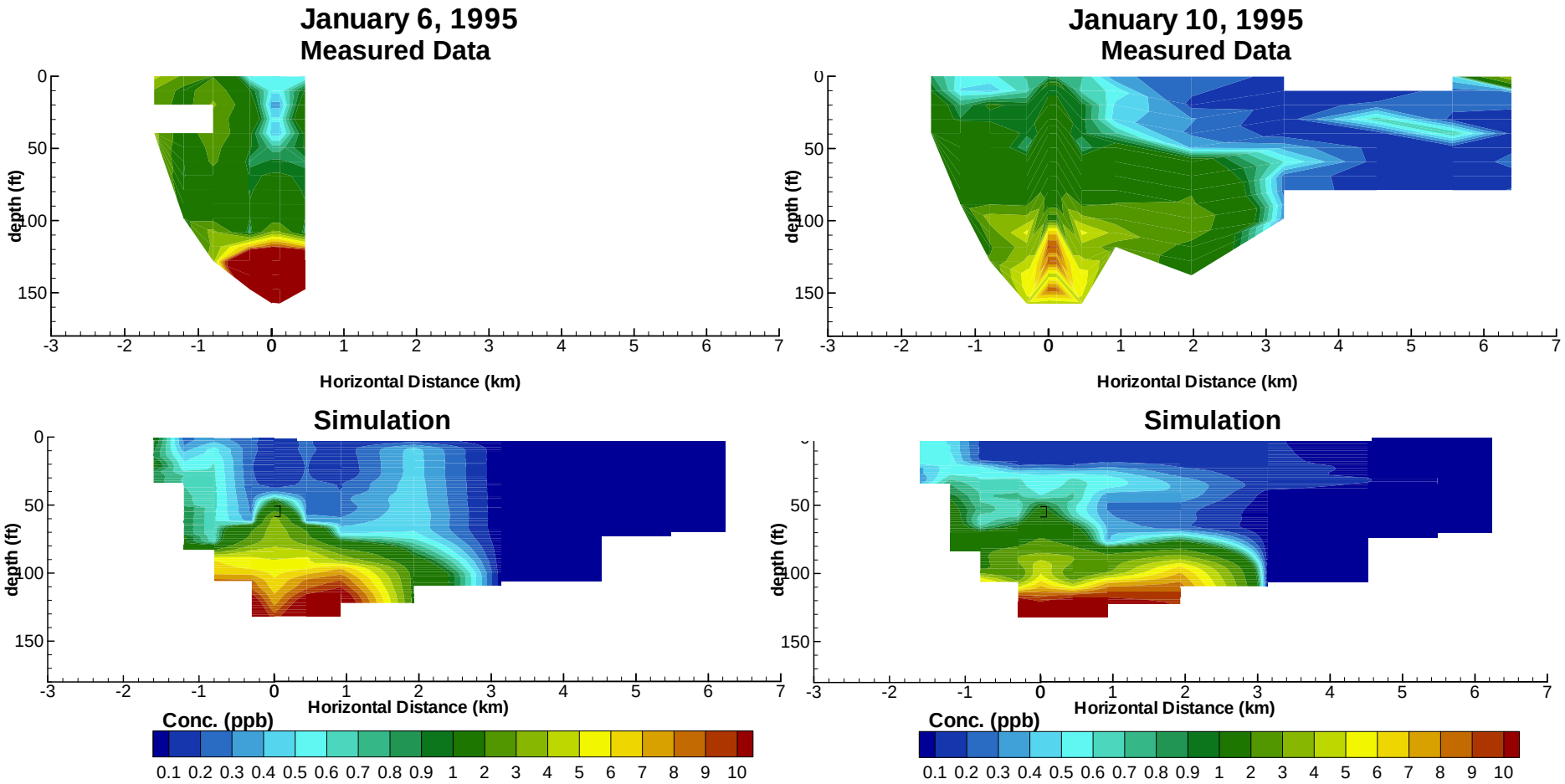

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Figure C-16

FLOW SCIENCE®

San Vicente Reservoir

1995 Tracer Winter Study – Measured Tracer versus Simulated Conservative Tracer

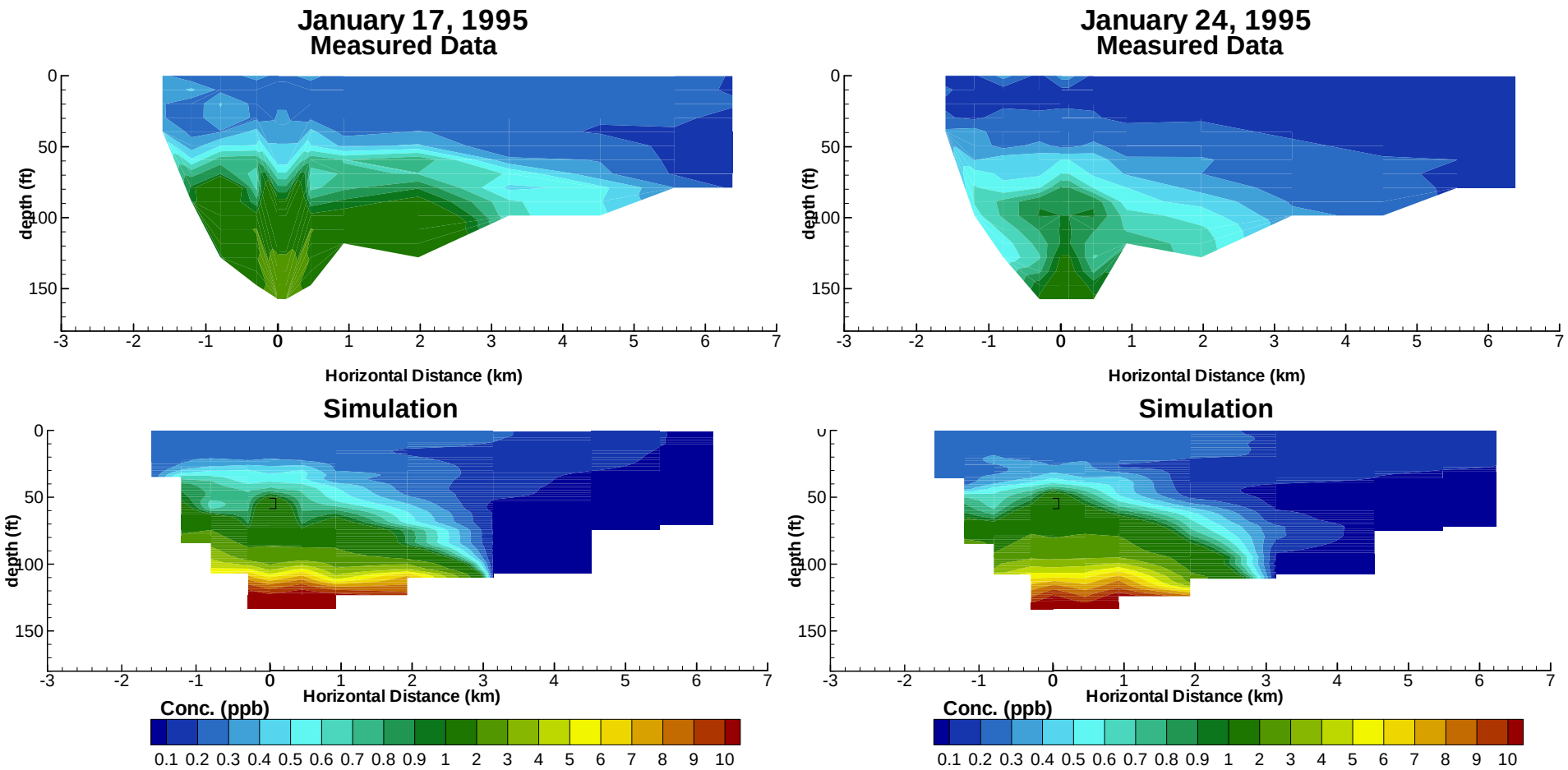

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Figure C-17

FLOW SCIENCE®

San Vicente Reservoir

1995 Tracer Winter Study – Measured Tracer versus Simulated Conservative Tracer

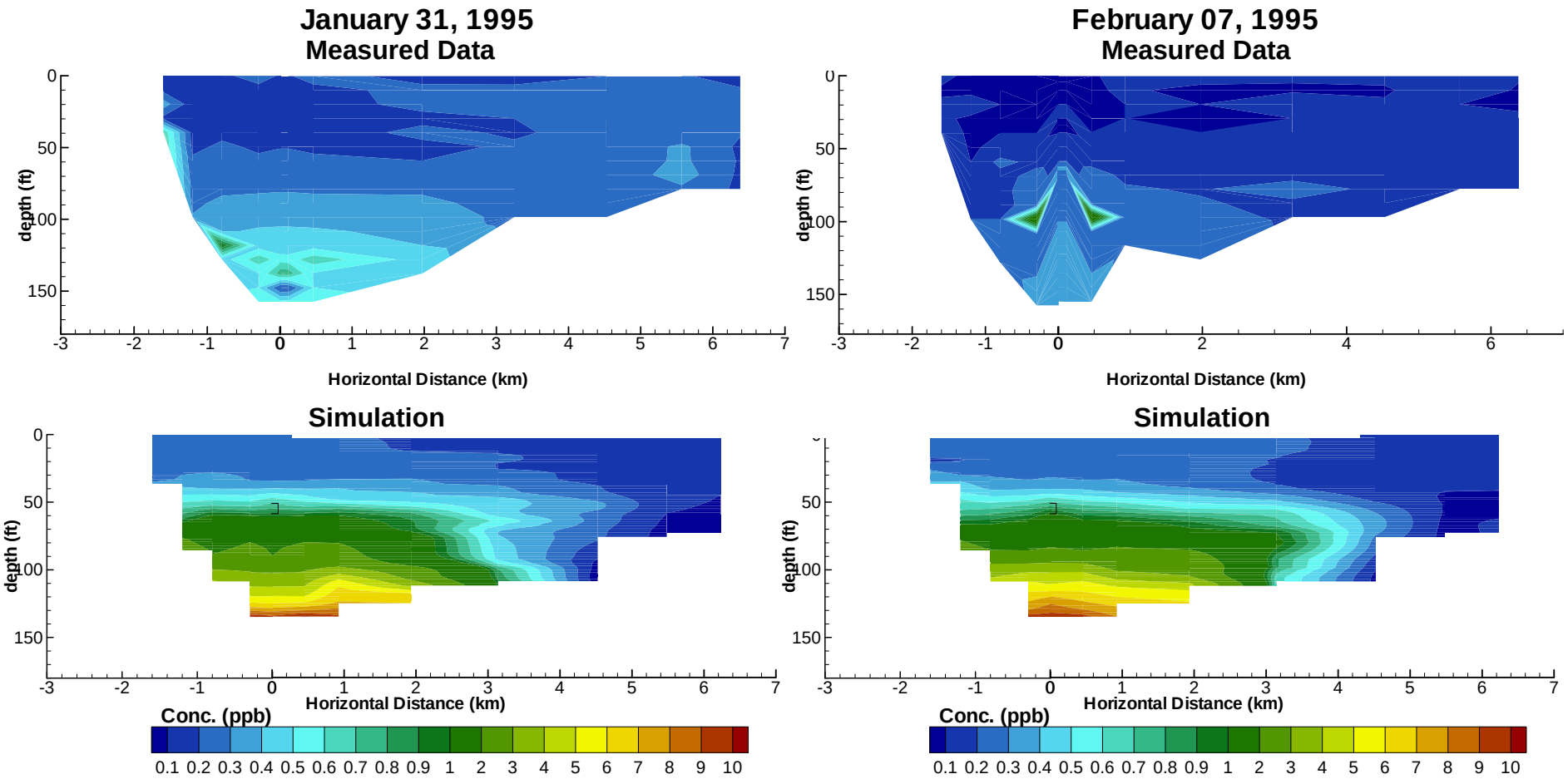

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Figure C-18

FLOW SCIENCE®

San Vicente Reservoir

1995 Tracer Summer Study – Measured Tracer versus Simulated Conservative Tracer

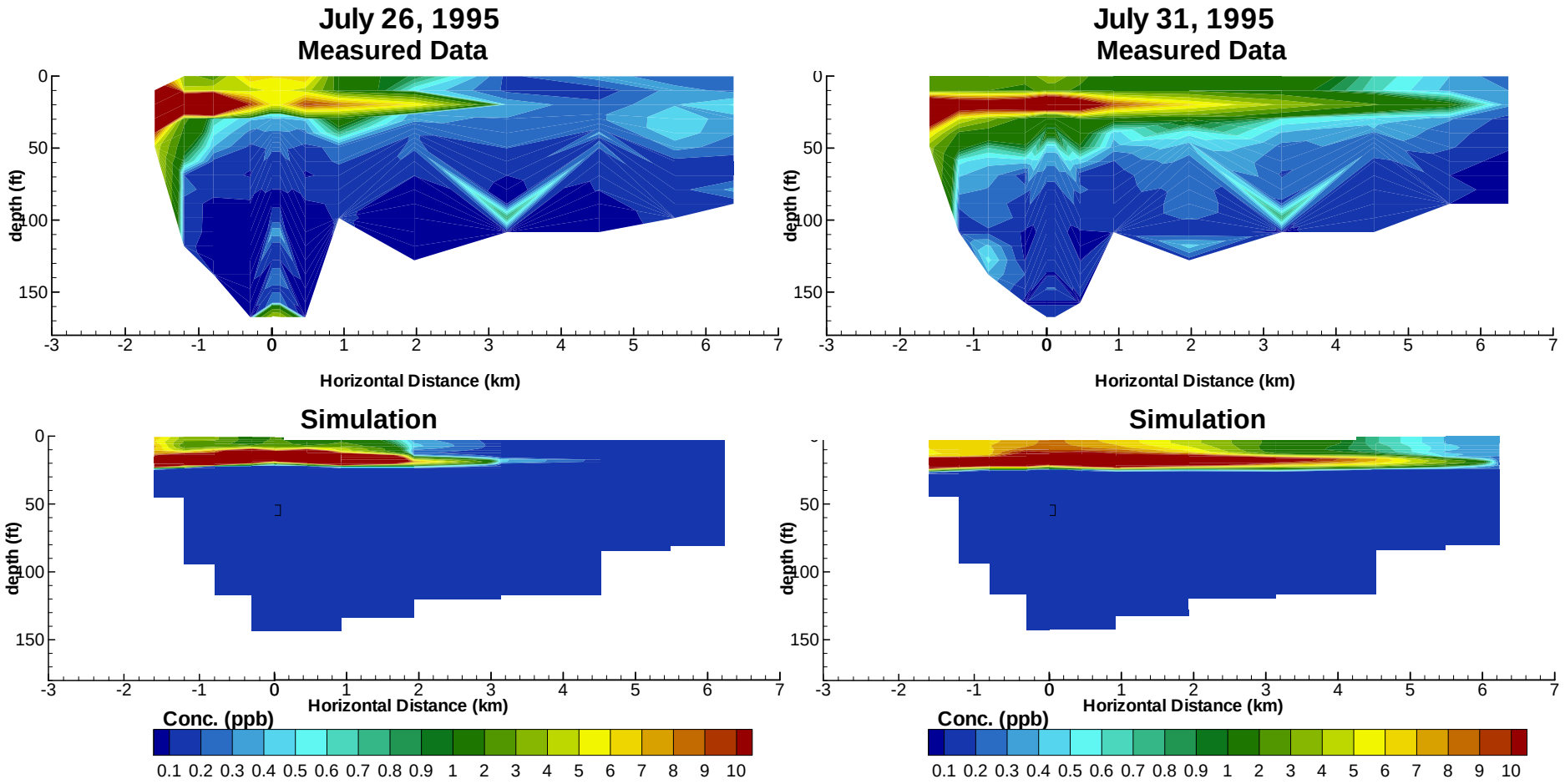

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Figure C-19

FLOW SCIENCE®

San Vicente Reservoir

1995 Tracer Summer Study – Measured Tracer versus Simulated Conservative Tracer

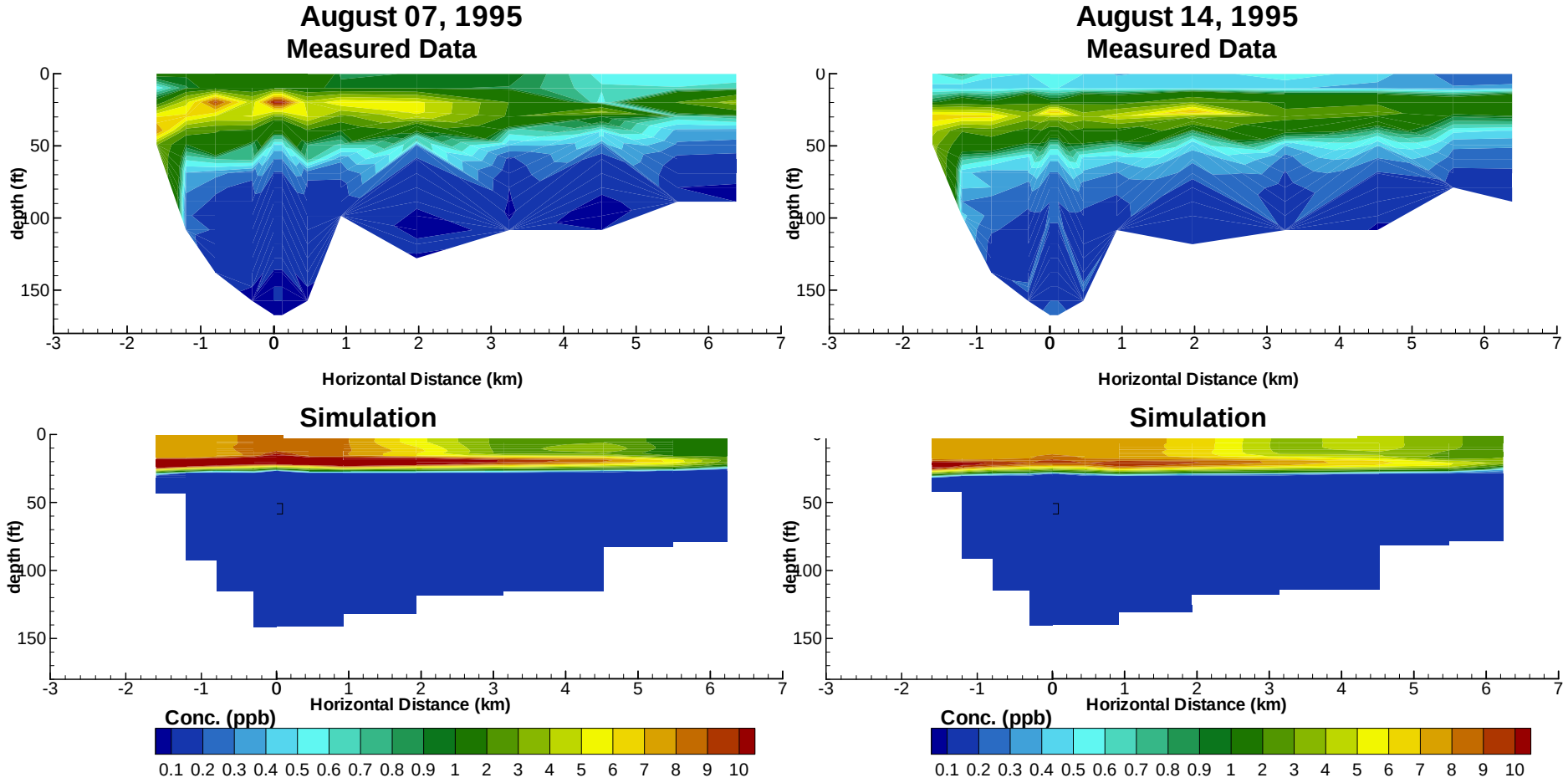

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Figure C-20

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San Vicente Reservoir

1995 Tracer Summer Study – Measured Tracer versus Simulated Conservative Tracer

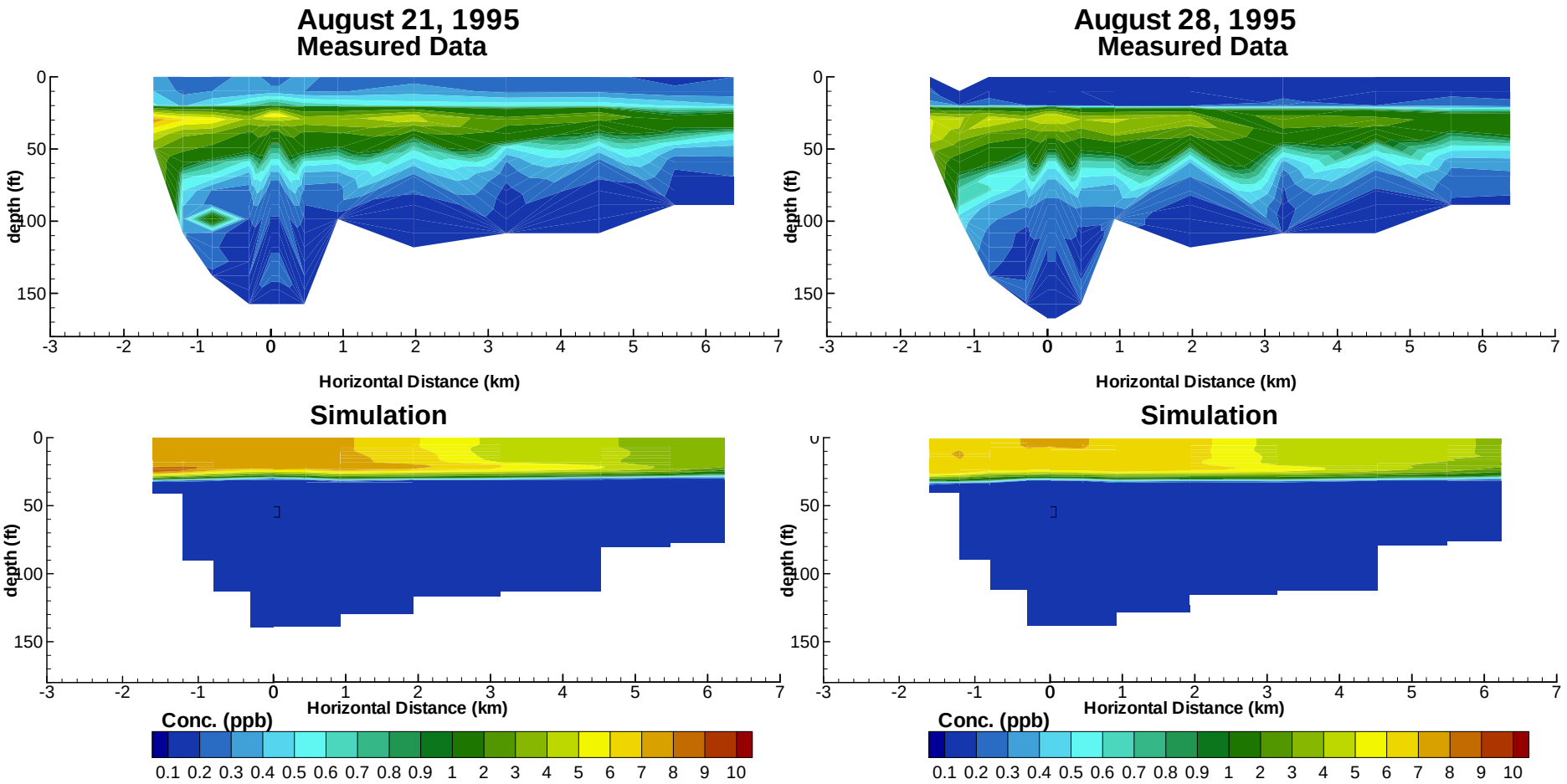

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Figure C-21

FLOW SCIENCE®

San Vicente Reservoir

1995 Tracer Summer Study – Measured Tracer versus Simulated Conservative Tracer

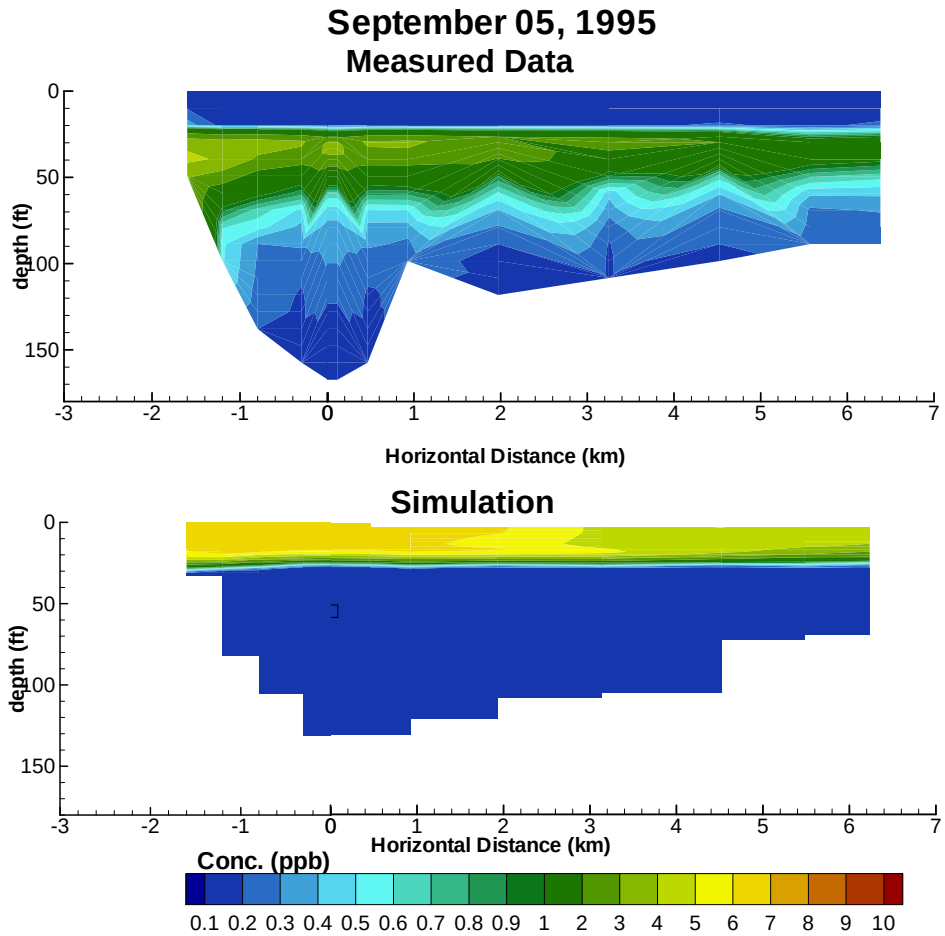

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Figure C-22

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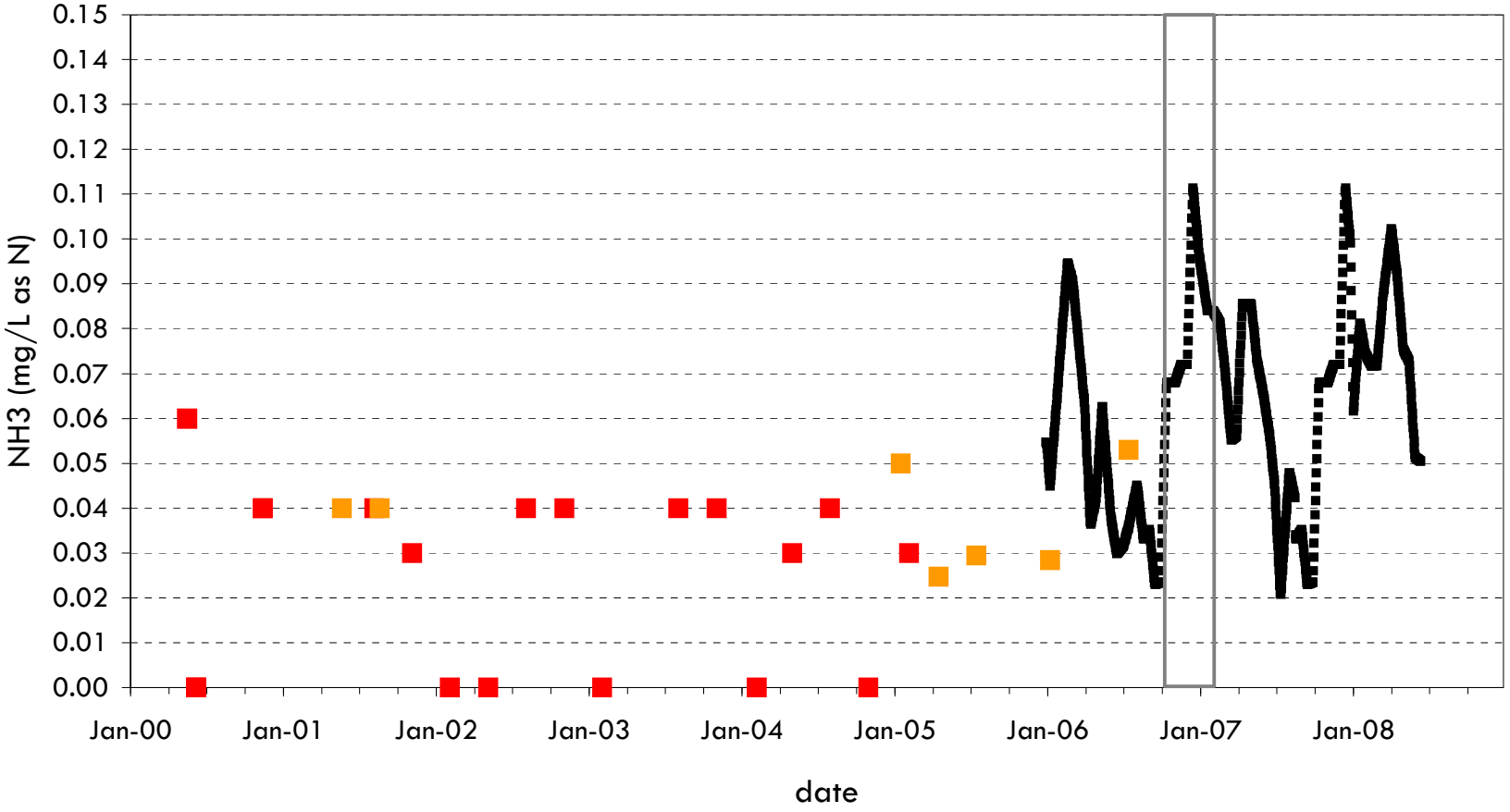
San Vicente Reservoir

Aqueduct Inflow Ammonia Data



■ Lake Skinner Outlet Conduit ■ SD Canal (bypassing) ▪ Model Input Data (estimated as 20% of NO3)

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Figure C-23

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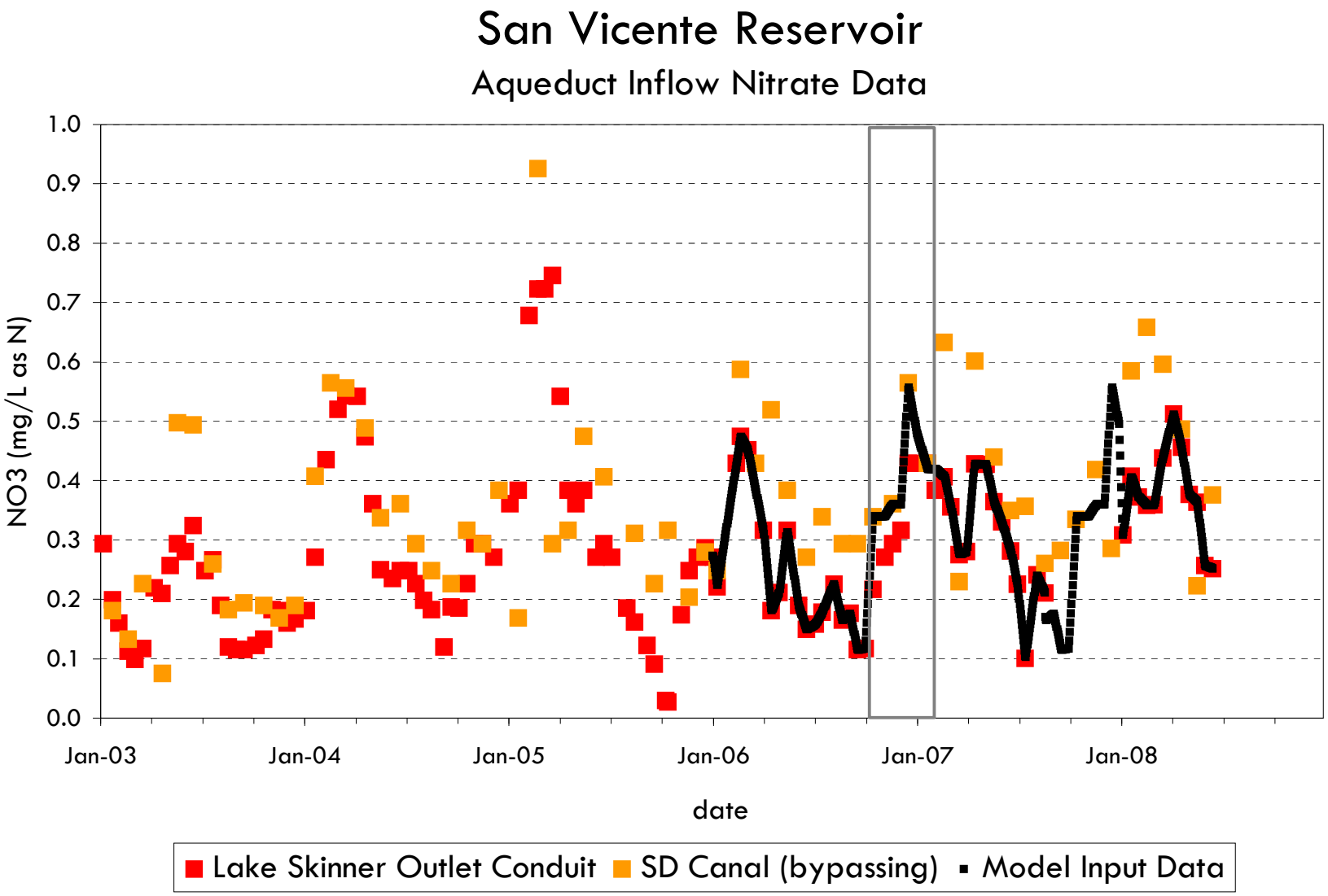

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Figure C-24

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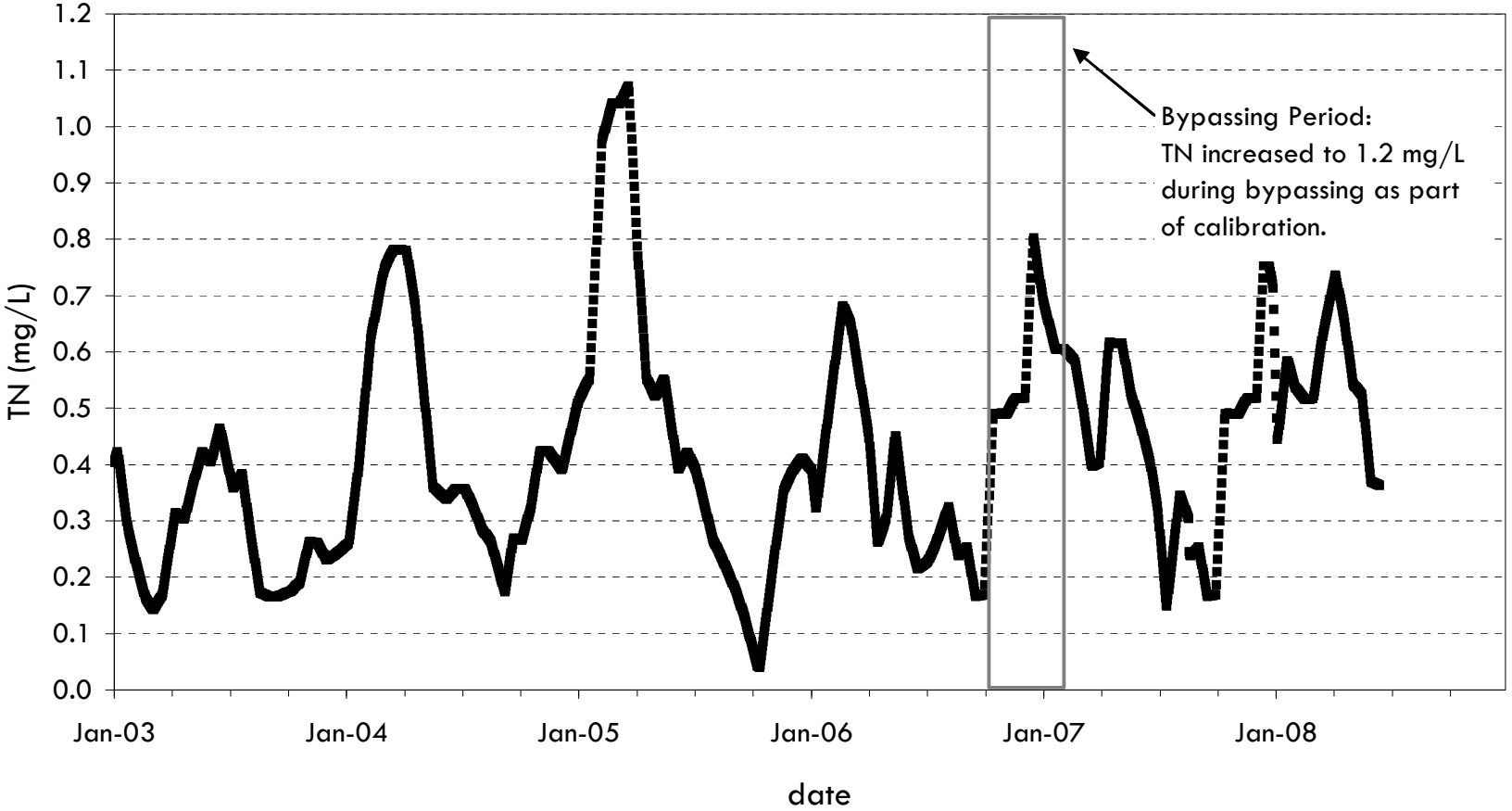
San Vicente Reservoir

Aqueduct Inflow Total Nitrogen Estimate



▪ Model Input Data (estimated as 1.2*(NO3+NH4))

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Figure C-25

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San Vicente Reservoir

Aqueduct Inflow Ortho-Phosphate Data

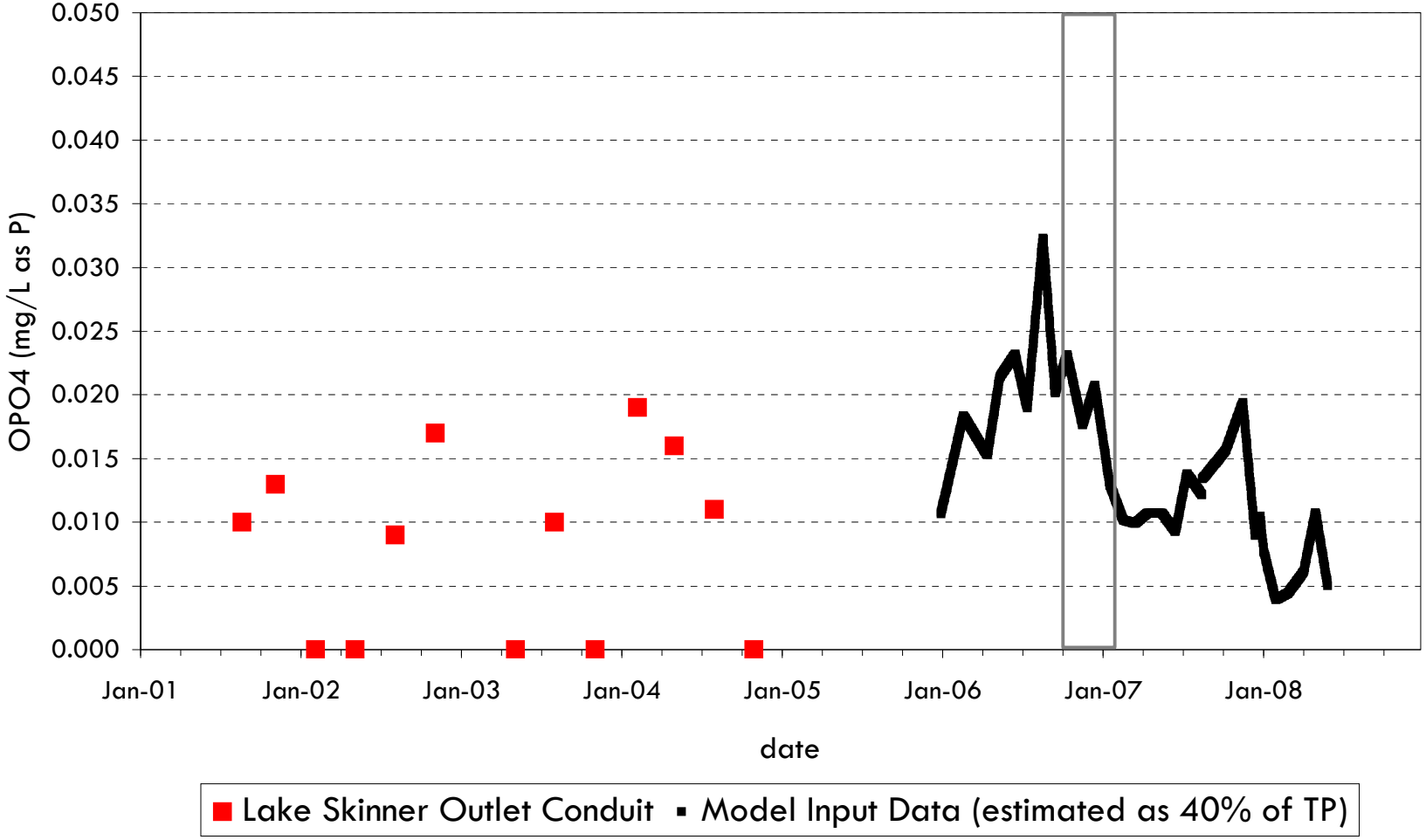

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Figure C-26

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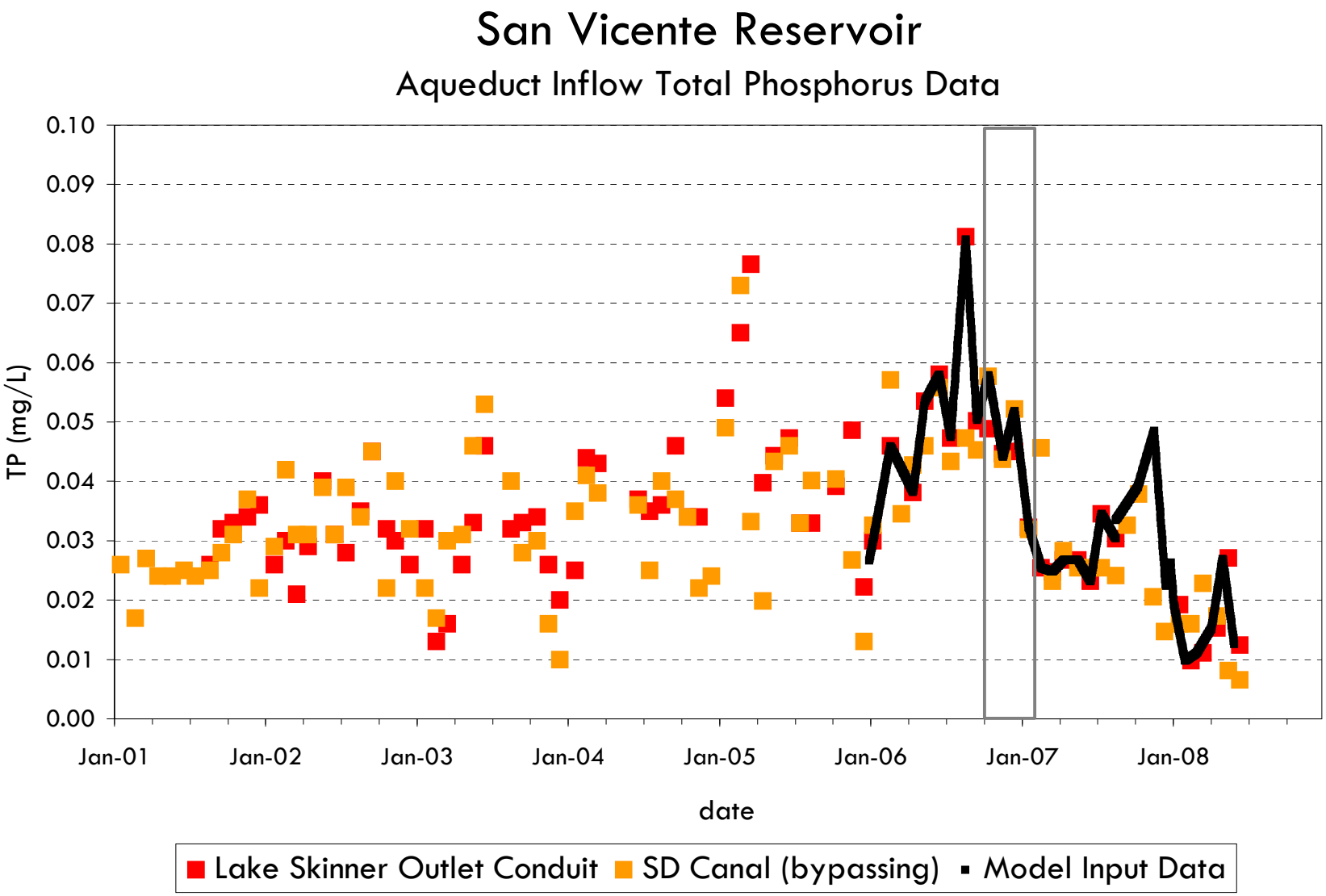

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Figure C-27

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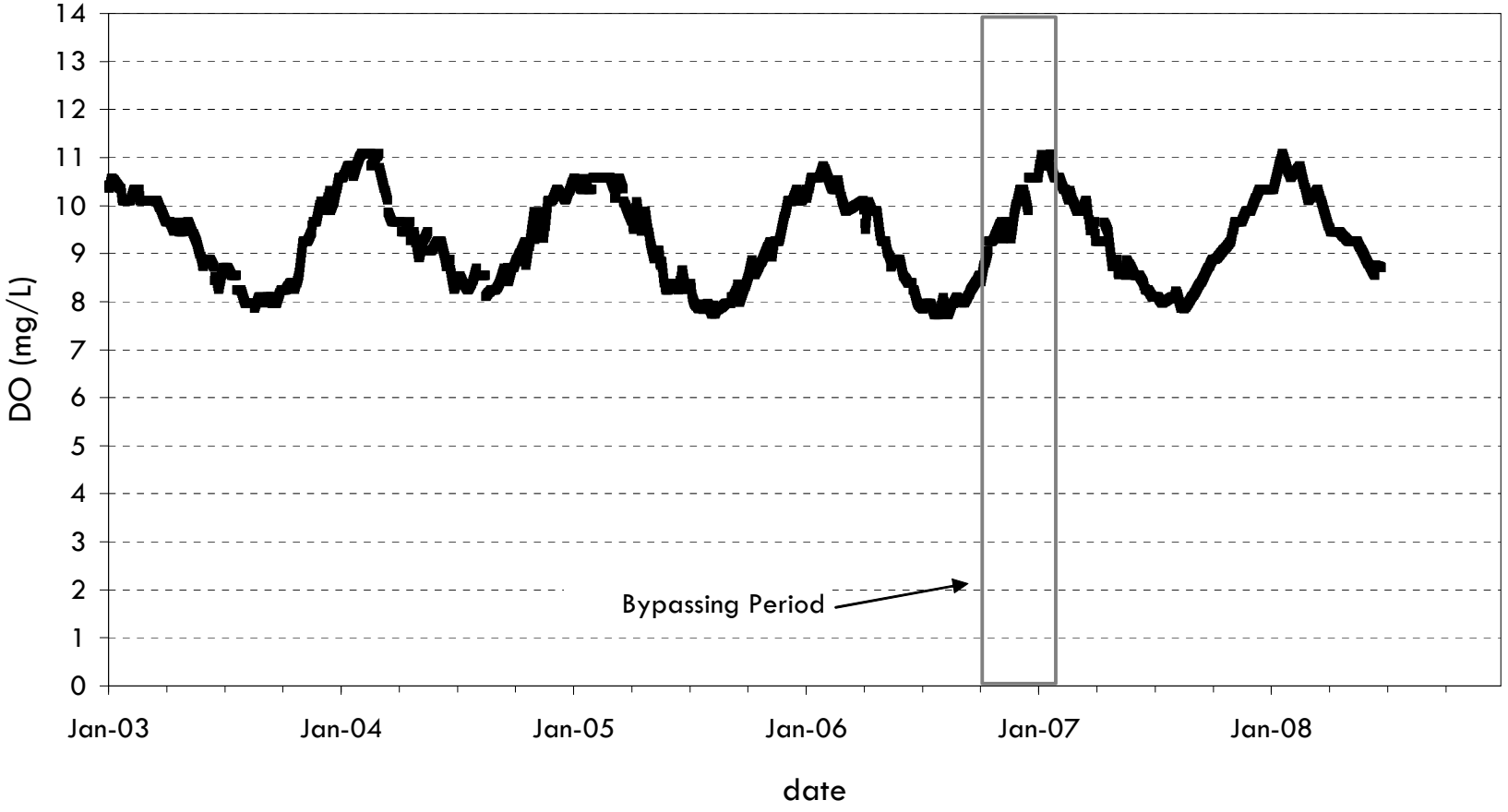
San Vicente Reservoir

Aqueduct Inflow Dissolved Oxygen



▪ Model Input Data (estimated based on temperature - 100% saturation)

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Figure C-28

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San Vicente Reservoir

Aqueduct Inflow pH Data

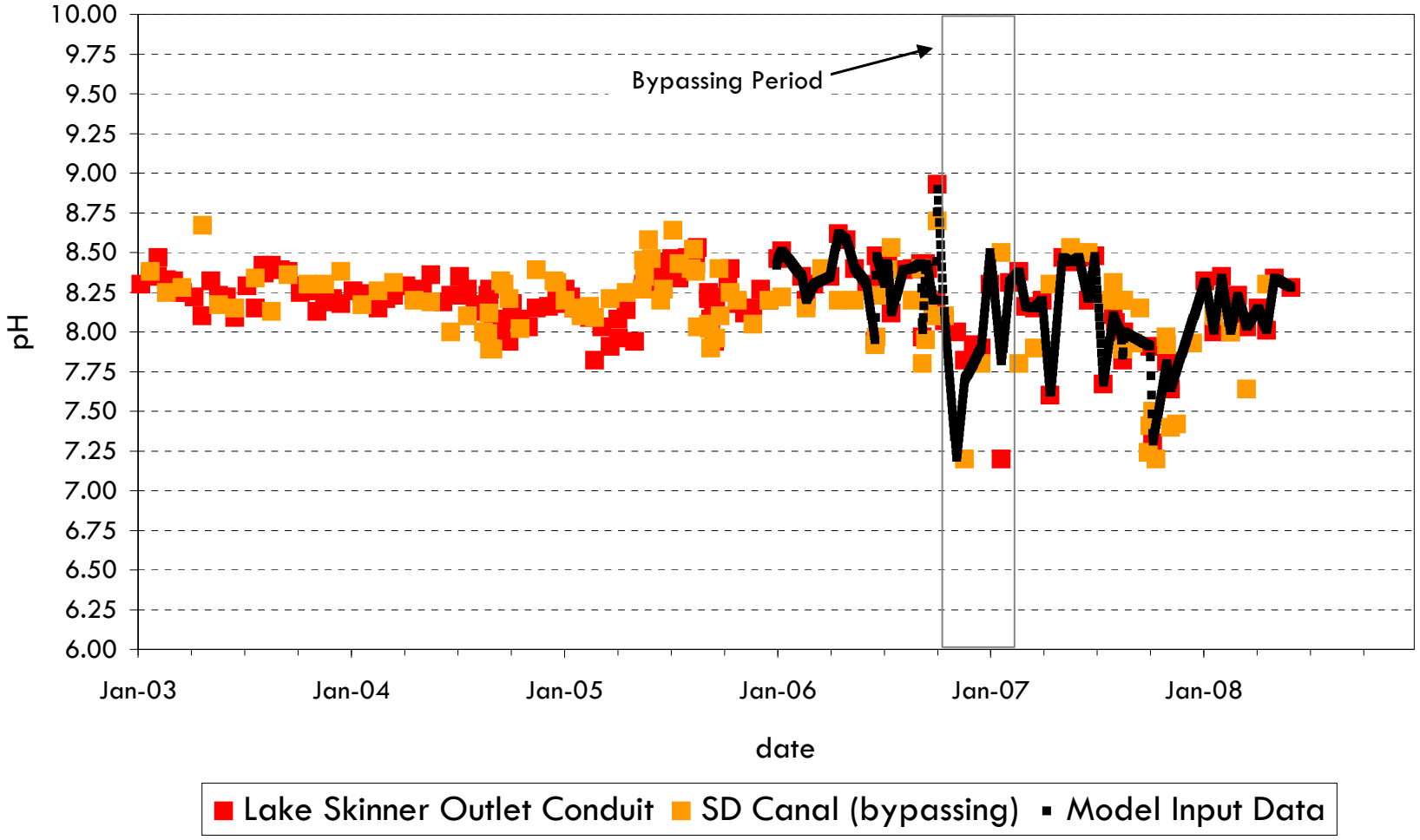

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Figure C-29

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San Vicente Reservoir

Runoff Inflow Ammonia

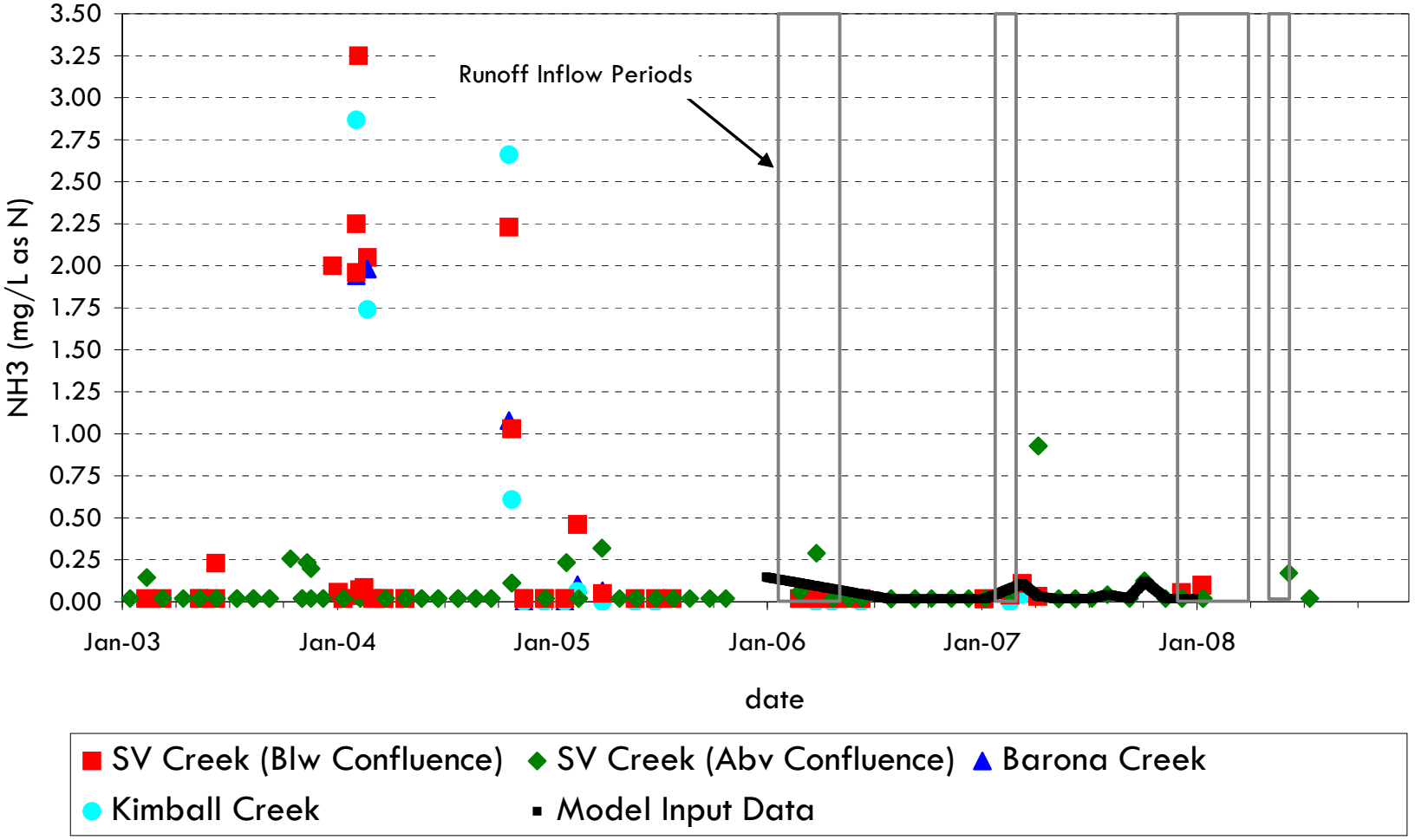

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Figure C-30

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San Vicente Reservoir

Runoff Inflow Nitrate

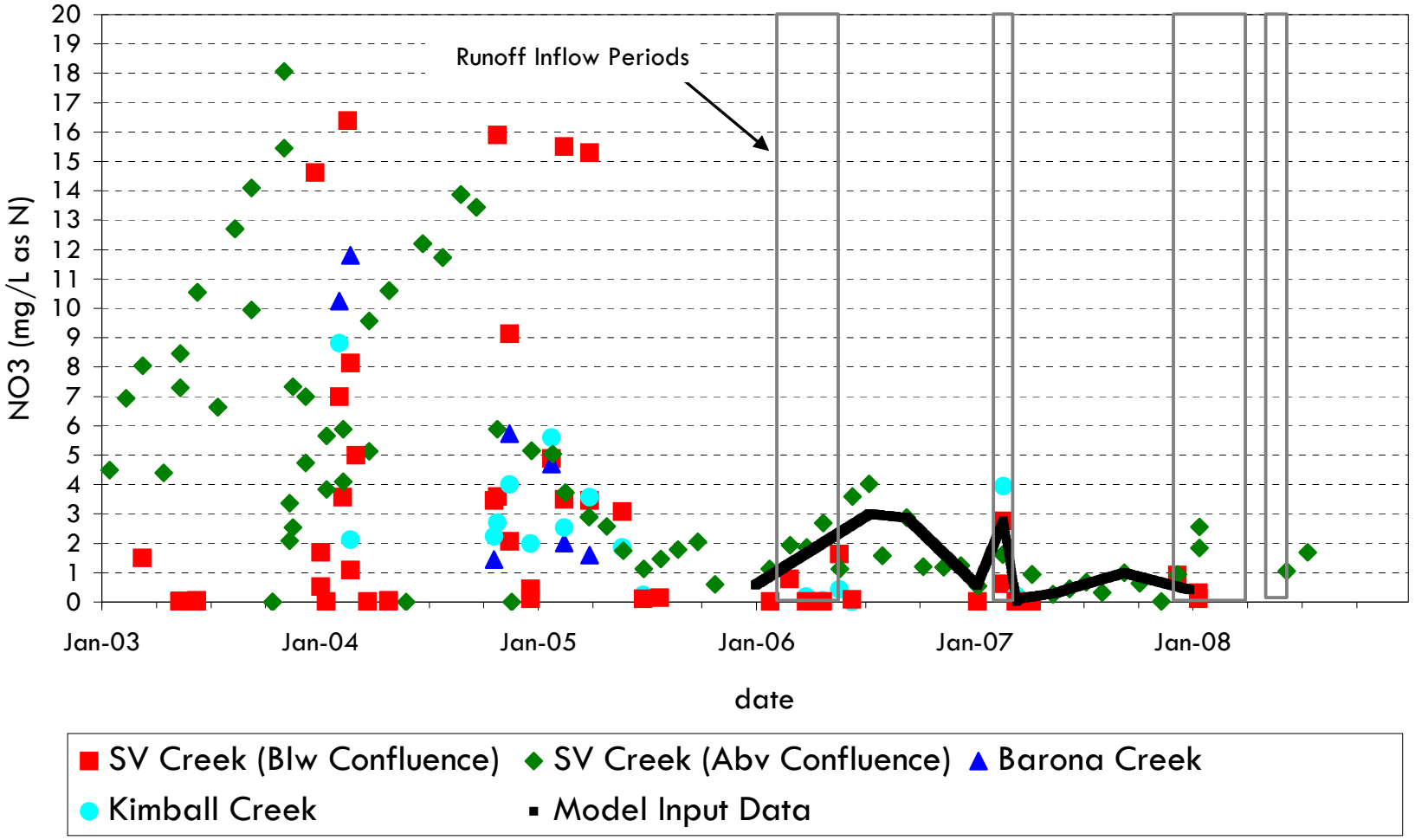

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Figure C-31

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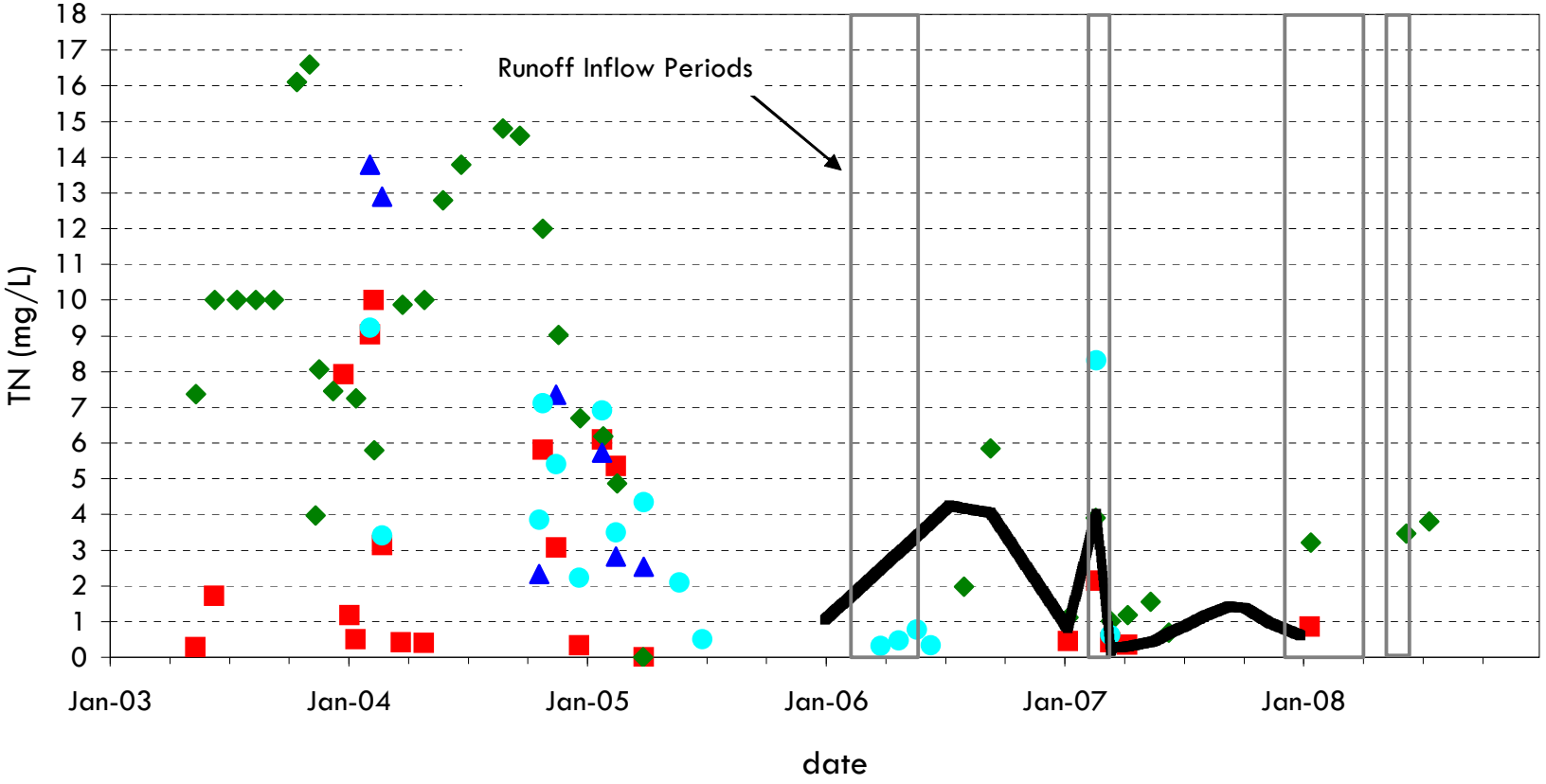
San Vicente Reservoir

Runoff Inflow Total Nitrogen



SV Creek (Blw Confluence) ◆ SV Creek (Abv Confluence) ▲ Barona Creek
● Kimball Creek ▪ Model Input Data

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Figure C-32

FLOW SCIENCE®

San Vicente Reservoir

Runoff Inflow Ortho-Phosphate

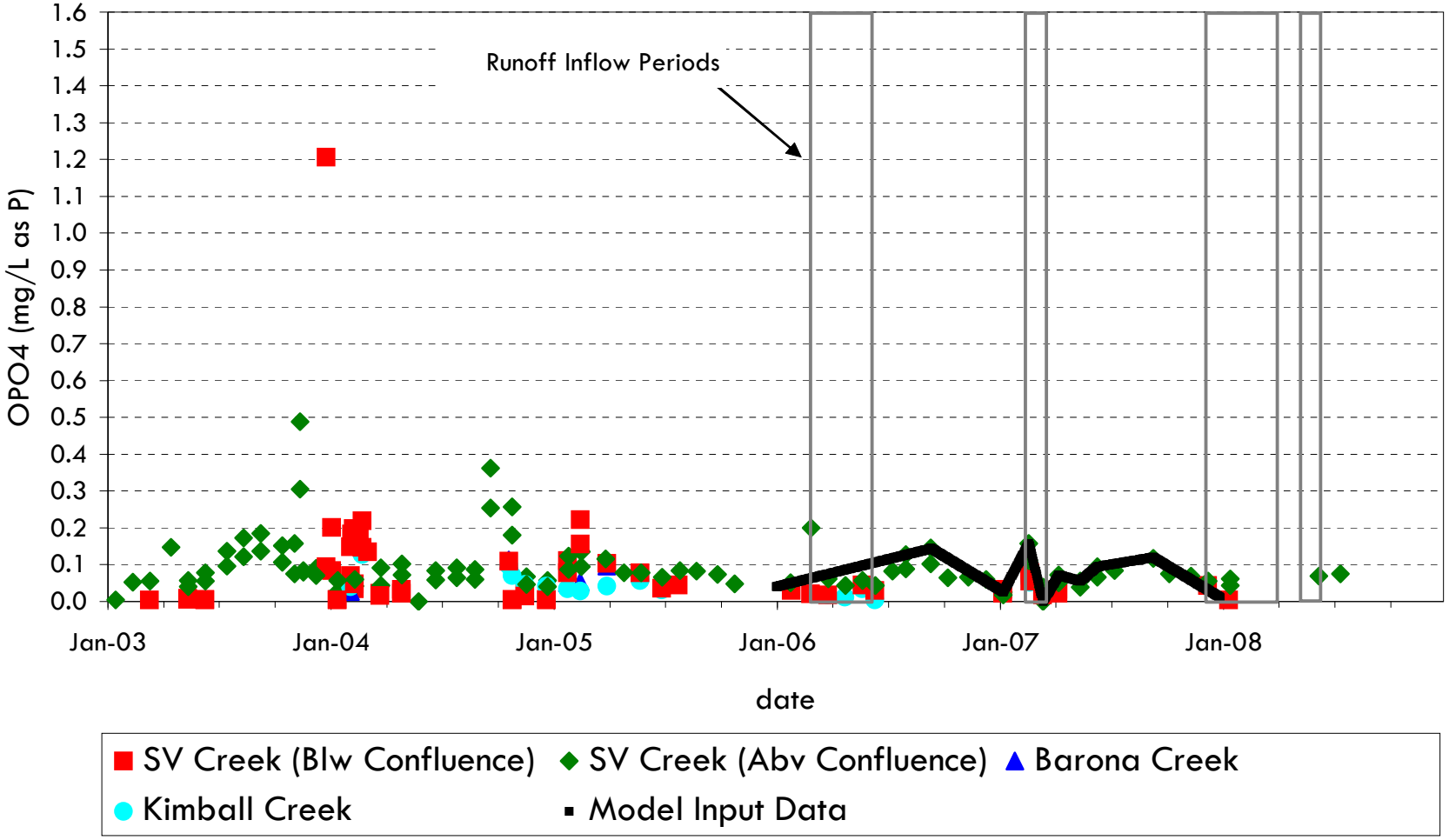

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Figure C-33

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San Vicente Reservoir

Runoff Inflow Total Phosphorus

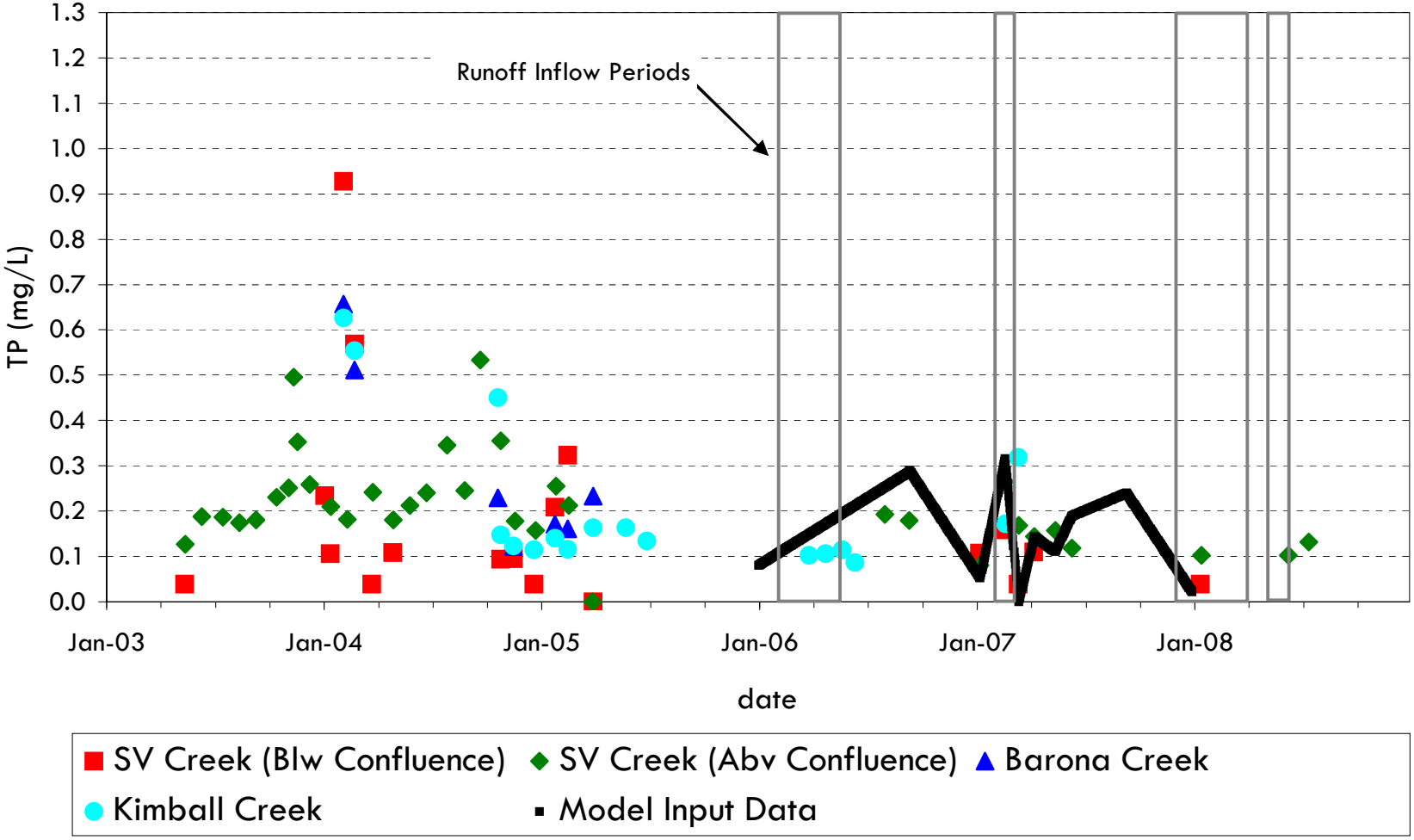

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Figure C-34

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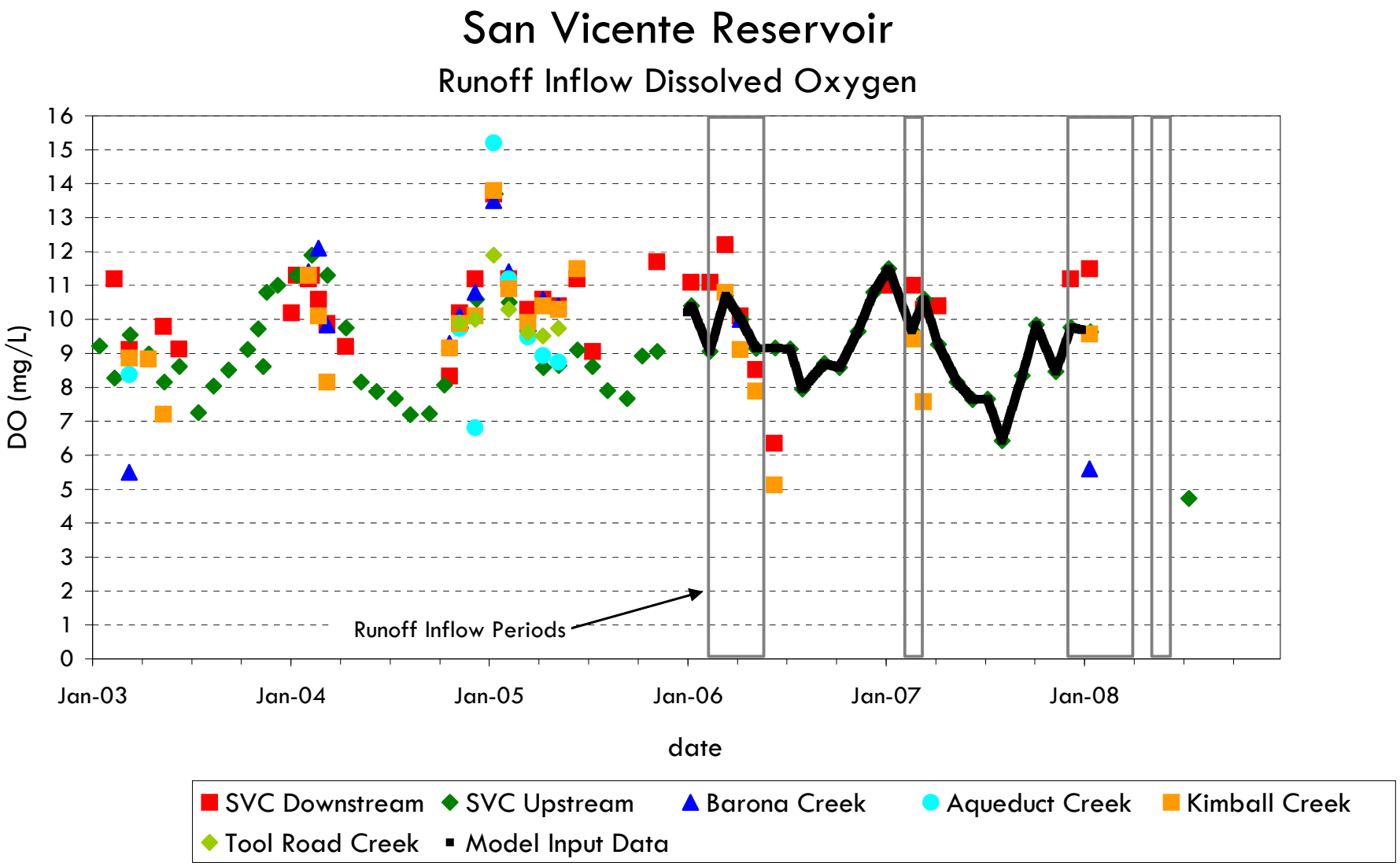

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Figure C-35

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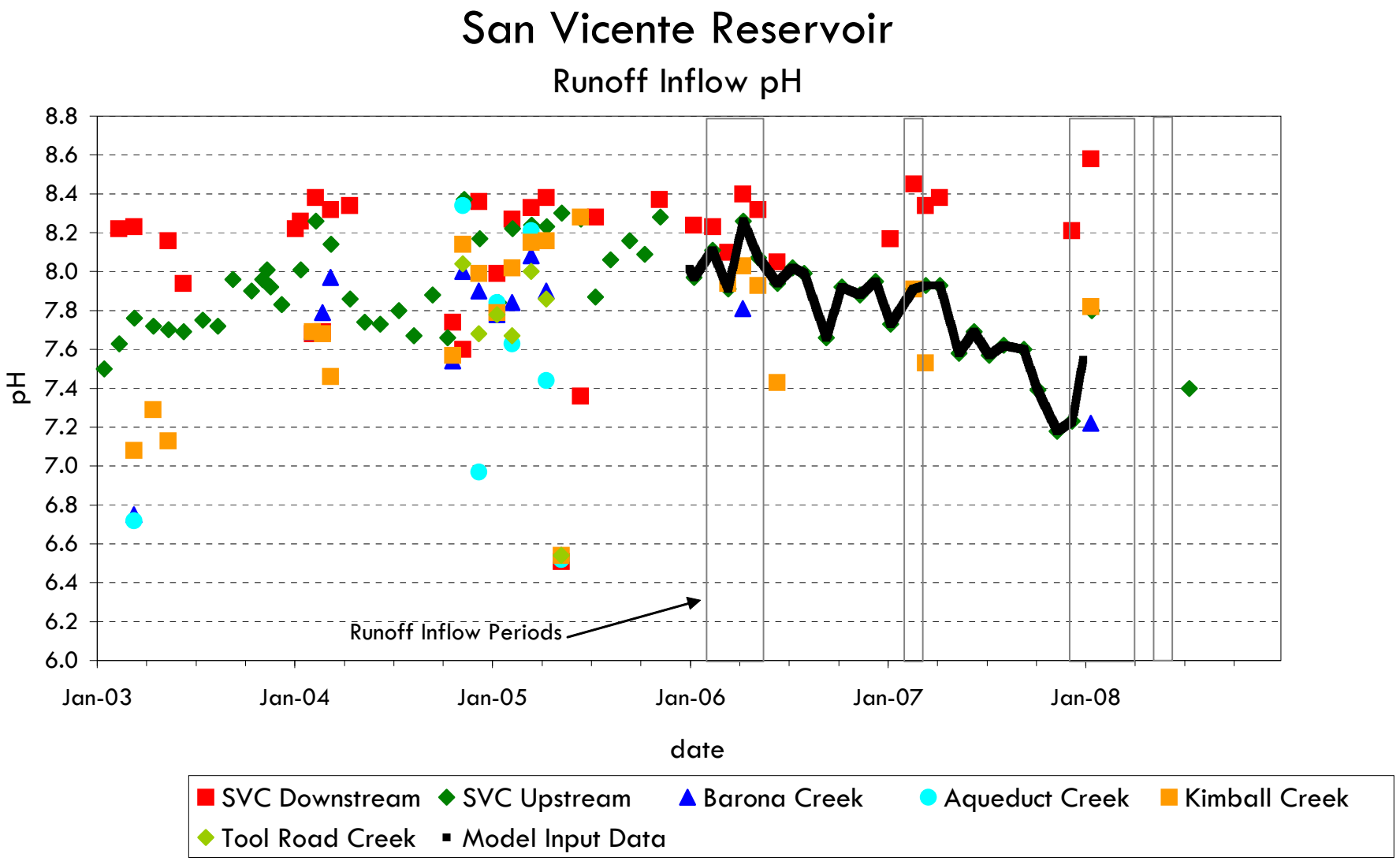

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Figure C-36

FLOW SCIENCE®

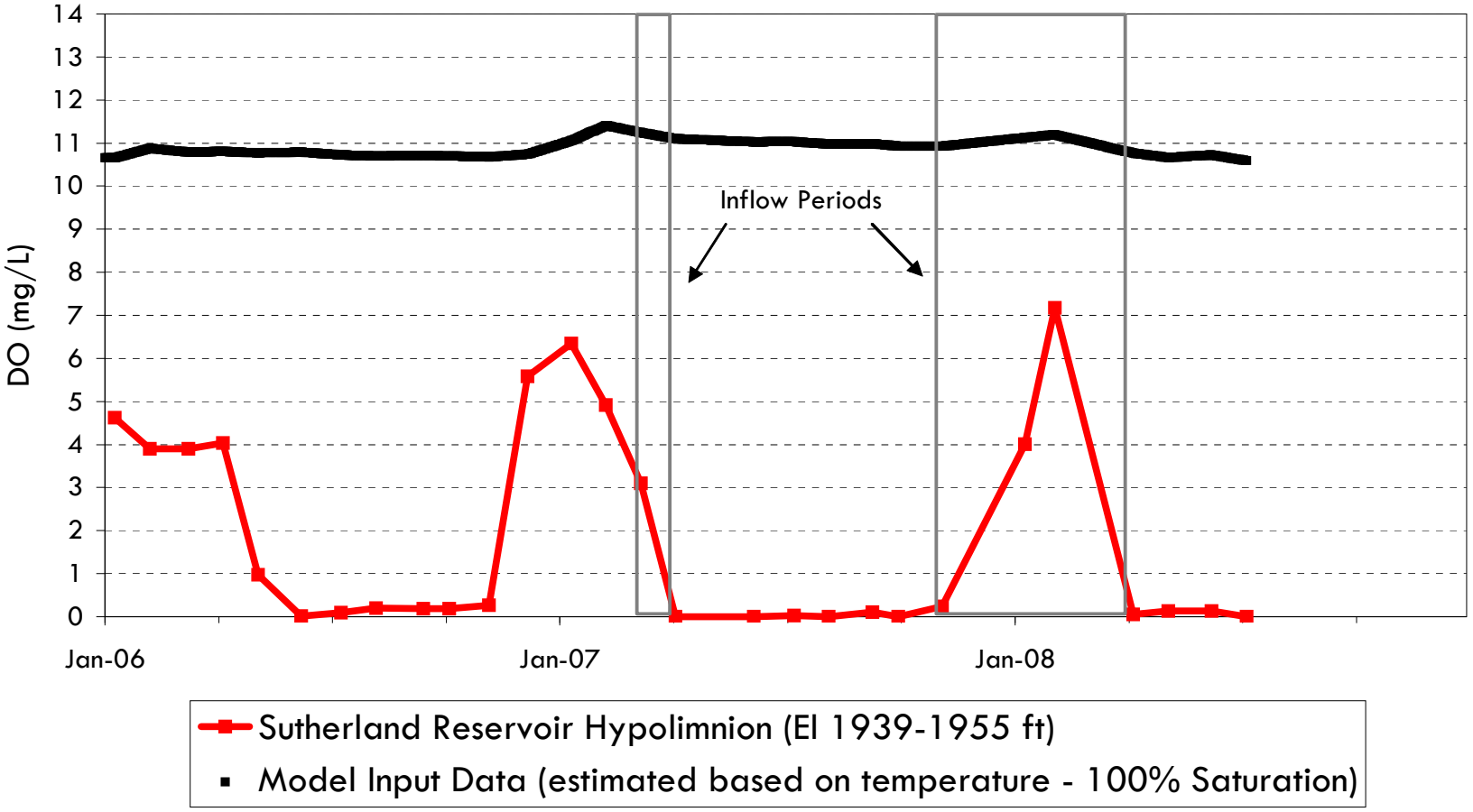
City of San Diego
Water Quality Laboratory
Sutherland Reservoir Station A Data
January 01, 2006 thru December 31, 2007

Sample Date	Nitrate (mg/L)	Total Nitrogen (mg/L)	Ortho-phosphate (mg/L)	Total Phosphorus (mg/L)
9-Jan-06	< 0.4	0.869	0.253	0.103
6-Apr-06	**< 0.4**	**0.578**	**< 0.2**	**0.109**
10-Jul-06	N/A	0.522	N/A	< 0.078
5-Oct-06	N/A	0.3	N/A	< 0.078
11-Jan-07	< 0.4	0.823	< 0.2	0.264
5-Apr-07	**N/A**	**0.62**	**N/A**	**< 0.078**
9-Jul-07	N/A	0.639	N/A	< 0.078
1-Oct-07	**< 0.4**	**0.493**	**< 0.2**	**< 0.078**
11-Jan-08	< 0.4	0.946	N/A	< 0.078
7-Apr-08	< 0.4	0.779	< 0.2	< 0.078
7-Jul-08	< 0.4	0.363	< 0.2	< 0.078

Figure C-37

San Vicente Reservoir

Sutherland Reservoir Dissolved Oxygen Near Outlet (El 1940 ft)



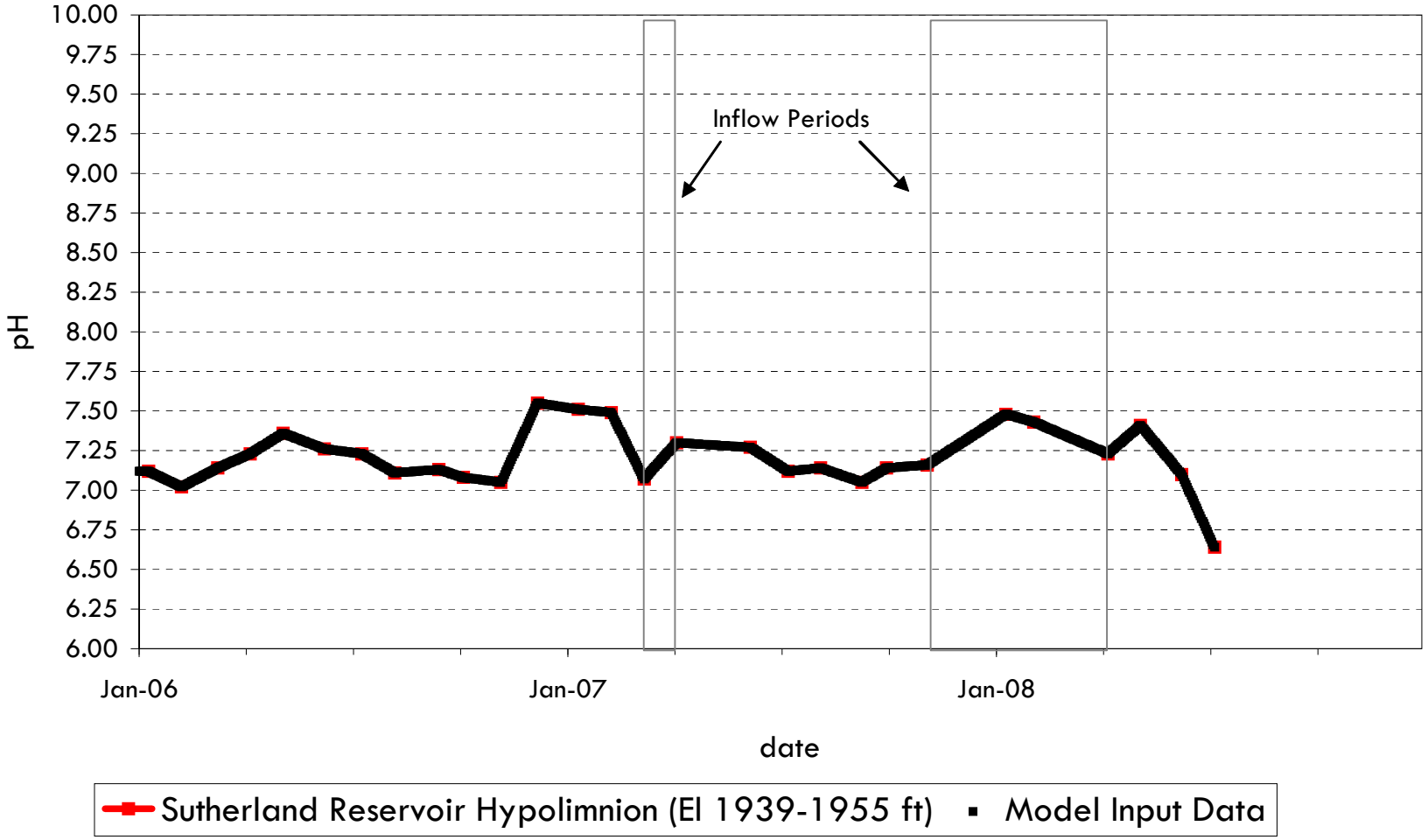
FSI V094005
May 01, 2012

Figure C-38

FLOW SCIENCE®

San Vicente Reservoir

Sutherland Reservoir pH Near Outlet (El 1940 ft)



FSI V094005
May 01, 2012

Figure C-39

FLOW SCIENCE®

San Vicente Reservoir

Sutherland Reservoir Chlorophyll a Near Outlet (El 1940 ft)

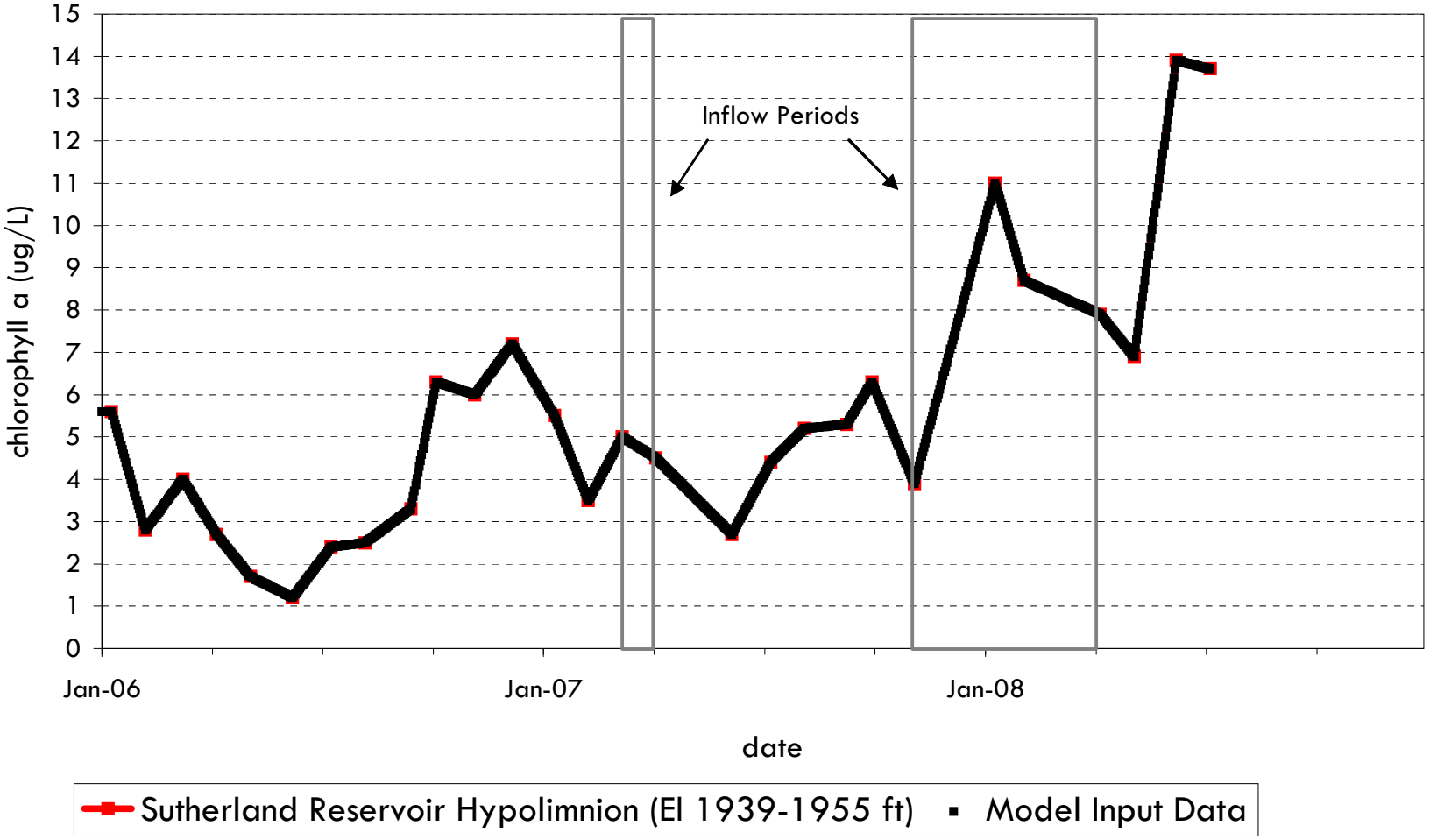


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Figure C-40

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APPENDIX D

LIST OF ANIMATIONS

INSTRUCTIONS FOR INSTALLING AND USING FRAMER TO VIEW ANIMATION FILES

Installation of Framer

Copy the files from the CD(s) to a directory on your computer.

Running Framer

1) In the Start Menu, choose "run." In this window, type "framer.exe." This should open a "Framer Open File" window, in which you find the proper directory and choose the file that you wish to view.

2) Commands for running the animation files are in the toolbar in the upper left corner of the framer window.

LIST OF ANIMATIONS

1) Appendix D_SVR_Aqueduct_Tracer.rm

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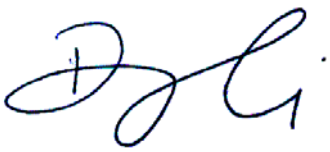
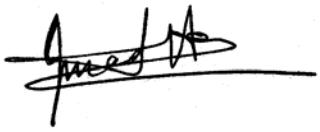
420 Neff Avenue, Suite 230, Harrisonburg, VA 22801
(540) 442-8433 • FAX (540) 442-8863

Water Purification Demonstration Project: Limnology and Reservoir Detention Study of San Vicente Reservoir - Hydrodynamic Modeling Study

Prepared for
City of San Diego
600 B Street, Suite 600,
San Diego, CA 92101





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FSI V094005
May 01, 2012

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SUMMARY

BACKGROUND

San Vicente Reservoir (SVR) is located near Lakeside, California, and is used as a source of drinking water supply by the City of San Diego (City), its owner and operator. The reservoir currently has a capacity of about 90,000 acre-feet (see **Figure 1**). It is undergoing an enlargement that will raise the dam 117 feet and increase the reservoir's storage to 247,000 acre-feet at the spillway level (or 242,000 acre-feet at the maximum operation level). The City is considering an option to augment SVR supply by bringing advanced purified recycled water (*i.e.,* purified water) from the advanced water purification facility to SVR. The purified water would be blended with other water in the reservoir. The current project – the Water Purification Demonstration Project (Demonstration Project) – will not actually put any purified water into the reservoir; rather it will study and model the reservoir augmentation process. A component of the Demonstration Project is the Limnology and Reservoir Detention Study of San Vicente Reservoir (Limnology Study).

As part of the Limnology Study, Flow Science Incorporated (FSI) has developed a three-dimensional water quality model that is used to evaluate hydrodynamic and water quality effects of using purified water to augment SVR. After the model was developed, its results were compared to existing field data and documented in the Calibration Technical Memorandum (TM) submitted to the City in 2010 (FSI, 2010). The Calibration TM has been peer-reviewed by the National Water Research Institute Independent Advisory Panel (NWRIIAP) that was assembled for the review of the City's Demonstration Project. After implementing suggestions proposed by the NWRIIAP, the model was deemed by NWRIIAP to be "an effective and robust tool, for 1) simulating thermoclines and hydrodynamics of the San Vicente Reservoir; 2) assessing biological water quality for nutrients; 3) assessing options for the purified water inlet location" (NWRI, 2010).

HYDRODYNAMIC EFFECTS OF RESERVOIR EXPANSION

In order to understand the background conditions where purified water will be stored, the hydrodynamic changes due to the expansion prior to adding purified water were first examined. This was accomplished by running a simulation that uses the same reservoir conditions (climate, inflow and outflow parameters etc.) as the 2006-2007 calibration simulation except for using a higher initial reservoir volume that is close to a full pool. The results from this simulation were compared against those from the original calibration simulation. Based on the comparisons, the following conclusions can be drawn:

- The expanded reservoir is predicted to start stratifying in about March of each year. In the spring and summer, the stratification will intensify. In the fall, the thermocline will start deepening appreciably until the reservoir becomes fully mixed in late fall or early winter. As a result, the reservoir is predicted to be stratified from about March to December, and will be destratified from December to February.

- Reservoir expansion will increase the volume of the hypolimnion but will have a negligible effect on the thermocline depth when the reservoir is stratified. Both surface and bottom reservoir temperatures are expected to remain unchanged due to increased water depth.

RESULTS FOR VARIOUS OPERATING SCENARIOS USING THE DESIGN PURIFIED WATER INLET LOCATION

The main objectives of this study were to use the calibrated and validated SVR computer model to determine the effectiveness of SVR as an environmental buffer and barrier for purified water introduced into SVR, and to evaluate any hydrodynamic changes in SVR induced by the purified water. To achieve these goals, reservoir simulations were conducted to evaluate a number of proposed future reservoir operating scenarios. Firstly, a Base Case simulation was performed to evaluate SVR under expected typical future conditions. This scenario considered a reservoir under median expected storage and normal expected operations. After that, a case was considered whereby no purified water is introduced in the reservoir, enabling a quantification of the effects of purified water addition on the reservoir behavior. Further scenarios were modeled to consider somewhat extreme operations: a scenario with an extended drought and another with emergency drawdown. These scenarios and associated annual flow volumes from various sources are listed in **Table S-1**. The simulations discussed in this section all utilized the Design Purified Water Inlet Location (see **Figure 1** for the location) as the point of release for purified water flow into SVR. Port #2 at the reservoir outlet tower structure was used for all water withdrawals from the reservoir throughout this study.

In these simulations various hypothetical tracers were added to the purified water inflow to illustrate the transport and mixing of the purified water within the reservoir. In particular, decaying tracers (decay rate of 1 log per month, *i.e.*, a reduction in concentration by a factor of 10 per month) were used to study the dilution and inactivation of potential pathogens entering the reservoir and to evaluate the ability of the reservoir to reduce pathogen concentrations before they reach the reservoir outlet. The decaying tracer was continuously released with the purified water inflow at a constant

concentration throughout the entire modeling period. In addition, hypothetical conservative (that is, non-decaying) tracers were added to the purified water inflow in order to simulate the potential effects of elevated concentrations of chemical constituents in the purified water entering SVR after "excursion events" at the water purification facility. These conservative tracers were tracked to determine the dilution and lag time provided by the reservoir (*i.e.*, the time interval between the release of the tracer and peak reservoir outflow concentration). In all simulations, such tracers were added to the reservoir's inflow over a 24-hour period and were thus referred to as 24-hour conservative tracers.

Table S-1. Modeled Operating Scenarios[1,2]

Operating Scenarios	Description	Initial /Final Reservoir Volume (acre-feet)	Annual Purified Water Inflow (acre-feet/year)	Annual Aqueduct inflow (acre-feet/year)	Annual Reservoir Outflow (acre-feet/year)
Base Case	median expected storage and normal expected operations	155,000 /155,000	15,000	3,000	19,000
No Purified Water	no purified water additions and an equal reduction in reservoir outflow	155,000 /155,000	0	3,000	4,000
Extended Drought	a hypothetical two-year drought situation	155,000 /100,000	15,000	3,000	48,000
Emergency Drawdown[3]	a situation where a total of 66,000 acre-feet water is withdrawn from the reservoir in January and February of Year 2 and the reservoir is subsequently refilled by adding 66,000 acre-feet water from the Aqueduct between March and July in Year 2	200,000 /200,000	15,000	69,000	85,000

Note: 1. There are no water transfers from Sutherland Reservoir into SVR.
2. Runoff flow rate is 4,500 acre-feet/year for all scenarios.
3. The table lists the flow volumes for Year 2 for this scenario. Flow volumes for Year 1 are the same as those for the Base Case.

Based on the simulation results, the following conclusions and observations are made for the Base Case:

- The addition of purified water in the expanded reservoir is predicted to slightly deepen the thermocline (*e.g.,* by less than 3 ft in September) and reduce conductivity in the reservoir (compared to the Calibration Run).

- The purified water generally has a lower density (lower conductivity and higher temperature) than the ambient reservoir water. This will cause the purified water to initially spread along the surface of the reservoir near the purified water inlet location. In the stratified reservoir period (typically March to December), the purified water will rapidly mix within the entire epilimnion. As the thermocline gradually deepens, the purified water will gradually approach successively lower ports on the reservoir outlet tower.

- In the unstratified period (December to February), the purified water is predicted to initially flow along the reservoir's surface, but then it will quickly mix over the entire depth, achieving rapid dilution over the entire reservoir volume.

- The proposed withdrawal strategy at SVR will generally utilize deeper ports (Port #2 was considered to be the open port throughout this investigation). Since the purified water will generally flow into the reservoir above the thermocline in the stratified period, it is predicted to typically take several weeks or months for newly released purified water to appear at the reservoir outlet, after undergoing large dilution (*i.e.*, achieving a dilution of at least 2,000). In the reservoir destratified period, the simulations indicate that the purified water can appear at the reservoir outlet within days or weeks after release, but only after undergoing significant dilution (*i.e.*, achieving a dilution of at least 2,000).

- For a decaying tracer released with the purified water (a surrogate for pathogens), the reservoir outflow from the reservoir is predicted to achieve at least a 2-log reduction[1] (100:1 reduction in concentration) in the unstratified period. In the stratified period, the reservoir will provide significantly higher reductions (as high as 9 logs; that is, a 1 trillion reduction).

[1] A log reduction is defined as a 10-fold reduction.

- For a 24-hour conservative tracer that enters the reservoir the simulations indicate that a dilution of at least 2,000 can be obtained in the reservoir outflow.

In the following, conclusions and observations for the Extended Drought and Emergency Drawdown scenarios are listed based on the simulation results. It should be noted that the release dates of the 24-hour conservative tracers for these two scenarios are different from those for the Base Case. The selection of 24-hour conservative tracer release dates for Extended Drought and Emergency Drawdown scenarios was based on identifying critical periods in which the highest reservoir outflow concentrations are most likely to occur (the timings for the 24-hour conservative tracer release for the Base Case were distributed more evenly over the year). From our understanding of the variations in 24-hour conservative tracer release concentrations in the Base Case, the most critical periods are expected to meet the following three conditions: 1) the reservoir is almost or fully mixed vertically; 2) the reservoir water volume is at a minimum; and 3) the occurrence of Santa Ana wind events (events where prevailing winds are expected to rapidly drive purified water introduced at the east side of the reservoir directly toward the reservoir outlet located near the southwest end of the reservoir).

- For a decaying tracer in the purified water inflow under the Extended Drought scenario, the analyses indicate that the reservoir can achieve a 2-log reduction in tracer concentration in the unstratified period and significantly higher values (typically 4-8 log reduction) for the remainder of the year. The minimum predicted dilution and its corresponding lag time for a 24-hour conservative tracer are about 900 and 5 days, respectively, and occurs at the end of Year Two when the reservoir volume is lowest.

- For a decaying tracer in the purified water inflow under the Emergency Drawdown scenario, the results indicate that the reservoir can achieve a 2-log reduction in the unstratified period and significantly higher values (typically 4-10 log reduction) for the remainder of the year. The minimum predicted dilution and its corresponding lag time for a 24-hour conservative tracer are about 1,400 and 8 days, respectively. The minimum predicted dilution here is higher than those obtained from both the Base Case and the Extended Drought scenarios, a result of the larger reservoir volume considered in the Emergency Drawdown Scenario during the winter months.

EFFECT OF PURIFIED WATER INLET LOCATION

Various purified water inlet locations were also evaluated under various operating conditions to examine the effects of varying the purified water inlet location. A total of four different purified water inlet locations were considered under the Base Case operating scenario. These are: the Design Purified Water Inlet Location, Existing Aqueduct Purified Water Inlet Location, New Aqueduct Purified Water Inlet Location, and Barona Arm Purified Water Inlet Location. The Design and New Aqueduct Purified Water Inlet Locations were further evaluated under the Extended Drought operating scenario. All simulations conducted for varying the purified water inlet locations are listed in **Table S-2** and results for the decaying tracer and 24-hour conservative tracers from these simulations are presented in **Table S-3**. Note that the release dates of the 24-hour conservative tracers for these runs are different from those for the runs listed in **Table S-1**.

Based on the simulation results, the conclusions and observations on the effects of varying the purified water inlet location are summarized as follows:

- In the stratified season, utilizing different inlet locations to introduce purified water into SVR is predicted to have little effect on both the decaying and 24-hour conservative tracer concentrations in the reservoir outflow under all scenarios considered (*i.e.*, Base Case and Extend Drought Scenarios).

- For the Design, Existing Aqueduct and Barona Arm Purified Water Inlet Locations, moving the purified water inlet location closer to the reservoir outlet is predicted to generally (but not always) result in slightly higher values in the reservoir outflow concentrations for both the decaying and 24-hour conservative tracers during the unstratified period. However, a minimum 2-log reduction for the decaying tracer and a minimum predicted dilution of 909 for the 24-hour conservative tracer are achieved under all scenarios considered (*i.e.*, Base Case and Extended Drought Scenarios). The lag times for the 24-hour conservative tracer range from 5 to 276 days.

- For the New Aqueduct Purified Water Inlet Location, the modeling shows higher peak concentration values for a 24-hour conservative tracer release in the reservoir outflow in the unstratified period than other purified water inlet locations due to its proximity to the reservoir outlet structure. The minimum achieved dilution is found to be about 385 for the Base Case and 200 for the Extend Drought scenario. The corresponding lag times are typically less than 2 days.

Table S-2. Simulations Conducted for Examining Various Purified Water Inlet Locations

Operating Scenario	Purified Water Inlet Location
Base Case	Design Purified Water Inlet Location
	New Aqueduct Purified Water Inlet Location
	Existing Aqueduct Purified Water Inlet Location
	Barona Arm Purified Water Inlet Location
Extended Drought	Design Purified Water Inlet Location
	New Aqueduct Purified Water Inlet Location

Table S-3. Summary of Simulation Results Using Various Purified Water Inlet Locations

Inlet Location	Operating Scenarios	Minimum Reduction for the Decaying Tracer	Lowest Minimum Dilution for 24-hour Conservative Tracers	Minimum Lag Time[1]
Design Purified Water Inlet Location	Base Case	2-log Reduction	2222	14 days
	Extended Drought	2-log Reduction	909	5 days
Existing Aqueduct Purified Water Inlet Location	Base Case	2-log Reduction	1000	10 days
Barona Arm Purified Water Inlet Location	Base Case	2-log Reduction	1923	39 days
New Aqueduct Purified Water Inlet Location	Base Case	Near 2-log Reduction	385	0.8 days
	Extended Drought	Near 2-log Reduction	196	1.3 days

Note: 1. The minimum lag time does not necessarily correspond to the 24-hour conservative tracer released that results in lowest minimum dilution

1. INTRODUCTION

1.1 BACKGROUND

San Vicente Reservoir (SVR) is located near Lakeside, California, and is used as a drinking water supply by the City of San Diego (City), its owner and operator (**Figure 1**). The reservoir currently has a capacity of about 90,000 acre-feet. It is undergoing an enlargement that will raise the dam by 117 feet and increase the reservoir's storage to 247,000 acre-feet at the spillway level (or 242,000 acre-feet at the maximum operation level).

A water reuse project, entitled Reservoir Augmentation, is being studied by the City. If implemented at full-scale, Reservoir Augmentation would bring advanced purified recycled water (*i.e.,* purified water) from the advanced water purification facility to SVR via a pipeline. The purified water would be blended with other water in the reservoir. The current project – the Water Purification Demonstration Project (Demonstration Project) – will not actually put any purified water into the reservoir; rather it will study and model the Reservoir Augmentation process. A component of the Demonstration Project is the Limnology and Reservoir Detention Study of San Vicente Reservoir (Limnology Study).

As part of the Limnology Study, Flow Science Incorporated (FSI) has developed a three-dimensional water quality model that is used to evaluate hydrodynamic and water quality effects of using purified water to augment SVR. After the model was developed, its results were compared to existing field data and documented in the Calibration Technical Memorandum (TM) submitted to the City in 2010 (FSI, 2010). The Calibration TM has been peer-reviewed by the National Water Research Institute Independent Advisory Panel (NWRIIAP) that was assembled for the review of the City's Demonstration Project. The model was deemed by NWRIIAP, with some fine-tuning, as "an effective and robust tool, for 1) simulating thermoclines and hydrodynamics of the San Vicente Reservoir; 2) assessing biological water quality for nutrients; 3) assessing options for the purified water inlet location" (NWRI, 2010). After the review, all the suggestions by NWRIIAP on fine-tuning the model have been addressed or implemented. Findings and results from the Calibration TM that are relevant to the work presented here are summarized in the next section.

This Technical Memorandum focuses on using the calibrated and validated SVR hydrodynamic model to evaluate the dilution, mixing, and circulation of the purified water in the expanded SVR under various projected reservoir operating scenarios. The detailed results include establishing dilution for purified water in the reservoir; assessing the potential for short-circuiting of purified water between the purified water inlet location and the dam outlet structure; and evaluating various potential purified water

reservoir inlet locations. This work has been performed by Flow Science Incorporated (FSI) of Pasadena, California, under contract to the City of San Diego, California. It is noted that another report that focuses on reservoir water quality (as opposed to hydrodynamics and mixing, which is the focus of this TM) within SVR will be forthcoming.

1.2 DESCRIPTION OF THE SVR MODEL

The three-dimensional SVR model consists of two coupled computer models that simulate both the hydrodynamics and water quality of SVR. These two models are the Estuary Lake and Coastal Ocean DYnamics Model (ELCOM) for hydrodynamic simulation and the Computational Aquatic Ecosystem DYnamics Model (CAEDYM) for water quality simulation. ELCOM requires the user to define boundary conditions, physical inputs, meteorological inputs, and bathymetry in a grid structure. The output from ELCOM consists of predictions for water velocities, temperature, salinity (*i.e.*, conductivity), and concentrations of decaying or conservative tracers in space and time within the body of water. CAEDYM is the water quality module that can be coupled to ELCOM. CAEDYM simulates changes in dissolved oxygen (DO), nutrients, organic matter, pH and chlorophyll *a*. ELCOM can be run independently of CAEDYM, as is the case for the work presented in this report, but CAEDYM requires the use of ELCOM. The coupled models are used to study the spatial and temporal relationships between physical, biological, and chemical variables in SVR. Details on ELCOM and CAEDYM can be found in **Appendix A**.

The modeling domain includes both the existing reservoir as well as the proposed expanded reservoir (**Figure 1**). A grid with a horizontal resolution of 50 × 50 m is used in this investigation – similar to the grid used in the calibration (**Figure 2**). A variable grid size was used in the vertical dimension with a grid size of 1.64 ft (0.5 m) near the surface and expanding in size with depth. This variable size grid enables the highest resolution in regions of steep gradients, while maintaining the execution time of the model within a reasonable span. The calibration was conducted for the two-year period of 2006 and 2007. The input data required by the calibration were either based on the measured data or derived from these data. ELCOM requires limited calibration effort in that the physical aspects of water movements in reservoirs are fairly well understood.

The calibrated model shows good agreement with the measured data for both water temperature and conductivity. The Calibration TM presents various comparisons between model and data. In the following, we discuss the highlights of the Calibration TM. For example, the onset and duration of thermal stratification as well as the deepening rate of the thermocline were predicted accurately by the model (**Figure 3**). In particular both the data and model show that winter water temperatures in the fully mixed reservoir are nearly uniform in the vertical direction at a value near 12 ^{o}C to 13 ^{o}C. By

April, increased solar radiation warms the water surface up to 17 ^{o}C to 18 ^{o}C and thermal stratification starts to develop. This process intensifies and by summer (July through September) the surface temperatures have risen to as high as 28 ^{o}C, while the temperature in the hypolimnion remains nearly unchanged at the winter temperature of 12 ^{o}C to 13 ^{o}C. This large temperature difference indicates that a strong vertical stratification is established in the lake. The thermocline is well defined and located at a depth ranging from 30 to 40 ft as shown in **Figure 3** for both the model and the data. In the fall, surface water temperatures steadily decrease due to reduced solar radiation. This generates convective plumes, which combined with more effective wind mixing, deepens the thermocline to a depth of 60 ft by November. The stratification continues to weaken until the reservoir totally destratifies and becomes fully mixed at the end of the year or beginning of the following year. The variation of conductivity in the reservoir was also well captured by the model (**Figure 4**).

After the model was calibrated, a validation was performed to compare the model against the results of previous tracer field studies. The field studies involved two separate episodes of tracer release in the reservoir (winter 1995 and summer 1995, FSI, 1995). The field studies clearly showed the impacts of stratification (or lack thereof) on the mixing and dispersion of the tracer. The ELCOM model was capable of replicating the main features of the tracer study (**Figures 5** and **6**). In particular, the model was capable of replicating the sinking of the inflow in the winter and its dispersion with time, as well as capturing the magnitude of the dilution (**Figure 5)**. In the summer, the model accurately predicted the insertion of the inflow at the level of the thermocline (**Figure 6)** and the gradual horizontal dispersion and dilution of the inflowing tracer. This validation provides verification and assurance that the model performance is reliable and accurate. Other results of the validation are discussed in the Calibration TM (FSI, 2010).

In conclusion, the SVR model is capable of replicating the stratification, concentration of tracers, as well as water movement in the reservoir. The simulation results are generally in good agreement with the field measurements. Thus the model provides "an effective and robust tool, for simulating thermoclines and hydrodynamics of the San Vicente Reservoir" and for "assessing options for the purified water inlet location" (findings from NWRIIAP, NWRI, 2010). The further ability of the model in "assessing biological water quality for nutrients" will be the subject of a subsequent Technical Memorandum.

1.3 HYDRODYNAMIC EFFECTS OF SVR EXPANSION

The existing SVR has a capacity of 90,000 acre-feet and is currently undergoing an expansion to 247,000 acre-feet that will be completed in 2013. The expanded SVR may then be used to store and dilute purified water from the advanced water purification facility. Thus, it is useful to study hydrodynamic changes due to the expansion prior to

adding purified water and understand the background conditions where purified water will be stored. This was accomplished by running a simulation that uses the same reservoir conditions (climate, inflow and outflow parameters etc.) as the 2006-2007 calibration simulation except for using a higher initial reservoir volume that is close to a full pool. The results from this simulation were compared against those from the original calibration simulation and differences between these two simulations were examined.

Figure 7 shows a comparison of water temperature for the existing reservoir (*i.e.*, the original calibration simulation) and the expanded reservoir (*i.e.*, the calibration simulation with a higher initial reservoir volume). The depth and deepening rate of the thermocline are fairly similar between these two simulations, indicating that the reservoir expansion will cause no major changes in the thickness of the epilimnion and the volume of the epilimnion is somewhat larger, but mostly because of the increase in surface area. However, the thickness and volume of the hypolimnion will be significantly larger for the expanded reservoir. With a larger hypolimnion, the expanded reservoir will destratify a few days later than the existing reservoir in the late fall.

Figure 8 shows a conductivity comparison between the existing and expanded reservoir. Note that conductivity is used to represent salinity in the reservoir throughout this report. As shown, the conductivity decreases in the spring of 2006 for the existing reservoir, a result of the low-conductivity levels from the Aqueduct inflow. For the expanded reservoir, the footprint of the low-conductivity Aqueduct inflow is attenuated in the early spring of 2006 because the Aqueduct inflow mixes with a significantly larger volume of water in the expanded reservoir. This shows that, compared to the existing reservoir, the expanded reservoir will provide a larger buffer that attenuates the effects of fluctuations in the inflow on the water quality in the reservoir. Other than in the spring of 2006, there is little difference in simulated conductivity between the expanded and existing reservoir.

In summary, the reservoir expansion is predicted to cause little change in the temperature, epilimnion depth and water conductivity in the reservoir but it will significantly enlarge the hypolimnion and provide a larger volume of water for dilution.

1.4 TECHNICAL MEMORANDUM ORGANIZATION

This TM provides a detailed description of hydrodynamic effects of discharging purified water into the reservoir, based on the SVR modeling results. **Chapter 2** of the report describes the study objectives and approach. **Chapter 3** presents details of the hydrodynamic simulation results. Conclusions and discussion are provided in **Chapter 4**.

2. STUDY OBJECTIVES AND APPROACH

2.1 STUDY OBJECTIVES

SVR provides a large volume of water for dilution of the repurified water, as well as a storage place where natural assimilation can occur. By holding water for several years on average, the reservoir acts as a settling basin, as well as provides a medium where potential pathogens can decay. In the case of potential spikes in concentration of chemical constituents in the purified water inflow resulting from "excursion events" at the advanced water purification facility, the reservoir also serves as an environmental barrier between the advanced water purification facility upstream and the drinking water treatment facility downstream. The reservoir acts as a barrier in two important ways. First, it offers a large volume of water for dilution and blending of incoming water. Second, the reservoir provides a lag time between the inflows and outflows.

The objectives of this study are to use the calibrated and validated SVR computer model to determine the effectiveness of SVR as an environmental buffer and barrier for purified water and to evaluate hydrodynamic changes in SVR induced by the addition of purified water. Specifically, answers to the following four questions are sought using the SVR model:

- Does purified water cause any hydrodynamic changes in the reservoir?
- Does the reservoir provide a robust year-round pathogen barrier?
- Does the reservoir provide substantial mixing and blending to reduce the effects of potential spikes in concentration of chemical constituents in the purified water inflow resulting from "excursion events" at the advanced water purification facility?
- Does the purified water inlet location within the reservoir affect the above findings?

2.2 APPROACH

To address the aforementioned questions, an analysis approach has been developed in conjunction with the City. It includes using decaying and conservative tracers as surrogates for pathogen and chemical constituents in the purified water to examine the fate and dilution of such constituents that flow into SVR. To achieve that, various tracers were added at specified times to the purified water inflow at a nominal concentration of 100. The movement of purified water in the reservoir is then visually illustrated by

following the contours of the tracer concentration. The dilution achieved by purified water at any location can be obtained by dividing the source tracer concentration (*i.e.*, 100) by the simulated tracer concentration at that location.

It is noted here that the released tracers employed in this study consisted of two types. The first type of tracer was used to simulate viral pathogens that are known to decay with time. As suggested by Welch (2011) and accepted by the NWRIIAP, a first-order exponential decay function with a decay rate of one log per month (half life = 9 days, or decay by a factor of 10 each month) was used to represent a reasonable and conservative method for estimating pathogen decay at SVR. The decaying tracer was continuously released in the purified water inflow at a nominal constant concentration of 100 throughout the whole two-year modeling period. A second type of tracer was used to simulate non-decaying constituents in the purified water that may inadvertently enter the reservoir as a result of a potential excursion event at the advanced water purification facility. In the simulation, such tracers were added to the reservoir's inflow over a 24-hour period and were considered to be conservative (that is, non-decaying). They are thus referred to as 24-hour conservative tracers hereafter.

The specific approaches and methodologies adopted to answer the four questions stated above are the following:

- Comparison of simulated reservoir water temperature and conductivity under various reservoir operation scenarios to examine hydrodynamic changes in the reservoir.

- Comparison of concentrations of the decaying tracer in the reservoir outflow under various reservoir operating scenarios to determine pathogen reduction in the reservoir outflow.

- Selecting critical dates during both the stratified and unstratified periods for the release of the 24-hour conservative tracer (*i.e.*, releasing a conservative tracer for 24 hour period) and then examining the corresponding concentrations and peaking times of these tracers in the reservoir outflow. This allows the calculation of the dilution and lag time provided by the reservoir.

- Comparison of concentrations of decaying and 24-hour conservative tracers in the reservoir outflow originating from different potential purified water inlet locations. This allows the optimal selection of the location where the purified water may be introduced in the reservoir.

3. SCENARIO MODELING RESULTS

In order to help understand the behavior of the reservoir in future conditions if purified water is introduced into SVR, several modeling scenarios were performed. The parameters for these modeling scenarios were determined in collaboration between the City, its consultants, and Flow Science, and based on information provided by the San Diego County Water Authority (SDCWA) about the expected operational schemes for SVR. Firstly, a Base Case simulation was performed to evaluate SVR under expected typical future conditions. This scenario considered a reservoir under median expected storage and normal expected operations. After that, a case was considered whereby no purified water is introduced in the reservoir, enabling a quantification of the effects of purified water addition on the reservoir behavior. Further scenarios were modeled to consider somewhat extreme operations: a scenario with an extended drought and another with emergency drawdown. All preceding operating scenarios utilized the Design Purified Water Inlet Location (see Figure 1 for the location) as the point of release for purified water flow into SVR. Port #2 at the reservoir outlet tower structure was used for all water withdrawals from the reservoir throughout this study. Finally, four alternate inlet locations for the purified water at SVR were evaluated. In the following, we discuss the results of each of these scenarios.

3.1 BASE CASE SCENARIO

The Base Case simulated a two-year period and used the same 2006-2007 meteorological data, Aqueduct inflow water quality data, and other modeling parameters as used in the Calibration, except for the initial reservoir volume, introduction of purified water, and modified inflow and outflow rates as discussed below. The real-world wind data used as inputs for the model included several Santa Ana Wind events that occurred in the winter of each simulated year. The City provided the initial reservoir volume, inflow and outflow rates for the Base Case. The initial reservoir volume for the Base Case is considered to be near the median of the expected future conditions with a volume of 155,000 acre-feet (determined in conjunction with SDCWA). It is considered that the daily flow for all inflows and outflows is constant throughout each month and that there are no water transfers from Sutherland Reservoir into SVR. A new surface inflow, purified water inflow, was added to represent incoming purified water from the advanced water purification facility at an annual rate of 15,000 acre-feet/year. The monthly inflow and outflow volumes for the Base Case are listed in **Table 1**. The purified water inlet for the Base Case is located at the "Design Purified Water Inlet Location" shown in **Figure 1**. As suggested by the City, the multi-year averages of weekly water temperatures at North City Water Reclamation Plant were used to characterize the purified water temperature (**Figure 9**). The salinity of the purified water was considered to be constant at 100 ppm. The available withdrawal elevations on the proposed reservoir outlet are

listed in **Table 2**. In all the simulations presented herein, Port #2 was used for all water withdrawals from the reservoir.

Table 1. Monthly Reservoir Inflow and Outflow Volumes for Base Case Operating Scenario

Month	Aqueduct Inflow (acre-feet)	Runoff Inflow (acre-feet)	Purified Water Inflow (acre-feet)	Withdrawal (acre-feet)
Jan-Year 1	0	0	1440	0
Feb-Year 1	0	1,500	1590	0
Mar-Year 1	0	1,500	1480	0
Apr-Year 1	1,000	1,500	1350	0
May-Year 1	1,000	0	1230	0
Jun-Year 1	1,000	0	1090	0
Jul-Year 1	0	0	900	2200
Aug-Year 1	0	0	1020	4200
Sep-Year 1	0	0	1090	4200
Oct-Year 1	0	0	1120	4200
Nov-Year 1	0	0	1210	4200
Dec-Year 1	0	0	1480	0
Jan-Year 2	0	0	1440	0
Feb-Year 2	0	1,500	1590	0
Mar-Year 2	0	1,500	1480	0
Apr-Year 2	1,000	1,500	1350	0
May-Year 2	1,000	0	1230	0
Jun-Year 2	1,000	0	1090	0
Jul-Year 2	0	0	900	2200
Aug-Year 2	0	0	1020	4200
Sep-Year 2	0	0	1090	4200
Oct-Year 2	0	0	1120	4200
Nov-Year 2	0	0	1210	4200
Dec-Year 2	0	0	1480	0

Table 2. Available Withdrawal Elevations on Proposed Reservoir Outlet Tower

Port	Withdrawal Elevation
6	733 ft
5	708 ft
4	683 ft
3	653 ft
2	623 ft
1	593 ft

Figure 10 shows time-sequenced profiles of simulated temperature and conductivity at Station A (see **Figure 1** for Station A location) for the Base Case. In general, simulated temperatures from the Base Case are similar to those from the Calibration (**Figure 3**) in terms of range of temperature and the development and vertical location of the thermocline. The main difference between the Base Case and the Calibration is the larger hypolimnion in the larger reservoir. The simulated conductivity values for the Base case vary between 740 and 820 µS/cm and are lower than those from the calibration (*i.e.*, 740 – 880 µS/cm). This reduction is mainly due to year-round inflow of purified water with relatively low conductivity.

Figure 11 presents contours of the temperature and decaying tracer along a profile path joining the Design Purified Water Inlet Location to the reservoir outlet near the dam (See **Figure 1** for the path). On the left hand side of **Figure 11** are three snapshots of the temperature contours on 7/1 and 11/30 of Year 1 as well as 1/8 of Year 2. On the right hand side of the figure are decaying tracer concentration contours on the same date. As shown in the top frame, a strong temperature stratification exists on 7/1. At that time, the highest concentrations of the decaying tracer are above the thermocline. This is a result of the fact that the purified water has a lower density than the ambient reservoir water (combination of elevated temperature and lower salinity than the ambient). The purified water initially flows near the surface and then is quickly mixed throughout the epilimnion. While there is some horizontal gradient in tracer concentration, the values above the thermocline are nearly uniform. As the thermocline deepens (11/30 of Year 1), the decaying tracer persists in the entire epilimnion albeit at a lower concentration (due to larger volume in the epilimnion). The concentrations of tracer in the hypolimnion are very low. When the lake completely destratifies (1/8 of Year 2), the decaying tracer concentration is nearly uniform throughout the reservoir. The animations in **Appendix B** show the above phenomena on a daily cycle. Note that the animations are not included in this copy of the report and the reader can contact the City to obtain the animations if needed.

Figure 12 shows the time series of simulated decaying tracer concentrations at all available withdrawal levels (*i.e.*, ports) at the reservoir outlet tower. It should be noted

that water was only withdrawn from Port #2 and the other ports were closed during the simulation. However, it is believed that concentrations sampled at the other ports (aside from Port #2) would approximately represent the reservoir outflow concentrations if that sampled port was open and actually used for withdrawal. Also note that the y-axis in **Figure 12** features a logarithmic scale. This means, for example, with the initial purified water tracer concentration set at 100, a reservoir outflow tracer concentration at 10^{-4} represents a 6-log reduction in concentration (*i.e.*, a million-fold reduction in concentration).

As shown in **Figure 12** and in the animations in **Appendix B**, Port #5, the shallowest port, is generally located inside the epilimnion in which the incoming purified water initially resides. The decaying tracer concentrations at Port #5 remain close to 1 (2-log reduction, this is equivalent to a 100:1 reduction) throughout the simulation period. At Port #1, the deepest port on the reservoir outlet tower, decaying tracer concentrations are generally similar to those at Port #5 during the destratified winter periods, but gradually decrease at the approximate rate of 1-log per month after the onset of stratification (when Port #1 is in the hypolimnion).

As discussed above, the thermocline in the summer months serves as a barrier to inhibit mixing between the epilimnion and hypolimnion. Thus the hypolimnion becomes isolated from the newly added purified water. As a result, hypolimnetic decaying tracer concentrations drop at a rate of 1-log per month throughout the stratified period. When the deepening thermocline reaches the elevation of Port #1 in late fall or early winter, tracer concentrations rise sharply to the level present in the epilimnion. The variation patterns of tracer concentrations at other ports are similar to those at Port #1. The main difference lies in the timing when the tracer concentrations start to rise: a shallower port exhibits an earlier rise in the decaying tracer concentrations in the fall. For reservoir outflow from Port #2, the simulation results show that decaying tracer achieves a 6-log reduction during the summer months and at least a 2-log reduction for the rest of the year.

Figure 13 shows the reservoir outflow concentrations of simulated releases of 24-hour conservative tracers. The tracer releases occurred on 2/1, 4/1, 7/1, 10/1 and 12/30 in the first year of the simulation period and each release lasted for 24 hours. The general trend for all tracers is that concentrations in the reservoir outflow remain very low until the thermocline reaches the level of Port #2. Subsequently, the concentrations rise quickly to a fixed level and stay near that level for the rest of the simulation period (the fixed concentration level can be estimated by considering that the tracer is well mixed in the layer above the port). Details on the maximum tracer concentration as well as the lag time to reach the maximum after release are listed in **Table 3**.

The maximum concentrations for all 24-hour conservative tracers released with purified water remain below 0.05 in the reservoir outflow, indicating a minimum dilution

of 2,000 prior to withdrawal at Port #2 (minimum dilution is computed as the initial concentration, 100 in this case, divided by the maximum observed concentration). The shortest lag time between the release of the 24-hour conservative tracer and peak reservoir outflow concentration (*i.e.*, lag time) is about 31 days and occurs for the tracer released on 12/30, Year 1, a period of reservoir destratification. The longest lag time is about 276 days and corresponds to the tracer released in early spring when the thermocline begins to form. This implies that the time it takes for purified water tracer to reach the reservoir outflow is more controlled by vertical mixing than by horizontal advection and dispersion.

Table 3. Summary of 24-hour Conservative Tracer Simulation Results for the Base Case

Date of Release	Reservoir Outflow Peak Tracer Concentration (%) / Minimum Dilution	Lag Time* (days)
2/1, Year 1	0.037 / 2703	49
4/1, Year 1	0.045 / 2222	276
7/1, Year 1	0.031 / 3226	185
10/1, Year 1	0.037 / 2703	93
12/30, Year 1	0.030 / 3333	31

Note: * Lag Time – time interval between the start of tracer release and occurrence of a concentration peak in the reservoir outflow at Port #2.

3.2 NO PURIFIED WATER SCENARIO

A scenario with no purified water addition was investigated. The inputs for this scenario are similar to those for the Base Case scenario, except for no purified water additions and an equal reduction in reservoir outflow volume. **Table 4** presents the monthly water volumes of inflows and outflow for the No Purified Water scenario. The purpose of conducting this simulation was, by comparing results with the Base Case, to evaluate the hydrodynamic effects of purified water addition on the expanded SVR.

Figures 14 and **15** show comparisons between the Base Case and No Purified Water scenarios for temperature and conductivity, respectively. Note that we use elevation as y-axis in all the figures hereafter to allow labeling the port elevations. The temperature patterns are fairly similar between these two scenarios with similar thermocline development patterns. However, note that the thermocline is slightly deeper for the Base Case (*e.g.*, less than 3 ft in September), a result of adding water in the epilimnion. Without addition of low-conductivity purified water, conductivity is higher for the No Purified Water scenario, especially in the epilimnion (**Figure 15**).

Table 4. Monthly Reservoir Inflow and Outflow Volumes for No Purified Water Scenario

Month	Aqueduct Inflow (acre-feet)	Runoff Inflow (acre-feet)	Purified Water Inflow (acre-feet)	Withdrawal (acre-feet)
Jan-Year 1	0	0	0	0
Feb-Year 1	0	1500	0	0
Mar-Year 1	0	1500	0	0
Apr-Year 1	1000	1500	0	0
May-Year 1	1000	0	0	0
Jun-Year 1	1000	0	0	0
Jul-Year 1	0	0	0	800
Aug-Year 1	0	0	0	800
Sep-Year 1	0	0	0	800
Oct-Year 1	0	0	0	800
Nov-Year 1	0	0	0	800
Dec-Year 1	0	0	0	0
Jan-Year 2	0	0	0	0
Feb-Year 2	0	1500	0	0
Mar-Year 2	0	1500	0	0
Apr-Year 2	1000	1500	0	0
May-Year 2	1000	0	0	0
Jun-Year 2	1000	0	0	0
Jul-Year 2	0	0	0	800
Aug-Year 2	0	0	0	800
Sep-Year 2	0	0	0	800
Oct-Year 2	0	0	0	800
Nov-Year 2	0	0	0	800
Dec-Year 2	0	0	0	0

3.3 EXTENDED DROUGHT AND EMERGENCY DRAWDOWN SCENARIOS

The Extended Drought scenario represents a hypothetical multi-year drought situation where a large and constant volume of water is withdrawn monthly from the reservoir without importing additional water (as compared to the Base Case) to refill the reservoir. **Table 5** lists the monthly inflow and outflow water volumes for this scenario while **Figure 16** shows an inflow and outflow rate comparison between this scenario and the

Base Case. Under the Extended Drought scenario, the volume of water stored in SVR decreases steadily throughout the modeling period from an initial 155,000 acre-feet to slightly below 100,000 acre-feet at the end of the simulation (**Figure 17**). This corresponds to a WSEL (water surface elevation) reduction from 710 ft to about 660 ft. In comparison, the volume of water stored in SVR for the Base Case remains above the initial volume of 155,000 acre-feet and reaches as high as about 170,000 acre-feet (WSEL of about 720 ft) in the middle of the simulation year (**Figure 17**).

Table 5. Monthly Reservoir Inflow and Outflow Volumes for the Extended Drought Scenario

Month	Aqueduct Inflow (acre-feet)	Runoff Inflow (acre-feet)	Purified Water Inflow (acre-feet)	Withdrawal (acre-feet)
Jan-Year 1	0	0	1440	4000
Feb-Year 1	0	1500	1590	4000
Mar-Year 1	0	1500	1480	4000
Apr-Year 1	1000	1500	1350	4000
May-Year 1	1000	0	1230	4000
Jun-Year 1	1000	0	1090	4000
Jul-Year 1	0	0	900	4000
Aug-Year 1	0	0	1020	4000
Sep-Year 1	0	0	1090	4000
Oct-Year 1	0	0	1120	4000
Nov-Year 1	0	0	1210	4000
Dec-Year 1	0	0	1480	4000
Jan-Year 2	0	0	1440	4000
Feb-Year 2	0	1500	1590	4000
Mar-Year 2	0	1500	1480	4000
Apr-Year 2	1000	1500	1350	4000
May-Year 2	1000	0	1230	4000
Jun-Year 2	1000	0	1090	4000
Jul-Year 2	0	0	900	4000
Aug-Year 2	0	0	1020	4000
Sep-Year 2	0	0	1090	4000
Oct-Year 2	0	0	1120	4000
Nov-Year 2	0	0	1210	4000
Dec-Year 2	0	0	1480	4000

The Emergency Drawdown scenario simulates a situation where a large volume of water is withdrawn from the reservoir in January and February of Year 2 and the reservoir is subsequently refilled by adding water from the Aqueduct between March and July in Year 2. The monthly inflow and outflow rates for this scenario are listed in **Table 6** and are plotted against flow rates from the Base Case and Extended Drought scenario in **Figure 16**. The volume of water stored in SVR over the two-year simulation period under this scenario (as well as the Base Case and Extended Drought) is plotted in **Figure 17**. Note that the initial volume of the Emergency Drawdown scenario is set at 200,000 acre-feet (WSEL of about 738 ft) compared to an initial volume for the Base Case and Extended Drought scenarios of 155,000 acre-feet (WSEL of about 710 ft). During the emergency drawdown period, the reservoir water volume is reduced to about 140,000 acre-feet (WSEL of 690 ft). It then climbs rapidly to above 200,000 acre-feet during the refill period.

The purified water inlet location used for both the Extended Drought and Emergency Drawdown scenarios is the "Design Purified Water Inlet Location" (see **Figure 1**), the same as that for the Base Case.

A comparison of simulated water temperature between the Base Case, Extended Drought, and Emergency Drawdown scenarios is shown in **Figure 18**. All three scenarios have a generally similar epilimnion thickness and thermocline deepening rate. A notable exception is the emergence of a thick epilimnion for the Emergency Drawdown scenario in the spring of the second year, a result of the influx of a large amount of inflow into the epilimnion in a short period of time. Since the epilimnion thickness is generally unchanged amongst these three scenarios, the *elevation* of the thermocline is mostly determined by the WSEL. For example, as a result of the steady decrease in WSEL for the Extended Drought scenario, the thermocline reaches the elevation of Port #2 in early September in Year 2 compared to mid-October for the Base Case. For the Emergency Drawdown scenario, the thermocline reaches the elevation of Port #2 in mid-December, a result of the higher WSEL.

A comparison of simulated conductivity between the Base Case, Extended Drought, and Emergency Drawdown scenarios is shown in **Figure 19**. Note that the values of conductivity in the purified water are lower than those in the Aqueduct water. Thus, the levels of conductivity in the reservoir are elevated in Year 2 of the Emergency Drawdown scenario compared to the other two scenarios, a result of using a large volume of Aqueduct water to refill the reservoir after the emergency drawdown. During the rest of simulation period, the conductivity is fairly similar among these three scenarios.

Table 6. Monthly Reservoir Inflow and Outflow Volumes for the Emergency Drawdown Scenario

Month	Aqueduct Inflow (acre-feet)	Runoff Inflow (acre-feet)	Purified Water Inflow (acre-feet)	Withdrawal (acre-feet)
Jan-Year 1	0	0	1440	0
Feb-Year 1	0	1500	1590	0
Mar-Year 1	0	1500	1480	0
Apr-Year 1	1000	1500	1350	0
May-Year 1	1000	0	1230	0
Jun-Year 1	1000	0	1090	0
Jul-Year 1	0	0	900	2200
Aug-Year 1	0	0	1020	4200
Sep-Year 1	0	0	1090	4200
Oct-Year 1	0	0	1120	4200
Nov-Year 1	0	0	1210	4200
Dec-Year 1	0	0	1480	0
Jan-Year 2	0	0	1440	33000
Feb-Year 2	0	1500	1590	33000
Mar-Year 2	19000	1500	1480	0
Apr-Year 2	15000	1500	1350	0
May-Year 2	12000	0	1230	0
Jun-Year 2	12000	0	1090	0
Jul-Year 2	11000	0	900	2200
Aug-Year 2	0	0	1020	4200
Sep-Year 2	0	0	1090	4200
Oct-Year 2	0	0	1120	4200
Nov-Year 2	0	0	1210	4200
Dec-Year 2	0	0	1480	0

Figure 20 shows a comparison of decaying tracer concentrations in the reservoir outflow at Port #2 between the Base Case, Extended Drought and Emergency Drawdown scenarios. In general, all three scenarios show many similarities: tracer concentrations are highest during the destratified winter period with at least a 2-log reduction, steadily decreasing in the summer due to decay, and rise sharply once the thermocline reaches the elevation of the reservoir outlet port. The main difference between these scenarios is the timing of the rise in reservoir outflow tracer concentration. As discussed previously, the

timing of the thermocline reaching the open reservoir outlet mainly depends on the WSEL: the higher the WSEL, the later is the rise. As such, the Extended Drought scenario has the earliest rise, followed by the Base Case then the Emergency drawdown scenario.

Simulated 24-hour conservative tracer concentrations in the reservoir outflow are shown in **Figures 21** and **22** for the Extended Drought and Emergency Drawdown scenarios respectively. It should be noted that the release dates of the 24-hour conservative tracers for these two scenarios are different from those for the Base Case. The selection of 24-hour conservative tracer release dates for these scenarios was based on identifying critical periods in which the highest reservoir outflow concentrations are most likely to occur (the timings for the 24-hour conservative tracer release for the Base Case were distributed more evenly over the year). From our understanding of the variations in 24-hour conservative tracer release concentrations in the Base Case, the critical periods are most likely to occur when the reservoir is near to, or fully, mixed and the water volume in the reservoir is at the lowest. In addition, Santa Ana winds, a wind event where strong and extremely dry east and northeast winds prevail in Southern California, are expected to rapidly drive purified water introduced at the east side of the reservoir directly toward the reservoir outlet located near the west end of the reservoir. Such an event could minimize dilution and lag time between the time when the water enters the reservoir and the time it reaches the reservoir outlet. Thus, the most critical periods are expected to meet the following three conditions: 1) the reservoir is almost or fully mixed vertically; 2) the reservoir water volume is at a minimum; and 3) the occurrence of Santa Ana wind events.

FSI conducted an analysis of meteorological data at SVR to identify Santa Ana wind events. Based on the analysis and the discussion above, the six 24-hour conservative tracer release dates were considered to be: 12/2 of Year 1, 1/6, 1/14, 1/21, 11/29 and 12/2 of Year 2 for the Extended Drought scenario (note that two release dates at the end of Year 2 were chosen for this scenario due to the lower WSEL at the end of Year 2). For the Emergency Drawdown scenario the dates were 12/2 of Year 1, 1/6, 1/14, 1/21, 2/20 and 2/25 of Year 2.

Figures 21 and **22** present simulated reservoir outflow concentrations for all 24-hour conservative tracer releases. The results are also summarized in **Tables 7** and **8**. For the Extended Drought scenario, the maximum observed concentrations at the outflow range from about 0.03 to 0.11, reflecting a minimum dilution range between 900 and 2,700. The smallest dilution occurs for the 24-hour conservative tracer released on 12/2 of Year 2 when the reservoir volume is near the low end of the range. The lag time ranges from 5 to 25 days. For the Emergency Drawdown scenario, the maximum observed concentrations at the outflow range from about 0.03 to 0.07, reflecting a minimum dilution of about 1,400 to 3,000. The lag time ranges from 8 to 120 days.

Table 7. Summary of 24-hour Conservative Tracer Simulation Results for the Extended Drought Scenario

Date of Release	Reservoir Outflow Peak Tracer Concentration (%) / Minimum Dilution	Lag Time* (days)
12/2, Year 1	0.077 / 1299	11
1/6, Year 2	0.034 / 2941	25
1/14, Year 2	0.037 / 2703	37
1/21, Year 2	0.058 / 1724	8
11/29, Year 2	0.11 / 909	5
12/2, Year 2	0.11 / 909	9

Note: * Lag Time – time interval between the start of tracer release and occurrence of tracer concentration peak in the reservoir outflow at Port #2.

Table 8. Summary of 24-hour Conservative Tracer Simulation Results for the Emergency Drawdown Scenario

Date of Release	Reservoir Outflow Peak Tracer Concentration (%) / Minimum Dilution	Lag Time* (days)
12/2, Year 1	0.043 / 2326	31
1/6, Year 2	0.023 / 4348	33
1/14, Year 2	0.025 / 4000	32
1/21, Year 2	0.042 / 2381	8
2/20, Year 2	0.072 / 1388	8
2/25, Year 2	0.031 / 3226	120

Note: * Lag Time – time interval between the start of tracer release and occurrence of tracer concentration peak in the reservoir outflow at Port #2.

3.4 COMPARISON OF VARIOUS PURIFIED WATER INLET LOCATIONS

All simulations discussed prior to this section utilized the "Design Purified Water Inlet Location" as the point of release for purified water flow into SVR. This section focuses on evaluating other potential purified water inlet locations and investigating the location impact on dilution and mixing under different reservoir operating scenarios. A total of four purified water inlet locations were considered under the Base Case operating scenario. Two of these four locations were further evaluated under the Extended Drought operating scenario.

3.4.1 Evaluation Under Base Case Operating Conditions

Four purified water inlet locations were considered under the Base Case operating scenario. These are: Design Purified Water Inlet Location, Existing Aqueduct Purified Water Inlet Location, New Aqueduct Purified Water Inlet Location, and Barona Arm Purified Water Inlet Location. These four locations are illustrated in **Figure 23**. As shown, the Barona Arm Purified Water Inlet Location is the furthest from the reservoir outlet and the New Aqueduct Purified Water Inlet Location is the nearest to the reservoir outlet.

A comparison of decaying tracer reservoir outflow concentrations for tracers released into these four purified water inlet locations is shown in **Figure 24**. The decaying tracer concentrations in the reservoir outflow are fairly similar for all purified water inlet locations. The Barona Arm Purified Water Inlet Location, the furthest from the reservoir outlet, produces slightly lower reservoir outflow tracer concentrations than the other three purified water inlet locations. On the other hand, the New Aqueduct Purified Water Inlet Location, the release point nearest to the reservoir outlet, produces slightly higher reservoir outflow concentrations than the other three. Overall, the differences in reservoir outflow concentrations between different purified water inlet locations are relatively small. All purified water inlet locations can achieve a 6-log reduction in concentration in the summer months and near a 2-log reduction in the destratified period.

Comparison of the 24-hour conservative tracer concentrations in the reservoir outflow for releases at various purified water inlet locations are presented in **Figures 25 – 30** and results are summarized in **Table 9**. **Figure 25** shows that, for a 24-hour conservative tracer released during the destratified period, the New Aqueduct Purified Water Inlet Location features the shortest lag time for the tracer to reach the reservoir outlet. Furthermore, the New Aqueduct Purified Water Inlet location has the highest concentration and lowest minimum dilution at the reservoir outlet. It is noted, however, that the minimum dilution for the New Aqueduct Purified Water Inlet location is over 1,200 (maximum concentration of 0.08).

For releases between April and October, the purified water inlet location has very little effect on the 24-hour conservative tracer concentration at the reservoir outlet, as shown in **Figures 26 – 28**. This finding is a result of the thermocline isolating the reservoir outflow from the purified water during the stratified season regardless of the purified water inlet location. The 24-hour conservative tracers released during the summer do not reach the reservoir outflow until the following late fall when the reservoir is nearly well mixed.

For the 1/5 and 1/15 of Year 2 tracer releases, the results shown in **Figures 29** and **30** indicate that the New Aqueduct Purified Water Inlet Location features the highest

concentrations and lowest minimum dilutions, followed by the Existing Aqueduct Purified Water Inlet Location, Design Purified Water Inlet Location, and Barona Arm Purified Water Inlet Location. Note that the main differences between the various scenarios during these unstratified periods occur in the first few days after tracer release.

As indicated in **Table 9**, minimum dilutions achieved in the reservoir outflow for these releases range from 385 to 3,448 and the lag times vary from 0.8 to 276 days. The purified water inlet location nearest to the reservoir outlet, the New Aqueduct Purified Water Inlet Location, produces the highest peak concentration (*i.e.*, 0.26, corresponding to a dilution of 385) in the reservoir outflow and the peak reaches the reservoir outflow within two days.

Table 9. Summary of 24-hour Conservative Tracer Simulation Results for Various Purified Water Inlet Locations Under Base Case Conditions

Date of Release	Design Purified Water Inlet Location		Existing Aqueduct Purified Water Inlet Location		New Aqueduct Purified Water Inlet Location		Barona Arm Purified Water Inlet Location	
	C/D*	LT**	C/D	LT	C/D	LT	C/D	LT
1/30 Year 1	0.030 / 3333	51	0.038/ 2632	27	0.081/ 1235	0.8	0.033/ 3030	39
4/1 Year 1	0.045 / 2222	276	0.038/ 2632	275	0.042/ 2381	271	0.052/ 1923	271
7/1 Year 1	0.036 / 2778	178	0.034/ 2941	180	0.032/ 3125	182	0.037/ 2703	180
10/1 Year 1	0.037/ 2703	93	0.041/ 2439	88	0.038/ 2632	87	0.045/ 2222	88
1/5 Year 2	0.033/ 3030	17	0.10/ 1000	10	0.26/ 385	1.5	0.030/ 3333	87
1/15 Year 2	0.031/ 3226	14	0.079/ 1266	10	0.13/ 769	0.8	0.029/ 3448	188

Note: * C/D – Reservoir outflow peak tracer concentration (%) / Minimum Dilution
** LT –lag time in days between the start of tracer release and occurrence of tracer concentration peak in the reservoir outflow Port #2.

3.4.2 Evaluation Under the Extended Drought Operating Conditions

The Design Purified Water Inlet Location and the New Aqueduct Purified Water Inlet Locations were further evaluated under the Extended Drought Operating Scenario. **Figure 31** shows a comparison of reservoir outflow decaying tracer concentrations for

tracer releases at these two purified water inlet locations. In general, the concentrations are fairly similar, but as expected the New Aqueduct Purified Water Inlet Location (location nearest to the reservoir outlet) produces slightly higher concentrations overall.

Figures 32-37 show comparisons of the 24-hour conservative tracer in the reservoir outflow for these two locations. The results are also summarized in **Table 10**. As shown in **Table 10,** the maximum concentrations are higher (and minimum dilutions therefore lower) for the New Aqueduct Purified Water Inlet Location. The maximum concentration and minimum dilution at the reservoir outlet are about 0.51 and 196, respectively, and occur for the 24-hour tracer release on 12/2, Year 2. It is noted that several days after release, any effect of the purified water inlet location has become negligible. Also note that in this analysis, all the purified water 24-hour conservative tracers were released in the destratified period. It is expected that little differences in dilutions between purified water inlet locations would be observed for 24-hour conservative tracers released in the stratified period.

Table 10. Summary of 24-hour Conservative Tracer Simulation Results for Various Purified Water Inlet Locations under the Extended Drought Conditions

Date of Release	Design Purified Water Inlet Location		New Aqueduct Purified Water Inlet Location	
	C/D*	LT**	C/D	LT
12/2, Year 1	0.077 /1299	11	0.15 /667	6
1/6, Year 2	0.034 /2941	25	0.19 /526	1.5
1/14, Year 2	0.037 /2703	37	0.25 /400	1.8
1/21, Year 2	0.058 /1724	8	0.24 /417	1.8
11/25, Year 2	0.11 /909	5	0.47 /213	2.5
12/2, Year 2	0.11 /909	9	0.51 /196	1.3

Note: * C/D – Reservoir outflow peak tracer concentration (%) / Minimum Dilution
** T – time lag in days between the start of tracer release and occurrence of tracer concentration peak in the reservoir outflow at Port #2.

4. CONCLUSIONS

The objectives of this study were to use the calibrated and validated SVR computer model to determine the effectiveness of SVR as an environmental buffer and barrier for purified water introduced into SVR, and to evaluate any hydrodynamic changes in SVR induced by the purified water. To achieve these goals, reservoir simulations were conducted to evaluate a number of proposed future reservoir operating scenarios.

First, the model was used to determine the impacts of reservoir expansion on mixing and dilution in the reservoir, without the introduction of any purified water. The model was then used to investigate the effects of the purified water addition on the general hydrodynamics of the reservoir for several different operational scenarios:

- Base Case ---- This scenario considered a reservoir under median expected storage and normal expected operations. The initial reservoir volume for the Base Case is set at 155,000 acre-feet. The annual flow rates for Aqueduct inflow, Runoff, purified water inflow and dam withdrawal are 3,000, 4,500, 15,000 and 19,000 acre-feet/year respectively. There are no water transfers from Sutherland Reservoir into SVR.

- No Purified Water ---- The inputs for this scenario are similar to those for the Base Case scenario, except for no purified water additions and an equal reduction in reservoir outflow. The initial reservoir volume for this scenario is set at 155,000 acre-feet. The annual flow rates for Aqueduct inflow, Runoff, purified water inflow and dam withdrawal are 3,000, 4,500, 0 and 4,000 acre-feet/year respectively. There are no water transfers from Sutherland Reservoir into SVR.

- Extended Drought ---- This scenario represents a hypothetical two-year drought situation where a large and constant volume of water is withdrawn monthly from the reservoir without importing additional water (as compared to the Base Case) to refill the reservoir. The initial reservoir volume for this scenario is set at 155,000 acre-feet. The annual flow rates for Aqueduct inflow, Runoff, purified water inflow and dam withdrawal are 3,000, 4,500, 15,000 and 48,000 acre-feet/year respectively. There are no water transfers from Sutherland Reservoir into SVR. The volume of water stored in SVR at the end of the two-year simulation period is about 100,000 acre-feet.

- Emergency Drawdown ---- The Emergency Drawdown scenario simulates a situation where a total of 66,000 acre-feet water is withdrawn from the reservoir in January and February of Year 2 and the reservoir is subsequently refilled by adding 66,000 acre-feet water from the Aqueduct between March

and July in Year 2. The rest of flow rates for all inflows and outflows are the same as the Base Case. The initial reservoir volume for this scenario is set at 200,000 acre-feet.

Note that all preceding simulations utilized the Design Purified Water Inlet Location as the point of release of purified water flow into SVR. Port #2 was used for all water withdrawals from the reservoir throughout this investigation.

In these simulations various hypothetical tracers were added to the purified water inflow to illustrate the transport and mixing of the purified water within the reservoir. In particular, decaying tracers (decay rate of 1 log per month, *i.e.*, a reduction in concentration by a factor of 10 per month) were used to study the dilution and inactivation of potential pathogens entering the reservoir and to evaluate the ability of the reservoir to reduce pathogen concentrations before they reach the reservoir outlet. The decaying tracer was continuously released with the purified water inflow at a constant concentration throughout the entire modeling period. In addition, hypothetical conservative (that is, non-decaying) tracers were added to the purified water inflow in order to simulate the potential effects of elevated concentrations of chemical constituents in the purified water entering SVR after "excursion events" at the water purification facility. These conservative tracers were tracked to determine the dilution and lag time provided by the reservoir (*i.e.*, the time interval between the release of the tracer and peak reservoir outflow concentration). In all simulations, such tracers were added to the reservoir's inflow over a 24-hour period and were thus referred to as 24-hour conservative tracers.

Finally, various purified water inlet locations were also evaluated under various operating conditions to examine the effects of varying the purified water inlet location. A total of four different purified water inlet locations were considered under the Base Case operating scenario. These are: the Design Purified Water Inlet Location, Existing Aqueduct Purified Water Inlet Location, New Aqueduct Purified Water Inlet Location, and Barona Arm Purified Water Inlet Location. The Design and New Aqueduct Purified Water Inlet Locations were further evaluated under the Extended Drought operating scenario.

Based on the simulation results, the following conclusions and observations are made:

GENERAL CONCLUSIONS ON RESERVOIR EXPANSION

- The expanded reservoir is predicted to start stratifying in about March of each year. In the spring and summer, the stratification will intensify. In the fall, the thermocline will start deepening appreciably until the reservoir becomes fully mixed in late fall or early winter. As a result, the reservoir is predicted

to be stratified from about March to December, and will be destratified from December to February.

- Reservoir expansion will increase the volume of the hypolimnion but will have a negligible effect on the thermocline depth when the reservoir is stratified. Both surface and bottom reservoir temperatures are expected to remain unchanged due to increased water depth.

CONCLUSIONS FOR BASE CASE (DESIGN PURIFIED WATER INLET LOCATION)

- Under the Base Case scenario, the addition of purified water in the expanded reservoir is predicted to slightly deepen the thermocline (*e.g.,* by less than 3 ft in September) and reduce conductivity in the reservoir (compared to the Calibration Run).

- The purified water generally has a lower density (lower conductivity and higher temperature) than the ambient reservoir water. This will cause the purified water to initially spread along the surface of the reservoir near the purified water inlet location. In the stratified reservoir period (typically March to December), the purified water will rapidly mix within the entire epilimnion. As the thermocline gradually deepens, the purified water will gradually approach successively lower ports on the reservoir outlet tower.

- In the unstratified period (December to February), the purified water is predicted to initially flow along the reservoir's surface, but then it will quickly mix over the entire depth, achieving rapid dilution over the entire reservoir volume.

- The proposed withdrawal strategy at SVR will generally utilize deeper ports (Port #2 was considered to be the open port throughout this investigation). Since the purified water will generally flow into the reservoir above the thermocline in the stratified period, it is predicted to typically take several weeks or months for newly released purified water to appear at the reservoir outlet, after undergoing large dilution (*i.e.*, achieving a dilution of at least 2,000). In the reservoir destratified period, the simulations indicate that the purified water can appear at the reservoir outlet within days or weeks after release, but only after undergoing significant dilution (*i.e.*, achieving a dilution of at least 2,000).

- For a decaying tracer released with the purified water (a surrogate for pathogens), the reservoir outflow from the reservoir is predicted to achieve at least a 2-log reduction[2] (100:1 reduction in concentration) in the unstratified period. In the stratified period, the reservoir will provide significantly higher reductions (as high as 9 logs; that is, a 1 trillion reduction).

- For a 24-hour conservative tracer that enters the reservoir the simulations indicate that a dilution of at least 2,000 can be obtained in the reservoir outflow.

CONCLUSIONS FOR EXTENDED DROUGHT & EMERGENCY DRAWDOWN SCENARIOS (DESIGN PURIFIED WATER INLET LOCATION)

- For a decaying tracer in the purified water inflow under the Extended Drought scenario, the analyses indicate that the reservoir can achieve a 2-log reduction in tracer concentration in the unstratified period and significantly higher values (typically 4-8 log reduction) for the remainder of the year. The minimum predicted dilution and its corresponding lag time for a 24-hour conservative tracer are about 900 and 5 days, respectively, and occurs at the end of Year Two when the reservoir volume is lowest.

- For a decaying tracer in the purified water inflow under the Emergency Drawdown scenario, the results indicate that the reservoir can achieve a 2-log reduction in the unstratified period and significantly higher values (typically 4-10 log reduction) for the remainder of the year. The minimum predicted dilution and its corresponding lag time for a 24-hour conservative tracer are about 1,400 and 8 days, respectively. The minimum predicted dilution here is higher than those obtained from both the Base Case and the Extended Drought scenarios, a result of the larger reservoir volume considered in the Emergency Drawdown Scenario during the winter months.

[2] A log reduction is defined as a 10-fold reduction.

EFFECT OF THE PURIFIED WATER INLET LOCATION

- In the stratified season, utilizing different inlet locations to introduce purified water into SVR is predicted to have little effect on both the decaying and 24-hour conservative tracer concentrations in the reservoir outflow under all scenarios considered (*i.e.*, Base Case and Extend Drought Scenarios).

- For the Design, Existing Aqueduct and Barona Arm Purified Water Inlet Locations, moving the purified water inlet location closer to the reservoir outlet is predicted to generally (but not always) result in slightly higher values in the reservoir outflow concentrations for both the decaying and 24-hour conservative tracers during the unstratified period. However, a minimum 2-log reduction for the decaying tracer and a minimum predicted dilution of 909 for the 24-hour conservative tracer are achieved under all scenarios considered (*i.e.*, Base Case and Extended Drought Scenarios). The lag times for the 24-hour conservative tracer range from 5 to 276 days.

- For the New Aqueduct Purified Water Inlet Location, the modeling shows higher peak concentration values for a 24-hour conservative tracer release in the reservoir outflow in the unstratified period than other purified water inlet locations due to its proximity to the reservoir outlet structure. The minimum achieved dilution is found to be about 385 for the Base Case and 200 for the Extend Drought scenario. The corresponding lag times are typically less than 2 days.

5. REFERENCES

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Welch, M.R. (2011). "Potential Pathogen Inactivation at San Vicente Reservoir", dated May, 2011 and submitted to the City of San Diego.

6. GLOSSARY

Advanced Water Purification Facility: The demonstration facility located at the North City Water Reclamation Plant. The facility is considered "advanced" because of the high level of treatment utilizing reverse osmosis and advanced oxidation.

Blending: Mixing or combining one water source with another such as purified water with raw water sources.

Conductivity: see "Salinity".

Constituent: In water, a constituent is a dissolved chemical element or compound or a suspended material that is carried in the water.

Drought: A defined period of time when rainfall and runoff in a geographic area are much less than average.

Epilimnion: Natural thermal stratification exists for much of the year in almost all temperate lakes and reservoirs and creates three vertical zones. The upper, warmer water is called the epilimnion, the deeper, colder water is called the hypolimnion, whereas the middle portion separating these two layers, where the rate of vertical temperature change is greatest, is called the metalimnion, or thermocline.

Excursion events at the advanced purification facility: Events in which the water quality of the recycled water into the advanced purification facility deviates from the normal or expected conditions. They result in that the final outflow from the advanced purification facility may contain chemical constituents at higher level than normal concentrations when no such events occur.

Hypolimnion: see "epilimnion".

Pathogens: Disease-causing organisms. The general groupings of pathogens are viruses, bacteria, protozoa, and fungi.

Periods of mixing: Periods when water temperatures become vertically uniform in the water body and they generally occur in the winter.

Purified water: Recycled water that has been treated to an advanced level beyond tertiary treatment, so that it can be added to water supplies ultimately used for drinking water. The treatment includes membrane filtration with microfiltration or ultrafiltration, reverse osmosis (RO), and advanced oxidation that consists of disinfection with

ultraviolet light (UV) and hydrogen peroxide (H_2O_2). Purified water may be released into a groundwater basin or surface water reservoir that supplies water to a drinking water treatment facility.

Purified water inflow: Purified water that is transported from the advanced purified water treatment facility to the SVR.

Purified water inlet: Point of release in the SVR for purified water inflow. Note that the purified water is assumed to be released at the surface of the SVR.

Recycled water: Water that originated from homes, businesses and drains as municipal wastewater and has undergone a high level of treatment at a reclamation facility so that it can be beneficially reused for a variety of purposes. This is the water that comes into the AWP Facility.

Reservoir: A manmade lake or tank used to collect and store water.

Reservoir augmentation: The process of adding purified water to a surface water reservoir. The purified water undergoes advanced treatment (membrane filtration, reverse osmosis and UV disinfection/advanced oxidation). The purified water is then blended with untreated water in a reservoir. The blended water is then treated and disinfected at a conventional drinking water treatment plant and is distributed into the drinking water delivery system. Also known as "surface water augmentation."

Reservoir outflow: The flow withdrawal through the opening port located at the outlet structure near the dam.

Reservoir outlet: The opening port at the outlet structure near the dam. In this study, the opening port is assumed to be Port #2.

Salinity: The concentration of mineral salts dissolved in water. Salinity may be measured by weight (total dissolved solids or TDS) or by electrical conductivity. Salinity and TDS are both measures of the amount of salt dissolved in water, and the terms are often used interchangeably. Generally, salinity is used when referring to water with a lot of salt (*e.g.*, seawater), whereas TDS is used to refer to water with little salt (*e.g.*, freshwater).

Storage: Water held in a reservoir for later use.

Surface water: Water located on the Earth's surface, in a river, stream, lake, pond or surface water reservoir.

Thermocline: see "epilimnion".

Water Purification Demonstration Project (Demonstration Project): The second phase of the City of San Diego's Water Reuse Program. During this test phase the Advanced Water Purification Facility will operate for approximately one year and will produce 1 million gallons of purified water per day. A study of the San Vicente Reservoir is being conducted to test the key functions of reservoir augmentation and to determine the viability of a full-scale project. No purified water will be sent to the reservoir during the demonstration phase.

Water Measurement Terms

Milligrams per liter (mg/L) ***also known as parts per million (ppm):*** A measurement describing the amount of a substance (such as a mineral, chemical or contaminant) in a liter of water; a unit used to measure concentration of water constituents (parts of something per million parts of water). One part per million is equal to one milligram per liter. (This term is becoming obsolete as instruments measure smaller concentrations.) This is equivalent to one drop of water diluted into 50 liters (roughly the fuel tank capacity of a compact car) or about thirty seconds out of a year.

Acre-foot (AF): A unit of water commonly used in the water industry to measure large volumes of water. It equals the volume of water required to cover one acre to a depth of one foot. An acre-foot is 325,851 gallons (43,560 cubic feet) and is considered enough water to meet the needs of two families of four with a house and yard for one year.

µS/cm: A basic unit of water conductivity. It stands for microSiemens per meter. Distilled water has a conductivity in the range of 0.5 to 3 µS/cm. The conductivity of rivers in the United States generally ranges from 50 to 1500 µS/cm.

FIGURES

Map of San Vicente Reservoir

Plan View of Existing and Expanded Reservoir and Inflow/Outflow Locations

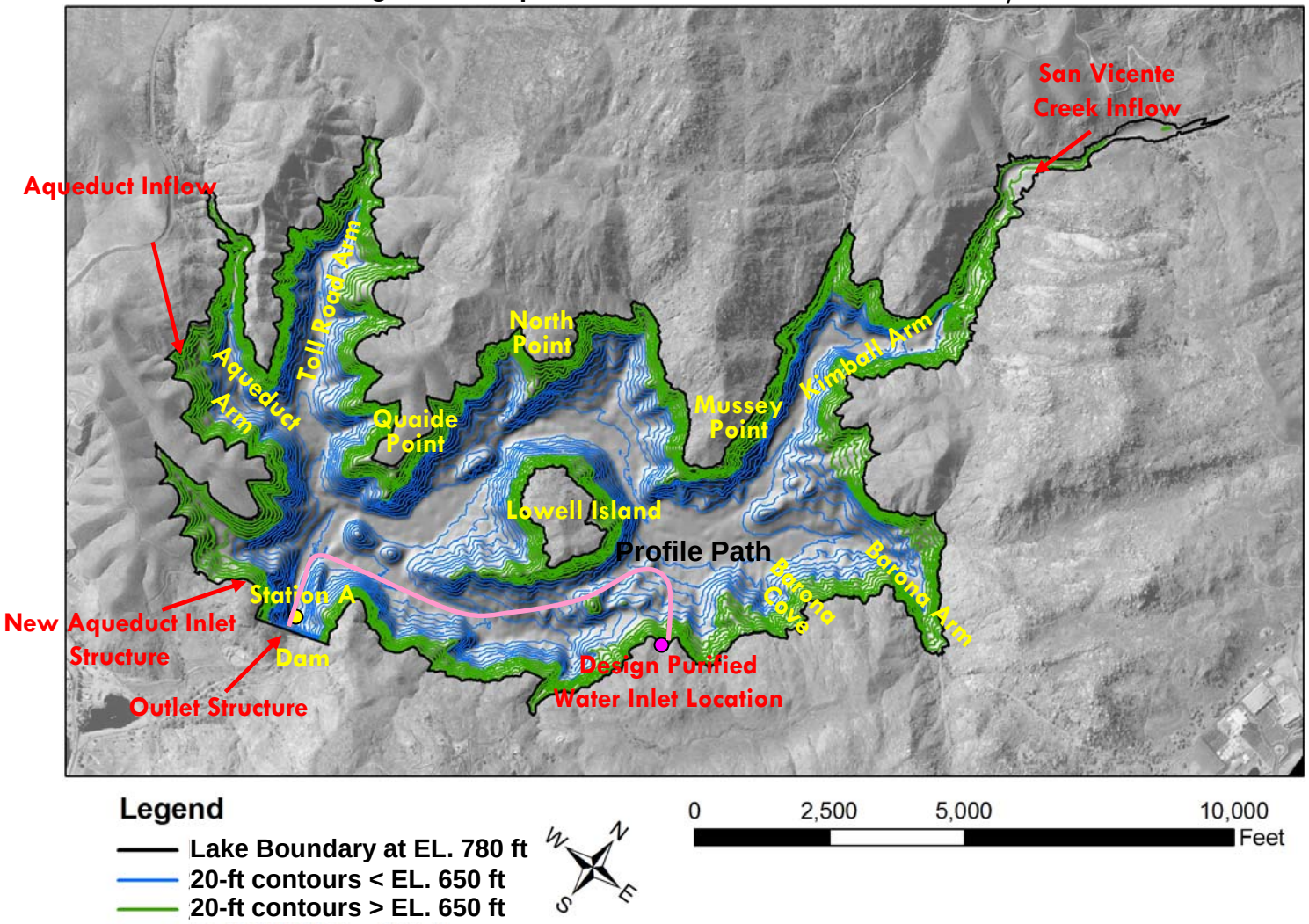

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Figure 1

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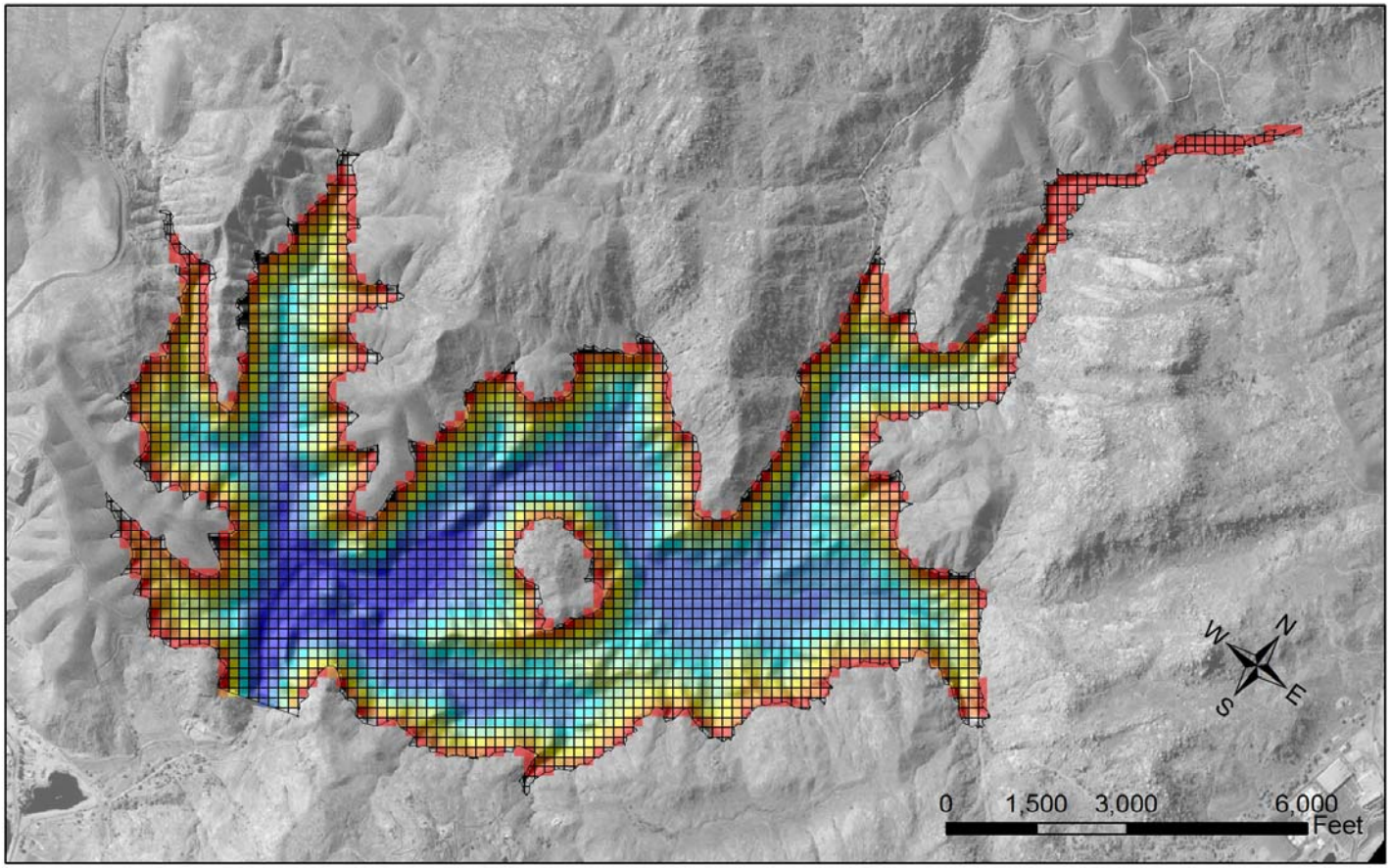
SVR Hydrodynamic Model Grid

(Grid Size = 50 m)



Legend

—— Lake Boundary at 780 ft

Elevation (ft)

480 - 510	541 - 569	630 - 659	719 - 748
511 - 540	570 - 599	660 - 689	749 - 778
	600 - 629	690 - 718	

Figure 2

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SVR Hydrodynamic Model Calibration Results

Station A – Water Temperature Comparison

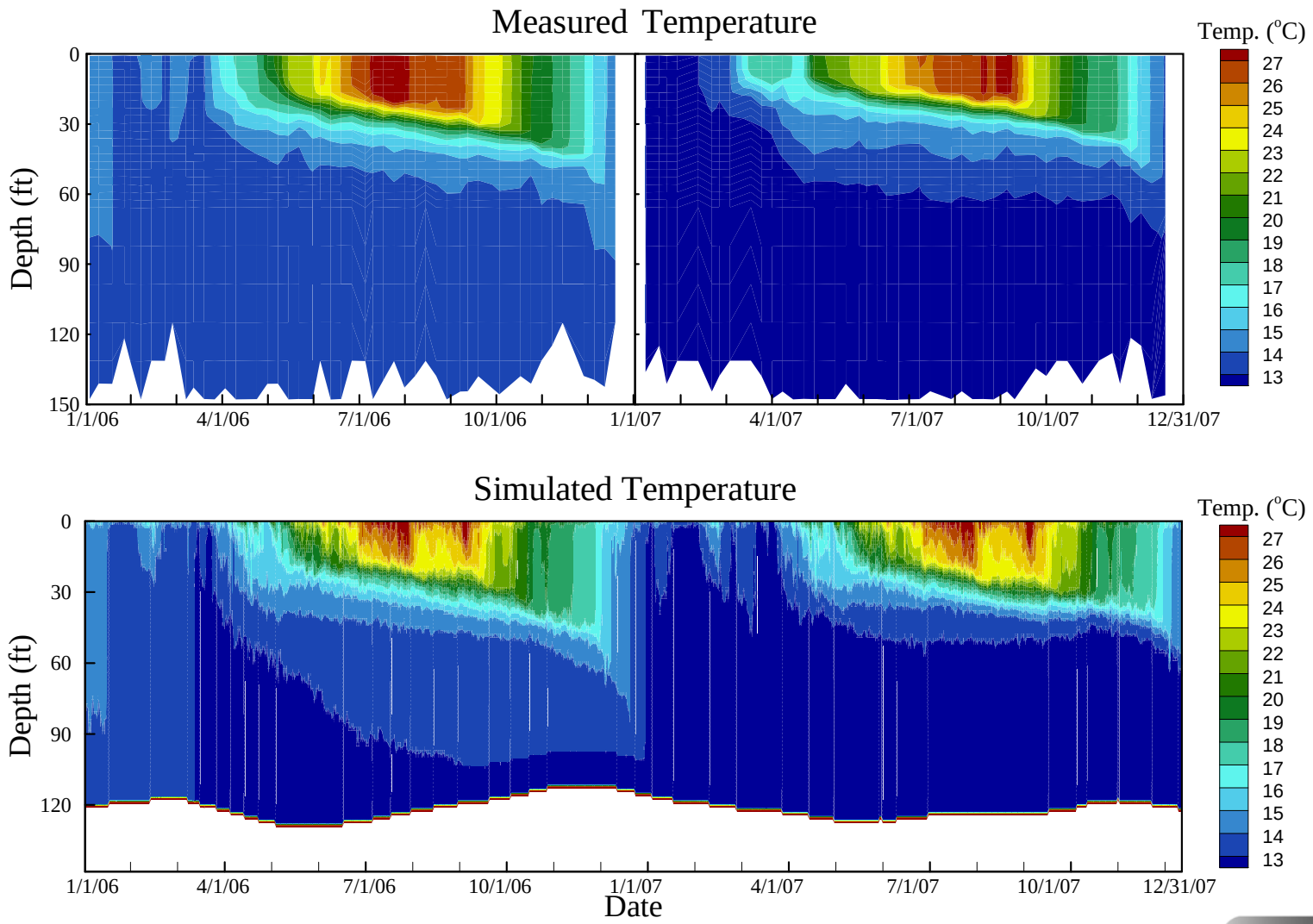

Figure 3

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SVR Hydrodynamic Model Calibration Results

Station A – Conductivity Comparison

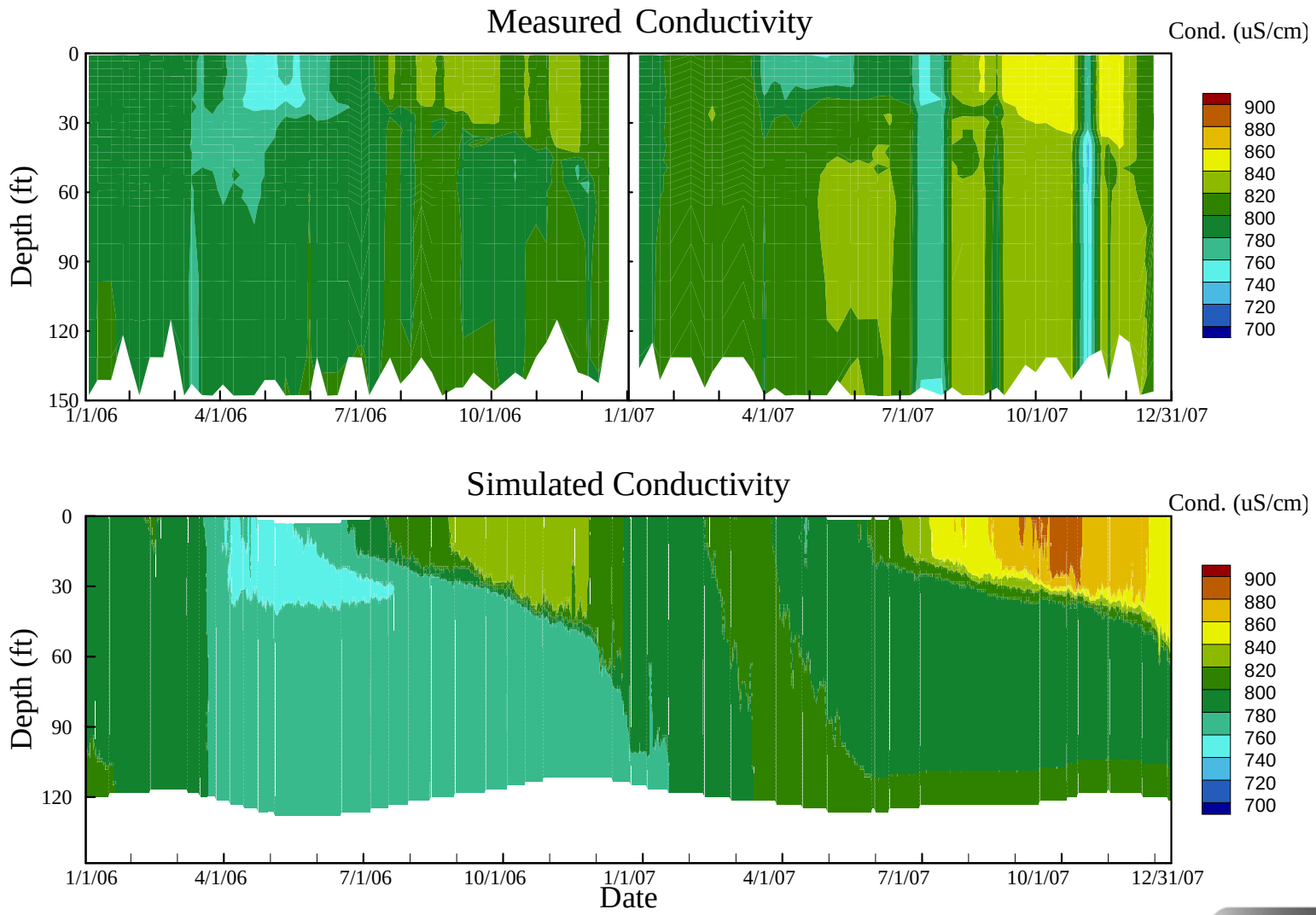

Figure 4

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SVR Hydrodynamic Model Calibration Results

1995 Winter Tracer Study – Measured versus Simulated Lanthanum Concentrations

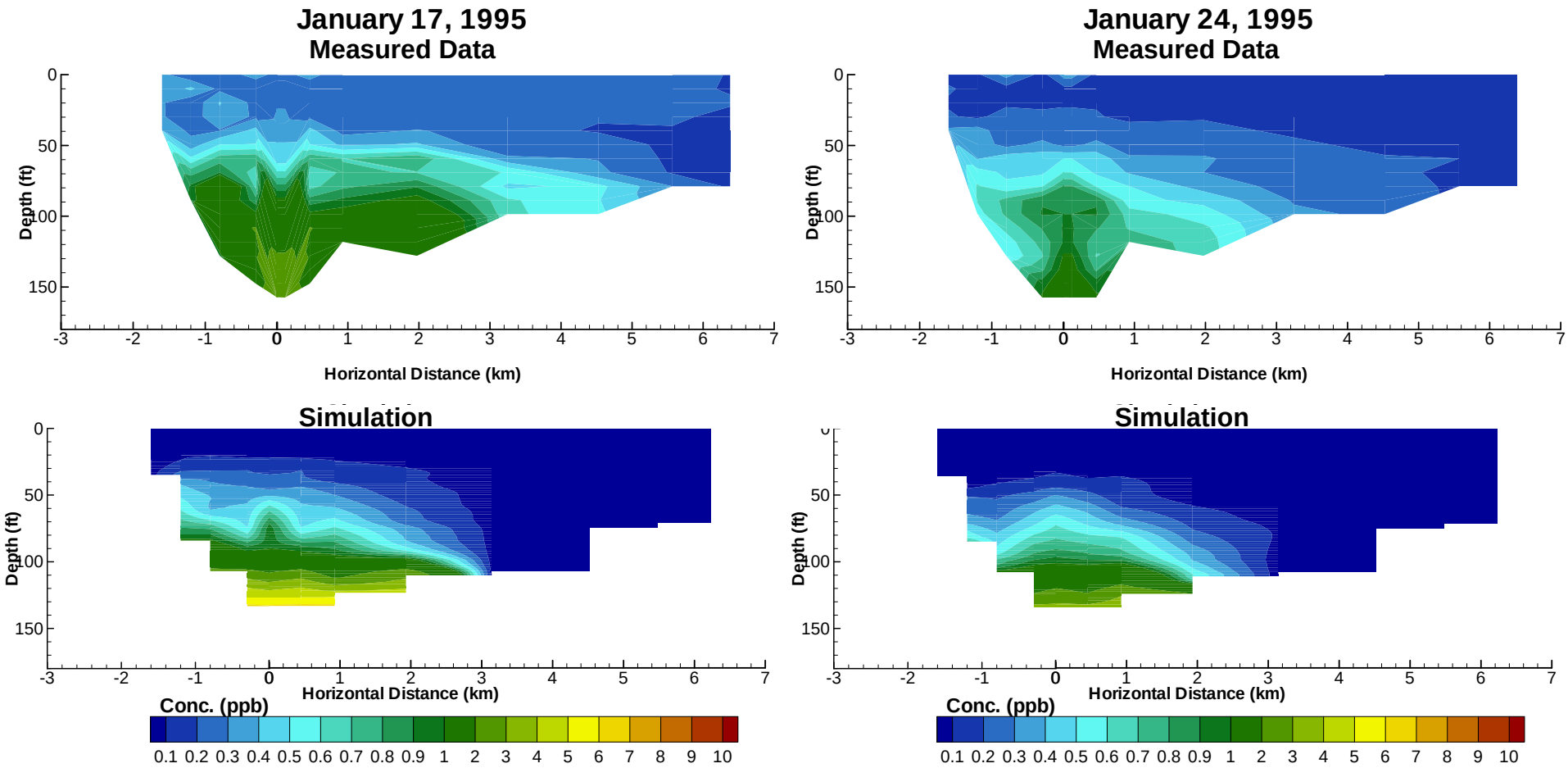

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Figure 5

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SVR Hydrodynamic Model Calibration Results

1995 Summer Tracer Study – Measured versus Simulated Lanthanum Concentrations

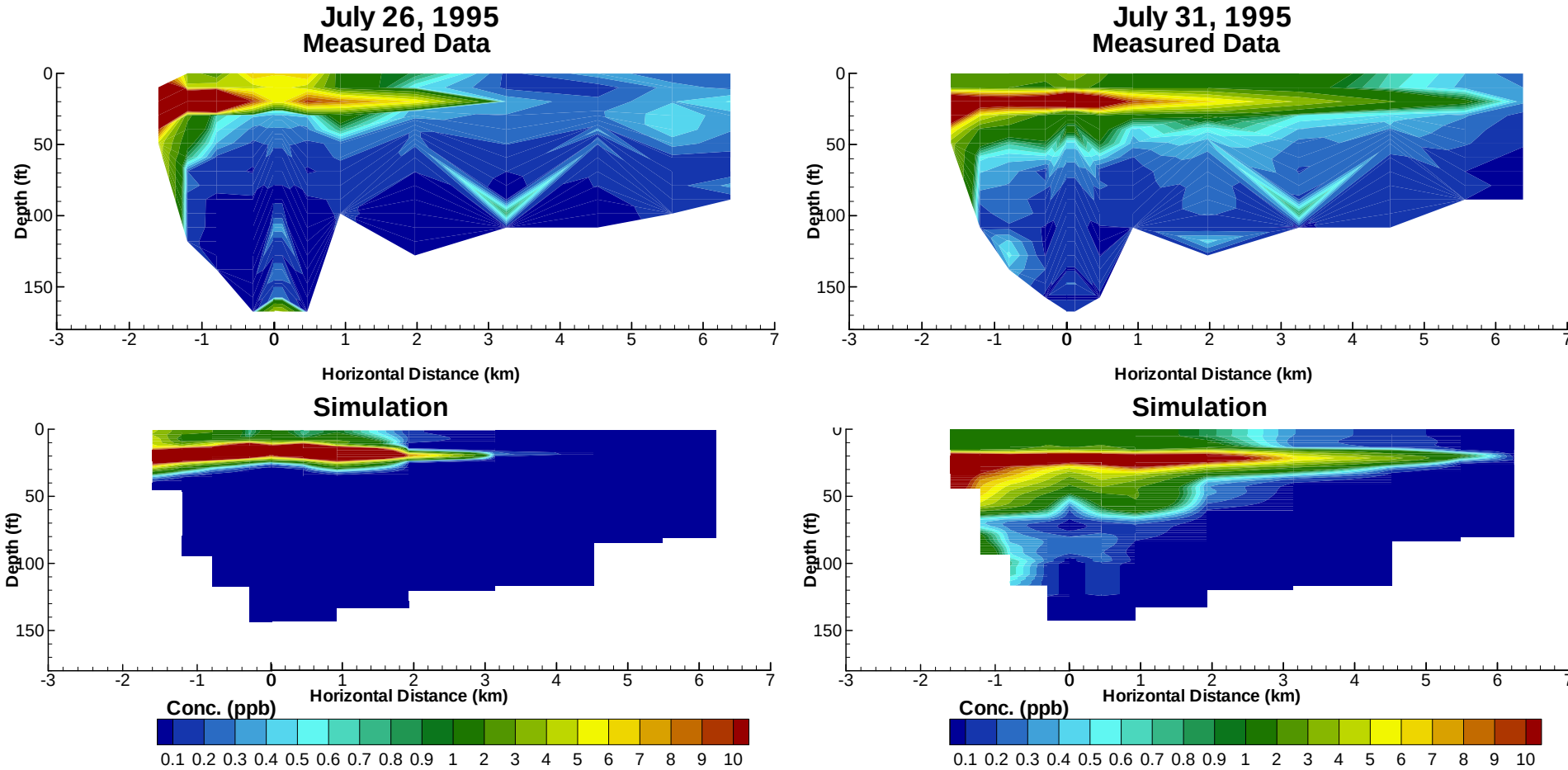

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Figure 6

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Comparison of Existing and Expanded Reservoir

Simulated Water Temperature at Station A

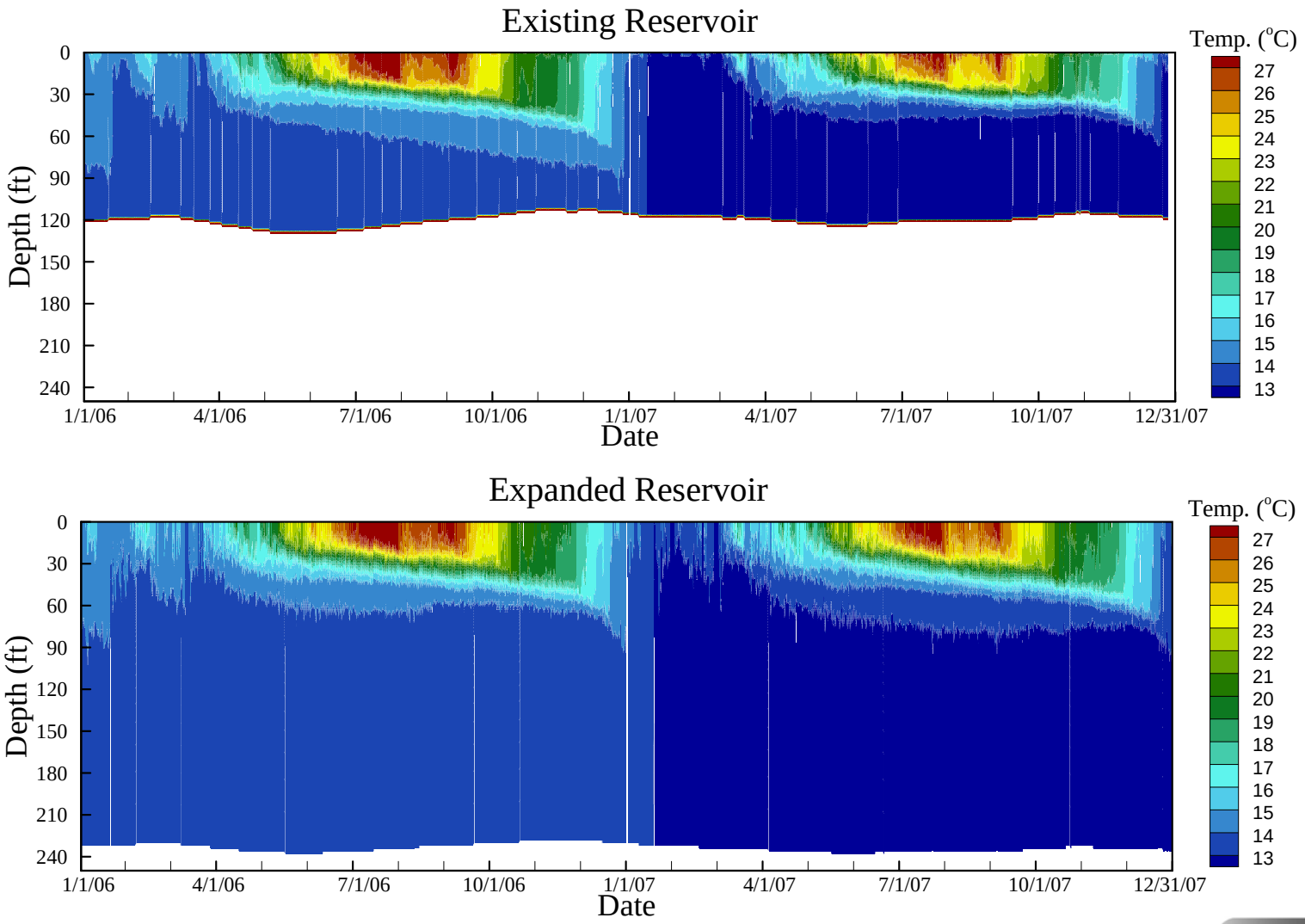

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Figure 7

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Comparison of Existing and Expanded Reservoir

Simulated Conductivity at Station A

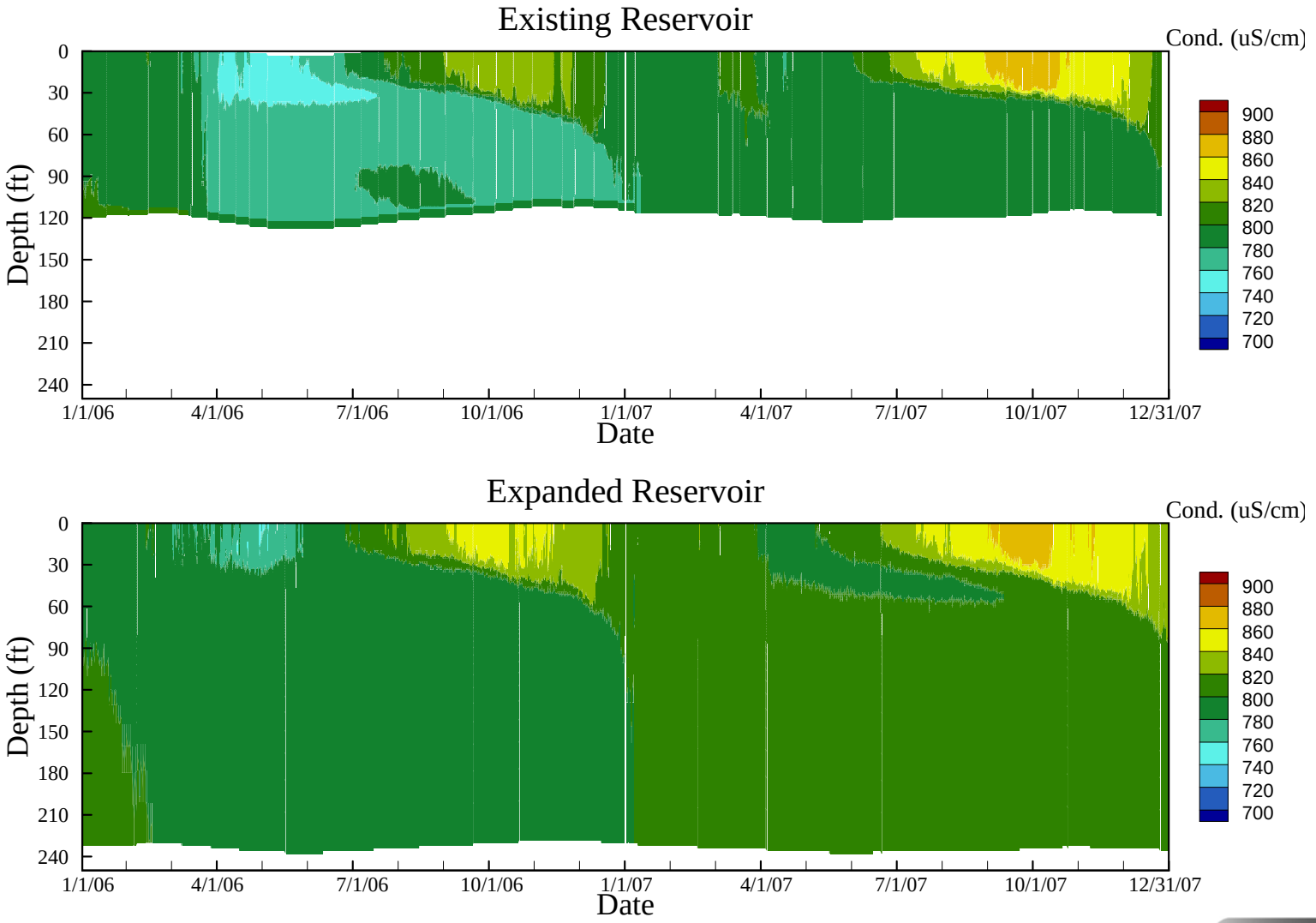

Figure 8

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Base Case: Purified Water Inflow Temperature

(Using multi-year averages of weekly water temperatures at North City Water Reclamation Plant; Provided by the City)

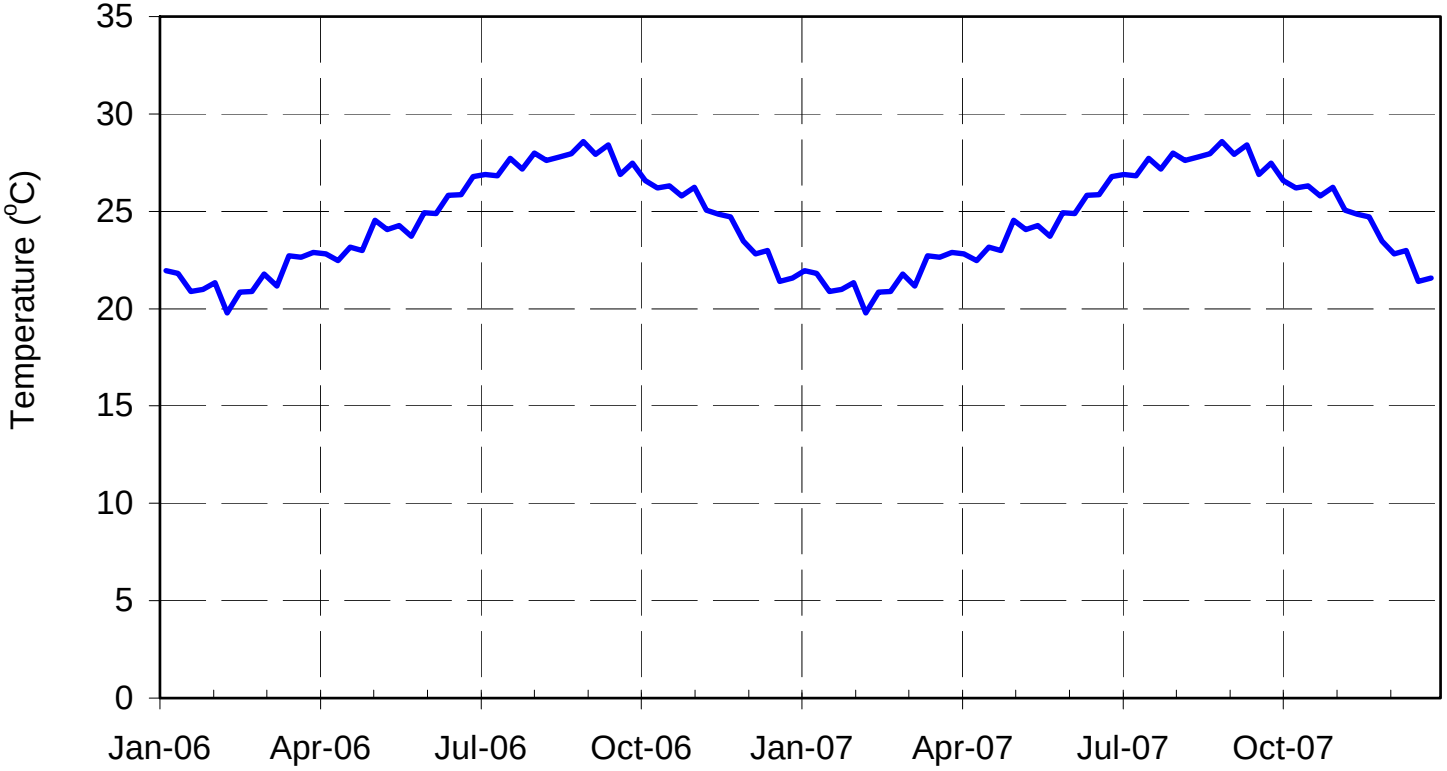

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Figure 9

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Base Case: Simulated Water Temperature and Conductivity at Station A

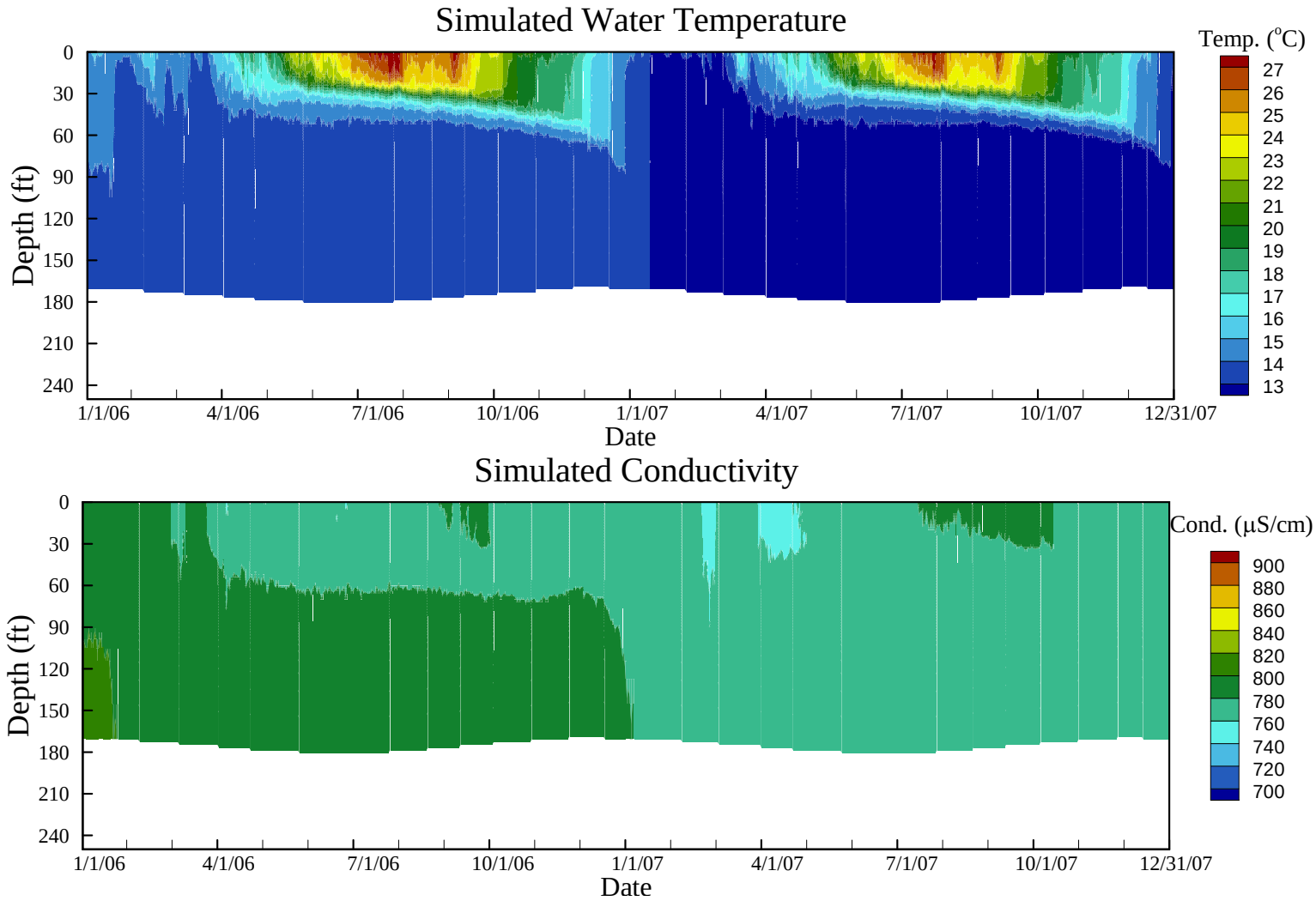

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Figure 10

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Base Case: Contours of Simulated Temperature and Decaying Tracer

(Initial Inflow Concentration = 100%; Decay Rate = One Log Reduction Per Month)

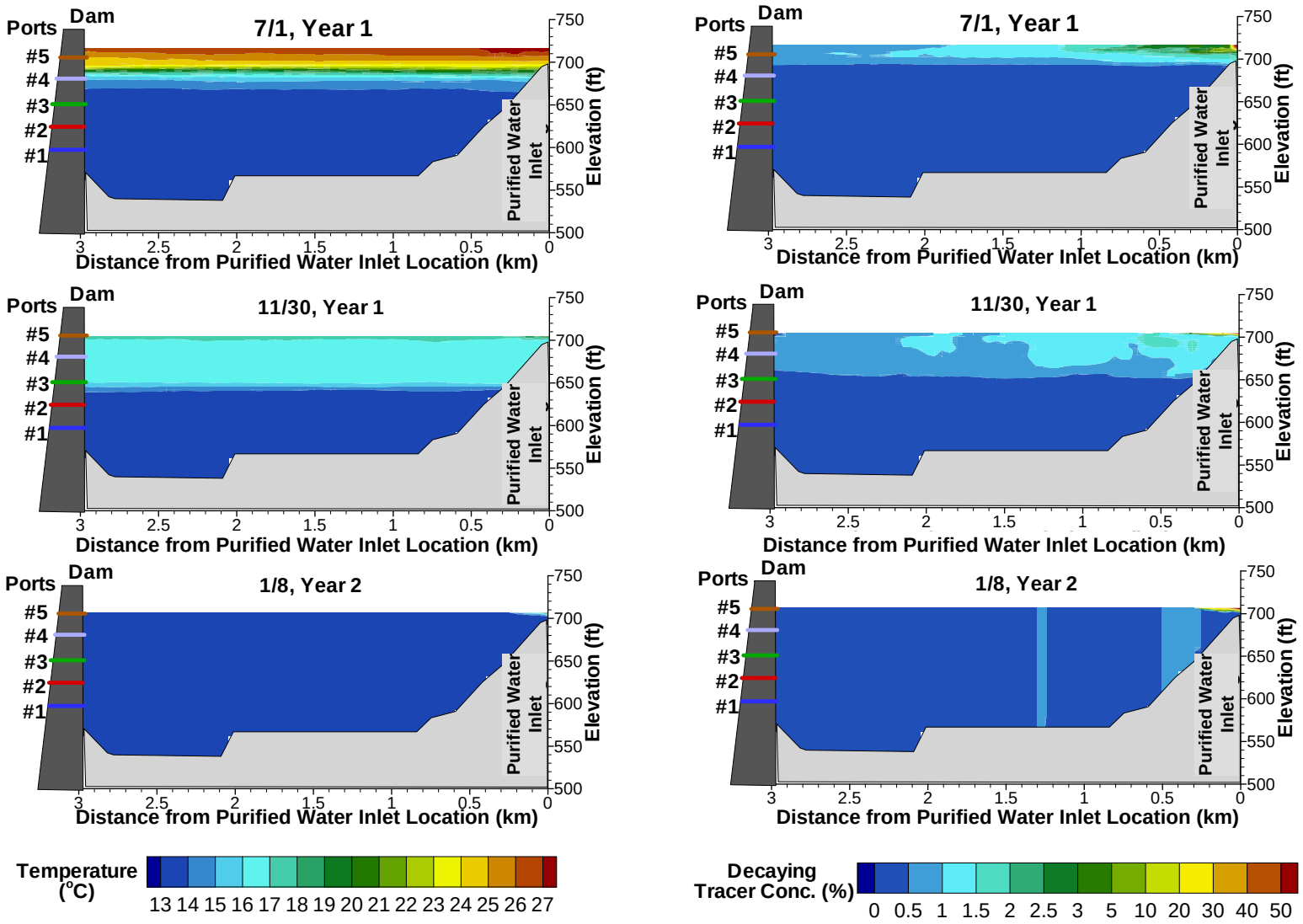

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Figure 11

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Base Case: Simulated Decaying Tracer at the Reservoir Outlet Tower

(Initial Inflow Concentration = 100%; Decay Rate = One Log Reduction Per Month)

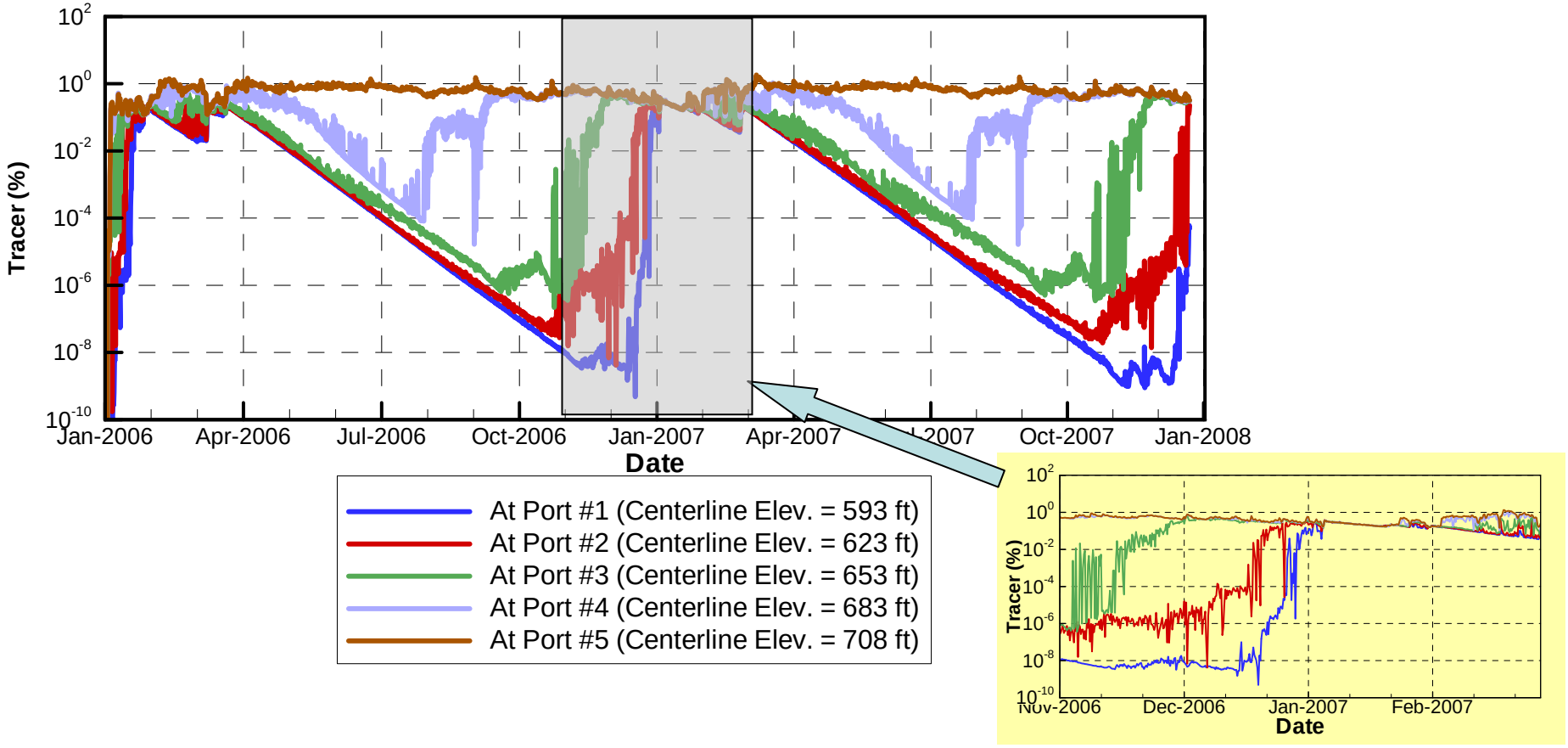

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Figure 12

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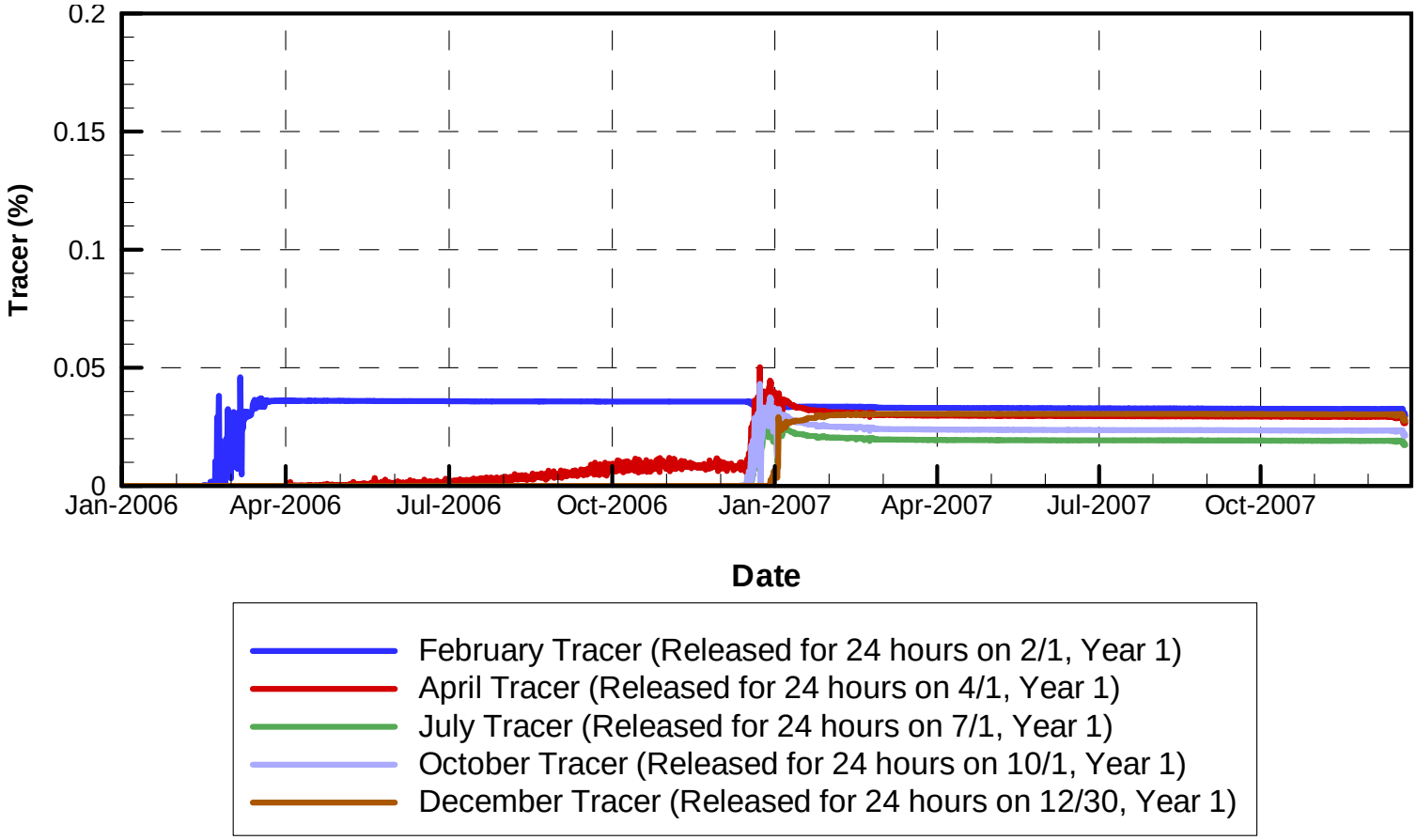
Base Case: Simulated 24-hour Conservative Tracer Concentrations in Reservoir Outflow*

(Initial Inflow Concentration = 100%; Open Port #2)



* Concentrations of trace within the reservoir at the outlet tower at the depth of the outlet port

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Figure 13

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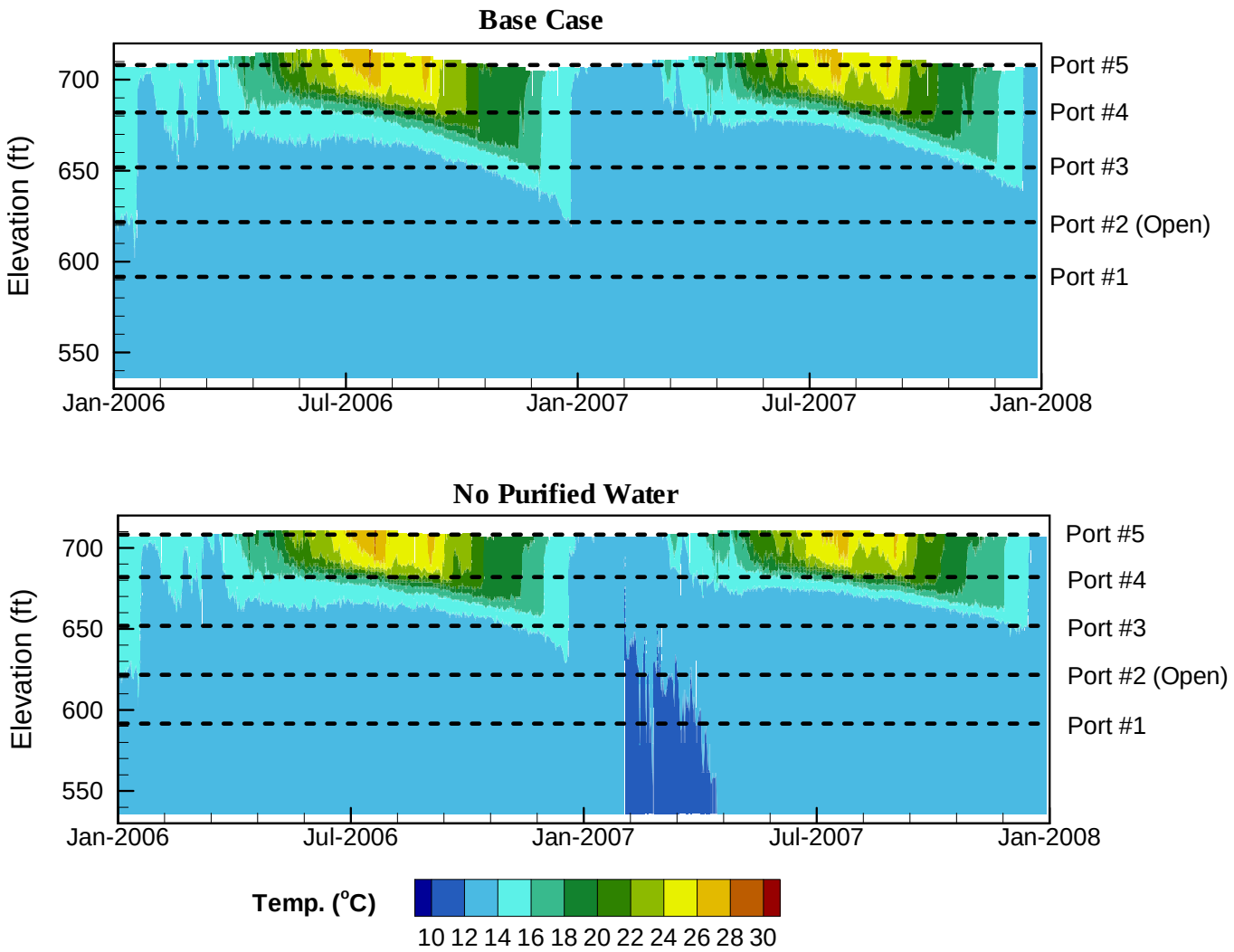
Comparison of Base Case and No Purified Water Scenario

Simulated Water Temperature at Station A



* Note that y-axis in this figure is elevation in ft for allowing labels of the port elevations in the figure

Figure 14

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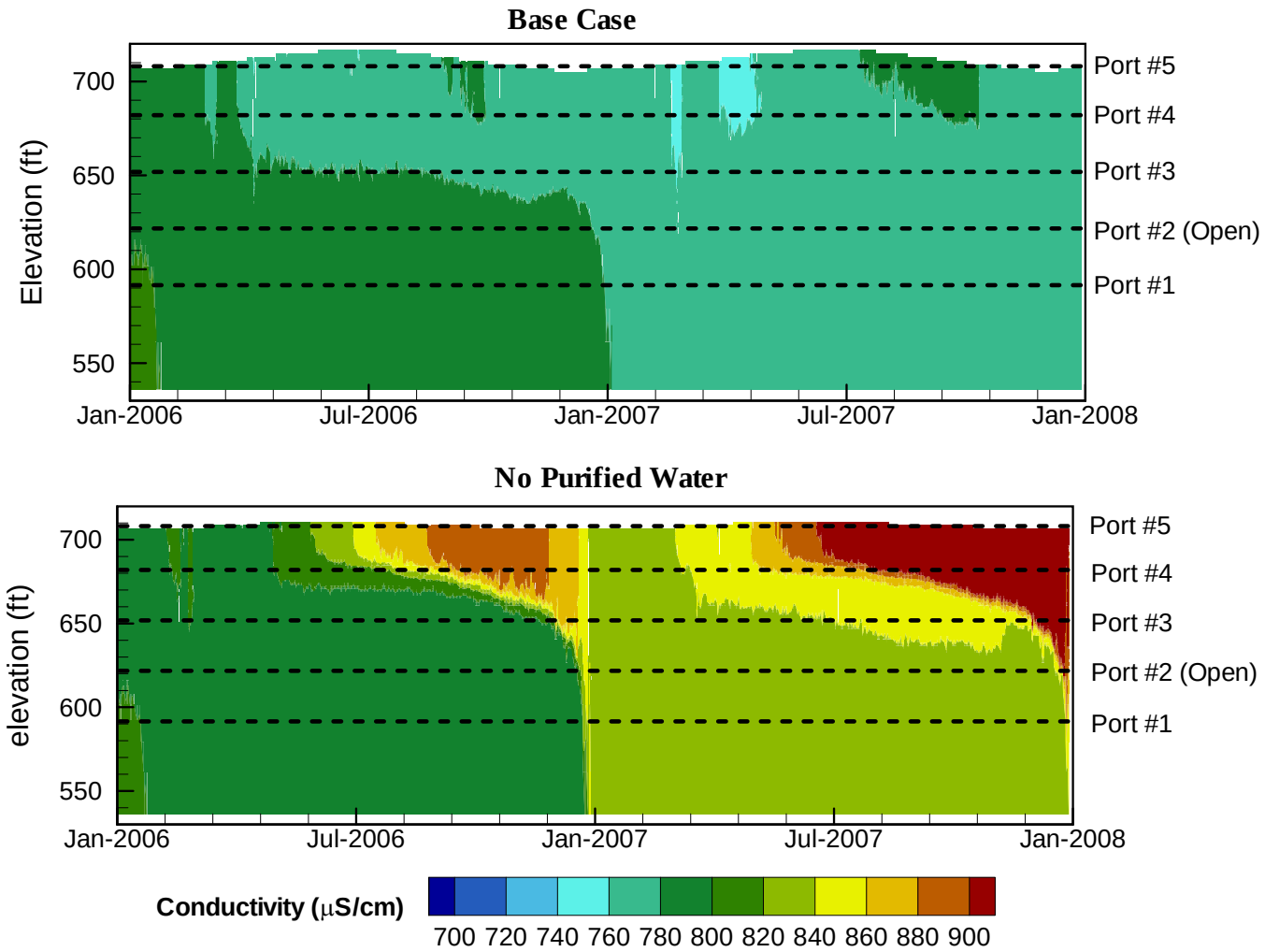
Comparison of Base Case and No Purified Water Scenario

Simulated Conductivity at Station A



* Note that y-axis in this figure is elevation in ft for allowing labels of the port elevations in the figure

Figure 15

Inflow and Outflow Rates of Base Case, Extended Drought and Emergency Drawdown Scenarios

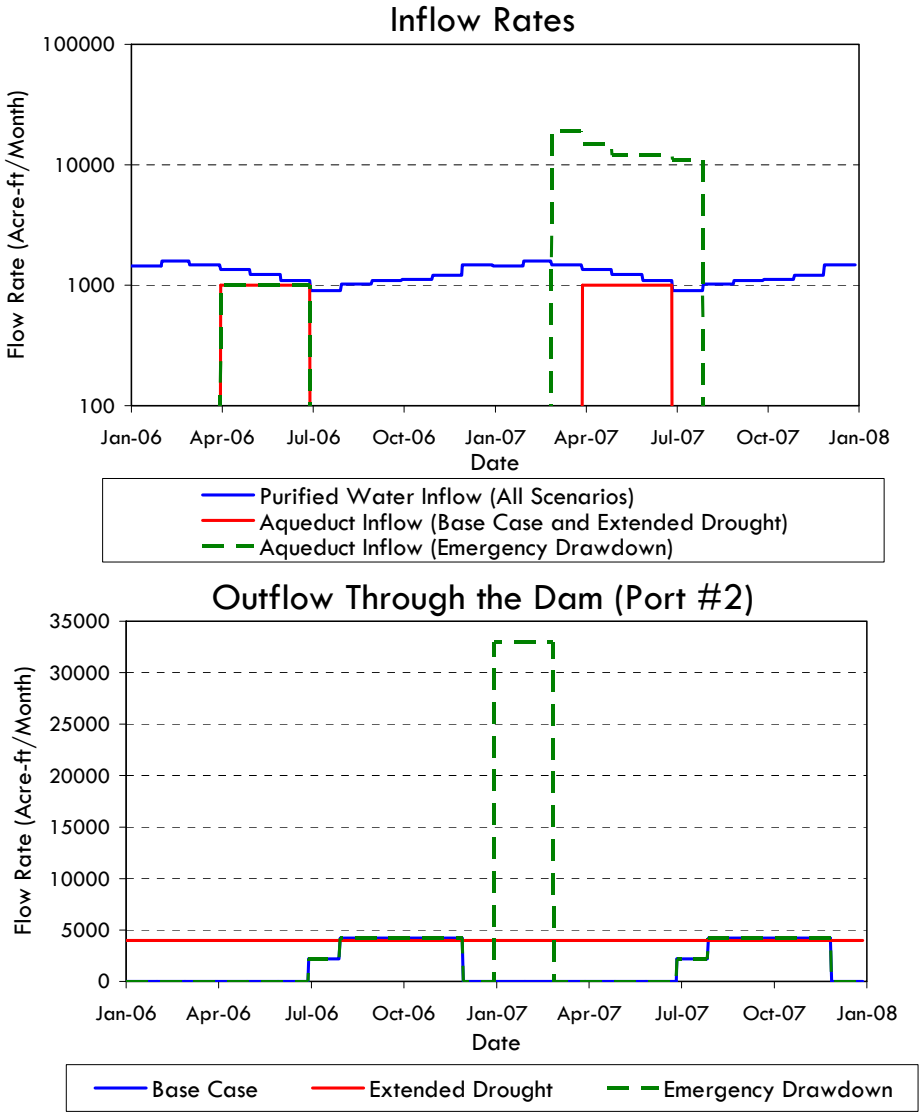


Figure 16

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Water Volumes of Base Case, Extended Drought and Emergency Drawdown Scenarios

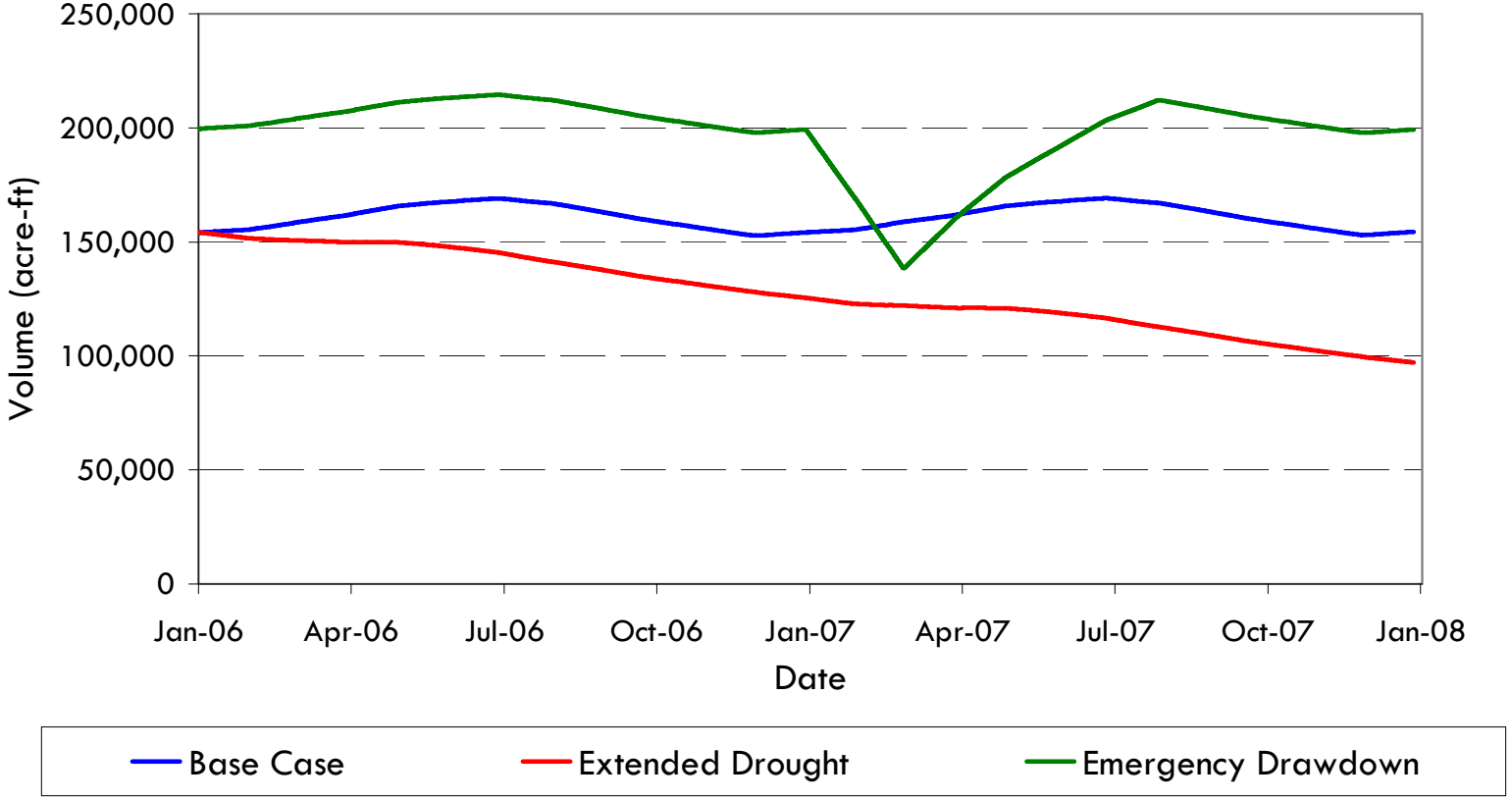

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Figure 17

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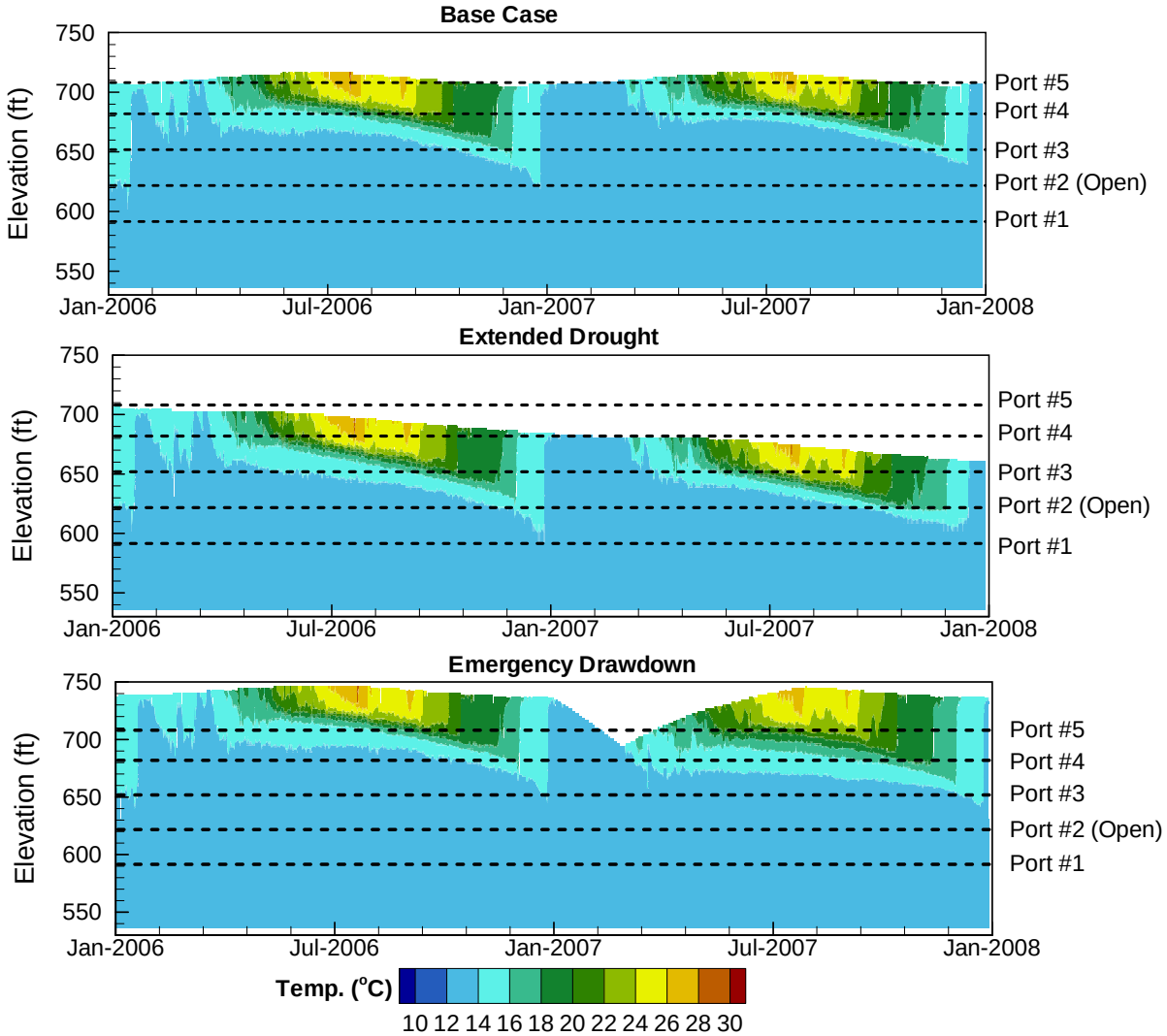
Comparison of Base Case, Extended Drought and Emergency Drawdown Scenarios

Simulated Water Temperature at Station A



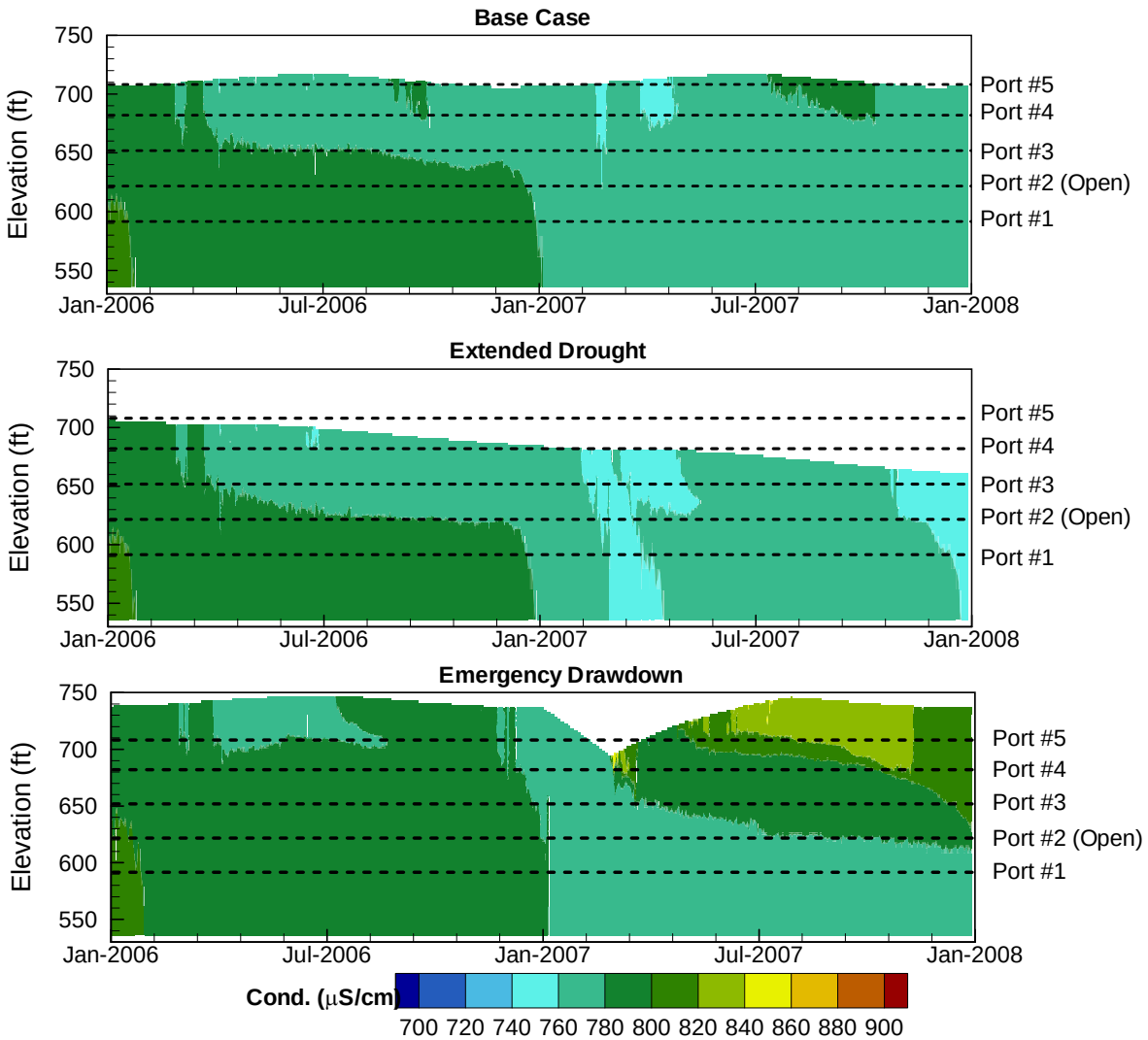
* Note that y-axis in this figure is elevation in ft for allowing labels of the port elevations in the figure

Figure 18

FLOW SCIENCE®

Comparison of Base Case, Extended Drought and Emergency Drawdown Scenarios

Simulated Conductivity at Station A



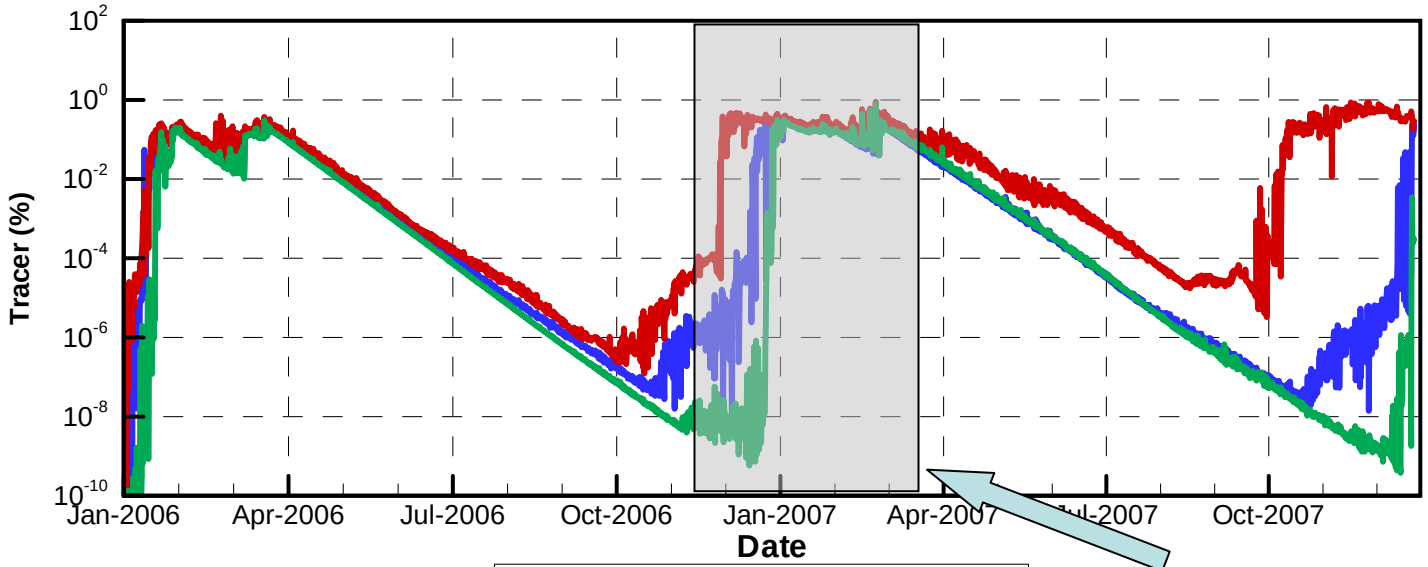
* Note that y-axis in this figure is elevation in ft for allowing labels of the port elevations in the figure

Figure 19

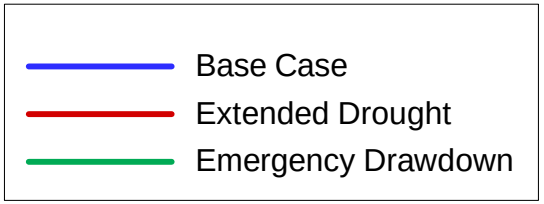
Comparison of Base Case, Extended Drought and Emergency Drawdown Scenarios

Simulated Decaying Tracer Concentrations in the Reservoir Outflow*

(Open Port #2; Initial Inflow Concentration = 100%; Decay Rate = One Log Reduction Per Month)



* Concentrations of tracer within the reservoir at the outlet tower at the depth of the open outlet port



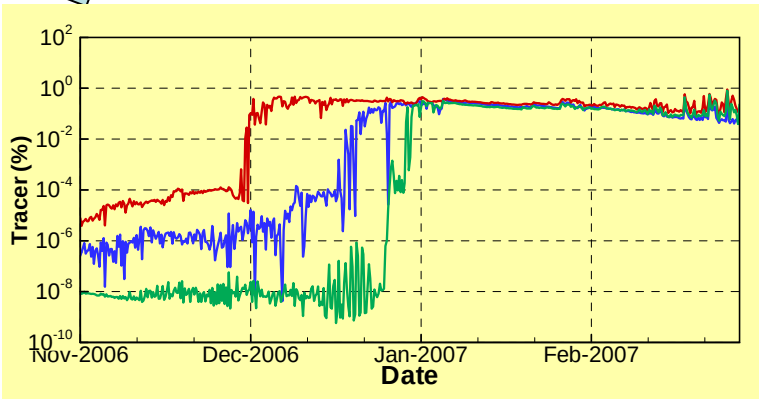


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Figure 20

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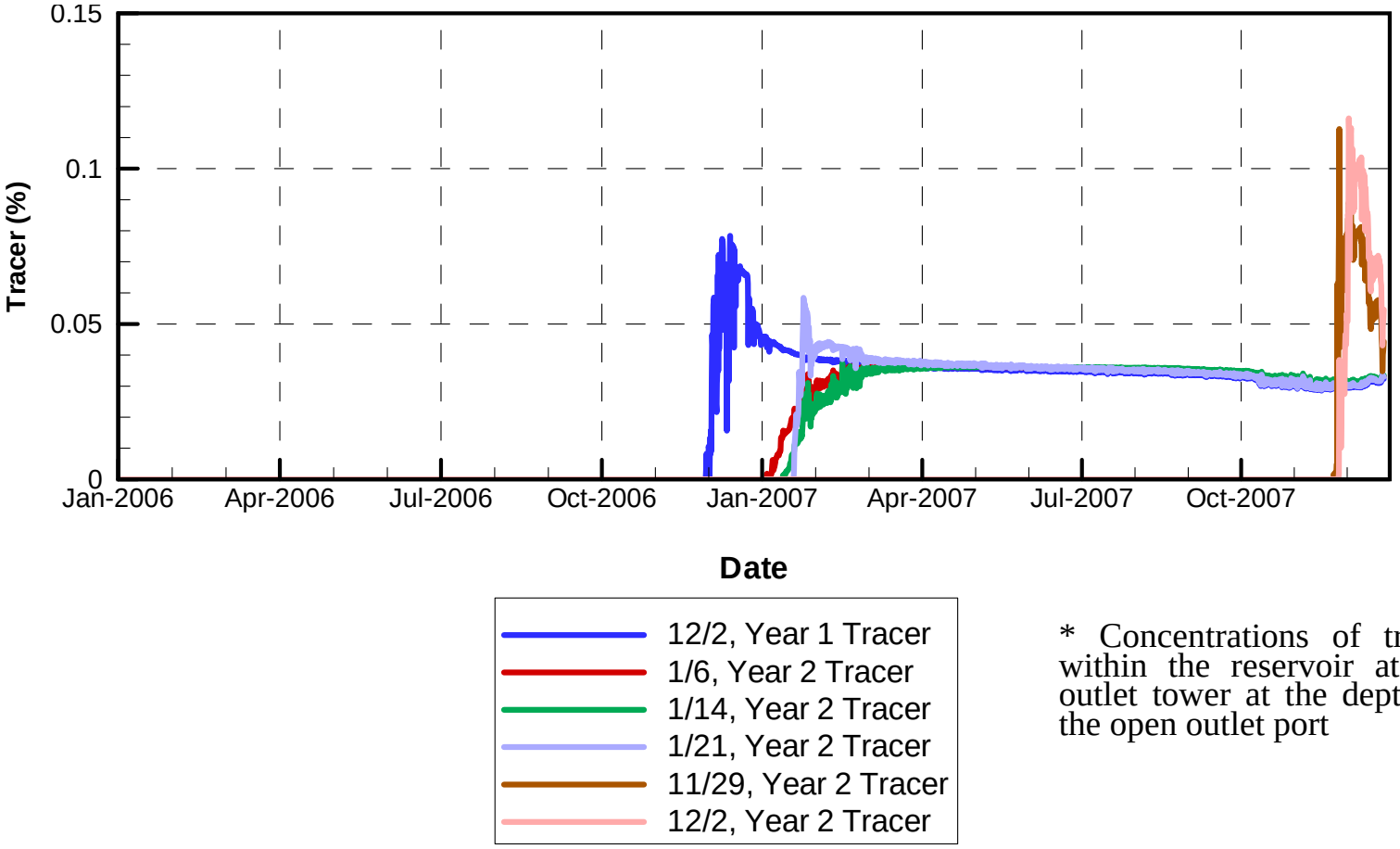
Extended Drought Scenario Simulated 24-hour Conservative Tracer Concentrations in the Reservoir Outflow*

(Open Port #2; Initial Inflow Concentration = 100%)



* Concentrations of tracer within the reservoir at the outlet tower at the depth of the open outlet port

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Figure 21

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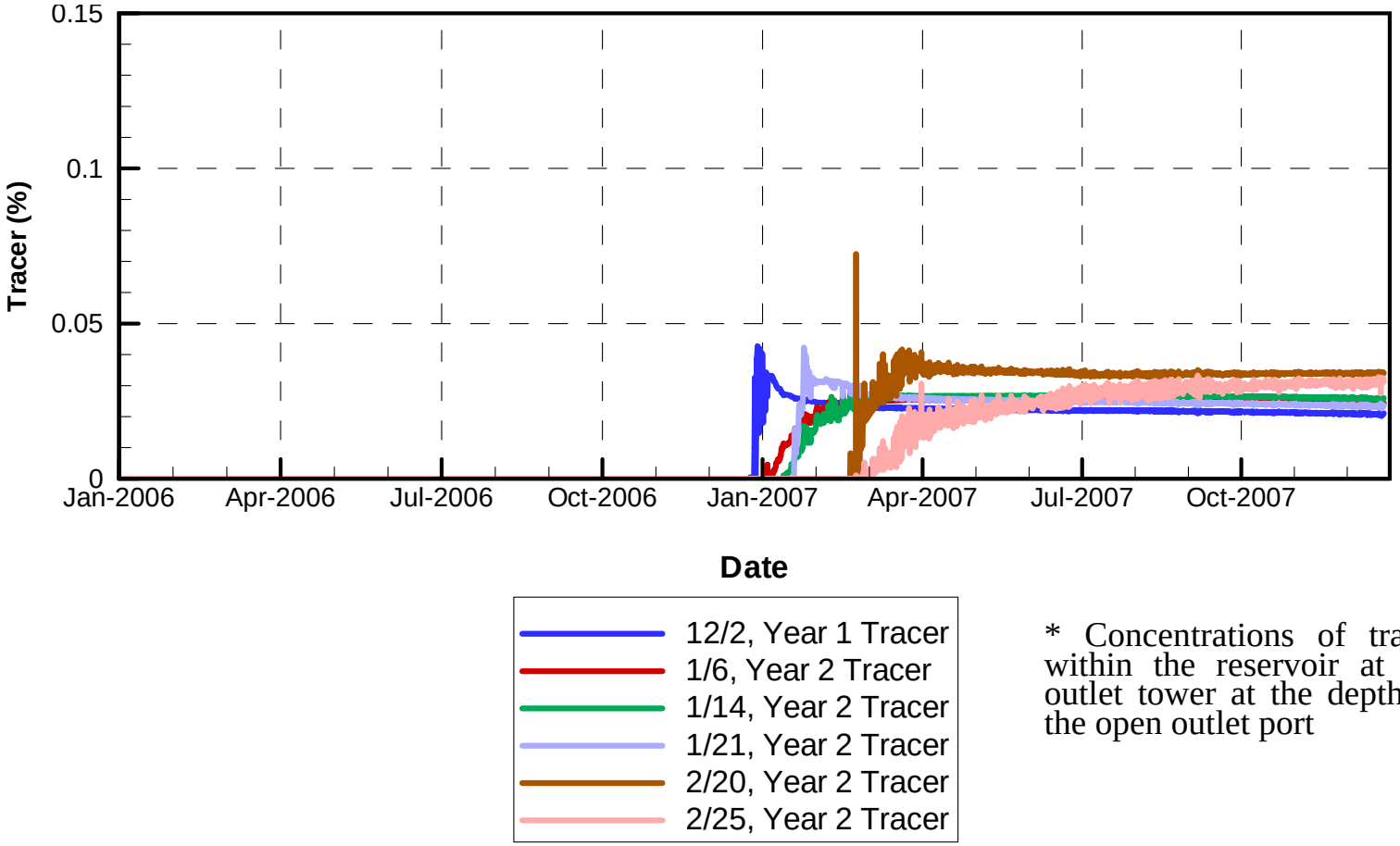
Emergency Drawdown Scenario Simulated 24-hour Conservative Tracer Concentrations in the Reservoir Outflow*

(Open Port #2; Initial Inflow Concentration = 100%)



* Concentrations of tracer within the reservoir at the outlet tower at the depth of the open outlet port

Figure 22

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Map of Modeled Purified Water Inlet Locations

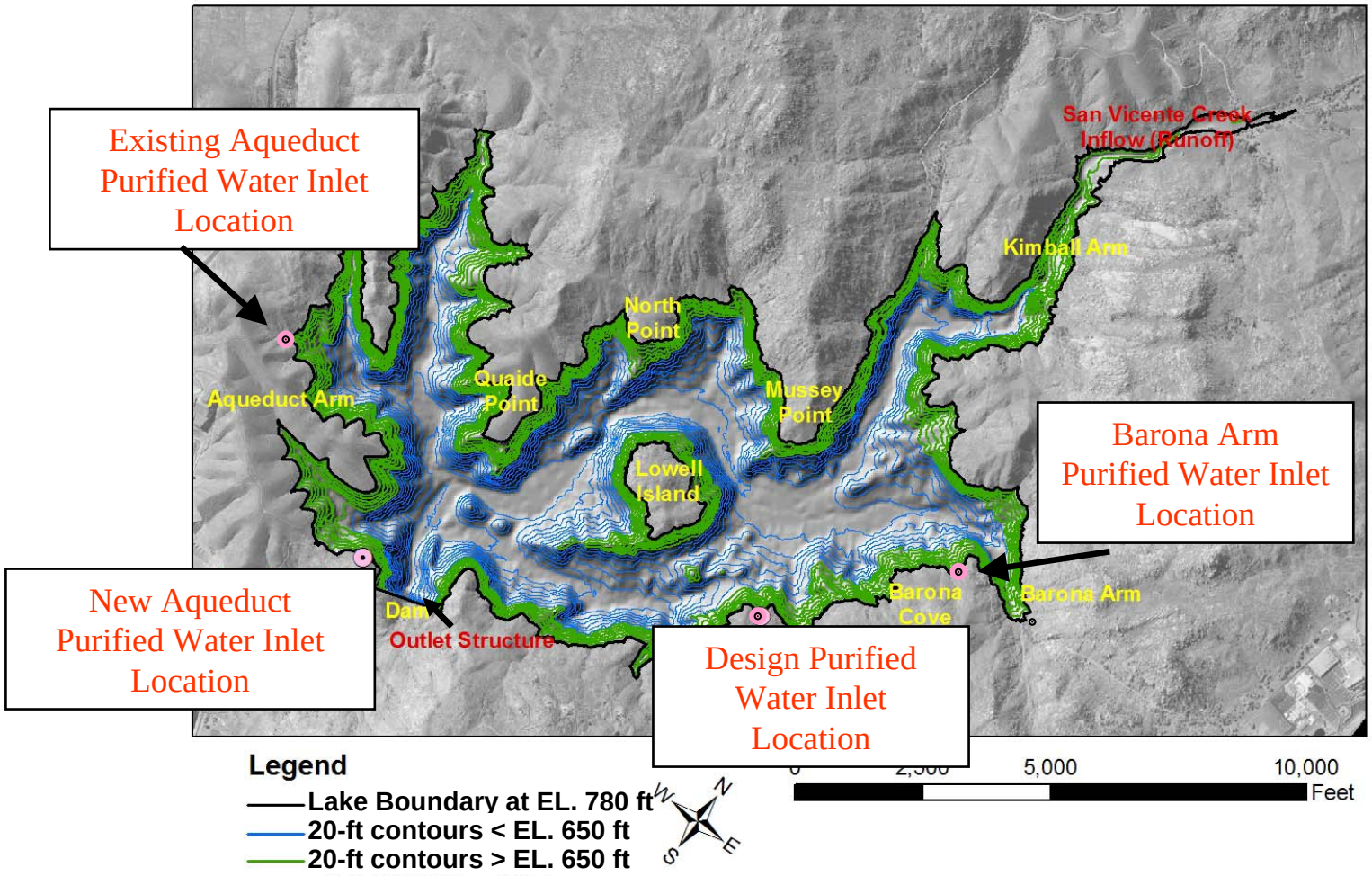

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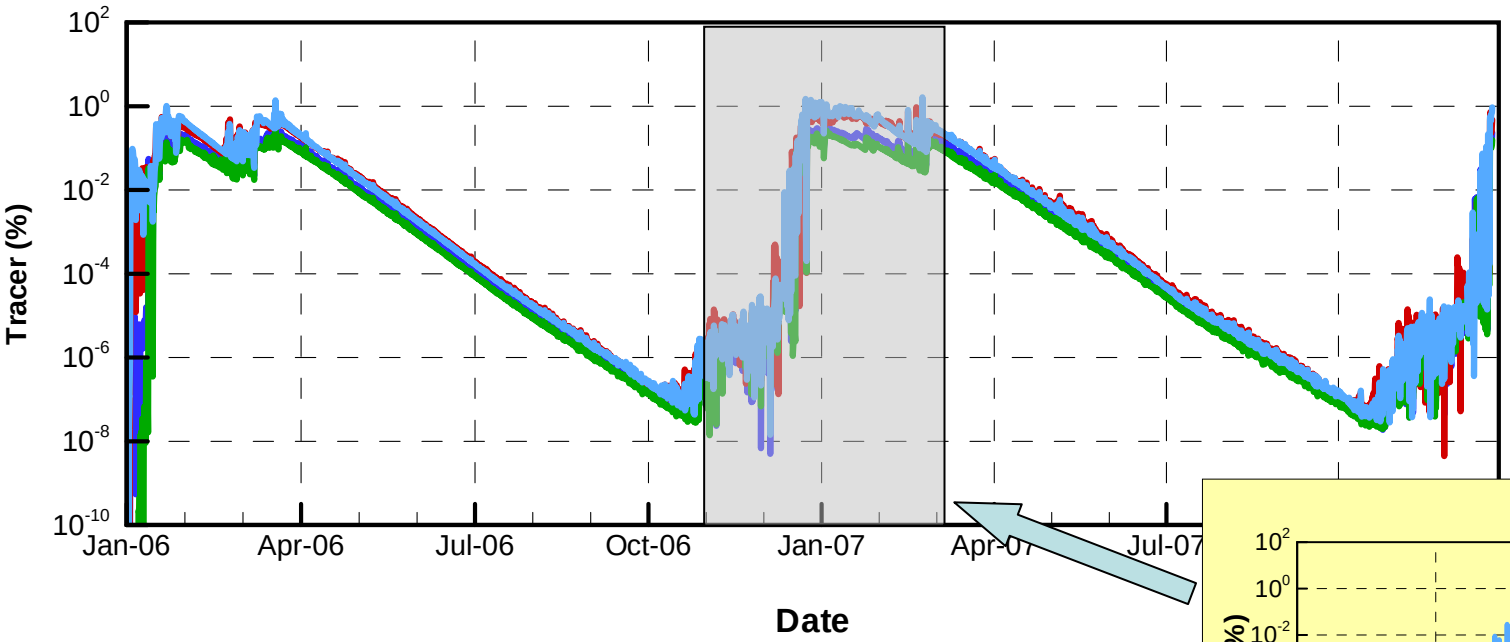
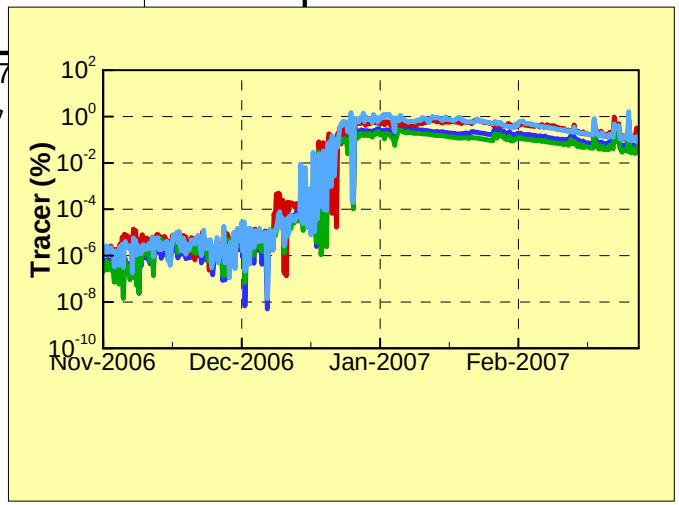
Figure 23

FLOW SCIENCE®

Comparison of Reservoir Outflow Decaying Tracer Concentrations* from Different Purified Water Inlet Locations Under Base Case Operating Scenario

(Open Port #2; Initial Inflow Concentration = 100%;
Decay Rate = One Log Reduction Per Month)





* Concentrations of tracer within the reservoir at the outlet tower at the depth of the open outlet port.

- Design Purified Water Inlet Location
- Existing Aqueduct Purified Water Inlet Location
- Barona Arm Purified Water Inlet Location
- New Aqueduct Purified Water Inlet Location

Figure 24

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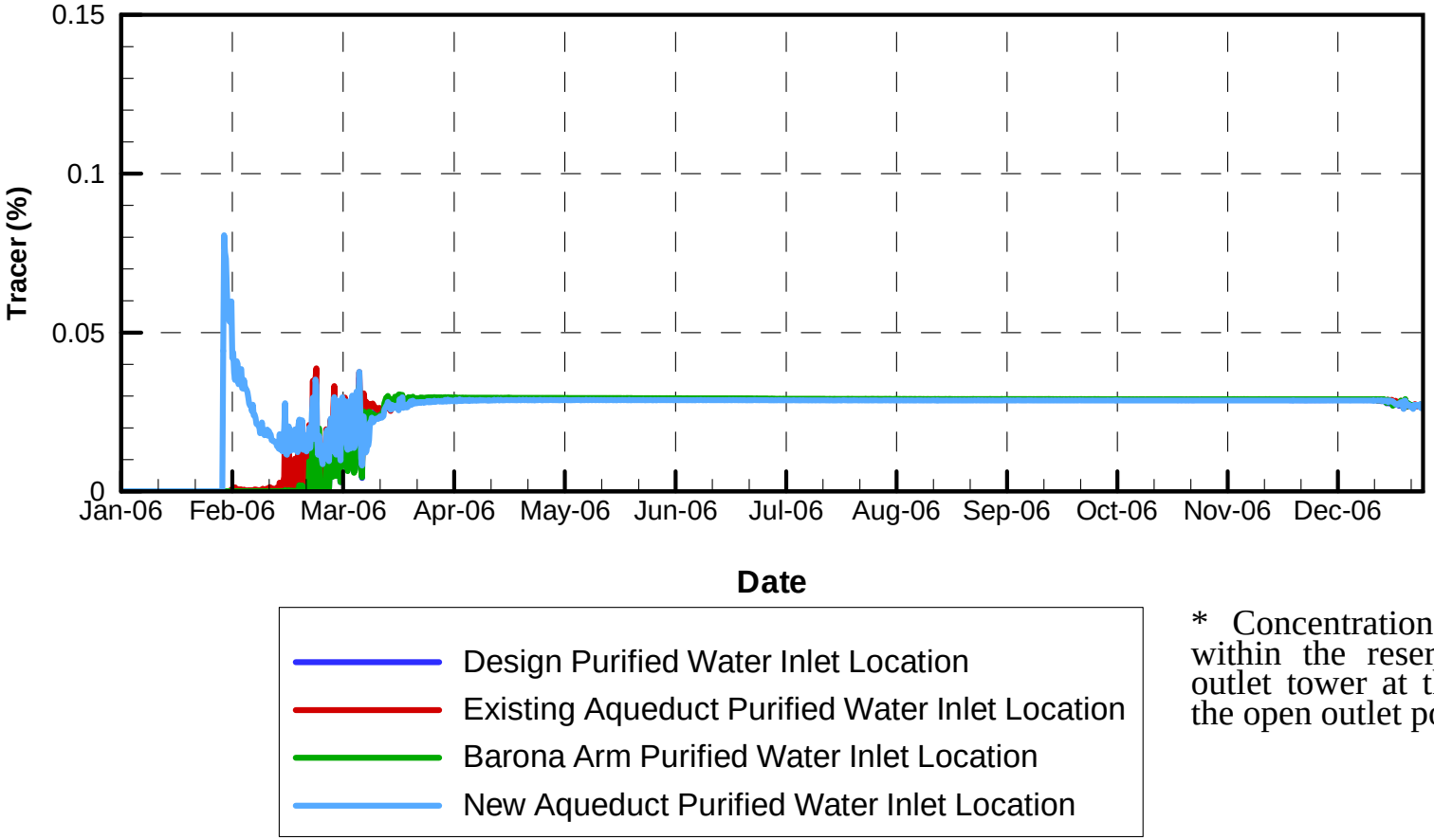
Comparison of Reservoir Outflow 24-hour Conservative Tracer Concentrations* from Different Purified Water Inlet Locations Under Base Case Operating Scenario

Tracer Released on 1/30, Year 1 for 24 hours

(Open Port #2; Initial Inflow Concentration = 100%)



* Concentrations of tracer within the reservoir at the outlet tower at the depth of the open outlet port

Figure 25

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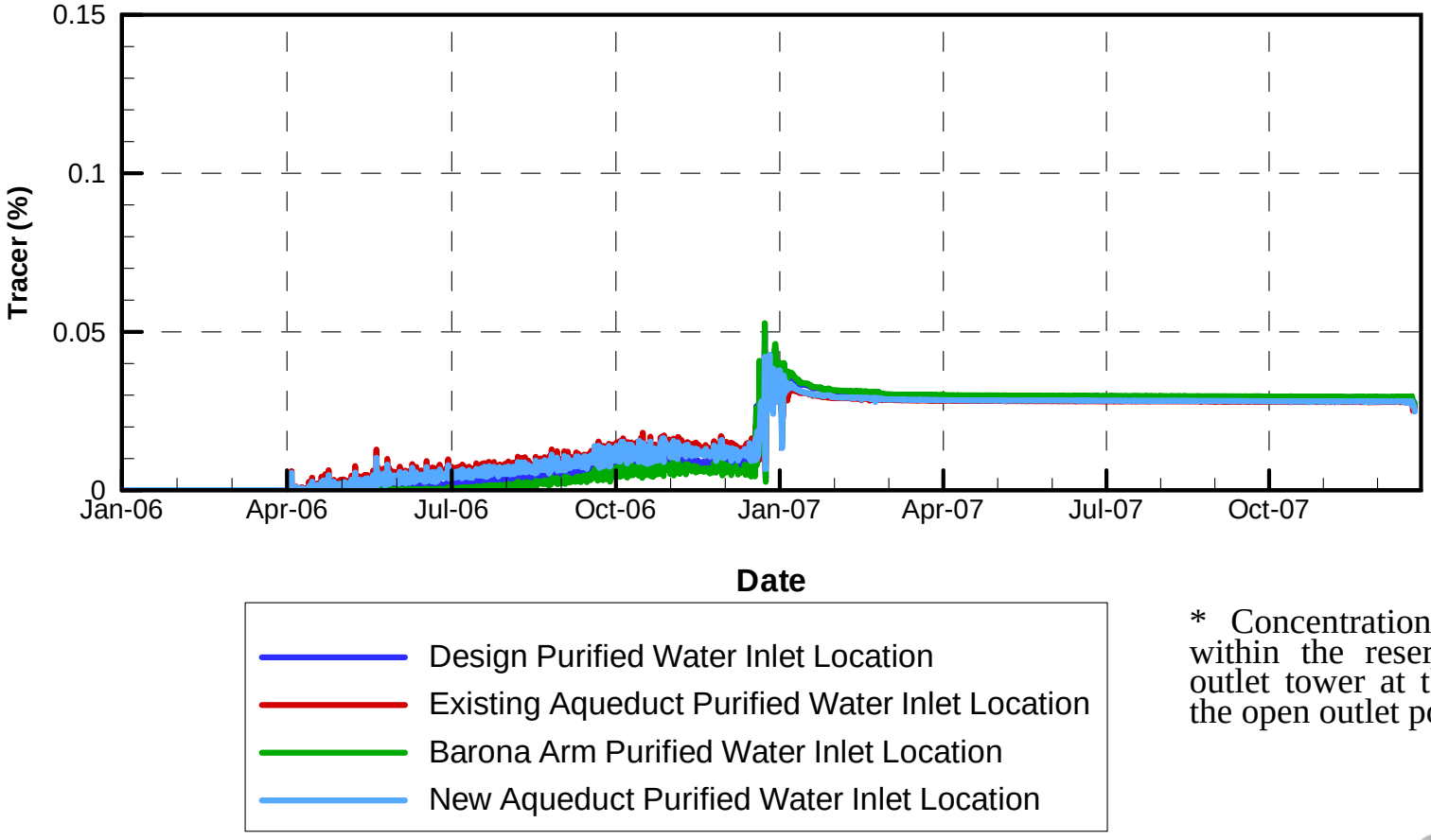
Comparison of Reservoir Outflow 24-hour Conservative Tracer Concentrations* from Different Purified Water Inlet Locations Under Base Case Operating Scenario

Tracer released on 4/1, Year 1 for 24 hours

(Open Port #2; Initial Inflow Concentration = 100%)



* Concentrations of tracer within the reservoir at the outlet tower at the depth of the open outlet port

Figure 26

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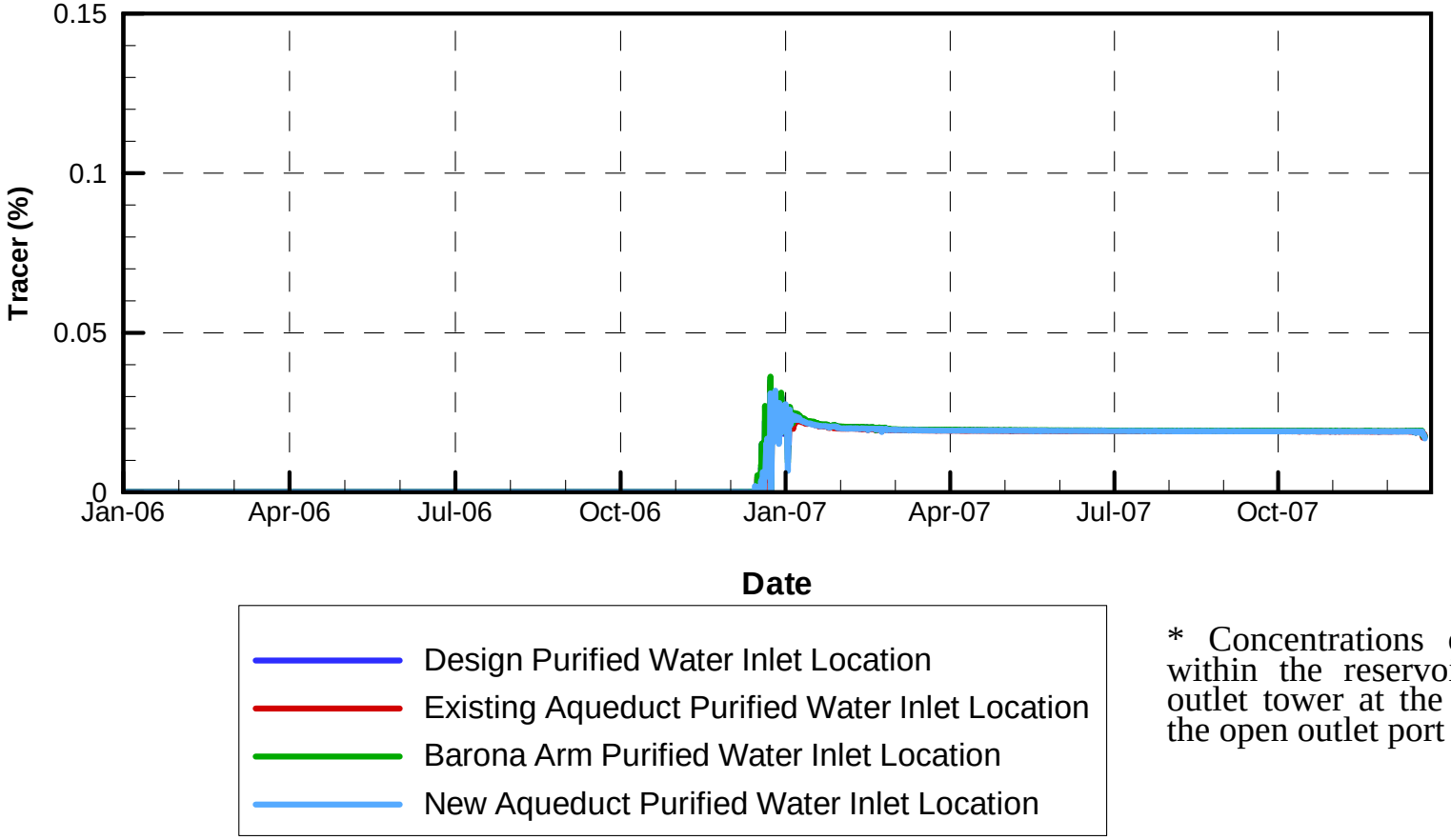
Comparison of Reservoir Outflow 24-hour Conservative Tracer Concentrations* from Different Purified Water Inlet Locations Under Base Case Operating Scenario

Tracer released on 7/1, Year 1 for 24 hours

(Open Port #2; Initial Inflow Concentration = 100%)



* Concentrations of tracer within the reservoir at the outlet tower at the depth of the open outlet port

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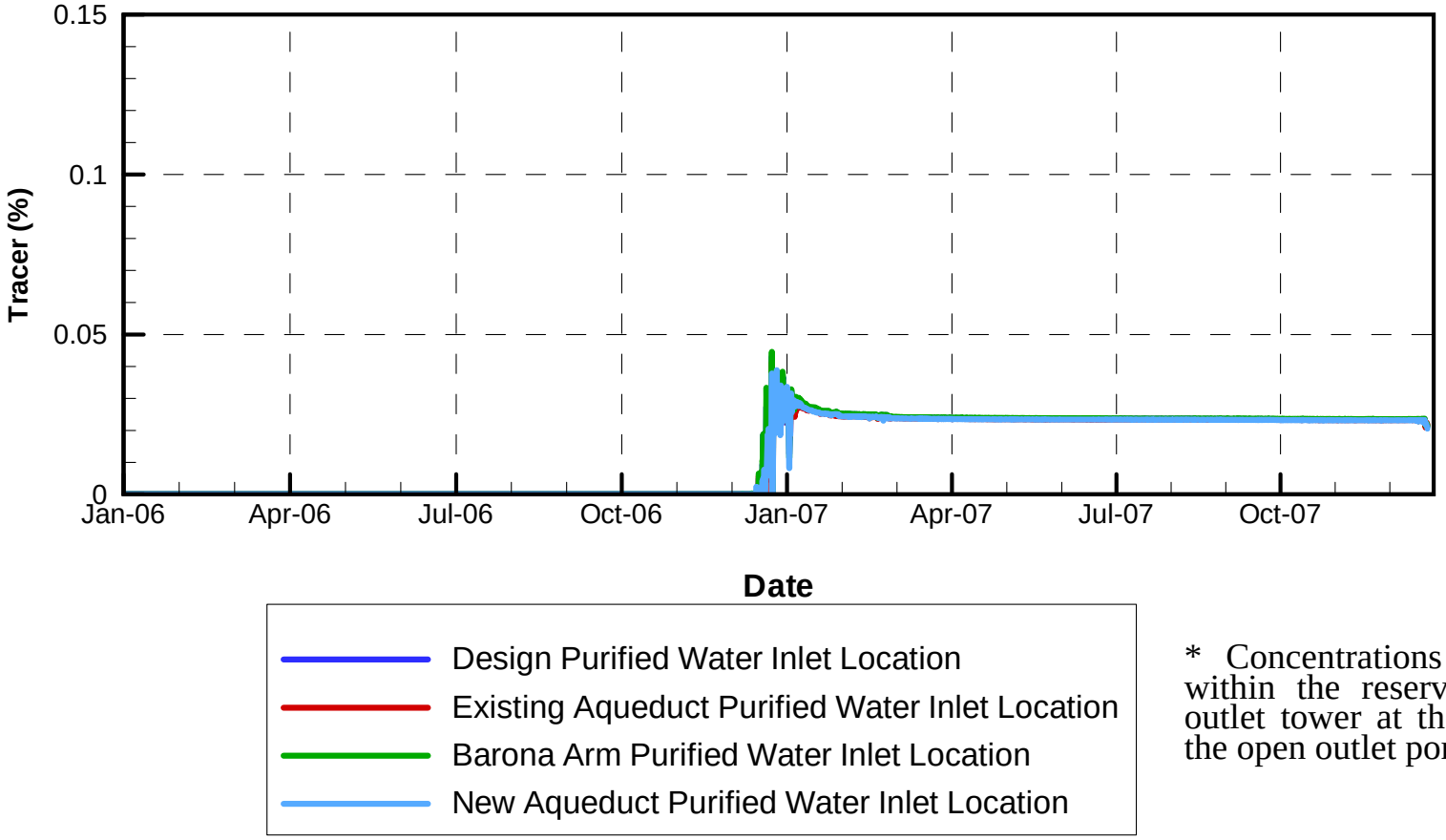
Figure 27

FLOW SCIENCE®

Comparison of Reservoir Outflow 24-hour Conservative Tracer Concentrations* from Different Purified Water Inlet Locations Under Base Case Operating Scenario

Tracer released on 10/1, Year 1 for 24 hours

(Open Port #2; Initial Inflow Concentration = 100%)



* Concentrations of tracer within the reservoir at the outlet tower at the depth of the open outlet port

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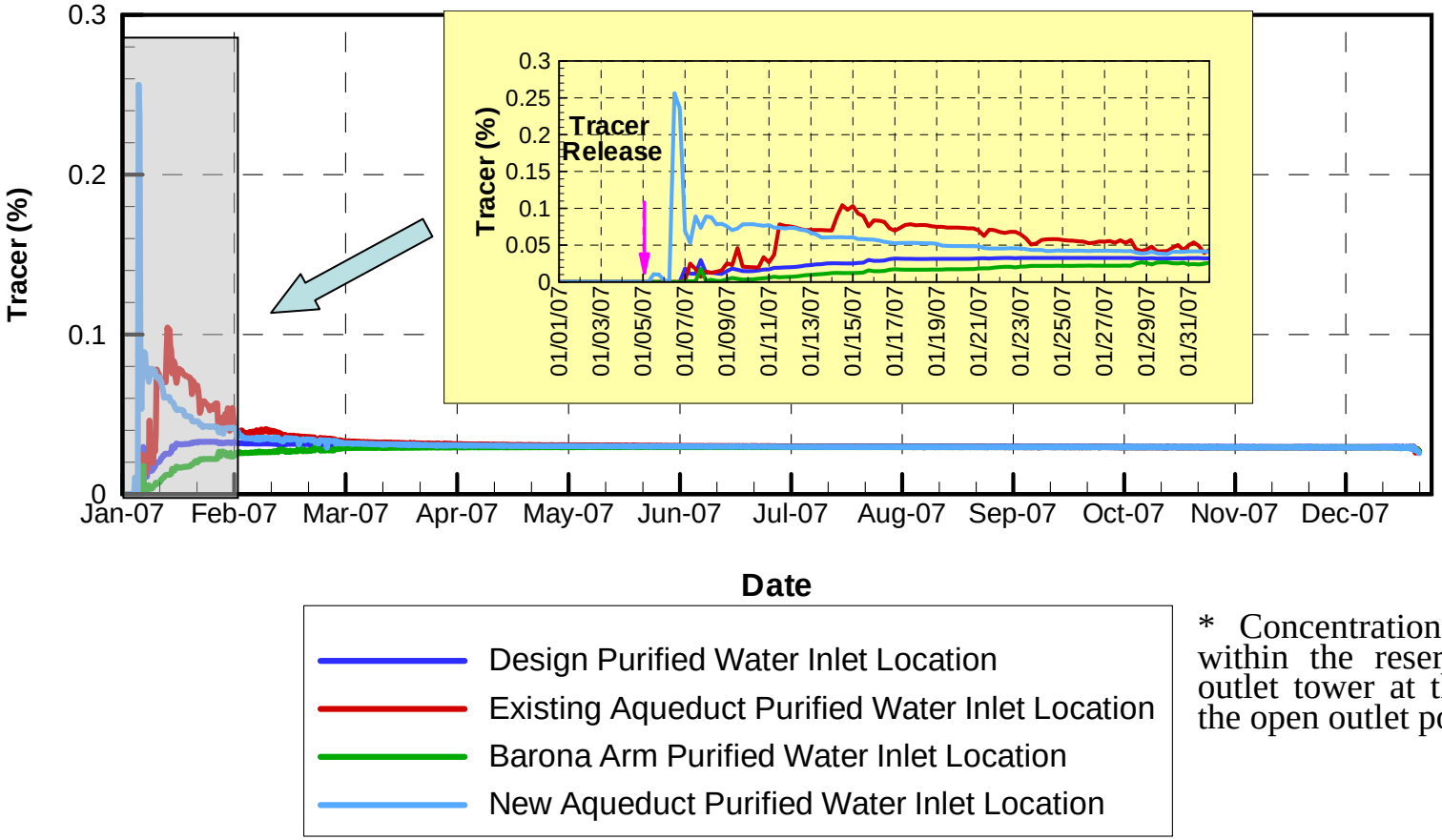
Figure 28

FLOW SCIENCE®

Comparison of Reservoir Outflow 24-hour Conservative Tracer Concentrations* from Different Purified Water Inlet Locations Under Base Case Operating Scenario

Tracer released on 1/5, Year 2 for 24 hours

(Open Port #2; Initial Inflow Concentration = 100%)



* Concentrations of tracer within the reservoir at the outlet tower at the depth of the open outlet port

Figure 29

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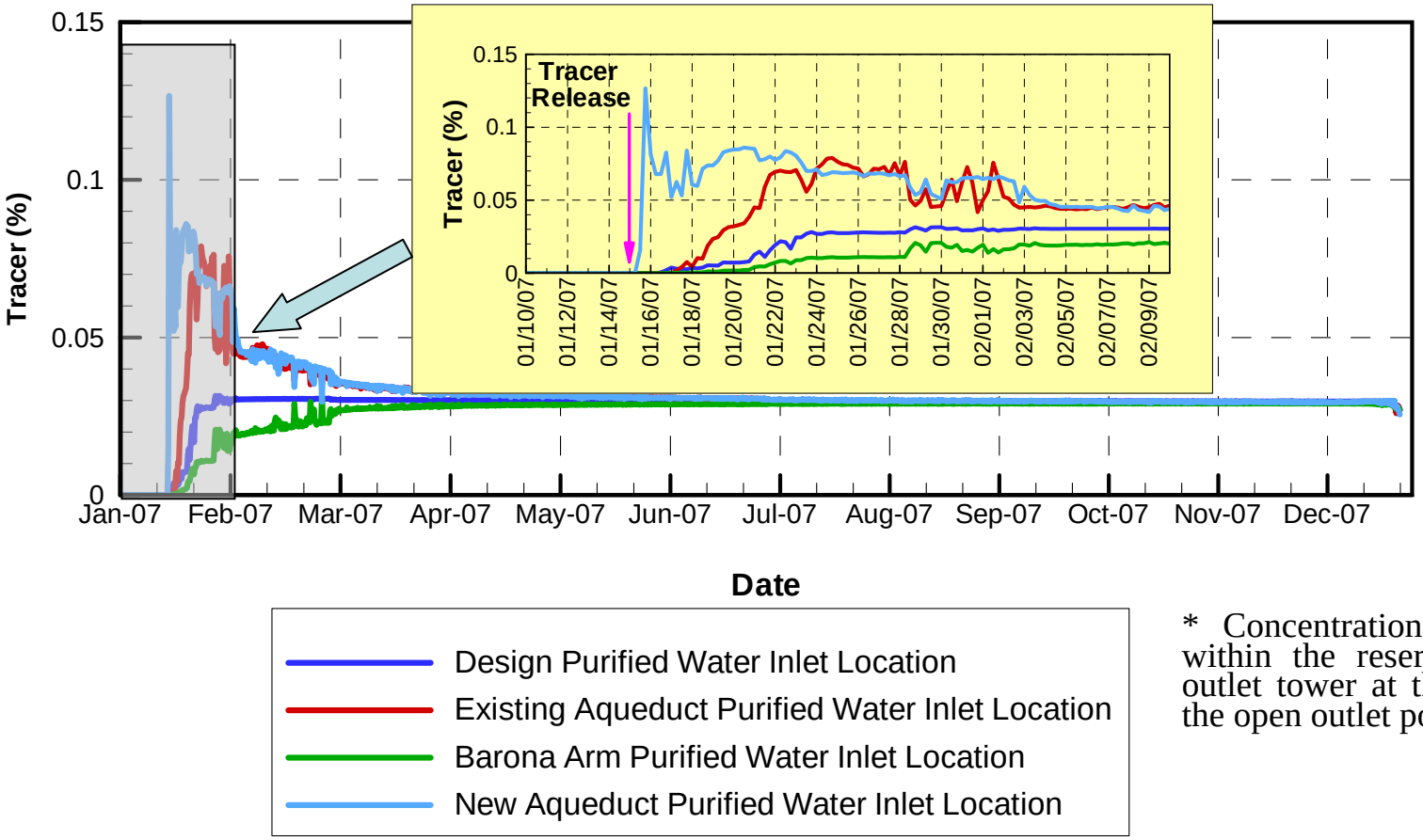
Comparison of Reservoir Outflow 24-hour Conservative Tracer Concentrations* from Different Purified Water Inlet Locations Under Base Case Operating Scenario

Tracer released on 1/15, Year 2 for 24 hours

(Open Port #2; Initial Inflow Concentration = 100%)



* Concentrations of tracer within the reservoir at the outlet tower at the depth of the open outlet port

Figure 30

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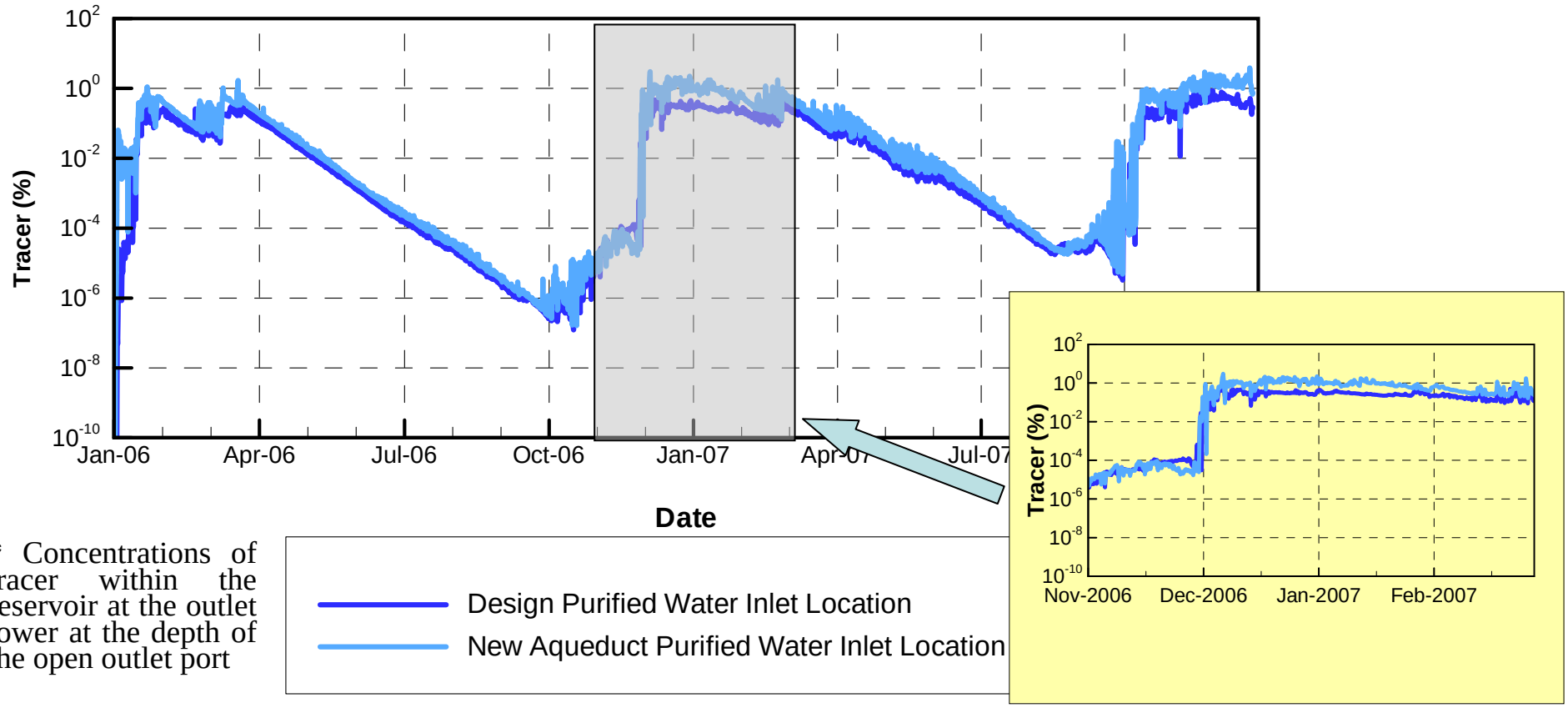
Comparison of Reservoir Outflow 24-hour Decaying Tracer Concentrations* from Different Purified Water Inlet Locations Under Extended Drought Scenario

(Open Port #2; Initial Inflow Concentration = 100%;
Decay Rate = One Log Reduction Per Month)



* Concentrations of tracer within the reservoir at the outlet tower at the depth of the open outlet port

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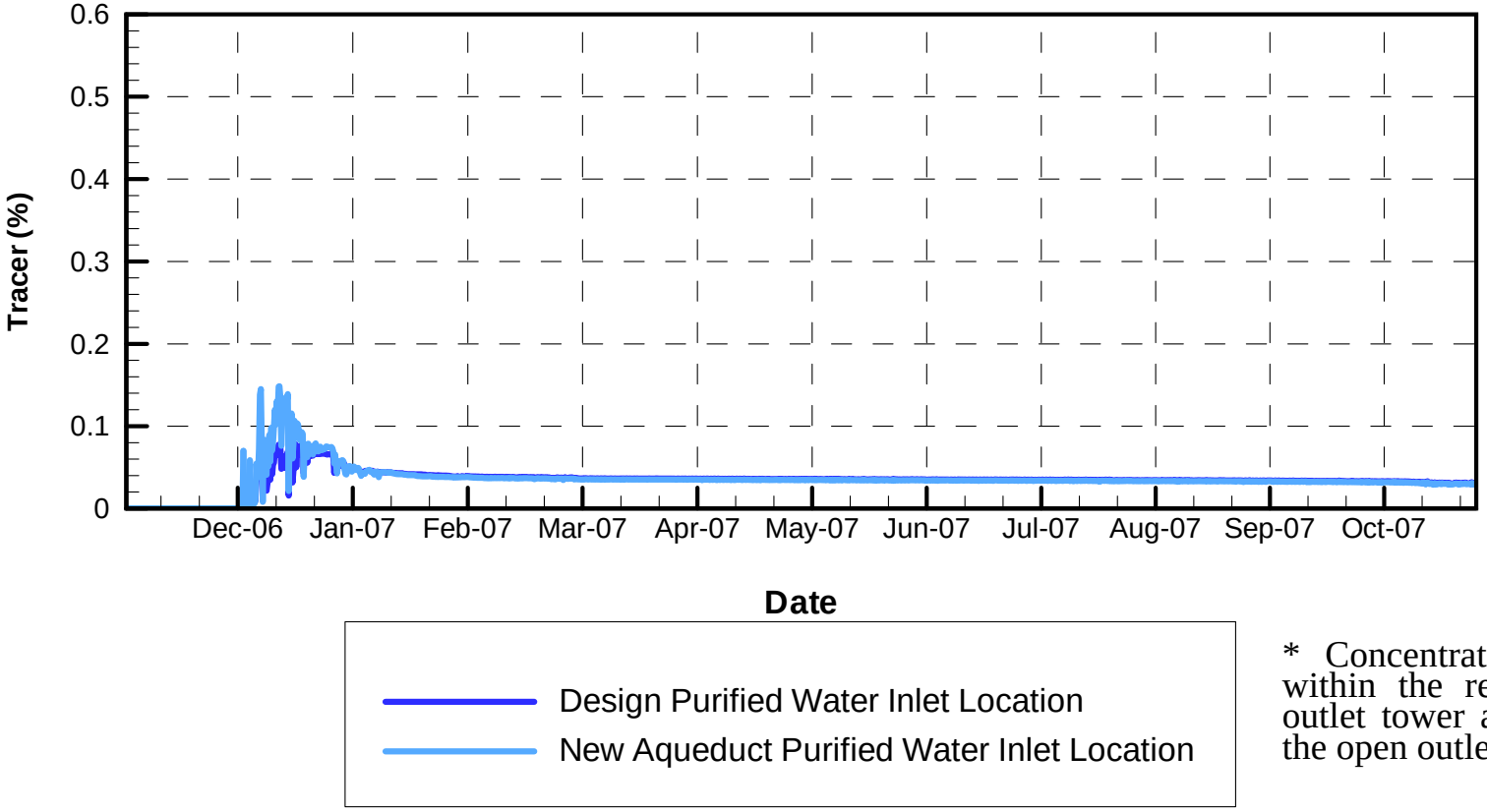
Figure 31

FLOW SCIENCE®

Comparison of Reservoir Outflow 24-hour Conservative Tracer Concentrations* from Different Purified Water Inlet Locations Under Extended Drought Scenario

Tracer Released on 12/2, Year 1 for 24 hours

(Open Port #2; Initial Inflow Concentration = 100%)



* Concentrations of tracer within the reservoir at the outlet tower at the depth of the open outlet port

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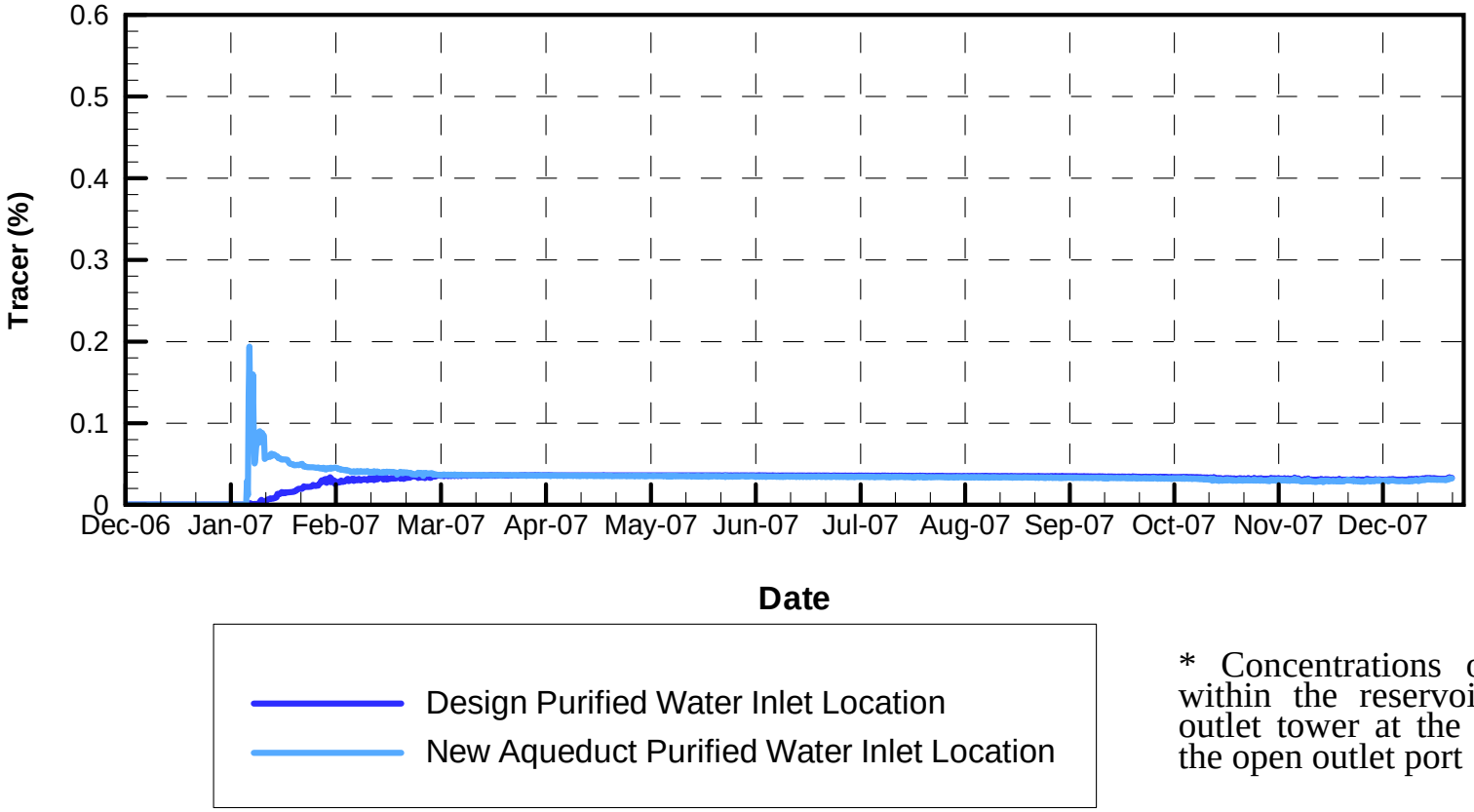
Figure 32

FLOW SCIENCE®

Comparison of Reservoir Outflow 24-hour Conservative Tracer Concentrations* from Different Purified Water Inlet Locations Under Extended Drought Scenario

Tracer Released on 1/6, Year 2 for 24 hours

(Open Port #2; Initial Inflow Concentration = 100%)



* Concentrations of tracer within the reservoir at the outlet tower at the depth of the open outlet port

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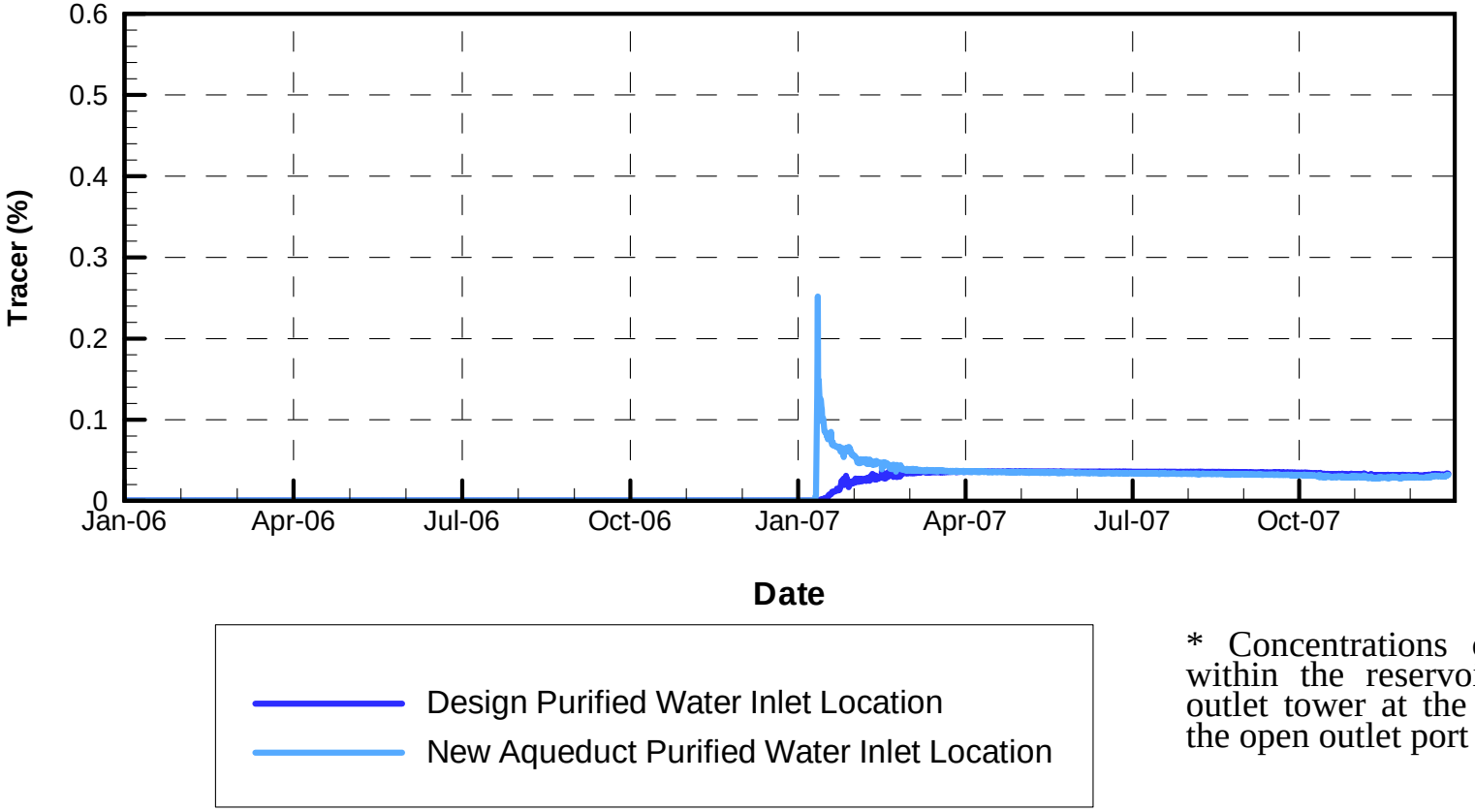
Figure 33

FLOW SCIENCE®

Comparison of Reservoir Outflow 24-hour Conservative Tracer Concentrations* from Different Purified Water Inlet Locations Under Extended Drought Scenario

Tracer Released on 1/14, Year 2 for 24 hours

(Open Port #2; Initial Inflow Concentration = 100%)



* Concentrations of tracer within the reservoir at the outlet tower at the depth of the open outlet port

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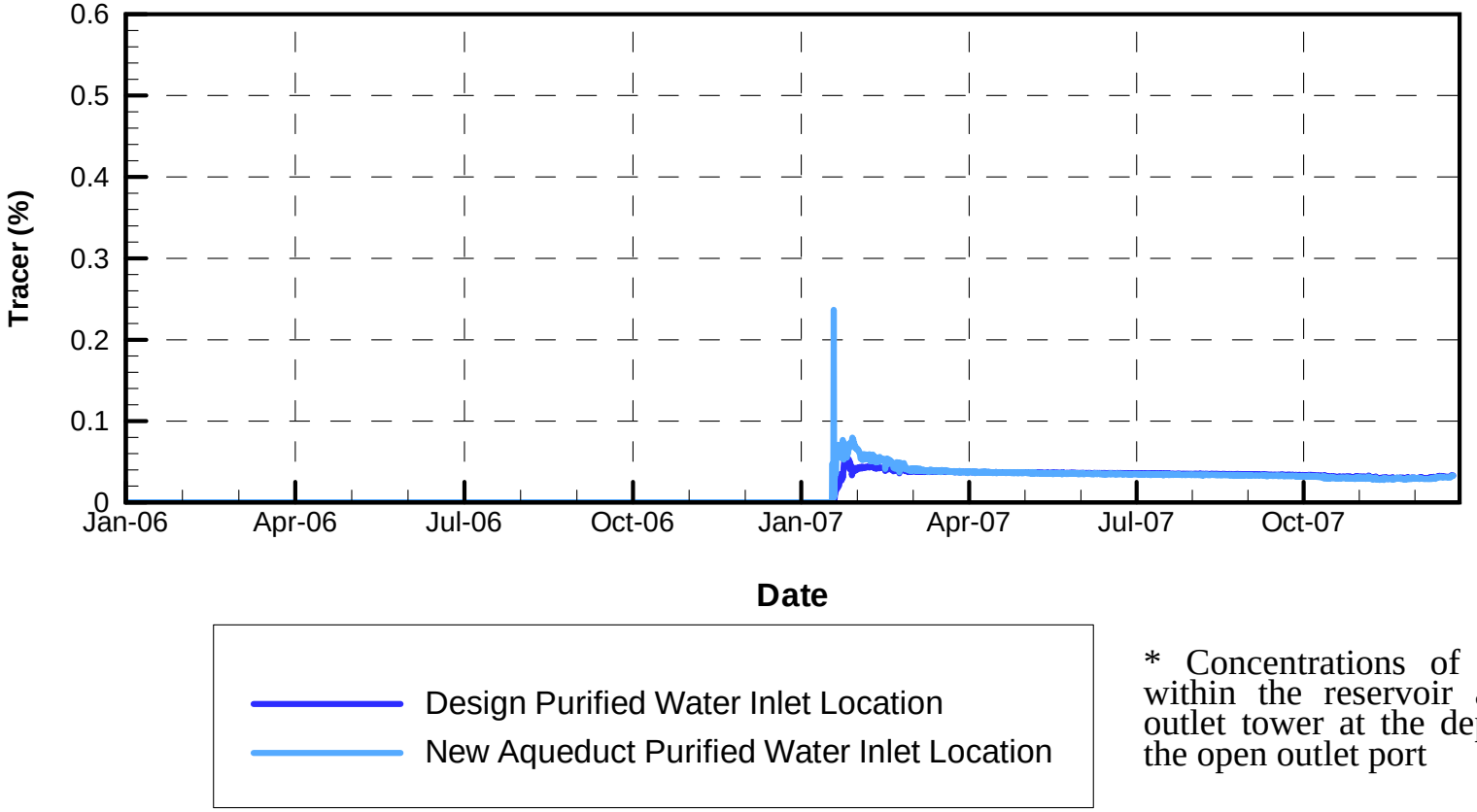
Figure 34

FLOW SCIENCE®

Comparison of Reservoir Outflow 24-hour Conservative Tracer Concentrations* from Different Purified Water Inlet Locations Under Extended Drought Scenario

Tracer Released on 1/21, Year 2 for 24 hours

(Open Port #2; Initial Inflow Concentration = 100%)



* Concentrations of tracer within the reservoir at the outlet tower at the depth of the open outlet port

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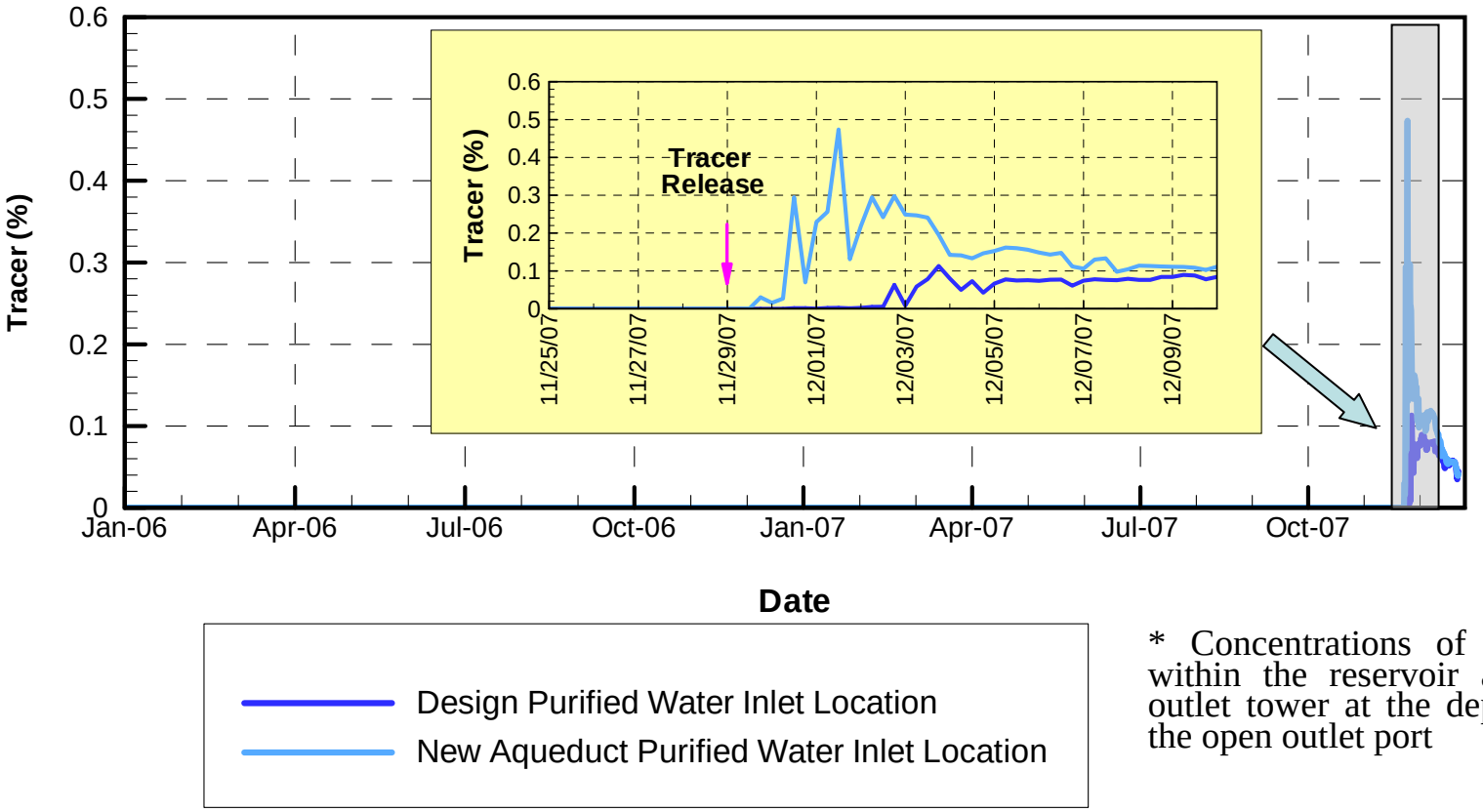
Figure 35

FLOW SCIENCE®

Comparison of Reservoir Outflow 24-hour Conservative Tracer Concentrations* from Different Purified Water Inlet Locations Under Extended Drought Scenario

Tracer Released on 11/29, Year 2 for 24 hours

(Open Port #2; Initial Inflow Concentration = 100%)



* Concentrations of tracer within the reservoir at the outlet tower at the depth of the open outlet port

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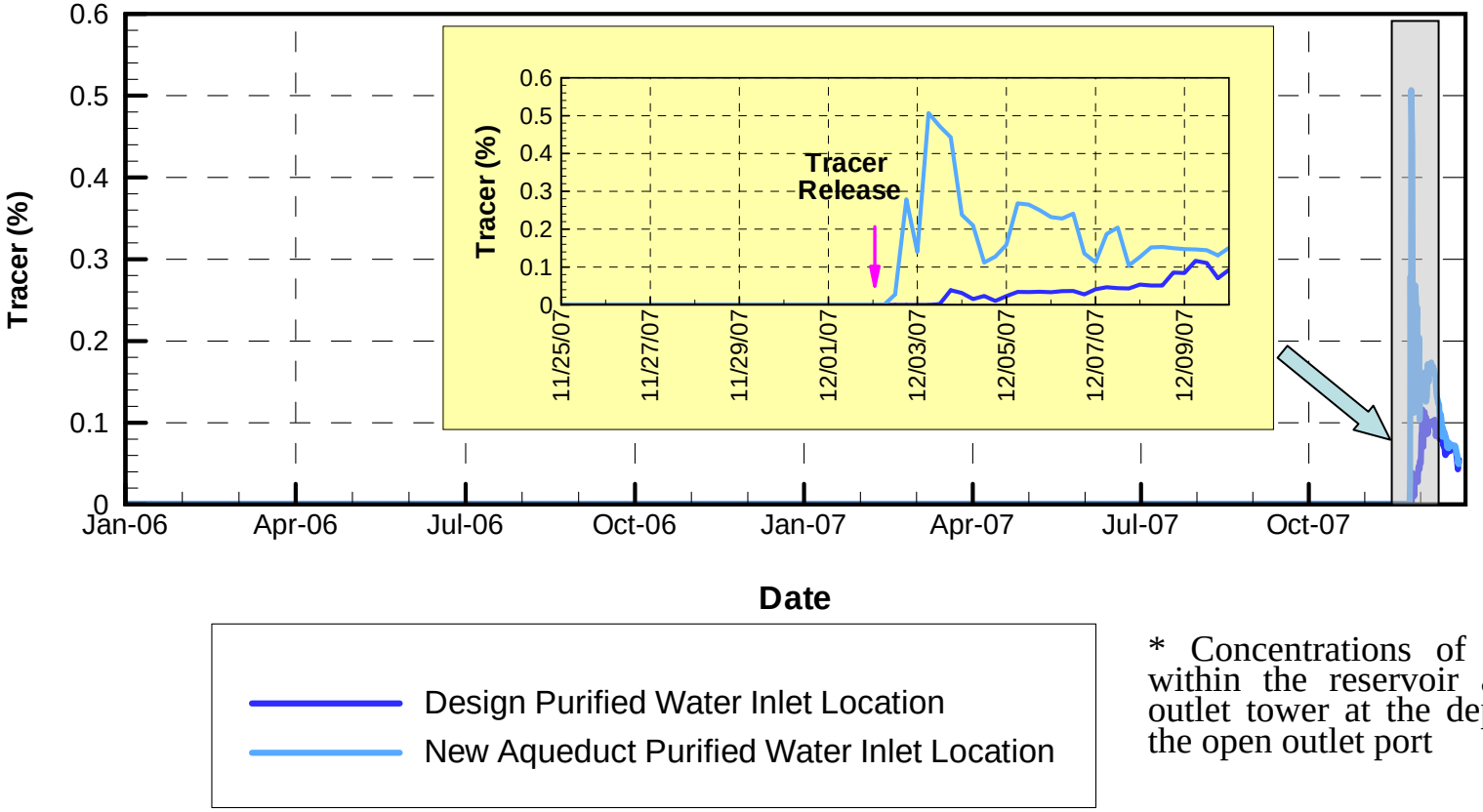
Figure 36

FLOW SCIENCE®

Comparison of Reservoir Outflow 24-hour Conservative Tracer Concentrations* from Different Purified Water Inlet Locations Under Extended Drought Scenario

Tracer Released on 12/2, Year 2 for 24 hours

(Open Port #2; Initial Inflow Concentration = 100%)



* Concentrations of tracer within the reservoir at the outlet tower at the depth of the open outlet port

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Figure 37

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APPENDIX A

Description of ELCOM/CAEDYM/Visual Plumes Models and Evidence of Validation

DESCRIPTION OF ELCOM/CAEDYM MODELS AND EVIDENCE OF VALIDATION

The coupling of biogeochemical and hydrodynamic processes in numerical simulations is a fundamental tool for research and engineering studies of water quality in coastal oceans, estuaries, lakes, and rivers. A modeling system for aquatic ecosystems has been developed that combines a three-dimensional hydrodynamic simulation method with a suite of water quality modules that compute interactions between biological organisms and the chemistry of their nutrient cycles. This integrated approach allows for the feedback and coupling between biogeochemical and hydrodynamic systems so that a complete representation of all appropriate processes can be included in an analysis. The hydrodynamic simulation code is the Estuary Lake and Coastal Ocean Model (ELCOM) and the biogeochemical model is the Computational Aquatic Ecosystem Dynamics Model (CAEDYM).

The purpose of this appendix is to demonstrate that ELCOM and CAEDYM are accepted models that have been systematically tested and debugged, and then successfully validated in numerous applications. A history of the models is provided, followed by an outline of the general model methodology and evolution that emphasizes the basis of the ELCOM/ CAEDYM codes in previously validated models and research. Then the process of code development, testing, and validation of ELCOM/CAEDYM is detailed. Specific model applications are described to illustrate how the ELCOM/CAEDYM models have been applied to coastal oceans, estuaries, lakes, and rivers throughout the world and the results successfully validated against field data. Finally, a general description of the governing equations, numerical models, and processes used in the models is provided along with an extensive bibliography of supporting material.

A comprehensive description of the equations and methods used in the models is provided in the "Estuary Lake and Coastal Ocean Model: ELCOM v2.2 Science Manual" by Hodges and Dallimore (2006), "Estuary Lake and Coastal Ocean Model: ELCOM v2.2 User Manual" by Hodges and Dallimore (2007), "Computational Aquatic Ecosystem Dynamics Model: CAEDYM: v2.2 Science Manual" by Hipsey, Romero, Antenucci and Hamilton (2005), and the "Computational Aquatic Ecosystem Dynamics Model: CAEDYM: v2.2 User Manual" by Hipsey, Romero, Antenucci and Hamilton (2005).

A.1.1 MODEL HISTORY

The ELCOM/CAEDYM models were originally developed at the Centre for Water Research (CWR) at the University of Western Australia, although the hydrodynamics

code ELCOM is an outgrowth of a hydrodynamic model developed earlier by Professor Vincenzo Casulli in Italy and now in use at Stanford University under the name TRIM-3D. The CAEDYM model was essentially developed at CWR as an outgrowth of earlier water quality modules used in the one-dimensional model, Dynamic Reservoir Simulation Model - Water Quality (DYRESM-WQ, Hamilton and Schladow, 1997).

The original ELCOM/CAEDYM models, as developed by CWR, were implemented in Fortran 90 (with F95 extensions) on a UNIX computer system platform. In 2001, the codes for both models were ported to a personal computer (PC) platform through an extensive recompiling and debugging effort by Flow Science Incorporated (Flow Science) in Pasadena, California. Since then, Flow Science has updated the PC version of the code several times when new versions of the code have been released by CWR.

A.1.2 MODEL METHODOLOGY

ELCOM is a three-dimensional numerical simulation code designed for practical numerical simulation of hydrodynamics and thermodynamics for inland and coastal waters. The code links seamlessly with the CAEDYM biogeochemical model undergoing continuous development at CWR, as shown graphically in **Figure A.1**. The

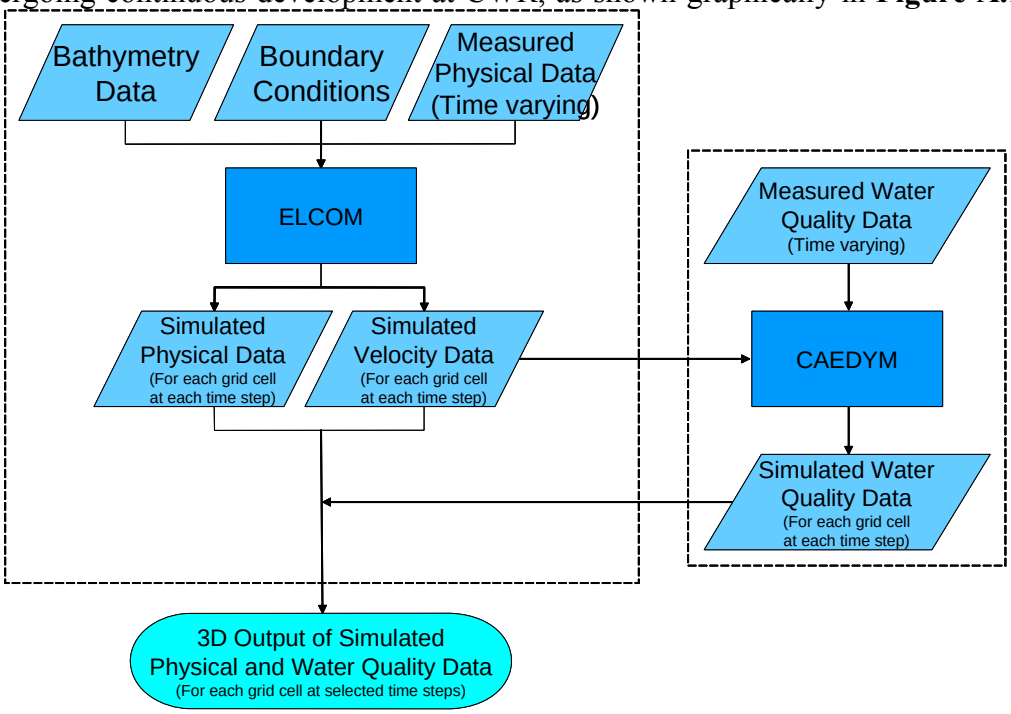

Figure A.1 Flow chart showing the integration of the linked ELCOM/CAEDYM models.

combination of the two codes provides three-dimensional simulation capability for examination of changes in water quality that arise from anthropogenic changes in either quality of inflows or reservoir operations.

The numerical method used in ELCOM is based on the TRIM-3D model scheme of Casulli and Cheng (1992) with adaptations made to improve accuracy, scalar conversion, numerical diffusion, and implementation of a mixed-layer model. The ELCOM model also extends the TRIM-3D scheme by including conservative advection of scalars. The unsteady Reynolds-averaged, Navier-Stokes equations, and the scalar transport equations serve as the basis of ELCOM. The pressure distribution is assumed hydrostatic and density changes do not impact the inertia of the fluid (the Boussinesq approximation), but are considered in the fluid body forces. There is an eddy-viscosity approximation for the horizontal turbulence correlations that represent the turbulent momentum transfer. Vertical momentum transfer is handled by a Richardson number-based diffusion coefficient. Since numerical diffusion generally dominates molecular processes, molecular diffusion in the vertical direction is neglected in ELCOM.

Both ELCOM and TRIM-3D are three-dimensional, computational fluid dynamics (CFD) models. CFD modeling is a validated and well-established approach to solving the equations of fluid motions in a variety of disciplines. Prior to the development of TRIM-3D, there were difficulties in modeling density-stratified flows and such flows required special numerical methods. With TRIM-3D, Casulli and Cheng (1992) developed the first such successful method to model density-stratified flows, such as occur in the natural environment. Since then, TRIM-3D has been validated by numerous publications. ELCOM is based on the same proven method, but incorporates additional improvements as described above. Furthermore, the ELCOM model is based on governing equations and numerical algorithms that have been used in the past (*e.g.,* in validated models such as TRIM-3D), and have been validated in refereed publications. For example:

- The hydrodynamic algorithms in ELCOM are based on the Euler-Lagrange method for advection of momentum with a conjugate gradient solution for the free-surface height (Casulli and Cheng, 1992).

- The free-surface evolution is governed by vertical integration of the continuity equation for incompressible flow applied to the kinematic boundary condition (*e.g.*, Kowalik and Murty, 1993).

- The numerical scheme is a semi-implicit solution of the hydrostatic Navier-Stokes equations with a quadratic Euler-Lagrange, or semi-Lagrangian (Staniforth and Côté, 1991).

- Passive and active scalars (*i.e.,* tracers, salinity, and temperature) are advected using a conservative ULTIMATE QUICKEST discretization (Leonard, 1991). The ULTIMATE QUICKEST approach has been implemented in two-dimensional format and demonstration of its effectiveness in estuarine flows has been documented by Lin and Falconer (1997).

- Heat exchange is governed by standard bulk transfer models found in the literature (*e.g.*, Smooch and DeVries, 1980; Imberger and Patterson, 1981; Jacquet, 1983).

- The vertical mixing model is based on an approach derived from the mixing energy budgets used in one-dimensional lake modeling as presented in Imberger and Patterson (1981), Spigel et al (1986), and Imberger and Patterson (1990). Furthermore, Hodges presents a summary of validation using laboratory experiments of Stevens and Imberger (1996). This validation exercise demonstrates the ability of the mixed-layer model to capture the correct momentum input to the mixed-layer and reproduce the correct basin-scale dynamics, even while boundary-induced mixing is not directly modeled.

- The wind momentum model is based on a mixed-layer model combined with a model for the distribution of momentum over depth (Imberger and Patterson, 1990).

The numerical approach and momentum and free surface discretization used in ELCOM are defined in more detail in Hodges, Imberger, Saggio, and Winters (1999). Similarly, the water quality processes and methodology used in CAEDYM are described in more detail in Hamilton and Schladow (1997). Further technical details on ELCOM and CAEDYM are provided in Sections 0 and 0 below.

A.1.3 VALIDATION AND APPLICATION OF ELCOM/CAEDYM

Since initial model development, testing and validation of ELCOM and/or CAEDYM have been performed and numerous papers on model applications have been presented, written, and/or published as described in more detail below. In summary:

- ELCOM solves the full three-dimensional flow equations with small approximations.

- ELCOM/CAEDYM was developed, tested, and validated over a variety of test cases and systems by CWR.

- Papers on ELCOM/CAEDYM algorithms, methodology, and applications have been published in peer reviewed journals such as the *Journal of Geophysical Research*, the *Journal of Fluid Mechanics*, the *Journal of Hydraulic Engineering*, the *International Journal for Numerical Methods in Fluids*, and *Limnology and Oceanography*.

- ELCOM/CAEDYM was applied by Flow Science to Lake Mead, Nevada. As part of this application, mass balances were verified and results were presented to a model review panel over a two-year period. The model review panel, the National Park Service, the United States Bureau of Reclamation, the Southern Nevada Water Authority, and the Clean Water Coalition (a consortium of water and wastewater operators in the Las Vegas, Nevada, region) all accepted the ELCOM/CAEDYM model use and validity.

- There are numerous applications of ELCOM/CAEDYM in the literature that compare the results to data, as summarized in Section 0.

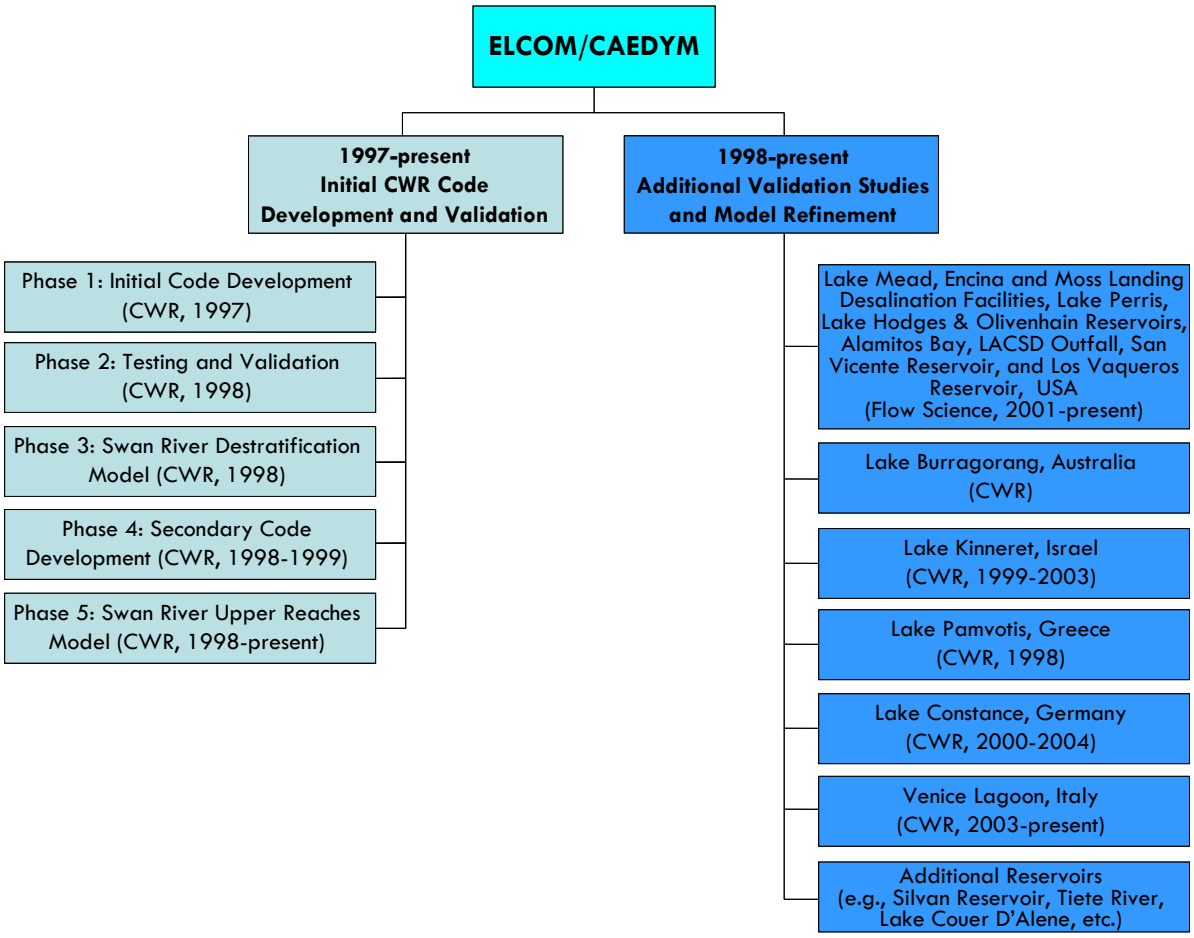

Figure A.2 ELCOM/CAEDYM code development, testing, validation, and applications by CWR and Flow Science Incorporated.

The process of code development, testing, and validation of ELCOM/CAEDYM by CWR, and the ongoing validation and refinement of the codes through further application of the models are detailed in the following subsections. The major components of the development, testing, and validation process are summarized in **Figure A.2**.

A.1.3.1 CWR Code Development, Testing, and Validation

Initial development of the code by CWR occurred from March through December 1997 (Phase 1), followed by a period of testing and validation from January through April 1998 (Phases 2 and 3). Secondary code development by CWR occurred from September 1998 through February 1999 (Phase 4). Testing and validation were

performed over a variety of test cases and systems to ensure that all facets of the code were tested. In addition, Phase 5 modeling of the Swan River since 1998 has been used to gain a better understanding of the requirements and limitations of the model (Hodges et al, 1999).

A.1.3.1.1 *Phase 1: Initial Code Development*

The ELCOM code was initially conceived by CWR as a Fortran 90/95 adaptation of the TRIM-3D model of Casulli and Cheng (1992) in order to: 1) link directly to the CAEDYM water quality module developed concurrently at CWR and 2) provide a basis for future development in a modern programming language. Although written in Fortran 77, TRIM-3D is considered a state-of-the-art numerical model for estuarine applications using a semi-implicit discretization of the Reynolds-averaged hydrostatic Navier-Stokes equations and an Euler-Lagrange method for momentum and scalar transport.

During development of ELCOM, it became clear that additional improvements to the TRIM-3D algorithm were required for accurate solution of density-stratified flows in estuaries. After the basic numerical algorithms were written in Fortran 90, subroutine-by-subroutine debugging was performed to ensure that each subroutine produced the expected results. Debugging and testing of the entire model used a series of test cases that exercised the individual processes in simplified geometries. This included test cases for the functioning of the open boundary condition (tidal forcing), surface wave propagation, internal wave propagation, scalar transport, surface thermodynamics, density underflows, wind-driven circulations, and flooding/drying of shoreline grid cells. Shortcomings identified in the base numerical algorithms were addressed during secondary code development (Phase 4).

Towards the end of the initial code development, ELCOM/CAEDYM were coupled and test simulations were run to calibrate the ability of the models to work together on some simplified problems. Results showing the density-driven currents induced by phytoplankton shading were presented at the Second International Symposium on Ecology and Engineering (Hodges and Herzfeld, 1997). Further details of modeling of density-driven currents due to combinations of topographic effects and phytoplankton shading were presented at a joint meeting of the American Geophysical Union (AGU) and the American Society of Limnology and Oceanography (ASLO) by Hodges et al. (1998), and at a special seminar at Stanford University (Hodges 1998). Additionally, presentations by Hamilton (1997), Herzfeld et al. (1997), and Herzfeld and Hamilton (1998) documented the concurrent development of the CAEDYM ecological model.

A.1.3.1.2 *Phase 2: Testing and Validation*

The simplified geometry tests of Phase I revealed deficiencies in the TRIM-3D algorithm including the inability of the TRIM-3D Euler-Lagrange method (ELM) to provide conservative transport of scalar concentrations (e.g., salinity and temperature). Thus, a variety of alternate scalar transport methods were tested, with the best performance being a flux-conservative implementation of the ULTIMATE filter applied to third-order QUICKEST discretization based on the work of Leonard (1991).

Model testing and validation against simple test cases was again undertaken. In addition, a simulation of a winter underflow event in Lake Burragorang in New South Wales, Australia, was performed to examine the ability of the model to capture a density underflow in complex topography in comparison to field data taken during the inflow event. These tests showed that the ability to model underflows is severely constrained by the cross-channel grid resolution.

A.1.3.1.3 *Phase 3: Swan River Destratification Model*

Phase 3 involved examining a linked ELCOM/CAEDYM destratification model of the Swan River system during a period of destratification in 1997 when intensive field monitoring had been conducted. The preliminary results of this work were presented at the Swan-Canning Estuary Conference (Hertzfeld *et al,* 1998). More comprehensive results were presented at the Western Australian Estuarine Research Foundation (WAERF) Community Forum (Imberger, 1998).

A.1.3.1.4 *Phase 4: Secondary Code Development*

In conducting the Phase 3 Swan River destratification modeling, it became clear to CWR that long-term modeling of the salt-wedge propagation would require a better model for mixing dynamics than presently existed. Thus, the availability of an extensive field data set for Lake Kinneret, Israel, led to its use as a test case for development of an improved mixing algorithm for stratified flows (Hodges *et al*, 1999).

A further problem appeared in the poor resolution of momentum terms using the linear ELM discretization (i.e., as used in the original TRIM-3D method). Since the conservative ULTIMATE QUICKEST method (used for scalar transport, see Phase 1 above) does not lend itself to efficient use for discretization of momentum terms in a semi-implicit method, a quadratic ELM approach was developed for more accurate discretization of the velocities.

A.1.3.1.5 *Phase 5: Swan River Upper Reaches Model*

Phases 1-4 developed and refined the ELCOM code for accurate modeling of three-dimensional hydrodynamics where the physical domain is well resolved. Phase 5 is an ongoing process of model refinement that concentrates on developing a viable approach to modeling longer-term evolution hydrodynamics and water quality in the Swan River where fine-scale resolution of the domain is not practical. The Swan River application is also used for ongoing testing and calibration of the CAEDYM water quality module.

The Swan River estuary is located on the Swan Coastal Plain, Western Australia. It is subject to moderate to high nutrient loads associated with urban and agricultural runoff and suffered from *Microcystis aeruginosa* blooms in January 2000. In an effort to find a viable means of conducting seasonal to annual simulations of the Swan River that retain the fundamental along-river physics and the cross-channel variability in water quality parameters, CWR has developed and tested ELCOM/CAEDYM extensively. A progress report by Hodges et al (1999) indicates that ELCOM is capable of accurately reproducing the hydrodynamics of the Swan River over long time scales with a reasonable computational time.

Furthermore, studies conducted by Robson and Hamilton (2002) proved that ELCOM/CAEDYM accurately reproduced the unusual hydrodynamic circumstances that occurred in January 2000 after a record maximum rainfall, and predicted the magnitude and timing of the *Microcystis* bloom. These studies show that better identification and monitoring procedures for potentially harmful phytoplankton species could be established with ELCOM/CAEDYM and will assist in surveillance and warnings for the future.

A.1.3.2 Model Applications

In addition to the initial code development, testing, and validation by CWR, numerous other applications of ELCOM/CAEDYM have been developed by CWR and validated against field data. Additionally, Flow Science has applied ELCOM/CAEDYM extensively at Lake Mead (USA) and validated the results against measured data. The results of numerous ELCOM/CAEDYM model applications are presented below.

A.1.3.2.1 *Lake Mead (Nevada, USA)*

An ELCOM/CAEDYM model of Boulder Basin, Lake Mead near Las Vegas, Nevada, was used to evaluate alternative discharge scenarios for inclusion in an Environmental Impact Statement (EIS) for the Clean Water Coalition (CWC), a

consortium of water and wastewater operators in the Las Vegas region. **Figure A.3** is a cut-away of the three-dimensional model grid used for Boulder Basin, showing the varying grid spacing in the vertical direction.

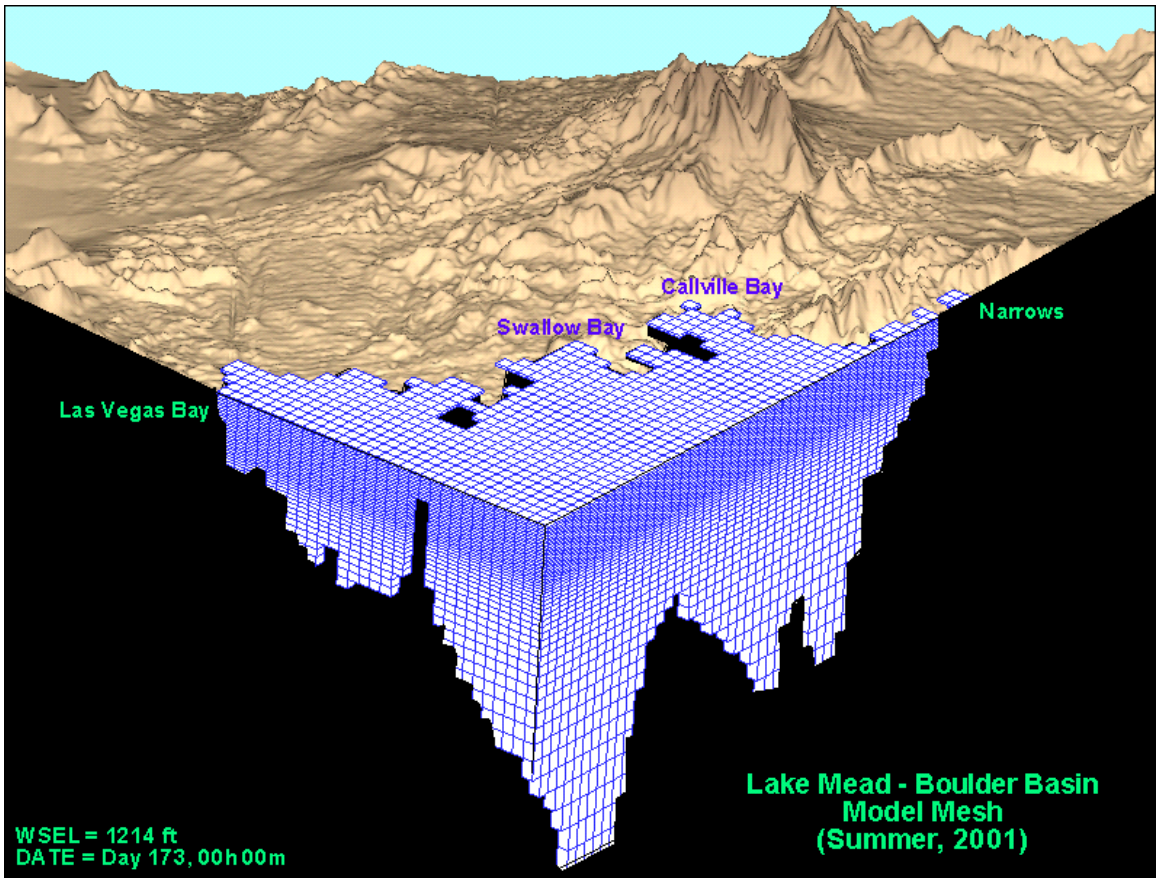

Figure A.3 Model grid for Lake Mead Boulder Basin model.

As part of the EIS process, a model review panel met monthly for two years to review the validation of the ELCOM/CAEDYM model, its calibration against field data, and its application. The modeling committee approved the use of the model. Subsequently, a scientific Water Quality Advisory Panel concluded that the ELCOM/CAEDYM model was applicable and acceptable. The members of the Water Quality Advisory Panel were diverse and included Jean Marie Boyer, Ph.D., P.E. (Water Quality Specialist/Modeler, Hydrosphere), Chris Holdren, Ph.D., CLM (Limnologist, United States Bureau of Reclamation), Alex Horne, Ph.D. (Ecological Engineer, University of California Berkeley), and Dale Robertson, Ph.D. (Research Hydrologist, United States Geological

Survey). More specifically, the Water Quality Advisory Panel agreed on the following findings:

- The ELCOM/CAEDYM model is appropriate for the project.
- There are few three-dimensional models available for reservoirs. ELCOM is one of the best hydrodynamic models and has had good success in the Boulder Basin of Lake Mead and other systems.
- The ELCOM model accurately simulates most physical processes.
- The algorithms used in CAEDYM are widely accepted (a biological consultant, Professor David Hamilton of The University of Waikato, New Zealand, was retained to review the CAEDYM coefficients and algorithms).

The Boulder Basin ELCOM/CAEDYM model was calibrated against four years of measured data for numerous physical and water quality parameters including temperature, salinity, conductivity, dissolved oxygen, pH, nutrients (nitrogen and phosphorus), chlorophyll *a*, perchlorate, chloride, sulfate, bromide, and total organic carbon. Detailed results of this calibration and the subsequent evaluation of alternative discharge scenarios were made available in late 2005 in the CWC EIS that was being prepared for this project. An example of the calibration results for chlorophyll *a* for 2002 is presented in **Figure A.4** below. In this figure, simulated concentrations are compared against field data measured in the lake by the United States Bureau of Reclamation (USBR) and the City of Las Vegas (COLV).

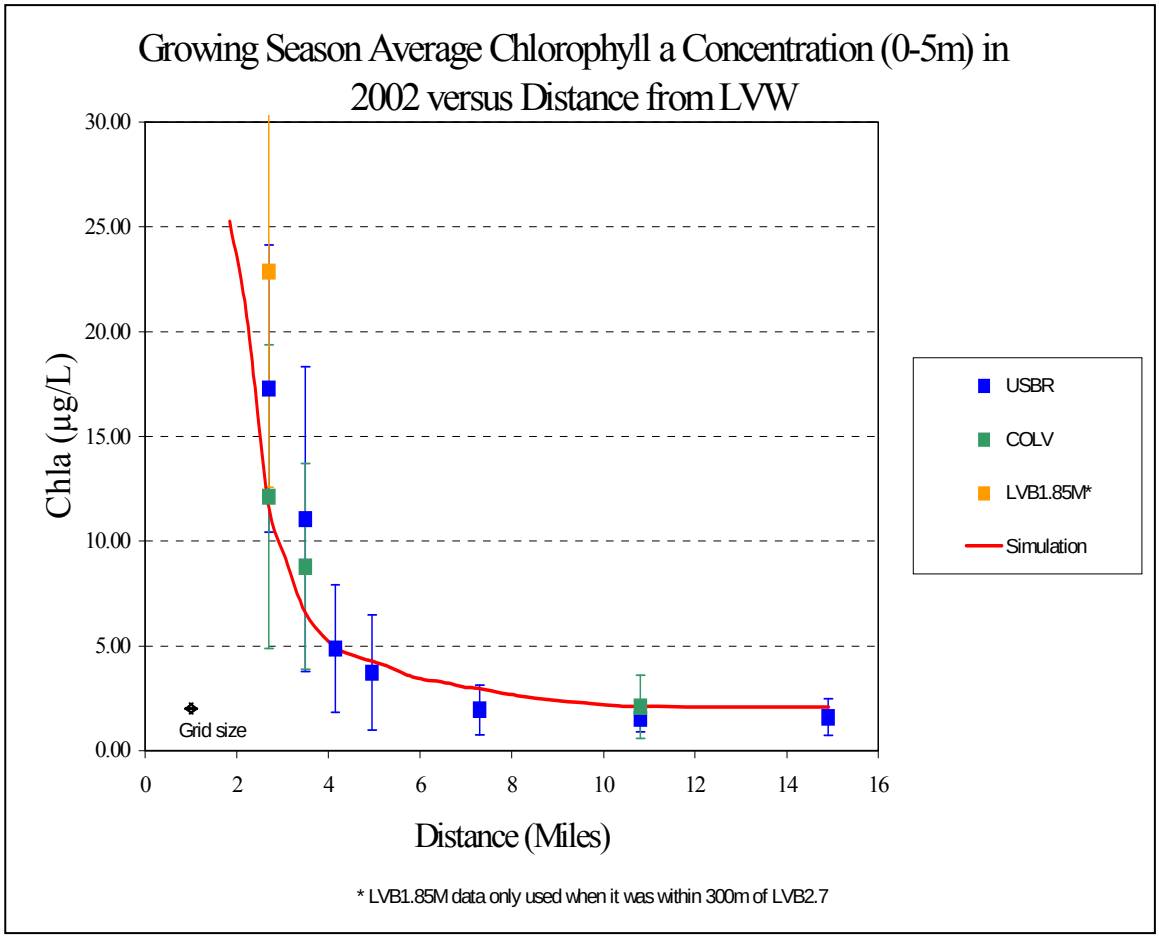

Figure A.4 ELCOM/CAEDYM calibration results for chlorophyll a in Boulder Basin for 2002 as a function of distance from the inflow at Las Vegas Wash.

Most recently, the original Boulder Basin model was extended to include all of Lake Mead, including the Overton Arm and Gregg Basin. The extended whole lake ELCOM/CAEDYM model has been calibrated against nine (9) years of data for use in informing design and operations management decisions. Specifically, the model has been used to simulate temperature (including stratification patterns), salinity, conductivity, dissolved oxygen, nutrients, chlorophyll *a* (as a surrogate for algae), perchlorate, total organic carbon, bromide, and suspended solids. **Figure A.5** below shows the extent of the expanded whole lake domain and the calibration results for conductivity for February 2005.

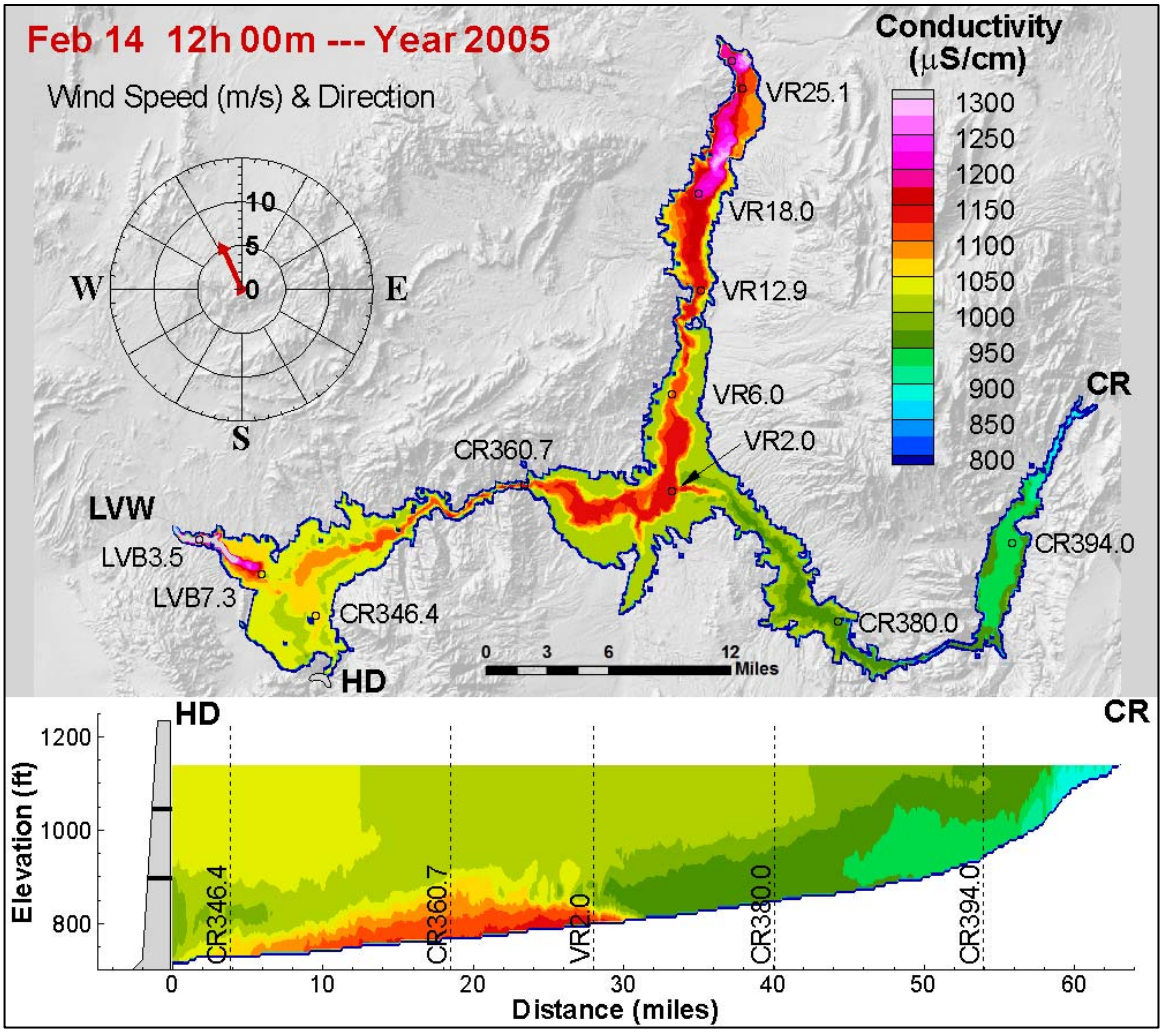

Figure A.5 ELCOM/CAEDYM calibration results for conductivity in the Lake Mead Whole Lake Model (including plan view of entire lake and cross-section from Hoover Dam to the mouth of the Colorado River).

ELCOM/CAEDYM model of the entire Lake Mead is being continually updated and calibrated on approximately a yearly basis, with funding having been provided by the CWC, the Southern Nevada Water Authority, and the National Park Service. These various stakeholders have demonstrated a long term commitment to maintaining the model because it has proven to be a worthy and successful tool. Additional funding for

ELCOM/CAEDYM modeling of the impacts of climate change on Lake Mead is being provided by the USBR under the WaterSMART grant program.

A.1.3.2.2 *Lake Burragorang (New South Wales, Australia)*

ELCOM was applied and validated for Lake Burragorang in order to rapidly assess the potential impacts on water quality during an underflow event (CWR). Underflows usually occur during the winter when inflow water temperature is low compared to the reservoir. This causes the upheaval of hypolimnetic water at the dam wall, and as a result it transports nutrient rich waters into the euphotic zone.

The thermal dynamics during the underflow event were reproduced accurately by ELCOM for the case with idealized bathymetry data with coarse resolutions (straightened curves and rotating the lake in order to bypass the resolution problem), but not for the simulation with the complex, actual bathymetry. This is because the model tests showed that the ability to model underflows is severely constrained by the cross-channel grid resolution. When the cross-channel direction is poorly resolved at bends and curves, an underflow is unable to propagate downstream without a significant loss of momentum. Nevertheless, the simulations with the coarse idealized domain certainly can be used as aids and tools to visualize the behavior of reservoirs. Particularly, ELCOM was able to capture the traversal of the underflow down the length of Lake Burragorang and then had sufficient momentum to break against the wall causing the injection of underflow waters into the epilimnion near the dam. This simulated dynamic was in agreement with what was measured in the field.

A.1.3.2.3 *Lake Kinneret (Israel)*

ELCOM was applied to model basin-scale internal waves that are seen in Lake Kinneret, Israel, since understanding of basin-scale internal waves behaviors provide valuable information on mixing and transport of nutrients below the wind-mixed layer in stratified lakes. In studies done by Hodges et al. (1999) and Laval et al (2003), the ELCOM simulation results were compared with field data under summer stratification conditions to identify and illustrate the spatial structure of the lowest-mode basin-scale Kelvin and Poincare waves that provide the largest two peaks in the internal wave energy spectra. The results demonstrated that while ELCOM showed quantitative differences in the amplitude and steepness of the waves as well as in the wave phases, the basin-scale waves were resolved very well by ELCOM. In particular, the model captures the qualitative nature of the peaks and troughs in the thermocline and the depth of the wind-mixed layer at relatively coarse vertical grid resolutions (Hodges et al, 1999).

A.1.3.2.4 *Lake Pamvotis (Greece)*

ELCOM/CAEDYM was applied to Lake Pamvotis, a moderately sized (22 km^2), shallow (4 m average depth) lake located in northwest Greece. Since the lake has undergone eutrophication over the past 40 years, many efforts are directed at understanding the characteristics of the lake and developing watershed management and restoration plans.

Romero and Imberger (1999) simulated Lake Pamvotis over a one month period during May to June, 1998, and compared the simulated thermal and advective dynamics of the lake with data obtained from a series of field experiments. The simulation results over-predicted heating; however, diurnal fluctuations in thermal structures were similar to those measured. Since the meteorological site was sheltered from the winds, the wind data used in the simulation was believed to be too low, causing insufficient evaporative heat-loss and subsequent over-heating by ELCOM. An increase in the wind speed by a factor of three gave temperature profiles in agreement with the field data. Moreover, the study demonstrated that the model is capable of predicting the substantial diurnal variations in the intensity and direction of both vertical and horizontal velocities. Romero and Imberger were also able to illustrate the functionality of ELCOM when coupled to the water quality model, CAEDYM, and confirmed that the model could be used to evaluate the effect of various strategies to improve poor water quality in localized areas in the lake.

A.1.3.2.5 *Lake Constance (Germany, Austria, Switzerland)*

Appt (2000) and Appt et al. (2004) applied ELCOM to characterize the internal wave structures and motions in Lake Constance [Bodensee] since internal waves are a key factor in understanding the transport mechanisms for chemical and biological processes in a stratified lake such as Lake Constance. Lake Constance is an important source of drinking water and a major tourism destination for its three surrounding countries of Germany, Austria, and Switzerland. Due to anthropogenic activities and climatic changes, Lake Constance water quality has deteriorated and its ecosystem has changed.

It was shown that ELCOM was able to reproduce the dominant internal wave and major hydrodynamic processes occurring in Lake Constance. For instance, three types of basin-scale waves were found to dominate the wave motion: the vertical mode-one Kelvin wave, the vertical mode-one Poincare waves, and a vertical mode-two Poincare wave. Moreover, an upwelling event was also reproduced by ELCOM suggesting that the width and length ratio of the basin, spatial variations in the wind, and Coriolis effects play critical roles in the details of the upwelling event. This on-going research has shown

that ELCOM can be used as a tool to predict and understand hydrodynamics and water quality in lakes.

A.1.3.2.6 *Venice Lagoon (Italy)*

ELCOM/CAEDYM is being used to develop a hydrodynamic and sediment transport model of Venice Lagoon, Italy, since future gate closures at the mouth of the lagoon are likely to impact flushing patterns. This project is an integral part of the Venice Gate Projects in Italy that was launched in May 2003 to prevent flooding.

ELCOM was validated for the tidal amplitude and phase using the data obtained from 12 tidal stations located throughout the lagoon (Yeates, 2004). Remaining tasks include model validation of temperature, salinity, and velocity against measurements made in the major channels of the lagoon.

A.1.3.2.7 *Silvan Reservoir (Australia)*

ELCOM is currently being applied to reproduce the circulation patterns observed in Silvan Reservoir, Australia, during a field experiment that was conducted in March 2004 to determine the transport pathways in the lake. This experiment confirmed the upwelling behavior of the lake and the strong role of the inflows in creating hydraulic flows in the reservoir (Antenucci, 2004).

A.1.3.2.8 *Billings and Barra Bonita Reservoirs (Brazil)*

ELCOM/CAEDYM is being applied to Billings and Barra Bonita Reservoirs in Brazil. Billings Reservoir is an upstream reservoir that feeds Barra Bonita via the Tiete River. The objective of the project is to develop an integrated management tool for these reservoirs and river reaches for use in the future planning of water resource utilization in Sao Paulo, Brazil (Romero and Antenucci, 2004).

A.1.3.2.9 *Lake Coeur D'Alene (Idaho, USA)*

ELCOM/CAEDYM is being applied to investigate the trade-off between reducing heavy metal concentrations and a potential increase in eutrophication due to remediation procedures in Lake Coeur D'Alene, Idaho. In order to investigate heavy metal fate and transport, CAEDYM is being improved further to include heavy metals and a feedback loop to phytoplankton based on metal toxicity (Antenucci, 2004).

A.1.3.2.10 *Seawater Desalination at Encina (California, USA)*

Flow Science conducted ELCOM modeling in 2004-2006 for a proposed desalination facility to be sited adjacent to the Encina Power Plant in Carlsbad, California. The proposed Encina facility involved source water taken from inside Agua Hedionda Lagoon and discharge of brines with the power plant cooling water via a surface channel across the beach south of the lagoon mouth. Flow Science used both a fine grid model to simulate water quality and dilution local to the intake and outfall and a larger grid model to simulate the effect of treated wastewater discharges and ocean currents and tides in the ocean near the lagoon. For the Encina study, Flow Science also used ELCOM to predict mixing in the vicinity of the plant discharge. The study area encompassed about 100 square miles of the ocean and also included some inland lagoons. The model resolved various tidal conditions and plant operating scenarios. The model compared favorably to existing oceanic data in the vicinity of the discharge.

A.1.3.2.11 *Moss Landing Desalination Project (California, USA)*

Flow Science applied ELCOM to simulate the flow and mixing in the entire Monterey Bay, including Elkhorn Slough. The purpose of the modeling was to evaluate the impacts of the proposed Moss Landing Desalination facility on receiving waters. The desalination facility was proposed to utilize a nearby existing power plant intake in Moss Landing Harbor and discharge to the ocean via the power plant's existing outfall, which is a submerged outfall located in Monterey Bay offshore of the harbor entrance. The ELCOM model resolved the details of the mixing in the vicinity of the power plant/desalination facility combined discharge. The model results compared favorably to existing measured water quality parameters. The results were used to determine compliance with water quality regulations for the combined outfall. The study was performed in 2004-2006.

A.1.3.2.12 *Lake Perris (California, USA)*

In 2005, ELCOM was applied to Lake Perris in order to compare the impacts of several recreational use strategies on measured fecal coliform concentrations at the reservoir outlet tower. The physical results of the simulation were validated against measured temperature and salinity data over a one-year period. The comparison of fecal coliform concentrations against measured data was fair due to a lack of data describing the timing and magnitude of loading and the settling and re-suspension of fecal matter.

The ELCOM model was expanded in 2006-2007 to include CAEDYM in order to evaluate the performance of a proposed hypolimnetic oxygenation system and observed

water quality benefits. The model was calibrated against two years of historical data and used to assess the magnitude and extent of oxygenation in the hypolimnion as a result of system operation. Impacts on dissolved oxygen concentrations and nutrient dynamics and algal production potential (as represented by chlorophyll *a*) were also evaluated, and recommendations were provided for final design of the system. The project has not yet been constructed due to seismic safety risks with the dam that must first be addressed.

A.1.3.2.13 *Lake Hodges and Olivenhain Reservoir (California, USA)*

The San Diego County Water Authority (SDCWA) is planning a tunnel connection between Lake Hodges and Olivenhain Reservoir. The tunnel and an associated hydroelectric turbine will allow for operation of the two reservoirs as part of a pumped storage project. Due to the difference in water quality between the two reservoirs, the SDCWA was concerned that the planned pumped storage project could adversely impact water quality in Olivenhain Reservoir. In order to evaluate the water quality impacts of the planned pumped storage operations on Olivenhain Reservoir, Flow Science developed a coupled ELCOM model of the two reservoirs in 2007-2008 to simulate temperature and salinity and several tracers in order to characterize the extent of mixing of the pumped storage inflow water from Lake Hodges within Olivenhain Reservoir and the percentages of Lake Hodges and Olivenhain Reservoir water throughout each reservoir due to the pumped storage operations and subsequent mixing.

A.1.3.2.14 *Lower San Gabriel River, Intake Channel, and Alamitos Bay (California, USA)*

The Los Angeles Department of Water and Power (LADWP) Haynes Generating Station (HnGS) and AES Generating Station (AES) each utilize three outfalls located on the east and west bank of the Lower San Gabriel River, respectively, and discharge cooling water to the Lower San Gabriel River Flood Control Channel (LSGR). Flow Science conducted ELCOM modeling from 2003-2010 to evaluate the mixing of flows within the river channel and found that, under typical operating conditions, the cooling water discharges form a “barrier” between freshwater from the upstream river channel and ocean water downstream of the LSGR. Both modeling and field work (conducted by others) confirmed that the net direction of flow downstream of HnGS and AES is downstream, even during flood tide conditions. Flow Science’s modeling also evaluated temperature, salinity, and mixing in the LSGR for a wide range of potential future conditions and for hypothetical conditions in which both HnGS and AES cooling water flows are removed from the LSGR. Water quality in the adjacent Alamitos Bay, which is strongly influenced by flushing induced by cooling water flows from HnGS and AES, was also evaluated using ELCOM. In addition, Flow Science used CAEDYM to evaluate

nutrient concentrations, algae, and dissolved oxygen within the Bay for a range of actual and potential future operating conditions. The HnGS Intake Channel (which connects Alamitos Bay to HnGS) was also evaluated with ELCOM/CAEDYM.

Results of the Flow Science analyses have been used by LADWP in NPDES permit discussions with the Regional Water Board, in CEQA evaluations supporting the potential future repowering of HnGS Units 5 and 6, and in comments on the State's draft Once-Through Cooling (OTC) policy.

A.1.3.2.15 *Joint Water Pollution Control Plant Outfall Evaluation (California, USA)*

The Sanitation Districts of Los Angeles County (LACSD) are conducting a detailed study to evaluate the feasibility of a proposed new ocean outfall to carry treated wastewater from the Joint Water Pollution Control Plant (JWPCP) in Carson, California, to an ocean discharge location off the southern California coast near the Palos Verdes and San Pedro Shelves. As part of the Feasibility Study, Flow Science developed an ELCOM model in 2007 to evaluate the impact of this proposed ocean outfall. The near-field effluent discharge model, NRFIELD2, coupled with the far field hydrodynamic model, ELCOM, was used to simulate the mixing and determine the concentrations of a conservative effluent tracer and various indicator bacteria (assuming no chlorination). The coupled model was validated using measured current and temperature data in the vicinity of the potential discharge sites. The water quality impacts of five proposed diffuser discharge sites were evaluated, and the modeling results will be used by LACSD to estimate concentrations of indicator bacteria at selected locations at the shore and inshore regions that would result from a discharge without chlorination. Ongoing ELCOM modeling will be performed to assist LACSD in selecting a preferred diffuser location. An example of the simulated effluent tracer concentrations during summer for one of the potential diffuser sites is presented in **Figure A.6** below.

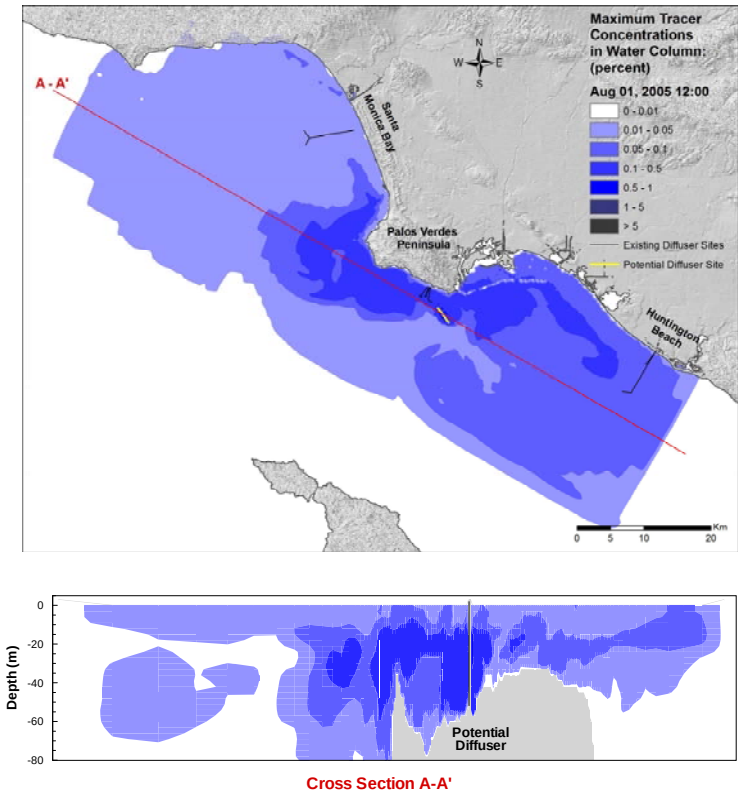

Figure A.6 Plan and section views of ELCOM simulated effluent tracer concentrations from proposed diffuser Site 1 in summer (August 1, 2005).

A.1.3.2.16 *San Vicente Reservoir (California, USA)*

Flow Science is assisting the City of San Diego in assessing the mixing and dilution potential resulting from the potential injection of highly treated effluent into San Vicente Reservoir. In 2010, Flow Science developed an ELCOM/CAEDYM model to assess the mixing and dispersion properties in San Vicente Reservoir as well as a field program to validate the modeling. The ELCOM/CAEDYM model includes temperature, salinity, conductivity, dissolved oxygen, nutrients, chlorophyll *a* (as a surrogate for algae), and multiple tracers. The model provides an accurate three-dimensional representation of water quality within the reservoir. The model was calibrated for the reservoir at its

current capacity against two years of historical data. The calibrated model has since been applied to the expanded reservoir to evaluate the impacts of the advanced water treatment (AWT) water. The model is being used to predict water quality conditions in the future enlarged reservoir and will also be used to help manage water quality in the enlarged reservoir once it is filled. The work is being reviewed by an expert panel being overseen by the National Water Research Institute. The panel is expected to complete its review and accept the use of the modeling.

A.1.3.2.17 *Los Vaqueros Reservoir (California, USA)*

In conjunction with the Contra Costa Water District (CCWD), Flow Science developed a three-dimensional ELCOM/CAEDYM model of Los Vaqueros Reservoir beginning in 2006 that is capable of providing an accurate, three-dimensional representation of water quality including temperature, salinity/TDS, nutrients and algae. The ELCOM model was calibrated against two years of historical data and validated against four years of data, while the CAEDYM model was calibrated for four years of historical data. **Figure A.7** shows a comparison of the measured versus simulated annual and growing season average chlorophyll *a* concentrations which show very good agreement. In ongoing work, Flow Science is using the ELCOM/CAEDYM model to evaluate the water quality of the reservoir under future conditions where the impounding dam is raised. This will expand the capacity of the reservoir from 100,000 acre-ft to 160,000 acre ft. The water quality model is being used to determine the changes in outflow water quality resulting from the expansion and to provide preliminary design recommendations for the inlet/outlet facilities with respect to improving water quality.

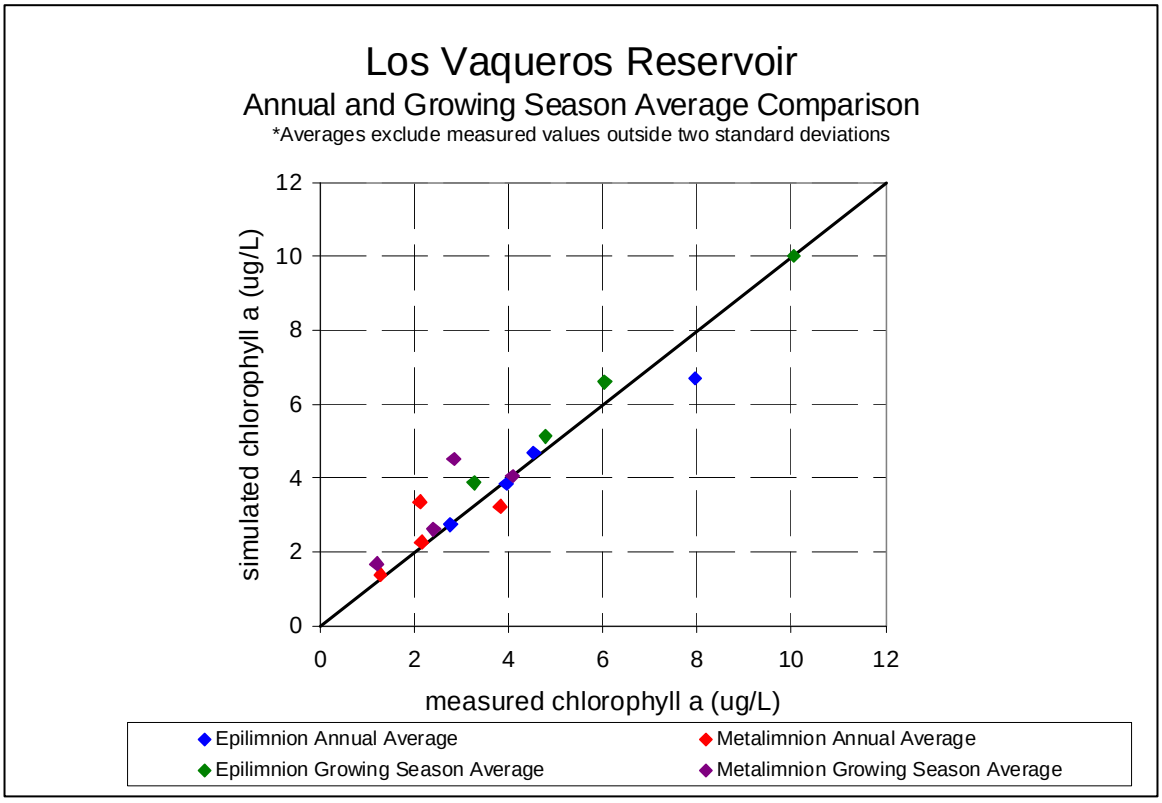

Figure A.7 Comparison of simulated ELCOM/CAEDYM results and measured chlorophyll *a* data for 2006-2009.

A.1.3.2.18 *Other Applications*

Other ELCOM/CAEDYM applications and development in on-going research at CWR include:

- Plume dynamics and horizontal dispersion (Marmion Marine Park, Australia).
- Inflow and pathogen dynamics (Helena, Myponga and Sugarloaf Reservoirs, Australia).
- Mixing and dissipation in stratified environments (Tone River, Japan, and Brownlee Reservoir, USA).

- Tidally forced estuaries and coastal lagoons (Marmion Marine Park and Barbamarco Lagoon, Italy).
- Three-dimensional circulation induced by wind and convective exchange (San Roque Reservoir, Argentina, and Prospect Reservoir, Australia).
- Sea-surface temperature fluctuation and horizontal circulation (Adriatic Sea).
- Response of bivalve mollusks to tidal forcing (Barbamarco Lagoon, Italy).

A.1.4 TECHNICAL DESCRIPTION OF ELCOM

As outlined above, ELCOM solves the unsteady, viscous Navier-Stokes equations for incompressible flow using the hydrostatic assumption for pressure. ELCOM can simulate the hydrodynamics and thermodynamics of a stratified system, including baroclinic effects, tidal forcing, wind stresses, heat budget, inflows, outflows, and transport of salt, heat and passive scalars. Through coupling with the CAEDYM water quality module, ELCOM can be used to simulate three-dimensional transport and interactions of flow physics, biology, and chemistry. The hydrodynamic algorithms in ELCOM are based upon the proven semi-Lagrangian method for advection of momentum with a conjugate-gradient solution for the free-surface height (Casulli and Cheng, 1992) and a conservative ULTIMATE QUICKEST transport of scalars (Leonard, 1991). This approach is advantageous for geophysical-scale simulations since the time step can be allowed to exceed the Courant-Friedrichs-Lewy (CFL) condition for the velocity without producing instability or requiring a fully-implicit discretization of the Navier-Stokes equations.

A.1.4.1 Governing Equations

Significant governing equations and approaches used in ELCOM include:

- Three-dimensional simulation of hydrodynamics (unsteady Reynolds-averaged Navier-Stokes equations).
- Advection and diffusion of momentum, salinity, temperature, tracers, and water quality variables.
- Hydrostatic approximation for pressure.
- Boussinesq approximation for density effects.

- Surface thermodynamics module accounts for heat transfer across free surface.
- Wind stress applied at the free surface.
- Dirichlet boundary conditions on the bottom and sides.

A.1.4.2Numerical Method

Significant numerical methods used in ELCOM include:

- Finite-difference solution on staggered-mesh Cartesian grid.
- Implicit volume-conservative solution for free-surface position.
- Semi-Lagrangian advection of momentum allows time steps with CFL > 1.0.
- Conservative ULTIMATE QUICKEST advection of temperature, salinity, and tracers.
- User-selectable advection methods for water quality scalars using upwind, QUICKEST, or semi-Lagrangian to allow trade-offs between accuracy and computational speed.
- Solution mesh is Cartesian and allows non-uniformity (i.e. stretching) in horizontal and vertical directions.

The implementation of the semi-Lagrangian method in Fortran 90 includes sparse-grid mapping of three-dimensional space into a single vector for fast operation using array-processing techniques. Only the computational cells that contain water are represented in the single vector so that memory usage is minimized. This allows Fortran 90 compiler parallelization and vectorization without platform-specific modification of the code. A future extension of ELCOM will include dynamic pressure effects to account for nonlinear dynamics of internal waves that may be lost due to the hydrostatic approximation.

Because the spatial scales in a turbulent geophysical flow may range from the order of millimeters to kilometers, it is presently impossible to conduct a Direct Navier-Stokes (DNS) solution of the equations of motion (i.e. an exact solution of the equations). Application of a numerical grid and a discrete time step to a simulation of a geophysical domain is implicitly a filtering operation that limits the resolution of the equations.

Numerical models (or closure schemes) are required to account for effects that cannot be resolved for a particular grid or time step. There are four areas of modeling in the flow physics: (l) turbulence and mixing, (2) heat budgets, (3) hydrodynamic boundary conditions, and (4) sediment transport.

A.1.4.3 Turbulence Modeling and Mixing

ELCOM presently uses uniform fixed eddy viscosity as the turbulence closure scheme in the horizontal plane (in future versions a Smagorinsky 1963 closure scheme will be implemented to represent subgrid-scale turbulence effects as a function of the resolves large-scale strain-rates). These methods are the classic "eddy viscosity" turbulence closure. With the implementation of the Smagorinsky closure, future extensions will allow the eddy-viscosity to be computed on a local basis to allow improvements in modeling local turbulent events and flow effects of biological organisms (e.g., drag induced by macroalgae or seagrass).

In the present code, the user has the option to extend the eddy-viscosity approach to the vertical direction by setting different vertical eddy-viscosity coefficients for each grid layer. However, in a stratified system, this does not adequately account for vertical turbulent mixing that may be suppressed or enhanced by the stratification (depending on the stability of the density field and the magnitude of the shear stress). To model the effect of density stratification on turbulent mixing the CWR has developed a closure model based on computation of a local Richardson number to scale. The latter is generally smaller than the time step used in geophysical simulations, so the mixing is computed in a series of partial time steps. When the mixing time-scale is larger than the simulation time step, the mixing ratio is reduced to account for the inability to obtain mixing on very short time scales. This model has the advantage of computing consistent mixing effects without regard to the size of the simulation time-step (i.e. the model produces mixing between cells that is purely a function of the physics and not the numerical step size).

A.1.4.4 Heat Budget

The heat balance at the surface is divided into short-wave (penetrative) radiation and a heat budget for surface heat transfer effects. The surface heat budget requires user input of the net loss or gain through conduction, convection, and long wave radiation in the first grid layer beneath the free surface. The short wave range is modeled using a user-prescribed input of solar radiation and an exponential decay with depth that is a function of a bulk extinction coefficient (a Beer's law formulation for radiation absorption). This coefficient is the sum of individual coefficients for the dissolved

organics ("gilvin"), phytoplankton biomass concentration, suspended solids, and the water itself. The extinction coefficients can either be computed in the water quality module (CAEDYM) or provided as separate user input.

A.1.4.5 Hydrodynamic Boundary Conditions

The hydrodynamic solution requires that boundary conditions on the velocity must be specified at each boundary. There are six types of boundary conditions: (1) free surface, (2) open edge, (3) inflow-outflow, (4) no-slip, (5) free-slip, and (6) a Chezy-Manning boundary stress model (the latter is presently not fully implemented). For the free surface, the stress due to wind and waves is required. The user can either input the wind/wave stress directly, or use a model that relates the surface stress to the local wind speed and direction *via* a bulk aerodynamic drag coefficient. Open boundaries (e.g. tidal inflow boundaries for estuaries) require the user to supply the tidal signature to drive the surface elevation. Transport across open boundaries is modeled by enforcing a Dirichlet condition on the free-surface height and allowing the inflow to be computed from the barotropic gradient at the boundary. Inflow-outflow boundary conditions (e.g. river inflows) are Dirichlet conditions that specify the flow either at a particular boundary location *or inside the domain*. Allowing an inflow-outflow boundary condition to be specified for an interior position (i.e. as a source or sink) allows the model to be used for sewage outfalls or water outlets that may not be located on a land boundary. Land boundaries can be considered zero velocity (no-slip), zero-flux (free-slip) or, using a Chezy-Manning model, assigned a computed stress.

A.1.4.6 Sediment Transport

While sediment transport is fundamentally an issue of flow physics, the algorithms for the sediment transport are more conveniently grouped with the water quality algorithms in CAEDYM. Settling of suspended particulate matter is computed using Stokes law to obtain settling velocities for the top and bottom of each affected grid cell. This allows the net settling flux in each cell to be computed. A two-layer sediment model has been developed that computes resuspension, deposition, flocculation, and consolidation of sediment based on (1) the shear stress at the water/sediment interface, (2) the type of sediment (cohesive/non-cohesive), and (3) the thickness of the sediment layer. Determination of the shear stress at the water/sediment interface requires the computation of bottom shear due to current, wind, and waves. A model has been developed to account for the effects of small-scale surface waves that cannot be resolved on a geophysical-scale grid. This model computes the theoretical wave height and period for small-scale surface waves from the wind velocity, water depth, and domain fetch. From these, the wavelength and orbital velocities are calculated. The wave-induced shear

stress at the bottom boundary resulting from the wave orbital velocities is combined with a model for the current-induced shear stress to obtain the total bottom shear that effects sediment resuspension. The cohesiveness of the sediment determines the critical shear stresses that are necessary to resuspend or deposit the sediments. A model of consolidation of the sediments is used to remove lower sediment layers from the maximum mass that may be resuspended.

A.1.5 TECHNICAL DESCRIPTION OF CAEDYM

CAEDYM is an outgrowth of previous CWR water quality modules in DYRESM-WQ and the Estuary Lake Model - Water Quality (ELMO-WQ) codes. CAEDYM is designed as a set of subroutine modules that can be directly coupled with one, two, or three-dimensional hydrodynamic "drivers", catchment surface hydrological models, or groundwater models. Additionally, it can be used in an uncoupled capacity with specification of velocity, temperature, and salinity distributions provided as input files rather than as part of a coupled computation. The user can specify the level of complexity in biogeochemical process representation so both simple and complex interactions can be studied. Direct coupling to a hydrodynamic driver (e.g. ELCOM) allows CAEDYM to operate on the same spatial and temporal scales as the hydrodynamics. This permits feedbacks from CAEDYM into ELCOM for water quality effects such as changes in light attenuation or effects of macroalgae accumulation on bottom currents. **Figure A.8** shows an illustration of the interactions of modeled parameters in CAEDYM. Being an “N-P-Z” (nutrient-phytoplankton-zooplankton) model, CAEDYM can be used to assess eutrophication. Unlike the traditional general ecosystem model, CAEDYM serves as a species- or group-specific model (i.e. resolves various phytoplankton species). Furthermore, oxygen dynamics and several other state variables are included in CAEDYM.

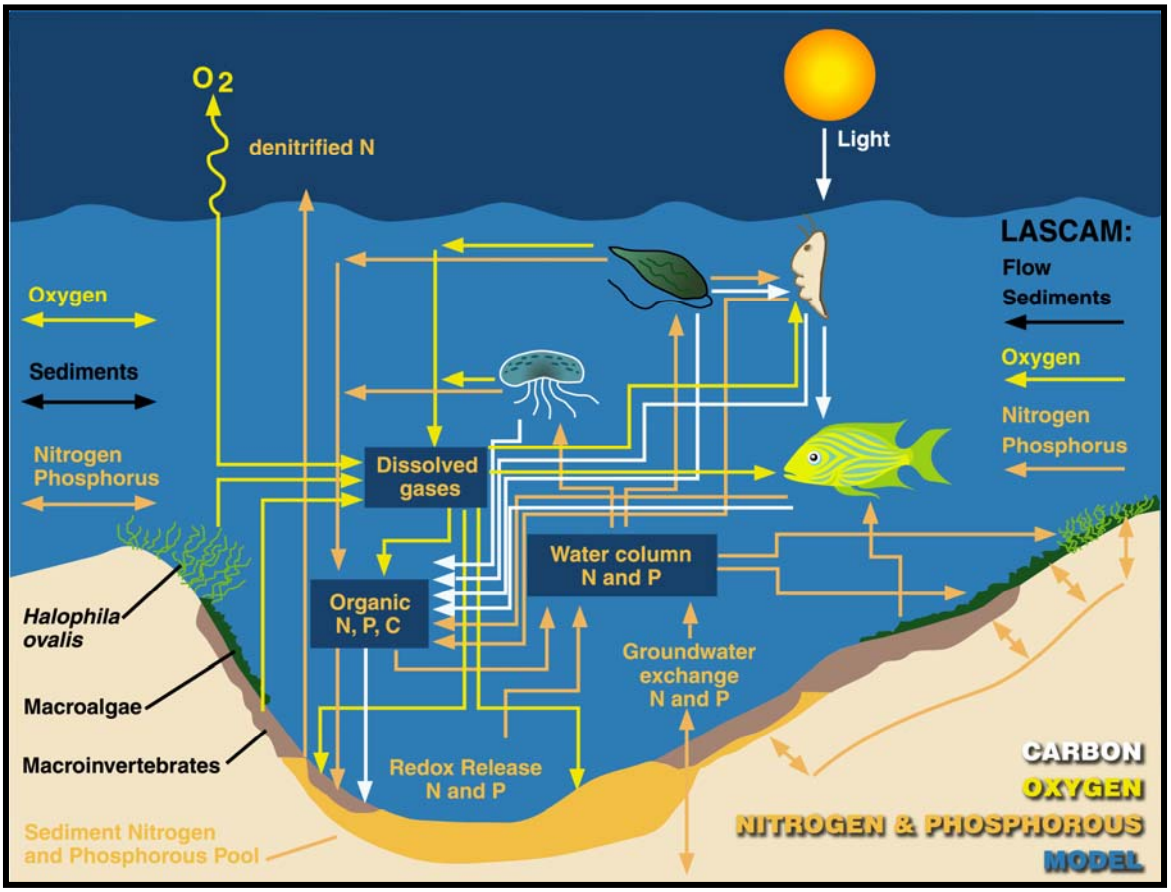

Figure A.8 Illustration of interactions of modeled parameters in CAEDYM.

The representation of biogeochemical processes in ecological models has, historically, been treated in a simple manner. In fact, the pioneering work on modeling marine ecosystems (Riley et al, 1949; Steel, 1962) is still used as a template for many of the models that are currently used (Hamilton and Schladow, 1997). The level of sophistication and process representation included in CAEDYM is of a level hitherto unseen in any previous aquatic ecosystem model. This enables many different components of the system to be examined, as well as providing a better representation of the dynamic response of the ecology to major perturbations to the system (e.g. the response to various management strategies). **Figure A.9** shows the major state variables included in the CAEDYM model. Using CAEDYM to aid in management decisions and system understanding requires (1) a high level of process representation, (2) process

interactions and species differentiation of several state variables, and (3) applicability over a spectrum of spatial and temporal scales. The spectrum of scales relates to the need for managers to assess the effects of temporary events, such as anoxia at specific

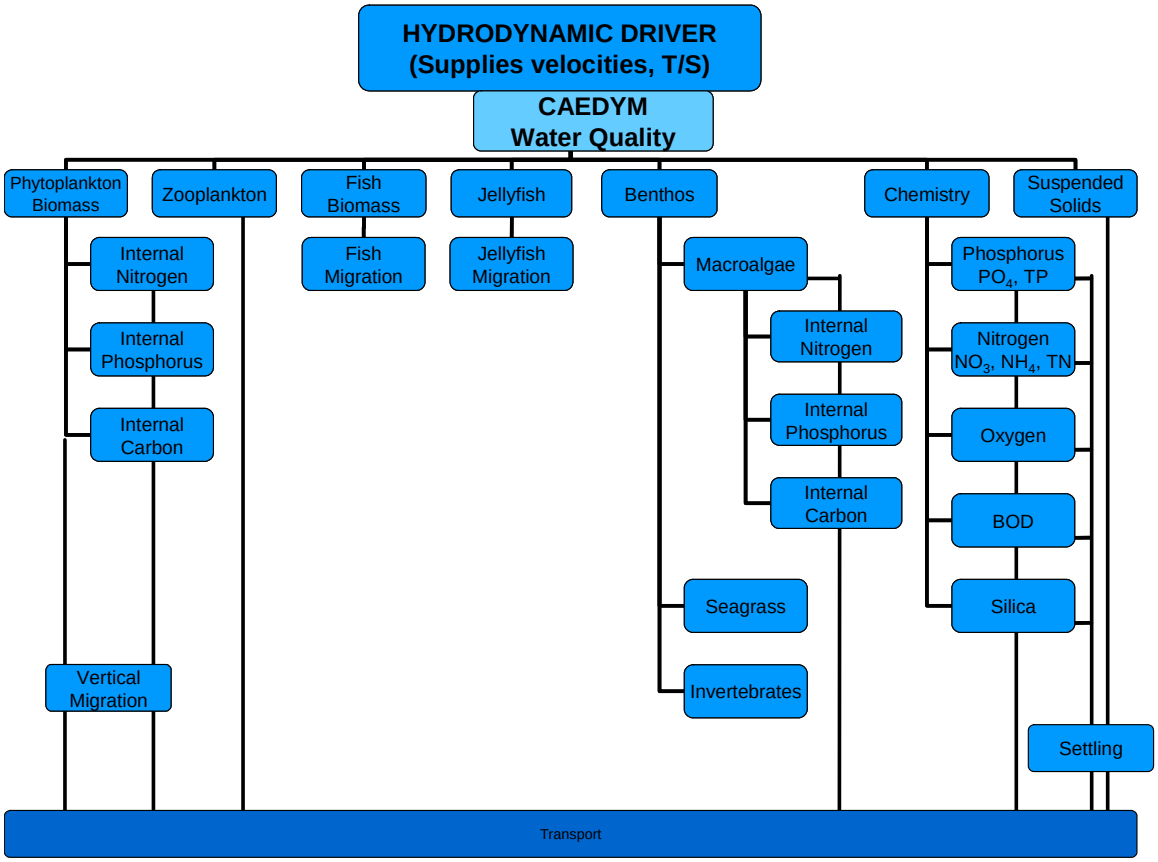

Figure A.9 Major state variables included in the CAEDYM model.

locations, through to understanding long-term changes that may occur over seasons or years. There is considerable flexibility in the time step used for the ecological component. Long time steps (relative to the hydrodynamic advective scale) may be used to reduce the frequency of links to ELCOM when long-term (i.e. seasonal or annual) simulations are run.

A.1.5.1 Biological Model

The biological model used in CAEDYM consists of seven phytoplankton groups, five zooplankton groups, six fish groups, four macroalgae groups and three invertebrate groups, as well as models of seagrass and jellyfish. This set will be expanded as biological models are developed, tested, and calibrated to field data. There is flexibility for the user in choosing which species to include in a simulation. Vertical migration is simulated for motile and non-motile phytoplankton, and fish are migrated throughout the model domain according to a migration function based on their mortality. A weighted grazing function is included for zooplankton feeding on phytoplankton and fish feeding on zooplankton. The biomass grazed is related to both food availability and preference of the consumer for its food supply. Improved temperature, respiration and light limitation functions have been developed to represent the environmental response of the organisms. The benthic processes included a self-shading component and beach wrack function for macroalgae, sediment bioturbation and nutrient cycling by polychaetes, and effects of seagrass on sediment oxygen status.

In particular, the seven phytoplankton groups modeled are dinoflagellates, freshwater diatoms, marine/estuarine diatoms, freshwater cyanobacteria, marine estuarine cyanobacteria, chlorophytes, and cryptophytes. Phytoplankton biomass is represented in terms of chlorophyll *a*. Phytoplankton concentrations are affected by the following processes:

- Temperature growth function
- Light limitation
- Nutrient limitation by phosphorus and nitrogen (and when diatoms are considered, silica)
- Loss due to respiration, natural mortality, excretion, and grazing
- Salinity response
- Vertical migration and settling

A.1.5.2 Nutrients, Metals, and Oxygen Dynamics

The transport and chemical cycling of nutrients is an important part of simulating the interaction of biological organisms in an ecosystem. CAEDYM includes as state variables the following:

- Nutrients (dissolved inorganic phosphorus, total phosphorus, total nitrogen, ammonium nitrate, and silica).
- Dissolved oxygen and biochemical oxygen demand.
- Metals (dissolved and particulate forms of iron and manganese).
- Suspended sediment (the particulate and colloidal fractions).
- pH

The model incorporates oxygen dynamics and nutrient cycling in both the sediments and water column. A sediment pool of organic detritus and inorganic sediments, both of which may be resuspended into the water column, is included. Redox-mediated release of dissolved nutrients is simulated from the sediments to the water column.

Processes included in the water and sediment oxygen dynamics include:

- Atmospheric exchange (Wanninkhof, 1992).
- Oxygen production and consumption through phytoplankton, macroalgae, and seagrass/macrophyte photosynthesis and respiration, respectively.
- Utilization of dissolved oxygen due to respiration of higher organisms such as zooplankton and fish and due to photosynthesis and respiration in jellyfish
- Water column consumption of oxygen during nitrification.
- Biochemical oxygen demand due to mineralization of organic matter in the water column and in the sediments.

Oxygen flux from the water column to the sediments, sediment oxygen demand (SOD), as developed from Fick's law of diffusion.

The last two processes are used together with a sediment porosity and diffusion coefficient (Ullman and Aller, 1982) in order to define the depth of the toxic layer in the sediments.

Nutrient processes included in the sediment and water column dynamics include:

- Phytoplankton nutrient uptake, with provision for luxury storage of nutrients.
- Release of dissolved inorganic nutrients from phytoplankton excretion.
- Excretion of nutrients as fecal material by zooplankton.
- Nitrification and denitrification by bacterial mediated action.
- Generation of inorganic nutrients from organic detritus.
- Transfer of nutrients through the food chain (e.g. phytoplankton--zooplankton--fish).
- Uptake of nutrients by macroalgae and seagrasses.
- Adsorption/desorption of nutrients from inorganic suspended sediments.
- Sediment/water transfer of nutrients (*via* such processes as sediment resuspension, sedimentation, redox-mediated nutrient release, and bioturbation).

In essence, CAEDYM represents the type of interactive processes that occur amongst the ecological and chemical components in the aquatic ecosystem. As a broad generalization, one component of the system cannot be manipulated or changed within the model without affecting other components of the system. Similarly in nature, changing an integral component in the aquatic system will have wide-ranging and follow-on effects on many of the other system components. CAEDYM is designed to have the complexity and flexibility to be able to handle the continuum of responses that will be elicited as components of a system that are manipulated. Thus, the model represents a valuable tool to examine responses under changed conditions, as for example, when new approaches to managing an ecosystem are adopted.

A.2 DESCRIPTION OF ELCOM/CAEDYM/VISUAL PLUMES (ECP)

A.2.1 INTRODUCTION

Outfalls are commonly used to discharge treated effluent into open waters. The hydrodynamics of an effluent discharged through an outfall can be conceptualized as a mixing process occurring in two separate regions: a near-field region and a far-field region. In the near-field region the effluent generally experiences a significant amount of mixing, and dilution occurs very rapidly. In this region, the initial jet characteristics of momentum flux, buoyancy flux, flow rate, as well as outfall geometry greatly influence the effluent trajectory and degree of mixing (Fischer et al, 1979). As the effluent plume travels further away from the source, the source characteristics become less important and the far-field region is attained. Mixing of the effluent plume in this region is caused by spatial and temporal variations of ambient velocity fields and dilution generally occurs slowly over a long distance, but may be rapid if there is a high degree of turbulence in the environment.

Due to different dominant temporal and spatial scales of flow velocity and effluent concentration in the near and far field region, a complete model that accounts for all important spatial and temporal scales in both the near-field and far-field regions is not feasible. Instead, these two regions are usually treated by separate models termed the near-field model and the far-field model respectively.

The near-field model has been under intensive study from the 1950s through the early 1990s. Thorough reviews of these studies are provided by Fischer et al. (1979), Baumgartner et al. (1994), and Roberts et al. (1989 a, b, c). These studies have produced a number of near-field models that were verified by both field and laboratory data. Among them, Visual Plumes (VP or PLUMES), endorsed by the U.S. Environmental Protection Agency (USEPA), is the most popular model and has been widely used by regulatory agencies and outfall designers to estimate the near-field dilution.

A variety of models can be used to model far-field mixing processes. These include ELCOM/ CAEDYM, Princeton Ocean Model (POM), and MIT General Circulation Model (MITGCM). All of these models obtain a velocity field from the numerical calculation of the equations of motion and account for influences by tide, wind stress, and pressure gradient due to free surface gradients (barotropic) or density gradients (baroclinic). Given the velocity field, the pollutant concentration field is

typically obtained by solving the Eulerian advective diffusion equation in three dimensions or by using the Lagrangian particle-tracking method.

In simple water bodies with well-defined uni-directional current regimes, the use of near-field models alone may suffice to evaluate a design of an outfall discharge that meets regulations. However, in regions with multiple current regimes (inertial, tide, wind, and buoyancy driven) and with large pollutant loadings, especially where several sources may interact, near-field models must be supplemented by far-field transport and water quality models. The latter are capable of prediction, over a greater distance in the water body, of the concentration distributions for different pollutants, nutrients, and other bio-chemical parameters. They do not, however, have the high spatial resolution that is required to predict near-field mixing processes. Thus, a coupled approach is necessary. In the following sections, a method of coupling the near-field model PLUMES and the far-field model ELCOM/CAEDYM is discussed. The coupled code is referred to as ELCOM/CAEDYM/PLUMES (ECP). Note that there is no standard procedure for the coupling of near and far field models and the coupling procedure varies from code to code mainly because of the different code structures among all of the near-field and far-field models.

A.2.2 NEAR-FIELD MODEL – PLUMES

PLUMES is an interface program that contains the near-field models such as the Roberts, Snyder, and Baumgartner model (RSB) and UM and CORnell MIXing Zone Expert System (CORMIX) (Baumgartner et al., 1994). In ECP, the UM model is chosen to simulate near-field dilution. The UM model is an integral near-field model that uses one-dimensional conservation equations for mass, momentum, salinity and temperature, to model the growth of the plume once the effluent has left the port. Assumptions are made about the shape of the plume and the distribution of pollutant concentration within the plume. Several mechanisms of entrainment such as aspirated, forced, and turbulent diffusion are considered. Both positively and negatively buoyant plumes, single source and multi-port diffuser configurations can be modeled. Model outputs include average dilution, centerline dilution, and horizontal distance of the effluent plume. The major limitation of UM lies in the assumption of an infinite receiving water body, similar to all other available integral-type models (e.g. RSB model). Thus, UM should only be used for deep-water outfalls without boundary interactions. More details on UM and PLUMES can be found in Baumgartner et al. (1994).

A.2.3 FAR-FIELD MODEL – ELCOM/CAEDYM

ELCOM is a three-dimensional hydrodynamic model for lakes and reservoirs and is used to predict the velocity, temperature, and salinity distribution in natural water bodies subjected to external environmental forcing, such as wind stress, surface heating, or cooling. Through coupling with the CAEDYM water quality module, ELCOM can be used to simulate three dimensional transport and interactions of flow physics, biology, and chemistry. ELCOM/CAEDYM is the chosen far-field model in ECP.

A.2.4 COUPLING PLUMES AND ELCOM/CAEDYM

The adopted coupling procedure is based on four steps: ambient conditions modeling, near-field modeling, coupling of near-field and far-field models, and far-field modeling.

1. Ambient conditions modeling

   The near-field model, UM, needs the input of ambient conditions such as the prevailing velocity, temperature, and salinity profiles in the vicinity of the outfall. These profiles are extracted from the ELCOM/CAEDYM simulation at the beginning of a time step at a vertical column of grid cells containing or overlapping the diffuser (the "Diffuser Cell Column" in **Figure A.10**). The depth of the diffuser is also updated based on the surface elevation at that time step.

2. Near-field modeling

   The UM model is applied at each time step using the ambient conditions extracted from ELCOM/CAEDYM. Furthermore, effluent data is obtained from input files for ELCOM/CAEDYM, and the diffuser geometry is specified in the input file called "diffuser_config.dat." The UM model is modified to consider the trapping or surfacing of the plume as the end of the near-field region. The computed average dilution along the trajectory of the plume is then stored for the following coupling step.

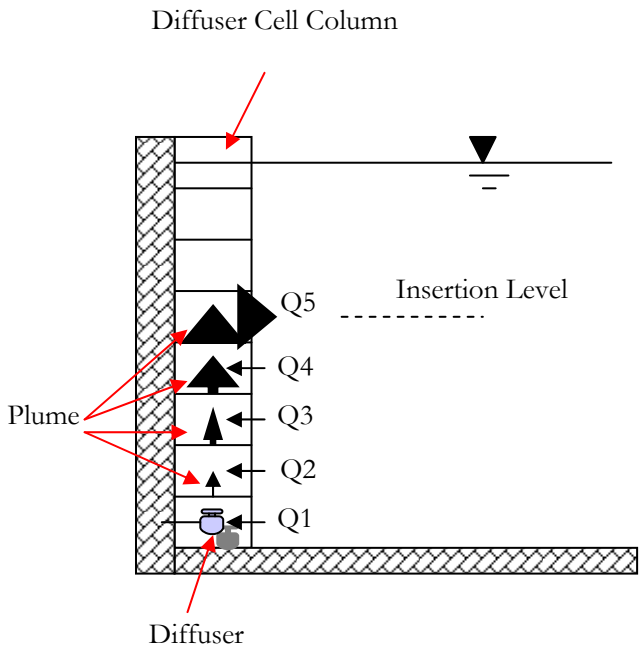

Figure A.10 Schematic of coupling procedure for near-field and far-field models.

3. Coupling of near-field and far-field models

After identifying the "Diffuser Cell Column" (**Figure A.10**), the dilution in each of the cells along this column can be calculated from the linear interpolation of results from UM. Water is then withdrawn from each of these cells based on the dilution occurring in the cell. This withdrawn water is then mixed with the effluent to form the effluent plume and passed to the cell above. Finally, the diluted effluent is then inserted into the cell where the UM model indicates the occurrence of trapping or surfacing (**Figure A.10**). Flow rate, temperature, salinity, and tracer concentrations within this inserted inflow are determined by mass conservation.

4. Far-field modeling

ELCOM/CAEDYM treats the previous coupling process as a series of outflows and inflows along the "Diffuser Cell Column" and proceeds with its time-marching far-field simulation for the time step. Steps 1 - 4 are then repeated for the next time step until the simulation ends.

A.2.5 VERIFICATION OF ECP

The UM model was originally written in TURBO PASCAL and was converted into FORTRAN and included in ECP. The comparison between the results from UM of PLUMES and UM of ECP shows an exact match (**Figure A.11**) and the conversion of the UM model is verified.

Output from UM Model of PLUMES

depth (m)	dilution (m)	horiz dis	
50.000	1.000	0.000	
49.761	1.971	0.005	
49.311	3.913	0.035	
48.585	7.797	0.127	
47.525	15.566	0.327	
46.035	31.104	0.696	
45.928	32.424	0.725	merging
43.228	62.180	1.529	
37.335	124.335	3.385	
25.609	248.651	7.517	
22.323	285.625	8.893	trap level
15.436	395.624	12.750	begin overlap, dilution overestimated
14.308	442.027	13.760	surface hit

Output from UM Model of ECP

depth (m)	dilution (m)	horiz dis	
50.000	1.000	0.000	
49.761	1.971	0.005	
49.311	3.913	0.035	
48.585	7.797	0.127	
47.525	15.566	0.327	
46.035	31.104	0.696	
45.928	32.424	0.725	merging
43.228	62.180	1.529	
37.335	124.335	3.385	
25.609	248.651	7.517	
22.323	285.625	8.893	trap level
15.436	395.624	12.750	begin overlap, dilution overestimated
14.308	442.027	13.760	surface hit

Figure A.11 Comparison of outputs from UM of PLUMES and ECP

Mass conservation within ECP was tested by simulating an idealized lake with a single outfall (inflow) and no outflow. Total mass of both a conservative tracer and total phosphorus (TP) in the lake was calculated at each time step and compared with a similar simulation using ELCOM/CAEDYM (where the outfall was treated as a single inflow). Less than 0.1% difference was found for the conservative tracer and less than 1% difference was found for TP at the end of a one-year simulation. These small differences indicate that mass conservation within the ECP code is comparable to that of ELCOM/CAEDYM.

The accuracy of ECP can also be qualitatively evaluated by simulating the behavior of a plume under stratified and unstratified ambient conditions. **Figure A.12** shows that ECP correctly predicts surfacing of the plume under unstratified conditions and the level of insertion of the plume under stratified conditions.

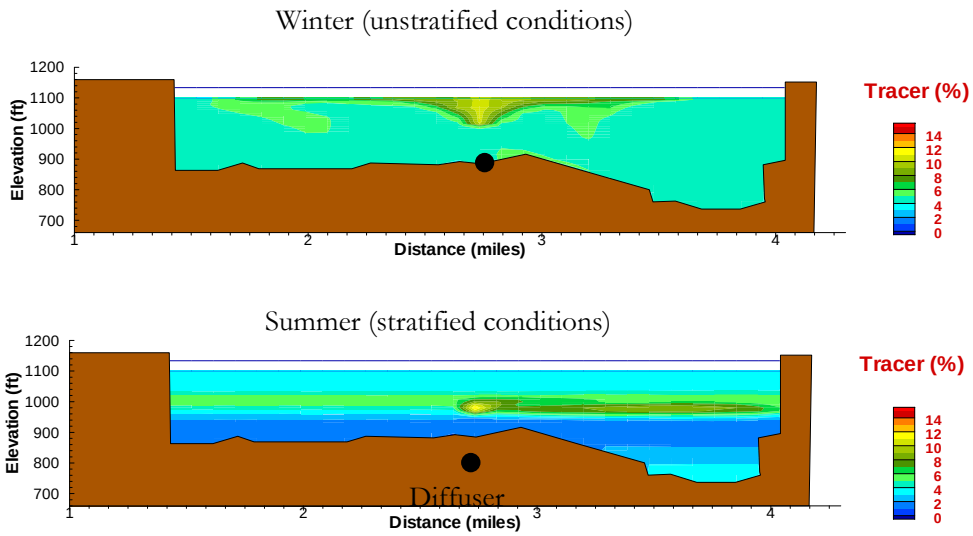

Figure A.12 Comparison of tracer concentrations released from an outfall under stratified and unstratified conditions using ECP.

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APPENDIX B

ANIMATIONS

INSTRUCTIONS FOR INSTALLING AND USING FRAMER TO VIEW ANIMATION FILES

Installation of Framer

Copy the files from the CD(s) to a directory on your computer.

Running Framer

1) In the Start Menu, choose "run." In this window, type "framer.exe." This should open a "Framer Open File" window, in which you find the proper directory and choose the file that you wish to view.

2) Commands for running the animation files are in the toolbar in the upper left corner of the framer window.

LIST OF ANIMATIONS

1) SVR_BaseCase_Temperature.rm: Animation of predicted water temperature for the Base Case

2) SVR_BaseCase_DecayingTracer.rm: Animation of predicted decaying tracer concentration for the Base Case

3) SVR_Extended_Drought_DecayingTracer.rm: Animation of predicted decaying tracer concentration for the Extended Drought scenario

4) SVR_Emergency_Drawdown_DecayingTracer.rm: Animation of predicted decaying tracer concentration for the Emergency Drawdown scenario

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Water Purification Demonstration Project: Limnology and Reservoir Detention Study of San Vicente Reservoir – Nutrient and Algae Modeling Results

Prepared for
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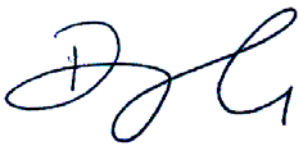
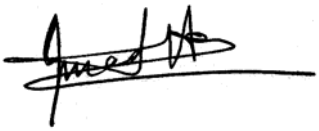

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SUMMARY

San Vicente Reservoir (SVR) is located near Lakeside, California, and is used as a source of drinking water supply by the City of San Diego (City), its owner and operator. The reservoir currently has a capacity of about 90,000 acre-feet (see Figure 1). It is undergoing an expansion that will raise the dam 117 feet (ft) and increase the reservoir's storage to 247,000 acre-feet at the spillway level (or 242,000 acre-feet at the maximum operation level). The City is considering an option to augment SVR supply by bringing advanced purified recycled water (*i.e.*, purified water) from the advanced water purification facility to SVR. The purified water would be blended with other water in the reservoir. The current project – the Water Purification Demonstration Project (Demonstration Project) – will not actually put any purified water into the reservoir; rather it will study and model the reservoir augmentation process. A component of the Demonstration Project is the Limnology and Reservoir Detention Study of San Vicente Reservoir (Limnology Study).

As part of the Limnology Study, Flow Science Incorporated (FSI) has developed a three-dimensional water quality model that is used to evaluate hydrodynamic and water quality effects of using purified water to augment SVR. After the model was developed, its results were compared to existing field data and documented in a Technical Memorandum (TM #1) submitted to the City in 2010 (FSI, 2010). The TM #1 has been peer-reviewed by the National Water Research Institute Independent Advisory Panel (NWRIIAP) that was assembled for the review of the City's Demonstration Project. After implementing suggestions proposed by the NWRIIAP, the model was deemed by NWRIIAP to be "an effective and robust tool, for 1) simulating thermoclines and hydrodynamics of the San Vicente Reservoir; 2) assessing biological water quality for nutrients; 3) assessing options for the purified water inlet location" (NWRIIAP, 2010).

Upon completion of the SVR model calibration and validation, FSI conducted simulations of purified water delivery to the expanded SVR under various projected future operating conditions using the calibrated/validated model. The simulation results and findings are presented in two separate Technical Memorandums (TM #2 and TM #3). The TM #2 summarizes the hydrodynamic aspects of the modeling results and was submitted to the City on November 28, 2011. This report, TM #3, focuses on the water quality aspects of the modeling results and findings, with emphasis on nutrients (phosphorus and nitrogen), dissolved oxygen (DO), and algal concentration levels. The water quality parameters evaluated include chlorophyll *a* (a surrogate measure of algal growth), DO, pH, nitrate as N, ammonia as N, Total Nitrogen (TN), Soluble Reactive Phosphorus (SRP), Total Phosphorus (TP) and Secchi depth.

The goal of this work is to determine the effects of purified water delivery on the reservoir's water quality under anticipated future conditions in the expanded reservoir.

Because both the reservoir expansion and augmentation with purified water are expected to affect the reservoir water quality, a two-step approach was taken in this study to examine the water quality effects caused by the reservoir expansion and argumentation, respectively.

RESERVOIR EXPANSION

First, the SVR model was used to determine the effects of the reservoir expansion on water quality, without the introduction of any purified water. This was accomplished by performing a simulation (referred to as Expanded Reservoir Case) that uses the same reservoir conditions (climate, inflow and outflow volumes and concentrations etc.) as the 2006 - 2007 calibration simulation (*i.e.*, Existing Case), except for using a higher initial reservoir volume that is set at 155,000 acre-feet (median expected future storage). The results from the Expanded Reservoir Case were compared against those from the Existing Case. The differences between the results of these two simulations demonstrate the effects of the expansion on the reservoir's water quality in the absence of any purified water discharge to the reservoir.

Based on the results of these two simulations, the following conclusions and observations on the effects of the reservoir expansion can be made:

- As evidenced in **Table S-1**, the reservoir expansion is predicted to extend the duration of the hypolimnetic anoxia by an average of 27 days per year (from 189 days per year to 216 days per year) and enlarge the volume of water under anoxic condition by at least two fold.

- The reservoir expansion will produce lower surface chlorophyll *a* concentrations and higher Secchi depths *(i.e.*, better water clarity) in the reservoir. It is predicted that the annual average chlorophyll *a* concentration will decrease from 5.8 micrograms per liter (µg/L) to 3.4 µg/L and the annual average Secchi depth will increase from 3.2 meters (m) to 4.7 m after the expansion.

- Based on a nutrient loading calculation, the internal nutrient loadings *(i.e.*, nutrients released from sediment) are larger than all external loadings combined over the two-year modeling period for both the Existing Case and Expanded Reservoir Case. Meanwhile, the reservoir expansion is predicted to lead to a significant increase in sediment nutrient release, likely due to the larger hypolimnetic bottom area and extended hypolimnetic anoxia period. However, despite the significantly higher sediment release, surface TN concentrations are actually lower after the reservoir expansion, a result of the significantly larger volume of water for the Expanded Reservoir Case. The resulting lower nutrient concentrations are believed to be one of the main factors that lead to lower surface

chlorophyll *a* concentrations for the Expanded Reservoir Case (compared to the Existing Reservoir Case).

Table S-1. Summary of Bottom Anoxia[1] Occurrence for Existing Case and Expanded Reservoir Case

Simulation	Days Under Anoxia: Total Days (Percentage)[2]	Average Surface Chlorophyll *a* (µg/L)	Average Secchi Depth (m)
Existing Case	189 (52%)	5.8	3.2
Expanded Reservoir Case	216 (59%)	3.4	4.7

Notes:1. Anoxia is defined here as the bottom DO less than 0.5 mg/L
2. Both the total number of days and percentage under anoxia are yearly values averaged over the two-year simulation period.

FUTURE OPERATING CONDITIONS

After the effects of the reservoir expansion were determined, the model was used to examine the water quality in the expanded reservoir under future operating conditions both with and without purified water augmentation. Specifically, the following two future scenarios were simulated:

- Base Case (includes purified water inflow) ---- This scenario considered an expanded reservoir under median expected storage and expected future operations. The initial reservoir volume for the Base Case is set at 155,000 acre-feet. The following annual flow rates were assumed: for aqueduct inflow 3,000 acre-feet/year (a-f/y); runoff 4,500 a-f/y; purified water inflow 15,000 a-f/y; and dam withdrawal 19,000 a-f/y, with no water transfers from Sutherland Reservoir into SVR.

- No Purified Water ---- The inputs for this scenario are similar to those for the Base Case scenario, except for no purified water additions and an equal reduction in reservoir outflow. The initial reservoir volume for this scenario is set at 155,000 acre-feet. The annual flow rates for aqueduct inflow, runoff, purified water inflow and dam withdrawal are 3,000, 4,500, 0 and 4,000 acre-feet/year respectively. There are no water transfers from Sutherland Reservoir into SVR.

Results from the Base Case and No Purified Water scenarios were compared against those obtained from the Existing Case simulations (*i.e.*, no reservoir expansion). Based on the simulation results, the following conclusions and observations on the effects of the purified water and future operating conditions are made:

- The hypolimnetic anoxia period is predicted to last an average of 189 days per year for the Existing Case (**Table S-2**). For the No Purified Water scenario, the hypolimnetic anoxia period is predicted to increase to 207 days per year, an addition of 18 days per year. Adding purified water into the reservoir under future operating conditions (*i.e.*, Base Case) will further extend the average duration of the hypolimnetic anoxia period by 8 days, to a total of 215 days per year.

- The No Purified Water scenario produces lower algae levels *(i.e.*, lower surface chlorophyll *a* concentrations) and higher Secchi depths (*i.e.*, better water clarity) compared to the Existing Case. For example, the annual average chlorophyll *a* concentration and Secchi depth are predicted to be 5.8 µg/L and 3.2 m respectively for the Existing Case (**Table S-2**). By comparison, the annual average chlorophyll *a* concentration and Secchi depth are predicted to be 3.1 µg/L and 4.8 m, respectively, for the No Purified Water scenario in the expanded reservoir. This is a reduction of 2.7 µg/L for the average chlorophyll *a* concentration and an increase of 1.6 m for the average Secchi depth compared to the Existing Case.

- The Base Case scenario also produces lower algae levels *(i.e.*, lower surface chlorophyll *a* concentrations) and higher Secchi depths (*i.e.*, better water clarity) compared to the Existing Case. The Base Case is predicted to produce 3.7 µg/L for the annual average chlorophyll *a* concentration and 4.3 m for the annual average Secchi depth (**Table S-2**). This is a reduction of 2.1 µg/L for the average chlorophyll *a* concentration and an increase of 1.1 m for the average Secchi depth compared to the Existing Case.

- Nutrient loading calculations show that nutrient sediment release constitutes a significant portion of all nutrient loadings into SVR for all future scenarios as well as the Existing Case. The future operating scenarios (*i.e.*, Base Case and No Purified Water) produce sediment nutrient loadings significantly larger than those for the Existing Case, likely a result of the larger hypolimnetic bottom area and extended hypolimnetic anoxia period. However, despite the significantly higher sediment release for the future operating scenarios, surface TN concentrations are actually lower for the future scenarios compared to the Existing Reservoir Case, a result of the larger volume of water in the expanded reservoir. The resulting

lower nutrient concentrations are believed to be one of the main factors that lead to lower surface chlorophyll *a* concentrations for the future operating scenarios (compared to the Existing Reservoir Case).

- Nutrient limitation in SVR can be affected by various factors including the nutrient loadings from all the inflows and the sediments. As a result, nutrient limitation at any point may vary based on existing conditions. However, note that the N:P ratio of the purified water is expected to reach about 159, indicating that algal growth in the future reservoir may tend to become more phosphorus-limited.

Table S-2. Summary of Simulated DO, Chlorophyll *a* and Secchi Depth for Modeling Scenarios

Operating Scenarios	Days Under Anoxia[1]: Total Days (Percentage)[2]	Average Surface Chlorophyll *a* (µg/L)	Average Secchi Depth (m)
Existing Case	189 (52%)	5.8	3.2
No Purified Water	207 (57%)	3.1	4.8
Base Case	215 (59%)	3.7	4.3

Notes: 1. Anoxia is defined here as the bottom DO less than 0.5 mg/L.
2. Both the total days and percentage under anoxia are yearly values averaged over the two-year simulation period.

1. INTRODUCTION

1.1 BACKGROUND

San Vicente Reservoir (SVR) is located near Lakeside, California, and is used as a drinking water supply by the City of San Diego (City), its owner and operator (**Figure 1**). The reservoir currently has a capacity of about 90,000 acre-feet. It is undergoing an expansion that will raise the dam by 117 feet and increase the reservoir's storage to 247,000 acre-feet at the spillway level (or 242,000 acre-feet at the maximum operation level). The reservoir expansion is scheduled to be completed in 2013.

In the meantime, a water reuse project, entitled Reservoir Augmentation, is being studied by the City. If implemented at full-scale, Reservoir Augmentation would bring advanced purified recycled water (*i.e.*, purified water) from the advanced water purification facility to the expanded SVR via a pipeline. The purified water would be blended with other water in the reservoir. The current project – the Water Purification Demonstration Project (Demonstration Project) – will not actually put any purified water into the reservoir; rather it will study and model the Reservoir Augmentation process. A component of the Demonstration Project is the Limnology and Reservoir Detention Study of San Vicente Reservoir (Limnology Study).

As part of the Limnology Study, Flow Science Incorporated (FSI) has developed a three-dimensional computer model that is used to evaluate hydrodynamic and water quality effects of using purified water to augment SVR. After the model was developed, its results were compared to existing field data and documented in a Technical Memorandum (TM #1) submitted to the City in 2010 (FSI, 2010). The TM #1 has been peer-reviewed by the National Water Research Institute Independent Advisory Panel (NWRIIAP) that was assembled for the review of the City's Demonstration Project. The model was deemed by NWRIIAP, with some fine-tuning, as "an effective and robust tool, for 1) simulating thermoclines and hydrodynamics of the San Vicente Reservoir; 2) assessing biological water quality for nutrients; 3) assessing options for the purified water inlet location" (NWRIIAP, 2010). After the review, all the suggestions by NWRIIAP on fine-tuning the model have been addressed or implemented. Findings and results from the TM #1 that are relevant to the work presented here are summarized in the next section.

Upon completion of the SVR model calibration and validation, FSI conducted simulations of purified water release to the expanded reservoir under various projected future operating conditions using the calibrated/validated model. The simulation results and findings are presented in two separate Technical Memorandums (TM #2 and TM #3). The TM #2 summarizes the hydrodynamic aspects of the modeling results and was submitted to the City on November 28, 2011. The highlights of TM#2 are included in the

next section. This current report, TM #3, focuses on the water quality aspects of the modeling results and findings with emphasis on nutrients (phosphorus and nitrogen), DO, and algal concentration levels. The water quality parameters evaluated include chlorophyll *a* (a surrogate measure of algal growth), DO, pH, nitrate as N, ammonia as N, Total Nitrogen (TN), Soluble Reactive Phosphorus (SRP), Total Phosphorus (TP) and Secchi depth.

This work has been performed by Flow Science Incorporated (FSI) of Pasadena, California, under contract to the City of San Diego, California.

1.2 THE SVR MODEL

1.2.1 General Description of the SVR Model

The three-dimensional SVR model consists of two coupled computer models that simulate both the hydrodynamics and water quality of SVR. These two models are the Estuary Lake and Coastal Ocean DYnamics Model (ELCOM) for hydrodynamic simulation and the Computational Aquatic Ecosystem DYnamics Model (CAEDYM) for water quality simulation. ELCOM requires the user to define boundary conditions, physical inputs, meteorological inputs, and bathymetry in a grid structure. The output from ELCOM consists of predictions for water velocities, temperature, salinity (*i.e.*, conductivity), and concentrations of decaying or conservative tracers in space and time within the body of water. CAEDYM is a suite of water quality modules that compute interactions between biological organisms and the chemistry of their nutrient cycles (**Figure 2**). It is coupled with ELCOM to simulate the biochemical parameters of an aquatic ecosystem including carbon, nitrogen, phosphorus, silicon, organic matter, DO, pH, inorganic suspended solids, metals, carbon, fish and chlorophyll *a*. In this study, we focus on simulation results for nutrients (*i.e.*, nitrogen and phosphorus), DO and algae in the expanded SVR. Detailed information and technical descriptions concerning ELCOM and CAEDYM are included in **Appendix A**.

The SVR modeling domain includes both the existing reservoir as well as the proposed expanded reservoir (**Figure 1**). A grid with a horizontal resolution of 100 × 100 m is used in this study – similar to the grid used in the water quality calibration (**Figure 3**). It should be noted that the horizontal grid used in the water quality simulation is coarser than the grid used in the hydrodynamic simulation (*i.e.*, 50 × 50 m in resolution) in order to ensure a reasonable computational time. The vertical grid used in the water quality simulation is the same as that used in the hydrodynamic simulation, with a grid size of 1.64 ft (0.5 m) near the surface and expanding in size with depth. A test has been conducted (and presented in TM #1) to evaluate the accuracy of the coarse grid in simulating temperature and conductivity. It concluded that using either the fine or coarse grids will result in almost identical predicted conductivity and temperature

profiles. Therefore, it is appropriate to use the coarse grid in the water quality simulation to ensure adequate model resolution and reasonable model run times.

1.2.2 Model Calibration/Validation

The model calibration was conducted for the two-year period of 2006 and 2007. The input data required by the calibration were either based on the measured data or derived from these data. Various comparisons between model and data are presented in the TM #1 and they include temperature, conductivity, DO, pH, nutrients (nitrogen and phosphorus), chlorophyll *a* and Secchi depth. In the following, we discuss the highlights of TM #1.

1.2.2.1 Hydrodynamic (ELCOM) Calibration/Validation

The calibrated/validated ELCOM model shows good agreement with the measured data for both water temperature and conductivity. For example, the onset and duration of thermal stratification as well as the deepening rate of the thermocline were predicted accurately by the model (**Figure 4**). In particular both the field data and model show that winter water temperatures in the fully mixed reservoir were nearly uniform in the vertical direction at a value near 12 ^{o}C to 13 ^{o}C. By April, increased solar radiation warmed the water surface up to 17 ^{o}C to 18 ^{o}C and thermal stratification started to develop. This process intensified and by summer (July through September) the surface temperatures had risen to as high as 28 ^{o}C, while the temperature in the hypolimnion remained nearly unchanged at the winter temperature of 12 ^{o}C to 13 ^{o}C. This large temperature difference between surface and bottom indicates that a strong vertical stratification was established in the lake. The thermocline was well defined and located at a depth ranging from approximately 30 to 40 ft, as shown in **Figure 4** for both the model and the data. In the fall, surface water temperatures steadily decreased due to reduced solar radiation and cooler air temperatures. This generated convective plumes within the reservoir, which combined with more effective wind mixing, deepened the thermocline to a depth of 60 ft by November. The stratification continued to weaken until the reservoir totally destratified and became well mixed at the end of the year, or at the beginning of the following year. The variation of conductivity in the reservoir was also well captured by the model (see Figures 18-20 in TM #1 for the calibration results in conductivity).

After the ELCOM model was calibrated, a validation was performed to compare the model against the results of previous tracer field studies. The validation shows that the model was capable of replicating the main features of the tracer study. This provides verification and assurance that the model performance is reliable and accurate in simulating hydrodynamics in the reservoir.

1.2.2.2 Water Quality (CAEDYM) Calibration

For all the simulated water quality parameters, the calibrated CAEDYM model shows overall good agreement with measured data. For example, both field data and simulation show that DO concentrations at the surface remained high throughout the years as a result of both the supply of oxygen directly from the atmosphere and of oxygen produced by photosynthetic activity near the surface (**Figure 5**). At high rates of photosynthesis, oxygen production by algae exceeded the diffusion of oxygen out of the system and this resulted in occasional oxygen supersaturation in the spring of 2006 and 2007. At the beginning of the simulation period, DO near the bottom of the reservoir was near saturation levels, a result of strong vertical mixing in the winter period. However, during the spring and summer, strong stratification at SVR inhibited vertical mixing and the DO at the bottom was quickly depleted by the decay of organic material (primarily algae cells) settling through the water column and organic matter in the sediments (*i.e.*, Sediment Oxygen Demand or SOD). The water in the hypolimnion became anoxic (defined as DO < 0.5 milligrams per liter [mg/L] herein) in the spring and anoxia lasted through the fall for both years, until the reservoir became destratified in the winter. **Figure 5** shows that the simulated DO concentrations captured the major trends in the measured DO concentrations, including the onset, duration, and magnitude of anoxia in the hypolimnion, the hypolimnetic DO decay rate in the spring, and the high surface DO concentrations resulting from algae blooms.

The available in-reservoir chlorophyll *a* data were qualitatively measured using a fluorometer that had not been calibrated. The calibration of chlorophyll *a* was conducted indirectly through comparisons with measured Secchi depth (**Figure 6**). Note that the formula used to derive Secchi depths using surface chlorophyll *a* concentrations is presented in the figure and this formula was also used in this study to obtain Secchi depths in all scenarios presented here. As shown in **Figure 6**, the Secchi depths from the calibration match fairly well with the measured Secchi depths, indicating a reasonably good calibration for chlorophyll *a*.

In conclusion, the SVR model is capable of capturing both the hydrodynamic features and the water quality variations in the reservoir. The simulation results are generally in good agreement with the field measurements. Thus the model provides “an effective and robust tool, for simulating thermoclines and hydrodynamics of the San Vicente Reservoir” and for “assessing biological water quality for nutrients” (findings from NWRIIAP, 2010). For more details of the calibration/validation refer to TM #1 (FSI, 2010).

1.3 SUMMARY OF HYDRODYNAMIC RESULTS IN TM #2

TM #2 presented the hydrodynamic results of various projected future operating scenarios for the expanded SVR. In particular, simulation results for temperature, conductivity and tracers are included in TM #2 for evaluation of reservoir hydrodynamics. Note that TM #2 has been peer-reviewed by NWRIIAP, which concluded that "the modeling is sufficiently predictive for purposes of evaluating the input of advanced treated recycled water" (NWRIIAP, 2012). In the simulations presented in TM #2, various hypothetical tracers were added to the purified water inflow to illustrate dilution, mixing and transport of the purified water within the reservoir. In particular, decaying tracers were used to study the dilution and inactivation of potential pathogens entering the reservoir; conservative tracers (*i.e.*, non-decaying) were used to simulate potential effects of elevated concentrations of chemical constituents in the purified water entering SVR after "excursion events" at the water purification facility.

Based on the simulation results, several key conclusions for the reservoir hydrodynamics were drawn in TM #2 and are listed here:

- Reservoir expansion will increase the volume of the hypolimnion but will have a negligible effect on overall temperature variation patterns as well as the thermocline depth during stratified periods.

- For all simulated future operating scenarios, decaying tracer concentrations in the reservoir outflow are predicted to achieve a 2-log reduction (100:1 reduction in concentration) in the unstratified period and significantly higher reductions (at least 4 logs; that is, a 10,000:1 reduction) in the stratified period.

- The minimum predicted dilution in the reservoir outflow for conservative tracers is about 900:1 for all simulated future operating scenarios.

- Moving the purified water inlet location closer to the reservoir outlet is predicted to generally (but not always) result in slightly higher values in the reservoir outflow concentrations for both the decaying and conservative tracers during the unstratified period. During the stratified period, different purified water inlet locations have little effect on decaying and conservative tracer concentrations in the reservoir outflow.

1.4 APPROACH AND REPORT ORGANIZATION

The goal of the work presented here is to determine the effects of purified water on the reservoir's water quality under anticipated future operating conditions in the expanded reservoir. Both the reservoir expansion and augmentation with purified water are expected to affect the reservoir water quality. Thus, a two-step approach was taken with the intent of examining the effects caused by each of these two changes. First, water quality effects caused solely by the reservoir expansion are investigated in **Chapter 2** by comparing results from two simulations that are different in the initial reservoir water volume, but otherwise identical. In **Chapter 3**, the water quality of the expanded reservoir under future operating conditions is examined, both with and without purified water augmentation to demonstrate the combined effects of argumentation and expansion under future operating conditions. Finally, conclusions and discussion are provided in **Chapter 4**.

2. EFFECTS OF RESERVOIR EXPANSION

The existing SVR has a capacity of 90,000 acre-feet and is currently undergoing an expansion to a capacity of 247,000 acre-feet that will be completed in 2013. Absent the Reservoir Augmentation project, SVR will be filled with imported water, local runoff, and water transferred from Sutherland Reservoir. Should the Reservoir Augmentation project go forward, the purified water would substitute for some of the imported water. The purified water would be diluted with other water stored in the reservoir. It is expected that the reservoir expansion alone could cause changes in the reservoir water quality. Thus, it is useful to investigate these anticipated changes in order to understand the future baseline conditions in the expanded reservoir. This was accomplished by performing a simulation that uses the same reservoir conditions (climate, inflow and outflow parameters etc.) as the 2006 - 2007 calibration simulation, except for using a higher initial reservoir volume that is set at 155,000 acre-ft (median expected future storage, see **Table 1**). This simulation is referred to herein as the Expanded Reservoir Case and the results from this simulation are compared to those from the original calibration in the unexpanded reservoir (henceforth referred as the Existing Case). The differences between the Existing Case and Expanded Reservoir Case therefore demonstrate the effects of the reservoir's expansion on water quality under the same operating conditions.

It should be noted that the nutrient levels in all the existing inflows to SVR are highly variable. **Figure 7** shows an example of nutrient levels in one of the main inflows to SVR, the aqueduct inflow, during the modeling period. The highest concentration of TN, for example, is almost four times that of the lowest concentration. This is expected to lead to variable nutrient and algae levels in the reservoir.

2.1 COMPARISON OF MODELING RESULTS

Figure 8 shows a comparison of simulated water temperatures from the Existing Case and Expanded Reservoir Case. The depth and deepening rate of the thermocline are fairly similar between these two simulations, indicating that the reservoir expansion will cause no major changes in the thickness of the epilimnion. Note that the volume of the epilimnion is somewhat larger for the Expanded Reservoir Case, mostly a result of the increase in the reservoir's surface area. However, the thickness and volume of the hypolimnion will be significantly larger for the Expanded Reservoir Case. With a larger hypolimnion, the reservoir from the Expanded Reservoir Case is predicted to destratify in the late fall or early winter a few days later than that from the Existing Case.

Table 1. Summary of Bottom Anoxia[1] Occurrence for Existing Case and Expanded Reservoir Case

Simulation	Year	Initial Reservoir Volume (acre-feet)	Bottom Anoxia Period	Days Under Anoxia: Total Days (Percentage)[2]	Average Surface Chlorophyll *a* (µg/L)	Average Secchi Depth (m)
Existing Case	2006	64,000	1/1 – 1/15 7/10 – 12/14	189 (52%)	5.8	3.2
	2007	60,000	6/8 – 12/28			
Expanded Reservoir Case	2006	155,000	1/1 – 1/19 6/21 – 12/23	216 (59%)	3.4	4.7
	2007	149,000	5/21 – 12/31			

Notes:1. Anoxia is defined here as the bottom DO less than 0.5 mg/L
2. Both the total number of days and percentage under anoxia are yearly values averaged over the two-year simulation period.

Figure 9 shows contours of simulated DO from the Existing Case and Expanded Reservoir Case at Station A (see **Figure 1** for Station A location). Time series of simulated surface and bottom DO at the same station are presented in **Figure 10**. As shown, the simulated DO exhibits similar patterns between the Existing Case and Expanded Reservoir Case. At the surface, DO concentrations are relatively high due to the oxygen replenishment from the atmosphere and algal production. At the bottom, DO concentrations steadily decrease during the stratified period because of algae decay and SOD, then rise sharply during the unstratified period as vertical mixing transports surface water with high DO towards the bottom.

Despite the similarities in overall DO profiles, reservoir expansion produces a few changes in DO concentrations in the reservoir as well. First, reservoir expansion significantly increases the volume of water under anoxic condition. **Table 2** lists volumes of water under an anoxic condition on several selected days during the two-year simulation period for both the Existing Case and the Expanded Reservoir Case. It shows that the volume of water under an anoxic condition in the Expanded Reservoir Case is at least twice and sometimes five times, as large as for the Existing Case. Secondly, during the unstratified period, DO concentrations in the Expanded Reservoir Case are predicted to be lower than those in the Existing Case. This is a result of the increased reservoir depth and the somewhat slower destratification rate for the Expanded Reservoir Case. This is one of the factors that lead to the predicted early onset of hypolimnetic anoxia for the Expanded Reservoir Case. For example, the hypolimnetic anoxia period starts on 6/21 in 2006 for the Expanded Reservoir Case compared to 7/10 for the Existing Case. Finally, the reservoir expansion delays destratification and prolongs the duration of hypolimnetic anoxia in the reservoir. In the Existing Case in 2006, the hypolimnetic

anoxia period is predicted to end on 12/14. In the Expanded Reservoir Case, the hypolimnetic anoxia period is predicted to end on 12/23, a delay of 9 days. Overall, the hypolimnetic anoxia period from the Existing Case consists of 52% of the time per year on average, which is equivalent to 189 days per year (**Table 1**). With the reservoir expansion, the reservoir experiences hypolimnetic anoxia for 59% of the time or for 216 days per year on average. Thus, given the same operating conditions the reservoir expansion is predicted to extend the hypolimnetic anoxia period by an average of 27 days per year.

Table 2. Predicted Volume of Water under Anoxic Conditions in the Existing Case and Expanded Reservoir Case

Date	Existing Case (acre-ft)	Expanded Reservoir Case (acre-ft)
8/1/06	15,900	48,000
10/1/06	17,600	64,600
12/1/06	15,900	82,300
8/1/07	25,000	57,600
10/1/07	32,500	66,500
12/1/07	24,000	82,300

Note: The volume of water under an anoxic condition is defined as the layer with DO less than 0.5 mg/L

Predicted time series of ammonia (as N), nitrate (as N), TN, SRP and TP at the surface and bottom of the reservoir are presented in **Figures 11 - 15**. Note that TN (TP) is defined as the sum of all particulate and soluble forms of nitrogen (phosphorus). Except for nitrate, all nutrients behave in a similar fashion. At the surface, nutrient concentrations (nitrogen and phosphorus) are generally low during the spring and summer due to algal consumption, and are generally high during the unstratified period when surface water is mixed with the nutrient-rich hypolimnion. At the bottom, nutrient concentrations (except for nitrate) generally show an opposite trend from surface nutrient concentrations: they rise during the stratified period as a result of sediment nutrient release and fall sharply during the unstratified period after being mixed with the surface water in which nutrients are depleted by algae. For nitrate, variation patterns are different from those displayed by other nutrient components. Nitrate levels are low in the summer and high in the winter at both the surface and the bottom (**Figure 12**). In the summer, algal growth consumes most of surface nitrate and the hypolimnetic anoxic condition leads to the loss of the bottom nitrate through denitrification or conversion to ammonia. In the winter, large influxes of nitrate from surface runoff and aqueduct inflow are mostly responsible for the rise in nitrate concentration at the surface and bottom within the reservoir.

Figure 16 shows predicted time series of surface chlorophyll *a* concentrations and **Figure 17** shows time series of Secchi depths derived from simulated chlorophyll *a*. Both figures indicate that the reservoir expansion will lower surface chlorophyll *a* levels and increases Secchi depth in the reservoir. **Table 1** lists predicted annual averages of surface chlorophyll *a* concentration and Secchi depth. With the expansion, the annual average surface chlorophyll *a* concentration is predicted to decrease from 5.8 µg/L to 3.4 µg/L, a 41% reduction in annual algal growth. This leads to a 47% increase in the annual average Secchi depth after expansion; the annual average Secchi depth increases from 3.2 m for the Existing Case to 4.7 m for the Expanded Reservoir Case.

A comparison of simulated pH between the Existing Case and Expanded Reservoir Case is presented in **Figure 18.** As shown, the pH is fairly similar for both simulations.

2.2 NUTRIENT LOADINGS

Phosphorus and nitrogen loadings have been computed for all inflows to SVR, as well as estimated for sediment release for both the Existing Case and Expanded Reservoir Case (**Tables 3** and **4**). The external nutrient loadings (*i.e.*, loadings from inflows) are calculated as the product of water inflow rate and the associated nutrient concentrations. The model does not directly output the total nutrient loadings from the sediments (*i.e.*, internal loadings). However, an order-of-magnitude estimate was computed for the sediment nutrient loading by multiplying the hypolimnetic volume of the reservoir by the rise in nutrient concentration at the reservoir bottom. Nutrient fluxes by atmospheric deposition are considered to be negligible.

As shown in **Tables 3** and **4**, estimated sediment nutrient loadings constitute a significant portion of the total nutrient loadings to the reservoir. In fact, the reservoir is calculated to receive more nutrients from the sediments than those from all inflows combined over the two-year modeling period. For example, in the Expanded Reservoir Case, the sediments release calculations shows about 26.6 tons TP over the two-year period and the total TP loading from all inflows is calculated to be 9.2 tons over the same period. In the Existing Case, the calculated sediment TP loading and the sum of all inflow TP loadings are 11.7 and 9.2 tons, respectively, over the two-year period.

In general, the limiting factor for algal growth is considered to be nitrogen if N:P < 10 and phosphorus if N:P > 10 (Horne and Goldman, 1994). From **Tables 3** and **4**, the ratios of TN:TP total loadings for the Existing Reservoir and Expanded Reservoir range from 3-6, indicating algal growth is likely limited by nitrogen in the reservoir. Note, however, that the inflow water quality is very variable and depends on both the water source and seasonality so the nutrient limitation at any specific instant may vary.

Tables 3 and **4** also show that the estimated total amount of nutrients released by sediments are generally larger in the Expanded Reservoir Case than in the Existing Case, partly a result of the larger hypolimnetic bottom area and extended hypolimnetic anoxia period for the Expanded Reservoir Case. The sediments are estimated to release a total of 26.6 tons TP over the two-year period in the Expanded Reservoir Case, more than twice of that in the Existing Case (*i.e.*, 11.7 tons TP). For TN, the estimated sediment release in the anoxic period is 80.6 tons for the Expanded Reservoir Case, almost three times the amount for the Existing Case (*i.e.*, 27.6 tons).

In conclusion, the reservoir expansion is predicted to slightly extend the duration of the hypolimnetic anoxia and enlarge the volume of water under anoxic condition. The reservoir expansion also produces lower surface chlorophyll *a* concentrations and higher Secchi depth *(i.e.*, more water clarity). Based on a nutrient loading calculation, the internal nutrient loadings *(i.e.*, sediment release) are larger than all external loadings combined over the two-year modeling period for both the Existing Case and Expanded Reservoir Case. Meanwhile, the reservoir expansion leads to an increase in sediment nutrient release due to the larger hypolimnetic bottom area and extended hypolimnetic anoxia period. However, despite the significantly higher sediment release, surface TN concentrations are actually lower after the reservoir expansion (**Figure 13**), a result of the significantly larger volume of water for the Expanded Reservoir Case. The resulting lower nutrient concentrations are believed to be one of the main factors that lead to lower surface chlorophyll a concentrations for the Expanded Reservoir Case (compared to the Existing Reservoir Case).

Table 3. Estimated Annual Phosphorus Loadings[1] for the Existing and Expanded Reservoir

Sources	SRP				TP			
	Existing Case		Expanded Reservoir Case		Existing Case		Expanded Reservoir Case	
	2006	2007	2006	2007	2006	2007	2006	2007
Purified Water	0	0	0	0	0	0	0	0
Runoff	0.1	0.8	0.1	0.8	2.9	3.3	2.9	3.3
Aqueduct Inflow	0.7	0.5	0.7	0.5	1.7	1.3	1.7	1.3
Sediment Release	9.0	2.6	19.5	7.0	9.0	2.7	19.5	7.1
Total Loadings	9.8	3.9	20.3	8.3	13.6	7.3	24.1	11.7

Note: 1. All units for loadings are in tons/year (*i.e.*, 2000 lbs/year)

Table 4. Estimated Annual Nitrogen Loadings[1] for the Existing and Expanded Reservoir

Sources	$(NO_3 + NH_4)$ as N				TN			
	Existing Case		Expanded Reservoir Case		Existing Case		Expanded Reservoir Case	
	2006	2007	2006	2007	2006	2007	2006	2007
Purified Water	0	0	0	0	0	0	0	0
Runoff	3.4	5.4	3.4	5.4	4.8	7.6	4.8	7.6
Aqueduct Inflow	14.6	15.5	14.6	15.5	22.4	21.1	22.4	21.1
Sediment Release	13.2	14.3	61.8	17.7	13.3	14.3	61.9	18.7
Total Loadings	31.2	35.2	79.8	38.6	40.5	43.0	89.1	46.4

Note: 1. All units for loadings are in tons/year (*i.e.*, 2000 lbs/year)

3. MODELING RESULTS FOR FUTURE CONDITIONS

3.1 MODELING SCENARIOS

Two scenarios have been modeled to evaluate the water quality in the expanded reservoir under future operating conditions. The first scenario considered the expected typical future conditions with purified water at median expected storage and normal expected operations, and is referred to herein as the Base Case. The second scenario addresses the expanded reservoir under future operating conditions but with no added purified water, referred to herein as No Purified Water. This latter case is identical to the Base Case except no purified water is introduced into the reservoir (with a compensating equal reduction in outflow).

The comparison of these two future scenarios enables a quantification of the effects of purified water addition on the expanded reservoir behavior under future operating conditions. The parameters for these two modeling scenarios were determined in collaboration between the City, its consultants, and Flow Science, and are based on information provided by the San Diego County Water Authority (SDCWA) about the expected future operational schemes for SVR. The Base Case utilized the Design Purified Water Inlet Location (see **Figure 1** for the location) as the point of release for purified water inflow into SVR. The two scenarios considered Port #2 at the reservoir outlet tower structure to be the open port for all water withdrawals from the reservoir. It should be noted that hydrodynamic results of the modeling for these two scenarios are included in the TM #2 (FSI, 2011) and are not included here. Only the results of the water quality analyses are presented in this report, focusing on DO, nutrients, chlorophyll *a* and Secchi depth. In the following, details of each of these two modeling scenarios are discussed.

3.1.1 Base Case

The Base Case simulated a two-year period of reservoir operations and used the same 2006 - 2007 meteorological data, aqueduct inflow water quality data, runoff water quality data, and other modeling parameters as used in the Existing Case, except for the initial reservoir volume, introduction of purified water, and modified inflow and outflow rates as discussed below. Note also that the measured wind data used as inputs for the model included several Santa Ana Wind events that occurred in the winter of each simulated year.

The City provided the initial reservoir volume and inflow and outflow rates for the Base Case. The initial reservoir volume for the Base Case is considered to be near the median of the expected future conditions with a volume of 155,000 acre-feet (determined

in conjunction with SDCWA). It is considered that the daily inflows and outflows will be constant throughout each month and it was also assumed that there would be no water transfers from Sutherland Reservoir into SVR in the modeling period. For the Base Case, a new surface inflow, the purified water inflow, was added to represent incoming purified water from the advanced water purification facility at an annual rate of 15,000 a-f/y. The detailed monthly inflow and outflow volumes for each source for the Base Case are listed in **Table 5**. The available withdrawal elevations on the proposed reservoir outlet are listed in **Table 6** and Port #2 was used for all water withdrawals from the reservoir. The multi-year averages of weekly water temperatures at North City Water Reclamation Plant were used to characterize the purified water temperature and the salinity of the purified water was considered to be constant at 100 parts per million (ppm).

The water quality for the purified water inflow was determined by analyzing water quality field data measured in the effluent from the advanced water purification facility (these data are available separately). After consulting with the City and analyzing the effluent data, FSI provided the final values for water quality of purified water used in the simulations. These are listed in **Table 7** as well as the nutrient concentrations for other inflows. Note that particulate and organic nutrients are considered to be negligible in the purified water. Thus, the concentration of TN in the purified water is 0.78 mg/L, the sum of ammonia, nitrate and nitrite in the purified water; the concentration of TP in the purified water is 0.004 mg/L and equal to the concentration of SRP.

3.1.2 No Purified Water Scenario

The data inputs for the No Purified Water scenario are similar to those for the Base Case scenario, except for no purified water additions and an equal reduction in reservoir outflow volume (to obtain similar reservoir storage volumes). The purpose of conducting this simulation was, by comparison with the Base Case, to evaluate the water quality effects of the purified water addition on the expanded SVR. **Table 8** presents the monthly water volumes of inflows and outflow for the No Purified Water scenario.

Table 5. Monthly Reservoir Inflow and Outflow Volumes for Base Case Operating Scenario

Month	Aqueduct Inflow (acre-feet)	Runoff Inflow (acre-feet)	Purified Water Inflow (acre-feet)	Withdrawal (acre-feet)
Jan-Year 1	0	0	1440	0
Feb-Year 1	0	1,500	1590	0
Mar-Year 1	0	1,500	1480	0
Apr-Year 1	1,000	1,500	1350	0
May-Year 1	1,000	0	1230	0
Jun-Year 1	1,000	0	1090	0
Jul-Year 1	0	0	900	2200
Aug-Year 1	0	0	1020	4200
Sep-Year 1	0	0	1090	4200
Oct-Year 1	0	0	1120	4200
Nov-Year 1	0	0	1210	4200
Dec-Year 1	0	0	1480	0
Jan-Year 2	0	0	1440	0
Feb-Year 2	0	1,500	1590	0
Mar-Year 2	0	1,500	1480	0
Apr-Year 2	1,000	1,500	1350	0
May-Year 2	1,000	0	1230	0
Jun-Year 2	1,000	0	1090	0
Jul-Year 2	0	0	900	2200
Aug-Year 2	0	0	1020	4200
Sep-Year 2	0	0	1090	4200
Oct-Year 2	0	0	1120	4200
Nov-Year 2	0	0	1210	4200
Dec-Year 2	0	0	1480	0

Table 6. Available Withdrawal Elevations on Proposed Reservoir Outlet Tower

Port	Withdrawal Elevation
6	733 ft
5	708 ft
4	683 ft
3	653 ft
2	623 ft
1	593 ft

Table 7. Inflow Water Quality Parameters

Water Quality Parameter	Purified Water	Aqueduct Inflow	Runoff
$(NO_3 + NO_2) - N$ (mg/L)	0.64	0.12 – 0.47	0.02 – 3.00
$NH_4 - N$ (mg/L)	0.14	0.02 – 0.09	0.02 – 0.15
TN (mg/L)	0.78	0.17 – 0.68	0.18 – 4.22
SRP (mg/L)	0.004	0.009 – 0.031	0.007 – 0.16
TP (mg/L)	0.004	0.024 – 0.081	0.022 – 0.32

Table 8. Monthly Reservoir Inflow and Outflow Volumes for No Purified Water Scenario

Month	Aqueduct Inflow (acre-feet)	Runoff Inflow (acre-feet)	Purified Water Inflow (acre-feet)	Withdrawal (acre-feet)
Jan-Year 1	0	0	0	0
Feb-Year 1	0	1500	0	0
Mar-Year 1	0	1500	0	0
Apr-Year 1	1000	1500	0	0
May-Year 1	1000	0	0	0
Jun-Year 1	1000	0	0	0
Jul-Year 1	0	0	0	800
Aug-Year 1	0	0	0	800
Sep-Year 1	0	0	0	800
Oct-Year 1	0	0	0	800
Nov-Year 1	0	0	0	800
Dec-Year 1	0	0	0	0
Jan-Year 2	0	0	0	0
Feb-Year 2	0	1500	0	0
Mar-Year 2	0	1500	0	0
Apr-Year 2	1000	1500	0	0
May-Year 2	1000	0	0	0
Jun-Year 2	1000	0	0	0
Jul-Year 2	0	0	0	800
Aug-Year 2	0	0	0	800
Sep-Year 2	0	0	0	800
Oct-Year 2	0	0	0	800
Nov-Year 2	0	0	0	800
Dec-Year 2	0	0	0	0

3.2 COMPARISON OF MODELING RESULTS

In this section, results from the Base Case are compared with those from the Existing Case and No Purified Water scenarios. **Figure 19** provides a comparison of inflow rates among the Existing Case, No Purified Water and Base Case. **Figure 20** shows a comparison of reservoir water volume during the two-year modeling period for these

three scenarios. The main differences in flow rate and water volume among the scenarios are summarized in **Table 9**.

Table 9. Modeled Operating Scenarios

Operating Scenarios	Description	Initial Reservoir Volume (acre-feet)	Annual Purified Water Inflow (acre-feet/year)	Annual Aqueduct inflow (acre-feet/year)	Annual Reservoir Outflow (acre-feet/year)
Existing Case[1] (06/07)	existing conditions during 2006 - 2007	64,000 /60,000	0	27,018 /30,810	28,417 /22,185
No Purified Water[2]	no purified water additions and an equal reduction in reservoir outflow	155,000	0	3,000	4,000
Base Case[2]	median expected storage and normal expected operations	155,000	15,000	3,000	19,000

Notes: 1. The total volume of runoff and water transfers from Sutherland is 1,556 acre-feet for 2006 and 5,902 acre-feet for 2007.
2. Runoff flow rate is 4,500 acre-feet/year and there are no water transfers from Sutherland Reservoir into SVR.

Figure 21 shows a comparison of simulated water temperature among the Existing Case, No Purified Water scenario, and Base Case at Station A. Note that the vertical axis in all figures hereafter is defined as elevation (and not depth) to allow labeling of the reservoir outlet port elevations. The temperature patterns are fairly similar among all three scenarios with similar thermocline development patterns. However, since the reservoir is significantly shallower in the Existing Case, the destratification in the winter appears to occur earlier in that case than in the other two scenarios. A comparison between the Base Case and the No Purified Water scenario shows that the thermocline is slightly deeper for the Base Case (*e.g.*, little less than 3 ft deeper in September), a result of adding purified water in the epilimnion.

A comparison of simulated surface and bottom DO among the Existing Case, No Purified Water, and Base Case is shown in **Figure 22**. **Table 10** lists the hypolimnetic anoxia period of these three scenarios. The hypolimnetic anoxia period is predicted to last an average of 189 days per year (or 52% of the time in a year) for the Existing Case. For the future No Purified Water scenario, the hypolimnetic anoxia period increases to 207 days per year, an addition of 18 days per year. Adding purified water into the reservoir under future operating conditions (*i.e.*, Base Case) further extends the average duration of the hypolimnetic anoxia period by 8 days, to a total of 215 days per year.

Table 10. Summary of Simulated DO, Chlorophyll *a* and Secchi Depth for Modeling Scenarios

Operating Scenarios	Year	Initial Reservoir Volume (acre-feet)	Bottom Anoxia Period	Days Under Anoxia: Total Days (Percentage)[2]	Average Surface Chlorophyll *a* (µg/L)	Average Secchi Depth (m)
Existing Case	2006	64,000	1/1 – 1/15 7/10 – 12/14	189 (52%)	5.8	3.2
	2007	60,000	6/8 – 12/28			
No Purified Water	2006	155,000	1/1 – 1/21 6/25 – 12/23	207 (57%)	3.1	4.8
	2007	155,000	6/5 – 12/31			
Base Case	2006	155,000	1/1 – 1/24 6/23 – 12/31	215 (59%)	3.7	4.3
	2007	155,000	1/1, 6/3 – 12/31			

Notes: 1. Anoxia is defined here as the bottom DO less than 0.5 mg/L.
2. Both the total days and percentage under anoxia are yearly values averaged over the two-year simulation period.

Figures 23 - 27 show comparisons for nitrate, ammonia, TN, SRP and TP among the Existing Case, Base Case and No Purified Water scenarios. In general, the Base Case and No Purified Water scenarios show similarities in variation trends and both are somewhat different from the Existing Case in overall patterns (mostly a result of different inflow/outflow sources and temporal patterns). The Base Case generally shows slightly higher nitrogen concentrations (**Figures 23 - 25**) and slightly lower phosphorus concentrations (**Figures 26** and **27**) than the No Purified Water scenario. This is a result of year-round inflow of purified water with relatively high nitrogen levels and low phosphorus levels.

Comparisons of simulated surface chlorophyll *a* concentrations and derived Secchi depths among the Existing Case, Base Case and No Purified Water are shown in **Figures 28** and **29** respectively. As shown, variation patterns for the Base Case and No Purified Water (*i.e.*, two future operating scenarios) resemble each other and the Base Case shows slightly higher chlorophyll *a* levels and slightly lower Secchi depths. In contrast, the Existing Case features significantly higher algal levels and lower Secchi depths than the Base Case or No Purified Water scenarios. In addition, the temporal variations in chlorophyll *a* concentration and Secchi depth for the Existing Case are different from the future operating scenarios, likely because of significant differences in the timing and magnitude of nutrient loadings between these scenarios.

Annual average surface chlorophyll *a* concentration and Secchi depth are listed in **Table 10** for all three scenarios. The annual chlorophyll *a* concentration and Secchi depth are predicted to be 5.8 µg/L and 3.2 m respectively for the Existing Case. In comparison, the annual average chlorophyll *a* concentration and Secchi depth are 3.1 µg/L and 4.8 m respectively for the No Purified Water scenario. This is a reduction of 2.7 µg/L for the average chlorophyll *a* concentration and an increase of 1.6 m for the average Secchi depth when the operating conditions change from the Existing Case to the No Purified Water scenario in the expanded reservoir. Meanwhile, the Base Case is predicted to produce 3.7 µg/L for the annual average chlorophyll *a* concentration and 4.3 m for the annual average Secchi depth. This is a reduction of 2.1 µg/L for the annual average chlorophyll *a* concentration and an increase of 1.1 m for the annual average Secchi depth compared to the Existing Case. This indicates that both the No Purified Water scenario and Base Case are predicted to produce lower algal levels *(i.e.,* lower surface chlorophyll *a* concentrations) and higher water clarity (*i.e.*, high Secchi depths) compared to the Existing Case.

A comparison of simulated pH among the Existing Case, Base Case and No Purified Water scenarios is presented in **Figure 30.** As shown, the pH is fairly similar for all three runs.

3.3 NUTRIENT LOADINGS

Tables 11 – 14 present, respectively, the nutrient loadings for SRP, TP, the sum of nitrate and ammonia, and TN, for the Existing Case, Base Case and No Purified Water scenarios.

For phosphorus (**Tables 11** and **12**), the loadings from the sediments are generally larger than other loadings and consist of 30 - 90% of all phosphorus loadings into SVR. Both the Base Case and No Purified Water scenarios produce sediment nutrient loadings that are twice as large as those from the Existing Case, likely a result of the larger hypolimnetic bottom area and extended hypolimnetic anoxia period. There is little difference in the sediment releases between the Base Case and No Purified Water scenarios.

For nitrogen (**Tables 13** and **14),** the loadings from the sediments are significant as well and consist of about 30 – 80% of all nitrogen loadings into SVR. Sediment nutrient loadings are generally higher for the future scenarios (*i.e.*, Base Case and No Purified Water scenarios) than the Existing Case.

However, despite the significantly higher sediment release for the future operating scenarios, surface TN concentrations are actually lower for the future scenarios compared to the Existing Reservoir Case (**Figure 25**), a result of the larger volume of water in the

expanded reservoir. The resulting lower nutrient concentrations are believed to be one of the main factors that lead to lower surface chlorophyll a concentrations for the future operating scenarios (compared to the Existing Reservoir Case).

It is noted that the N:P ratio (*i.e.*, calculated as the ratio of the TN loading to TP loading in this case) in the purified water, the major inflow to SVR in the Base Case, is about 159. As shown, this overall ratio for the reservoir can be affected by many factors including the nutrient loadings from inflows as well as sediments. However, given the extremely high N:P ratio of the purified water inflow, algal growth in the future reservoir may tend to become more phosphorus-limited.

Table 11. Annual SRP Loadings[1]

Sources	Existing Case		No Purified Water		Base Case	
	2006	2007	2006	2007	2006	2007
Purified Water	0	0	0	0	0.1	0.1
Runoff	0.1	0.8	0.5	0.5	0.5	0.5
Aqueduct Inflow	0.7	0.5	0.1	0.1	0.1	0.1
Sediment Release[2]	9.0	2.6	19.4	7.0	19.4	7.0
Total Loadings	9.8	3.9	20.0	7.6	20.1	7.7

Note: 1. All units for the loadings are in tons/year (*i.e.*, 2000 lbs/year)

Table 12. Annual TP Loadings[1]

Sources	Existing Case		No Purified Water		Base Case	
	2006	2007	2006	2007	2006	2007
Purified Water	0	0	0	0	0.1	0.1
Runoff	2.9	3.3	0.9	0.9	0.9	0.9
Aqueduct Inflow	1.7	1.3	0.2	0.1	0.2	0.1
Sediment Release[2]	9.0	2.7	19.4	7.0	19.4	7.0
Total Loadings	13.6	7.3	20.5	8.0	20.6	8.1

Note: 1. All units for the loadings are in tons/year (*i.e.*, 2000 lbs/year)

Table 13. Annual (NO_3+NH_4)-N Loadings[1]

Sources	Existing Case		No Purified Water		Base Case	
	2006	2007	2006	2007	2006	2007
Purified Water	0	0	0	0	15.9	15.9
Runoff	3.4	5.4	9.9	6.4	9.9	6.4
Aqueduct Inflow	14.6	15.5	1.1	1.7	1.1	1.7
Sediment Release[2]	13.2	14.3	60.1	14.2	68.9	23.0
Total Loadings	31.2	35.2	71.1	22.3	95.8	47.0

Note: 1. All units for the loadings are in tons/year *(i.e.*, 2000 lbs/year)

Table 14. Annual TN Loadings[1]

Sources	Existing Case		No Purified Water		Base Case	
	2006	2007	2006	2007	2006	2007
Purified Water	0	0	0	0	15.9	15.9
Runoff	4.8	7.6	14.0	9.1	14.0	9.1
Aqueduct Inflow	22.4	21.1	1.3	2.1	1.3	2.1
Sediment Release[2]	13.3	14.3	60.1	14.2	68.9	23.0
Total Loadings	40.5	43.0	75.4	25.4	100.1	50.1

Note: 1. All units for the loadings are in tons/year *(i.e.*, 2000 lbs/year)

4. CONCLUSIONS AND DISCUSSION

The objectives of this study were to use the calibrated and validated SVR ELCOM/CAEDYM water quality model to evaluate the effects of purified water on water quality in the expanded SVR. To achieve these goals, a two-step approach was taken to examine the effects caused by the reservoir expansion and augmentation with purified water, respectively. This work focused on water quality results for nutrients DO, and algal growth.

RESERVOIR EXPANSION

First, the model was used to determine the effects of the reservoir expansion on water quality, without the introduction of any purified water. This was accomplished by performing a simulation that uses the same reservoir conditions (climate, inflow and outflow volumes and concentrations etc.) as the 2006 - 2007 calibration simulation (Existing Case), except for using a higher initial reservoir volume that is set at 155,000 acre-feet (median expected future storage). The results from this simulation (Expanded Reservoir Case) were compared against those obtained from the Existing Case simulation. The differences between the results of these two simulations demonstrate the effects of the expansion on the reservoir's water quality.

Based on the results of these two simulations, the following conclusions and observations on the effects of the reservoir expansion can be made:

- The reservoir expansion is predicted to extend the duration of the hypolimnetic anoxia by an average of 27 days per year (from 189 days per year to 216 days per year) and enlarge the volume of water under anoxic condition by at least two fold.

- The reservoir expansion will produce lower surface chlorophyll *a* concentrations and higher Secchi depths *(i.e.*, better water clarity) in the reservoir. It is predicted that the annual average chlorophyll *a* concentration will decrease from 5.8 µg/L to 3.4 µg/L and the annual average Secchi depth will increase from 3.2 m to 4.7 m after the expansion.

- Based on a nutrient loading calculation, the internal nutrient loadings *(i.e.*, nutrients released from sediment) are larger than all external loadings combined over the two-year modeling period for both the Existing Case and Expanded Reservoir Case. Meanwhile, the reservoir expansion is predicted to lead to a significant increase in sediment nutrient release, likely due to the larger hypolimnetic bottom area and extended hypolimnetic anoxia period. However, despite the significantly higher sediment release, surface TN concentrations are actually lower after the reservoir expansion, a result of the significantly larger

volume of water for the Expanded Reservoir Case. The resulting lower nutrient concentrations are believed to be one of the main factors that lead to lower surface chlorophyll *a* concentrations for the Expanded Reservoir Case (compared to the Existing Reservoir Case).

FUTURE OPERATING CONDITIONS

After the effects of the reservoir expansion were determined, the model was used to examine the water quality in the expanded reservoir under future operating conditions both with and without purified water augmentation. Specifically, the following two future scenarios were simulated:

- Base Case (includes purified water inflow) ---- This scenario considered an expanded reservoir under median expected storage and expected future operations. The initial reservoir volume for the Base Case is set at 155,000 acre-feet. The following annual inflow rates were assumed: for aqueduct inflow 3,000 a-f/y; runoff 4,500 a-f/y; purified water inflow 15,000 a-f/y; and dam withdrawal 19,000 a-f/y, with no water transfers from Sutherland Reservoir into SVR.

- No Purified Water ---- The inputs for this scenario are similar to those for the Base Case scenario, except for no purified water additions and an equal reduction in reservoir outflow. The initial reservoir volume for this scenario is set at 155,000 acre-feet. The annual rates for aqueduct inflow, runoff, purified water inflow and dam withdrawal are 3,000, 4,500, 0 and 4,000 a-f/y respectively. There are no water transfers from Sutherland Reservoir into SVR.

Results from the Base Case and No Purified Water scenarios were compared against those obtained from the Existing Case simulations (*i.e.*, no reservoir expansion). The purpose is to quantify the water quality effects of purified water by comparing the Base Case against the No Purified Water scenario, and to evaluate the effects of future operating conditions in the expanded reservoir (prior to adding purified water) by comparing the No Purified Water scenario against the Existing Case.

Based on the simulation results, the following conclusions and observations on the effects of the purified water and future operating conditions are made:

- The hypolimnetic anoxia period is predicted to last an average of 189 days per year for the Existing Case. For the No Purified Water scenario, the hypolimnetic anoxia period is predicted to increase to 207 days per year, an addition of 18 days per year. Adding purified water into the reservoir under

future operating conditions (*i.e.*, Base Case) will further extend the average duration of the hypolimnetic anoxia period by 8 days, to a total of 215 days per year.

- The No Purified Water scenario produces lower algae levels *(i.e.*, lower surface chlorophyll *a* concentrations) and higher Secchi depths (*i.e.*, better water clarity) compared to the Existing Case. For example, the annual average chlorophyll *a* concentration and Secchi depth are predicted to be 5.8 µg/L and 3.2 m respectively for the Existing Case. By comparison, the annual average chlorophyll *a* concentration and Secchi depth are predicted to be 3.1 µg/L and 4.8 m, respectively, for the No Purified Water scenario in the expanded reservoir. This is a reduction of 2.7 µg/L for the average chlorophyll *a* concentration and an increase of 1.6 m for the average Secchi depth compared to the Existing Case.

- The Base Case scenario also produces lower algae levels *(i.e.*, lower surface chlorophyll *a* concentrations) and higher Secchi depths (*i.e.*, better water clarity) compared to the Existing Case. The Base Case is predicted to produce 3.7 µg/L for the annual average chlorophyll *a* concentration and 4.3 m for the annual average Secchi depth. This is a reduction of 2.1 µg/L for the average chlorophyll *a* concentration and an increase of 1.1 m for the average Secchi depth compared to the Existing Case.

- Nutrient loading calculations show that nutrient sediment release constitutes a significant portion of all nutrient loadings into SVR for all future scenarios as well as the Existing Case. The future operating scenarios (*i.e.*, Base Case and No Purified Water) produce sediment nutrient loadings significantly larger than those for the Existing Case, likely a result of the larger hypolimnetic bottom area and extended hypolimnetic anoxia period. However, despite the significantly higher sediment release for the future operating scenarios, surface TN concentrations are actually lower for the future scenarios compared to the Existing Reservoir Case, a result of the larger volume of water in the expanded reservoir. The resulting lower nutrient concentrations are believed to be one of the main factors that lead to lower surface chlorophyll *a* concentrations for the future operating scenarios (compared to the Existing Reservoir Case).

- Nutrient limitation in SVR can be affected by various factors including the nutrient loadings from all the inflows and the sediments. As a result, nutrient limitation at any point may vary based on existing conditions. However, note that the N:P ratio of the purified water is expected to reach about 159,

indicating that algal growth in the future reservoir may tend to become more phosphorus-limited.

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6. GLOSSARY

Advanced Water Purification Facility: The demonstration facility located at the North City Water Reclamation Plant. The facility is considered "advanced" because of the high level of treatment utilizing reverse osmosis and advanced oxidation.

Blending: Mixing or combining one water source with another such as purified water with raw water sources.

Conductivity: See "Salinity".

Constituent: In water, a constituent is a dissolved chemical element or compound or a suspended material that is carried in the water.

Drought: A defined period of time when rainfall and runoff in a geographic area are much less than average.

Epilimnion: Natural thermal stratification exists for much of the year in almost all temperate lakes and reservoirs and creates three vertical zones. The upper, warmer water is called the epilimnion, the deeper, colder water is called the hypolimnion, whereas the middle portion separating these two layers, where the rate of vertical temperature change is greatest, is called the metalimnion, or thermocline.

Excursion events at the advanced purification facility: Events in which the water quality of the recycled water into the advanced purification facility deviates from the normal or expected conditions. They result in the final outflow from the advanced purification facility may contain chemical constituents at higher level than normal concentrations when no such events occur.

Hypolimnion: See "epilimnion".

Pathogens: Disease-causing organisms. The general groupings of pathogens are viruses, bacteria, protozoa, and fungi.

Periods of mixing: Periods when water temperatures become vertically uniform in the water body and they generally occur in the winter.

Purified water: Recycled water that has been treated to an advanced level beyond tertiary treatment, so that it can be added to water supplies ultimately used for drinking water. The treatment includes membrane filtration with microfiltration or ultrafiltration, reverse osmosis (RO), and advanced oxidation that consists of disinfection with

ultraviolet light (UV) and hydrogen peroxide (H_2O_2). Purified water may be released into a groundwater basin or surface water reservoir that supplies water to a drinking water treatment facility.

Purified water inflow: Purified water that is transported from the advanced purified water treatment facility to SVR.

Purified water inlet: Point of release in SVR for purified water inflow. Note that the purified water is assumed to be released at the surface of SVR.

Recycled water: Water that originated from homes, businesses and drains as municipal wastewater and has undergone a high level of treatment at a reclamation facility so that it can be beneficially reused for a variety of purposes. This is the water that comes into the AWP Facility.

Reservoir: A manmade lake or tank used to collect and store water.

Reservoir augmentation: The process of adding purified water to a surface water reservoir. The purified water undergoes advanced treatment (membrane filtration, reverse osmosis and UV disinfection/advanced oxidation). The purified water is then blended with untreated water in a reservoir. The blended water is then treated and disinfected at a conventional drinking water treatment plant and is distributed into the drinking water delivery system. Also known as "surface water augmentation."

Reservoir outflow: The flow withdrawal through the opening port located at the outlet structure near the dam.

Reservoir outlet: The opening port at the outlet structure near the dam. In this study, the opening port is assumed to be Port #2.

Salinity: The concentration of mineral salts dissolved in water. Salinity may be measured by weight (total dissolved solids or TDS) or by electrical conductivity. Salinity and TDS are both measures of the amount of salt dissolved in water, and the terms are often used interchangeably. Generally, salinity is used when referring to water with a lot of salt (*e.g.*, seawater), whereas TDS is used to refer to water with little salt (*e.g.*, freshwater).

Storage: Water held in a reservoir for later use.

Soluble Reactive Phosphorus (SRP): A measure of orthophosphate, the filterable (soluble, inorganic) fraction of phosphorus, the form directly taken up by plant cells.

Surface water: Water located on the Earth's surface, in a river, stream, lake, pond or surface water reservoir.

Thermocline: See "epilimnion".

Total Nitrogen (TN): A measure of all the forms of nitrogen, dissolved or particulate, that are found in a sample.

Total Phosphorus (TP): A measure of all the forms of phosphorus, dissolved or particulate, that are found in a sample.

Water Purification Demonstration Project (Demonstration Project): The second phase of the City of San Diego's Water Reuse Program. During this test phase the Advanced Water Purification Facility will operate for approximately one year and will produce 1 million gallons of purified water per day. A study of the San Vicente Reservoir is being conducted to test the key functions of reservoir augmentation and to determine the viability of a full-scale project. No purified water will be sent to the reservoir during the demonstration phase.

Water Measurement Terms

Milligrams per liter (mg/L) ***also known as parts per million (ppm):*** A measurement describing the amount of a substance (such as a mineral, chemical or contaminant) in a liter of water; a unit used to measure concentration of water constituents (parts of something per million parts of water). One part per million is equal to one milligram per liter. (This term is becoming obsolete as instruments measure smaller concentrations.) This is equivalent to one drop of water diluted into 50 liters (roughly the fuel tank capacity of a compact car) or about thirty seconds out of a year.

Acre-foot (AF): A unit of water commonly used in the water industry to measure large volumes of water. It equals the volume of water required to cover one acre to a depth of one foot. An acre-foot is 325,851 gallons (43,560 cubic feet) and is considered enough water to meet the needs of two families of four with a house and yard for one year.

Micrograms per liter (µg/L) also known as parts per billion (ppb): A frequently used measurement for water concentration (parts of something per billion parts of water). One part per billion is equivalent to one second of time in 32 years or one drop of water in a swimming pool. One thousand parts per billion is equal to one part per million.

FIGURES

Map of San Vicente Reservoir

Plan View of Existing and Expanded Reservoir and Inflow/Outflow Locations

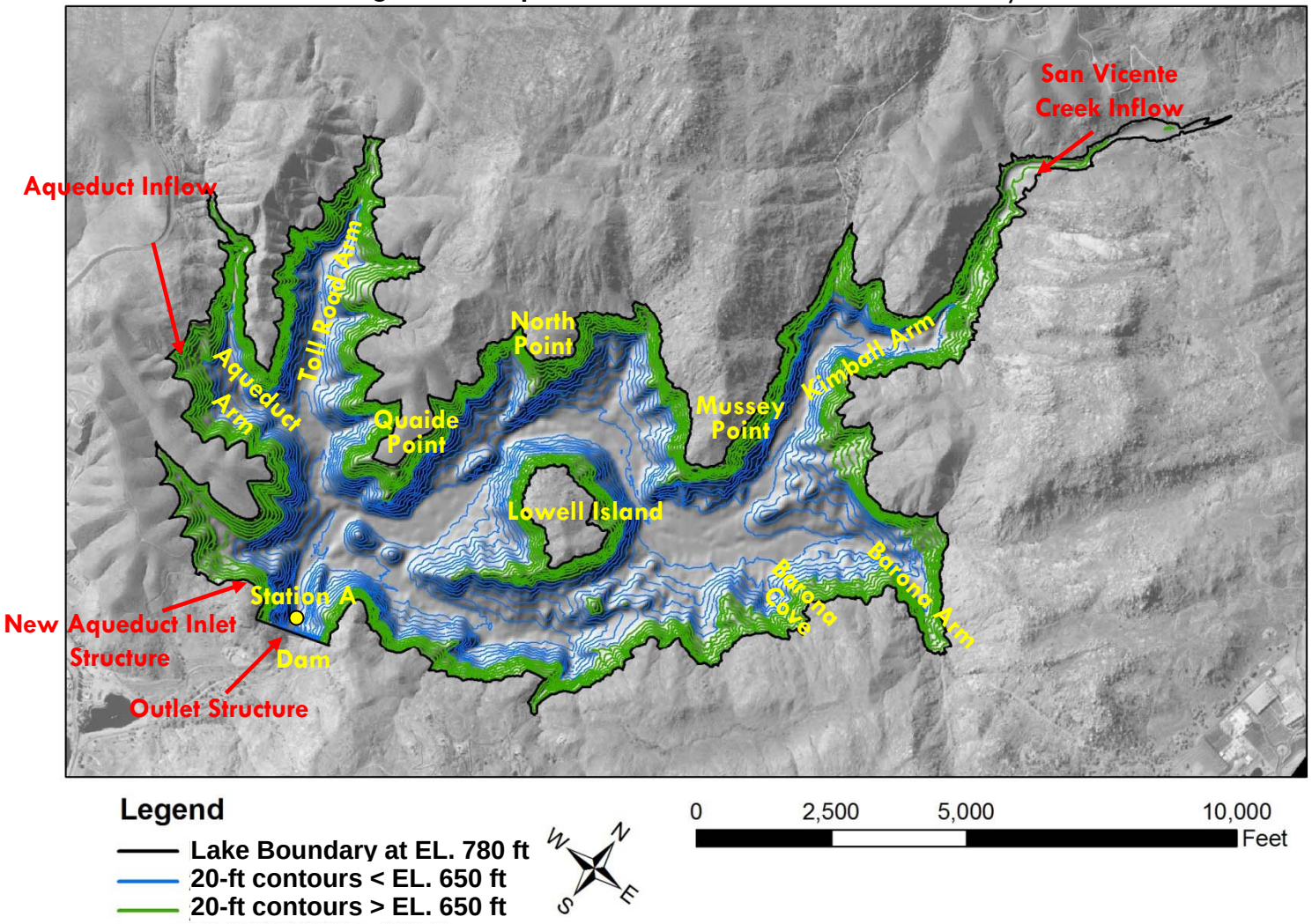

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Figure 1

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ELCOM-CAEDYM

Schematic of Processes Modeled in ELCOM-CAEDYM

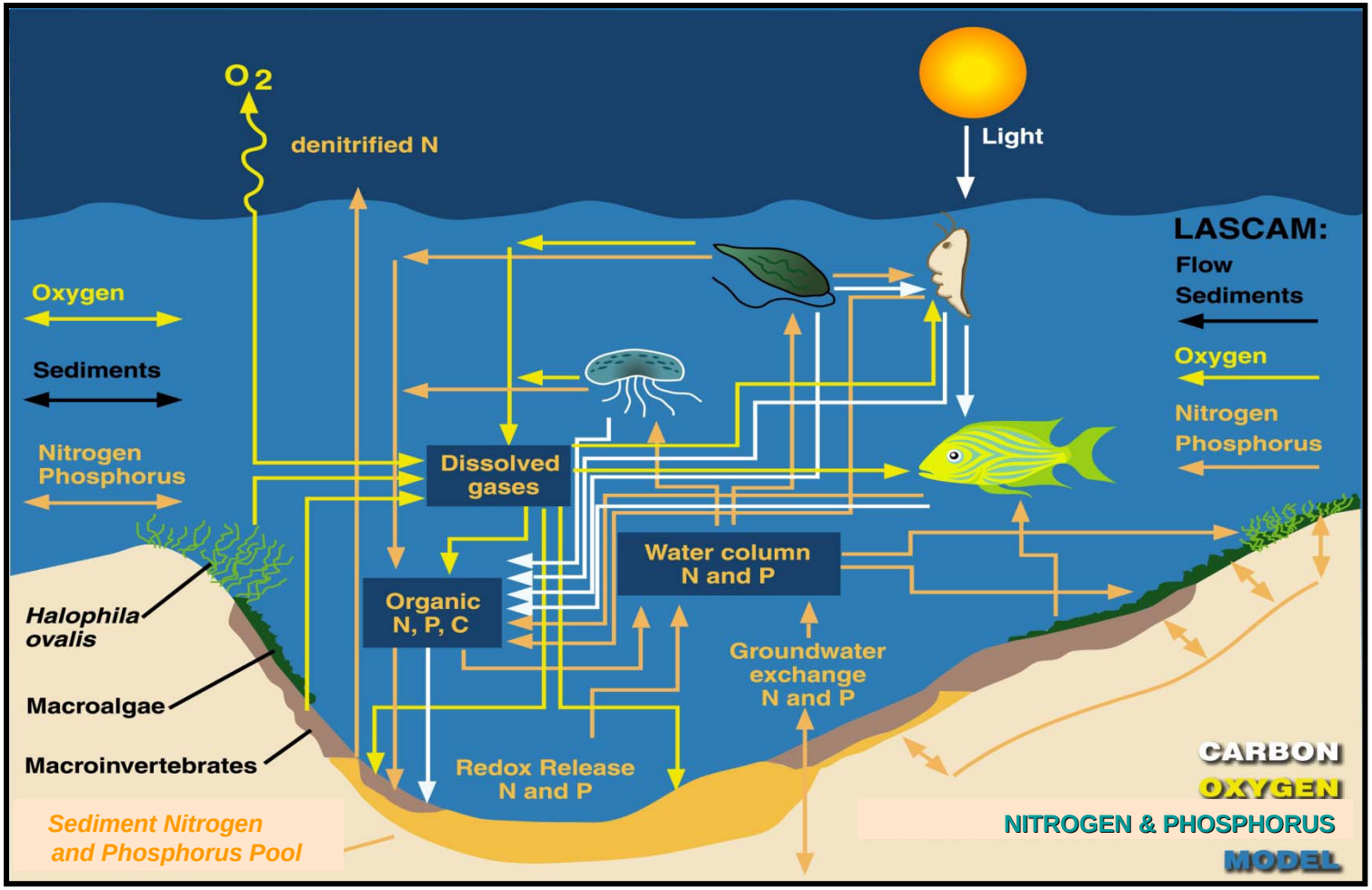

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Figure 2

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SVR Water Quality Model Grid

(Grid Size = 100 m)

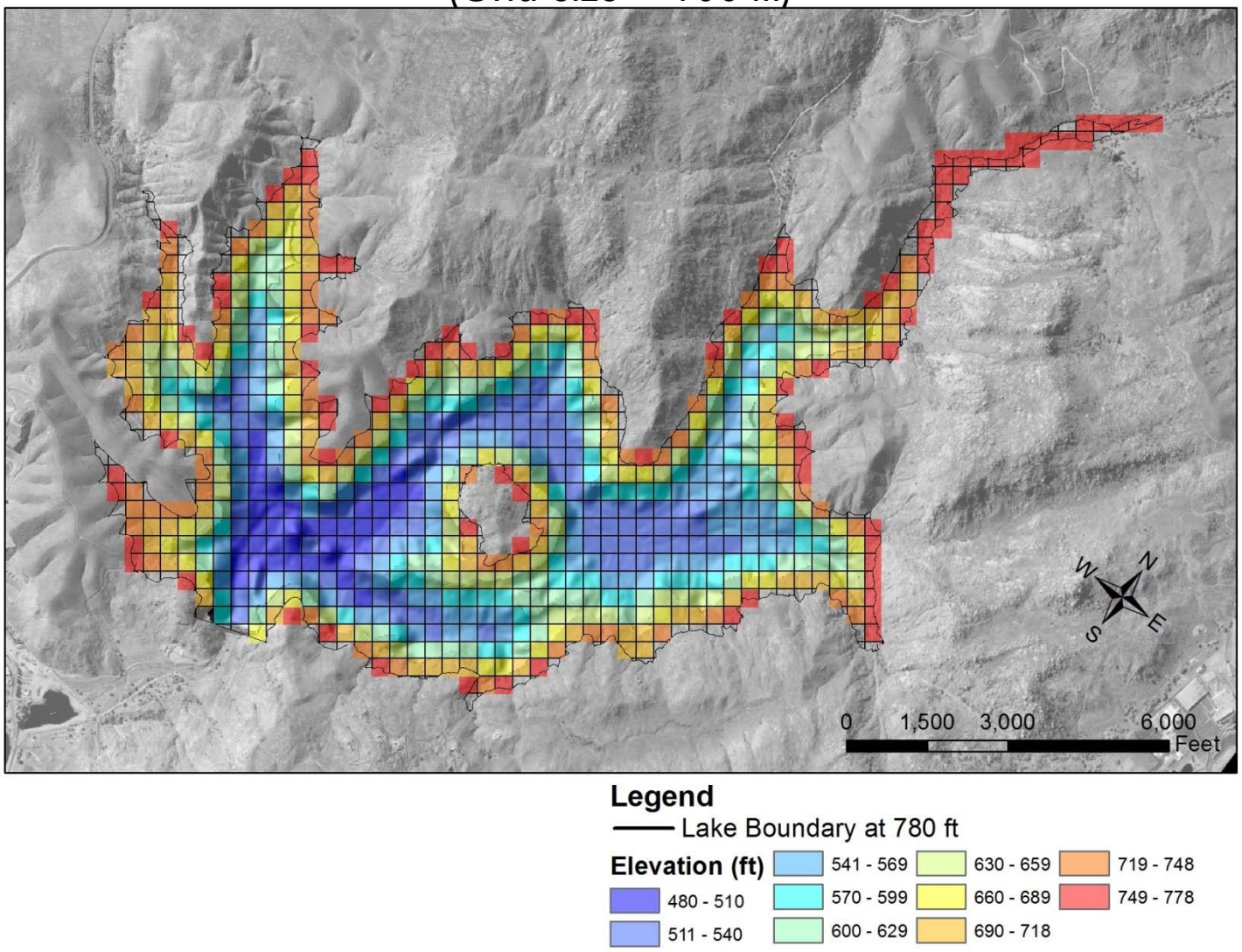

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Figure 3

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SVR Water Quality Model Calibration Results

Station A – Water Temperature Comparison

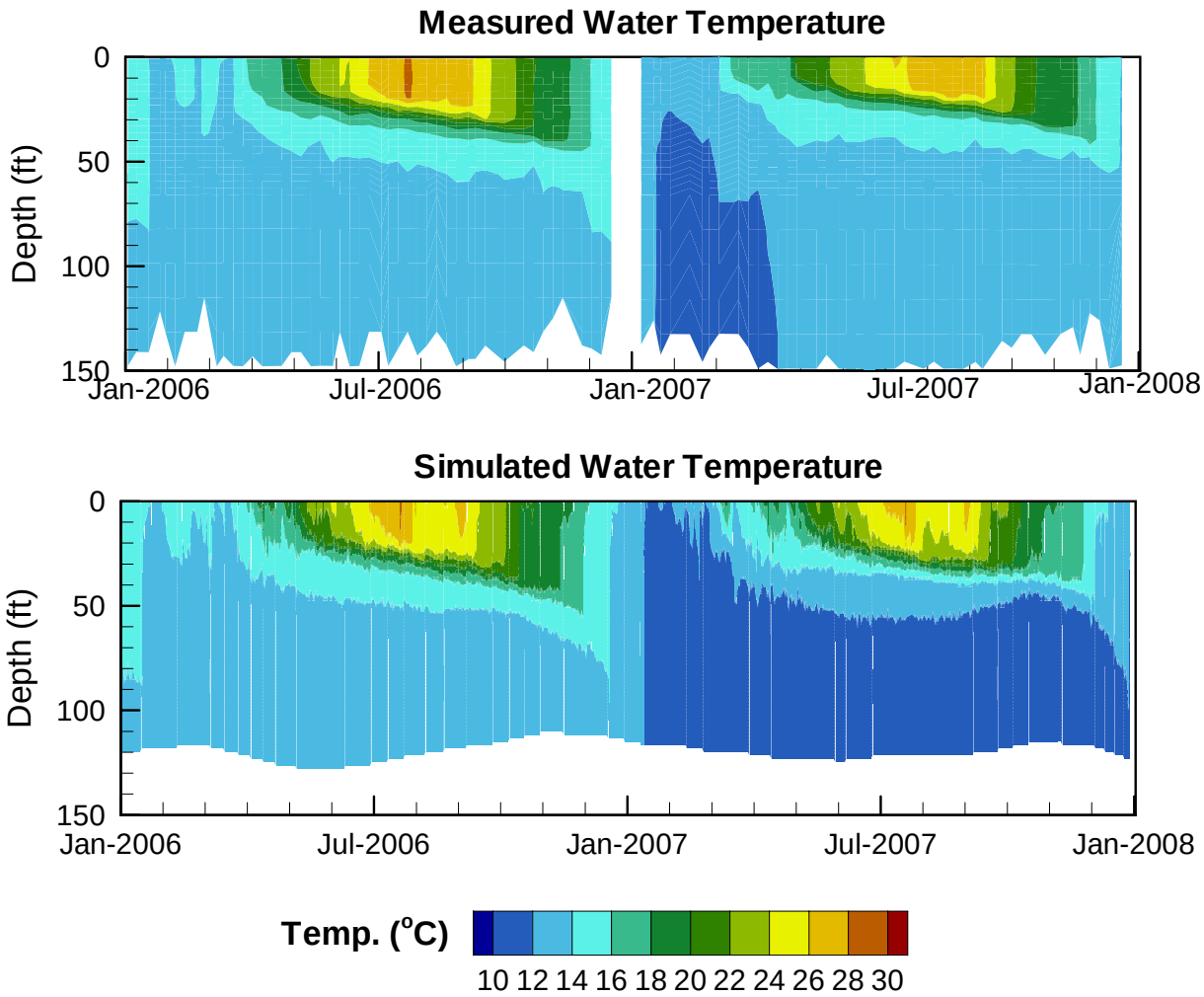

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Figure 4

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SVR Water Quality Model Calibration Results

Station A – Dissolved Oxygen Comparison

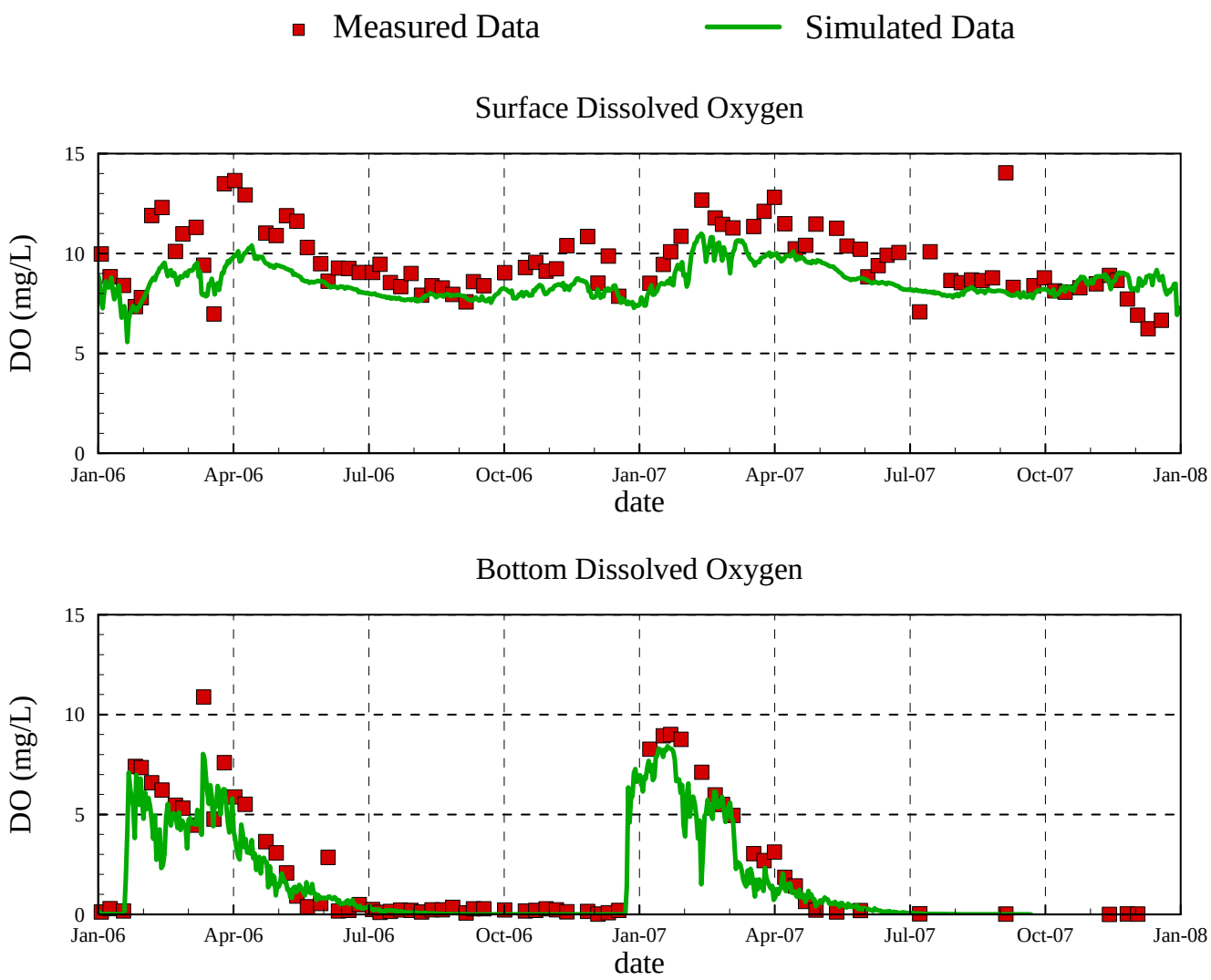

Figure 5

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SVR Water Quality Model Calibration Results

Station A – Secchi Depth Comparison

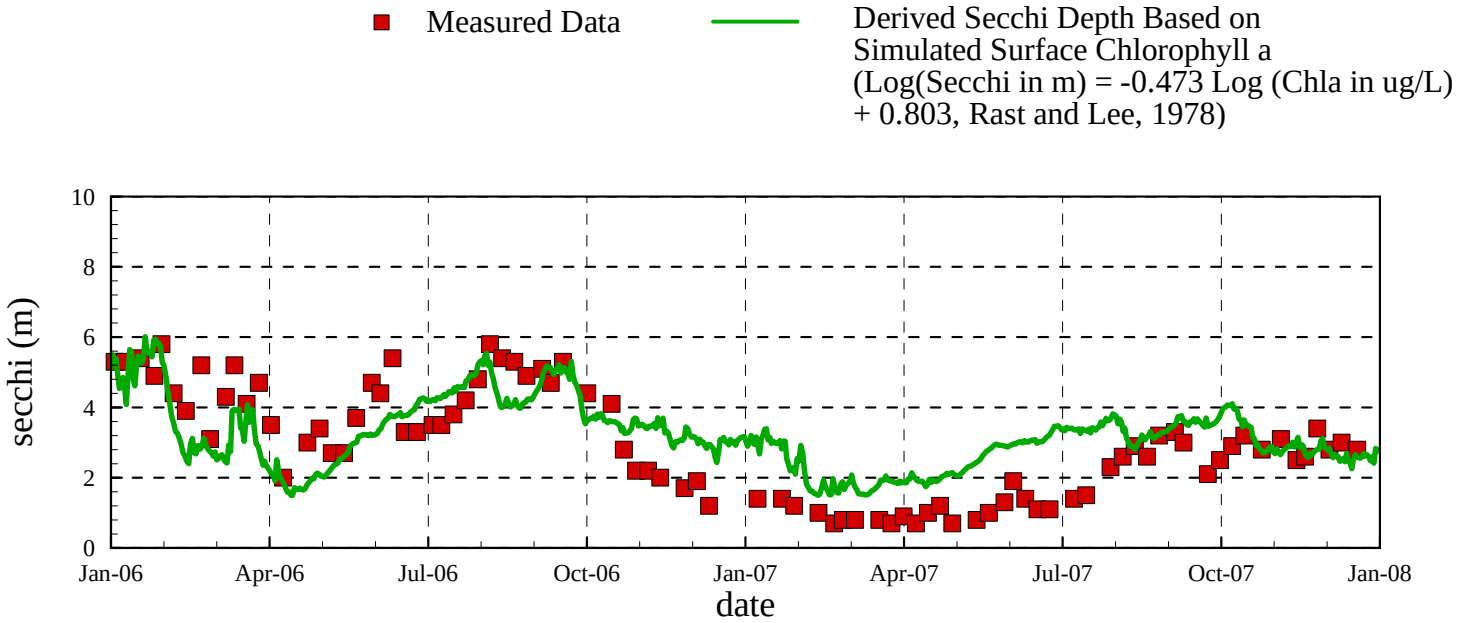

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Figure 6

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Aqueduct Inflow Nutrient Concentrations

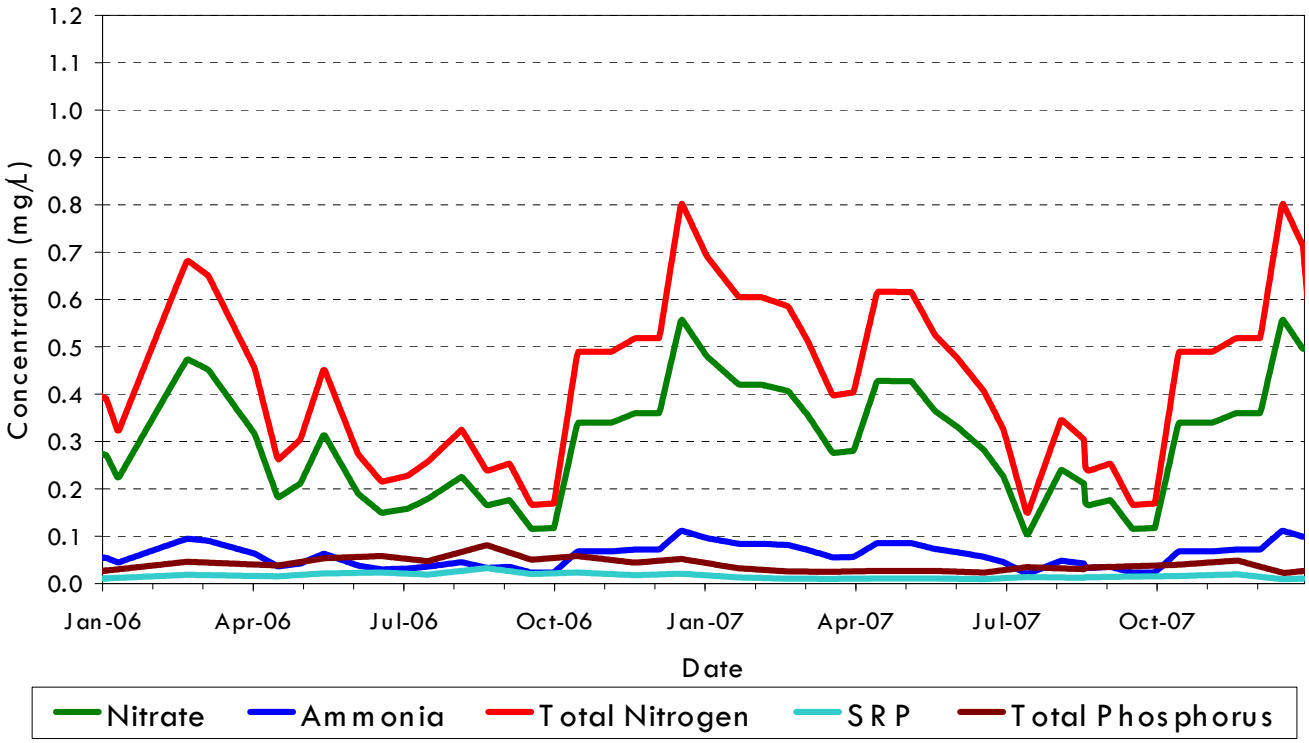

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Figure 7

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Comparison of Existing Case and Expanded Reservoir Case

Simulated Temperature at Station A

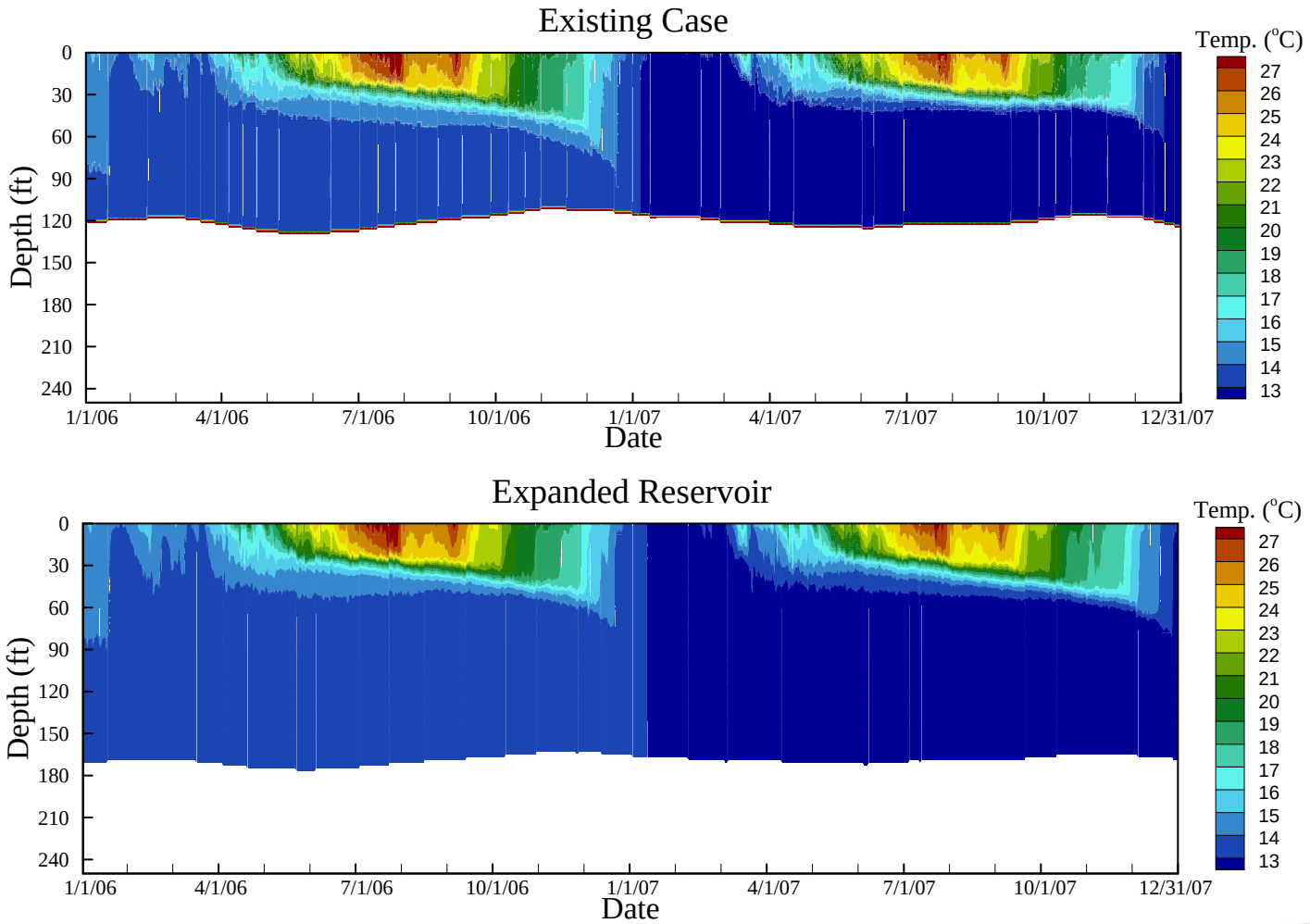

Figure 8

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Comparison of Existing Case and Expanded Reservoir Case

Simulated Dissolved Oxygen at Station A

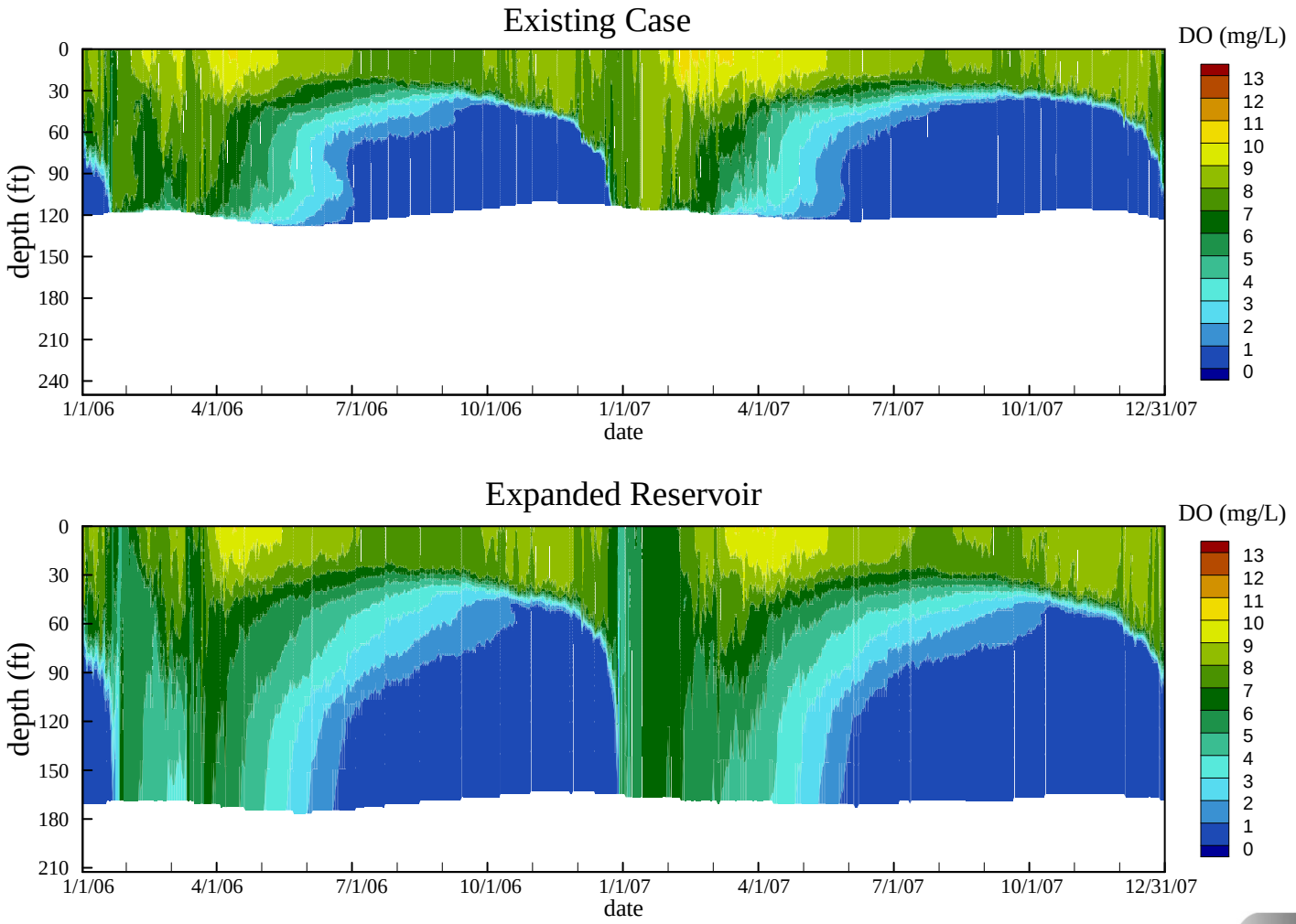

Figure 9

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Comparison of Existing Case and Expanded Reservoir Case

Simulated Surface and Bottom Dissolved Oxygen at Station A

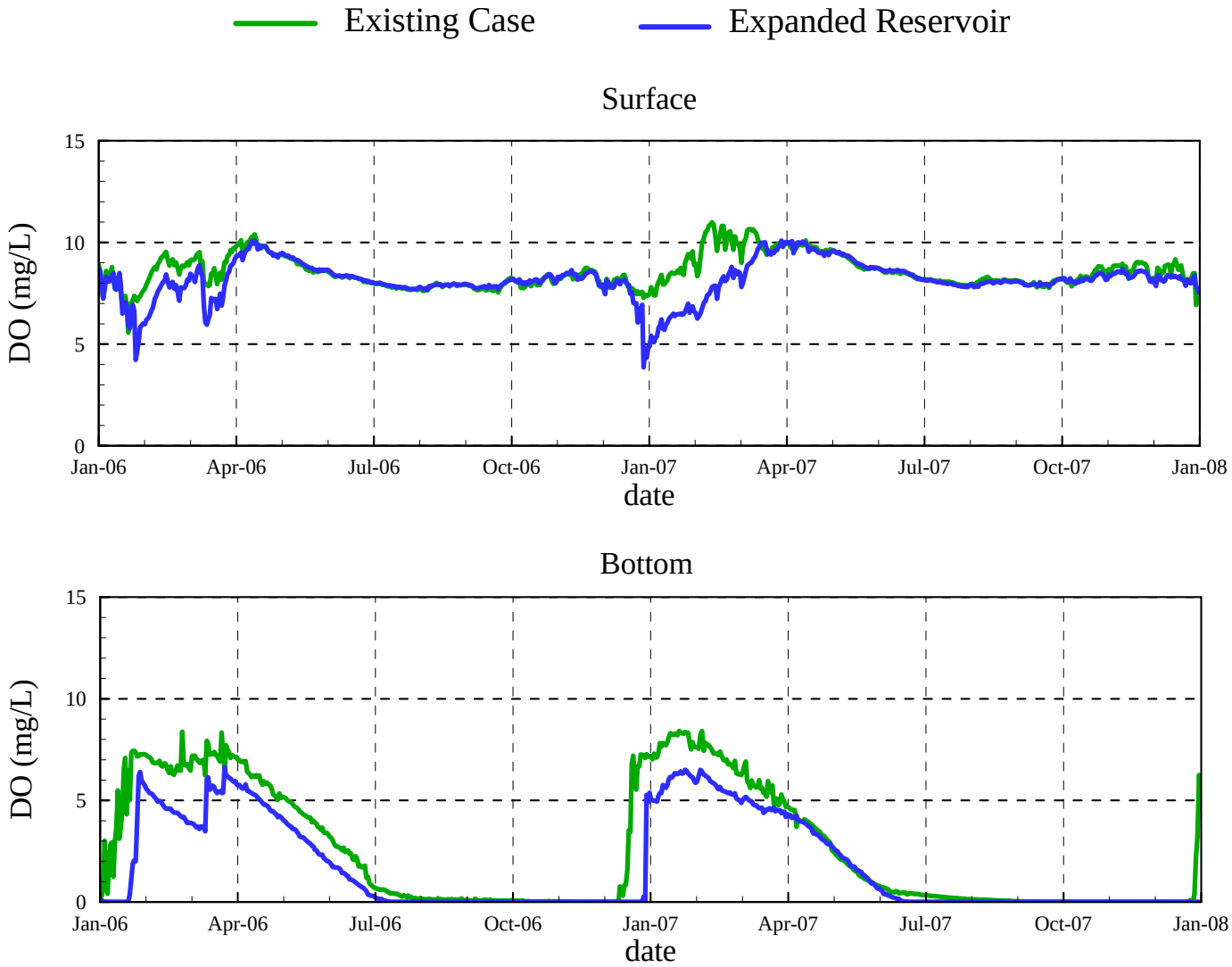

Figure 10

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Comparison of Existing Case and Expanded Reservoir Case

Simulated Surface and Bottom Ammonia (as N) at Station A

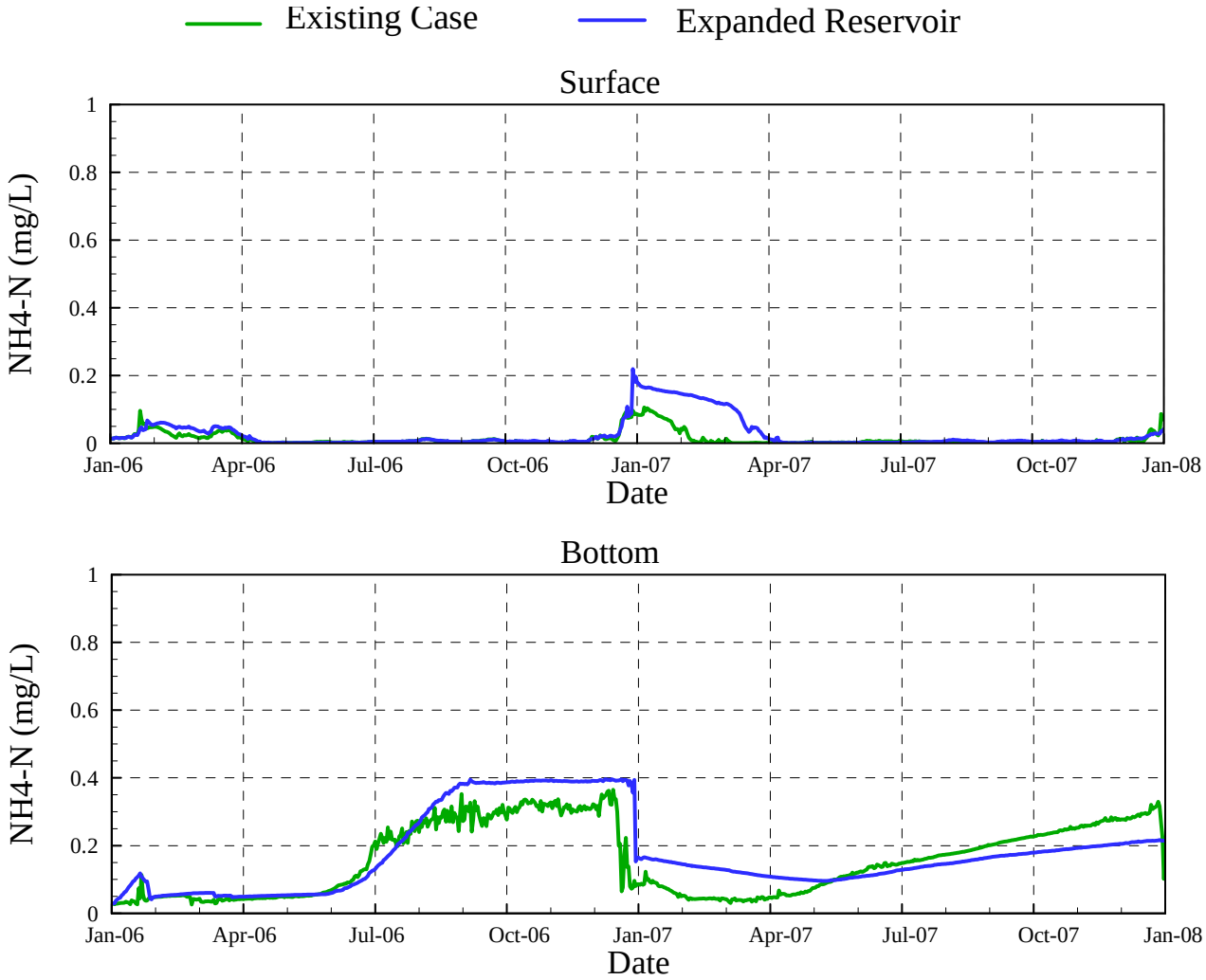

Figure 11

FLOW SCIENCE®

Comparison of Existing Case and Expanded Reservoir Case

Simulated Surface and Bottom Nitrate (as N) at Station A

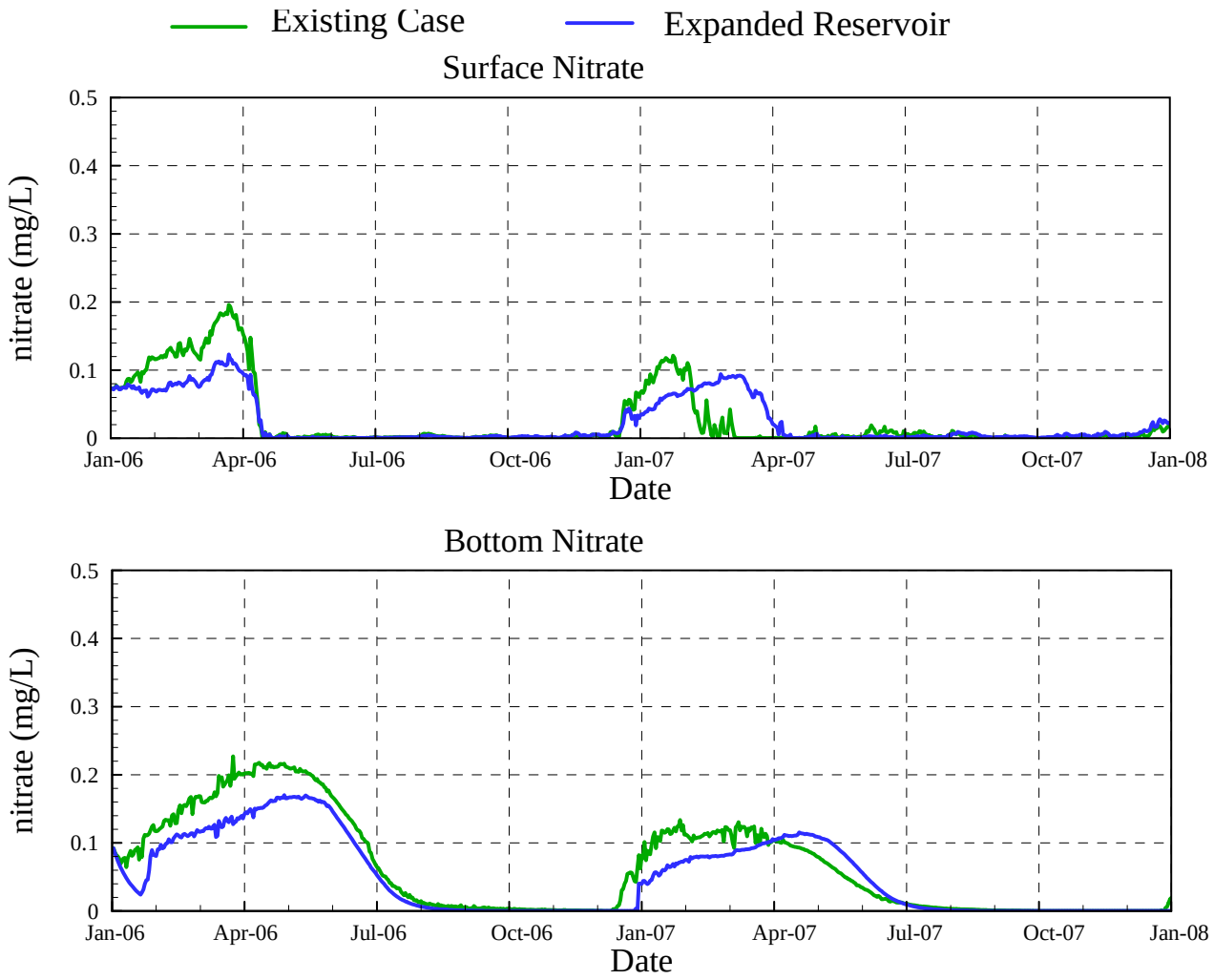

Figure 12

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Comparison of Existing Case and Expanded Reservoir Case

Simulated Surface and Bottom TN at Station A

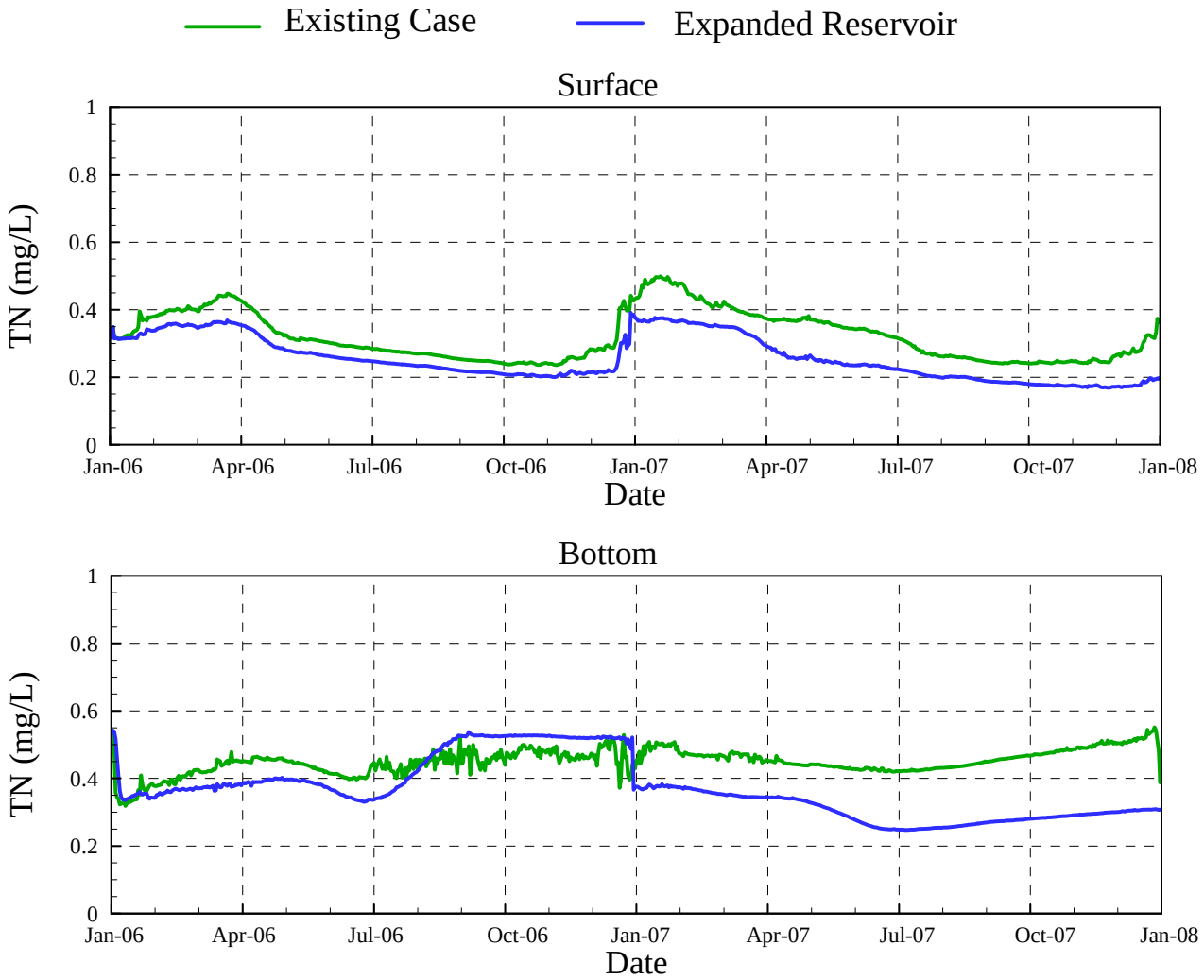

Figure 13

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Comparison of Existing Case and Expanded Reservoir Case

Simulated Surface and Bottom SRP at Station A

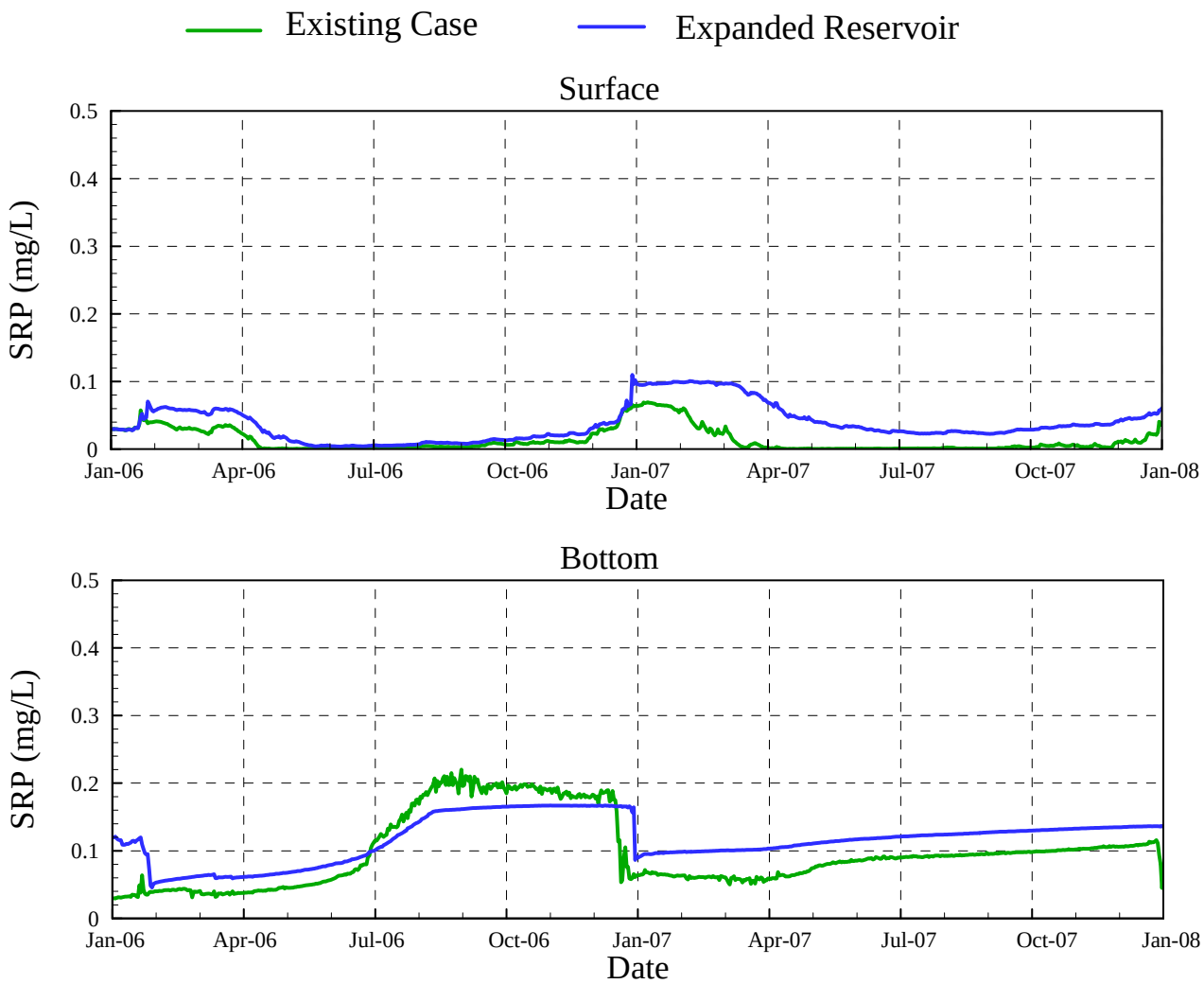

Figure 14

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Comparison of Existing Case and Expanded Reservoir Case

Simulated Surface and Bottom TP at Station A

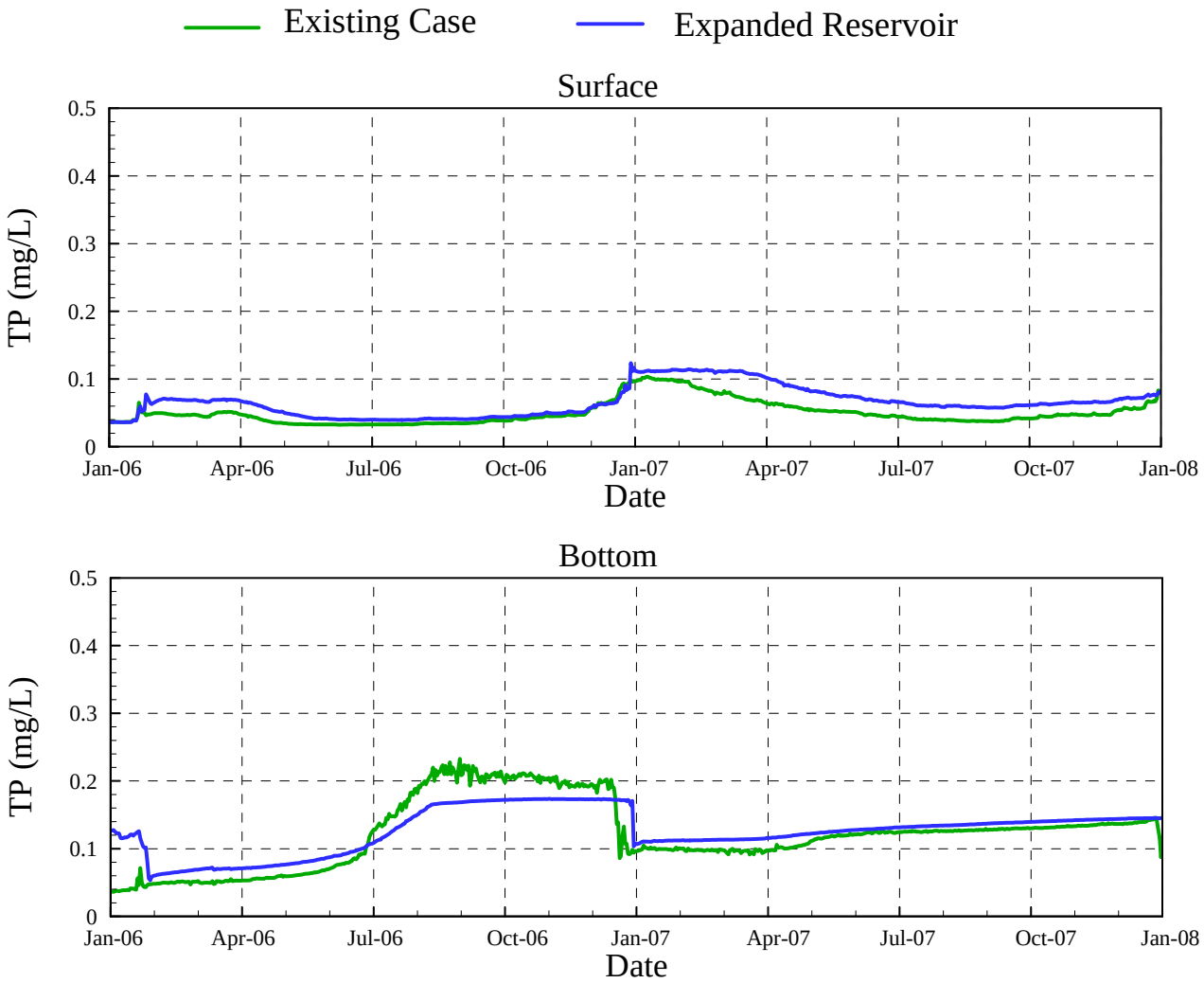

Figure 15

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Comparison of Existing Case and Expanded Reservoir Case

Simulated Surface Chlorophyll a at Station A

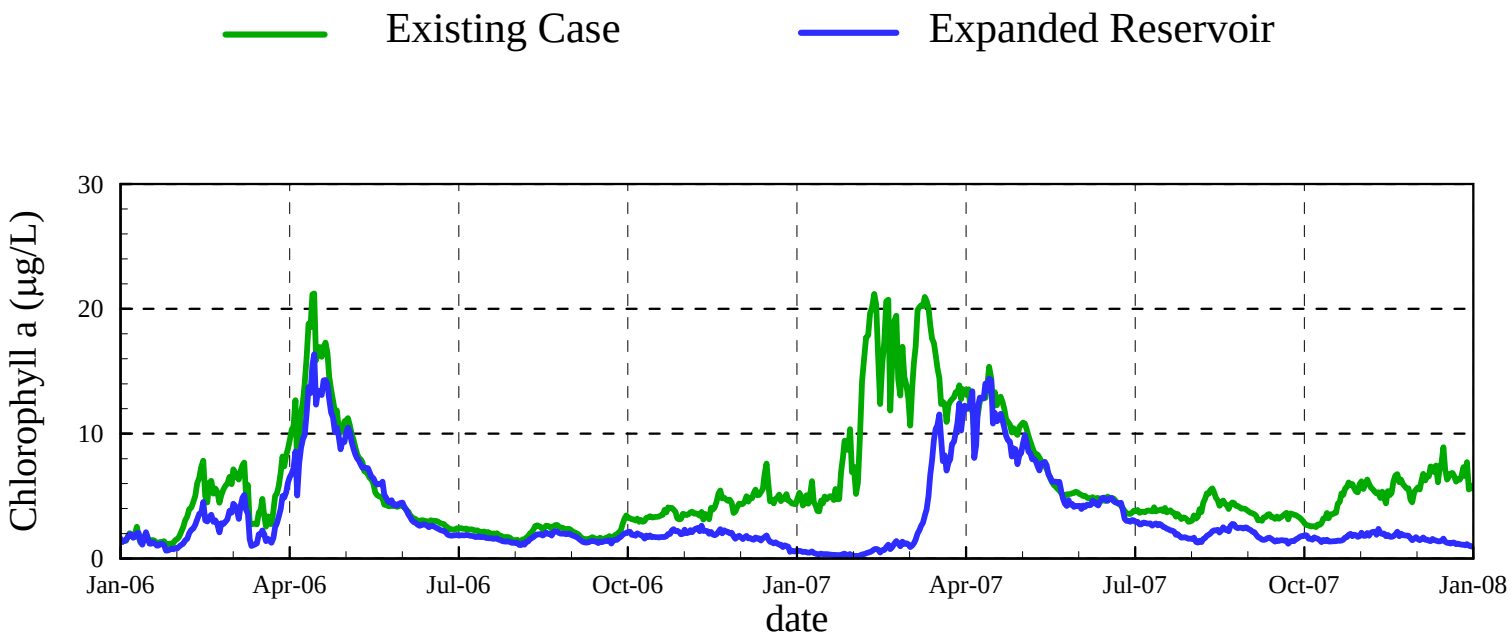

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Figure 16

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Comparison of Existing Case and Expanded Reservoir Case

Simulated Secchi Depth at Station A

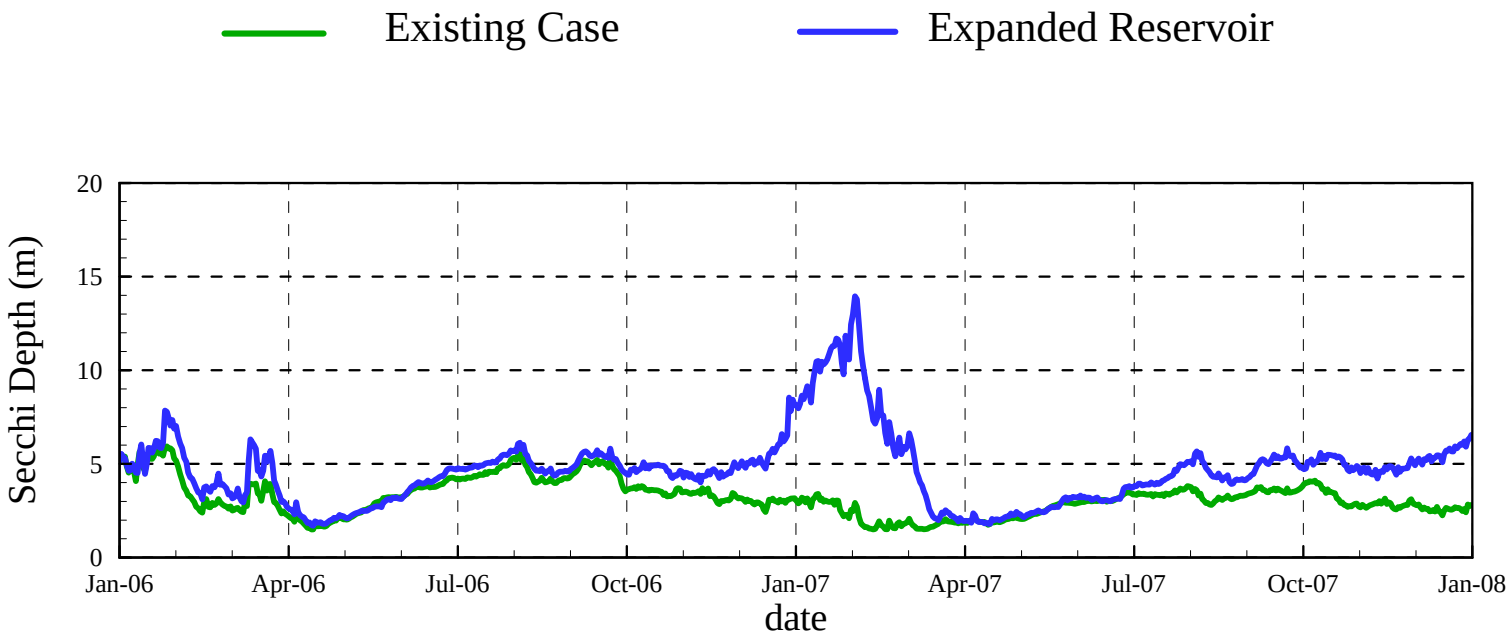

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Figure 17

FLOW SCIENCE®

Comparison of Existing Case and Expanded Reservoir Case

Simulated Surface and Bottom pH at Station A

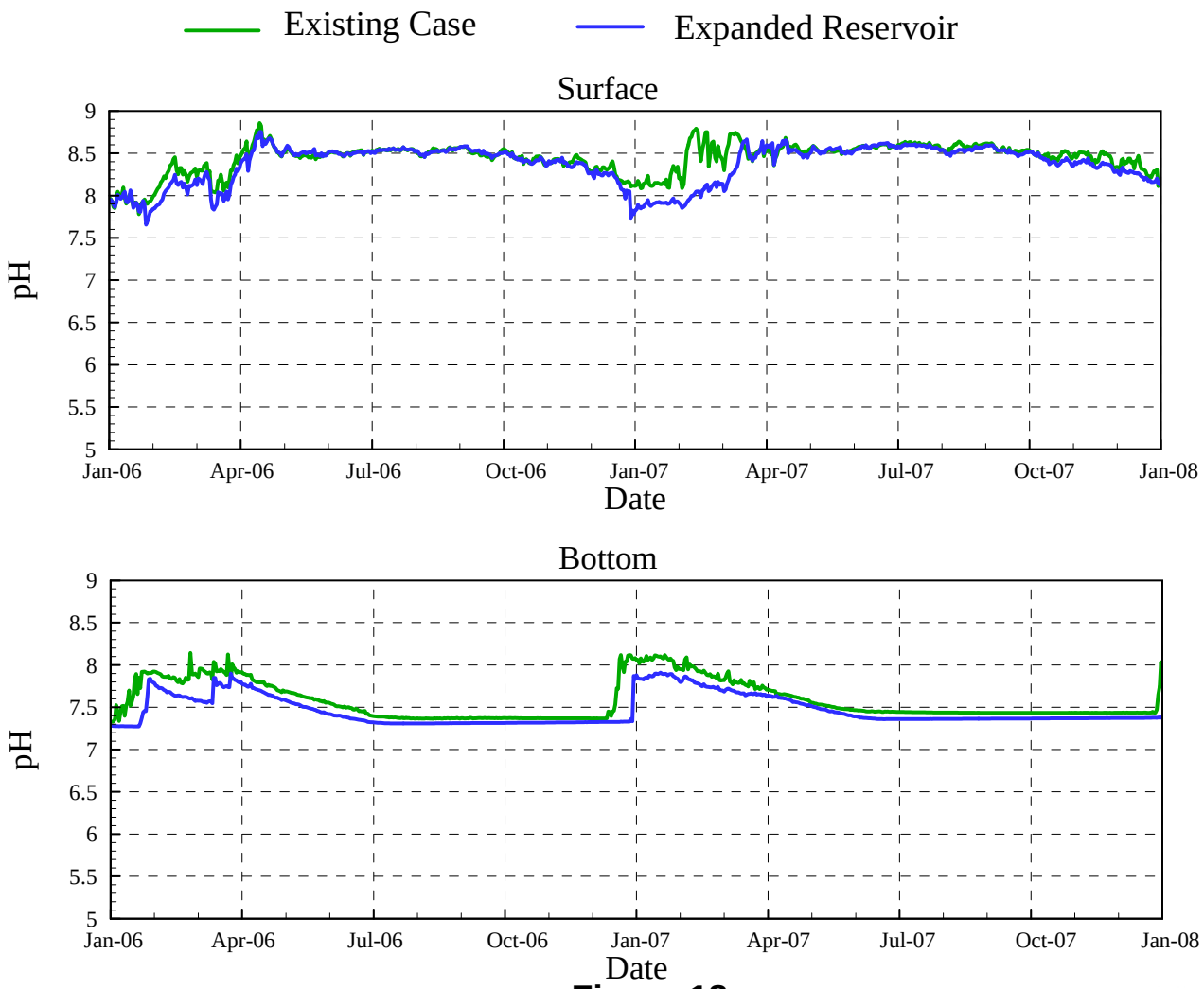

Figure 18

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Purified Water and Aqueduct Inflow Rates of Existing Case, No Purified Water and Base Case Scenarios

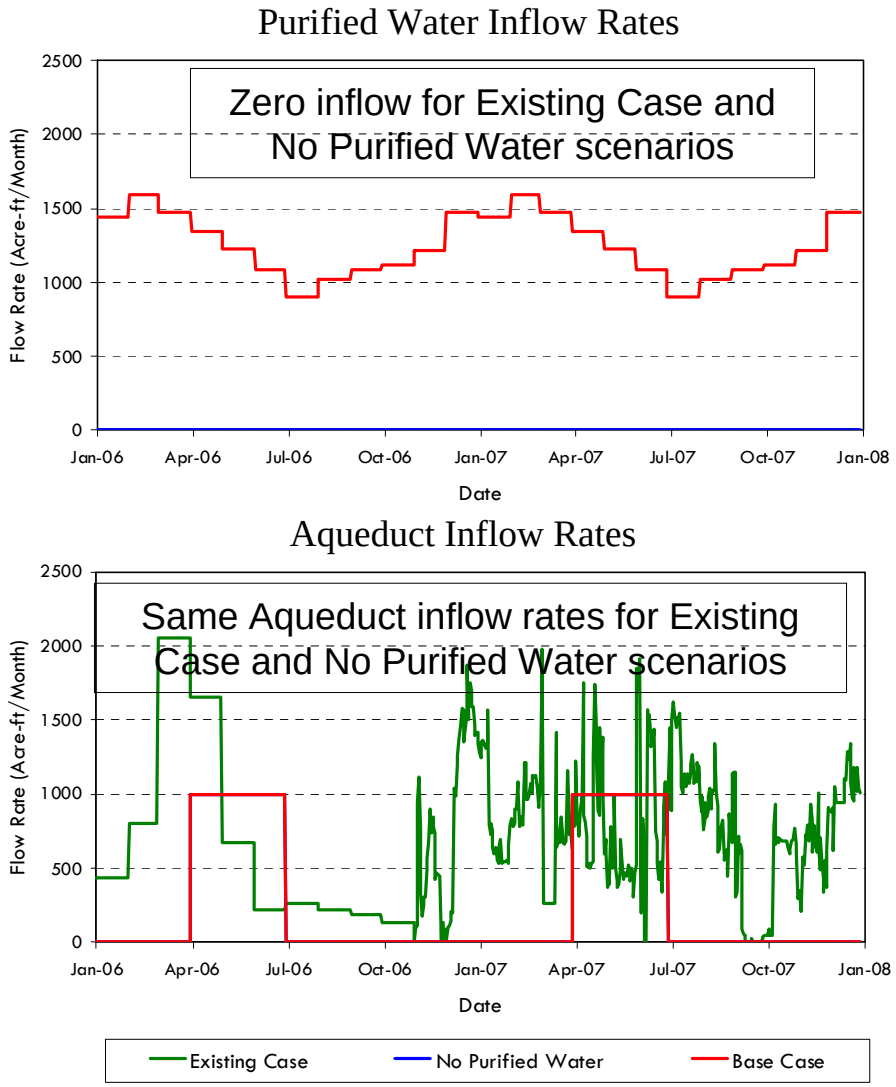

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Figure 19

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Reservoir Water Volumes for Existing Case, No Purified Water and Base Case Scenarios

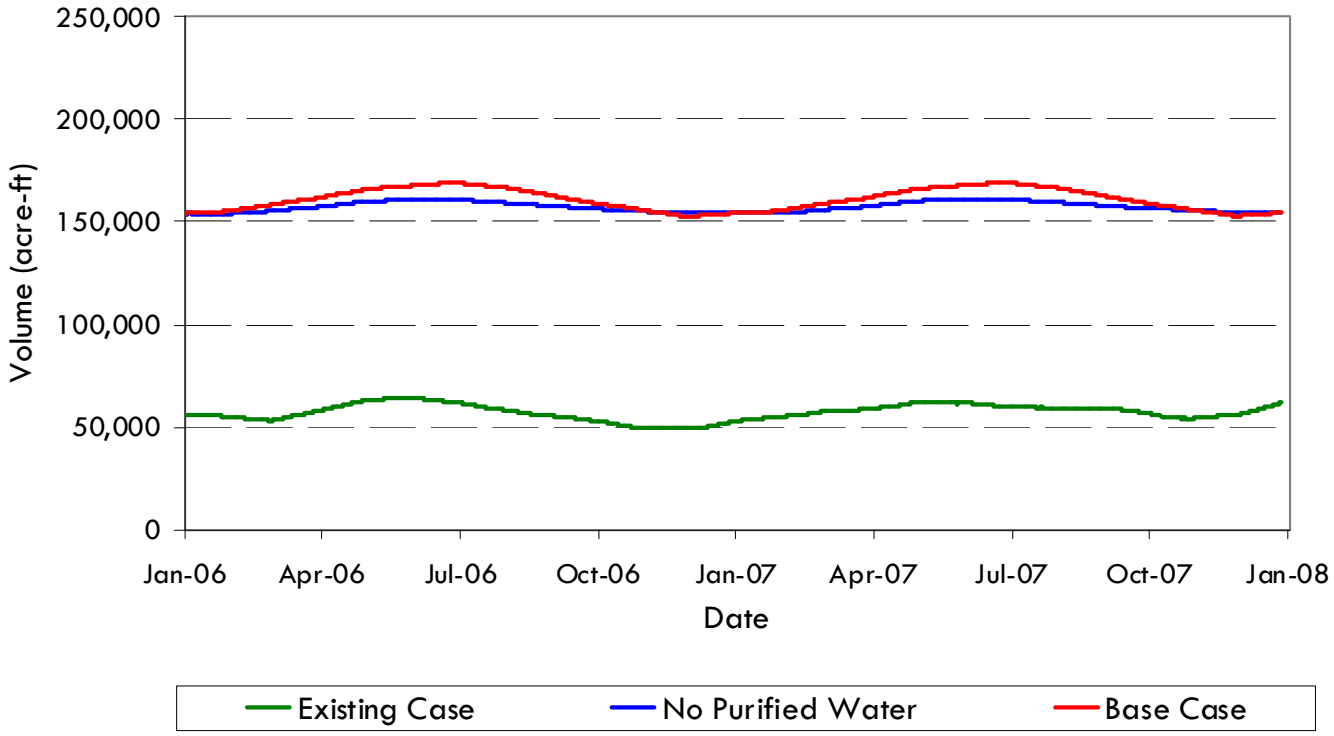

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Figure 20

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Comparison of Existing Case, No Purified Water and Base Case Scenarios

Simulated Water Temperature at Station A

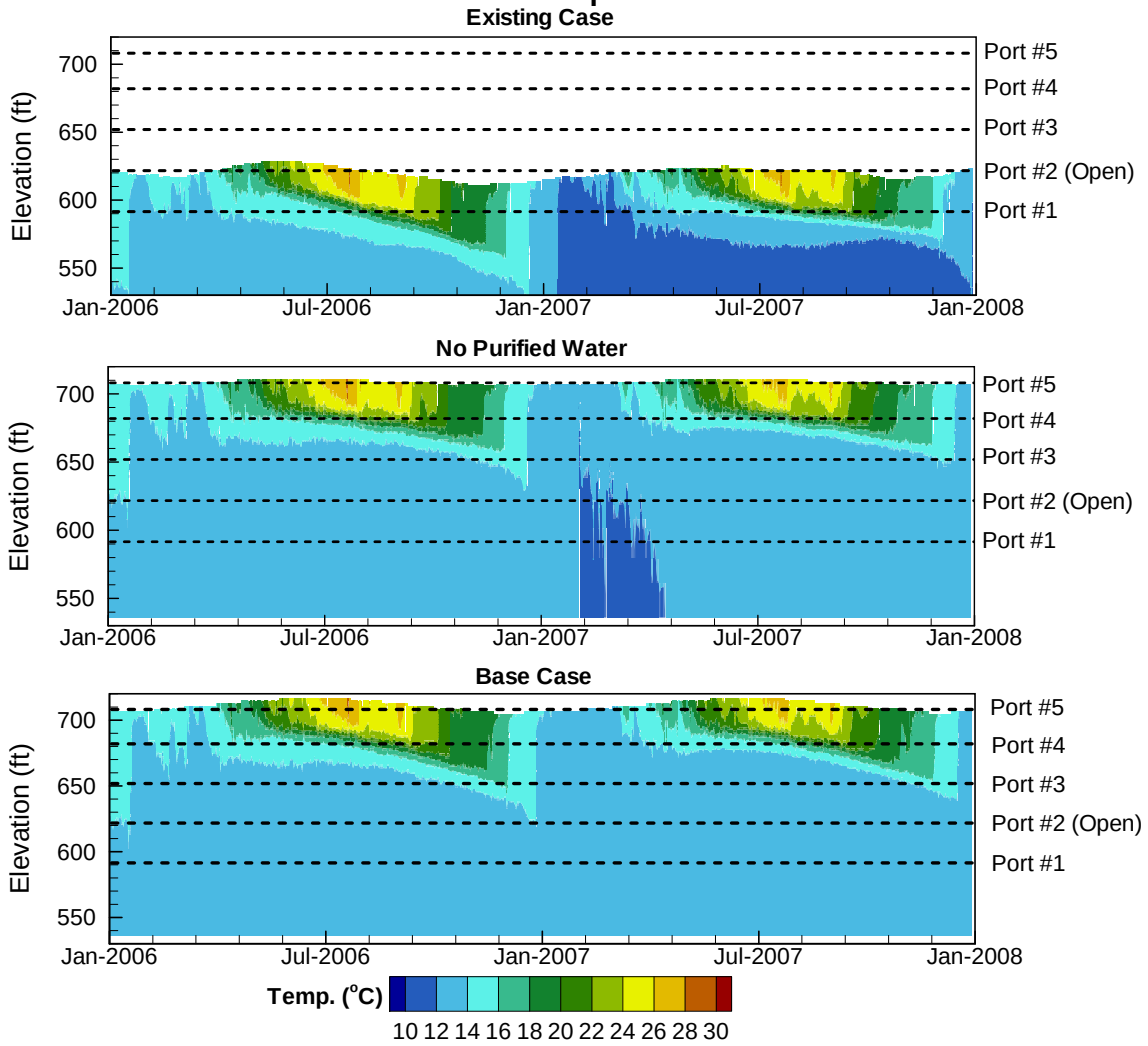

Figure 21

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Comparison of Existing Case, No Purified Water and Base Case Scenarios

Simulated Surface and Bottom Dissolved Oxygen at Station A

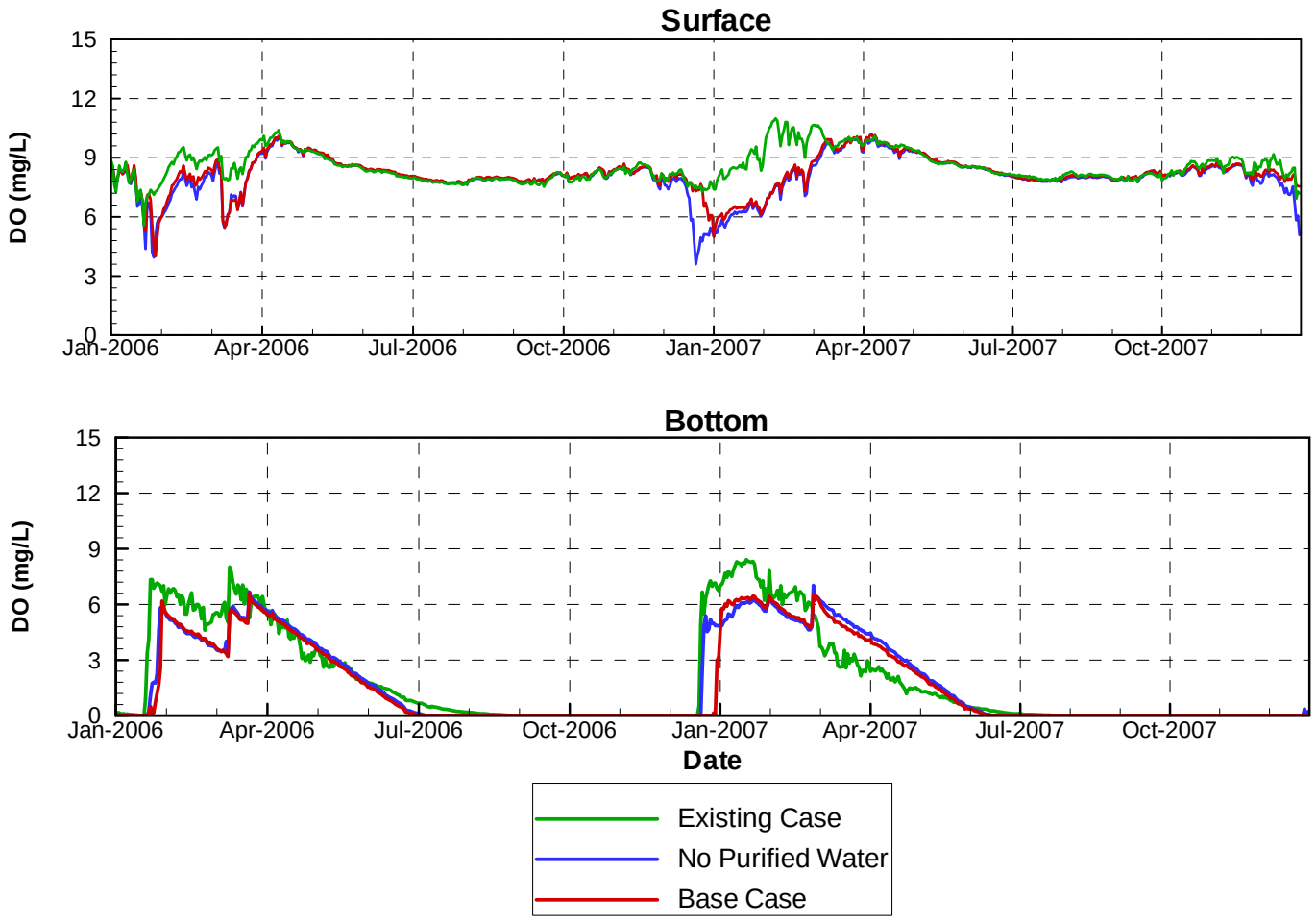

Figure 22

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Comparison of Existing Case, No Purified Water and Base Case Scenarios

Simulated Surface and Bottom Nitrate (as N) at Station A

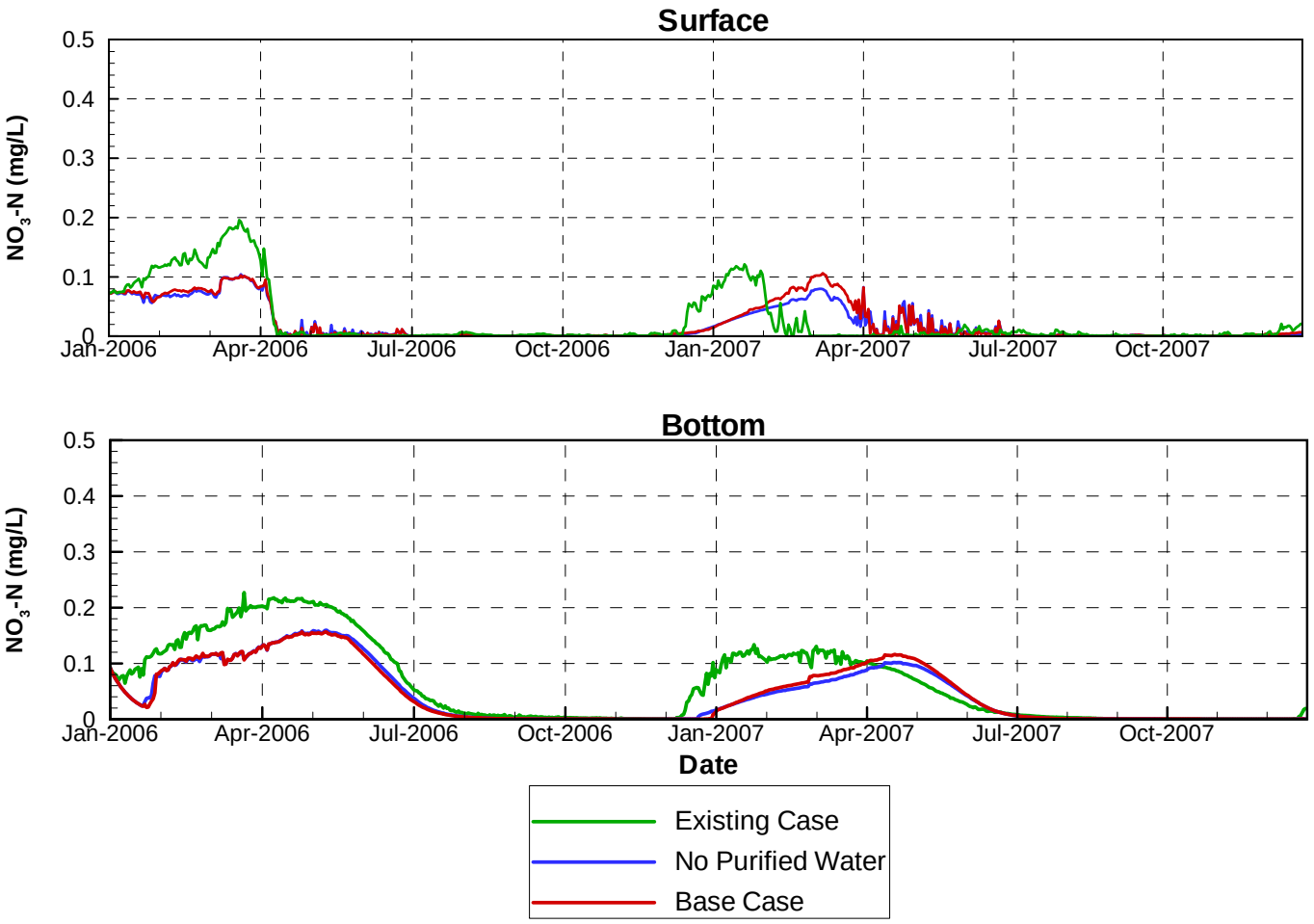

Figure 23

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Comparison of Existing Case, No Purified Water and Base Case Scenarios

Simulated Surface and Bottom Ammonia (as N) at Station A

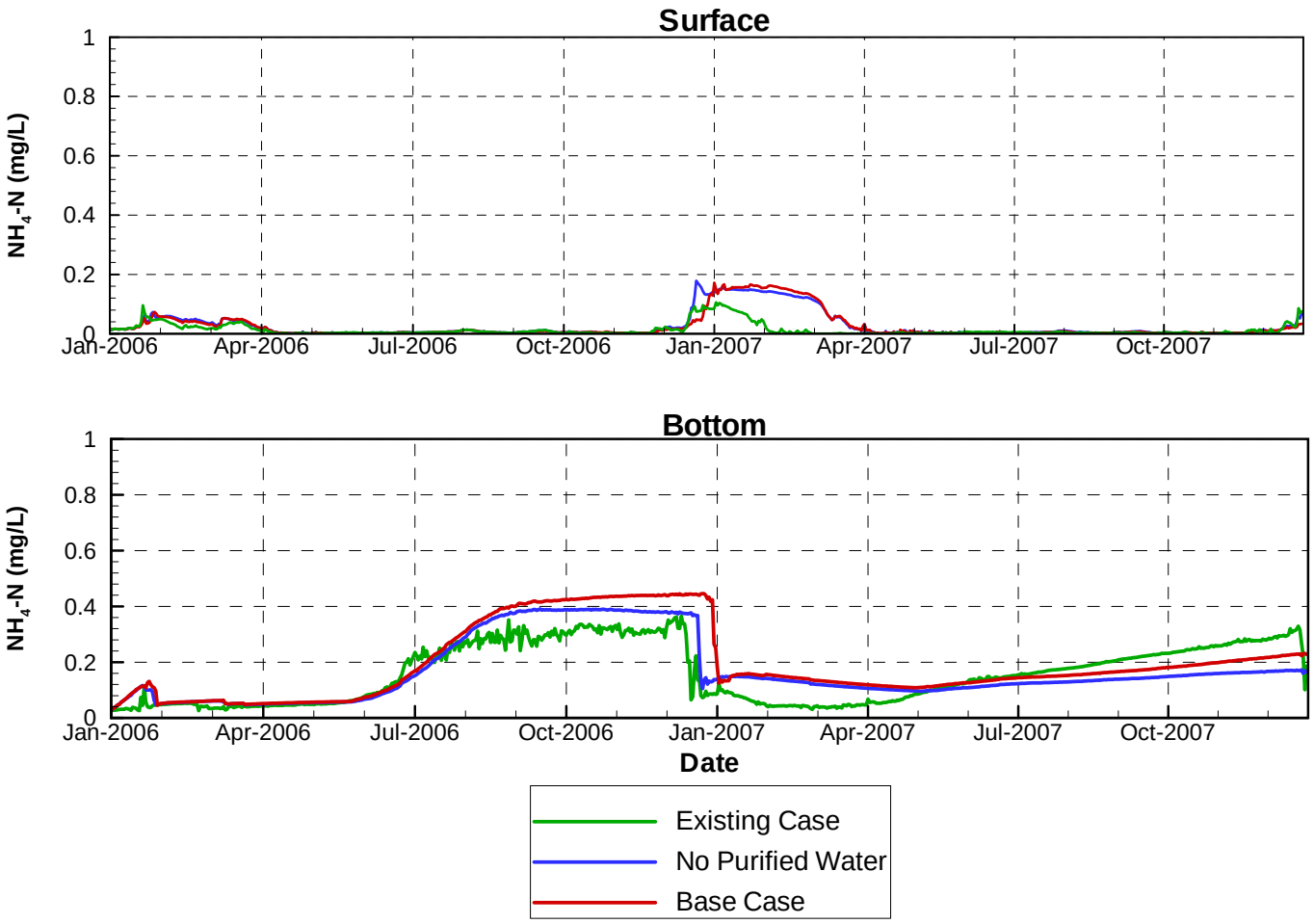

Figure 24

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Comparison of Existing Case, No Purified Water and Base Case Scenarios

Simulated Surface and Bottom Total Nitrogen at Station A

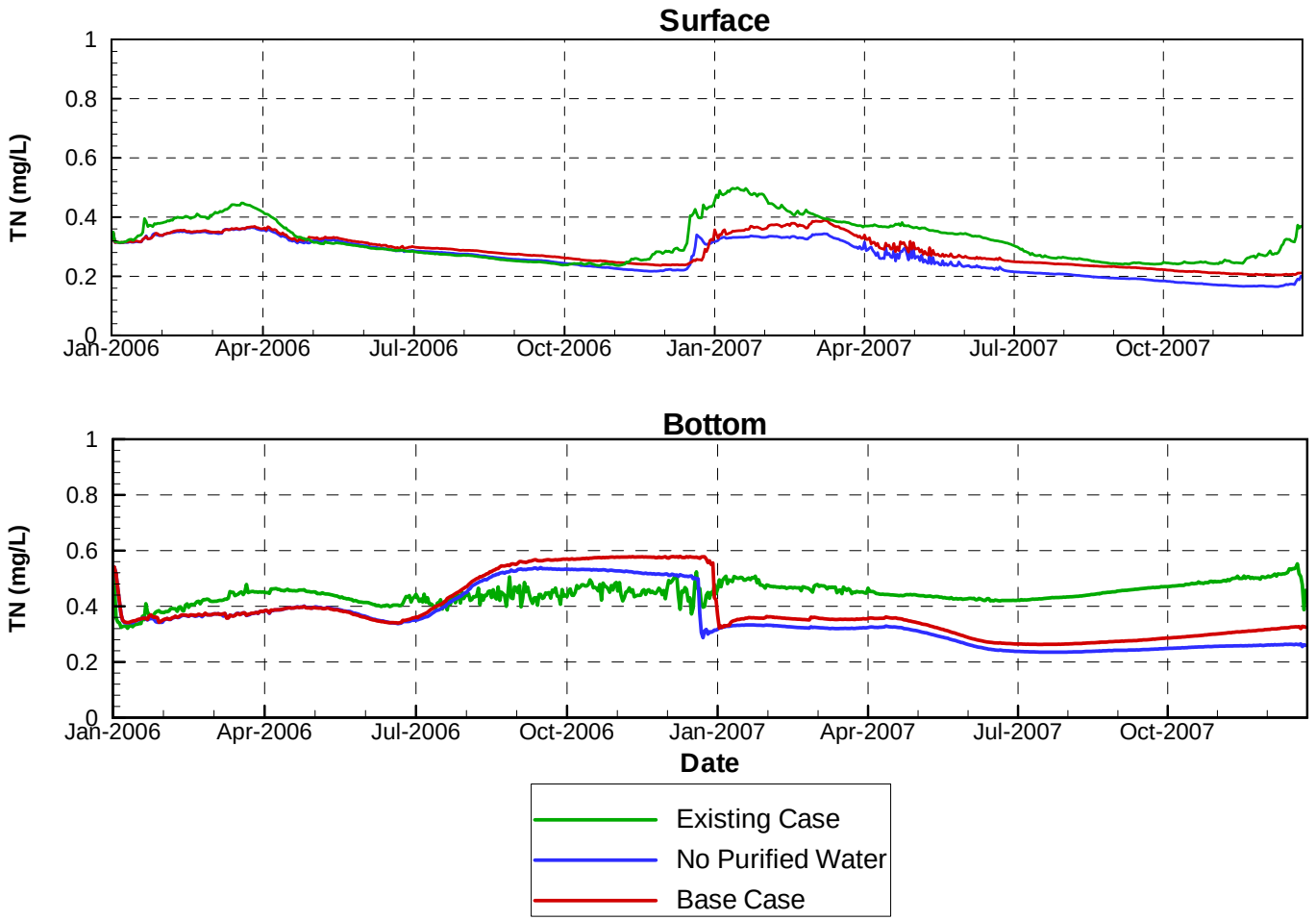

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Figure 25

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Comparison of Existing Case, No Purified Water and Base Case Scenarios

Simulated Surface and Bottom SRP at Station A

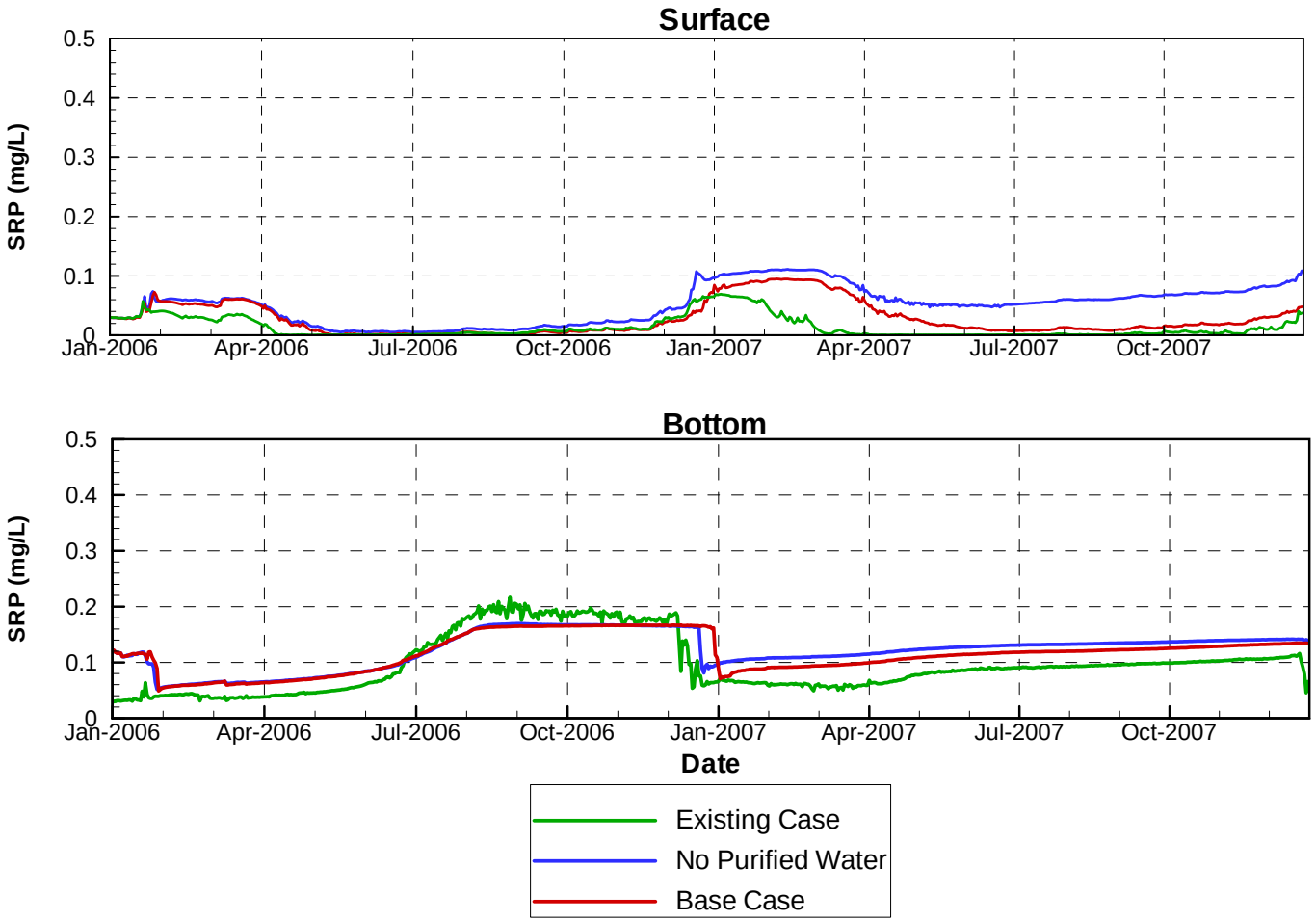

Figure 26

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Comparison of Existing Case, No Purified Water and Base Case Scenarios

Simulated Surface and Bottom TP at Station A

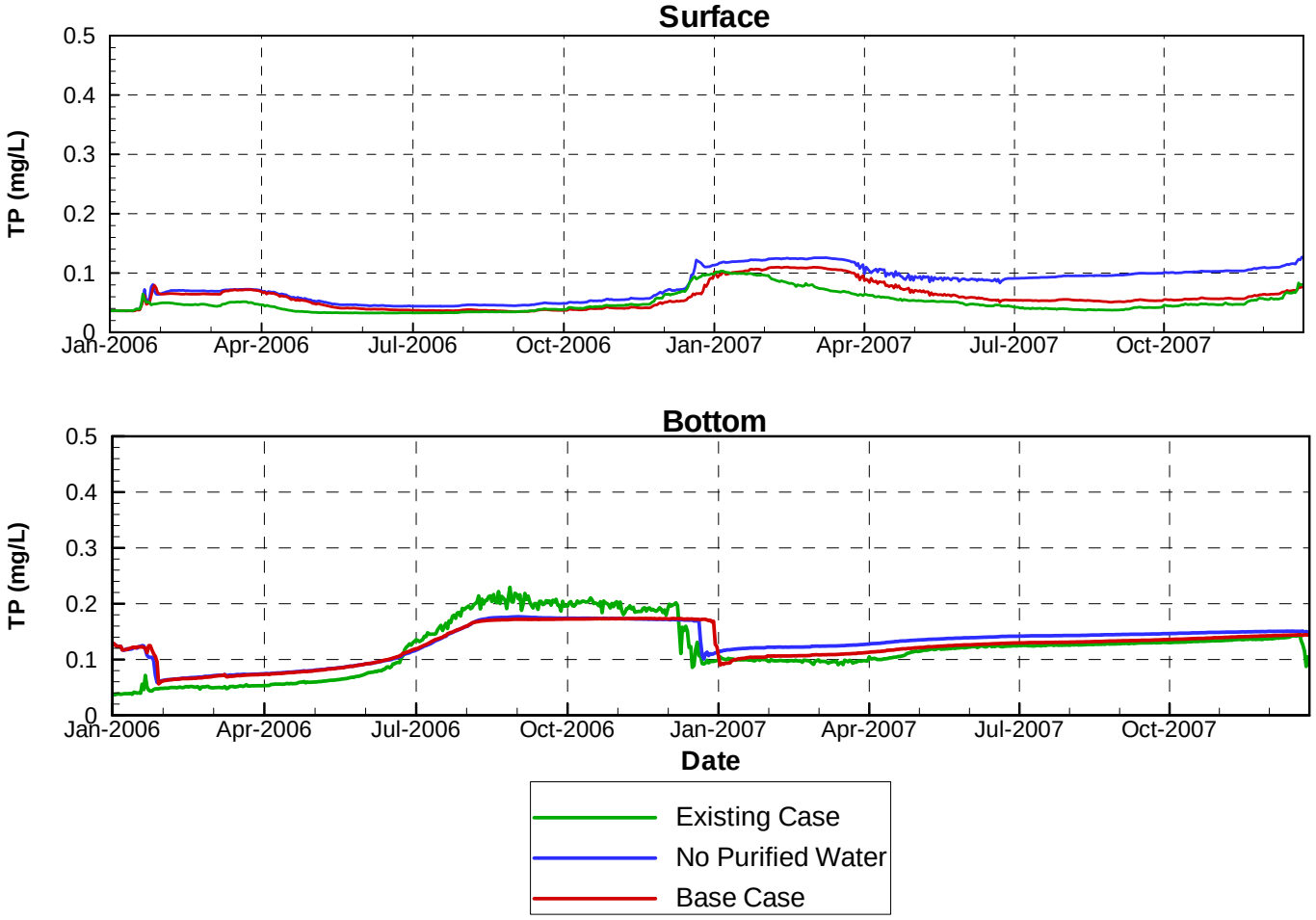

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Figure 27

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Comparison of Existing Case, No Purified Water and Base Case Scenarios

Simulated Surface Chlorophyll a at Station A

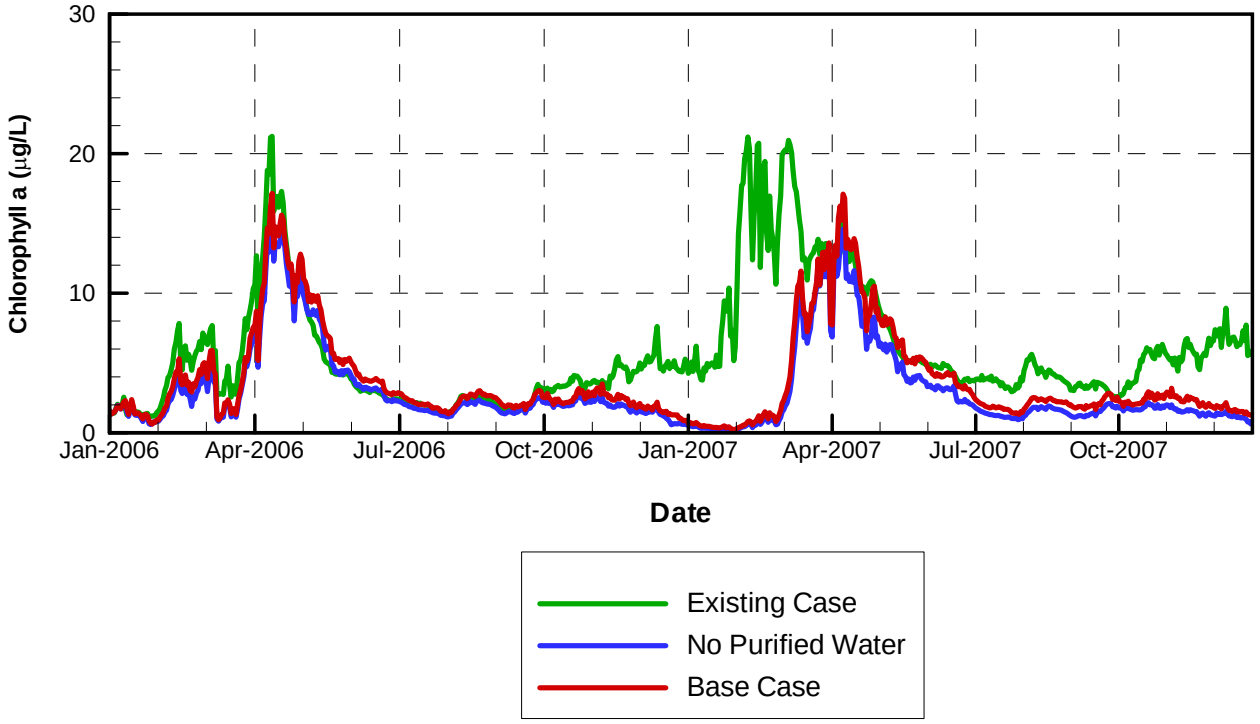

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Figure 28

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Comparison of Existing Case, No Purified Water and Base Case Scenarios

Secchi Depth at Station A

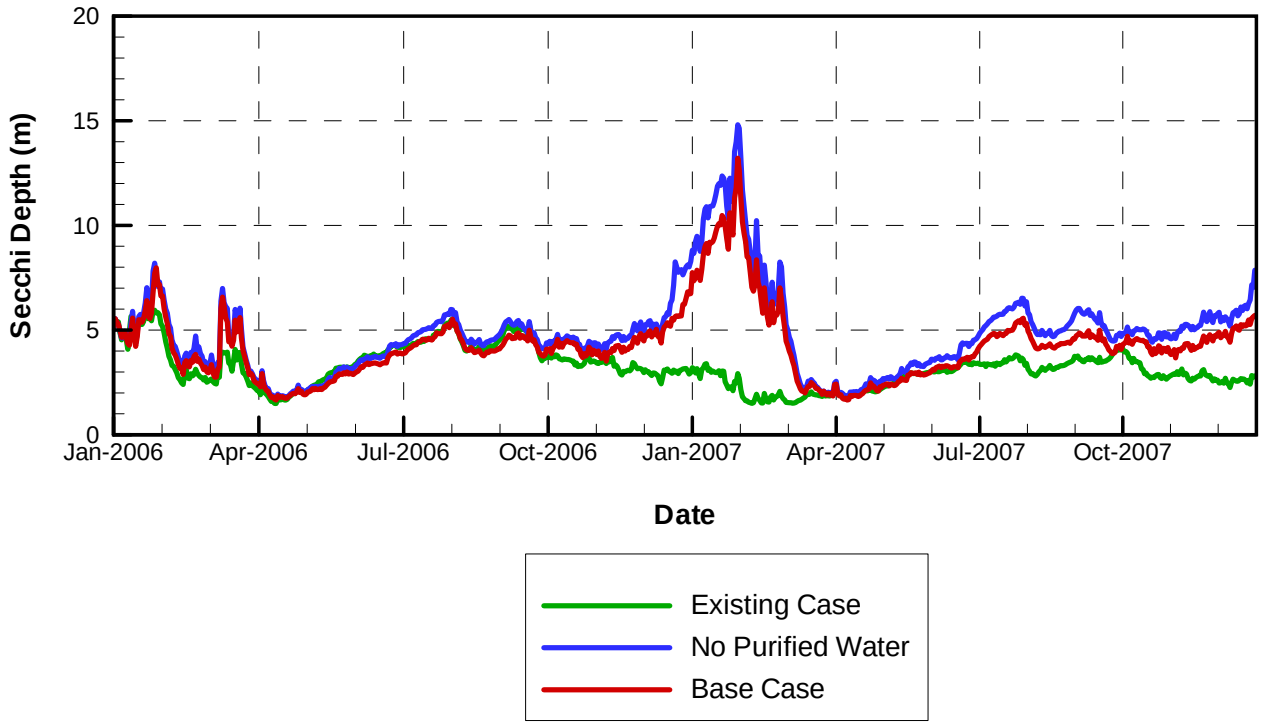

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Figure 29

FLOW SCIENCE®

Comparison of Existing Case, No Purified Water and Base Case Scenarios

Simulated Surface and Bottom pH at Station A

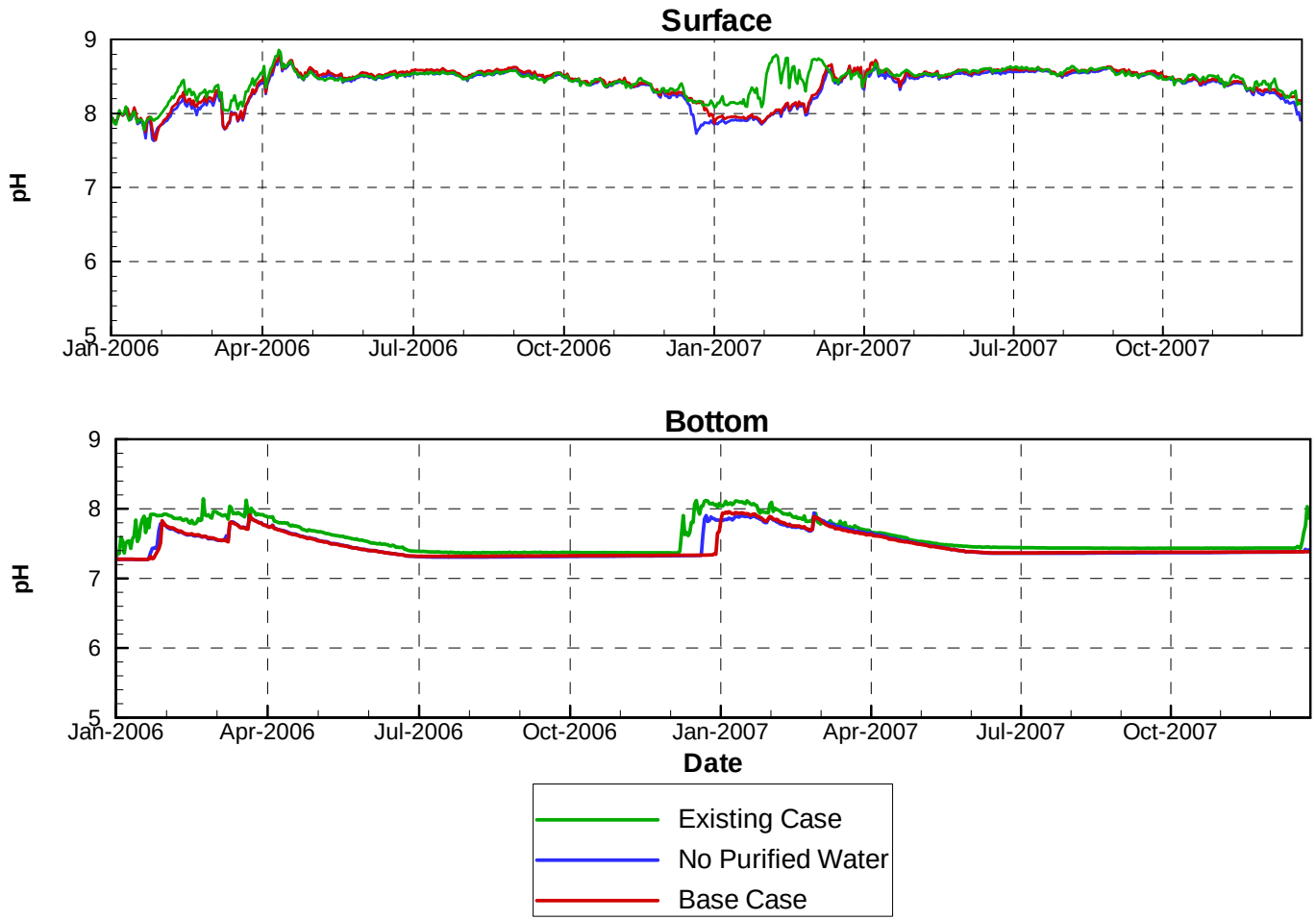

Figure 30

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APPENDIX A

Description of ELCOM/CAEDYM/Visual Plumes Models and Evidence of Validation

DESCRIPTION OF ELCOM/CAEDYM MODELS AND EVIDENCE OF VALIDATION

The coupling of biogeochemical and hydrodynamic processes in numerical simulations is a fundamental tool for research and engineering studies of water quality in coastal oceans, estuaries, lakes, and rivers. A modeling system for aquatic ecosystems has been developed that combines a three-dimensional hydrodynamic simulation method with a suite of water quality modules that compute interactions between biological organisms and the chemistry of their nutrient cycles. This integrated approach allows for the feedback and coupling between biogeochemical and hydrodynamic systems so that a complete representation of all appropriate processes can be included in an analysis. The hydrodynamic simulation code is the Estuary Lake and Coastal Ocean Model (ELCOM) and the biogeochemical model is the Computational Aquatic Ecosystem Dynamics Model (CAEDYM).

The purpose of this appendix is to demonstrate that ELCOM and CAEDYM are accepted models that have been systematically tested and debugged, and then successfully validated in numerous applications. A history of the models is provided, followed by an outline of the general model methodology and evolution that emphasizes the basis of the ELCOM/ CAEDYM codes in previously validated models and research. Then the process of code development, testing, and validation of ELCOM/CAEDYM is detailed. Specific model applications are described to illustrate how the ELCOM/CAEDYM models have been applied to coastal oceans, estuaries, lakes, and rivers throughout the world and the results successfully validated against field data. Finally, a general description of the governing equations, numerical models, and processes used in the models is provided along with an extensive bibliography of supporting material.

A comprehensive description of the equations and methods used in the models is provided in the "Estuary Lake and Coastal Ocean Model: ELCOM v2.2 Science Manual" by Hodges and Dallimore (2006), "Estuary Lake and Coastal Ocean Model: ELCOM v2.2 User Manual" by Hodges and Dallimore (2007), "Computational Aquatic Ecosystem Dynamics Model: CAEDYM: v2.2 Science Manual" by Hipsey, Romero, Antenucci and Hamilton (2005), and the "Computational Aquatic Ecosystem Dynamics Model: CAEDYM: v2.2 User Manual" by Hipsey, Romero, Antenucci and Hamilton (2005).

A.1.1 MODEL HISTORY

The ELCOM/CAEDYM models were originally developed at the Centre for Water Research (CWR) at the University of Western Australia, although the hydrodynamics

code ELCOM is an outgrowth of a hydrodynamic model developed earlier by Professor Vincenzo Casulli in Italy and now in use at Stanford University under the name TRIM-3D. The CAEDYM model was essentially developed at CWR as an outgrowth of earlier water quality modules used in the one-dimensional model, Dynamic Reservoir Simulation Model - Water Quality (DYRESM-WQ, Hamilton and Schladow, 1997).

The original ELCOM/CAEDYM models, as developed by CWR, were implemented in Fortran 90 (with F95 extensions) on a UNIX computer system platform. In 2001, the codes for both models were ported to a personal computer (PC) platform through an extensive recompiling and debugging effort by Flow Science Incorporated (Flow Science) in Pasadena, California. Since then, Flow Science has updated the PC version of the code several times when new versions of the code have been released by CWR.

A.1.2 MODEL METHODOLOGY

ELCOM is a three-dimensional numerical simulation code designed for practical numerical simulation of hydrodynamics and thermodynamics for inland and coastal waters. The code links seamlessly with the CAEDYM biogeochemical model undergoing continuous development at CWR, as shown graphically in **Figure A.1**. The

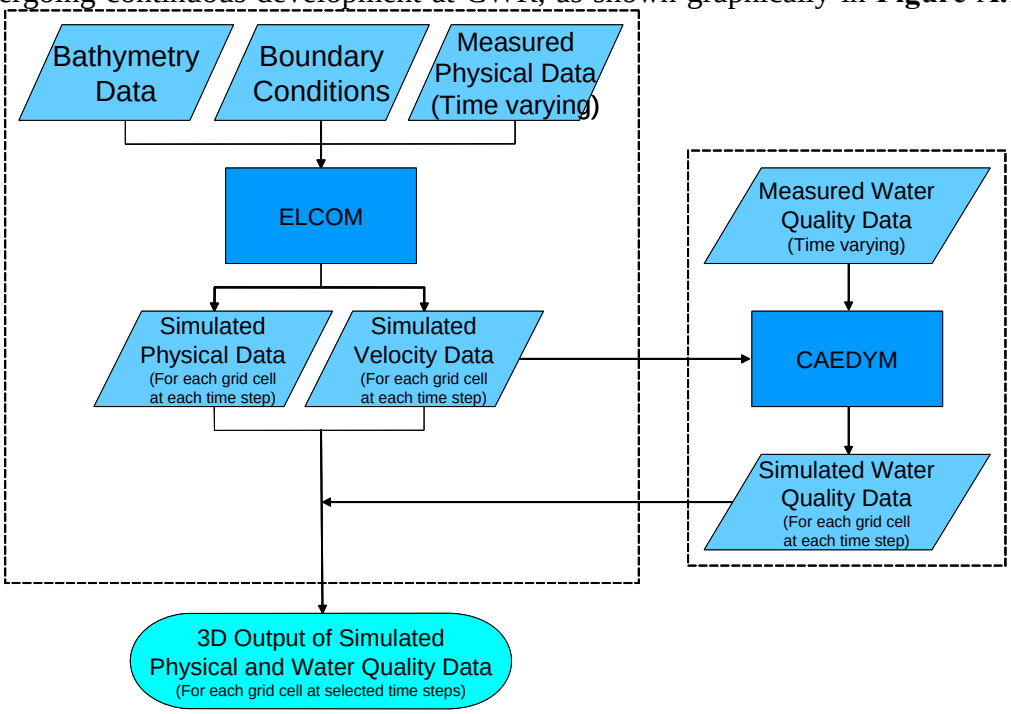

Figure A.1 Flow chart showing the integration of the linked ELCOM/CAEDYM models.

combination of the two codes provides three-dimensional simulation capability for examination of changes in water quality that arise from anthropogenic changes in either quality of inflows or reservoir operations.

The numerical method used in ELCOM is based on the TRIM-3D model scheme of Casulli and Cheng (1992) with adaptations made to improve accuracy, scalar conversion, numerical diffusion, and implementation of a mixed-layer model. The ELCOM model also extends the TRIM-3D scheme by including conservative advection of scalars. The unsteady Reynolds-averaged, Navier-Stokes equations, and the scalar transport equations serve as the basis of ELCOM. The pressure distribution is assumed hydrostatic and density changes do not impact the inertia of the fluid (the Boussinesq approximation), but are considered in the fluid body forces. There is an eddy-viscosity approximation for the horizontal turbulence correlations that represent the turbulent momentum transfer. Vertical momentum transfer is handled by a Richardson number-based diffusion coefficient. Since numerical diffusion generally dominates molecular processes, molecular diffusion in the vertical direction is neglected in ELCOM.

Both ELCOM and TRIM-3D are three-dimensional, computational fluid dynamics (CFD) models. CFD modeling is a validated and well-established approach to solving the equations of fluid motions in a variety of disciplines. Prior to the development of TRIM-3D, there were difficulties in modeling density-stratified flows and such flows required special numerical methods. With TRIM-3D, Casulli and Cheng (1992) developed the first such successful method to model density-stratified flows, such as occur in the natural environment. Since then, TRIM-3D has been validated by numerous publications. ELCOM is based on the same proven method, but incorporates additional improvements as described above. Furthermore, the ELCOM model is based on governing equations and numerical algorithms that have been used in the past (*e.g.*, in validated models such as TRIM-3D), and have been validated in refereed publications. For example:

- The hydrodynamic algorithms in ELCOM are based on the Euler-Lagrange method for advection of momentum with a conjugate gradient solution for the free-surface height (Casulli and Cheng, 1992).

- The free-surface evolution is governed by vertical integration of the continuity equation for incompressible flow applied to the kinematic boundary condition (*e.g.*, Kowalik and Murty, 1993).

- The numerical scheme is a semi-implicit solution of the hydrostatic Navier-Stokes equations with a quadratic Euler-Lagrange, or semi-Lagrangian (Staniforth and Côté, 1991).

- Passive and active scalars (*i.e.*, tracers, salinity, and temperature) are advected using a conservative ULTIMATE QUICKEST discretization (Leonard, 1991). The ULTIMATE QUICKEST approach has been implemented in two-dimensional format and demonstration of its effectiveness in estuarine flows has been documented by Lin and Falconer (1997).

- Heat exchange is governed by standard bulk transfer models found in the literature (*e.g.*, Smooch and DeVries, 1980; Imberger and Patterson, 1981; Jacquet, 1983).

- The vertical mixing model is based on an approach derived from the mixing energy budgets used in one-dimensional lake modeling as presented in Imberger and Patterson (1981), Spigel et al (1986), and Imberger and Patterson (1990). Furthermore, Hodges presents a summary of validation using laboratory experiments of Stevens and Imberger (1996). This validation exercise demonstrates the ability of the mixed-layer model to capture the correct momentum input to the mixed-layer and reproduce the correct basin-scale dynamics, even while boundary-induced mixing is not directly modeled.

- The wind momentum model is based on a mixed-layer model combined with a model for the distribution of momentum over depth (Imberger and Patterson, 1990).

The numerical approach and momentum and free surface discretization used in ELCOM are defined in more detail in Hodges, Imberger, Saggio, and Winters (1999). Similarly, the water quality processes and methodology used in CAEDYM are described in more detail in Hamilton and Schladow (1997). Further technical details on ELCOM and CAEDYM are provided in Sections **Error! Reference source not found.** and **Error! Reference source not found.** below.

A.1.3 VALIDATION AND APPLICATION OF ELCOM/CAEDYM

Since initial model development, testing and validation of ELCOM and/or CAEDYM have been performed and numerous papers on model applications have been presented, written, and/or published as described in more detail below. In summary:

- ELCOM solves the full three-dimensional flow equations with small approximations.

- ELCOM/CAEDYM was developed, tested, and validated over a variety of test cases and systems by CWR.

- Papers on ELCOM/CAEDYM algorithms, methodology, and applications have been published in peer reviewed journals such as the *Journal of Geophysical Research*, the *Journal of Fluid Mechanics*, the *Journal of Hydraulic Engineering*, the *International Journal for Numerical Methods in Fluids*, and *Limnology and Oceanography*.

- ELCOM/CAEDYM was applied by Flow Science to Lake Mead, Nevada. As part of this application, mass balances were verified and results were presented to a model review panel over a two-year period. The model review panel, the National Park Service, the United States Bureau of Reclamation, the Southern Nevada Water Authority, and the Clean Water Coalition (a consortium of water and wastewater operators in the Las Vegas, Nevada, region) all accepted the ELCOM/CAEDYM model use and validity.

- There are numerous applications of ELCOM/CAEDYM in the literature that compare the results to data, as summarized in Section **Error! Reference source not found.**.

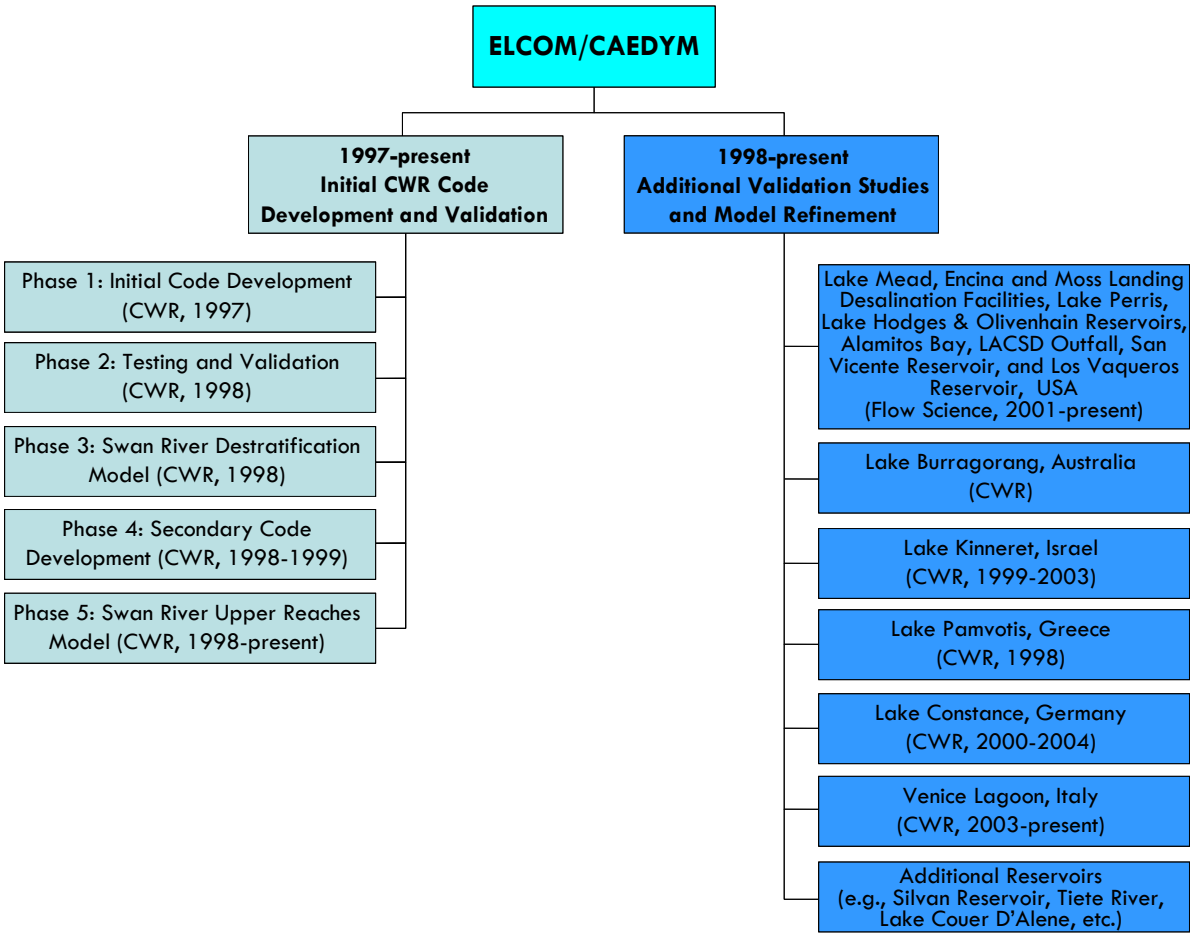

Figure A.2 ELCOM/CAEDYM code development, testing, validation, and applications by CWR and Flow Science Incorporated.

The process of code development, testing, and validation of ELCOM/CAEDYM by CWR, and the ongoing validation and refinement of the codes through further application of the models are detailed in the following subsections. The major components of the development, testing, and validation process are summarized in **Figure A.2**.

A.1.3.1 CWR Code Development, Testing, and Validation

Initial development of the code by CWR occurred from March through December 1997 (Phase 1), followed by a period of testing and validation from January through April 1998 (Phases 2 and 3). Secondary code development by CWR occurred from September 1998 through February 1999 (Phase 4). Testing and validation were

performed over a variety of test cases and systems to ensure that all facets of the code were tested. In addition, Phase 5 modeling of the Swan River since 1998 has been used to gain a better understanding of the requirements and limitations of the model (Hodges et al, 1999).

A.1.3.1.1 *Phase 1: Initial Code Development*

The ELCOM code was initially conceived by CWR as a Fortran 90/95 adaptation of the TRIM-3D model of Casulli and Cheng (1992) in order to: 1) link directly to the CAEDYM water quality module developed concurrently at CWR and 2) provide a basis for future development in a modern programming language. Although written in Fortran 77, TRIM-3D is considered a state-of-the-art numerical model for estuarine applications using a semi-implicit discretization of the Reynolds-averaged hydrostatic Navier-Stokes equations and an Euler-Lagrange method for momentum and scalar transport.

During development of ELCOM, it became clear that additional improvements to the TRIM-3D algorithm were required for accurate solution of density-stratified flows in estuaries. After the basic numerical algorithms were written in Fortran 90, subroutine-by-subroutine debugging was performed to ensure that each subroutine produced the expected results. Debugging and testing of the entire model used a series of test cases that exercised the individual processes in simplified geometries. This included test cases for the functioning of the open boundary condition (tidal forcing), surface wave propagation, internal wave propagation, scalar transport, surface thermodynamics, density underflows, wind-driven circulations, and flooding/drying of shoreline grid cells. Shortcomings identified in the base numerical algorithms were addressed during secondary code development (Phase 4).

Towards the end of the initial code development, ELCOM/CAEDYM were coupled and test simulations were run to calibrate the ability of the models to work together on some simplified problems. Results showing the density-driven currents induced by phytoplankton shading were presented at the Second International Symposium on Ecology and Engineering (Hodges and Herzfeld, 1997). Further details of modeling of density-driven currents due to combinations of topographic effects and phytoplankton shading were presented at a joint meeting of the American Geophysical Union (AGU) and the American Society of Limnology and Oceanography (ASLO) by Hodges et al. (1998), and at a special seminar at Stanford University (Hodges 1998). Additionally, presentations by Hamilton (1997), Herzfeld et al. (1997), and Herzfeld and Hamilton (1998) documented the concurrent development of the CAEDYM ecological model.

A.1.3.1.2 *Phase 2: Testing and Validation*

The simplified geometry tests of Phase I revealed deficiencies in the TRIM-3D algorithm including the inability of the TRIM-3D Euler-Lagrange method (ELM) to provide conservative transport of scalar concentrations (e.g., salinity and temperature). Thus, a variety of alternate scalar transport methods were tested, with the best performance being a flux-conservative implementation of the ULTIMATE filter applied to third-order QUICKEST discretization based on the work of Leonard (1991).

Model testing and validation against simple test cases was again undertaken. In addition, a simulation of a winter underflow event in Lake Burragorang in New South Wales, Australia, was performed to examine the ability of the model to capture a density underflow in complex topography in comparison to field data taken during the inflow event. These tests showed that the ability to model underflows is severely constrained by the cross-channel grid resolution.

A.1.3.1.3 *Phase 3: Swan River Destratification Model*

Phase 3 involved examining a linked ELCOM/CAEDYM destratification model of the Swan River system during a period of destratification in 1997 when intensive field monitoring had been conducted. The preliminary results of this work were presented at the Swan-Canning Estuary Conference (Hertzfeld *et al*, 1998). More comprehensive results were presented at the Western Australian Estuarine Research Foundation (WAERF) Community Forum (Imberger, 1998).

A.1.3.1.4 *Phase 4: Secondary Code Development*

In conducting the Phase 3 Swan River destratification modeling, it became clear to CWR that long-term modeling of the salt-wedge propagation would require a better model for mixing dynamics than presently existed. Thus, the availability of an extensive field data set for Lake Kinneret, Israel, led to its use as a test case for development of an improved mixing algorithm for stratified flows (Hodges *et al*, 1999).

A further problem appeared in the poor resolution of momentum terms using the linear ELM discretization (*i.e.*, as used in the original TRIM-3D method). Since the conservative ULTIMATE QUICKEST method (used for scalar transport, see Phase 1 above) does not lend itself to efficient use for discretization of momentum terms in a semi-implicit method, a quadratic ELM approach was developed for more accurate discretization of the velocities.

A.1.3.1.5 *Phase 5: Swan River Upper Reaches Model*

Phases 1-4 developed and refined the ELCOM code for accurate modeling of three-dimensional hydrodynamics where the physical domain is well resolved. Phase 5 is an ongoing process of model refinement that concentrates on developing a viable approach to modeling longer-term evolution hydrodynamics and water quality in the Swan River where fine-scale resolution of the domain is not practical. The Swan River application is also used for ongoing testing and calibration of the CAEDYM water quality module.

The Swan River estuary is located on the Swan Coastal Plain, Western Australia. It is subject to moderate to high nutrient loads associated with urban and agricultural runoff and suffered from *Microcystis aeruginosa* blooms in January 2000. In an effort to find a viable means of conducting seasonal to annual simulations of the Swan River that retain the fundamental along-river physics and the cross-channel variability in water quality parameters, CWR has developed and tested ELCOM/CAEDYM extensively. A progress report by Hodges et al (1999) indicates that ELCOM is capable of accurately reproducing the hydrodynamics of the Swan River over long time scales with a reasonable computational time.

Furthermore, studies conducted by Robson and Hamilton (2002) proved that ELCOM/CAEDYM accurately reproduced the unusual hydrodynamic circumstances that occurred in January 2000 after a record maximum rainfall, and predicted the magnitude and timing of the *Microcystis* bloom. These studies show that better identification and monitoring procedures for potentially harmful phytoplankton species could be established with ELCOM/CAEDYM and will assist in surveillance and warnings for the future.

A.1.3.2 Model Applications

In addition to the initial code development, testing, and validation by CWR, numerous other applications of ELCOM/CAEDYM have been developed by CWR and validated against field data. Additionally, Flow Science has applied ELCOM/CAEDYM extensively at Lake Mead (USA) and validated the results against measured data. The results of numerous ELCOM/CAEDYM model applications are presented below.

A.1.3.2.1 *Lake Mead (Nevada, USA)*

An ELCOM/CAEDYM model of Boulder Basin, Lake Mead near Las Vegas, Nevada, was used to evaluate alternative discharge scenarios for inclusion in an Environmental Impact Statement (EIS) for the Clean Water Coalition (CWC), a

consortium of water and wastewater operators in the Las Vegas region. **Figure A.3** is a cut-away of the three-dimensional model grid used for Boulder Basin, showing the varying grid spacing in the vertical direction.

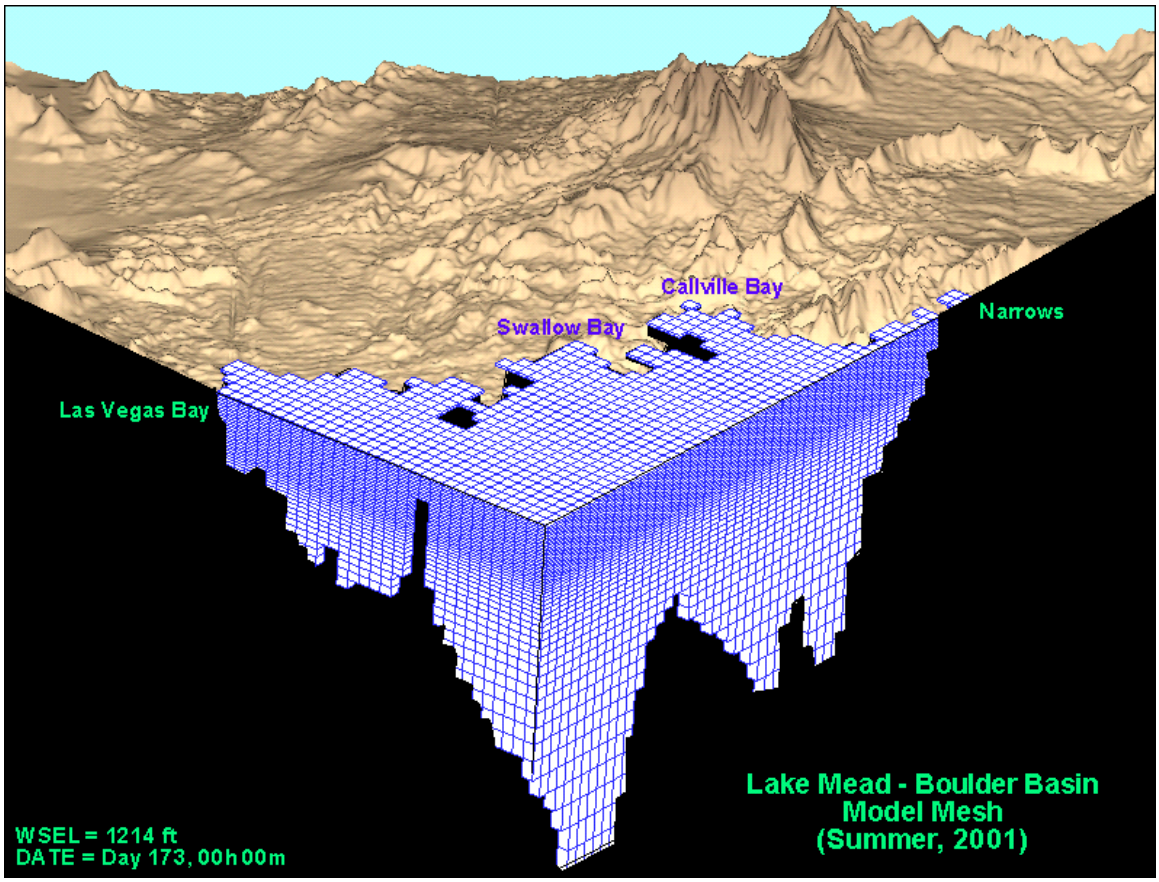

Figure A.3 Model grid for Lake Mead Boulder Basin model.

As part of the EIS process, a model review panel met monthly for two years to review the validation of the ELCOM/CAEDYM model, its calibration against field data, and its application. The modeling committee approved the use of the model. Subsequently, a scientific Water Quality Advisory Panel concluded that the ELCOM/CAEDYM model was applicable and acceptable. The members of the Water Quality Advisory Panel were diverse and included Jean Marie Boyer, Ph.D., P.E. (Water Quality Specialist/Modeler, Hydrosphere), Chris Holdren, Ph.D., CLM (Limnologist, United States Bureau of Reclamation), Alex Horne, Ph.D. (Ecological Engineer, University of California Berkeley), and Dale Robertson, Ph.D. (Research Hydrologist, United States Geological

Survey). More specifically, the Water Quality Advisory Panel agreed on the following findings:

- The ELCOM/CAEDYM model is appropriate for the project.
- There are few three-dimensional models available for reservoirs. ELCOM is one of the best hydrodynamic models and has had good success in the Boulder Basin of Lake Mead and other systems.
- The ELCOM model accurately simulates most physical processes.
- The algorithms used in CAEDYM are widely accepted (a biological consultant, Professor David Hamilton of The University of Waikato, New Zealand, was retained to review the CAEDYM coefficients and algorithms).

The Boulder Basin ELCOM/CAEDYM model was calibrated against four years of measured data for numerous physical and water quality parameters including temperature, salinity, conductivity, dissolved oxygen, pH, nutrients (nitrogen and phosphorus), chlorophyll *a*, perchlorate, chloride, sulfate, bromide, and total organic carbon. Detailed results of this calibration and the subsequent evaluation of alternative discharge scenarios were made available in late 2005 in the CWC EIS that was being prepared for this project. An example of the calibration results for chlorophyll *a* for 2002 is presented in **Figure A.4** below. In this figure, simulated concentrations are compared against field data measured in the lake by the United States Bureau of Reclamation (USBR) and the City of Las Vegas (COLV).

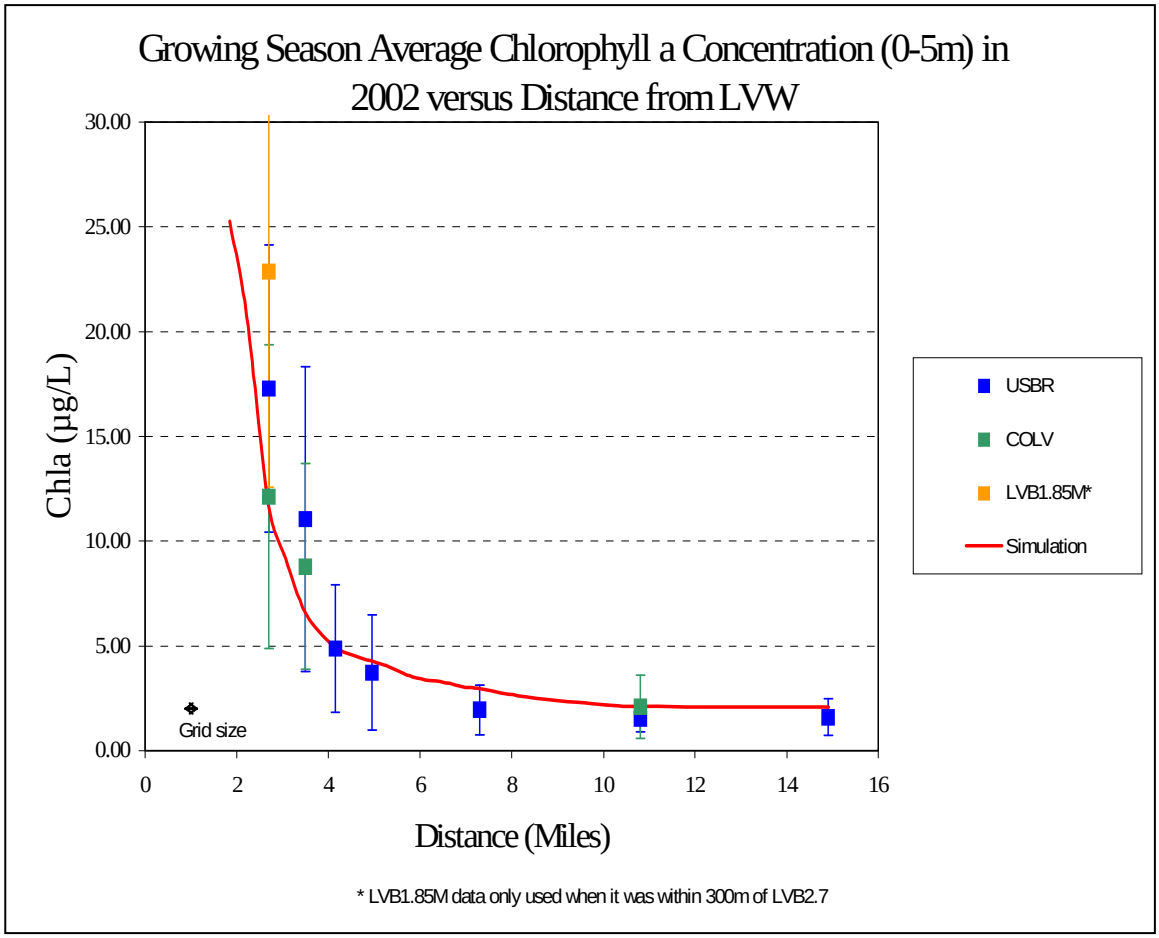

Figure A.4 ELCOM/CAEDYM calibration results for chlorophyll a in Boulder Basin for 2002 as a function of distance from the inflow at Las Vegas Wash.

Most recently, the original Boulder Basin model was extended to include all of Lake Mead, including the Overton Arm and Gregg Basin. The extended whole lake ELCOM/CAEDYM model has been calibrated against nine (9) years of data for use in informing design and operations management decisions. Specifically, the model has been used to simulate temperature (including stratification patterns), salinity, conductivity, dissolved oxygen, nutrients, chlorophyll *a* (as a surrogate for algae), perchlorate, total organic carbon, bromide, and suspended solids. **Figure A.5** below shows the extent of the expanded whole lake domain and the calibration results for conductivity for February 2005.

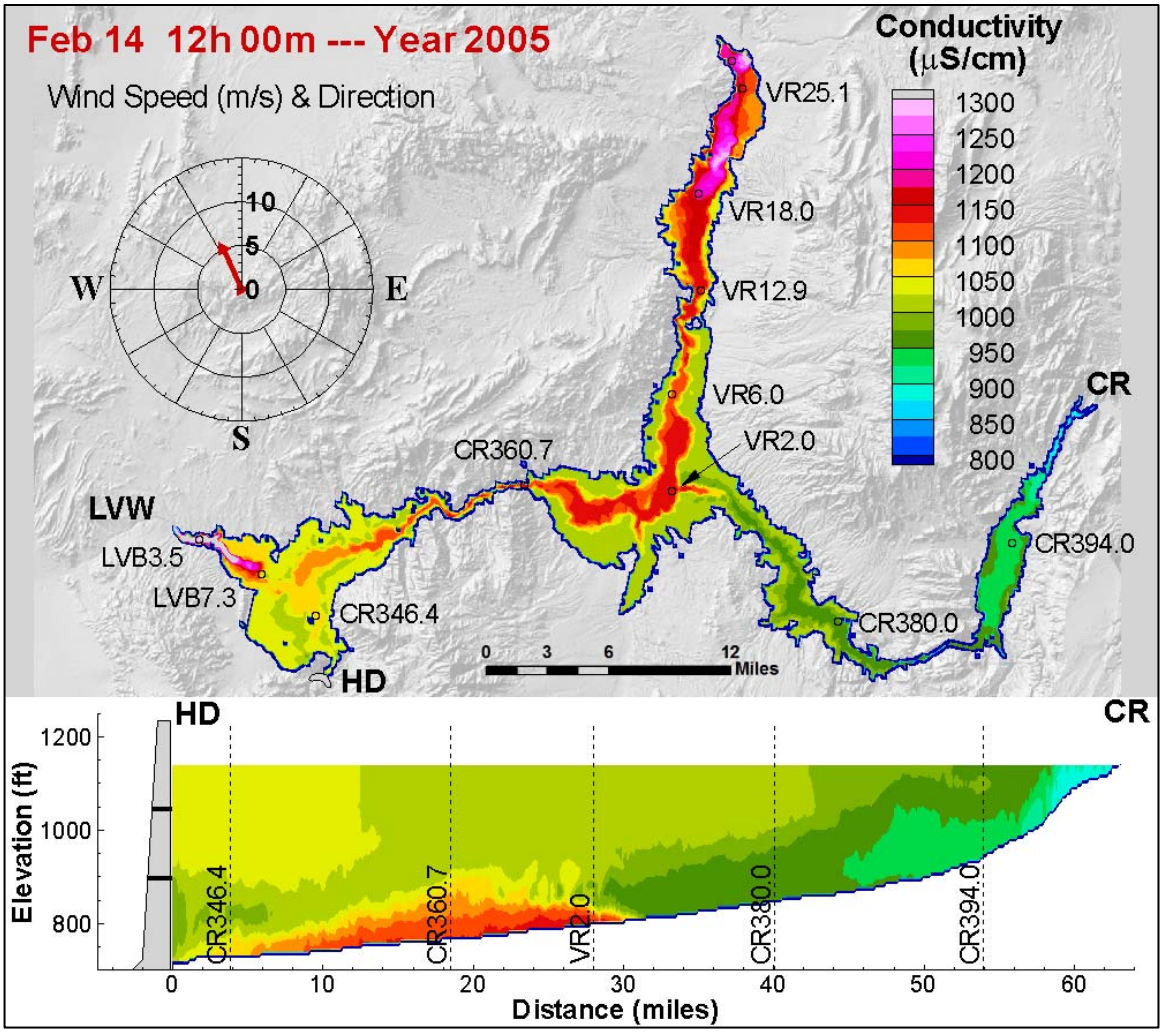

Figure A.5 ELCOM/CAEDYM calibration results for conductivity in the Lake Mead Whole Lake Model (including plan view of entire lake and cross-section from Hoover Dam to the mouth of the Colorado River).

ELCOM/CAEDYM model of the entire Lake Mead is being continually updated and calibrated on approximately a yearly basis, with funding having been provided by the CWC, the Southern Nevada Water Authority, and the National Park Service. These various stakeholders have demonstrated a long term commitment to maintaining the model because it has proven to be a worthy and successful tool. Additional funding for

ELCOM/CAEDYM modeling of the impacts of climate change on Lake Mead is being provided by the USBR under the WaterSMART grant program.

A.1.3.2.2 *Lake Burragorang (New South Wales, Australia)*

ELCOM was applied and validated for Lake Burragorang in order to rapidly assess the potential impacts on water quality during an underflow event (CWR). Underflows usually occur during the winter when inflow water temperature is low compared to the reservoir. This causes the upheaval of hypolimnetic water at the dam wall, and as a result it transports nutrient rich waters into the euphotic zone.

The thermal dynamics during the underflow event were reproduced accurately by ELCOM for the case with idealized bathymetry data with coarse resolutions (straightened curves and rotating the lake in order to bypass the resolution problem), but not for the simulation with the complex, actual bathymetry. This is because the model tests showed that the ability to model underflows is severely constrained by the cross-channel grid resolution. When the cross-channel direction is poorly resolved at bends and curves, an underflow is unable to propagate downstream without a significant loss of momentum. Nevertheless, the simulations with the coarse idealized domain certainly can be used as aids and tools to visualize the behavior of reservoirs. Particularly, ELCOM was able to capture the traversal of the underflow down the length of Lake Burragorang and then had sufficient momentum to break against the wall causing the injection of underflow waters into the epilimnion near the dam. This simulated dynamic was in agreement with what was measured in the field.

A.1.3.2.3 *Lake Kinneret (Israel)*

ELCOM was applied to model basin-scale internal waves that are seen in Lake Kinneret, Israel, since understanding of basin-scale internal waves behaviors provide valuable information on mixing and transport of nutrients below the wind-mixed layer in stratified lakes. In studies done by Hodges et al. (1999) and Laval et al (2003), the ELCOM simulation results were compared with field data under summer stratification conditions to identify and illustrate the spatial structure of the lowest-mode basin-scale Kelvin and Poincare waves that provide the largest two peaks in the internal wave energy spectra. The results demonstrated that while ELCOM showed quantitative differences in the amplitude and steepness of the waves as well as in the wave phases, the basin-scale waves were resolved very well by ELCOM. In particular, the model captures the qualitative nature of the peaks and troughs in the thermocline and the depth of the wind-mixed layer at relatively coarse vertical grid resolutions (Hodges et al, 1999).

A.1.3.2.4 *Lake Pamvotis (Greece)*

ELCOM/CAEDYM was applied to Lake Pamvotis, a moderately sized (22 km^2), shallow (4 m average depth) lake located in northwest Greece. Since the lake has undergone eutrophication over the past 40 years, many efforts are directed at understanding the characteristics of the lake and developing watershed management and restoration plans.

Romero and Imberger (1999) simulated Lake Pamvotis over a one month period during May to June, 1998, and compared the simulated thermal and advective dynamics of the lake with data obtained from a series of field experiments. The simulation results over-predicted heating; however, diurnal fluctuations in thermal structures were similar to those measured. Since the meteorological site was sheltered from the winds, the wind data used in the simulation was believed to be too low, causing insufficient evaporative heat-loss and subsequent over-heating by ELCOM. An increase in the wind speed by a factor of three gave temperature profiles in agreement with the field data. Moreover, the study demonstrated that the model is capable of predicting the substantial diurnal variations in the intensity and direction of both vertical and horizontal velocities. Romero and Imberger were also able to illustrate the functionality of ELCOM when coupled to the water quality model, CAEDYM, and confirmed that the model could be used to evaluate the effect of various strategies to improve poor water quality in localized areas in the lake.

A.1.3.2.5 *Lake Constance (Germany, Austria, Switzerland)*

Appt (2000) and Appt et al. (2004) applied ELCOM to characterize the internal wave structures and motions in Lake Constance [Bodensee] since internal waves are a key factor in understanding the transport mechanisms for chemical and biological processes in a stratified lake such as Lake Constance. Lake Constance is an important source of drinking water and a major tourism destination for its three surrounding countries of Germany, Austria, and Switzerland. Due to anthropogenic activities and climatic changes, Lake Constance water quality has deteriorated and its ecosystem has changed.

It was shown that ELCOM was able to reproduce the dominant internal wave and major hydrodynamic processes occurring in Lake Constance. For instance, three types of basin-scale waves were found to dominate the wave motion: the vertical mode-one Kelvin wave, the vertical mode-one Poincare waves, and a vertical mode-two Poincare wave. Moreover, an upwelling event was also reproduced by ELCOM suggesting that the width and length ratio of the basin, spatial variations in the wind, and Coriolis effects play critical roles in the details of the upwelling event. This on-going research has shown

that ELCOM can be used as a tool to predict and understand hydrodynamics and water quality in lakes.

A.1.3.2.6 *Venice Lagoon (Italy)*

ELCOM/CAEDYM is being used to develop a hydrodynamic and sediment transport model of Venice Lagoon, Italy, since future gate closures at the mouth of the lagoon are likely to impact flushing patterns. This project is an integral part of the Venice Gate Projects in Italy that was launched in May 2003 to prevent flooding.

ELCOM was validated for the tidal amplitude and phase using the data obtained from 12 tidal stations located throughout the lagoon (Yeates, 2004). Remaining tasks include model validation of temperature, salinity, and velocity against measurements made in the major channels of the lagoon.

A.1.3.2.7 *Silvan Reservoir (Australia)*

ELCOM is currently being applied to reproduce the circulation patterns observed in Silvan Reservoir, Australia, during a field experiment that was conducted in March 2004 to determine the transport pathways in the lake. This experiment confirmed the upwelling behavior of the lake and the strong role of the inflows in creating hydraulic flows in the reservoir (Antenucci, 2004).

A.1.3.2.8 *Billings and Barra Bonita Reservoirs (Brazil)*

ELCOM/CAEDYM is being applied to Billings and Barra Bonita Reservoirs in Brazil. Billings Reservoir is an upstream reservoir that feeds Barra Bonita via the Tiete River. The objective of the project is to develop an integrated management tool for these reservoirs and river reaches for use in the future planning of water resource utilization in Sao Paulo, Brazil (Romero and Antenucci, 2004).

A.1.3.2.9 *Lake Coeur D'Alene (Idaho, USA)*

ELCOM/CAEDYM is being applied to investigate the trade-off between reducing heavy metal concentrations and a potential increase in eutrophication due to remediation procedures in Lake Coeur D'Alene, Idaho. In order to investigate heavy metal fate and transport, CAEDYM is being improved further to include heavy metals and a feedback loop to phytoplankton based on metal toxicity (Antenucci, 2004).

A.1.3.2.10 *Seawater Desalination at Encina (California, USA)*

Flow Science conducted ELCOM modeling in 2004-2006 for a proposed desalination facility to be sited adjacent to the Encina Power Plant in Carlsbad, California. The proposed Encina facility involved source water taken from inside Agua Hedionda Lagoon and discharge of brines with the power plant cooling water via a surface channel across the beach south of the lagoon mouth. Flow Science used both a fine grid model to simulate water quality and dilution local to the intake and outfall and a larger grid model to simulate the effect of treated wastewater discharges and ocean currents and tides in the ocean near the lagoon. For the Encina study, Flow Science also used ELCOM to predict mixing in the vicinity of the plant discharge. The study area encompassed about 100 square miles of the ocean and also included some inland lagoons. The model resolved various tidal conditions and plant operating scenarios. The model compared favorably to existing oceanic data in the vicinity of the discharge.

A.1.3.2.11 *Moss Landing Desalination Project (California, USA)*

Flow Science applied ELCOM to simulate the flow and mixing in the entire Monterey Bay, including Elkhorn Slough. The purpose of the modeling was to evaluate the impacts of the proposed Moss Landing Desalination facility on receiving waters. The desalination facility was proposed to utilize a nearby existing power plant intake in Moss Landing Harbor and discharge to the ocean via the power plant's existing outfall, which is a submerged outfall located in Monterey Bay offshore of the harbor entrance. The ELCOM model resolved the details of the mixing in the vicinity of the power plant/desalination facility combined discharge. The model results compared favorably to existing measured water quality parameters. The results were used to determine compliance with water quality regulations for the combined outfall. The study was performed in 2004-2006.

A.1.3.2.12 *Lake Perris (California, USA)*

In 2005, ELCOM was applied to Lake Perris in order to compare the impacts of several recreational use strategies on measured fecal coliform concentrations at the reservoir outlet tower. The physical results of the simulation were validated against measured temperature and salinity data over a one-year period. The comparison of fecal coliform concentrations against measured data was fair due to a lack of data describing the timing and magnitude of loading and the settling and re-suspension of fecal matter.

The ELCOM model was expanded in 2006 - 2007 to include CAEDYM in order to evaluate the performance of a proposed hypolimnetic oxygenation system and observed

water quality benefits. The model was calibrated against two years of historical data and used to assess the magnitude and extent of oxygenation in the hypolimnion as a result of system operation. Impacts on dissolved oxygen concentrations and nutrient dynamics and algal production potential (as represented by chlorophyll *a*) were also evaluated, and recommendations were provided for final design of the system. The project has not yet been constructed due to seismic safety risks with the dam that must first be addressed.

A.1.3.2.13 *Lake Hodges and Olivenhain Reservoir (California, USA)*

The San Diego County Water Authority (SDCWA) is planning a tunnel connection between Lake Hodges and Olivenhain Reservoir. The tunnel and an associated hydroelectric turbine will allow for operation of the two reservoirs as part of a pumped storage project. Due to the difference in water quality between the two reservoirs, the SDCWA was concerned that the planned pumped storage project could adversely impact water quality in Olivenhain Reservoir. In order to evaluate the water quality impacts of the planned pumped storage operations on Olivenhain Reservoir, Flow Science developed a coupled ELCOM model of the two reservoirs in 2007-2008 to simulate temperature and salinity and several tracers in order to characterize the extent of mixing of the pumped storage inflow water from Lake Hodges within Olivenhain Reservoir and the percentages of Lake Hodges and Olivenhain Reservoir water throughout each reservoir due to the pumped storage operations and subsequent mixing.

A.1.3.2.14 *Lower San Gabriel River, Intake Channel, and Alamitos Bay (California, USA)*

The Los Angeles Department of Water and Power (LADWP) Haynes Generating Station (HnGS) and AES Generating Station (AES) each utilize three outfalls located on the east and west bank of the Lower San Gabriel River, respectively, and discharge cooling water to the Lower San Gabriel River Flood Control Channel (LSGR). Flow Science conducted ELCOM modeling from 2003-2010 to evaluate the mixing of flows within the river channel and found that, under typical operating conditions, the cooling water discharges form a “barrier” between freshwater from the upstream river channel and ocean water downstream of the LSGR. Both modeling and field work (conducted by others) confirmed that the net direction of flow downstream of HnGS and AES is downstream, even during flood tide conditions. Flow Science’s modeling also evaluated temperature, salinity, and mixing in the LSGR for a wide range of potential future conditions and for hypothetical conditions in which both HnGS and AES cooling water flows are removed from the LSGR. Water quality in the adjacent Alamitos Bay, which is strongly influenced by flushing induced by cooling water flows from HnGS and AES, was also evaluated using ELCOM. In addition, Flow Science used CAEDYM to evaluate

nutrient concentrations, algae, and dissolved oxygen within the Bay for a range of actual and potential future operating conditions. The HnGS Intake Channel (which connects Alamitos Bay to HnGS) was also evaluated with ELCOM/CAEDYM.

Results of the Flow Science analyses have been used by LADWP in NPDES permit discussions with the Regional Water Board, in CEQA evaluations supporting the potential future repowering of HnGS Units 5 and 6, and in comments on the State's draft Once-Through Cooling (OTC) policy.

A.1.3.2.15 *Joint Water Pollution Control Plant Outfall Evaluation (California, USA)*

The Sanitation Districts of Los Angeles County (LACSD) are conducting a detailed study to evaluate the feasibility of a proposed new ocean outfall to carry treated wastewater from the Joint Water Pollution Control Plant (JWPCP) in Carson, California, to an ocean discharge location off the southern California coast near the Palos Verdes and San Pedro Shelves. As part of the Feasibility Study, Flow Science developed an ELCOM model in 2007 to evaluate the impact of this proposed ocean outfall. The near-field effluent discharge model, NRFIELD2, coupled with the far field hydrodynamic model, ELCOM, was used to simulate the mixing and determine the concentrations of a conservative effluent tracer and various indicator bacteria (assuming no chlorination). The coupled model was validated using measured current and temperature data in the vicinity of the potential discharge sites. The water quality impacts of five proposed diffuser discharge sites were evaluated, and the modeling results will be used by LACSD to estimate concentrations of indicator bacteria at selected locations at the shore and inshore regions that would result from a discharge without chlorination. Ongoing ELCOM modeling will be performed to assist LACSD in selecting a preferred diffuser location. An example of the simulated effluent tracer concentrations during summer for one of the potential diffuser sites is presented in **Figure A.6** below.

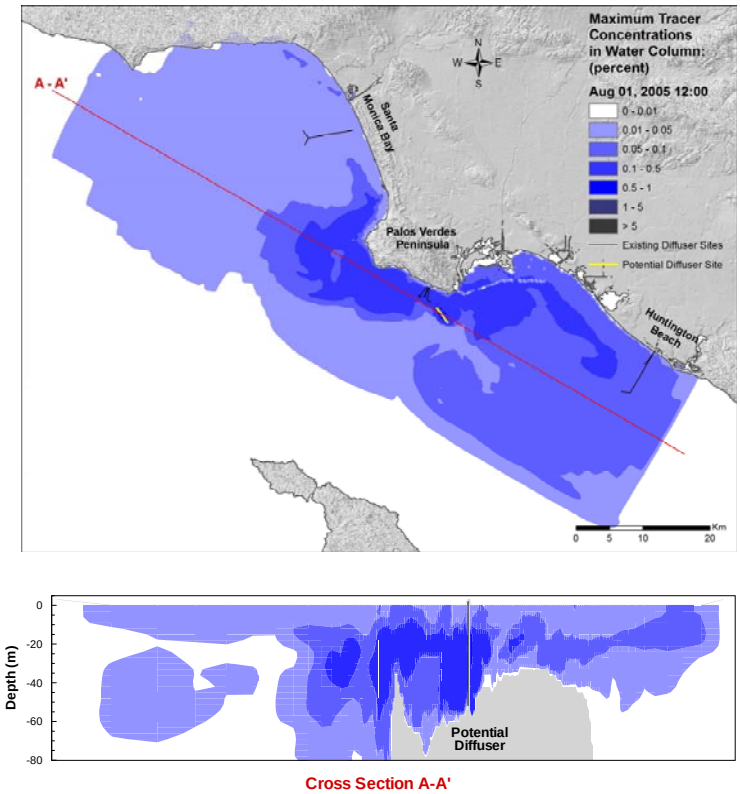

Figure A.6 Plan and section views of ELCOM simulated effluent tracer concentrations from proposed diffuser Site 1 in summer (August 1, 2005).

A.1.3.2.16 *San Vicente Reservoir (California, USA)*

Flow Science is assisting the City of San Diego in assessing the mixing and dilution potential resulting from the potential injection of highly treated effluent into San Vicente Reservoir. In 2010, Flow Science developed an ELCOM/CAEDYM model to assess the mixing and dispersion properties in San Vicente Reservoir as well as a field program to validate the modeling. The ELCOM/CAEDYM model includes temperature, salinity, conductivity, dissolved oxygen, nutrients, chlorophyll *a* (as a surrogate for algae), and multiple tracers. The model provides an accurate three-dimensional representation of water quality within the reservoir. The model was calibrated for the reservoir at its

current capacity against two years of historical data. The calibrated model has since been applied to the expanded reservoir to evaluate the impacts of the advanced water treatment (AWT) water. The model is being used to predict water quality conditions in the future enlarged reservoir and will also be used to help manage water quality in the enlarged reservoir once it is filled. The work is being reviewed by an expert panel being overseen by the National Water Research Institute. The panel is expected to complete its review and accept the use of the modeling.

A.1.3.2.17 *Los Vaqueros Reservoir (California, USA)*

In conjunction with the Contra Costa Water District (CCWD), Flow Science developed a three-dimensional ELCOM/CAEDYM model of Los Vaqueros Reservoir beginning in 2006 that is capable of providing an accurate, three-dimensional representation of water quality including temperature, salinity/TDS, nutrients and algae. The ELCOM model was calibrated against two years of historical data and validated against four years of data, while the CAEDYM model was calibrated for four years of historical data. **Figure A.7** shows a comparison of the measured versus simulated annual and growing season average chlorophyll *a* concentrations which show very good agreement. In ongoing work, Flow Science is using the ELCOM/CAEDYM model to evaluate the water quality of the reservoir under future conditions where the impounding dam is raised. This will expand the capacity of the reservoir from 100,000 acre-ft to 160,000 acre ft. The water quality model is being used to determine the changes in outflow water quality resulting from the expansion and to provide preliminary design recommendations for the inlet/outlet facilities with respect to improving water quality.

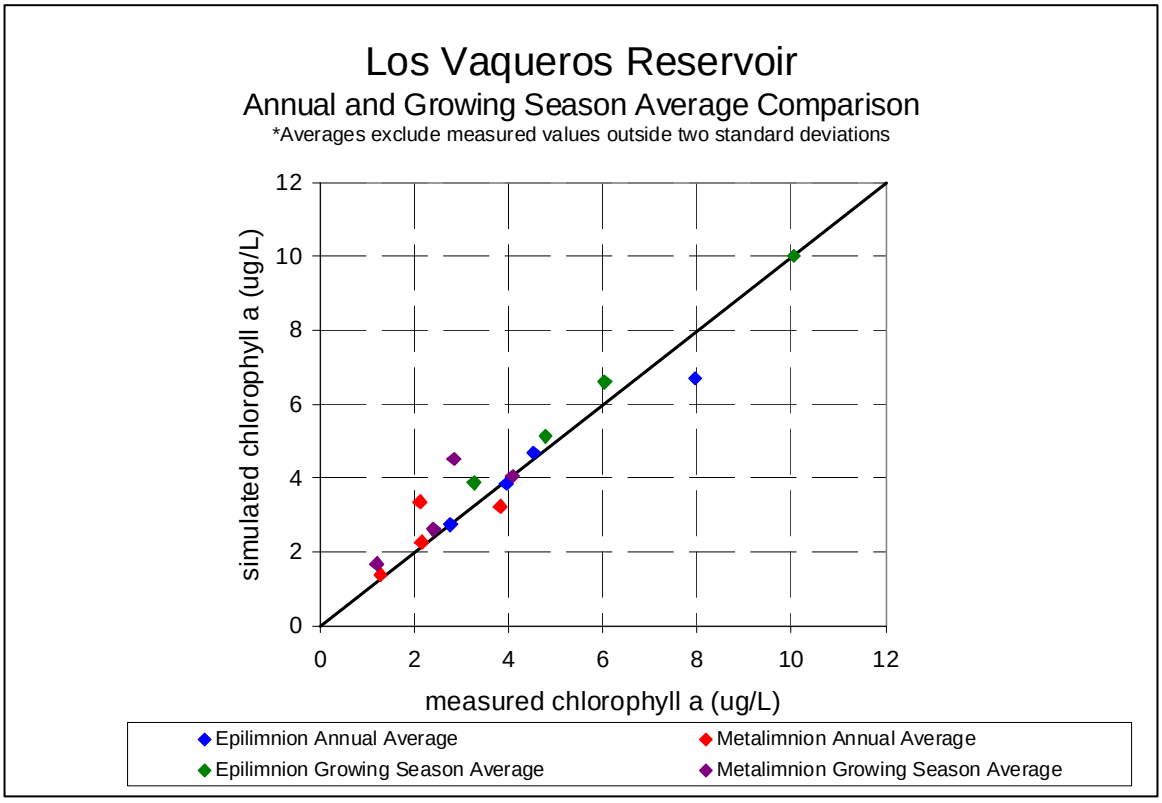

Figure A.7 Comparison of simulated ELCOM/CAEDYM results and measured chlorophyll *a* data for 2006-2009.

A.1.3.2.18 *Other Applications*

Other ELCOM/CAEDYM applications and development in on-going research at CWR include:

- Plume dynamics and horizontal dispersion (Marmion Marine Park, Australia).
- Inflow and pathogen dynamics (Helena, Myponga and Sugarloaf Reservoirs, Australia).
- Mixing and dissipation in stratified environments (Tone River, Japan, and Brownlee Reservoir, USA).

- Tidally forced estuaries and coastal lagoons (Marmion Marine Park and Barbamarco Lagoon, Italy).
- Three-dimensional circulation induced by wind and convective exchange (San Roque Reservoir, Argentina, and Prospect Reservoir, Australia).
- Sea-surface temperature fluctuation and horizontal circulation (Adriatic Sea).
- Response of bivalve mollusks to tidal forcing (Barbamarco Lagoon, Italy).

A.1.4 TECHNICAL DESCRIPTION OF ELCOM

As outlined above, ELCOM solves the unsteady, viscous Navier-Stokes equations for incompressible flow using the hydrostatic assumption for pressure. ELCOM can simulate the hydrodynamics and thermodynamics of a stratified system, including baroclinic effects, tidal forcing, wind stresses, heat budget, inflows, outflows, and transport of salt, heat and passive scalars. Through coupling with the CAEDYM water quality module, ELCOM can be used to simulate three-dimensional transport and interactions of flow physics, biology, and chemistry. The hydrodynamic algorithms in ELCOM are based upon the proven semi-Lagrangian method for advection of momentum with a conjugate-gradient solution for the free-surface height (Casulli and Cheng, 1992) and a conservative ULTIMATE QUICKEST transport of scalars (Leonard, 1991). This approach is advantageous for geophysical-scale simulations since the time step can be allowed to exceed the Courant-Friedrichs-Lewy (CFL) condition for the velocity without producing instability or requiring a fully-implicit discretization of the Navier-Stokes equations.

A.1.4.1 Governing Equations

Significant governing equations and approaches used in ELCOM include:

- Three-dimensional simulation of hydrodynamics (unsteady Reynolds-averaged Navier-Stokes equations).
- Advection and diffusion of momentum, salinity, temperature, tracers, and water quality variables.
- Hydrostatic approximation for pressure.
- Boussinesq approximation for density effects.

- Surface thermodynamics module accounts for heat transfer across free surface.
- Wind stress applied at the free surface.
- Dirichlet boundary conditions on the bottom and sides.

A.1.4.2 Numerical Method

Significant numerical methods used in ELCOM include:

- Finite-difference solution on staggered-mesh Cartesian grid.
- Implicit volume-conservative solution for free-surface position.
- Semi-Lagrangian advection of momentum allows time steps with CFL > 1.0.
- Conservative ULTIMATE QUICKEST advection of temperature, salinity, and tracers.
- User-selectable advection methods for water quality scalars using upwind, QUICKEST, or semi-Lagrangian to allow trade-offs between accuracy and computational speed.
- Solution mesh is Cartesian and allows non-uniformity (*i.e.* stretching) in horizontal and vertical directions.

The implementation of the semi-Lagrangian method in Fortran 90 includes sparse-grid mapping of three-dimensional space into a single vector for fast operation using array-processing techniques. Only the computational cells that contain water are represented in the single vector so that memory usage is minimized. This allows Fortran 90 compiler parallelization and vectorization without platform-specific modification of the code. A future extension of ELCOM will include dynamic pressure effects to account for nonlinear dynamics of internal waves that may be lost due to the hydrostatic approximation.

Because the spatial scales in a turbulent geophysical flow may range from the order of millimeters to kilometers, it is presently impossible to conduct a Direct Navier-Stokes (DNS) solution of the equations of motion (*i.e.* an exact solution of the equations). Application of a numerical grid and a discrete time step to a simulation of a geophysical domain is implicitly a filtering operation that limits the resolution of the equations.

Numerical models (or closure schemes) are required to account for effects that cannot be resolved for a particular grid or time step. There are four areas of modeling in the flow physics: (l) turbulence and mixing, (2) heat budgets, (3) hydrodynamic boundary conditions, and (4) sediment transport.

A.1.4.3 Turbulence Modeling and Mixing

ELCOM presently uses uniform fixed eddy viscosity as the turbulence closure scheme in the horizontal plane (in future versions a Smagorinsky 1963 closure scheme will be implemented to represent subgrid-scale turbulence effects as a function of the resolves large-scale strain-rates). These methods are the classic "eddy viscosity" turbulence closure. With the implementation of the Smagorinsky closure, future extensions will allow the eddy-viscosity to be computed on a local basis to allow improvements in modeling local turbulent events and flow effects of biological organisms (e.g., drag induced by macroalgae or seagrass).

In the present code, the user has the option to extend the eddy-viscosity approach to the vertical direction by setting different vertical eddy-viscosity coefficients for each grid layer. However, in a stratified system, this does not adequately account for vertical turbulent mixing that may be suppressed or enhanced by the stratification (depending on the stability of the density field and the magnitude of the shear stress). To model the effect of density stratification on turbulent mixing the CWR has developed a closure model based on computation of a local Richardson number to scale. The latter is generally smaller than the time step used in geophysical simulations, so the mixing is computed in a series of partial time steps. When the mixing time-scale is larger than the simulation time step, the mixing ratio is reduced to account for the inability to obtain mixing on very short time scales. This model has the advantage of computing consistent mixing effects without regard to the size of the simulation time-step (*i.e.* the model produces mixing between cells that is purely a function of the physics and not the numerical step size).

A.1.4.4 Heat Budget

The heat balance at the surface is divided into short-wave (penetrative) radiation and a heat budget for surface heat transfer effects. The surface heat budget requires user input of the net loss or gain through conduction, convection, and long wave radiation in the first grid layer beneath the free surface. The short wave range is modeled using a user-prescribed input of solar radiation and an exponential decay with depth that is a function of a bulk extinction coefficient (a Beer's law formulation for radiation absorption). This coefficient is the sum of individual coefficients for the dissolved

organics ("gilvin"), phytoplankton biomass concentration, suspended solids, and the water itself. The extinction coefficients can either be computed in the water quality module (CAEDYM) or provided as separate user input.

A.1.4.5 Hydrodynamic Boundary Conditions

The hydrodynamic solution requires that boundary conditions on the velocity must be specified at each boundary. There are six types of boundary conditions: (1) free surface, (2) open edge, (3) inflow-outflow, (4) no-slip, (5) free-slip, and (6) a Chezy-Manning boundary stress model (the latter is presently not fully implemented). For the free surface, the stress due to wind and waves is required. The user can either input the wind/wave stress directly, or use a model that relates the surface stress to the local wind speed and direction *via* a bulk aerodynamic drag coefficient. Open boundaries (e.g. tidal inflow boundaries for estuaries) require the user to supply the tidal signature to drive the surface elevation. Transport across open boundaries is modeled by enforcing a Dirichlet condition on the free-surface height and allowing the inflow to be computed from the barotropic gradient at the boundary. Inflow-outflow boundary conditions (e.g. river inflows) are Dirichlet conditions that specify the flow either at a particular boundary location *or inside the domain*. Allowing an inflow-outflow boundary condition to be specified for an interior position (*i.e.* as a source or sink) allows the model to be used for sewage outfalls or water outlets that may not be located on a land boundary. Land boundaries can be considered zero velocity (no-slip), zero-flux (free-slip) or, using a Chezy-Manning model, assigned a computed stress.

A.1.4.6 Sediment Transport

While sediment transport is fundamentally an issue of flow physics, the algorithms for the sediment transport are more conveniently grouped with the water quality algorithms in CAEDYM. Settling of suspended particulate matter is computed using Stokes law to obtain settling velocities for the top and bottom of each affected grid cell. This allows the net settling flux in each cell to be computed. A two-layer sediment model has been developed that computes resuspension, deposition, flocculation, and consolidation of sediment based on (1) the shear stress at the water/sediment interface, (2) the type of sediment (cohesive/non-cohesive), and (3) the thickness of the sediment layer. Determination of the shear stress at the water/sediment interface requires the computation of bottom shear due to current, wind, and waves. A model has been developed to account for the effects of small-scale surface waves that cannot be resolved on a geophysical-scale grid. This model computes the theoretical wave height and period for small-scale surface waves from the wind velocity, water depth, and domain fetch. From these, the wavelength and orbital velocities are calculated. The wave-induced shear

stress at the bottom boundary resulting from the wave orbital velocities is combined with a model for the current-induced shear stress to obtain the total bottom shear that effects sediment resuspension. The cohesiveness of the sediment determines the critical shear stresses that are necessary to resuspend or deposit the sediments. A model of consolidation of the sediments is used to remove lower sediment layers from the maximum mass that may be resuspended.

A.1.5 TECHNICAL DESCRIPTION OF CAEDYM

CAEDYM is an outgrowth of previous CWR water quality modules in DYRESM-WQ and the Estuary Lake Model - Water Quality (ELMO-WQ) codes. CAEDYM is designed as a set of subroutine modules that can be directly coupled with one, two, or three-dimensional hydrodynamic "drivers", catchment surface hydrological models, or groundwater models. Additionally, it can be used in an uncoupled capacity with specification of velocity, temperature, and salinity distributions provided as input files rather than as part of a coupled computation. The user can specify the level of complexity in biogeochemical process representation so both simple and complex interactions can be studied. Direct coupling to a hydrodynamic driver (e.g. ELCOM) allows CAEDYM to operate on the same spatial and temporal scales as the hydrodynamics. This permits feedbacks from CAEDYM into ELCOM for water quality effects such as changes in light attenuation or effects of macroalgae accumulation on bottom currents. **Figure A.8** shows an illustration of the interactions of modeled parameters in CAEDYM. Being an “N-P-Z” (nutrient-phytoplankton-zooplankton) model, CAEDYM can be used to assess eutrophication. Unlike the traditional general ecosystem model, CAEDYM serves as a species- or group-specific model (*i.e.* resolves various phytoplankton species). Furthermore, oxygen dynamics and several other state variables are included in CAEDYM.

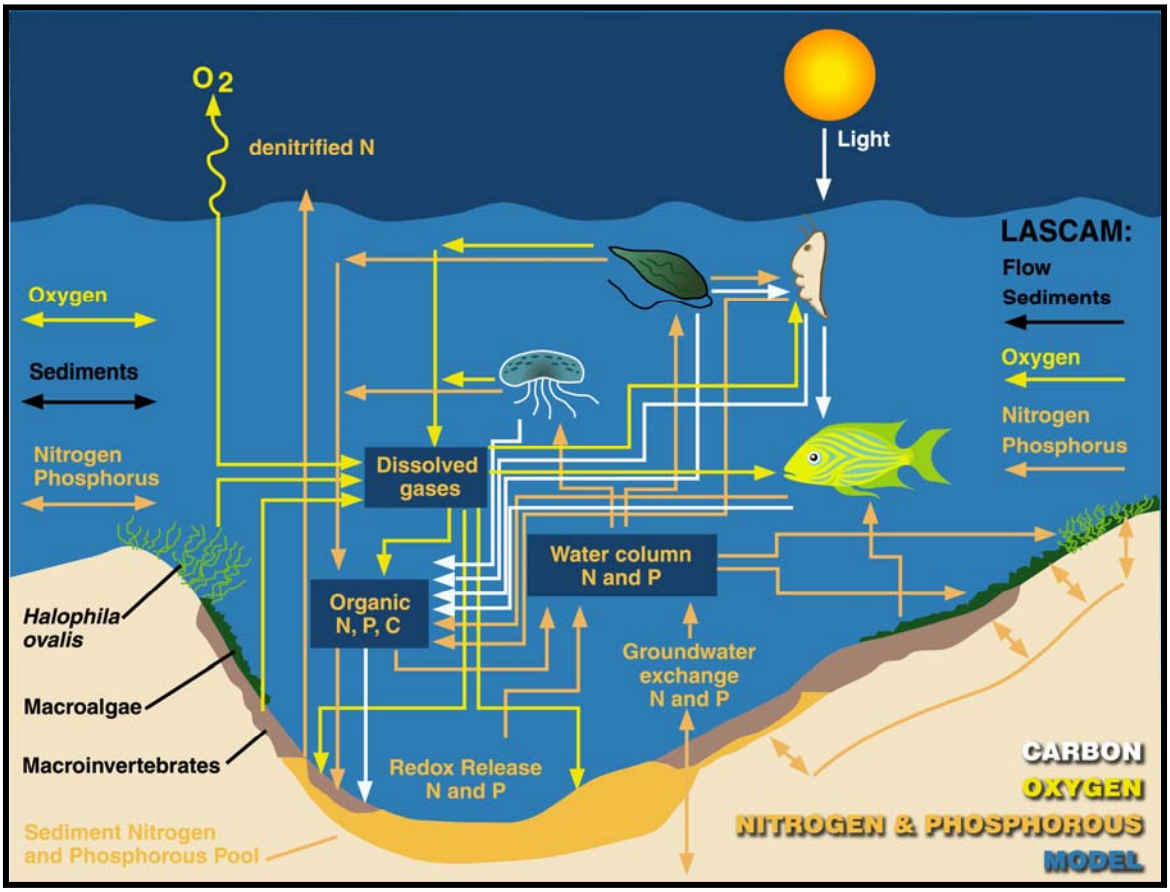

Figure A.8 Illustration of interactions of modeled parameters in CAEDYM.

The representation of biogeochemical processes in ecological models has, historically, been treated in a simple manner. In fact, the pioneering work on modeling marine ecosystems (Riley et al, 1949; Steel, 1962) is still used as a template for many of the models that are currently used (Hamilton and Schladow, 1997). The level of sophistication and process representation included in CAEDYM is of a level hitherto unseen in any previous aquatic ecosystem model. This enables many different components of the system to be examined, as well as providing a better representation of the dynamic response of the ecology to major perturbations to the system (e.g. the response to various management strategies). **Figure A.9** shows the major state variables included in the CAEDYM model. Using CAEDYM to aid in management decisions and system understanding requires (1) a high level of process representation, (2) process

interactions and species differentiation of several state variables, and (3) applicability over a spectrum of spatial and temporal scales. The spectrum of scales relates to the need for managers to assess the effects of temporary events, such as anoxia at specific

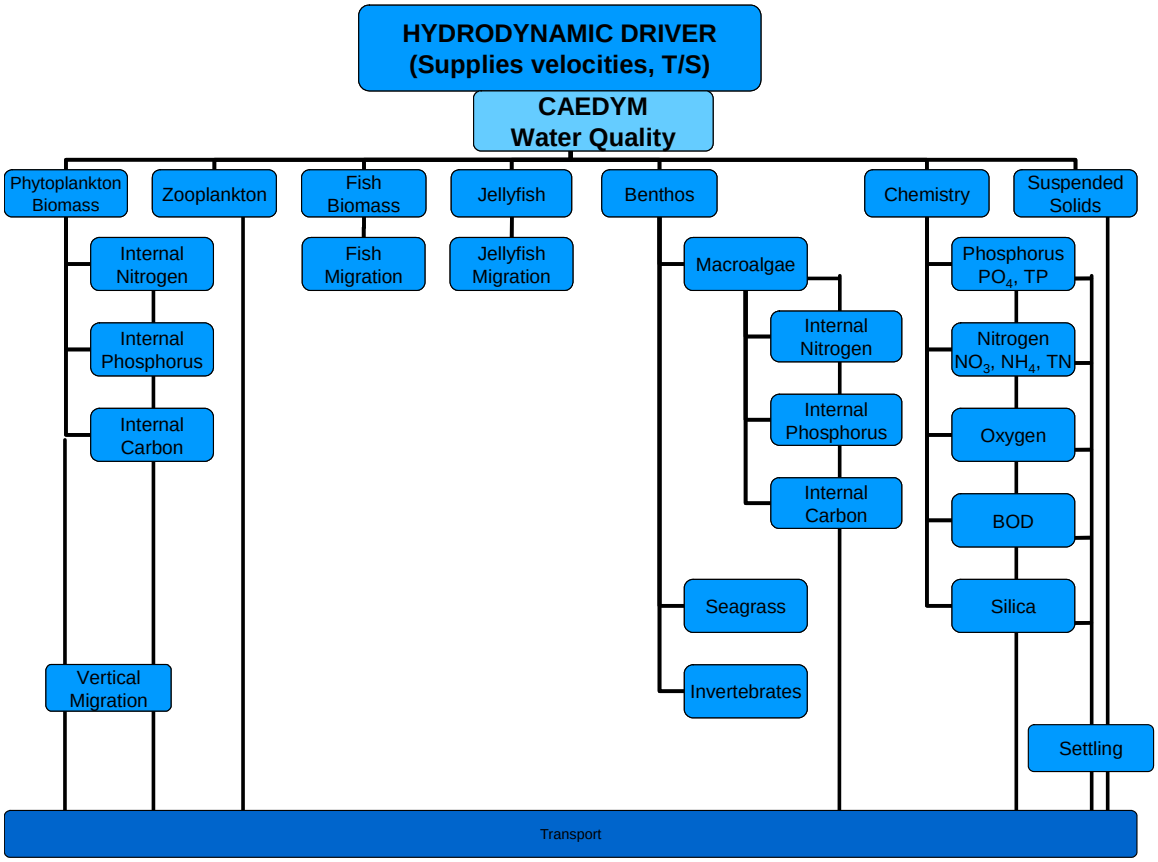

Figure A.9 Major state variables included in the CAEDYM model.

locations, through to understanding long-term changes that may occur over seasons or years. There is considerable flexibility in the time step used for the ecological component. Long time steps (relative to the hydrodynamic advective scale) may be used to reduce the frequency of links to ELCOM when long-term (*i.e.* seasonal or annual) simulations are run.

A.1.5.1 Biological Model

The biological model used in CAEDYM consists of seven phytoplankton groups, five zooplankton groups, six fish groups, four macroalgae groups and three invertebrate groups, as well as models of seagrass and jellyfish. This set will be expanded as biological models are developed, tested, and calibrated to field data. There is flexibility for the user in choosing which species to include in a simulation. Vertical migration is simulated for motile and non-motile phytoplankton, and fish are migrated throughout the model domain according to a migration function based on their mortality. A weighted grazing function is included for zooplankton feeding on phytoplankton and fish feeding on zooplankton. The biomass grazed is related to both food availability and preference of the consumer for its food supply. Improved temperature, respiration and light limitation functions have been developed to represent the environmental response of the organisms. The benthic processes included a self-shading component and beach wrack function for macroalgae, sediment bioturbation and nutrient cycling by polychaetes, and effects of seagrass on sediment oxygen status.

In particular, the seven phytoplankton groups modeled are dinoflagellates, freshwater diatoms, marine/estuarine diatoms, freshwater cyanobacteria, marine estuarine cyanobacteria, chlorophytes, and cryptophytes. Phytoplankton biomass is represented in terms of chlorophyll *a*. Phytoplankton concentrations are affected by the following processes:

- Temperature growth function
- Light limitation
- Nutrient limitation by phosphorus and nitrogen (and when diatoms are considered, silica)
- Loss due to respiration, natural mortality, excretion, and grazing
- Salinity response
- Vertical migration and settling

A.1.5.2 Nutrients, Metals, and Oxygen Dynamics

The transport and chemical cycling of nutrients is an important part of simulating the interaction of biological organisms in an ecosystem. CAEDYM includes as state variables the following:

- Nutrients (dissolved inorganic phosphorus, total phosphorus, total nitrogen, ammonium nitrate, and silica).
- Dissolved oxygen and biochemical oxygen demand.
- Metals (dissolved and particulate forms of iron and manganese).
- Suspended sediment (the particulate and colloidal fractions).
- pH

The model incorporates oxygen dynamics and nutrient cycling in both the sediments and water column. A sediment pool of organic detritus and inorganic sediments, both of which may be resuspended into the water column, is included. Redox-mediated release of dissolved nutrients is simulated from the sediments to the water column.

Processes included in the water and sediment oxygen dynamics include:

- Atmospheric exchange (Wanninkhof, 1992).
- Oxygen production and consumption through phytoplankton, macroalgae, and seagrass/macrophyte photosynthesis and respiration, respectively.
- Utilization of dissolved oxygen due to respiration of higher organisms such as zooplankton and fish and due to photosynthesis and respiration in jellyfish
- Water column consumption of oxygen during nitrification.
- Biochemical oxygen demand due to mineralization of organic matter in the water column and in the sediments.

Oxygen flux from the water column to the sediments, sediment oxygen demand (SOD), as developed from Fick's law of diffusion.

The last two processes are used together with a sediment porosity and diffusion coefficient (Ullman and Aller, 1982) in order to define the depth of the toxic layer in the sediments.

Nutrient processes included in the sediment and water column dynamics include:

- Phytoplankton nutrient uptake, with provision for luxury storage of nutrients.
- Release of dissolved inorganic nutrients from phytoplankton excretion.
- Excretion of nutrients as fecal material by zooplankton.
- Nitrification and denitrification by bacterial mediated action.
- Generation of inorganic nutrients from organic detritus.
- Transfer of nutrients through the food chain (e.g. phytoplankton--zooplankton--fish).
- Uptake of nutrients by macroalgae and seagrasses.
- Adsorption/desorption of nutrients from inorganic suspended sediments.
- Sediment/water transfer of nutrients (*via* such processes as sediment resuspension, sedimentation, redox-mediated nutrient release, and bioturbation).

In essence, CAEDYM represents the type of interactive processes that occur amongst the ecological and chemical components in the aquatic ecosystem. As a broad generalization, one component of the system cannot be manipulated or changed within the model without affecting other components of the system. Similarly in nature, changing an integral component in the aquatic system will have wide-ranging and follow-on effects on many of the other system components. CAEDYM is designed to have the complexity and flexibility to be able to handle the continuum of responses that will be elicited as components of a system that are manipulated. Thus, the model represents a valuable tool to examine responses under changed conditions, as for example, when new approaches to managing an ecosystem are adopted.

A.2 DESCRIPTION OF ELCOM/CAEDYM/VISUAL PLUMES (ECP)

A.2.1 INTRODUCTION

Outfalls are commonly used to discharge treated effluent into open waters. The hydrodynamics of an effluent discharged through an outfall can be conceptualized as a mixing process occurring in two separate regions: a near-field region and a far-field region. In the near-field region the effluent generally experiences a significant amount of mixing, and dilution occurs very rapidly. In this region, the initial jet characteristics of momentum flux, buoyancy flux, flow rate, as well as outfall geometry greatly influence the effluent trajectory and degree of mixing (Fischer et al, 1979). As the effluent plume travels further away from the source, the source characteristics become less important and the far-field region is attained. Mixing of the effluent plume in this region is caused by spatial and temporal variations of ambient velocity fields and dilution generally occurs slowly over a long distance, but may be rapid if there is a high degree of turbulence in the environment.

Due to different dominant temporal and spatial scales of flow velocity and effluent concentration in the near and far field region, a complete model that accounts for all important spatial and temporal scales in both the near-field and far-field regions is not feasible. Instead, these two regions are usually treated by separate models termed the near-field model and the far-field model respectively.

The near-field model has been under intensive study from the 1950s through the early 1990s. Thorough reviews of these studies are provided by Fischer et al. (1979), Baumgartner et al. (1994), and Roberts et al. (1989 a, b, c). These studies have produced a number of near-field models that were verified by both field and laboratory data. Among them, Visual Plumes (VP or PLUMES), endorsed by the U.S. Environmental Protection Agency (USEPA), is the most popular model and has been widely used by regulatory agencies and outfall designers to estimate the near-field dilution.

A variety of models can be used to model far-field mixing processes. These include ELCOM/ CAEDYM, Princeton Ocean Model (POM), and MIT General Circulation Model (MITGCM). All of these models obtain a velocity field from the numerical calculation of the equations of motion and account for influences by tide, wind stress, and pressure gradient due to free surface gradients (barotropic) or density gradients (baroclinic). Given the velocity field, the pollutant concentration field is

typically obtained by solving the Eulerian advective diffusion equation in three dimensions or by using the Lagrangian particle-tracking method.

In simple water bodies with well-defined uni-directional current regimes, the use of near-field models alone may suffice to evaluate a design of an outfall discharge that meets regulations. However, in regions with multiple current regimes (inertial, tide, wind, and buoyancy driven) and with large pollutant loadings, especially where several sources may interact, near-field models must be supplemented by far-field transport and water quality models. The latter are capable of prediction, over a greater distance in the water body, of the concentration distributions for different pollutants, nutrients, and other bio-chemical parameters. They do not, however, have the high spatial resolution that is required to predict near-field mixing processes. Thus, a coupled approach is necessary. In the following sections, a method of coupling the near-field model PLUMES and the far-field model ELCOM/CAEDYM is discussed. The coupled code is referred to as ELCOM/CAEDYM/PLUMES (ECP). Note that there is no standard procedure for the coupling of near and far field models and the coupling procedure varies from code to code mainly because of the different code structures among all of the near-field and far-field models.

A.2.2 NEAR-FIELD MODEL – PLUMES

PLUMES is an interface program that contains the near-field models such as the Roberts, Snyder, and Baumgartner model (RSB) and UM and CORnell MIXing Zone Expert System (CORMIX) (Baumgartner et al., 1994). In ECP, the UM model is chosen to simulate near-field dilution. The UM model is an integral near-field model that uses one-dimensional conservation equations for mass, momentum, salinity and temperature, to model the growth of the plume once the effluent has left the port. Assumptions are made about the shape of the plume and the distribution of pollutant concentration within the plume. Several mechanisms of entrainment such as aspirated, forced, and turbulent diffusion are considered. Both positively and negatively buoyant plumes, single source and multi-port diffuser configurations can be modeled. Model outputs include average dilution, centerline dilution, and horizontal distance of the effluent plume. The major limitation of UM lies in the assumption of an infinite receiving water body, similar to all other available integral-type models (e.g. RSB model). Thus, UM should only be used for deep-water outfalls without boundary interactions. More details on UM and PLUMES can be found in Baumgartner et al. (1994).

A.2.3 FAR-FIELD MODEL – ELCOM/CAEDYM

ELCOM is a three-dimensional hydrodynamic model for lakes and reservoirs and is used to predict the velocity, temperature, and salinity distribution in natural water bodies subjected to external environmental forcing, such as wind stress, surface heating, or cooling. Through coupling with the CAEDYM water quality module, ELCOM can be used to simulate three dimensional transport and interactions of flow physics, biology, and chemistry. ELCOM/CAEDYM is the chosen far-field model in ECP.

A.2.4 COUPLING PLUMES AND ELCOM/CAEDYM

The adopted coupling procedure is based on four steps: ambient conditions modeling, near-field modeling, coupling of near-field and far-field models, and far-field modeling.

1. Ambient conditions modeling

   The near-field model, UM, needs the input of ambient conditions such as the prevailing velocity, temperature, and salinity profiles in the vicinity of the outfall. These profiles are extracted from the ELCOM/CAEDYM simulation at the beginning of a time step at a vertical column of grid cells containing or overlapping the diffuser (the "Diffuser Cell Column" in **Figure A.10**). The depth of the diffuser is also updated based on the surface elevation at that time step.

2. Near-field modeling

   The UM model is applied at each time step using the ambient conditions extracted from ELCOM/CAEDYM. Furthermore, effluent data is obtained from input files for ELCOM/CAEDYM, and the diffuser geometry is specified in the input file called "diffuser_config.dat." The UM model is modified to consider the trapping or surfacing of the plume as the end of the near-field region. The computed average dilution along the trajectory of the plume is then stored for the following coupling step.

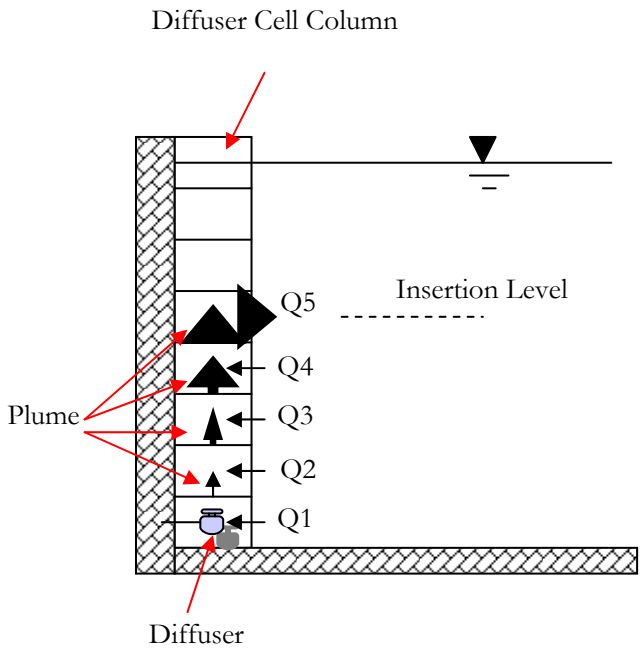

Figure A.10 Schematic of coupling procedure for near-field and far-field models.

3. Coupling of near-field and far-field models

After identifying the "Diffuser Cell Column" (**Figure A.10**), the dilution in each of the cells along this column can be calculated from the linear interpolation of results from UM. Water is then withdrawn from each of these cells based on the dilution occurring in the cell. This withdrawn water is then mixed with the effluent to form the effluent plume and passed to the cell above. Finally, the diluted effluent is then inserted into the cell where the UM model indicates the occurrence of trapping or surfacing (**Figure A.10**). Flow rate, temperature, salinity, and tracer concentrations within this inserted inflow are determined by mass conservation.

4. Far-field modeling

ELCOM/CAEDYM treats the previous coupling process as a series of outflows and inflows along the "Diffuser Cell Column" and proceeds with its time-marching far-field simulation for the time step. Steps 1 - 4 are then repeated for the next time step until the simulation ends.

A.2.5 VERIFICATION OF ECP

The UM model was originally written in TURBO PASCAL and was converted into FORTRAN and included in ECP. The comparison between the results from UM of PLUMES and UM of ECP shows an exact match (**Figure A.11**) and the conversion of the UM model is verified.

Output from UM Model of PLUMES

depth (m)	dilution (m)	horiz dis	
50.000	1.000	0.000	
49.761	1.971	0.005	
49.311	3.913	0.035	
48.585	7.797	0.127	
47.525	15.566	0.327	
46.035	31.104	0.696	
45.928	32.424	0.725	merging
43.228	62.180	1.529	
37.335	124.335	3.385	
25.609	248.651	7.517	
22.323	285.625	8.893	trap level
15.436	395.624	12.750	begin overlap, dilution overestimated
14.308	442.027	13.760	surface hit

Output from UM Model of ECP

depth (m)	dilution (m)	horiz dis	
50.000	1.000	0.000	
49.761	1.971	0.005	
49.311	3.913	0.035	
48.585	7.797	0.127	
47.525	15.566	0.327	
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22.323	285.625	8.893	trap level
15.436	395.624	12.750	begin overlap, dilution overestimated
14.308	442.027	13.760	surface hit

Figure A.11 Comparison of outputs from UM of PLUMES and ECP

Mass conservation within ECP was tested by simulating an idealized lake with a single outfall (inflow) and no outflow. Total mass of both a conservative tracer and total phosphorus (TP) in the lake was calculated at each time step and compared with a similar simulation using ELCOM/CAEDYM (where the outfall was treated as a single inflow). Less than 0.1% difference was found for the conservative tracer and less than 1% difference was found for TP at the end of a one-year simulation. These small differences indicate that mass conservation within the ECP code is comparable to that of ELCOM/CAEDYM.

The accuracy of ECP can also be qualitatively evaluated by simulating the behavior of a plume under stratified and unstratified ambient conditions. **Figure A.12** shows that ECP correctly predicts surfacing of the plume under unstratified conditions and the level of insertion of the plume under stratified conditions.

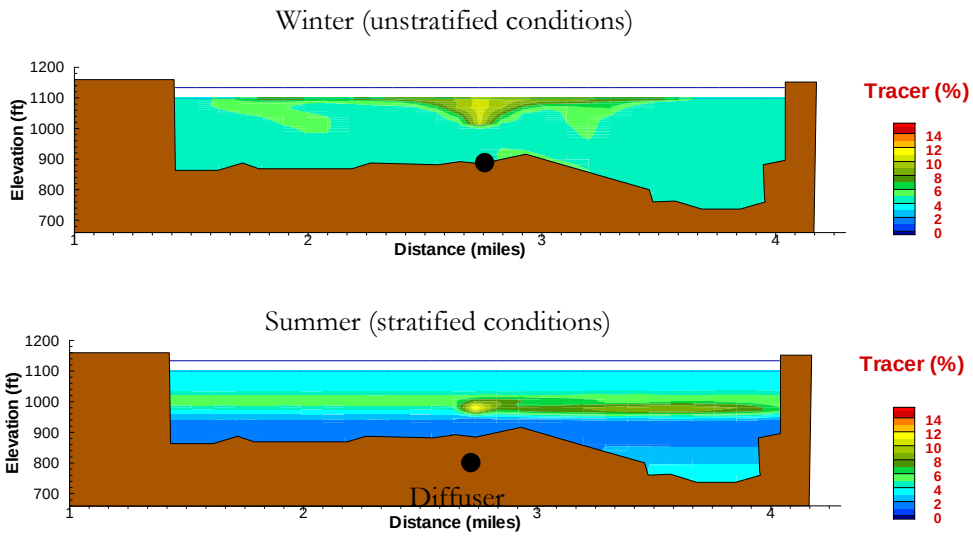

Figure A.12 Comparison of tracer concentrations released from an outfall under stratified and unstratified conditions using ECP.

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San Vicente Reservoir Proposed Water Quality Monitoring Program

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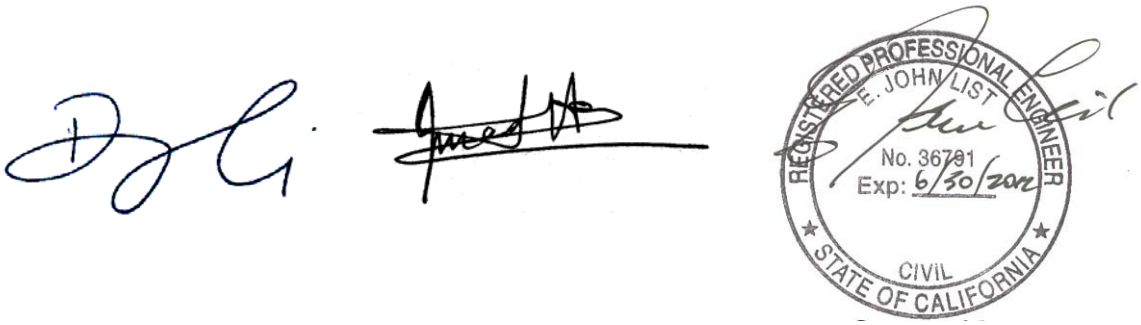

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1. INTRODUCTION

San Vicente Reservoir (SVR) is located near Lakeside, California, and is used as a source of drinking water supply by the City of San Diego (City), its owner and operator. The reservoir currently has a capacity of about 90,000 acre-feet (see **Figure 1**). It is undergoing an expansion that will raise the dam 117 feet and increase the reservoir's storage capacity to 247,000 acre-feet at the spillway level. The City is considering an option to augment the SVR supply by bringing advanced treated recycled water (*i.e.*, purified water) from an advanced water purification facility to SVR; *i.e.* an Indirect Potable Reuse / Reservoir Augmentation (IPR/RA) project. The purified water would be blended with other water in the reservoir. The current project – the Water Purification Demonstration Project (Demonstration Project) – will not actually put any purified water into the reservoir; rather it will study and model the reservoir augmentation process. A component of the Demonstration Project is the Limnology and Reservoir Detention Study of San Vicente Reservoir (Limnology Study).

As part of the Limnology Study, Flow Science Incorporated (FSI) has developed a numerical three-dimensional water quality model that is used to evaluate hydrodynamic and water quality effects of using purified water to augment SVR. After the model was developed its results were compared to existing field data. The results of this analysis were documented in a Technical Memorandum (TM #1) submitted to the City in 2010 (FSI, 2010). TM #1 has been peer-reviewed by the National Water Research Institute Independent Advisory Panel (IAP) that was assembled for the review of the City's Demonstration Project. After implementing suggestions proposed by the IAP, the model was deemed by IAP to be "an effective and robust tool, for 1) simulating thermoclines and hydrodynamics of the San Vicente Reservoir; 2) assessing biological water quality for nutrients; 3) assessing options for the purified water inlet location" (IAP, 2010).

Upon completion of the SVR model calibration and validation, FSI conducted simulations of purified water delivery to the expanded SVR under various projected future operating conditions using the calibrated and validated model. The simulation results and findings are presented in two separate Technical Memorandums (TM #2 and TM #3). TM #2 summarizes the hydrodynamic aspects of the modeling results and was submitted to the City on November 28, 2011 (FSI, 2011). TM #3 focuses on the water quality aspects of the modeling results and findings, with emphasis on nutrients (phosphorus and nitrogen), dissolved oxygen (DO), and algal productivity, and was submitted to the City on February 24, 2012 (FSI, 2012). Both TM#2 and TM#3 have been peer-reviewed by the IAP.

If SVR is augmented by purified water in the future, the three-dimensional model developed for the Limnology Study is expected to provide a tool for evaluating various reservoir management options, assessing residence time and dilution of the purified water within SVR, determining optimal reservoir operations for maximizing water quality, and

minimizing any potential short-circuiting between the inlet and outlet. It is expected that the model will be updated on a yearly basis using new data collected each year. In order to update the model and maintain it as a tool for assessing reservoir water quality and operations, data collection in the reservoir, as well as its inflows and outflows, will be needed. The goal of this document is to provide an outline of an initial reservoir monitoring plan to obtain these necessary data. Another goal of the monitoring plan is to identify monitoring efforts that may be needed to enhance water treatability and address future water quality regulatory issues. It is anticipated that this monitoring plan will be refined based on initial monitoring results and yet to be established regulatory requirements.

This memorandum is organized in four sections. Section 1 is this Introduction. Section 2 identifies the ongoing future data needs that are required to support the goals of the IPR/RA project. Such needs are deemed either "basic" or "optimal". Basic data needs refer to the minimum level of information required to support the goals of the project and future modeling. Optimal data needs define some additional monitoring efforts that may be required to support analysis of future regulatory issues, and to further enhance the water quality modeling ability.

Section 3 of this document identifies some special studies or monitoring efforts that are needed to enhance our understanding of the reservoir. Such studies are typically of short and limited duration. The specific goals of such studies are to clarify various reservoir mixing and water quality processes that can enhance the operational efficiency of the reservoir.

Section 4 of this document identifies data compilation and analysis needs that are necessary to the continuing success of the modeling effort and the understanding of water quality in the reservoir. A key proposed task is the compilation and archiving of all historical and future data (as they become available) into a central repository. After the data are archived, data analysis will be performed to identify various water quality trends. It is also recommended that a yearly data analysis report be issued as part of the future data collection effort.

2. SVR MONITORING PLAN

The SVR monitoring plan will include periodic sampling and measurement of physical, chemical, and biological parameters for inflows, outflows, and at in-reservoir locations. It also includes on-site measurements of meteorological data. Two alternate monitoring plans are proposed to match differing goals, resources, and funding. The "basic" monitoring plan is intended to meet minimum requirements for achieving the monitoring plan goals, while the "optimal" monitoring plan can provide a more comprehensive database to further improve understanding of the reservoir's limnology and enhance the water quality model with additional resources. The "optimal" monitoring plan is essentially an expanded version of the "basic" plan, but involves monitoring at more locations and reservoir depths, as well as more water quality parameters at a higher frequency.

Based on previous experience with modeling and analysis of historical data, the main interest in the spatial variability of water quality is expected to be along a path (i.e., a transect) connecting the location of the purified water discharge into the reservoir and the dam, as well as the path connecting San Vicente Creek (a main stream inflow with additional water transfer from Sutherland reservoir) and the dam. This expected variability was considered in selecting the in-reservoir monitoring stations. **Table 1** provides a list of proposed monitoring stations at the inflow locations, outflow locations, and in the reservoir. A map of these station locations is shown in **Figure 1**. It is noted that many of these stations have been monitored either routinely, or as part of the tracer studies that were performed in 1995 (FSI, 1995).

The selection of monitoring parameters depends on anticipated water quality issues. The important water quality parameters for SVR include metals, DO, nutrients (*i.e*., phosphorus and nitrogen) and associated biological productivity. Some additional physical, chemical, and biological parameters will also be measured to help with the basic understanding of the reservoir. Meteorological data are needed as they are important drivers for the water quality model.

The monitoring plan is divided into four categories: inflow monitoring, outflow monitoring, in-reservoir monitoring, and meteorological monitoring. The "optimal" and "basic" plans are proposed for each category and are discussed in greater detail in the following sections.

Table 1. SVR Monitoring Sites

Site #	Abbreviation	Type	Location	Notes
1	BAR	Inflow Station	Barona Creek	
2	SNC	Inflow Station	San Vicente Creek	Includes the water transfer from Sutherland
3	KIM	Inflow Station	Kimball Creek	Also known as West Fork San Vicente Creek
4	TOL	Inflow Station	Toll Road Creek	
5	AQA	Inflow Station	Aqueduct Creek	Aqueduct Creek is a natural water course. It is not to be confused with the First San Diego Aqueduct, which conveys imported water.
6	AQW	Inflow Station	The First San Diego Aqueduct	The imported water through the First San Diego Aqueduct
7	PWI	Inflow Station	Purified Water Inflow	Optional, can be replaced by using flow rate and water quality measured at the APWF effluent
8	SVPL	Outflow Station	Dam outflow	San Vicente Pipeline #1 downstream of dam
9	SVA	In-reservoir Station	Lat: 32.9129 Lon: -116.0250	Near the Dam, the original Station A currently sampled by the city
10	SVC	In-reservoir Station	Lat: 32.9225 Lon: -116.9221	Main body of the reservoir to the west of Lowell Island
11	SVG	In-reservoir Station	Lat: 32.9295 Lon: -116.9071	Main body of the reservoir to the east of Lowell Island
12	SVH	In-reservoir Station	Lat: 32.9400 Lon: -116.9097	In Kimball Arm and near the largest surface stream inflow, San Vicente Creek
13	SVN	In-reservoir Station	Lat: 32.9201 Lon: -116.9131	Near the Design Purified Water Inlet Location
14	SVWX East	Meteorological Station	On the east side of Lowell Island	Meteorology Station
15	SVWX West	Meteorological Station	On the west side of Lowell Island	Meteorology Station

2.1 INFLOW MONITORING

There are five surface streams that flow into SVR: Barona Creek, San Vicente Creek, Kimball Creek, Toll Road Creek, and Aqueduct Creek (Aqueduct Creek is different from the imported water inflow through the First San Diego Aqueduct). In addition, the imported water flows into SVR through the First San Diego Aqueduct (**Figure 1**). The water transfer from Sutherland Reservoir enters SVR through San Vicente Creek. Monitoring these inflows for water quantity and quality will be required in order to provide important input data for future modeling and water and nutrient loading calculations.

The list of suggested inflow monitoring parameters, locations, and monitoring frequency is provided in **Table 2** for the "basic" monitoring plan. Field measurements for parameters such as temperature and DO should be done *in situ* using a sonde (such as a YSI or Hydrolab profiler). For parameters that require laboratory analysis (such as nutrients, please refer to **Table 2**), discrete grab samples are required. Such samples would then be preserved and transferred to a laboratory for analysis. The purpose for monitoring certain parameters, listed in the table for reference, includes the need for model input, model verification, or water treatability. In the "basic" monitoring plan, the *in situ* measurements at the First San Diego Aqueduct (AQW) and San Vicente Creek (SNC) are suggested to be done continuously *i.e.*, daily or hourly results because the flows at these sites are more or less continuous and there is a man-made structure to locate autonomous monitoring equipment. The other four inflows (BAR, KIM, TOL, and AQA) have highly variable flows and are located in steep rocky natural channels. It is not possible to deploy autonomous monitoring equipment at these sites and each monitoring event is necessarily a stand-alone visit. It is suggested that monitoring be done monthly at these four creek inflows. For parameters that require laboratory analysis, monthly grab sampling is suggested for all inflow sites. This sampling frequency provides a modest resolution of the water quality's temporal variation in the inflows with relatively less resources required and a lower cost.

During wet-weather events (*i.e.*, storms), both flow and nutrient loadings may be large and highly variable. Thus, both flows and nutrient levels in the inflow need to be monitored during representative wet-weather events to characterize flow and nutrient loadings. A study of available historic precipitation data shows that there are a total of 8 days with daily precipitation greater than 0.5 inch between 10/26/2004 and 1/1/2008, a period of on-site precipitation data available to the authors, and they account for 10% of the total number of days with precipitation during this period. For the monitoring plan, it is suggested that a wet-weather event be defined as an event with expected daily precipitation greater than 0.5 inch. On average, it can be expected to have about two forecasted wet-weather events per year. It is suggested for the "basic" monitoring plan that up to two wet-weather events per year be monitored on an hourly basis. The specific parameters required to be monitored during wet-weather events for the "basic" monitoring plan are listed in **Table 2**. An alternative to the

hourly sampling of the inflows during wet-weather events is to use a flow-weighted composite sampling method. This involves using an autosampler to capture representative flow-weighted composite samples during wet-weather events. Details on this method can be found in Paulsen *et al*. (2011).

Table 2. Inflow Monitoring – Basic Plan

Parameter	Units	Preferred Detection Limit	Location	Frequency	Parameter Type	Purpose
Flow	cfs	±0.5	6 Locations[2]	Daily or monthly[1,3]	In-situ	Model Input
Temperature	°C	±0.10	6 Locations[2]	Daily or monthly[1,3]	In-situ	Model Input
Dissolved Oxygen [DO]	mg/L	±0.20	6 Locations[2]	Daily or monthly[1,3]	In-situ	Model Input
pH	N/A	±0.20	6 Locations[2]	Daily or monthly[1,3]	In-situ	Model Input
Oxidation-Reduction Potential [ORP]	mV	±20	6 Locations[2]	Daily or monthly[1,3]	In-situ	Model Input
Electrical Conductivity [EC]	mS/cm	±0.5%	6 Locations[2]	Daily or monthly[1,3]	In-situ	Model Input
Specific Conductance	mS/cm	±0.01	6 Locations[2]	Daily or monthly[1,3]	In-situ	Model Input
Total Dissolved Solids [TDS]	mg/L	±1	6 Locations[2]	Daily[1] or monthly[1,3]	In-situ	Model Input
Total Nitrogen [TN]	mg/L	0.05	6 Locations[2]	Monthly[1]	Grab Sample	Model Input
Total Phosphorus [TP]	mg/L	0.01	6 Locations[2]	Monthly[1]	Grab Sample	Model Input
Nitrate [NO_3]	mg/L	0.05	6 Locations[2]	Monthly[1]	Grab Sample	Model Input
Nitrite [NO_2]	mg/L	0.05	6 Locations[2]	Monthly[1]	Grab Sample	Model Input
Ammonia [NH_4]	mg/L	0.02	6 Locations[2]	Monthly[1]	Grab Sample	Model Input
Orthophosphate [PO_4]	mg/L	0.01	6 Locations[2]	Monthly[1]	Grab Sample	Model Input
SRP	mg/L	0.01	6 Locations[2]	Monthly[1]	Grab Sample	Model Input
TOC	mg/L	0.01	6 Locations[2]	Monthly[1]	Grab Sample	Model Input
Iron [Fe]	mg/L	0.01	6 Locations[2]	Monthly	Grab Sample	Treatability
Sodium [Na]	mg/L	0.01	6 Locations[2]	Monthly	Grab Sample	Treatability
Potassium [K]	mg/L	0.1	6 Locations[2]	Monthly	Grab Sample	Treatability
Manganese [Mn]	mg/L	0.01	6 Locations[2]	Monthly	Grab Sample	Treatability

Parameter	Units	Preferred Detection Limit	Location	Frequency	Parameter Type	Purpose
Calcium [Ca]	mg/L	0.01	6 Locations[2]	Monthly	Grab Sample	Treatability
Magnesium [Mg]	mg/L	0.01	6 Locations[2]	Monthly	Grab Sample	Treatability
Carbonate [CO_3]	mg/L	0.01	6 Locations[2]	Monthly	Grab Sample	Treatability
Bicarbonate [HCO_3]	mg/L	0.01	6 Locations[2]	Monthly	Grab Sample	Treatability
Alkalinity	mg/L	0.01	6 Locations[2]	Monthly	Grab Sample	Treatability
Sulfate [SO_4]	mg/L	0.1	6 Locations[2]	Monthly	Grab Sample	Treatability
Chloride [Cl]	mg/L	0.1	6 Locations[2]	Monthly	Grab Sample	Treatability
TDS	mg/L	10	6 Locations[2]	Monthly	Grab Sample	Model Input
Chlorophyll *a*	µg/L	1	6 Locations[2]	Monthly	Grab Sample	Model Input
Phycocyanin	µg/L	1	6 Locations[2]	Monthly	Grab Sample	Treatability

Notes: 1. Hourly sampling and measurements for up to two wet-weather events (*i.e.*, daily precipitation greater than 0.5 inch) per year.
2. BAR, SNC, KIM, TOL, AQA, AQW.
3. Daily at SNC and AQW; monthly at BAR, KIM, TOL, and AQA

Table 3 lists the "optimal" monitoring plan for the inflows. The main difference between the "basic" and "optimal" monitoring plan is that the "optimal" monitoring plan suggests increasing monitoring frequency for all of the parameters that require laboratory analysis from monthly to twice monthly and to increase stand-alone monitoring visits to the four creeks [BAR, KIM, TOL, and AQA] from monthly to twice per month. This will improve resolution of water quality temporal variation in the inflows. In addition, the "optimal" monitoring plan suggests monitoring all *in situ* parameters and parameters that require laboratory analysis on an hourly basis for all wet-weather events (*i.e.*, daily precipitation greater than 0.5 inch).

Table 3. Inflow Monitoring – Optimal Plan

Parameter	Units	Preferred Detection Limit	Location	Frequency	Parameter Type	Purpose
Flow	cfs	±0.5	7 Locations[2]	Daily or twice per month[1,3]	In-situ	Model Input
Temperature	°C	±0.10	7 Locations[2]	Daily or twice per month[1,3]	In-situ	Model Input

Parameter	Units	Preferred Detection Limit	Location	Frequency	Parameter Type	Purpose
Dissolved Oxygen [DO]	mg/L	±0.20	7 Locations[2]	Daily or twice per month[1,3]	In-situ	Model Input
pH	N/A	±0.20	7 Locations[2]	Daily or twice per month[1,3]	In-situ	Model Input
Oxidation-Reduction Potential [ORP]	mV	±20	7 Locations[2]	Daily or twice per month[1,3]	In-situ	Model Input
Electrical Conductivity [EC]	mS/cm	±0.5%	7 Locations[2]	Daily or twice per month[1,3]	In-situ	Model Input
Specific Conductance	mS/cm	±0.01	7 Locations[2]	Daily or twice per month[1,3]	In-situ	Model Input
Total Dissolved Solids [TDS]	mg/L	±1	7 Locations[2]	Daily or twice per month[1,3]	In-situ	Model Input
Total Nitrogen [TN]	mg/L	0.05	7 Locations[2]	Twice per month[1]	Grab Sample	Model Input
Total Phosphorus [TP]	mg/L	0.01	7 Locations[2]	Twice per month[1]	Grab Sample	Model Input
Nitrate [NO_3]	mg/L	0.05	7 Locations[2]	Twice per month[1]	Grab Sample	Model Input
Nitrite [NO_2]	mg/L	0.05	7 Locations[2]	Twice per month[1]	Grab Sample	Model Input
Ammonia [NH4]	mg/L	0.02	7 Locations[2]	Twice per month[1]	Grab Sample	Model Input
Orthophosphate [PO_4]	mg/L	0.01	7 Locations[2]	Twice per month[1]	Grab Sample	Model Input
SRP	mg/L	0.01	7 Locations[2]	Twice per month[1]	Grab Sample	Model Input
TOC	mg/L	0.01	7 Locations[2]	Twice per month[1]	Grab Sample	Model Input
Iron [Fe]	mg/L	0.01	7 Locations[2]	Twice per month[1]	Grab Sample	Treatability
Sodium [Na]	mg/L	0.01	7 Locations[2]	Twice per month[1]	Grab Sample	Treatability
Potassium [K]	mg/L	0.1	7 Locations[2]	Twice per month[1]	Grab Sample	Treatability

Parameter	Units	Preferred Detection Limit	Location	Frequency	Parameter Type	Purpose
Manganese [Mn]	mg/L	0.01	7 Locations[2]	Twice per month[1]	Grab Sample	Treatability
Calcium [Ca]	mg/L	0.01	7 Locations[2]	Twice per month[1]	Grab Sample	Treatability
Magnesium [Mg]	mg/L	0.01	7 Locations[2]	Twice per month[1]	Grab Sample	Treatability
Carbonate [CO3]	mg/L	0.01	7 Locations[2]	Twice per month[1]	Grab Sample	Treatability
Bicarbonate [HCO3]	mg/L	0.01	7 Locations[2]	Twice per month[1]	Grab Sample	Treatability
Alkalinity	mg/L	0.01	7 Locations[2]	Twice per month[1]	Grab Sample	Treatability
Sulfate [SO4]	mg/L	0.1	7 Locations[2]	Twice per month[1]	Grab Sample	Treatability
Chloride [Cl]	mg/L	0.1	7 Locations[2]	Twice per month[1]	Grab Sample	Treatability
TDS	mg/L	10	7 Locations[2]	Twice per month[1]	Grab Sample	Model Verification
Chlorophyll *a*	µg/L	1	7 Locations[2]	Twice per month[1]	Grab Sample	Model Verification
Phycocyanin	µg/L	1	7 Locations[2]	Twice per month[1]	Grab Sample	Treatability

Notes: 1. Hourly sampling and measurements for all wet-weather events (i.e., daily precipitation greater than 0.5 inch) at BAR, SNC, KIM, TOL and AQA.
2. BAR, SNC, KIM, TOL, AQA, AQW, PWI.
3. Daily at SNC, AQW and PWI; monthly at BAR, KIM, TOL, and AQA

2.2 OUTFLOW MONITORING

The only outflow from SVR is the water withdrawn through the intake structure at the dam. Keeping an accurate record of port opening history and monitoring daily outflow rate is essential for modeling accuracy. Water temperature is relatively easy to measure and can be used to verify the accuracy of port opening records. Thus, the open ports, water temperature, and outflow rates are suggested to be monitored for the "basic" monitoring plan (**Table 4**). For the "optimal" monitoring plan, a list of water quality parameters (**Table 5**) is suggested to be monitored to enhance the modeling effort and provide information for the reservoir operation management and water treatability for downstream water treatment plant.

Table 4. Outflow Monitoring – Basic Plan

Parameter	Units	Preferred Detection Limit	Location	Frequency	Parameter Type	Purpose
Open Ports			SVPL		In-situ	Model Input
Temperature	^{o}C	±0.10	SVPL	Daily	In-situ	Model Verification
Flow	cfs	±0.5	SVPL	Daily	In-situ	Model Input

Table 5. Outflow Monitoring – Optimal Plan

Parameter	Units	Preferred Detection Limit	Location	Frequency	Parameter Type	Purpose
Open Ports			SVPL		In-situ	Model Input
Temperature	^{o}C	±0.10	SVPL	Daily	In-situ	Model Verification
Dissolved Oxygen [DO]	mg/L	±0.20	SVPL	Daily	In-situ	Model Verification
pH	N/A	±0.20	SVPL	Daily	In-situ	Model Verification
Oxidation-Reduction Potential [ORP]	mV	±20	SVPL	Daily	In-situ	Model Verification
Electrical Conductivity [EC]	mS/cm	±0.5%	SVPL	Daily	In-situ	Model Verification
Specific Conductance	mS/cm	±0.01	SVPL	Daily	In-situ	Model Verification
Total Dissolved Solids [TDS]	mg/L	±1	SVPL	Daily	In-situ	Model Verification
Flow	cfs	±0.5	SVPL	Daily	In-situ	Model Verification
Total Nitrogen [TN]	mg/L	0.05	SVPL	Twice per month	Grab Sample	Model Verification
Total Phosphorus [TP]	mg/L	0.01	SVPL	Twice per month	Grab Sample	Model Verification
Nitrate [NO_3]	mg/L	0.05	SVPL	Twice per month	Grab Sample	Model Verification
Nitrite [NO_2]	mg/L	0.05	SVPL	Twice per month	Grab Sample	Model Verification
Ammonia [NH4]	mg/L	0.02	SVPL	Twice per month	Grab Sample	Model Verification
Orthophosphate [PO_4]	mg/L	0.01	SVPL	Twice per month	Grab Sample	Model Verification

Parameter	Units	Preferred Detection Limit	Location	Frequency	Parameter Type	Purpose
SRP	mg/L	0.01	SVPL	Twice per month	Grab Sample	Model Verification
TOC	mg/L	0.01	SVPL	Twice per month	Grab Sample	Model Verification
Iron [Fe]	mg/L	0.01	SVPL	Twice per month	Grab Sample	Treatability
Sodium [Na]	mg/L	0.01	SVPL	Twice per month	Grab Sample	Treatability
Potassium [K]	mg/L	0.1	SVPL	Twice per month	Grab Sample	Treatability
Manganese [Mn]	mg/L	0.01	SVPL	Twice per month	Grab Sample	Treatability
Calcium [Ca]	mg/L	0.01	SVPL	Twice per month	Grab Sample	Treatability
Magnesium [Mg]	mg/L	0.01	SVPL	Twice per month	Grab Sample	Treatability
Carbonate [CO3]	mg/L	0.01	SVPL	Twice per month	Grab Sample	Treatability
Bicarbonate [HCO3]	mg/L	0.01	SVPL	Twice per month	Grab Sample	Treatability
Alkalinity	mg/L	0.01	SVPL	Twice per month	Grab Sample	Model Treatability
Sulfate [SO4]	mg/L	0.1	SVPL	Twice per month	Grab Sample	Treatability
Chloride [Cl]	mg/L	0.1	SVPL	Twice per month	Grab Sample	Treatability
TDS	mg/L	10	SVPL	Twice per month	Grab Sample	Model Verification
Chlorophyll *a*	µg/L	1	SVPL	Twice per month	Grab Sample	Model Verification
Phycocyanin	µg/L	1	SVPL	Twice per month	Grab Sample	Treatability

2.3 IN-RESERVOIR MONITORING

The "basic" monitoring plan suggests measuring water temperature, pH, DO, ORP, EC, specific conductance, and TDS profiles every one meter vertically in the top 30 meters, then every five meters to the bottom using a sonde (**Table 6**). This will provide adequate resolution across the thermocline. Chlorophyll *a* and phycocyanin only need to be measured

using top five meter composite samples. For other grab sample parameters to be analyzed in the laboratory, the "basic" monitoring plan suggests that they be measured at the surface and bottom, as well as at the elevations of all the submerged intake tower ports. It is also suggested that the above mentioned parameters be monitored on a monthly frequency at two in-reservoir monitoring stations: SVA and SVN. These locations are recommended because they correspond to locations close to the outlet and purified water inlet, respectively.

The "optimal" monitoring plan will increase the monitoring frequency from monthly to twice monthly (**Table 7**), providing a more detailed view of the in-reservoir water quality. It also suggests monitoring these parameters at five in-reservoir stations so a more detailed spatial view of the reservoir can be developed and compared to the model. Grab sample parameters that require laboratory analysis are suggested to be monitored at the surface, bottom, and every 10 meters in between, to provide better vertical spatial resolution. The "optimal" monitoring plan also proposes to measure the cell count and biomass of different algal species in the reservoir to study the dominant algal species within the reservoir. It is suggested that a fluorometer be attached to the sonde to measure *in vivo* chlorophyll *a* profiles to provide information on the vertical distribution of algae. Note that the fluorometer should be calibrated and verified before and during the deployment following the protocol from the manufacturer.

Table 6. In-reservoir Monitoring – Basic Plan

Parameter	Units	Preferred Detection Limit	Location	Frequency	Parameter Type	Purpose	Sampling Depth
Depth	m	±0.01	SVA, SVN	Monthly	In-situ	Model Verification	Multiple[1]
Temperature	^{o}C	±0.10	SVA, SVN	Monthly	In-situ	Model Verification	Multiple[1]
Dissolved Oxygen [DO]	mg/L	±0.20	SVA, SVN	Monthly	In-situ	Model Verification	Multiple[1]
pH	N/A	±0.20	SVA, SVN	Monthly	In-situ	Model Verification	Multiple[1]
Oxidation-Reduction Potential [ORP]	mV	±20	SVA, SVN	Monthly	In-situ	Model Verification	Multiple[1]
Electrical Conductivity [EC]	mS/cm	±0.5%	SVA, SVN	Monthly	In-situ	Model Verification	Multiple[1]
Specific Conductance	mS/cm	±0.01	SVA, SVN	Monthly	In-situ	Model Verification	Multiple[1]
Total Dissolved Solids [TDS]	mg/L	±1	SVA, SVN	Monthly	In-situ	Model Verification	Multiple[1]
Chlorophyll *a* using profiling fluorometer	µg/L	1	SVA, SVN	Monthly	In-situ	Model Verification	Multiple[1]
Phycocyanin using profiling fluorometer	µg/L	1	SVA, SVN	Monthly	In-situ	Model Verification	Multiple[1]
Secchi Depth	m		SVA, SVN	Monthly	In-situ	Model Verification	

Parameter	Units	Preferred Detection Limit	Location	Frequency	Parameter Type	Purpose	Sampling Depth
Total Nitrogen [TN]	mg/L	0.05	SVA, SVN	Monthly	Grab Sample	Model Verification	Multiple[2]
Total Phosphorus [P]	mg/L	0.01	SVA, SVN	Monthly	Grab Sample	Model Verification	Multiple[2]
Nitrate [NO_3]	mg/L	0.05	SVA, SVN	Monthly	Grab Sample	Model Verification	Multiple[2]
Nitrite [NO_2]	mg/L	0.05	SVA, SVN	Monthly	Grab Sample	Model Verification	Multiple[2]
Ammonia [NH4]	mg/L	0.02	SVA, SVN	Monthly	Grab Sample	Model Verification	Multiple[2]
Orthophosphate [PO_4]	mg/L	0.01	SVA, SVN	Monthly	Grab Sample	Model Verification	Multiple[2]
SRP	mg/L	0.01	SVA, SVN	Monthly	Grab Sample	Model Verification	Multiple[2]
TOC	mg/L	0.01	SVA, SVN	Monthly	Grab Sample	Model Verification	Multiple[2]
Iron [Fe]	mg/L	0.01	SVA, SVN	Monthly	Grab Sample	Treatability	Multiple[2]
Sodium [Na]	mg/L	0.01	SVA, SVN	Monthly	Grab Sample	Treatability	Multiple[2]
Potassium [K]	mg/L	0.1	SVA, SVN	Monthly	Grab Sample	Treatability	Multiple[2]
Manganese [Mn]	mg/L	0.01	SVA, SVN	Monthly	Grab Sample	Treatability	Multiple[2]
Calcium [Ca]	mg/L	0.01	SVA, SVN	Monthly	Grab Sample	Treatability	Multiple[2]
Magnesium [Mg]	mg/L	0.01	SVA, SVN	Monthly	Grab Sample	Treatability	Multiple[2]
Carbonate [CO3]	mg/L	0.01	SVA, SVN	Monthly	Grab Sample	Treatability	Multiple[2]
Bicarbonate [HCO3]	mg/L	0.01	SVA, SVN	Monthly	Grab Sample	Treatability	Multiple[2]
Alkalinity	mg/L	0.01	SVA, SVN	Monthly	Grab Sample	Treatability	Multiple[2]
Sulfate [SO4]	mg/L	0.1	SVA, SVN	Monthly	Grab Sample	Treatability	Multiple[2]
Chloride [Cl]	mg/L	0.1	SVA, SVN	Monthly	Grab Sample	Treatability	Multiple[2]
TDS	mg/L	10	SVA, SVN	Monthly	Grab Sample	Model Verification	Multiple[2]
Chlorophyll *a*	µg/L	1	SVA, SVN	Monthly	Grab Sample/	Model Verification	Top 5 m composite
Phycocyanin	µg/L	1	SVA, SVN	Monthly	Grab Sample	Treatability	Top 5 m composite

Notes: 1. Sample every one meter in the top 30 meter water and every five meters for the rest water column.
2. Sample at Surface, Bottom, and at the elevations of all the submerged intake tower ports.

Table 7. In-reservoir Monitoring – Optimal Plan

Parameter	Units	Preferred Detection Limit	Location	Frequency	Parameter Type	Purpose	Sampling Depth
Depth	m	±0.01	5 Locations[3]	Twice per month	In-situ	Model Verification	Multiple[1]
Temperature	^{o}C	±0.10	5 Locations[3]	Twice per month	In-situ	Model Verification	Multiple[1]
Dissolved Oxygen [DO]	mg/L	±0.20	5 Locations[3]	Twice per month	In-situ	Model Verification	Multiple[1]
pH	N/A	±0.20	5 Locations[3]	Twice per month	In-situ	Model Verification	Multiple[1]
Oxidation-Reduction Potential [ORP]	mV	±20	5 Locations[3]	Twice per month	In-situ	Model Verification	Multiple[1]
Electrical Conductivity [EC]	mS/cm	±0.5%	5 Locations[3]	Twice per month	In-situ	Model Verification	Multiple[1]
Specific Conductance	mS/cm	±0.01	5 Locations[3]	Twice per month	In-situ	Model Verification	Multiple[1]
Total Dissolved Solids [TDS]	mg/L	±1	5 Locations[3]	Twice per month	In-situ	Model Verification	Multiple[1]
Chlorophyll *a* using profiling fluorometer	µg/L	1	5 Locations[3]	Twice per month	In-situ	Model Verification	Multiple[1]
Phycocyanin using profiling fluorometer	µg/L	1	5 Locations[3]	Twice per month	In-situ	Model Verification	Multiple[1]
Secchi Depth	m		5 Locations[3]	Twice per month	In-situ	Model Verification	
Total Nitrogen [TN]	mg/L	0.05	5 Locations[3]	Twice per month	Grab Sample	Model Verification	Multiple[2]
Total Phosphorus [TP]	mg/L	0.01	5 Locations[3]	Twice per month	Grab Sample	Model Verification	Multiple[2]
Nitrate [NO_3]	mg/L	0.05	5 Locations[3]	Twice per month	Grab Sample	Model Verification	Multiple[2]
Nitrite [NO_2]	mg/L	0.05	5 Locations[3]	Twice per month	Grab Sample	Model Verification	Multiple[2]
Ammonia [NH4]	mg/L	0.02	5 Locations[3]	Twice per month	Grab Sample	Model Verification	Multiple[2]
Orthophosphate [PO_4]	mg/L	0.01	5 Locations[3]	Twice per month	Grab Sample	Model Verification	Multiple[2]
SRP	mg/L	0.01	5 Locations[3]	Twice per month	Grab Sample	Model Verification	Multiple[2]
TOC	mg/L	0.01	5 Locations[3]	Twice per month	Grab Sample	Model Verification	Multiple[2]
Iron [Fe]	mg/L	0.01	5 Locations[3]	Twice per month	Grab Sample	Treatability	Multiple[2]
Sodium [Na]	mg/L	0.01	5 Locations[3]	Twice per month	Grab Sample	Treatability	Multiple[2]

Parameter	Units	Preferred Detection Limit	Location	Frequency	Parameter Type	Purpose	Sampling Depth
Potassium [K]	mg/L	0.1	5 Locations[3]	Twice per month	Grab Sample	Treatability	Multiple[2]
Manganese [Mn]	mg/L	0.01	5 Locations[3]	Twice per month	Grab Sample	Treatability	Multiple[2]
Calcium [Ca]	mg/L	0.01	5 Locations[3]	Twice per month	Grab Sample	Treatability	Multiple[2]
Magnesium [Mg]	mg/L	0.01	5 Locations[3]	Twice per month	Grab Sample	Treatability	Multiple[2]
Carbonate [CO3]	mg/L	0.01	5 Locations[3]	Twice per month	Grab Sample	Treatability	Multiple[2]
Bicarbonate [HCO3]	mg/L	0.01	5 Locations[3]	Twice per month	Grab Sample	Treatability	Multiple[2]
Alkalinity	mg/L	0.01	5 Locations[3]	Twice per month	Grab Sample	Treatability	Multiple[2]
Sulfate [SO4]	mg/L	0.1	5 Locations[3]	Twice per month	Grab Sample	Treatability	Multiple[2]
Chloride [Cl]	mg/L	0.1	5 Locations[3]	Twice per month	Grab Sample	Treatability	Multiple[2]
TDS	mg/L	10	5 Locations[3]	Twice per month	Grab Sample	Model Verification	Multiple[2]
Chlorophyll *a*	µg/L	1	5 Locations[3]	Twice per month	Grab Sample	Model Verification	Top 5 m composite
Phycocyanin	µg/L	1	5 Locations[3]	Twice per month	Grab Sample	Treatability	Top 5 m composite
Algae Species Cell count and Biomass			5 Locations[3]	Twice per month	Grab Sample	Model Verification	Top 5 m composite

Notes:
1. Sample every one meter in the top 30 meter water and every five meters for the rest water column.
2. Sample at Surface, Bottom, and every 10 meters in between.
3. SVA, SVC, SVG, SVH and SVN.

2.4 METEOROLOGICAL MONITORING

Monitoring meteorological data is commonly done by instruments that automatically measure and record the data at a pre-defined frequency. There is no difference between the "basic" and "optimal" plans for meteorological monitoring. Two meteorological stations are proposed for SVR: one on the east side of Lowell Island and the other on the west side of Lowell Island. This arrangement is suggested in order to capture the wind variation on the windward and leeward sides of the island. It is expected that the western station will provide

more representative wind data when the wind is blowing from the west, and similarly when the wind is predominantly from the east.

Table 8. Meteorological Data – Basic and Optimal Plan

Parameter	Units	Preferred Detection Limit	Location	Frequency	Parameter Type	Purpose
Air Temperature	^{o}C	±0.10	SVWX East, SVWX West	every 15 minutes	In-situ	Model Input
Barometric Pressure	mBar	±0.10	SVWX East, SVWX West	every 15 minutes	In-situ	Model Input
Relative Humidity	%	±3%	SVWX East, SVWX West	every 15 minutes	In-situ	Model Input
Wind Velocity	m/s	±3%	SVWX East, SVWX West	every 15 minutes	In-situ	Model Input
Wind Direction	deg true	±3%	SVWX East, SVWX West	every 15 minutes	In-situ	Model Input
Precipitation	Mm	±4%	SVWX East, SVWX West	every 15 minutes	In-situ	Model Input
Solar Irradiance	w/m^2	±5%	SVWX East, SVWX West	every 15 minutes	In-situ	Model Input
Photosynthetically active radiation	$Umol/s/ m^2$	±5%	SVWX East, SVWX West	every 15 minutes	In-situ	Model Input

3. SPECIAL STUDIES

Section 2 discussed the ongoing data needs to help support the modeling effort, water treatability, and analysis of potential regulatory issues. In this section, we identify some short-term investigations that can enhance our understanding of various reservoir processes.

3.1 SUTHERLAND RESERVOIR WATER QUALITY

In Section 2, routine monitoring of San Vicente Creek, which transports water from Sutherland Reservoir into SVR, is discussed and outlined. Aside from routine monitoring of the creek, it is suggested that a special study be conducted to better identify the water quality in Sutherland Reservoir. In this study, monthly water quality samples will be performed for a period of 12 months. The parameters to be measured would include vertical profiles using a sonde (temperature, DO, pH, ORP, EC, specific conductance, and TDS). Furthermore, samples at three different elevations (surface, bottom, and at the outlet level) should be collected and analyzed for the parameters listed as "grab sample" in **Table 2** on monthly basis.; except that Chlorophyll *a* and Phycocyanin only need to be sampled in the top 5 m. The goal of such a study is to understand the reservoir's water quality over a yearly cycle, and to identify whether water transfer timing can be optimized to maximize water quality in SVR.

3.2 ALGAL DYNAMICS STUDIES

Laboratory and in-lake studies can provide valuable information for modeling algal dynamics. In particular, the in-situ determinations of nutrient uptake rates by algae, as well as the rate of algal growth, are important for accurate modeling of algal dynamics (Tietjen, 2011). It is suggested that a one-time study of algal growth dynamics be conducted to determine the main relationships between nutrient uptake and algal growth in the reservoir.

3.3 SEDIMENT OXYGEN DEMAND AND NUTRIENT RELEASE

Sediment oxygen demand is an important feature in determining water quality in SVR. As the sediments utilize oxygen in the hypolimnetic waters, the DO eventually gets depleted. After DO depletion, various nutrients are released from the sediments, and may contribute a significant source for subsequent algal growth. As a result, the determination of sediment oxygen demand as well as sediment nutrient release rates is important. Such a study was completed in the 1990s (Buetel, 2001, and Buetel, *et al*, 2007), but a similar follow up study is recommended after the reservoir expansion.

3.4 TRACER STUDIES OF PURIFIED WATER

If required for demonstration purposes, tracer studies can be conducted to demonstrate the fate, mixing, and dilution of the purified water inflow. These studies will be similar to the 1995 tracer studies that were performed wherein a tracer is injected in the inflow for a short duration (approximately 24 hours). The concentration of the tracer within the lake at various stations and depths would then be measured. From the results, the dilution of the tracer can be computed, as well as the residence time distribution. At least two such studies are envisioned: one during the stratified season (late spring or summer), and another during the winter turnover period, when the purified water is expected to rapidly mix within the reservoir.

4. DATA COMPILATION AND ANALYSIS

The purpose of this task is to gather all historical and future data, compile it into a database, and analyze the data with the purpose of discerning any trends. The following tasks are envisioned.

4.1 ANALYSIS OF PRE IPR/RA PROJECT DATA

This task assesses all water quality data gathered before the IPR/RA project is operational. As part of this task, all pertinent historical water quality data will be gathered and compiled in a suitable database. The database format should allow for easy manipulation of the data. After the database is established, it is recommended that a detailed data analysis be performed to include:

- An analysis of historical trends for all available inflow and in-reservoir water quality parameters, including temperature, TDS, nutrients, DO, and chlorophyll *a*. There should be a review of data integrity to include a data set clean up, if needed. Various data trends should be identified and examined. The analysis should include plotting parameters of concern and producing summary charts and tables that will help assess the reservoir water quality.
- A statistical analysis of various data to determine seasonal, yearly, and multi-year data trends. Identify any relationships between inflow and in-reservoir water quality trends. Determine the range of variation and identify the maximum, minimum and standard deviation of various water quality parameters, such as DO, chlorophyll *a*, Secchi depth, and temperature.
- A determination whether the statistics can indicate a shift in the reservoir's water quality between the old and expanded reservoir.
- Construction of a water and nutrient budget (phosphorus and nitrogen) on a yearly basis.
- Preparation of an extensive data analysis report.

4.2 YEARLY ANALYSIS OF POST IPR/RA PROJECT DATA

This task assesses water quality data gathered subsequent to the IPR/RA project becoming operational. It is suggested that, if the IPR/RA project is implemented in SVR, the various water quality data obtained under Sections 2 and 3 be appended to the data set on a yearly (or shorter time frame) basis. The data should be reviewed and any data integrity issues identified and corrected. On a yearly basis, it is expected that the following tasks would be performed.

- Analysis of all available inflow and in-reservoir water quality parameters, including temperature, TDS, nutrients, DO, and chlorophyll *a*. There should be a review of data integrity to include clean up of the data set if needed. Data trends should be identified and examined. The analysis should include plotting various water quality parameters and the production of summary charts and tables that will help assess the reservoir water quality.
- A statistical analysis of available data and a comparison of the particular year to the historical reservoir trend. Identify any relationships between inflow and in-reservoir water quality trends. Determine the range of variation and identify the maximum, minimum and standard deviation of various water quality parameters, such as DO, chlorophyll *a*, Secchi depth, temperature etc.
- A determination if statistics can indicate a shift in the reservoir's water quality between pre and post IPR/RA project.
- Construction of a yearly water and nutrient budget (phosphorus and nitrogen).
- A comparison of data to model predictions.
- A determination if model or data adjustments are needed to improve our reservoir understanding.

The expected layout of the table of contents of a typical yearly report would be as follows:

1. Introduction and purpose of monitoring
2. Summary of measured data
3. Overall assessment of data quality
4. Actions needed to correct or clean up data set
5. Detailed presentation of the data set (figures, tables, etc.)
6. Trend analysis of data set
7. Nutrient and water budget
8. Statistical parameters obtained from data set
9. Comparison of current data to data from previous years
10. Detailed comparison to model predictions
11. Recommendations for changes in future monitoring or modeling
12. Conclusions

5. REFERENCES

Buetel, M, I. Hannoun, J. Pasek, and K.B. Kavenaugh. (2007) "Evaluation of Hypolimnetic Oxygen Demand in a Large Eutrophic Raw Water Reservoir, San Vicente Reservoir, California". J. Environ. Eng. 133:130-138.

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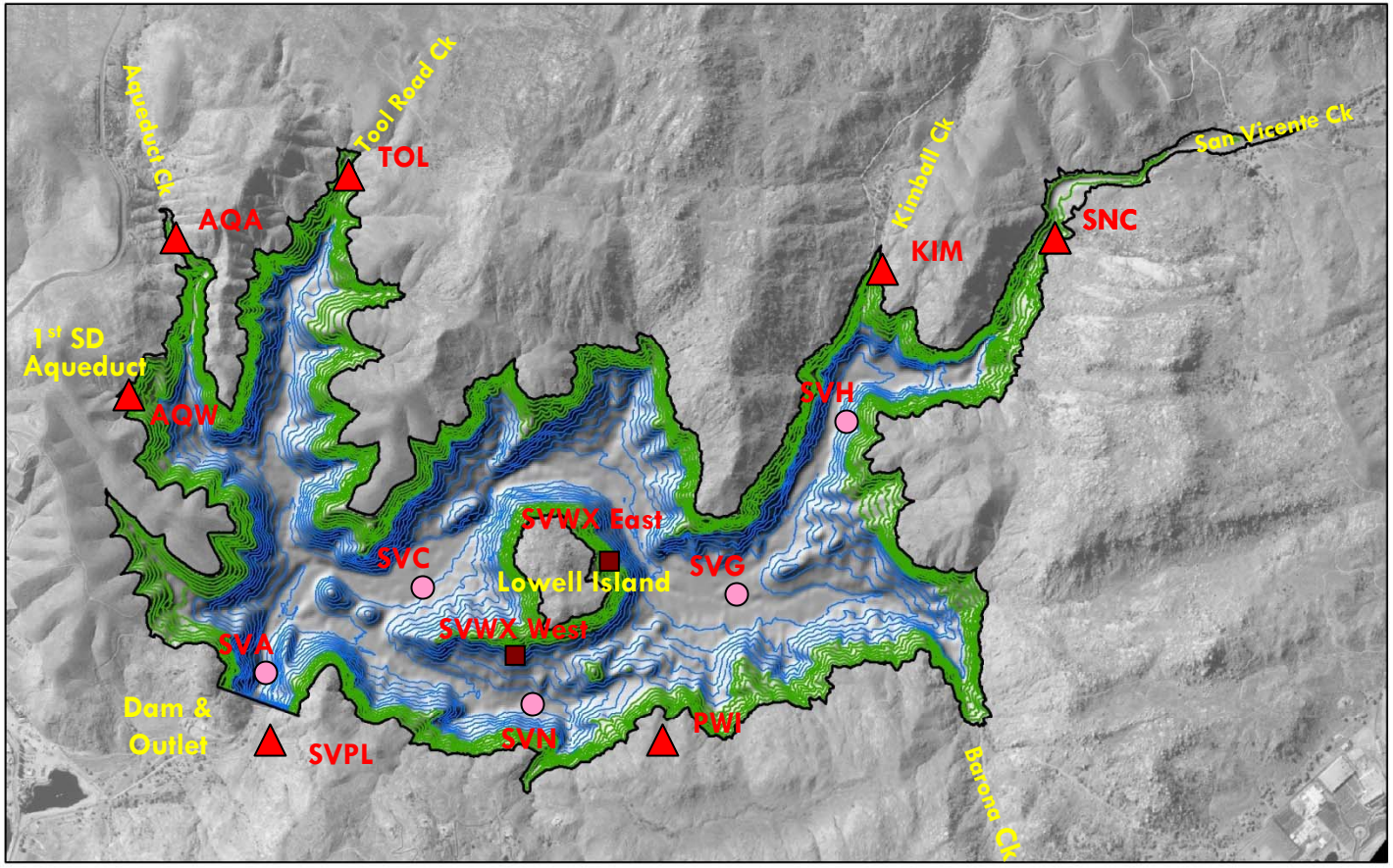
FIGURES

Map of San Vicente Reservoir Monitoring Stations



Legend

- Lake Boundary at EL. 780 ft
- 20-ft contours < EL. 650 ft
- 20-ft contours > EL. 650 ft
- Inflow/Outflow Monitoring Station
- In-reservoir Monitoring Station
- Meteorological Monitoring Station

N W E S

0 2,500 5,000 10,000 Feet

FSI V094005
July10, 2012

Figure 1

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