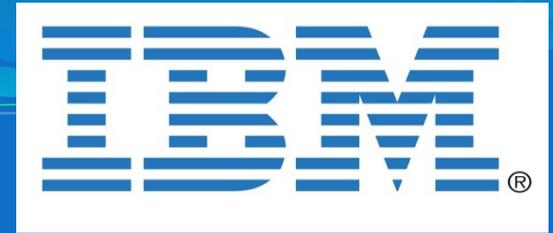


# BRADY



## San Diego/BRADY/IBM Smart Water Pilot Study

### NRW Reduction in San Diego, CA

Wednesday, October 16, 2013

City of San Diego  
Natural Resources and  
Culture Committee

Project Partners



# BACKGROUND

- Richard Brady & Associates - Multi-discipline design and construction firm, specializing in water resources. Immense experience working with the City of San Diego, as well as many other large water purveyors throughout the Country.

- Richard Brady - Alvarado Water Treatment Plant Upgrade & Expansion (200 MGD)

## TEAMED WITH IBM



- IBM has spearheaded several IT and Analytics & Optimization projects throughout the world in the water domain.
  - Valley of the Moon Water Distribution (Sonoma, CA); Washington DC Water and Sewer Agency; Mei Raanana Water Utility (Israel); Enemalta Smarter Water and Energy Metering (Malta, Europe)
- Project Kickoff meeting in late January, 2012, involving BRADY, IBM, Neptune, and several different departments within the City of San Diego.

# CITY OF SAN DIEGO WATER DISTRIBUTION SYSTEM STATS\*

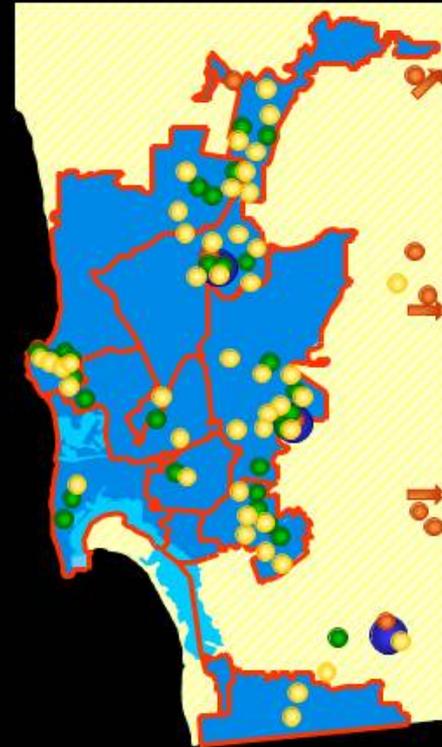
- Average Daily Demand (~1.3M people) – 171 million gallons per day
- Over 3,300 miles of water mains ranging in size from 4” to 84”
- 130 pressure zones
- 49 water pump stations
- More than 24,000 fire hydrants, 48,000 valves, 275,000 service connections and meters
- Approximately 200 million gallons of potable water storage capacity in 32 standpipes, elevated tanks, and reservoirs



\* According to an August, 2011 City of San Diego Public Utilities Department presentation

# City of San Diego Water System

- 3 water treatment plants
- 9 raw water reservoirs
- 29 distribution reservoirs and standpipes
- 49 pump stations
- More than 3,200 miles of distribution pipelines



# NON REVENUE WATER

System Input Volume	Authorized Consumption	Billed Authorized Consumption	Billed Metered Consumption	Revenue Water
			Billed Unmetered Consumption	
		Unbilled Authorized Consumption	Unbilled Metered Consumption	Non Revenue Water
			Unbilled Unmetered Consumption	
	<b>Water Losses</b>	<b>Apparent Losses</b>	<b>Unauthorized Consumption</b>	
			<b>Customer Meter Inaccuracies</b>	
		<b>Real Losses</b>	<b>Leakage on Transmission and Distribution Mains</b>	
			<b>Leakage and Overflows at Storage Tanks</b>	
			<b>Leakage on Service Connections up to point of Customer Meter</b>	

# NRW STATISTICS

- City of San Diego Citywide NRW Estimate ~ 9.3 %.
  - National Average according to US EPA ~ 14%.
  - City of Phoenix ~ 5.1%.
  - San Francisco Public Utilities Commission ~ 9%.
  - Philadelphia Water Department ~ 31.2%.
- Roughly 70% of the City's NRW could be attributed to real losses (leakage in the water network).
- 2010 City NRW Study showed this to correspond to approximately \$29.6M in lost revenue in 2009.
- Infrastructure Leakage Index – 2.39
  - Ideally around **1.0** ignoring financial considerations.

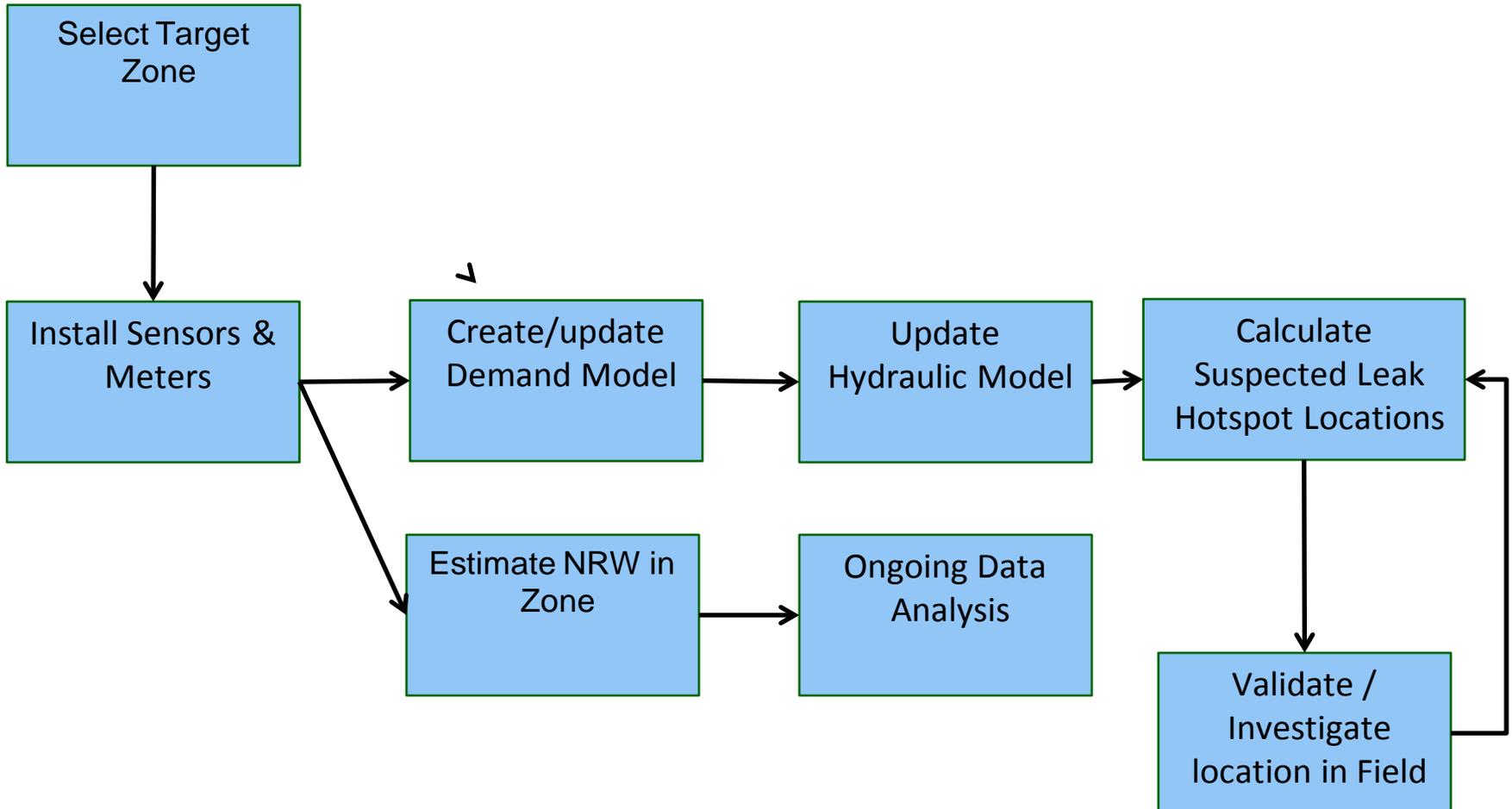
# GOAL OF THE PILOT

- Use data analysis and mathematical optimization, coupled with sound engineering practices and domain knowledge to demonstrate the ability to proactively detect leaks so as to reduce NRW.
- Show the City of San Diego the value of data integration and network monitoring in order to better understand what is going on within their system.
- Combine BRADY's hydraulic engineering expertise and familiarity with the City of San Diego, with IBM's Smarter Planet Initiatives, optimization technologies and advanced mathematical ingenuity and applications.



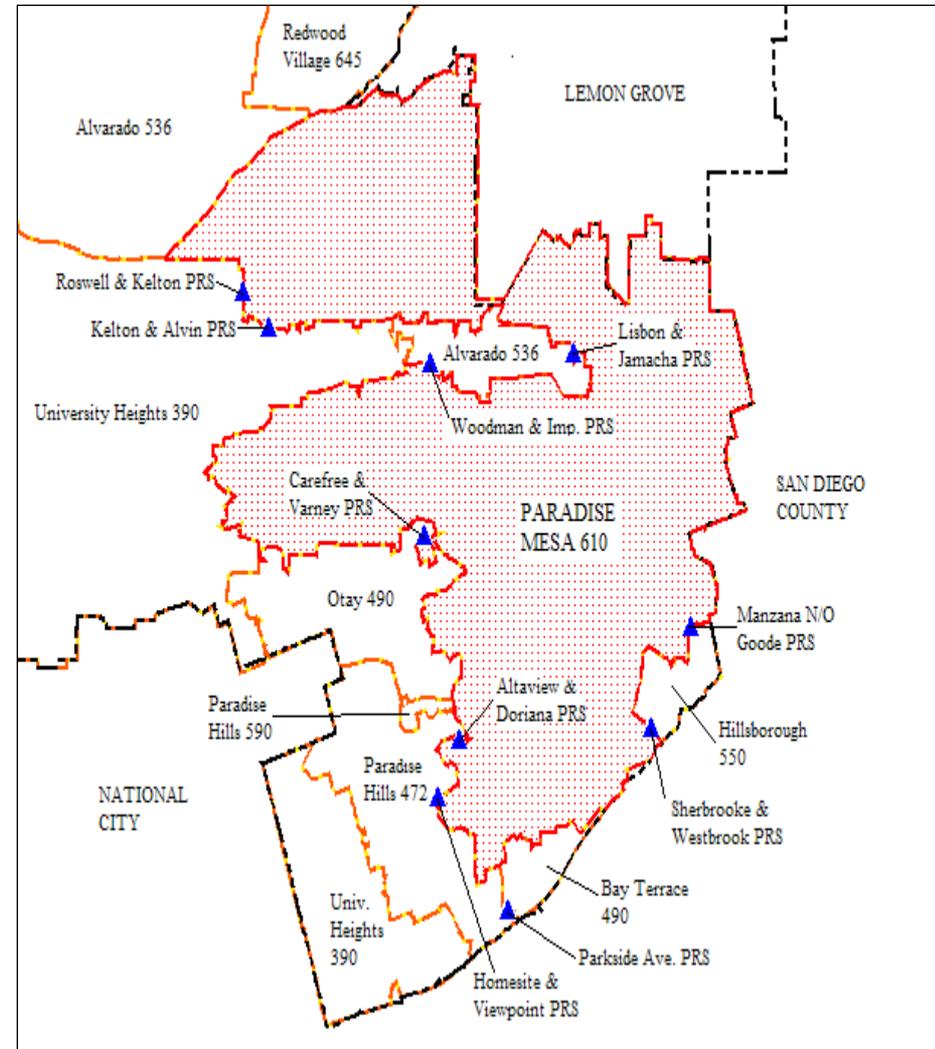
\*Leaks in images above not from City of San Diego Pilot

# PILOT PROCESS

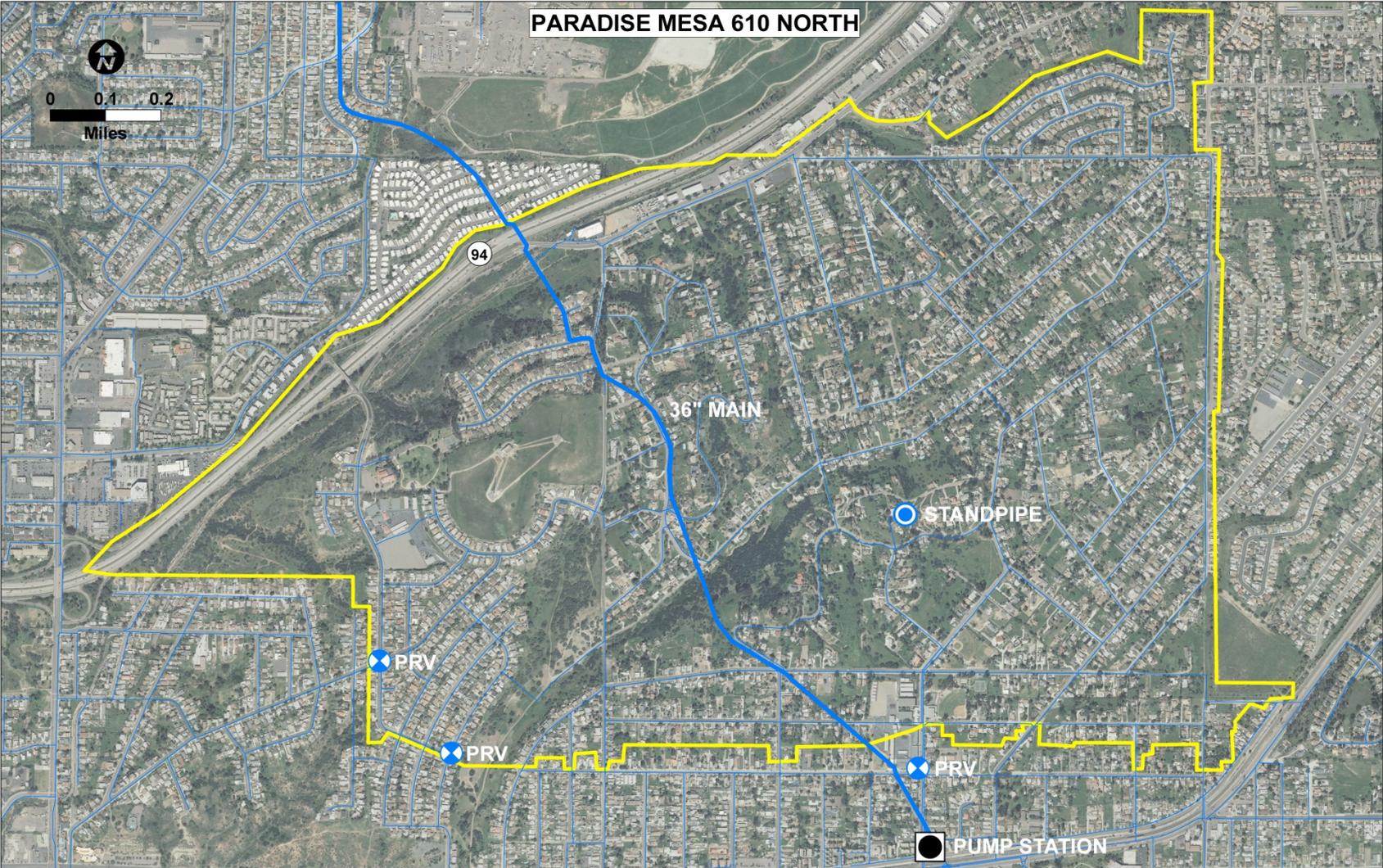


# PILOT PRESSURE ZONE

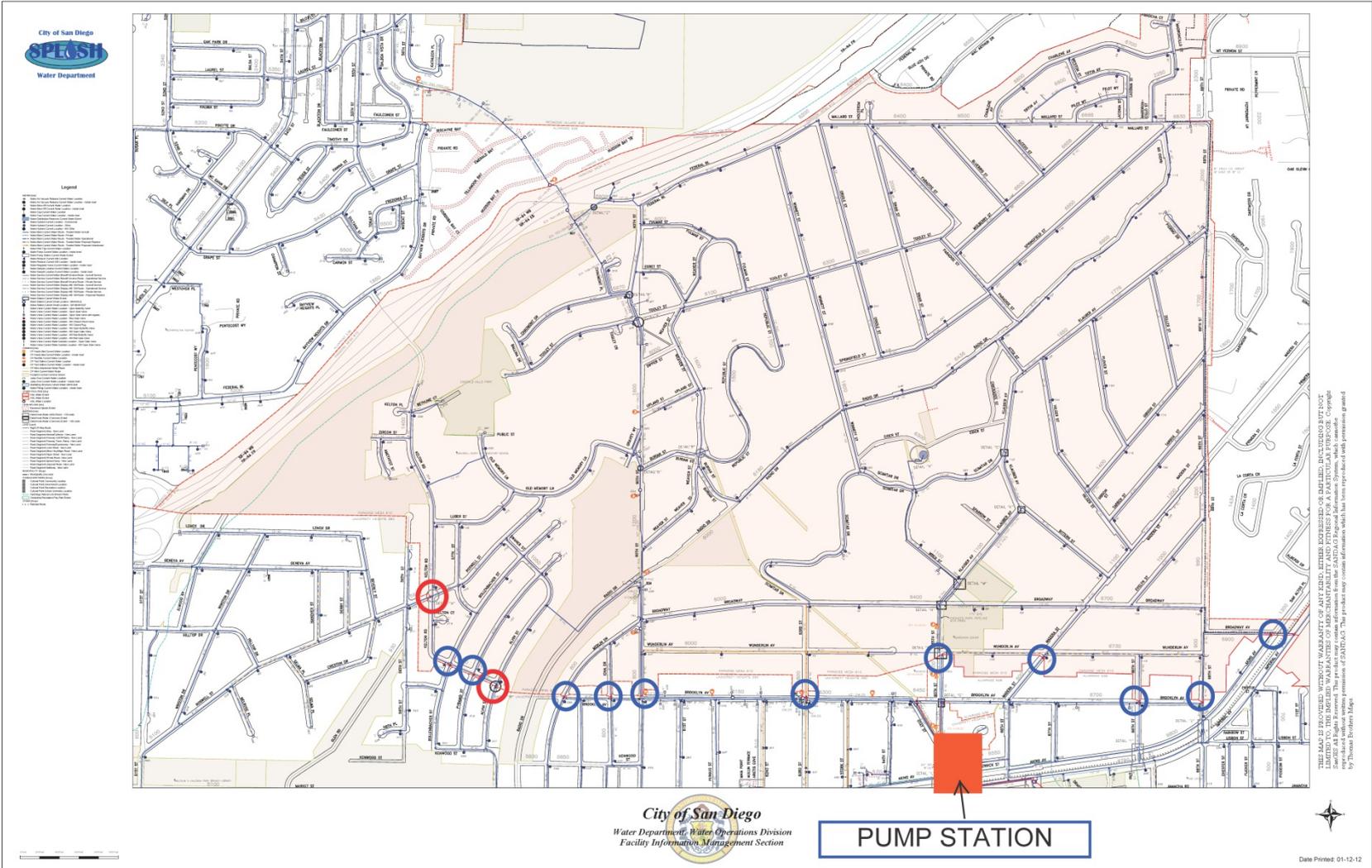
- Paradise Mesa 610 North Pressure Zone Statistics
  - Approximately 2 square miles, 2,200 services (mostly residential, some irrigational, commercial, and institutional).
  - Ability to be isolated from other pressure zones.
  - 1 Pump Station feeding the entire Northern Zone (65<sup>th</sup> & Herrick PS)
  - 2 Pressure Reducing Stations/Valves, 11 Border Valves connected to lower pressure zones. Normally closed, trapped shut for the pilot.
  - A combination of aging AC, CI, and PVC pipe ranging in sizes from 6" – 16".
  - 1 decommissioned standpipe.
  - No capital improvement projects scheduled during the pilot.
  - Expected to have a relatively high amount of leakage.



# PARADISE MESA 610 NORTH



# PARADISE MESA 610 NORTH



# EQUIPMENT

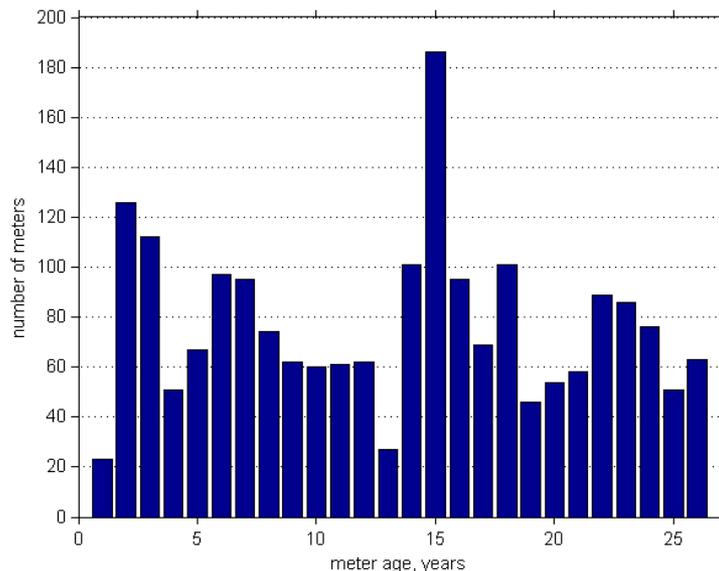
- 200 AMR Neptune R900 smart meters (3/4" – 2")
- Sparling TigerMag Magnetic Flow Meter at PS (previously installed before pilot, tied to City SCADA system)
- Suction & Discharge Pressure Gauge at PS (previously installed before pilot, tied to City SCADA system)
- Pressure Gauge at Emerald Hills Standpipe in pressure zone (Standpipe Out of Service)
- 4 Dickson Hydrant Pressure Loggers
- 16 Telog Hydrant Pressure Loggers



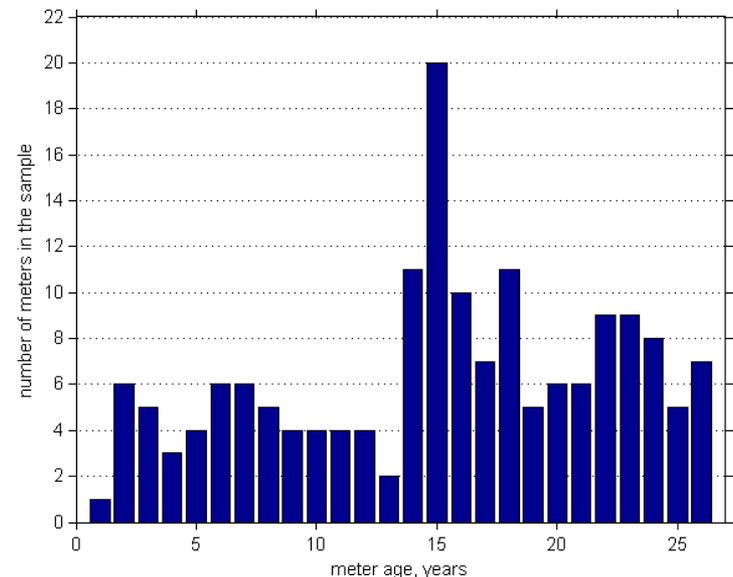
# EQUIPMENT – NEPTUNE METERS

- Selected AMR (Automatic Meter Reading) over AMI (Advanced Metering Infrastructure) due to time of installation for AMI equipment).
- Metered all irrigational, commercial, and institutional customers (total of 27).
- All meters 1.5” or larger were included.
- Higher meter coverage for services with larger demand, as well as meters with older age.
- Replaced 4.5 % of meters 1-3 years old, 6.5 % of meters 4-13, and 10.5 % of meters 14-26 years old.

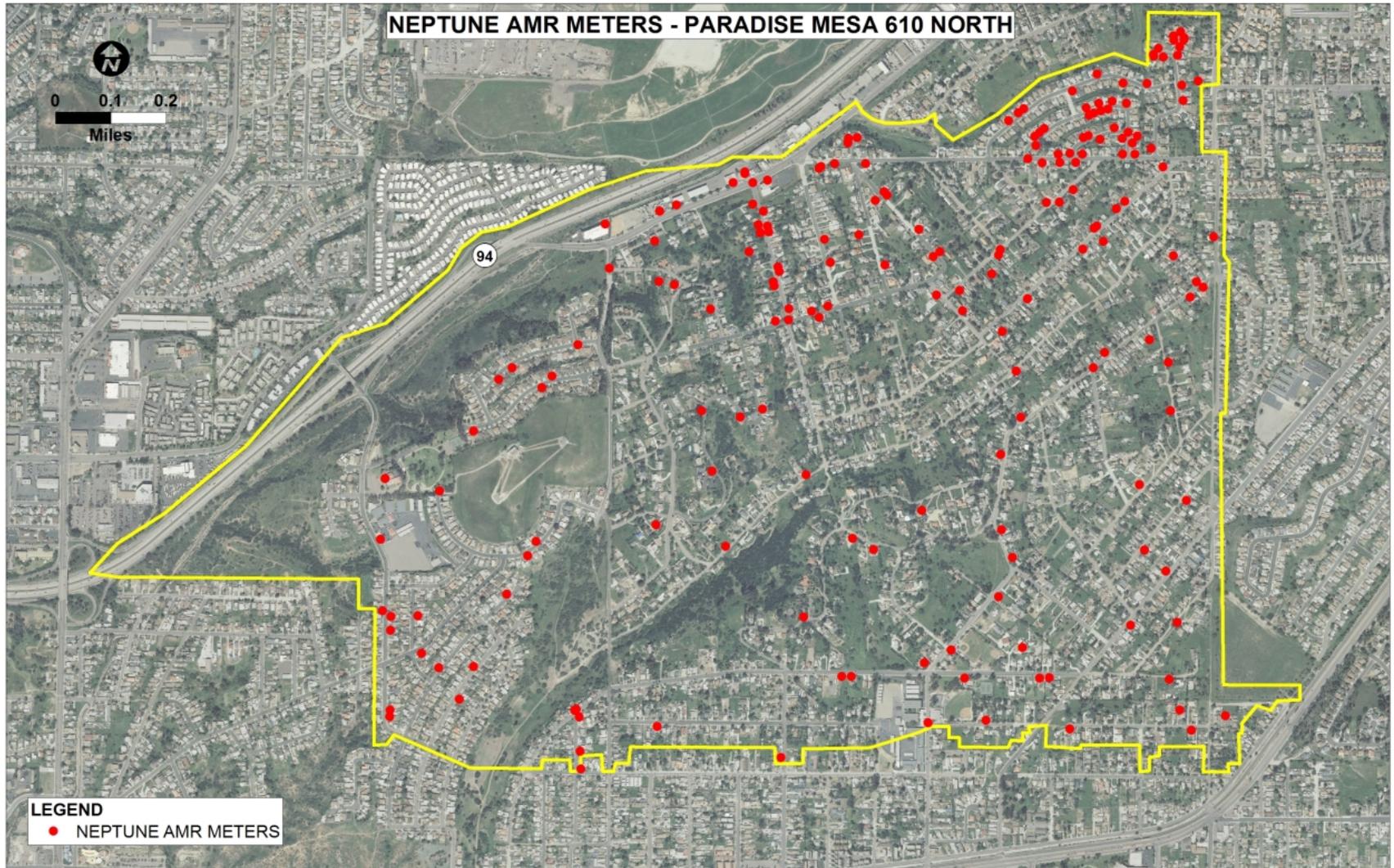
## Residential Customers Meter Age



## Meter Age of Meters to Replace



# NEPTUNE METER LOCATIONS



# EQUIPMENT – PRESSURE LOGGERS

## DICKSON LOGGERS

- PR-325 300 PSI Hydrant Pressure Logger
- Collected reading every 2 Minutes
- 4 Total



## TELOG LOGGERS

- HPR-31 300 PSI Hydrant Pressure Logger
- Collected Min., Max., and Average value in 2 minute span
- 16 Total



# NRW / Unaccounted for Water ESTIMATE

- The PM 610 North Pressure zone was for all intents and purposes, “isolated” for the pilot.
  - 2 Pressure Relief Valves and 11 Border Gate Valves connected to lower pressure zones trapped shut.
  - One source of water supply to the zone, 65<sup>th</sup> & Herrick Pump Station which solely feeds the PM 610 North zone.
- SCADA data available for discharge flow from the pump station for the previous 2 years.
- Billing data for all residential, commercial, irrigational, and institutional services available for the previous 2 years.
- Unaccounted for Water (UFW) = Water lost through bleeding valves or PRVs (not billed in PM 610 zone).
- With this considered:

*WATER IN (Pump Station) – WATER OUT (Billed Accounts) =  
NRW or UFW*

# NRW / Unaccounted for Water ESTIMATE

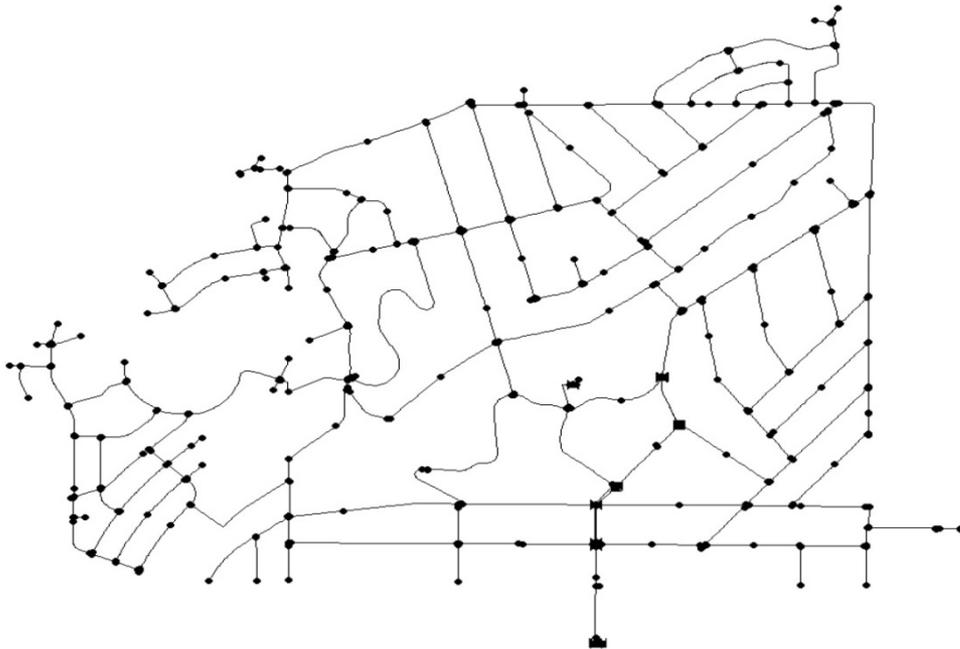
- AWWA recommends carrying out a Water Balance over a period of at least a year.
- Pump Station SCADA discharge flow.
  - February 1<sup>st</sup>, 2011 – January 31<sup>st</sup>, 2012.
  - Summing this data, we estimated total flow into the zone in this period to be **76,878,464** cubic feet.
- Customer Service billing data.
  - February 1<sup>st</sup>, 2011 – January 31<sup>st</sup>, 2012.
  - Not all meters read at the same time, an analysis of total consumption over this period had to be completed individually for each of the nearly 2,200 meters in the zone.
  - Summing the data from all meters, we estimated consumption in the zone during this period to be **25,781,519** cubic feet.
- Amounted to 67 % difference between water pumped into the zone and water consumed in the zone.
- Something appeared to be off.

# NRW ESTIMATE

- After further analysis and discussions with the modeling team and water operations, realized PRVs had been open for a portion of the analysis period.
- Water that flows through PRVs into lower zones is considered unaccounted for water, not Non-Revenue water.
  - Can be billed in another pressure zone.
- We needed a more accurate assessment.
- More accurate estimation of NRW / UFW came from a water balance on the more recent data, AMR cross-validation, and analysis and data from the City of SD hydraulic modeling team.
  - Performed water balance from March 27<sup>th</sup> to May 28<sup>th</sup>, and May 29<sup>th</sup> to July 29<sup>th</sup>, shorter than the AWWA recommended 1 year period.
- Independently narrowed in on a range of 32-40% NRW / UFW for the zone, which was then corroborated by the modeling team with their estimation of 35%.

# HYDRAULIC MODEL

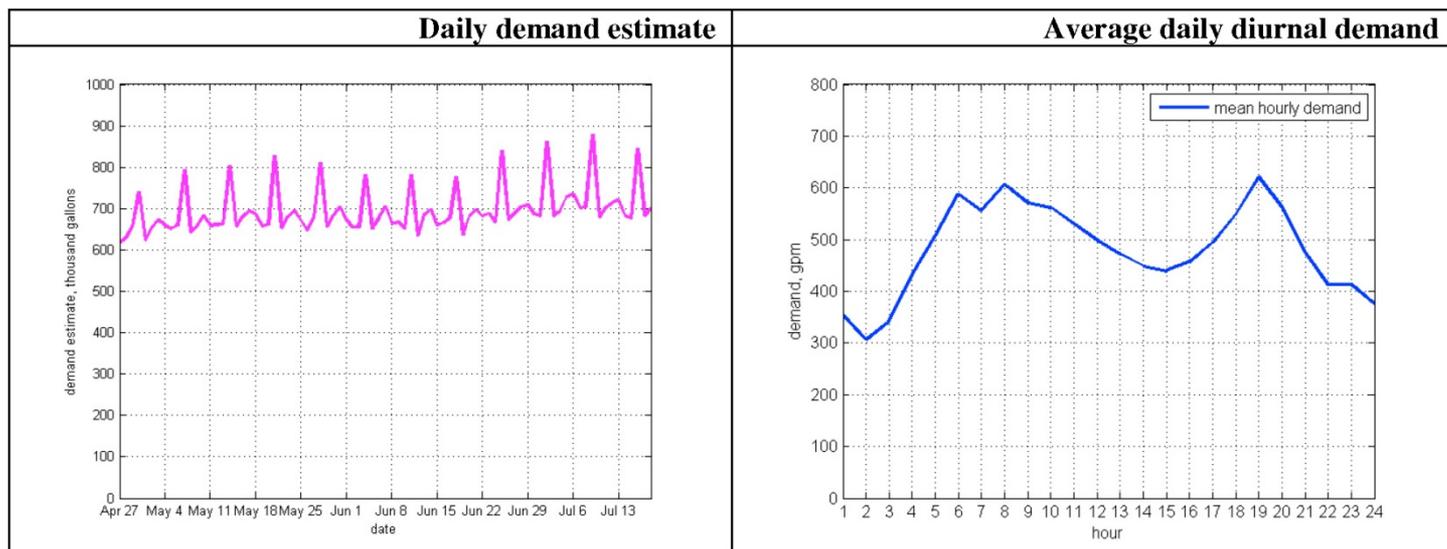
- City of San Diego existing hydraulic existed in Synergee water modeling software.
- Model calibrated by the City of San Diego hydraulic modeling team annually.
- IBM Model Adjustments: Shutting off and removing valves, Updated PS elevation based on As-BUILTs, Updating Pipe Material on sections replaced by CIP projects, added nodes at the locations of our hydrant pressure loggers.
- 572 Junctions, 602 Pipes. Pump Station modeled as a constant head reservoir for simplicity.



- Regular and As-Needed meetings with the City of SD hydraulic modeling team to smooth out clarify any modeling issues.
- Became the basis for the demand model and mathematical analysis.
- Physical hydrant logger pressure were compared to predicted node pressures in the model in order to determine approximate locations of leaks.

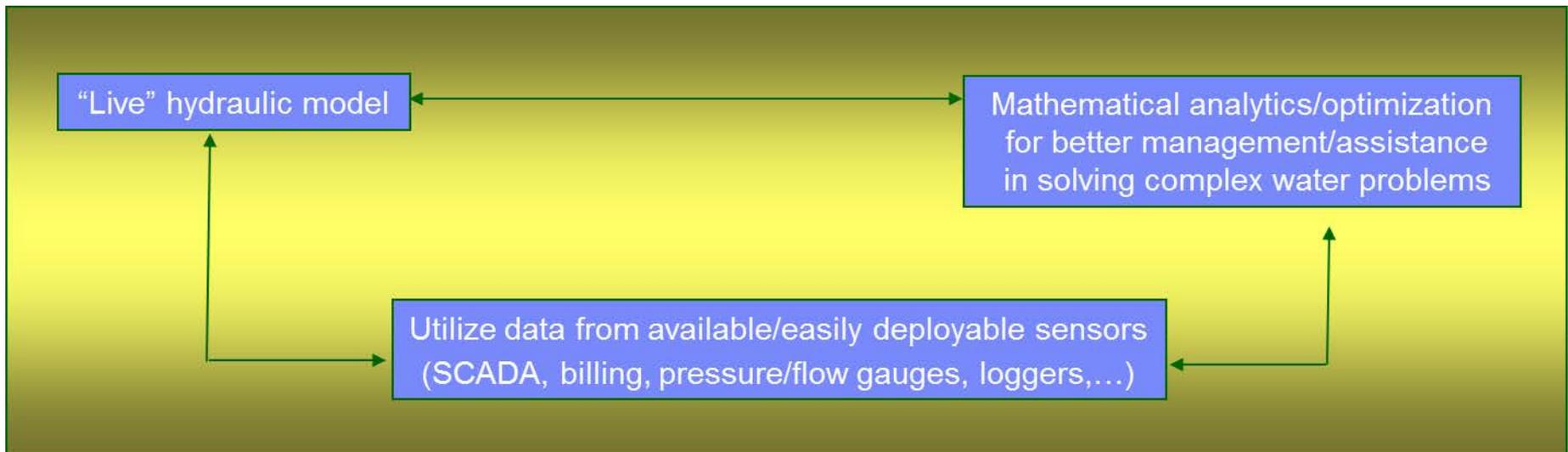
# NIGHT FLOW AND DEMAND MODEL ANALYSIS

- Accurate demand model and diurnal pattern is instrumental in obtaining reliable results from the hydraulic model.
- Also important in advanced analytics related to night-flow analysis and leak detection.
- Used a combination of billing and AMR data from our 200 pilot meters, historical billing data, and the mapping of the full list of customers to nodes in the model.
- Provided invaluable information about the zone, its customers, and flow/consumption patterns.
- Night flow analysis helped us develop a more accurate NRW estimate in the zone.
  - Larger than expected flows during night time hours: 1 AM – 3 AM.



# DATA ANALYSIS

- Includes data from a wide variety of sensors (SCADA data, pressure logger data, customer billing data, and AMR data).
- A hydraulic model simulates the behavior of the network under a wide variety of conditions. The water purveyor's model needs to be updated and accurate to provide the most up-to-date operational insights. City of SD does this.
- Mathematical Optimization Model that runs in unison with the hydraulic model.
  - What is the location of a leak(s) that would best explain the discrepancy between the ideal no leak model, and the actual data acquired from sensors in the zone?
- Constant data analysis of flow/pressure to detect anomalous events.



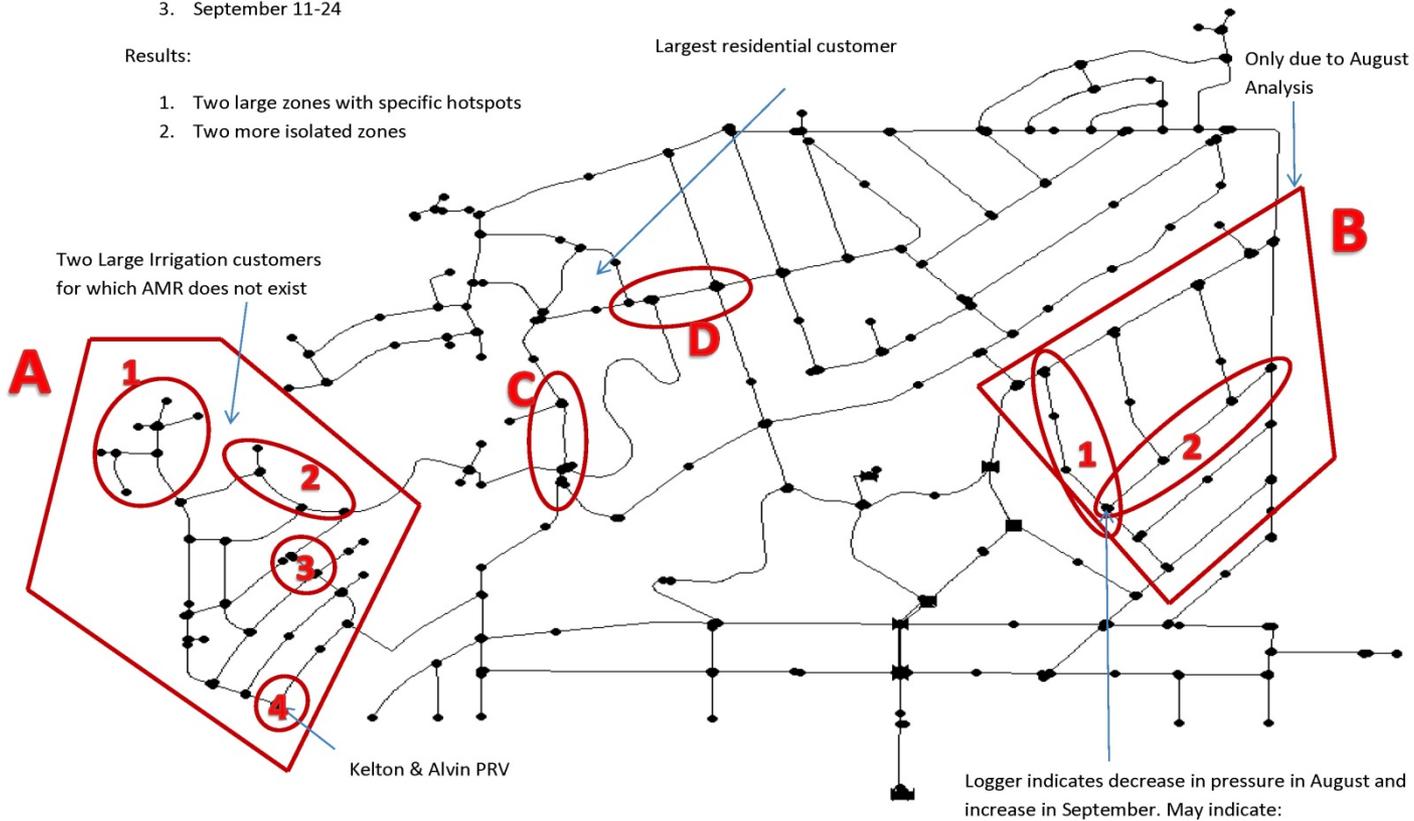
# ITERATION 1 ANALYSIS

Three periods:

1. June 16-30
2. August 1-10
3. September 11-24

Results:

1. Two large zones with specific hotspots
2. Two more isolated zones

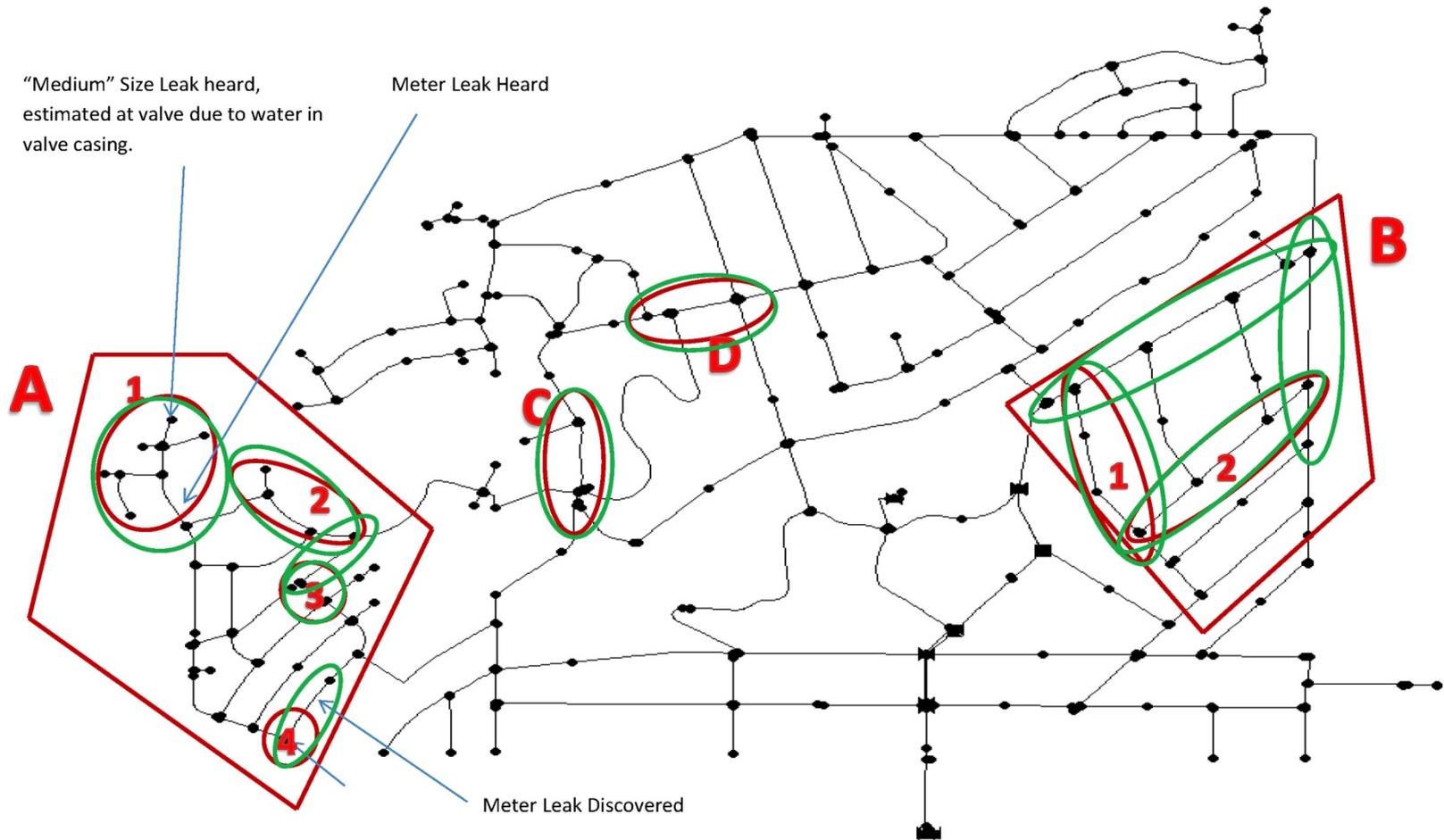


1. Faulty readings (Dickson Logger)
2. Leak (or usage) which was found and fixed

# ITERATION 1 VALIDATION

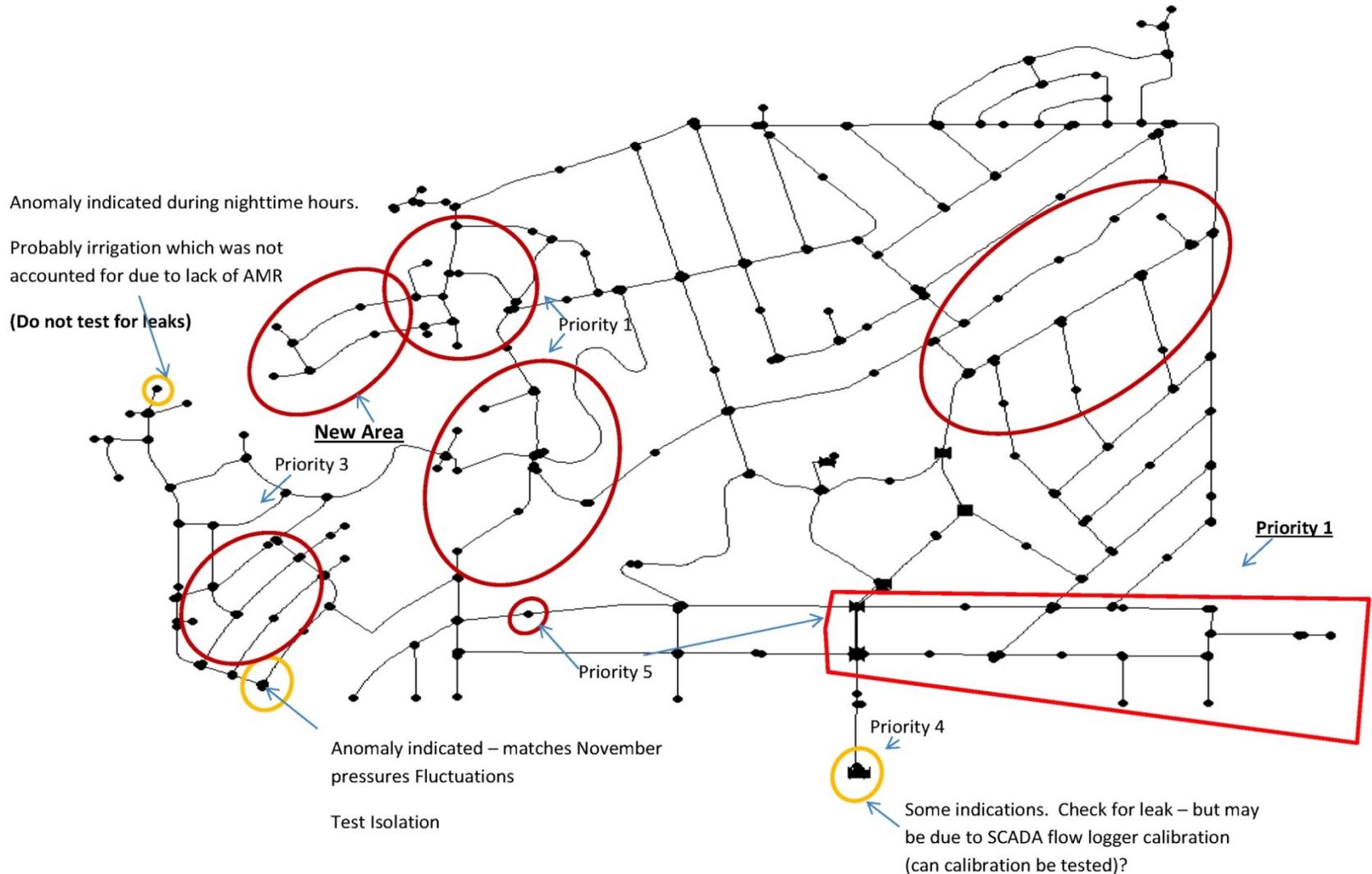
"Medium" Size Leak heard,  
estimated at valve due to water in  
valve casing.

Meter Leak Heard

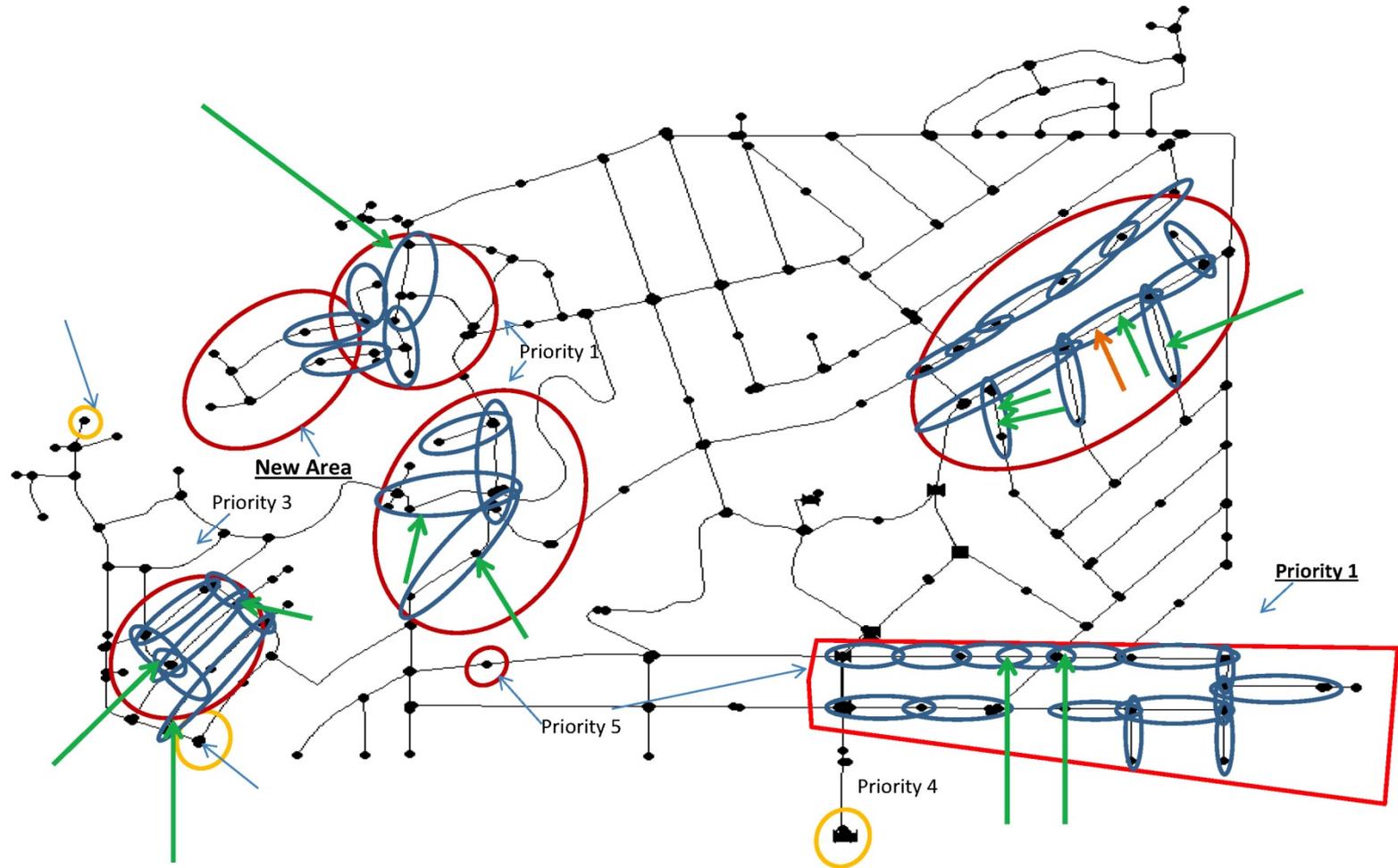


Areas Surveyed by City Staff using  
acoustic sounding equipment.

# ITERATION 2 ANALYSIS



# ITERATION 2 VALIDATION



→ Suspected Leak Location

→ Visible Leak Location \*



Areas surveyed by either acoustic sounding device or correlator.

\*Later discovered to be on customer side of meter.

# RESULTS SUMMARY AND CONTINUED ANALYSIS

- Several locations in which the correlator identified peaks or distinct acoustic signatures.
- We ruled out locations that corresponded to services, blow-offs, Ts or Crosses, etc.
- In locations in which potential leak locations were identified by correlator, we attempted to validate by acoustic sounding methods. Difficult due to nature of pipes.
- Potential, suspicious leak locations were identified.
- Final validation would require excavation, pot-holing.



# DEVELOPMENTS SINCE ACOUSTIC TESTING

- City follow up and investigation of the suspected locations.
  - Pressure testing at 4 of the locations.
  - No indications of leaks found by City staff.
- City investigated all red border valves and Pressure reducing valves.
  - No serious indication of bleeding into lower pressure zones.
  - Any bleeding into lower zones would be considered unaccounted for water.
- Investigation into the accuracy / calibration of the flow meter at the 65<sup>th</sup> & Herrick Pump Station.
  - Discovered malfunction in summer of 2012, manufacturer recommended replacement.
  - Accuracy and reliability of the flow meter in question during analysis period.
  - Could severely impact results and estimation of NRW / UFW.
- City crews excavated the study's suspected leak location.

# FIELD EXCAVATION

- It was agreed upon by all parties that two of the suspected locations would be excavated by City Staff.
- The City asked BRADY to provide the two locations that were most likely to contain a leak. BRADY marked out the two locations in the streets.
- 1 Location on Klauber Street, 1 Location at the intersection of Broadway & Madera.
- On Thursday, August 29<sup>th</sup>, City of San Diego field operations crews excavated approximately a 10' stretch of 12" pipe in front of 1875 Klauber Avenue.
  - Location selected through combination of advanced modeling analysis and acoustic testing.

# FIELD EXCAVATION

- No leak found at the pipe in Klauber Street. See photos below.
- It was decided after the first excavation not to move forward with the excavation of the 2<sup>nd</sup> location.



# FINAL THOUGHTS

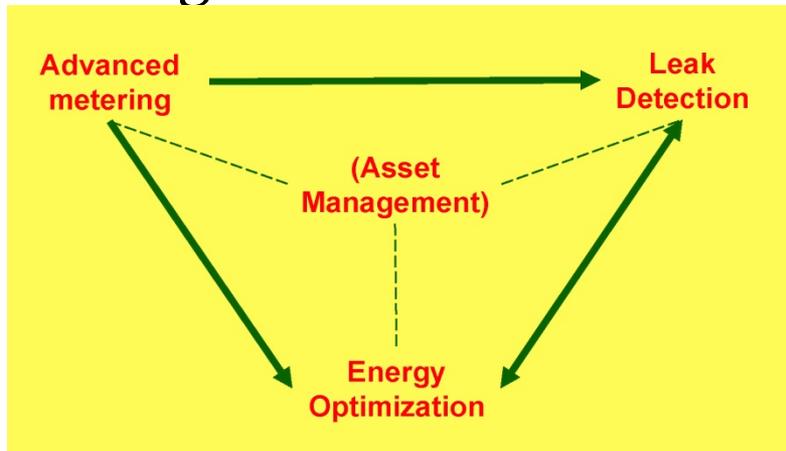
- The NRW / UFW estimate was estimated straight forward through the data, no technology used to calculate this number.
- Several potential explanations for high NRW / UFW number.
  - Inaccuracy of the flow meter at the Pump Station. Bleeding of water into other pressure zones (UFW). Inconsistencies in billing data and customers in the zone. Metering inaccuracies. Fire service/hydrant leaks. Theft. Meter inaccuracies.
- Initially we thought the likely explanation was leaks at indicated locations. Due to questionable input and other factors, we are no longer sure to a point where further excavation is justified.
  - After City excavation we agree that it is unlikely the leaks in the suggested areas are the explanation of NRW / UFW.
- The issue with the flow meter needs to be further explored. Manufacturer cited a malfunction in summer of 2012 and complete replacement necessary.

# LESSONS LEARNED / MOVING FORWARD

- Several potential explanations for high NRW / UFW numbers.
- Zone by zone analysis can provide insight on where to focus NRW reduction effort.
- Additional sensors, data analysis, and real time reporting can tell you new things about the network.
  - Pressure fluctuations in the zone and Pump Station anomalies.
  - Potentially used to understand and respond to system phenomenon quickly and efficiently.
  - Benefit must outweigh costs.
- Data integration from several sources can provide significant benefits in understanding the status in terms of NRW or UFW. The 35% NRW / UFW Estimate that we have found in this zone. This data is to include but is not limited to billing, SCADA, AMR/AMI, pressure and data loggers, and flow meters.
- Some indication that the methodology can be successful in identifying suspicious “leak locations” based on acoustic correlating device. However, field verification did not indicate a leak at the once location investigated.
- Can be a valuable supplement to acoustic leak detection methods.

# LESSONS LEARNED / MOVING FORWARD

- Integrate and expand upon what we have learned in the City of San Diego, develop and fine tune the technologies, and apply this application elsewhere, pioneering the expansion into the Smart Water realm. Just a matter of time before this is a widespread application.
- Smart Water Applications White Paper released in AWWA Magazine – “Information Engineering” and Water System Management



# FINAL BRADY/IBM RECOMMENDATIONS

- Investigate the TigerMag flow meter at Pump Station. Remove and test for proper function, reliability and accuracy.
- Continue with phased AMR implementation Citywide. “Smart Meters” provide the necessary data to build an accurate demand model. More instrumentation, more data, better results.
- In depth zone by zone analysis as done during this study. BRADY / IBM estimated ~ 35% NRW / UFW in this zone. A small number of zones can potentially make up a large portion of the Citywide average.
  - Focus capital improvement efforts and future Smart Water implementations.
- Explore pressure management strategies for NRW reduction.
- Continued efforts in full scale real time monitoring of the hydraulic network.
- At this time BRADY / IBM would not recommend expanding Smart Water leak detection technologies into other City of San Diego pressure zones.

# ITEMS NEEDED TO IMPLEMENT THIS TYPE OF LEAK DETECTION STUDY

- There needs to be an effective method to validate the results provided in Leak Detection report.
- (Currently the only method to validate is to excavate the “possible” leak locations)
- AMR/AMI Technology would provide faster field data collection. A larger sample or perhaps all water services using AMI/AMR would provide a more accurate depiction of water consumption in the pressure zone being analyzed. This implementation would result in more expenses for the Department.
- Additional Pressure Data Loggers to analyze more locations throughout the pressure zone.
- This implementation would result in more expenses for the Department.
- Better SCADA communication signals to avoid gap periods during the studies.
- Customer Support Division to have meter services data that can be sorted by pressure zone.
- This will require coordination between Customer Support Division Staff and Water Operations/EPM staff to assign the pressure zone to each meter service in the pressure zone being analyzed. It possibly may require new software for the Customer Support Division.
- The hydraulic water model will need to accurately depict each fire hydrant in each pressure zone being analyzed. The elevation of each fire hydrant will need to be accurately labeled in the model. Currently the water model is not detailed to this level.
- More Field Crews will need to be assigned to validate the findings of leak detection studies.
- This requires City leak detection staff and hydraulics crews for standby and traffic control.
- The larger the pressure zone it is, the more City staff will be required to support the consultants conducting the studies.
- It is important to conduct a Cost-Benefit Analysis before implementing this type of leak detection studies.

# SPECIAL THANKS TO THE CITY OF SAN DIEGO

- Provided BRADY/IBM with the necessary data.
  - Provided the hydraulic model, assistance, and any necessary support and coordination.
  - Removed old meters, and installed 200 AMR meters.
  - Coordinated and provided public relations to the residents of the pilot zone.
  - Procured, installed, and secured the 20 pressure loggers used throughout the zone.
  - Isolated the zone for the sake of the study.
  - Participated in Bi-Weekly project calls to ensure successful and efficient progress of the Pilot.
  - Participated in field investigations and acoustic surveying events.
  - Provided dedicated staffing for the pilot.
  - Amongst much, much more.
- Jesus Meda, PE, Deputy Director, Water System Operations
  - Stan Medina, Deputy Director, Water Construction & Maintenance
  - Michael Vogl, Deputy Director, Customer Support Division
  - Isam Hireish, PE, Senior Civil Engineer, Operations Engineering Section
  - Johnny Mitchell, Water Systems District Manager, Water Construction & Maintenance
  - Tatyana Fikhman, Senior Water Distribution Operations Supervisor, Water Systems Operations
  - Feryal Moshavegh, Associate Civil Engineer, Engineering & Program Management Division
  - Santiago Crespo, PE, Associate Civil Engineer, Operations Engineering Section
  - Michael Voss, PE, Assistant Civil Engineer, Operations Engineering Section
  - Ramon Mesta, SCADA Administrator, Water Systems Operations
  - Jimmy Evans, Water Systems Technician Supervisor, Water Construction & Maintenance
  - Aminda Rocha, Water Distribution Operator Supervisor, Water Systems Operations

# QUESTIONS AND DISCUSSION

Thank you for your time!

Feel free to contact me at:

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