C I T Y O F B O U L D E R
WATER RESOURCES ADVISORY BOARD
AGENDA ITEM

MEETING DATE: August 17, 2015

AGENDA TITLE: Information Item – Treated Water Distribution System Monitoring

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EXECUTIVE SUMMARY

The purpose of this Information Item is to update the Water Resources Advisory Board (WRAB) on the city's proactive efforts for treated water distribution system water quality monitoring and tools for optimizing water quality in the distribution system. Staff is not requesting any WRAB action at this time, but the item is intended to inform future recommendations including the capital improvements program.

BACKGROUND

The city's treated water distribution system begins at the two water treatment facility discharge points and includes: six storage facilities; three pressure zones; five inter-zone connections; multiple pumps and pressure reducing valves; four hydroelectric generators; and 454 miles of water mains. The distribution system is gravity-fed from the Betasso Water Treatment Facility. Water produced at the Boulder Reservoir Water Treatment Facility is pumped into the system.

Historically, water quality research and regulations have focused on source water protection and water treatment, but in recent years, emphasis has expanded into the distribution system. Because of the size and complexity of the distribution system, maintaining the physical infrastructure is a continuous task, as is maintaining continuous water delivery to customers, ensuring adequate fire flow, maintaining water pressure, and ensuring optimal water quality.

Distribution System Priority Developments

In 2006, the National Academy of Sciences (NAS) released a report from a study that had been requested by the EPA on water quality issues associated with public water supply distribution systems. The report identified seven issues most relevant to protecting public health and maintaining the integrity of drinking water system distribution systems:

1. Cross connections and backflow of contaminated water
2. Contamination due to storage facility design, operation, or maintenance
3. Contamination due to main installation, repair, or rehabilitation practices
4. Contaminant intrusion due to pressure conditions and physical gaps in distribution system infrastructure
5. Significance and control of biofilm and microbial growth
6. Nitrification issues that lead to public health effects
7. Accumulation and release of contaminants from distribution system scales and sediments

The report also focused on risk characterization and identified optimizing metrics related to physical, hydraulic, and water quality integrity. A subsequent 2010 EPA report identified and prioritized related research and information collection needs, with the goal that completed research would support future drinking water community risk management decisions including guidance, best management practices, regulations, and additional research needs. The American Water Works Association (AWWA) revised ANSI/AWWA Standard G200-09, Distribution Systems Operation and Management, also in 2010. The Water Research Foundation formed a new focus area in 2015 to define attributes and demonstrate benefits of intelligent distribution systems. The EPA is considering how distribution water quality can continue to be addressed during rule revisions as well as via non-regulatory channels, and is considering a Distribution System Rule.

Regulations Affecting the Distribution System

Federal and state drinking water regulations to date, in general, have focused more on treatment facilities than on distribution systems. Currently, monitoring requirements focused on distribution system water quality include monthly bacterial and disinfectant residual monitoring (TCR), quarterly disinfection byproduct monitoring (DBP), semi-annual lead and copper water quality parameters monitoring, tri-annual lead and copper monitoring, and tri-annual sanitary surveys.

Recent updates to the Colorado Primary Drinking Water Regulations, going into effect in April 2016, reflect growing attention to the drinking water distribution system. Distribution system related updates include: adoption of the Revised Total Coliform Rule, which sets a treatment technique requiring systems to conduct assessments and identify corrective actions; more explicit cross connection program requirements; a required chlorine residual of at least 0.2 mg/L in the system in 95 percent of monthly samples (compared to the current requirement of having a detectable level of chlorine residual); and storage tank inspection requirements for at least quarterly inspections and comprehensive inspections at least every five years. The city does not anticipate compliance issues with the updated regulations.

ANALYSIS – DISTRIBUTION SYSTEM TOOLS

The city has been proactively implementing and upgrading distribution system tools to provide real time monitoring of the quality of the water going to customers' taps and to optimize system water quality and operation. These tools help the city prepare for future regulations and better understand the extensive system, and are identified in studies above as critical to maintaining

hydraulic integrity and minimizing water residence times in pipes, storage facilities, and premise plumbing.

Online Water Quality Monitoring

The city's 2006 Water Supply System Vulnerability Assessment recommended continuous water quality monitoring instrumentation stations in the distribution system as a means of providing real-time warning of potential water quality contamination. Data from these stations can serve as an early warning of water quality issues and can be used to improve system water quality through operational modifications.

The city's Drinking Water Quality Program, in cooperation with the Utilities Engineering group, has installed continuously-monitoring water quality panels at five sites throughout the distribution system which provide up-to-the-minute information about distribution system water quality (Attachment A). Three of the panels are located at finished water reservoirs, and two of these three can monitor water from three different depths in the reservoir to ensure water quality is consistent throughout. The remaining two panels are at pump stations and can monitor water from either the suction or discharge side of the stations. To ensure accurate data collection, city staff performs monthly calibration, maintenance, and troubleshooting for the online instrumentation.

To help save costs, the panels have been installed in coordination with other facility site improvement projects. The panels monitor for turbidity, chlorine, pH, conductivity, and temperature, and output data to the water treatment and distribution supervisory control and data acquisition (SCADA) system. These parameters are standard for monitoring general water quality as they can detect bacterial growth, sudden chlorine demand, potential corrosion, or sediment in the system. These parameters are also consistent with other monitoring in the distribution system and at the water treatment facilities.

Data from the water quality instrumentation trigger alarms and emails to staff if the values fall outside of standard operating ranges, which are more restrictive than regulatory limits. For example, if the chlorine residual in water leaving a finished water reservoir is below target levels, Water Treatment operators will be automatically notified and can change reservoir fluctuation levels, or Utilities Maintenance staff may go flush the area to freshen residual chlorine. Occasionally, turbidity spikes in the water going through a pump station have been attributed to main breaks in the system.

BlueBox Early Notification System

The city's Vulnerability Assessment recommends adding more distribution system monitoring stations as an early notification system for accidental or intentional contamination. However, data from the existing sites has not always been dependable, despite a strong preventative maintenance program. Maintaining instruments at remote locations can be difficult due to power outages, heating/cooling system outages, drift in the readings, plumbing, and other issues. In addition, contaminants may be introduced to the system through a backflow incident, main break, or accidental or intentional contamination, and some known waterborne contaminants

have the potential to change water quality parameters so slightly that standard alarms may not trigger.

To improve dependability, increase the ability to differentiate between real and false alarms, and detect unusual combinations of water quality parameters that may not be detected by individual parameter changes, the city implemented a BlueBox Event Detection system in 2012 (Attachment B). This system analyzes data from water quality stations and builds a baseline multi-dimensional database, or 'fingerprint,' for each station from historical data. Anytime a data set falls within the fingerprint, operation is normal. If the combination of data points falls outside the fingerprint because it has not been seen before, or if it has been previously user-categorized as abnormal, the software sends a notification or an alarm. The system can also remember common events such as a turbidity spike after a pump comes online and will not send alarms in these situations.

Distribution System Hydraulic Model and Live Modeling

City staff built and maintains a full pipe distribution system hydraulic model using Innovyze Infowater software that matches the city's GIS water main layer. The model includes friction factors based on age and material, fire hydrants, seasonal diurnal use curves from actual SCADA data, demands from actual meter and billing data, pump and hydroelectric turbine curves, operational controls, elevations assigned from GIS contour layers, and seasonal operational scenarios.

The city's Infowater hydraulic model is well calibrated and an excellent representation of system hydraulics. The model is regularly used for planning to simulate demands from new development, facility outages or upgrades, water age, and fire flows. The model is also used to evaluate ongoing operations and system impacts, and model simulations can be steady state or extended period. A steady state simulation is essentially a snapshot of the system under a specific water demand condition, while an extended period simulation looks at system demand fluctuations and operational changes over a user-defined time period (Attachment C).

The city is one of the first utilities in the U.S. to also implement real-time hydraulic modeling which connects the hydraulic model with SCADA data from the distribution system and provides boundary conditions for each simulation (Attachment D). The live model can run in forecast or forensic mode. In forecast mode, the model uses real-time distribution system data to set the initial model conditions and projects the coming hours of system performance using current production and demand data. The model can automatically run every hour, simulating current and near future conditions in the system based on standard operating controls, and notifying staff should any modeled data fall outside of target operating ranges. The hourly runs can be adjusted to evaluate water age and pressure results from different operating scenarios such as valve closures or targeted tank fluctuation (Attachment E).

In forensic mode, the model recreates a past operating scenario from a start date selected by the user. There are no operating controls in a forensic model and the model runs exactly according to SCADA data. For example, if the Cherryvale pump was shut off by operators at hour 8, it will

be shut off at hour 8 of the scenario. Forensic mode is especially useful for performing a field calibration when the system is under stress (peak day or fire flow) (Attachment F).

In both modes, model results are compared to verification points from the system, which include pressures, flow rates, and reservoir levels. As the real-time hydraulic model continues to move ahead, it will be invaluable for further studies such as analysis of water age under different operating scenarios and optimization of pumping schedules that will yield the lowest operating cost while satisfying system performance requirements.

Storage Tank Monitoring

The water distribution system has six storage tanks with a total of 38 million gallons of water storage. Tanks are fluctuated as part of standard day-to-day operations. To monitor conditions inside the storage tanks, staff installed temperature probes at varying depths in all six tanks. The data is pulled twice a year and analyzed to determine if stratification is occurring in any of the tanks. Temperature stratification is typically an indication of a lack of mixing, which can lead to pockets of old water with low or no chlorine residuals.

The city has three pressure zones: zone 3 is the furthest west with its eastern boundary roughly along Broadway; zone 1 is the furthest east with its western boundary roughly along Foothills Parkway; and zone 2 encompasses the large area between zone 1 and 3. At Devil's Thumb storage tank, located in zone 3, temperature data indicated temperature stratification was occurring primarily during summer months. To address stratification, a passive mixing system was installed. Staff continues to monitor the temperature and will be evaluating the improvements from the mixing system. Similar mixing systems were previously installed at the two other zone 3 tanks, Booton and Chautauqua, to address similar stratification issues, and data from both tanks has indicated good mixing (Attachment G).

Temperature data from the Gunbarrel Tank, located in zone 1, has shown some stratification and continues to be monitored. Neither zone 2 tank, Maxwell or Kohler, has shown signs of temperature stratification.

Partnership for Safe Water for the Distribution System

The City of Boulder became a charter member in the Partnership for Safe Water Distribution System Optimization Program in 2011. The Partnership for Safe Water began in 1995 with its program to optimize water treatment plant performance and added the Distribution System Optimization Program in 2011. The goal of the Partnership is to implement prevention programs where legislation or regulation does not yet exist. The Partnership program provides tools to assess treatment plants and distribution systems and benchmark their performance in relation to other utilities in their region and across the nation.

There are four phases to the Partnership: Phase I – commitment; Phase II – baseline data collection and annual reporting; Phase III – self assessment; and, Phase IV – optimized system (*optional*). The Phase III self assessment is a self-paced, significant effort that allows the utility to examine the capabilities of the existing system's operation and administration and resultant

identification of those factors that limit performance. Once the utility has performed this self examination, it develops a plan for implementation of improvements. The Phase III completion report summarizes the self-assessment results and is reviewed by a team from the Partnership Program Effectiveness Assessment Committee (a group of trained utility professional peers) to make sure the process is productive, effective, and unbiased.

The city's Water Treatment staff achieved Water Treatment Phase III for both treatment facilities in 2011. In 2015, Drinking Water Program staff will start the Distribution System Phase III self assessment, a significant multi-group effort. The program analyzes the following distribution system metrics:

- disinfectant residual
- pressure management
- main break frequency
- cross connection control / backflow
- disinfection by-product control
- energy management
- external corrosion
- flushing
- maintaining valves / hydrants / blowoffs
- internal corrosion control
- pipeline installation / replacement / rehabilitation
- post precipitation control
- security, emergency management
- storage facility operation and management
- water age and the hydraulic model
- water loss control
- water quality sampling and response
- asset inventory
- pipeline materials
- pumping facilities
- valves and hydrants
- application of operational concepts
- administrative factors
- an action implementation plan

NEXT STEPS

Surveillance and Response System (SRS)

Surveillance and Response Systems (SRS) are software systems that incorporate inputs from several components which may include online water quality monitoring and event detection systems, sampling, enhanced security (such as security cameras), customer complaints, public health information, and work order management systems. These data are used as an early warning system of contamination in the distribution system.

SRSs are relatively new systems that have been developed in mostly large scale utilities. A recent Water Research Foundation study found that SRS drivers include security concerns, grant availability, customer demands for information, internal distribution system water quality and security initiatives, and specific events degrading water quality. SRS benefits to utilities include improved operations and reduced operations costs, improved levels of service, demonstration of due diligence to public and regulators, reduced repair/replacement costs, improved coordination across utility divisions, improved interagency cooperation, and improved documentation of procedures. Barriers to SRS implementation are significant cost, increased complexity, achieving buy-in, and public perception.

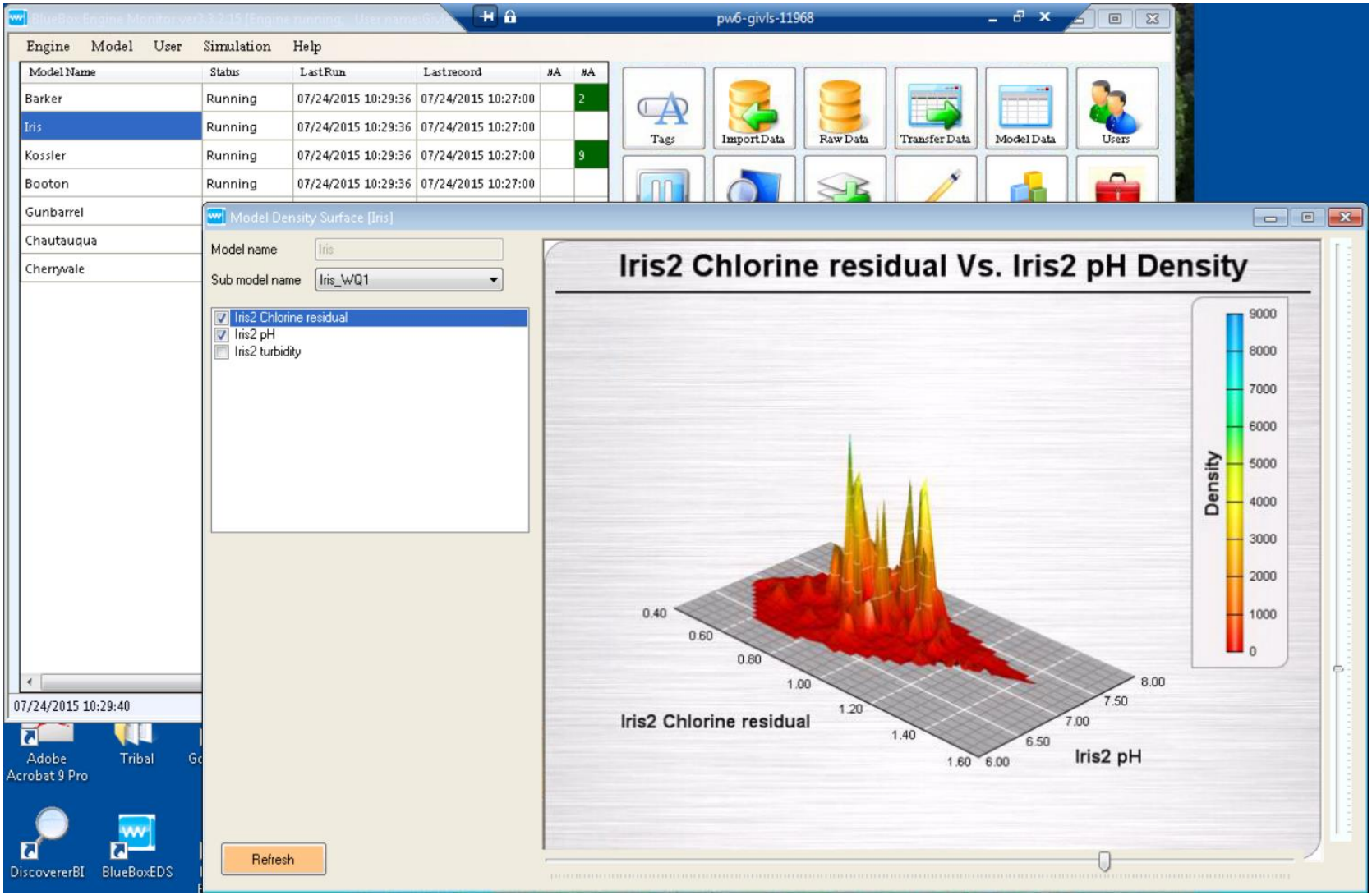
Under current conditions, if the distribution system experiences a potential water quality event, Drinking Water Program staff may check all of the above components individually. Streamlining information flow through an SRS system would significantly improve incident identification and response time. Identification and response time will improve when the city Utility Maintenance Management System software is upgraded in coming years. A full scale SRS implementation is not planned at this time, but an achievable and desirable goal is to incorporate components in steps in coming years.

ATTACHMENTS:

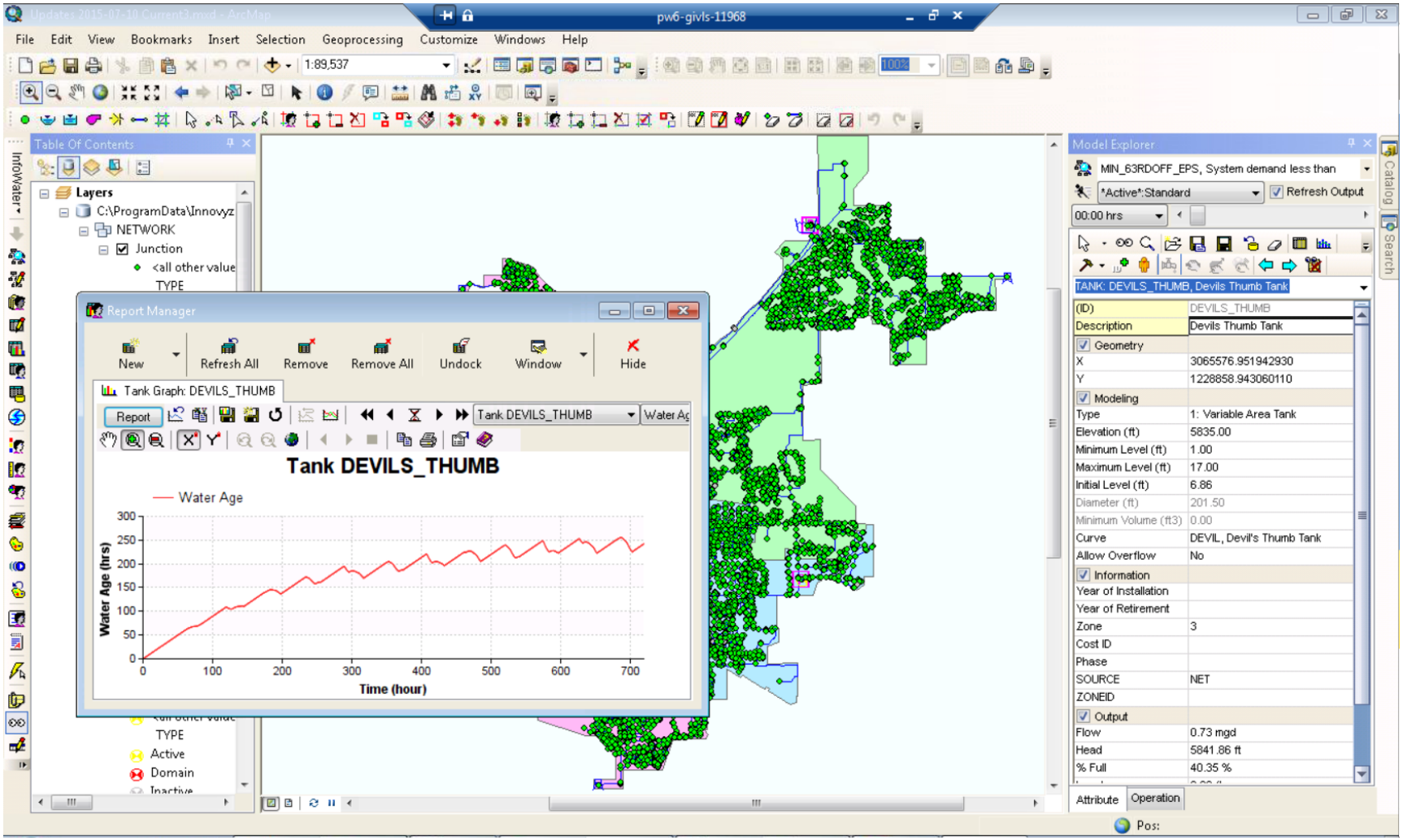
A – Iris Pump Station Online Water Quality Monitoring Panel
B – BlueBox Event Detection System Screenshot
C – Infowater Hydraulic Model – 30 Day Simulation – Water Age Example
D – SCADA Data Linked By Live Hydraulic Model
E – Running Operational Simulations to Prepare for Facility Outage - Example
F – Verifying Model Calibration Using Stressed Field Condition
G – Finished Water Tank Stratification Study Example

ATTACHMENT A
IRIS PUMP STATION ONLINE WATER QUALITY MONITORING PANEL

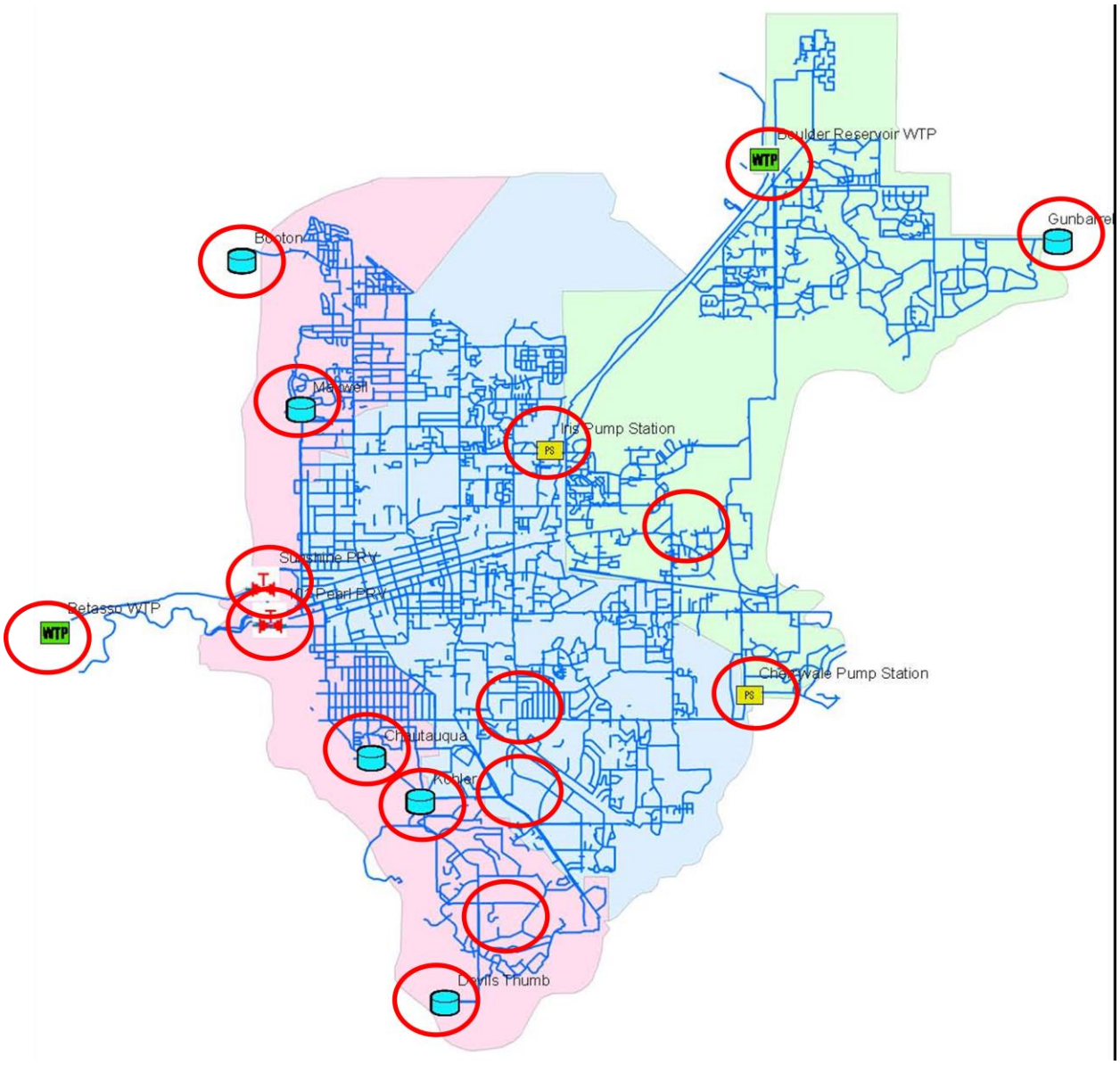
ATTACHMENT B
BLUEBOX EVENT DETECTION SYSTEM SCREENSHOT



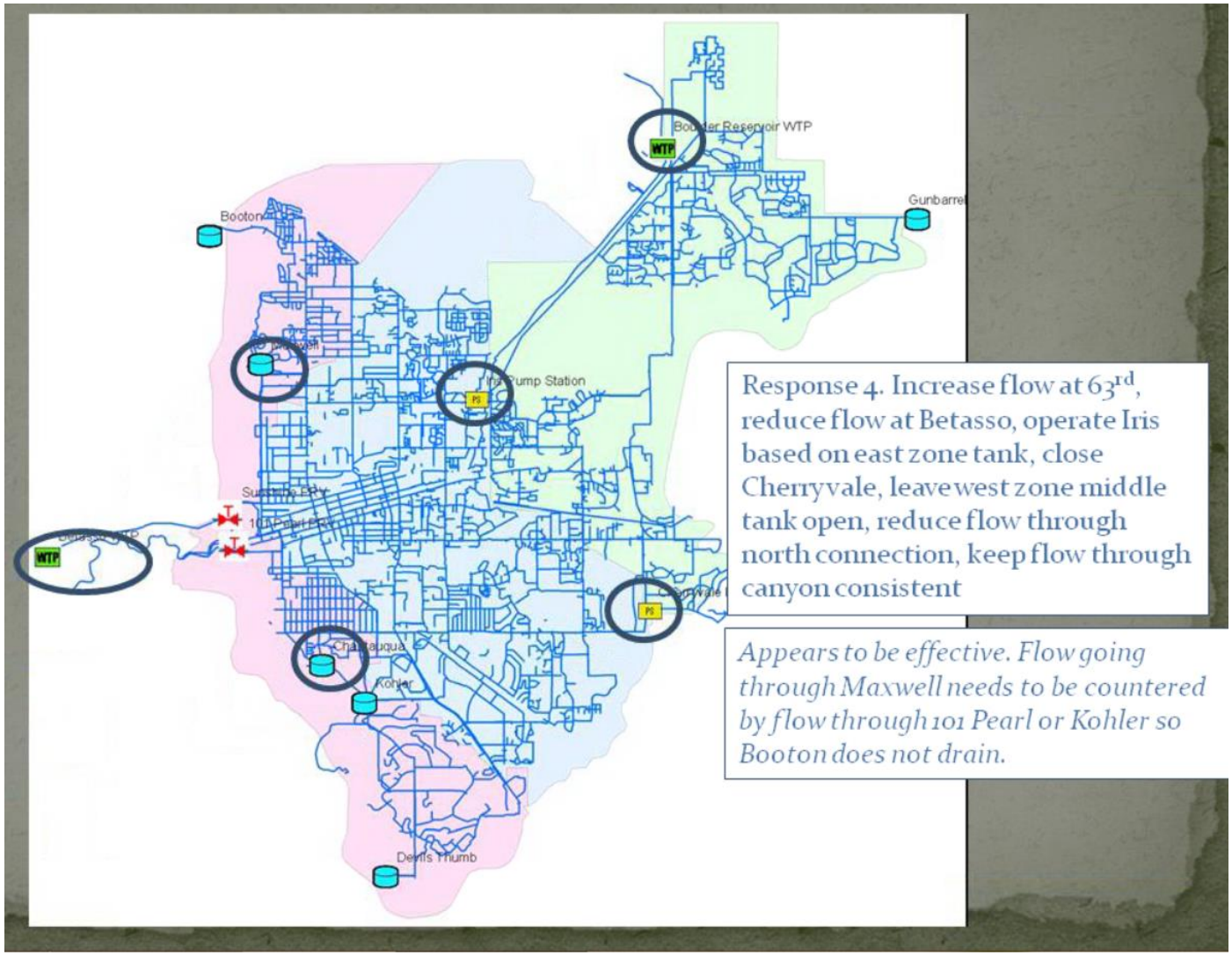
ATTACHMENT C
INFOWATER HYDRAULIC MODEL – 30 DAY SIMULATION - WATER AGE EXAMPLE



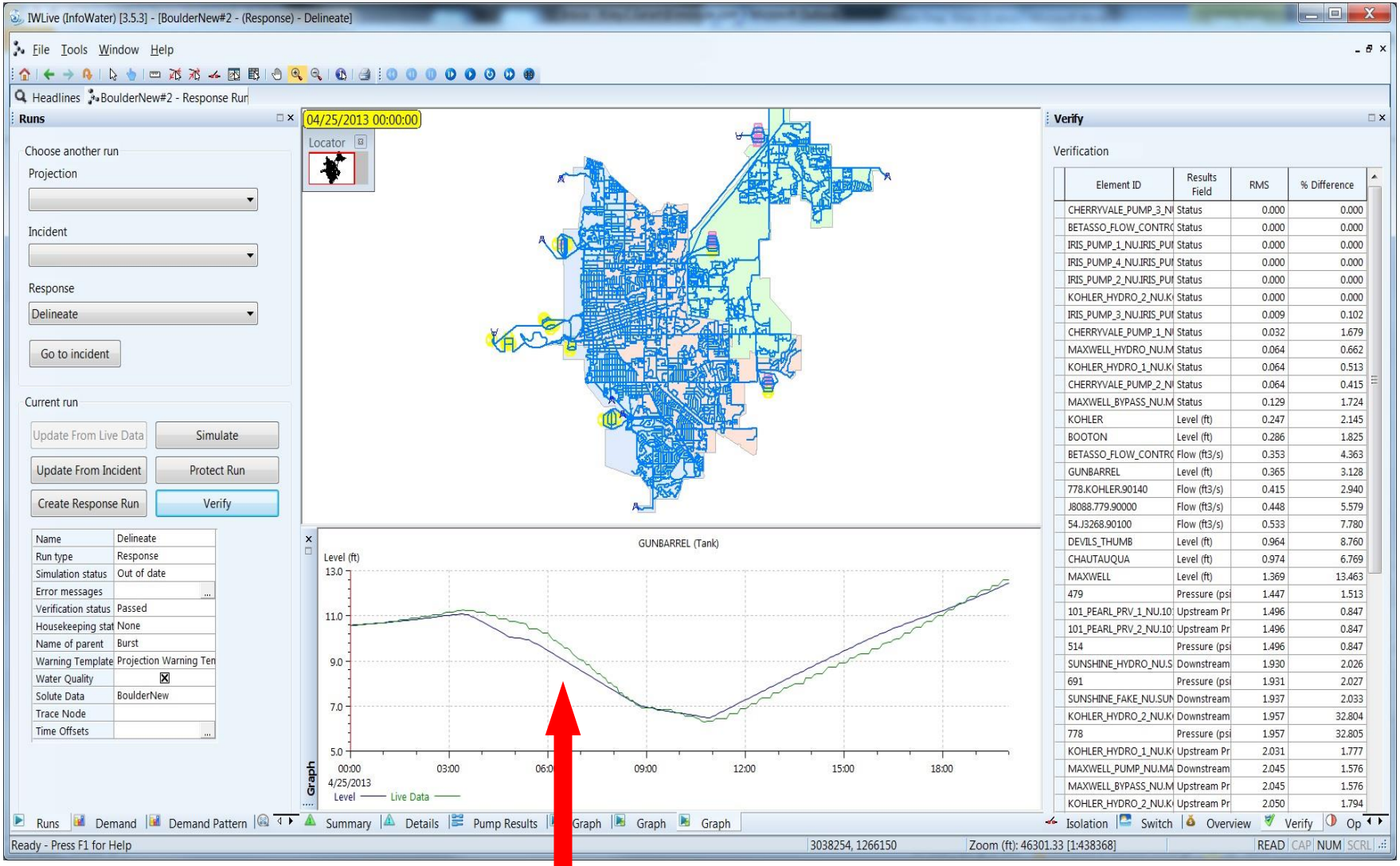
ATTACHMENT D
SCADA DATA LINKED BY LIVE HYDRAULIC MODEL
Red circles indicate water system assets with data feeds



ATTACHMENT E
RUNNING OPERATIONAL SIMULATIONS TO PREPARE FOR FACILITY OUTAGE - EXAMPLE



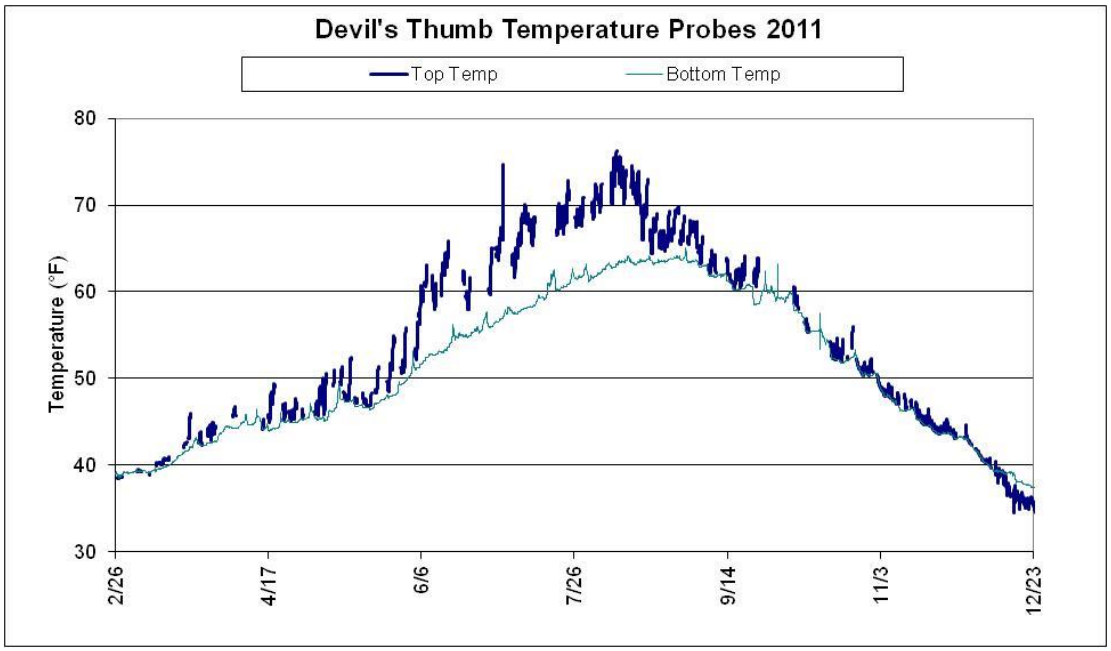
ATTACHMENT F
VERIFYING MODEL CALIBRATION USING STRESSED FIELD CONDITION



Model results vs actual system data

ATTACHMENT G
FINISHED WATER TANK STRATIFICATION STUDY EXAMPLE

Onset Hobo Water Temperature Data Logger



Temperature Probe Data – indicating temperature differences between the top and bottom probes

Tideflex valves installed Devil's Thumb Tank in May 2014