Putting Distribution System Modeling Results to Work

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Orange County is one of six central Florida counties covering an area of approximately 1,000 square miles. The Orange County Utilities Department (Utility) provides water, wastewater treatment, and reuse, as well as garbage disposal and recycling services, to residents and businesses in its service area. The Orange County Utilities Water Division operates 10 water supply facilities producing 20.9 billion gallons of water annually that are distributed through 1,703 miles of pipeline in unincorporated Orange County. The planning section of the Utility's Engineering Division maintains a hydraulic/water quality model of its transmission system (typically 12-inch diameter pipe and larger) to help plan, design, operate, and optimize water pressure and quality in the transmission system. With advances in hydraulic/water quality modeling software and the availability of powerful and cost-effective hardware, the Utility recently extended its hydraulic modeling capabilities into the distribution system (2-inch to10-inch diameter pipe).

A distribution level water quality model provides the water division staff a powerful tool to assist with predictive system performance monitoring, benchmarking, operations optimization, and regulatory compliance. Many tools are available to a utility to facilitate distribution system water quality management, including implementation of an intuitive GIS-based water quality application. The proposed application will provide on-demand access to hydraulic model simulation results for scenarios simulated by modeling staff, field sampling, and field hydrant testing data using the GIS infrastructure as the intuitive base layer to present the information. This information will allow Utility staff to make informed decisions to improve distribution system hydraulics and water quality.

Goals to Optimize Water Quality

As the dynamics of drinking water systems become better understood, water utilities have increasingly focused their attention on water quality in the distribution system, which has mainly been driven by regulatory requirements. Regulations will continue to drive water quality management activities, as revised laws, including the Total Coliform Rule and the Stage 2 Disinfection By-Product Rule, come into effect. Research has established that distribution systems should not be viewed as a static network of inert pipes, but as biological and chemical reactors with complex interactions and outcomes (Water Research Foundation, 2010). Water quality goals in the distribution system can generally be grouped under three major themes:

- Minimizing detention time
- Maintaining positive pressure
- Controlling the direction and velocity of bulk water

Minimizing detention times in the distribution system is one of the primary goals of maintaining water system quality. Detention time has an adverse impact on water quality because bulk water decay characteristics and the interaction of bulk water with pipe walls increases with longer detention times. This leads to decay of the disinfectant residual, taste and odor issues, and increases in disinfection by-product levels, resulting in an overall reduction in distribution system water quality. Designing distribution systems to meet the water pressure demands of firefighting often leads to the design of larger diameter water mains that can contribute to stagnation and increased water age, leading to lower water quality. Typical solutions available for reducing the detention time include turning over water on a regular basis or adjusting water levels in reservoirs, which run counter to traditional reservoir operation practices.

Maintaining adequate positive pressure in the distribution system is essential to prevent the entry of external contaminants. Events causing low or negative pressures in the distribution system, including sudden valve closures, can create rapid changes in water velocity that result in pressure transients that can cause low or negative pressures, leading to possible contamination of water in the system. Events such as sudden loss of power at critical treatment plant locations or pump stations can also result in surges that cause sudden changes in velocity and the direction of water.

Tools for Maintaining Distribution System Water Quality

Due to continuous innovations in the industry, water professionals now have a number of tools that can help them in sustaining and improving distribution system water quality. A reliable representation of the water infrastructure, such as a GIS repository, is one of the first weapons in the arsenal of a water professional. A good infrastructure repository helps identify areas that are susceptible to water quality problems (loops, terminal points, and areas of seasonal demands such as schools and tourist areas) and is the starting point for developing reliable hydraulic models.

A well-calibrated distribution system hydraulic model is another tool that can assist in predicting and maintaining minimum system water pressure (typically 20 psi) under extreme operating conditions such as high demand and fire-flow conditions. Simulating system transients can identify areas susceptible to rapid or extreme fluctuations in flow velocities (surges) that can loosen pipe wall deposits and lead to pipe failures. Extended period simulations can identify areas in the system that are susceptible to water quality impacts, such as increased detention times and extreme velocities. Unfortunately, most hydraulic models are sophisticated tools that need specialized skills to perform simulations and view model results.

Other useful tools include supervisory control and data acquisition (SCADA) systems that track and store performance parameters, such as chlorine levels, pressures and tank levels, data from field sampling activities that are usually stored in laboratory information management systems (LIMS), and data from hydrant testing and other field monitoring activities. These data sets provide water professionals valuable information that can be used to optimize distribution system water quality.

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Integrated Information Delivery is the Answer

While the tools listed previously are available at many utilities, it is generally difficult to make this information accessible to distribution system professionals in an intuitive and efficient manner. Tools such as GIS, hydraulic models, LIMS, and SCADA, are sophisticated systems and need specialized skills to leverage their information for distribution system water quality maintenance. In order to address this challenge, the Utility authorized a project to investigate and develop recommendations to assist the water division staff in proactively maintaining distribution system water quality and ensuring compliance with regulatory requirements. Findings from this study revealed an intuitive GIS-based data visualization tool that can be used by engineering, planning, water quality, production, and distribution staff to compare historical field, SCADA operations, and water quality modeling data in one location to help staff make informed decisions with respect to distribution system water regulatory compliance and protecting public health. This water quality application tool will summarize historical water quality data and water quality model simulation results, including model-predicted disinfectant residuals and other key data, which will assist water division staff in comparing field water quality observations with model results. The application would also show trends, statistics, and alarm ranges for each water quality sampling location based on historical data.

Functionality of Proposed Water Quality Application

The project team, comprised of Black & Veatch, Reiss Engineering Inc., and EPIC Engineering & Consulting group, LLC, conducted a needs assessment for the water quality application and developed a solution recommendation to meet the needs of the Utility staff. The needs assessment activities identified the following application functionalities as the priority functions to be implemented in phase 1 of the application:

- Provide simultaneous data access, visualization, and analysis capabilities of time series data for SCADA, historical water quality (LIMS), and water quality modeling predictions. Staff should be able to compare and correlate information from these three data sets to troubleshoot water quality problems and improve operational efficiencies.
- Provide hydrant flow test data compilation and analysis capabilities compared to model and field test results to highlight outliers. The water quality application can then display the data on a GIS map for Utility staff.
- The water quality model should support operations staff by providing "what if" analysis capabilities for planned system parameter changes (pressure, chlorine residual) at the water supply facilities. These simulations will be performed by modeling staff and the results will be made available to water division staff through the application. With this functionality, water division staff will be able to assess and visualize the impacts of planned system parameter changes on the distribution system.
- Identify optimal locations for new automatic line flushing devices in the distribution system. The hydraulic model can identify recommended locations for the flushing devices to improve water quality in the system. The model-recommended automatic line flushing device locations can be shown as a GIS layer for assisting the water operations staff.
- Assist with troubleshooting water quality and pressure problem areas by correlating field observations with model simulations.
- View the spatial distribution of outlier data for the parameters tracked. This capability can provide the Utility staff with the ability to identify patterns of water quality problems in the system and assist in the development of suitable solutions.
- Assist with improving the unidirectional flushing program (UDF) efficiency by tracking the chlorine residuals in UDF zones to study long-term pre- and post-UDF residuals and comparing them to water quality model results to develop UDF return trigger values. As a UDF zone's chlorine residual drops below the trigger value, distribution system UDF planners could target and schedule UDF return events. The UDF zones should be provided as a GIS layer visible through the water quality application interface.
- Assist with targeted valve exercising by providing a comparison of field chlorine residuals with model predicted results and identifying locations with significant differences.

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Figure 1 - GIS View of Water Quality Data

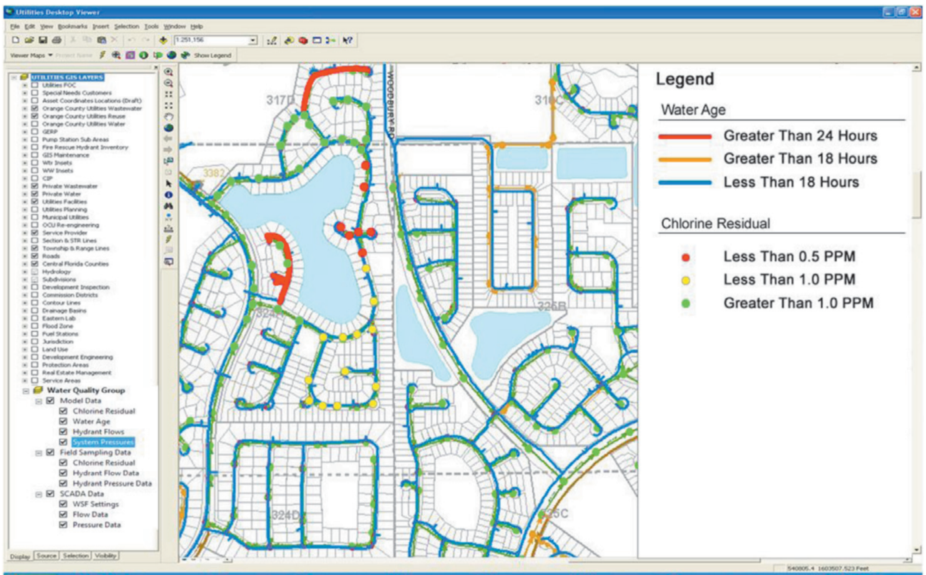
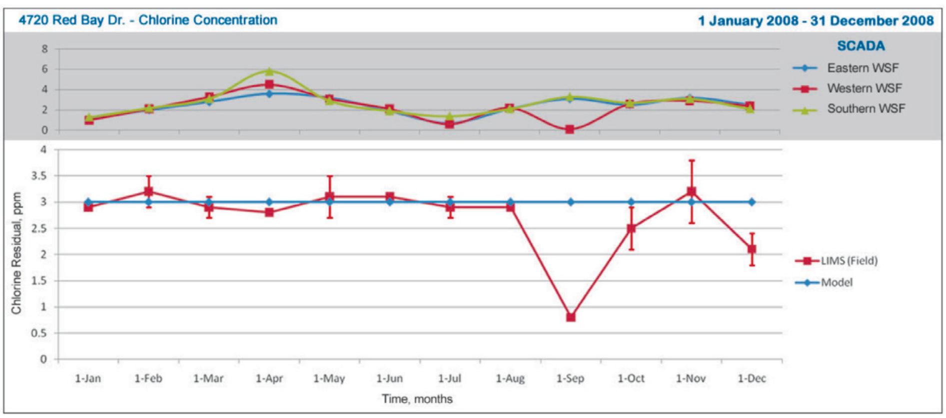


Figure 2 - Historical Data Visualization



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- Identify areas where seasonal flushing is required, based on significant seasonal variations in water consumption patterns (such as schools and tourist attractions).
- Provide maps and reports presenting the model-simulated water quality parameters, such as chlorine residuals and water age, with field data for these parameters. Reports should also provide the ability to export the data in tabular manner as a spreadsheet export.

The following requirements were identified for implementation in future phases of the application.

- Provide access to water supply facility pressures and disinfectant output concentrations for Utility modeling staff so that the water quality model can be validated. This is targeted for a future phase when this information becomes available for incorporation as a GIS data set.
- Facilitate water quality and pump station hydraulic calibration by incorporating SCADA and field monitoring data into the model calibration process, allowing rapid calibration of the water quality model.

Application Interface and Architecture

The proposed water quality application will include two major components: the data acquisition/storage component and the data visualization component. The data acquisition/storage component accesses information relevant to water quality application users from readily available data sources such as field sampling data and hydraulic model analysis results. The data visualization component presents the data to end users in an intuitive interface. The user interface would include a GIS view of the model and field results (Figure 1) and a graphical representation of historical information for selected infrastructure (Figure 2).

Figure 3 depicts a proposed high level technical architecture of the Water Quality Application. The application includes a mapping component and a time series visualization component. The Mapping component shows the model results, field sampling data, and hydrant testing data. The time series data visualization component will be a separate NET (Microsoft computing platform) application that will be integrated with the GIS desktop application. The component will be launched from the GIS desktop application when the users select the time series visualization function for a model/system element or sampling site.

Application Benefits

The application will include the following water quality modeling output: water age, bulk decay rates, pipe wall decay rates, chlorine residual, source trace, and water supply facility (WSF) chlorine residual set points. It will also include maximum/minimum ranges for typical average daily water system operation.

The anticipated benefits of the water quality application are as follows:

- Simultaneous access and evaluation of geospatially correlated SCADA data, historical water quality data, and water quality modeling predictions
- Quick access to system WSF pressures and disinfectant levels for model updates
- Efficient calibration of water quality and pressure source or pump station
- Intuitive interface to compare historical results and hydraulic model results
- Support for scheduling unidirectional flushing frequency
- Assistance in valve exercise planning activities

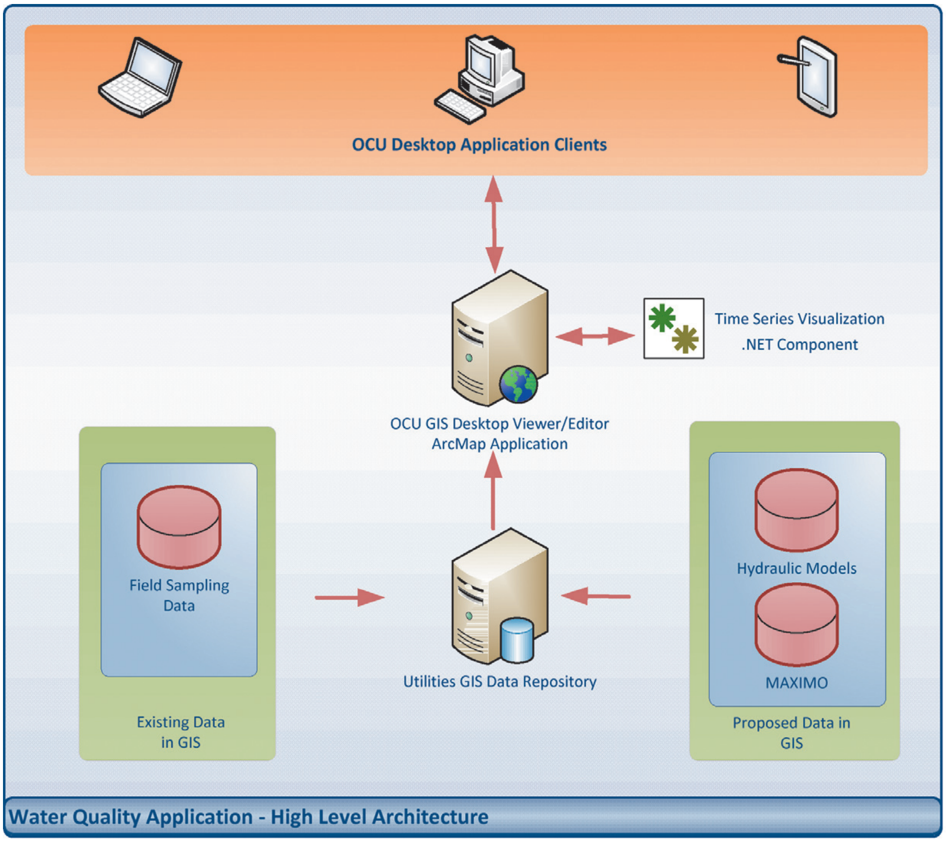

Figure 3 - High Level Architecture of Water Quality Application

Conclusions

Emerging regulatory requirements such as the revision to the Total Coliform Rule and the Stage 2 Disinfection By-Product Rule continue to increase the challenge for utility operations staff in maintaining distribution system compliance. Utilities can benefit from integrated access to information such as hydraulic model simulations, field sampling data, GIS infrastructure data, hydrant flow test data, and plant operations data for making decisions to improve water quality in the distribution system. Developing innovative and intuitive tools such as the proposed water quality application for the Utility removes the complexity in delivering disparate data sets to utilities staff and supports decision making towards sustaining and improving distribution system water quality.

References

"Research Topic on Distribution System Water Quality", Water Research Foundation, http://www.waterresearchfoundation.org/research/TopicsAndProjects/topicSnapshot.aspx?topic=DSWQ, September 2010

"Water Quality Application Project Specifications Report", Orange County Utilities, April 2010

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