How to Use Advanced Modeling and Animation to Evaluate Water Quality Improvements

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The City of Daytona Beach (city) has experienced challenges in maintaining an appropriate balance of its disinfection processes at the Brennan Water Treatment Plant (WTP) and two booster pump stations located in the potable water system. Figure 1 details the city's existing water distribution system network. This situation results in periods when chloramine residuals, disinfection contact times, and compliance with disinfection byproducts (DBPs) regulations are difficult to maintain. In particular, the city experiences water quality challenges associated with low chlorine residual levels (less than 3 mg/L) during seasonal demand periods and in areas where system hydraulics and potable water demands result in older water. The city has noted that water quality complaints often occur from a single entity within a given area, oftentimes where the user is located in a remote location near a dead-end distribution main.

To address these and other potable water system concerns, hydraulic and water quality modeling was performed to establish and corroborate existing field conditions and seek possible solutions to improve water quality.

Hydraulic Model Development

The initial phase of the project included data collection used to develop and update the city's existing potable water system hydraulic model. The model was updated using the following information:

- Previous H2ONET® hydraulic model
- Potable water system geographic information system (GIS) information
- Records of system changes (e.g., new pipes) since last model update
- Flow meter data
- Water treatment plant monthly operating reports
- Pump curves for booster pump stations
- Water distribution system operational strategies
- Flushing programs
- Historic water usage, pumping rates, and system pressures at various locations
- Water quality data (chlorine residual)
- Diurnal curves (with and without auto flushers)

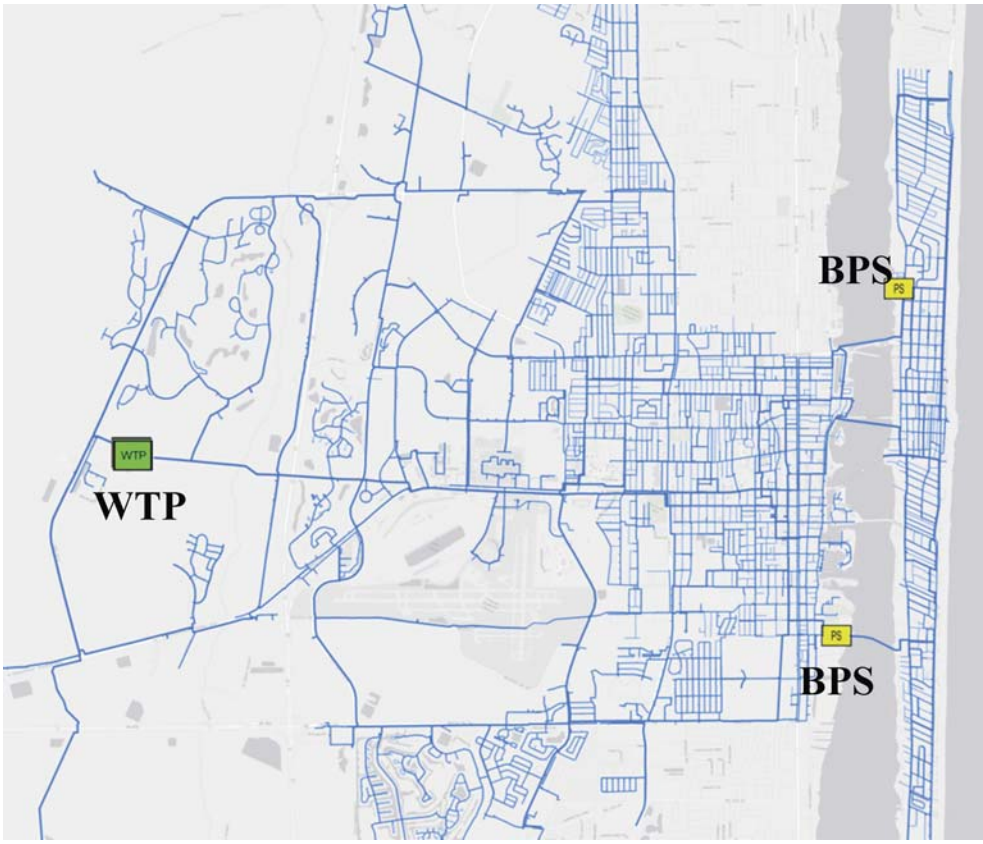

Figure 1. Water System Map

The model was converted to the ForceMain® modeling software, which was used, in part, to prepare visual animations of hydraulic and water quality modeling scenarios for review and discussion with the city. The following is a general summary of how the model was developed:

- H2ONET hydraulic was exported to GIS shapefiles
- GIS shapefiles were compared to city-provided GIS water system data
- GIS shapefiles were updated with city GIS information (e.g., pipe sizes, new pipes, connectivity, routing, and locations)
- Updated shapefile data was imported into ForceMain
- ForceMain model was updated based on input from the city

Initial model runs were performed using demands from the original model and results were reviewed with the city as a validation of the existing model. In general, initial modeling results were fairly indicative of residual pressures and showed that water pressures were good, with residual pressures greater than 50 pounds per sq in. (psi) throughout the potable water system.

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Hydraulic Modeling Summary and Results

The ForceMain model was updated with more detailed information provided by the city, including addresses and metered flows over extended periods. Using the extracted automatic meter reading (AMR) data provided (including over 27,000 rows of data), demands were applied locally in the model. Additionally, the model was updated with diurnal flow information taken during both flushing and nonflushing periods.

Hydraulic modeling was performed on the system using both AMR demands and diurnal flow information. Similar to the preliminary modeling, results showed that pressures in the system remain above 50 psi under each of the modeled conditions.

Fire Flow Analysis

Once updated demands and piping modifications were incorporated into the model, a desktop fire flow analysis was performed. Model elements simulating fire hydrants were set at five locations that were selected to represent a variety of potential fire flow conditions within the city. The model was set to maintain a minimum residual pressure of 20 psi at the simulated hydrants. It then calculated available fire flow at each location, while maintaining the selected minimum residual pressure of 20 psi (Table1).

Results of the desktop analysis show that sufficient fire flows are available as long as there is ample potable water supply.

Water Quality Modeling Summary and Results

Water quality modeling depends on having a calibrated hydraulic model with reasonably accurate flows and velocities in the pipes. As such, model-calculated potable water system residual pressures were confirmed with field measure data prior to beginning water quality modeling.

Water quality can be defined using many different parameters; for purposes of this project, water quality was measured by mg/L of chlorine residual and the city had a goal of maintaining a minimum chlorine residual of 3 mg/L in the water system. The following were the general parameters used for modeling:

- Bulk modulus (reaction-rate chlorine decay) was initially set at -0.5
- Booster pump stations were set to discharge 3.8 mg/L of chlorine

Based on input from the city, initial water quality modeling results indicated chlorine residuals were slightly higher than field data; therefore, the model was adjusted using a bulk modulus of -1 to simulate faster chlorine decay. Additional modeling was performed and results showed that model-predicted chlorine residuals were closer to the actual field data. Additionally, modeling indicated that water quality was generally good, with chlorine residuals over 3 mg/L for much of the overall system.

Improvement Alternatives

Based on results obtained from the water quality modeling, six specific areas within the city were identified as having chlorine residual levels below its goal of 3 mg/L. These areas included:

- Winston Park
- Fairway Estates
- Van Ness
- Tournament Drive
- Grande Champion Boulevard
- The Avenues

For each of these areas, the city provided additional input based on field operations, and this information was used to further develop the model. Once it was updated, several modeling scenarios were developed to evaluate potential water quality improvement projects. Each of the six areas with low chlorine residual is discussed, with a summary of information from the city and general results of the water quality modeling.

Table 1. Calculated Available Fire Flows

Fire Test	Location	Available Fire Flow
1	Intersection of Palm Street and Fleming Avenue	1,451 gpm
2	Peck Plaza	1,901 gpm
3	Bethune-Cookman University	5,657 gpm
4	North Beach Area	1,371 gpm
5	Pelican Bay Country Club	1,771 gpm

Alternative 1

Winston Park: This area had an existing 6-in. main missing from the model, which was updated with the pipe information. Once updated, additional modeling was performed on this area, which included closing the valves on the 8-in. main running west on Clearwater Road and at the intersection of Verona Street and Cambridge Avenue.

Winston Park Results: Once the model was updated to include the missing pipe, results showed existing system chlorine residuals of 0.5 to 1.5 mg/L in the area. The referenced 8-in. pipe was then closed and the model results showed chlorine residuals below 0.5 mg/L. Subsequently, a 6-in. pipe connecting two dead-end (6- and 12-in.) pipes near the end of Forest Glen Boulevard was added to the model. The model results indicated that chlorine residuals can be improved to over 3 mg/L in the general vicinity.

Alternative 2

Fairway Estates: In this area, alternate combinations of opening and closing the existing pipes, along with closing the valve located near the intersection of Peachtree Road and Wilder Boulevard, were evaluated.

Fairway Estates Results: Closing the referenced pipes and valves had little impact on water quality and seemed to transfer lower chlorine residuals to adjacent areas. There was discussion with the city about adding a chlorine booster pump to improve water quality, but the water quality animations for this area were reviewed and it was agreed that a booster pump would provide little or no benefit due to the direction of water flow. Based on modeling results obtained, no capital improvement projects (CIPs) were recommended for this area.

Alternative 3

Van Ness: The city initially suggested adding a new pipe to connect the water main along North Street to the 8-in. water main on Clyde Morris Boulevard. Modeling was performed on this area and showed a change in flow direction in the immediate vicinity.

Van Ness Results: The modeling that was performed showed a potential for marginal water quality improvements over a limited area. It was agreed that the city would continue to monitor water quality in the area and utilize the updated model to evaluate possible future improvements. Based on this information, there were no CIPs currently recommended for this area.

Alternative 4

Tournament Drive: This was an area of concern early on in the project. The problem was due to an existing 20-in. main that runs along Tournament Drive to the Champion Ele-

mentary School. Due to a combination of low demand and large pipe volume, chlorine results were very low (less than 0.5 mg/L). The following is a summary of the alternatives suggested by the city that were modeled in this area:

A. Close the existing 20-in. main on the west side of the intersection of Tournament Drive and Thornberry Branch Lane, while connecting a new 10-in. main to the existing 8-in. main along Tournament Drive to the school.
B. Close the existing 20-in. main west of the intersection of Tournament Drive and LPGA Boulevard and connect a new 10-in. main to the existing 8-in. main along Tournament Drive to the school.
C1. Close the existing 20-in. main running north on Dunn Avenue near the WTP.
C2. Close the existing 20-in. main running north on Dunn Avenue near the plant, while closing the 20-in. main along Tomoka Farms Road.
C3. Close only the existing 20-in. main along Tomoka Farms Road.

Using the results from these scenarios, a new scenario (Alternative D) was developed to include a new 10-psi hydraulic booster pump station (no chlorine addition) with a new section of 6-in. water main and valving modifications.

Tournament Drive Results: Based on water quality modeling results, chlorine residuals in this area can be increased from less than 0.5 mg/L to approximately 3 mg/L by implementing Alternative D as a future CIP. Included will be a new in-line submersible booster pump station with a design capacity of 220 gal per minute (gpm) at 23-ft total dynamic head (TDH). Additionally, approximately 3,000 lin ft of new 6-in. water main will be installed and the existing 20-in. water main located to the east of the proposed booster station will be valved off. These piping modifications were designed to impart a flushing or "racetrack" effect on the water from the proposed 6-in. main clockwise through the existing 20-in. main.

Refer to Figure 2 for a map depicting the proposed improvements for Tournament Drive.

Alternative 5

Grande Champion Boulevard: Preliminary modeling suggested that the piping network in this area was designed with the anticipation of significant growth, which has yet to occur. Similar to the Tournament Drive area, the combination of relatively large-diameter pipes with lower than expected demands resulted in older water age and the associated chlorine decay. The following is a general summary of modeling efforts performed on this area:

1. Various valves and combinations of valves were closed in this area and modeling was performed to see if there were any improvements to water quality.
2. A new 6-in. pipe was added along Gene Daniels Road.
3. Added new 6-in. pipes along Gene Daniels Road and along Masters Lane and included a new booster pump.
4. Items 2 and 3 were combined while closing the valves.

Grande Champion Boulevard Results: Adding the 6-in. pipes with a new booster pump station showed some potential to improve water quality; however, the city indicated that adding the new pipes was not feasible and that water quality in the area has probably improved due to recent growth and is expected to continue to

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improve. It was recommended that the city keep monitoring this area as the building construction continues and associated potable water demands in the area increase. Based on this information, there were currently no CIPs recommended at this time to improve water quality in the area.

Alternative 6

The Avenues: Based on water quality modeling results, this area has significant water quality issues, with chlorine residuals below 0.5 mg/L in the vicinity of Oak Street and Avenue A. The city provided a list of five parcels it owns in this vicinity that could be used for booster pump station locations to help improve water quality. Modeling was performed and the booster pump station location that showed the greatest potential for water quality improvements was located at Golf Avenue.

The Avenues Results: Based on modeling results, improvements in this area will improve water quality by increasing chlorine residuals from less than 0.5 mg/L to over 3 mg/L. Several modeling alternatives were evaluated and the recommended option included a booster pump station with a capacity of 289 gpm at 42-ft TDH, along with a chlorine storage and feed system at the Golf Avenue location. The pump station will connect to the existing system using approximately 2,300 lin ft of 6-in. water main running south through the power easement to Flomich Street. A new 6-in. main will also be installed from the northwest corner of Springleaf Drive running northwest to Avenue K, where a new parallel 6-in. main will be constructed and will run west to Oak Street. Modeling also showed significant water quality improvements with the installation of approximately 650 lin ft of 6-in. water main to connect the existing mains that run along Hand Avenue.

Figure 3 shows the proposed improvements at the Golf Avenue site to address water quality in the Avenues.

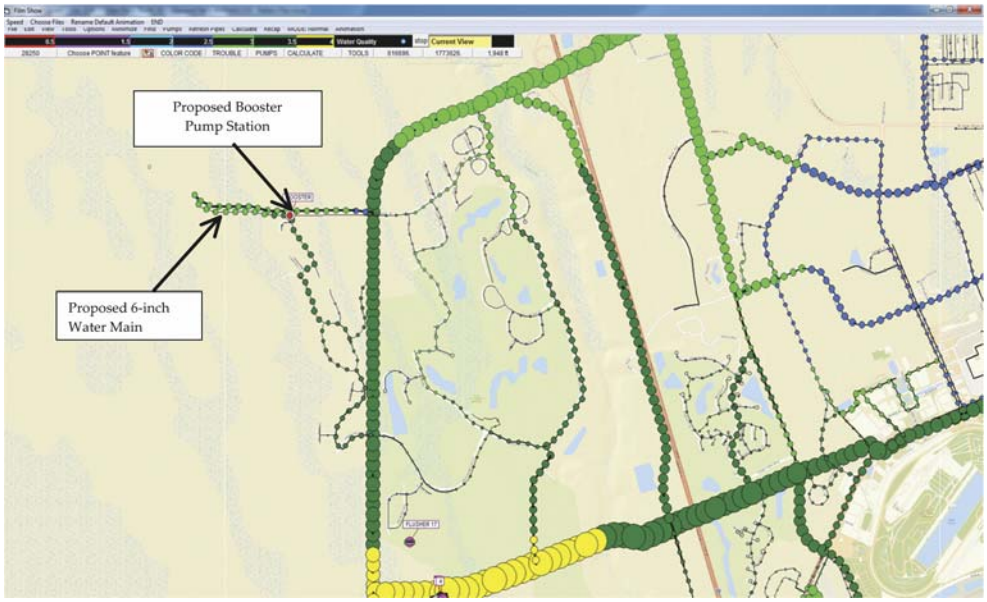

Figure 2 . Tournament Drive Proposed Improvements

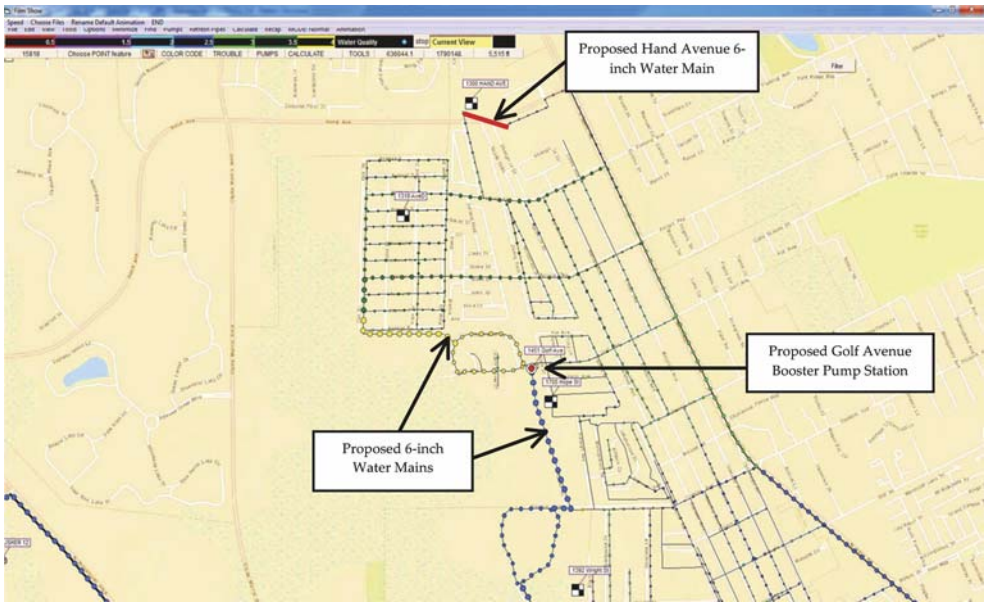

Figure 3. Golf Avenue Proposed Improvements

Summary and Recommendations

The following summarizes hydraulic and water quality modeling results, findings, and recommendations:

- Water pressure is very good across the city, with minimum pressures greater than 50 psi for the modeled scenarios.
- Other than six "pockets" in the city, water quality (as measured in mg/L of chlorine residual) is generally good; residuals are typically greater than the city's goal of 3 mg/L.
- Modeling performed along the Tournament Drive area showed that chlorine residuals can be increased from less than 0.5 mg/L to approximately 3 mg/L. It is recommended the city design and construct a new in-line booster pump station and install a new 6-in. water main to realize these water quality improvements.
- Modeling performed in the Avenues area showed that chlorine residuals can be increased from less than 0.5 mg/L to over 3 mg/L over a significant area. It is recommended the city design and construct a new Golf Avenue Booster Pump Station and install several new 6-in. water main segments to recognize these improvements.
- It is recommended that the city design and construct approximately 650 lin ft of new 6-in. water main along Hand Avenue to connect the existing 6-in. water mains to increase chlorine residuals from less than 0.5 mg/L to 3 mg/L in this area.
- The city's flushing program should continue and focus on areas where modeling showed no feasible improvements and also to address seasonal water quality issues.
- The city should continue to monitor water quality in the Grande Champion Boulevard area as construction continues. This new construction is anticipated to increase demands and improve water quality.