A More Perfect Union: Improving Design Through Distribution System Modeling

Kristen Cartwright, Richard Weatherly, Jason Ward, and Jared Barber

The City of Huntsville, Texas, (city) executed an aggressive $25 million bond program to modify its water system and hydraulically separate its two existing pressure planes. Without the modifications and accelerated bond program, the city risked violating minimum water system pressure requirements and being unable to serve increasing water demand due to growth.

The city's bond program involved 6 mi of water lines, two new pump stations, and a new elevated storage tank (EST). A unified design and hydraulic modeling team was key to addressing the challenges of a complex design and simultaneous project construction by providing the capability of evaluating design decisions in the model prior to implementation. By utilizing the hydraulic model during design, the city has saved approximately $2 million in construction costs based on a total of $21 million in awarded construction contracts, compared to the original construction estimate of $23 million.

Background

Freese and Nichols Inc. (FNI) was retained in 2015 by the city to prepare its water and wastewater condition and capacity assessment studies. The city is located 65 mi north of Houston and provides water and wastewater service to approximately 40,000 people, including seven Texas Department of Criminal Justice units and Sam Houston State University. By 2041, the population within the service area is projected to grow from 40,101 to 55,156 for water service and from 39,894 to 54,949 for wastewater service.

Kristen Cartwright, P.E., is project manager with Freese and Nichols Inc. in Winston-Salem, N.C. Richard Weatherly, P.E., is vice president, and Jared Barber, P.E., is project manager, with Freese and Nichols Inc. in Pearland, Texas. Jason Ward, P.E., is project manager with Freese and Nichols Inc. in Houston, Texas.

The city's water system, shown in Figure 1, consists of 279 mi of water lines, ranging in size from ¾ to 30 in. in diameter. The city relies on treated surface water from the Trinity River Authority Surface Water Treatment Plant and seven groundwater wells to provide water to its residents. The Palm Street and Spring Lake water plants distribute water throughout the city. The

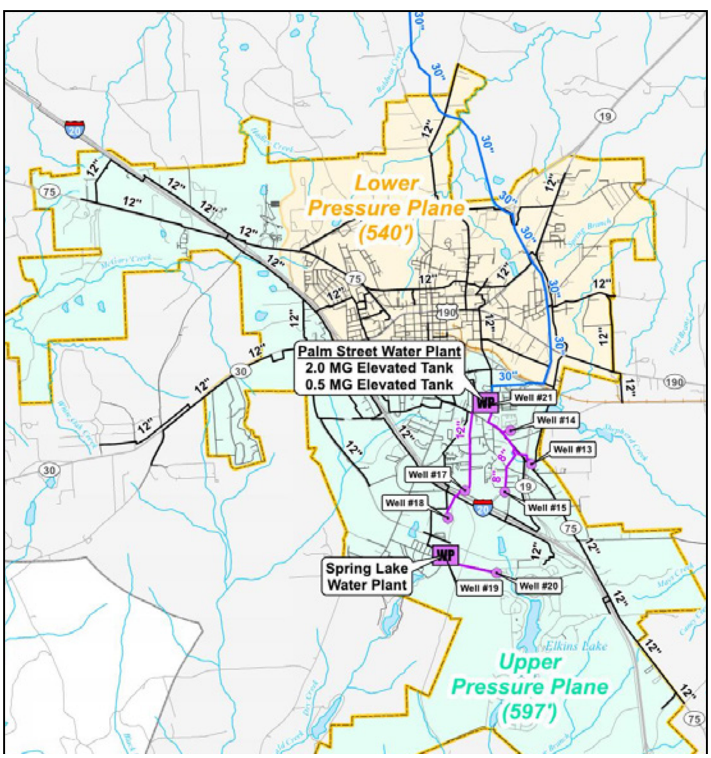

Figure 1. Existing City of Huntsville Water System

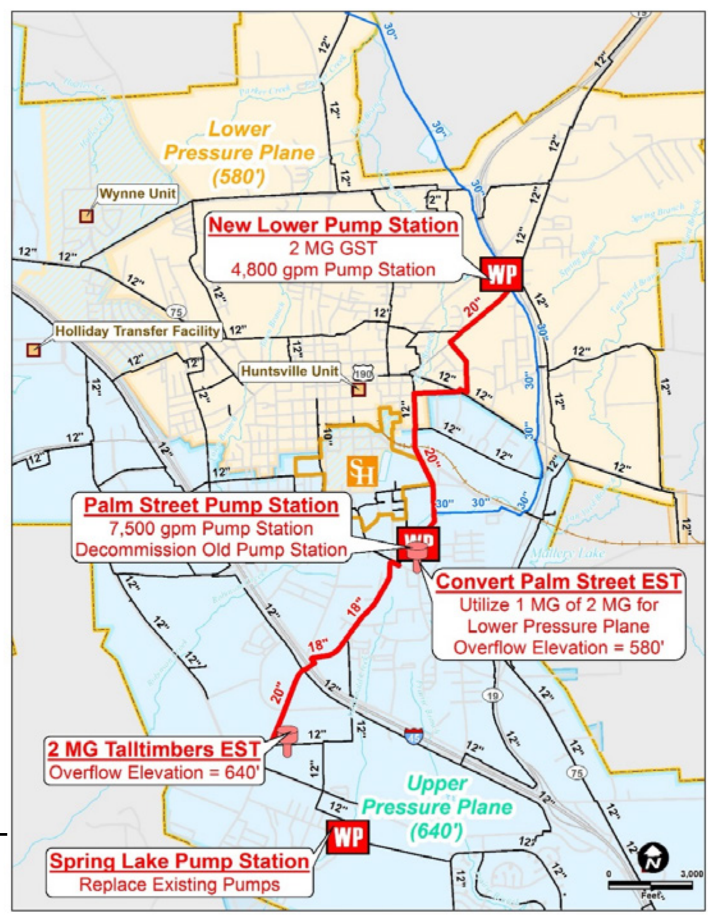

Figure 2. Recommended Capital Improvement Projects

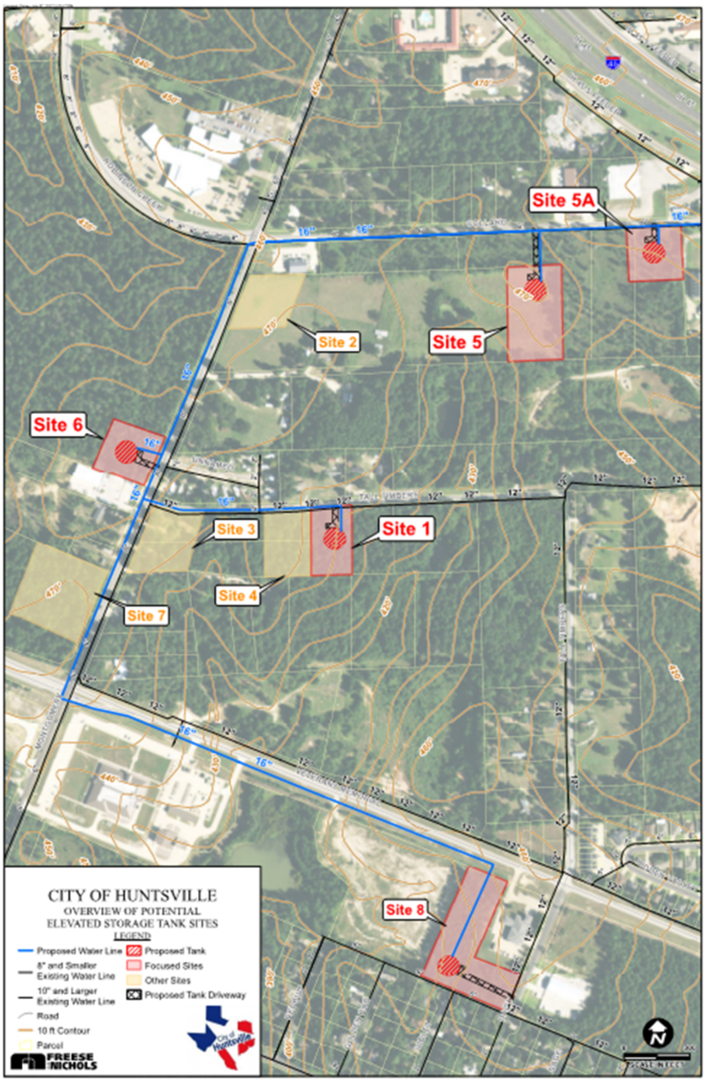

Figure 3. Potential Upper-Pressure Plane Elevated Storage Tank Sites

distribution system facilities also include four ground storage tanks and two ESTs. The city's water distribution system currently has two pressure planes (upper and lower) separated by 17 pressure-reducing valves (PRVs). A small PRV zone also exists in the Elkins Lake subdivision.

A hydraulic model was developed as a tool in the evaluation of the city's water distribution system. The city selected the WaterGEMS software by Bentley® for modeling the water system. Hydraulic analyses were conducted to identify deficiencies in the existing water distribution system and to identify capital improvements plan (CIP) projects to address deficiencies and meet projected water demands through 2041.

Major Water System Challenges

Challenges facing the water system include low water system pressure in high-elevation areas, high water system pressure in low-elevation areas, excessive headloss in undersized water lines, low fire flow availability, poor condition of the Palm Street pump

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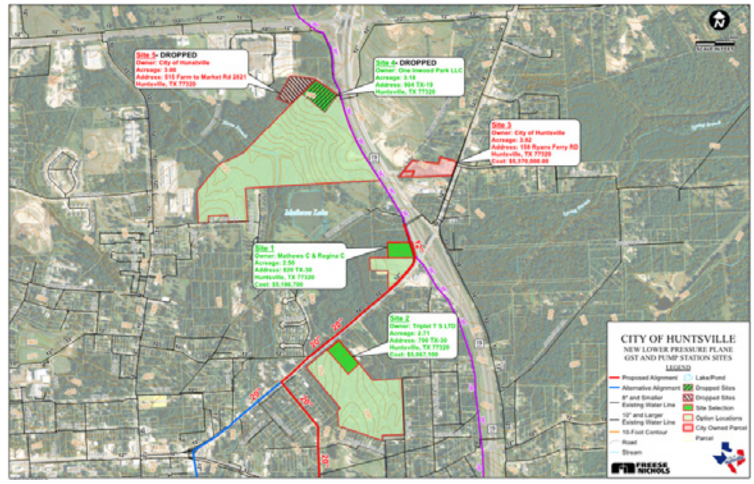

Figure 4. Potential Lower-Pressure Plane Pump Station Sites

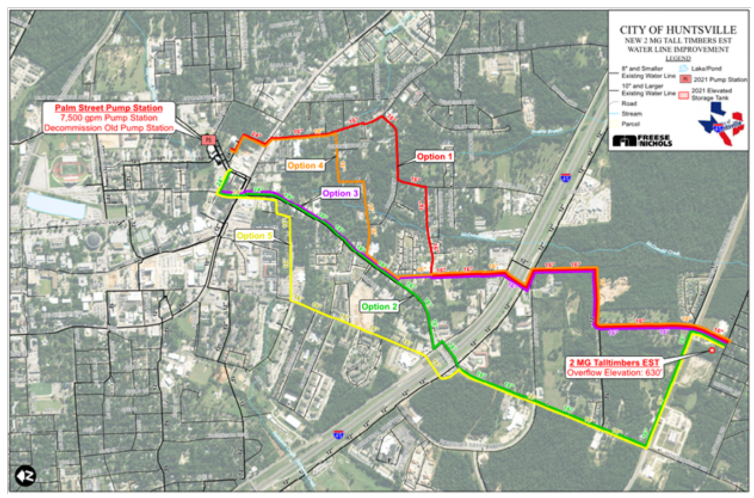

Figure 5. Potential Upper-Pressure Plane Water Line Routes

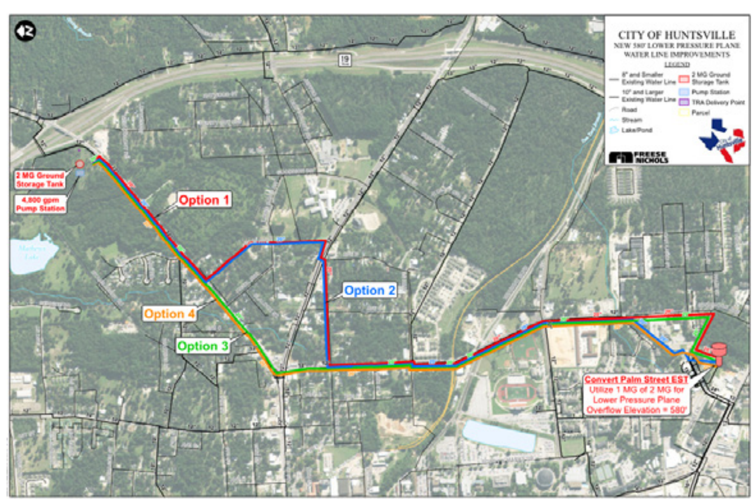

Figure 6. Potential Lower-Pressure Plane Water Line Routes

Continued from page 33
stations, and challenging operations. City staff and FNI developed and identified water system improvements to accommodate future growth, while optimizing the existing system operations and infrastructure.

The recommended operational changes and capital improvements (shown in Figure 2) to the distribution system included:

- New upper-pressure plane EST with higher overflow elevation
- Repurposing the existing Palm Street EST for use in the lower-pressure plane
- New Palm Street pump station for the upper-pressure plane
- New lower-pressure plane pump station
- Improved distribution system connectivity between pump stations and ESTs
- Pressure plane boundary modifications to address low pressures in the lower-pressure plane

The city had FNI design all projects simultaneously. The water model, developed as part of the water and wastewater study, was used to assist the design team and verify that the proposed water system improvements under design would operate as intended.

Hydraulic Modeling to Support Siting Studies

During the traditional design process, engineers would typically conduct facility-siting studies, based on a desktop analysis, with a narrow hydraulic analysis perspective and cost as the main drivers. The incorporation of hydraulic modeling allows the design and modeling teams to evaluate systemwide impacts, conduct operational analyses, and assess the impact of route selection on site performance.

For the new upper-pressure plane EST in the city, there were two main categories for site selection. The primary criteria consisted of generally siting the new EST south of the existing ESTs, staying outside or beneath Federal Aviation Administration height limitations, and locating a site with a ground elevation of at least 450 ft. Secondary criteria included elevation and EST height, length of the connecting water line, length of driveway access, cost of property acquisition, and cost of land clearing.

Nine potential sites were identified for the new EST and were reviewed with city staff; after considering cost and landowner restrictions, the number of potential sites was reduced to five, shown in Figure 3. After continued evaluation of the five sites, a sixth site was added for consideration and was ultimately selected as the site for the new EST. The site selected is the location of an existing city fire station and, in exchange for utilizing available space on the property, the new EST was designed to include firefighter training facilities, such as elevated windows and anchor points for rappelling.

In addition to the new EST site, a site selection process was developed for the new lower-pressure plane pump station. The selection criteria included ground elevation, proximity to the treated surface water supply line, cost of property acquisition, cost of pump station construction, and accessibility. Five potential sites were identified for evaluation, shown in Figure 4.

Early in the site selection process, two sites were removed from further evaluation due to landowner intentions for the property and accessibility issues. Site 1 was ultimately selected due to closest proximity to the treated surface water supply line and cost of property acquisition.

Hydraulic Modeling to Support Route Studies

Route studies typically involve a desktop analysis that assumes pipe sizing based on the original project description. Similar to siting studies, traditional route studies have a narrow hydraulic analysis perspective and are primarily cost-driven. Including hydraulic modeling as part of the route study allows for the potential to reduce the pipe sizing based on a systemwide assessment. The impact of site selection on the route study is also accounted for when hydraulic modeling is incorporated.

Two route studies were conducted by the city: one for the upper-pressure plane water line connecting the new Palm Street pump station with the new upper-pressure plane EST, and one for the lower-pressure plane water line connecting the new lower-pressure plane pump station and the existing Palm Street EST. The selection criteria included easement acquisition, stakeholder input, hydraulic analyses, constructability analyses, coordination with the city's water line renewal program, and road conditions. Routes are shown for the upper- and lower-pressure plane water lines in figures 5 and 6, respectively.

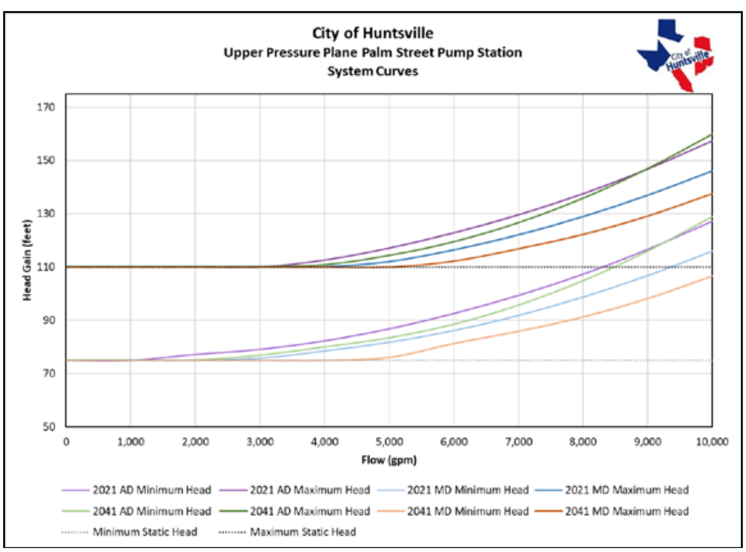

Figure 7. Model-Generated System Curves

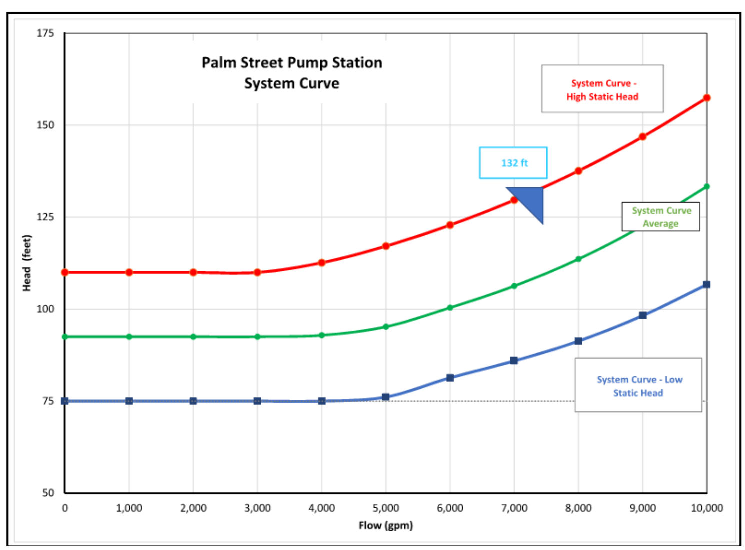

Figure 8. System Curves for Pump Selection

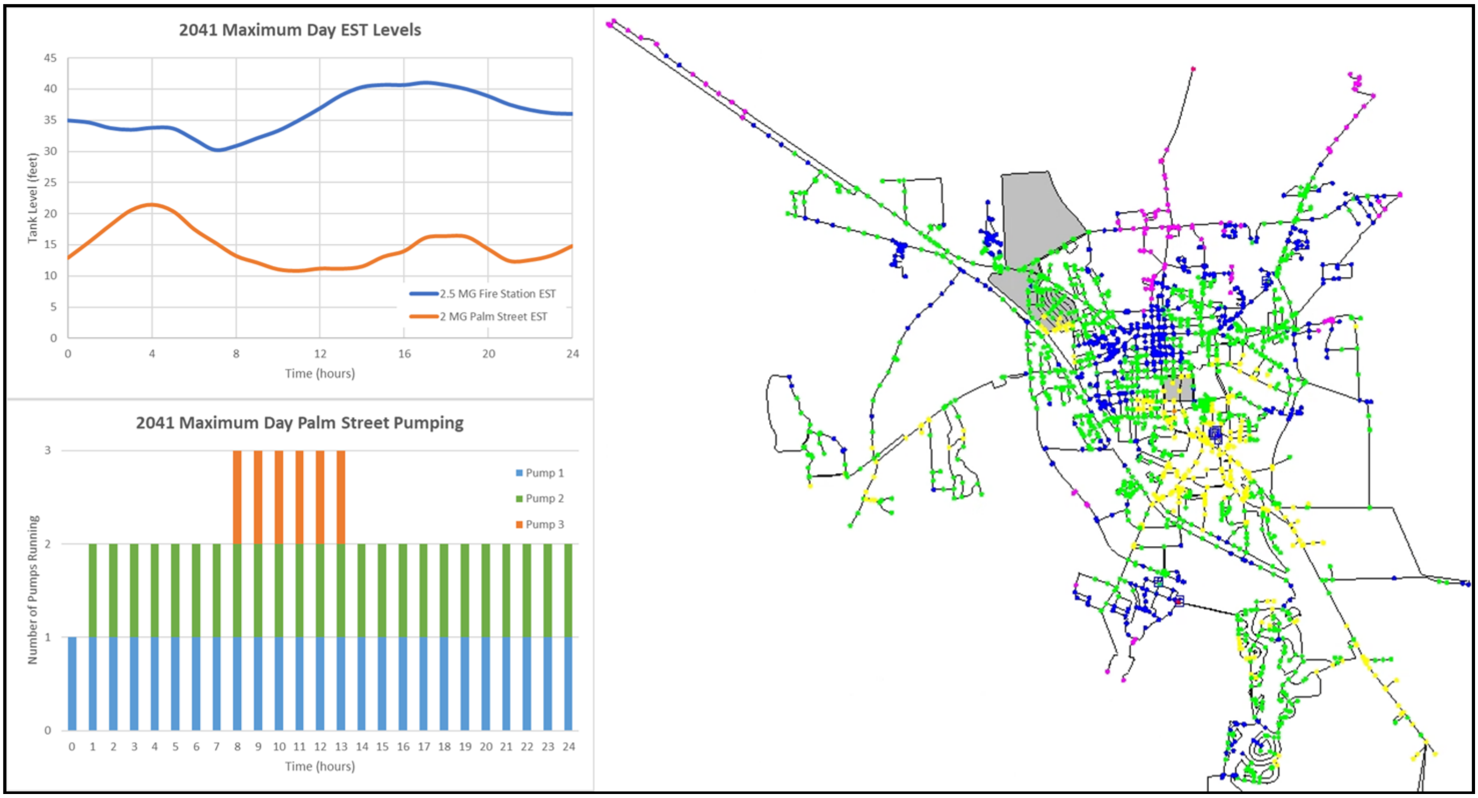

Figure 9. Hydraulic Modeling Results

Option 1 was selected as the preferred route for the upper-pressure plane water line since it had the shortest overall length, lowest cost, minimal interactions with the Texas Department of Transportation infrastructure, minimal disruption to residents, and coordinated with ongoing water line and roadway rehabilitation efforts. Option 4 was selected as the preferred route for the lower-pressure plane water line since it had the lowest cost, minimal street repaving, and allowed troublesome existing water lines to be abandoned.

During the route selection process, the hydraulic model was also used to evaluate possible reductions in the new water line sizing when installing the new water line parallel to existing infrastructure, instead of completely replacing existing water lines that were still in good condition. This resulted in a significant cost savings of more than $1.7 million in the water line components of the project.

Hydraulic Modeling to Support Pump Selection

Hydraulic conditions serve as the basis for pump selection during pump station design. Traditionally, pumps are selected based on a single design point or system curves generated from limited system information. It's challenging to change the pump selected if the project conditions, such as the site or the route, change during the design process. Hydraulic models allow for the quick generation of system curves that account for varying operating conditions and/or changes in the site or water line route selected.

For both of the new pump stations, the hydraulic model was used to develop system curves for average- and maximum-day, and near- and long-term, head conditions. This resulted in an envelope of system curves representing a full range of potential pump operating conditions, as shown in Figure 7. The envelope was simplified into a maximum, average, and minimum system curve for the actual evaluation of potential pumps, shown in Figure 8.

Summary of Benefits

Incorporating hydraulic modeling during the design process provides a systemwide perspective. Throughout the siting, routing, and pump selection process, the water model was used to assess tank drain and fill rates, EST turnover, minimum water system pressure, available fire flow, pipe velocities, and pump cycling. A portion of these results are shown collectively in Figure 9.

The ease and speed of evaluating multiple site and route options in a hydraulic model can lead to more-informed decision making, fewer assumptions, and results in cost savings when reevaluating changes during design. For the city, the use of the hydraulic model in the design process resulted in cost savings of more than $2 million, while also improving operations and optimizing system widgets.