The Unique Raw Water Supply Distribution System at the Heart of a Total Water Management Plan

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A community-owned utility located in northeast Florida, JEA has a drinking water production system that serves approximately 337,000 water customers in Duval County and parts of adjacent Clay, Nassau, and St. Johns counties. The water supply system consists of six service grids (Figure 1) containing 38 water treatment plants (WTPs), 147 Floridan aquifer production wells, and more than 4,000 mi of transmission and distribution mains. The two largest service grids, the North Grid and South Grid, are physically separated by the St. Johns River.

The system relies on groundwater from the Floridan aquifer for its raw water supply and the potable water production capacity has been challenged in its service area south and east of the St. Johns River (South Grid), which is also JEA's highest customer growth area. The South Grid is served by 12 WTPs interconnected by the transmission main grid. Each WTP has its own Floridan aquifer wellfield, each with a consumptive use permit (CUP) from the St. Johns River Water Management District.

Seven of the 12 wellfields are especially stressed because of production demands, and JEA considers them "wellfields of concern." Additionally, many of the South Grid wellfields were approaching their maximum CUP groundwater pumping allocation. In the early 2000s, JEA understood that alternatives needed to be explored to meet the future needs of its service area.

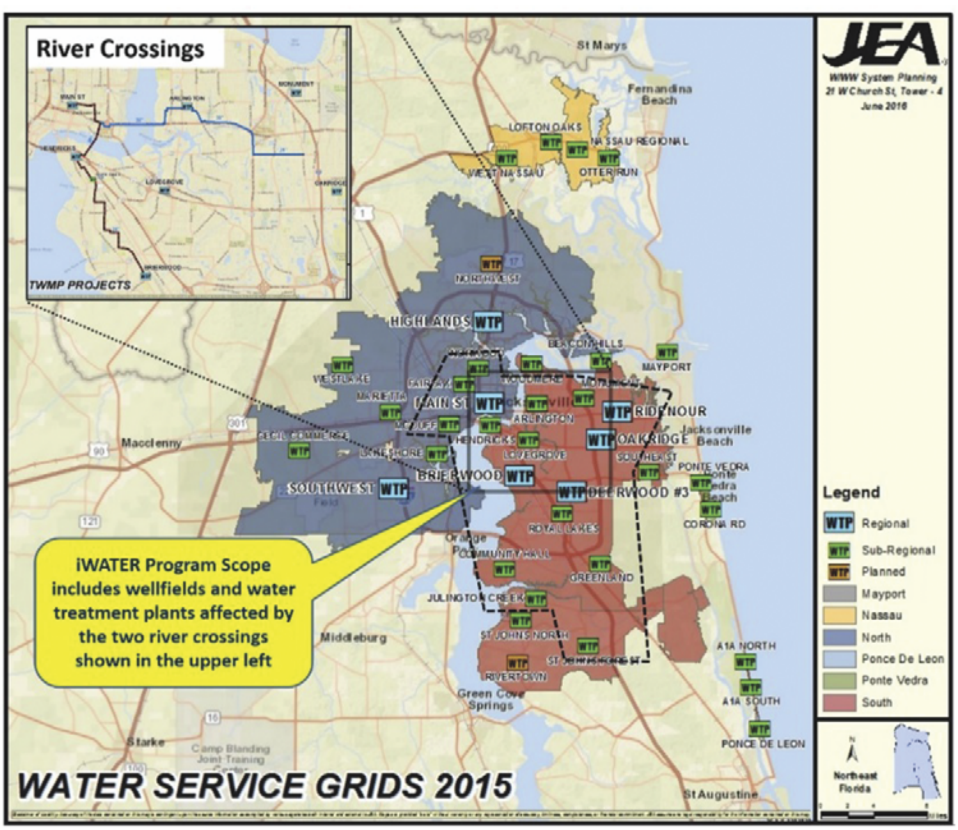

Figure 1. JEA Water System

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Total Water Management Plan: Phase 1

In the 2000s, early development of JEA's total water management plan (TWMP) included construction of two potable water pipeline crossings of the St. Johns River to transfer water from the North Grid to the South Grid. This water transfer supplemented the drinking water supply on the South Grid to boost the sustainability of its raw water source, and assisted in managing each WTP's wellfield CUP allocation. Two aspects of the system constrained its ability to transfer water:

1. The North Grid potable water was pumped from a single location (Main Street WTP) into the two river-crossing pipelines and then repumped on the South Grid at high pressure directly into the South Grid pressurized finished water distribution system at three locations in the very northern section of the South Grid. Repumping the water at high pressure into the distribution system limited the amount that could be transferred.
2. The connectivity of these three feedpoints, referred to as interties, was too localized and could not deliver water throughout the South Grid as was needed to supplement the water supply and operate the wellfields within the allowable CUP allocations.

The existing TWMP transmission system includes the two St. Johns River pipeline crossings: the East River Crossing and South River Crossing (Figure 2). At the Main Street WTP, six transfer pumps deliver water into the two pipes crossing the river to the South Grid. Based on a flow velocity of 5 ft per second (fps), the East

River Crossing pipe has a capacity of 23 mil gal per day (mgd) and the South River Crossing pipe has a capacity of 16 mgd, for a total capacity of 39 mgd. The water pressure is boosted on the East River Crossing by the Arlington Booster Station and on the south by the River Oaks Booster Station. Water repumped by the Arlington Booster Station is pumped into the South Grid pressurized transmission system through three interties. Water repumped from the River Oaks Booster Station is conveyed at low pressure to the Brierwood WTP, where it's treated and pumped into the South Grid transmission system. It partially serves to feed water to the southern-located Community Hall WTP, where it's repumped into the South Grid transmission system.

The current system actually transfers approximately 11 mgd to the South Grid (8 mgd through the East River Crossing pipeline and the Arlington Booster Station), and approximately 3 mgd through the River Oaks Booster Station. This is well below the maximum capacity of the two river-crossing mains.

Initiated planning was done by JEA in 2014 to determine the ability to meet South Grid water demand through 2040. Since the current TWMP system was having difficulty overcoming the backpressure from the South Grid WTPs and was ineffective at distributing water to meet demands in the South Grid growth areas, an alternative approach was needed to maximize the capacity of the two pipelines and realize the original TWMP performance objectives.

Sustainability of Local Wellfield Sources

Under JEA's CUP, the allowable withdrawals from the South Grid wellfields are lower than customer demands. The JEA's CUP required the wellfield allocations in the South Grid to be reduced incrementally starting in 2014, when the TWMP river-crossing pipes were fully operational, through 2021. To make up the deficit, JEA developed the TWMP to import and distribute water from its North Grid to the WTPs in the South Grid to supplement supply. North Grid wells have better water quality, are not at risk of quality degradation from poorer quality water in the lower Floridan aquifer, and are the highest-capacity wells in the JEA system. Also, implementation of the TWMP was a condition of JEA's CUP.

To protect its wellfields from further water quality decline, JEA's first course of action was to modify its operational and design standards for its South Grid supply wells, including reducing pumping rates; plugging off the lower zones of the wells to fend off the deeper, poor-quality water; and increasing the spacing between new wells to reduce concentrated stresses on the aquifer. Diligent design and operations practices offer the best approach (but no guarantee) for sustaining the withdrawal of high-quality groundwater from the South Grid wellfields. It was understood by JEA that the Floridan aquifer, like all resources, was limited, and responsible development of alternatives to protect it were needed.

Water Demand Projections

Jacobs conducted an expedited analysis for future water demand needs to determine the amount and location for additional water supply. It used the parcel–level population database and associated water use consumption factors for the land use categories to calculate population–based water demand projections for the 2020 through 2040 planning period.

Water demands were projected for the JEA South Grid service area in five-year increments from 2020 through 2040. For projections of future maximum day flow (MDF), the ratio of the MDF to the average day flow (ADF) was multiplied by the future-predicted ADF. The WTP production records were analyzed to calculate the systemwide MDF-to-ADF ratio of 1.45, and this factor was used for future planning.

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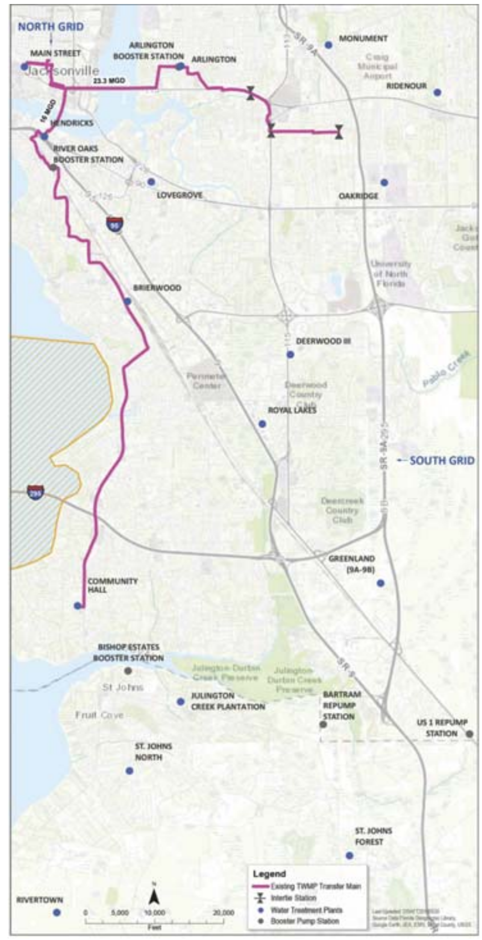

Figure 2. Current Total Water Management Plan (Phase 1)

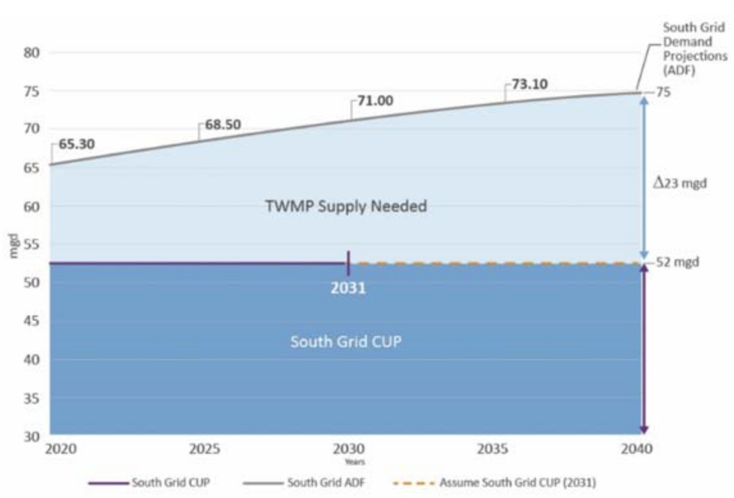

Figure 3. South Grid Supply Needs Met by the Total Water Management Plan

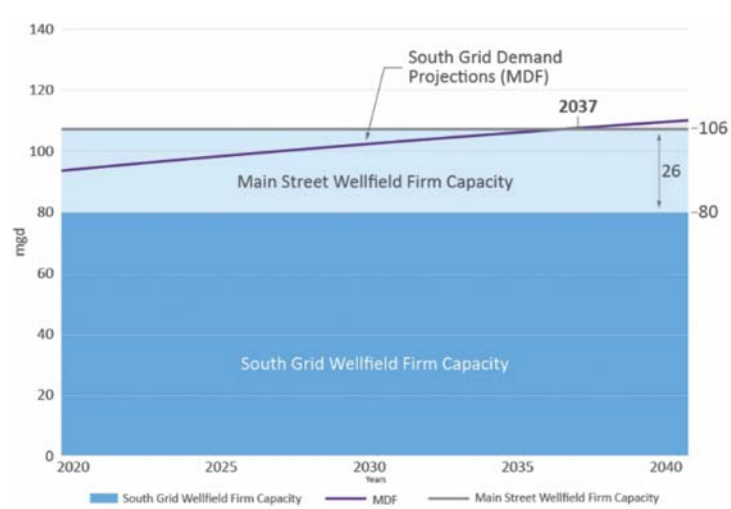

Figure 4. South Grid Demands: Maximum Day Flow

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Average Day Demands

The 2031 end-of-permit South Grid CUP allocation is 52 mgd, ADF. The primary source water for the TWMP is the Main Street WTP wellfield and its end-of-permit CUP allocation is 23 mgd, ADF. Under the TWMP, the Main Street WTP wellfield is dedicated to South Grid water transfer. The sum of the South Grid wellfield allocations and the Main Street WTP wellfield allocation is 75 mgd, ADF (Figure 3); this allocation is equal to the projected ADF demand of 75 mgd for the South Grid through 2040. To maintain South Grid CUP compliance, a minimum of 23 mgd would need to be transmitted through the TWMP. To meet the TWMP objectives, a plan was needed to transport the North Grid water to the South Grid where needed, for both water supply quality sustenance and CUP compliance.

Maximum Day Demands

While CUP compliance focuses on not exceeding groundwater allocations based on ADF, JEA, as a water utility, must meet the MDF demands of its South Grid customers. The estimated maximum sustainable capacity of the South Grid wellfields is 80 mgd after modifications, rehabilitation, and backplugging (also part of the TWMP) and then factoring in the firm capacity, where the largest capacity well in each wellfield is out of service. The estimated firm pumping rate for the Main Street WTP wellfield is 26 mgd, for a combined South Grid and Main Street WTP wellfields firm pumping capacity of 106 mgd. This value is slightly lower than the projected 2040 MDF of 109 mgd (Figure 4).

Total Water Management Plan, Phase 2: Southside Integrated Piping System

The Southside Integrated Piping System (SIPS) is JEA's new piping network program that reaches across two counties. Working with JEA, Jacobs identified an alternative plan to increase the capacity of the TWMP transfer system by converting it to a lower pressure operation, repurposing the transmission piping to dedicated transmission service, and extending the transfer piping to deliver raw water to the South Grid WTPs rather than directly into the high-pressure potable water transmission system. This alternative would enable delivery of additional raw water to specific South Grid WTPs, where the wellfields were vulnerable to quality degradation without the risk of overpumping those wells or exceeding their CUP groundwater withdrawal limits.

The transferred water would be pumped out to the South Grid customers using each WTP's high-service pumps. By importing the raw water through the high-service pumps to each South Grid WTP, JEA could use treatment, storage, and high-service pumping capacity that has been available but unused because of the WTP's CUP wellfield withdrawal limits.

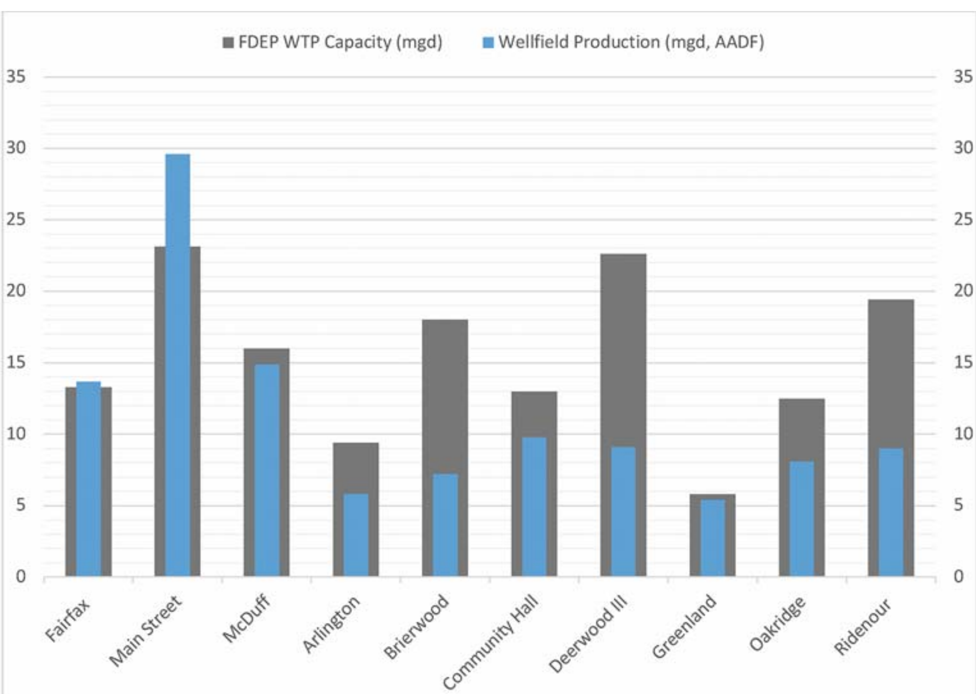

Figure 5. Water Treatment Plant Water Supply Versus Treatment Capacity

The South Grid system is a gridded system with multiple treatment plants and pumping stations delivering high-pressure water to customers, resulting in zones of blended water and WTP high-service pumping systems "competing" against each other. To determine supply capacity requirements to the South Grid wellfields, the following approach was used:

1. Run JEA's treated water transmission model under 2040 ADF conditions to determine the required output from each South Grid WTP to meet demands within its area of influence.
2. Compare the WTP's output under ADF conditions to its CUP allocation.
3. Compare the WTP's output under MDF conditions to its wellfield maximum firm capacity.
4. Develop a plan to bring TWMP water to supplement the local wellfield supply where WTP output exceeds its wellfield CUP allocation and/or maximum capacity.

The hydraulic model was used to evaluate the transmission and pumping system. The model was updated to include projected demands at the land parcel level based on the geographic information system (GIS) growth data furnished by JEA. This effort produced a more-complete allocation of demands throughout the model network than existed in JEA's prior version of the model. The model was used to identify deficiencies with regard to service pressure pipe flow velocities and head loss, fire flow capacity, and water age.

To develop the conceptual design of the SIPS distribution piping, JEA's hydraulic model was used to predict the future customer demands from each of the South Grid WTPs. All 12 WTPs and their high-service pump stations were modeled at their operating pressures to predict the optimum production rate based on discharge pressure, customer demands, and water transmission capacity. The optimum production rate was then used to determine the supplemental supply required from the SIPS to achieve wellfield CUP compliance and meet MDF demands. With this information, the supplemental raw water demands for each WTP were established and a hydraulic model of the raw water distribution piping was used to size and route the low-pressure transfer distribution mains.

Increased Use of Restrained Capacity

Water supply, WTP, and water transmission system capacities were evaluated for their surplus and deficiency limits. While some WTPs, such as Deerwood III, have large areas of influ-

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ence, no single WTP can serve the entire South Grid. Additionally, the existing CUP has capacity limits for each WTP that also limit the capacity of the WTP's production. If the WTP capacities are greater than the wellfield's capacities, additional raw water could be supplied to maximize the use of the WTP's rated capacity.

Each JEA WTP has a capacity rating established by the Florida Department of Environmental Protection (FDEP) and wellfield CUP allocation (Figure 5). The WTP capacity is expressed in terms of meeting the MDF and the capacity is based on the firm capacity (largest unit out of service) for wells, pumps, and treatment equipment. The total WTP capacity of the South Grid is 155 mgd, which is much greater than the 2040-projected MDF of 109 mgd.

The figure shows that the North Grid wellfields for the Main Street, Norwood, and McDuff WTPs closely matched or exceeded the WTP's rated capacity, and the South Grid wellfield capacities were significantly lower than the WTP's capacity rating. An objective of the SIPS is to deliver North Grid water to these underused South Grid WTPs and make better use of JEA's restrained investment in the capacity of these WTPs.

Conceptual Plan for the Southside Integrated Piping System

For the 2040 analysis, constraints in the existing (2018) model were removed, including the following:

- Removal of the three TWMP high-pressure interties. The transmission main serving the interties would be repurposed for low-pressure delivery of SIPS water to the South Grid WTPs. Each of the two river-crossing mains would be extended to distribute water to the wellfields of concern (Figures 6 and 7).
- Water transmitted through the SIPS would come from the Main Street WTP as a base-load flow. The SIPS flow would be distributed (untreated) and pumped under low pressure to selected South Grid WTPs, where it will be blended with water from the local wellfields to meet the balance of the South Grid demands, including MDF, peak hour, and fire flows. The SIPS and local wellfield water would be treated at each receiving WTP to include sulfide oxidation and disinfection.
- A new water delivery station would be needed between the SIPS mains and the existing WTPs (Figure 8). At each receiving WTP, the new intertie station will consist of a flowmeter and rate-of-flow control valve. The supervisory control and data acquisition (SCADA) system would require configuration to monitor the flow and control the feed valve. A SCADA-based flow control plan would be needed to manage and control the flows delivered throughout the TWMP distribution network. The primary objective of the flow control plan would be to deliver adequate flow to each WTP so the wellfields are not pumped in excess of their annual groundwater withdrawal allocation.
- Conversion of older TWMP transmission mains between the Hendricks WTP and Brierwood WTP to a fully dedicated low-pressure, raw water SIPS transmission main. This conversion required disconnecting existing distribution mains at this transmission main (already completed by JEA) and making new connections to the treated water distribution network.
- A new treated water low-pressure water main would be constructed from Community Hall WTP (Figure 2) to feed into the ground storage tanks at the Julington Creek Plantation WTP in St. Johns County. The existing 20-in. main crossing Julington Creek would be converted to a low-pressure treated water main to complete the transfer system to the Julington Creek Plantation WTP. A new project was

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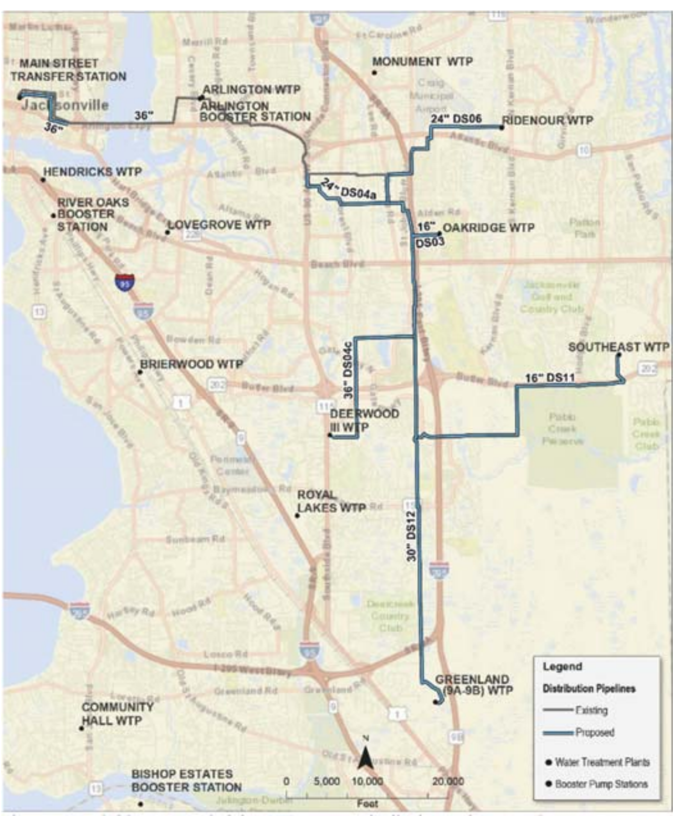

Figure 6. Southside Integrated Piping System East Distribution Main Network

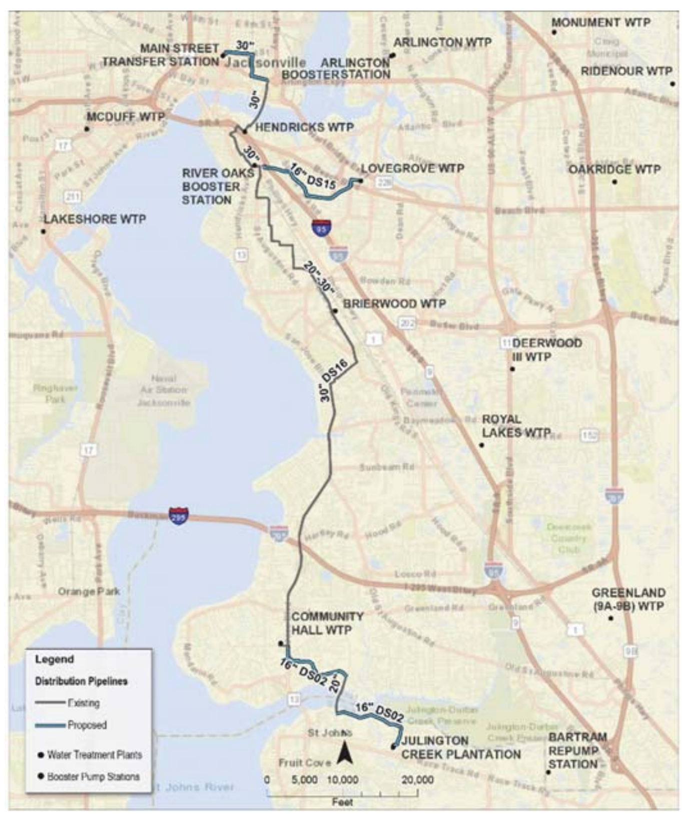

Figure 7. Southside Integrated Piping System South Distribution Main Network

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recommended to construct a low-pressure transfer pump station and water main to convey treated water from Community Hall WTP to the Julington Creek Plantation WTP ground storage tanks.

- The modeling exercise determined that the existing booster pump stations were well-suited to pump water to the southern extremes of the South Grid service area. As part of the modeling analysis, it was determined that each booster pump station could provide sufficient head and flow to reach the top of the existing tray aerators at the receiving WTP's ground storage tanks. The hydraulic gradeline of the east leg of the SIPS distribution main is shown in Figure 9. The two transfer pumping sources are in the Main Street WTP first, followed by boosting at the Arlington Booster Station.

Water Treatment Plan

Sulfide reduction is performed at the Main Street WTP through ozonation and tray aeration, which partially removes sulfide. Chlorine is not applied at the Main Street WTP to prevent chlorinated disinfection byproduct formation in the SIPS distribution system.

The travel time of the raw water to the most distant delivery points (Community Hall and Greenland WTPs) may take weeks and it's not possible to predict the water quality once it arrives at these distant locations. The impact on the raw water quality following introduction of high levels of oxygen from ozonation and tray aeration at the Main Street WTP is also unknown. Water quality monitoring was recommended to monitor for any biogrowth activity and taste and odor formation.

Phase 2 Implementation Plan

A $90 million program has begun to construct the SIPS transfer system over the next seven years. When complete, and coupled with a comprehensive wellfield rehabilitation and backup well construction plan, the SIPS program is expected to meet the growing South Grid water demands through 2040.

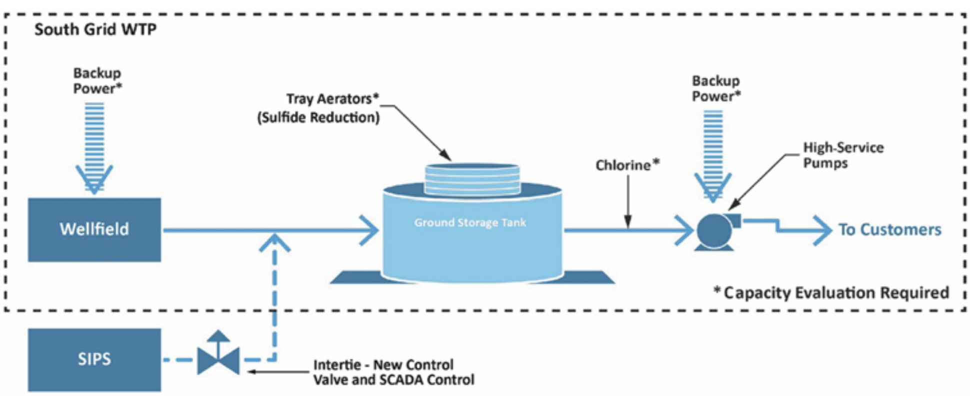

Figure 8. South Grid Southside Integrated Piping System Delivery Station

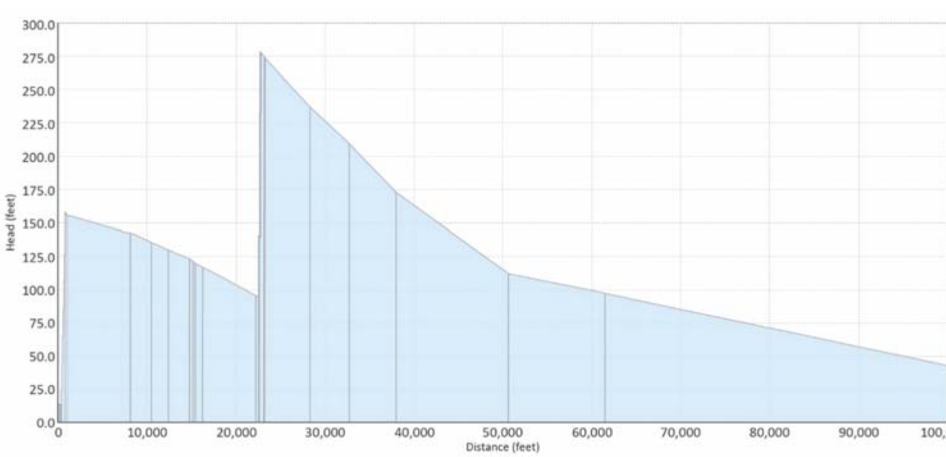

Figure 9. East River-Crossing Hydraulic Gradeline:
Main Street Water Treatment Plant to Greenland Water Treatment Plant

Beyond the Southside Integrated Piping System

As an extension of the TWMP, JEA initiated the integrated water supply testing, evaluation, and rehabilitation (iWATER) program to develop the facilities and operational plans for water supply, treatment, and transmission within the South Grid area.

Under iWATER, JEA plans to increase water supply capacity and reliability in the Main Street, Norwood, and McDuff wellfields through wellfield rehabilitation. The Norwood and McDuff wellfields, located on the North Grid, would supply additional water to the TWMP transfer system. In addition to improving capacity, well and wellhead rehabilitation with the new equipment would improve system reliability.

As described previously, SIPS maximization using the Main Street and South Grid wellfields as the water supply source is predicted to meet South Grid demands for about 20 years. Beyond 2040, supply to the SIPS may be increased by supplementing Main Street supply with raw water from the McDuff and Fairfax wellfields. The limiting factor will become the transmission capacity of the twin river-crossing pipelines. Additionally, relying solely on the SIPS carries risk, should any of the key components be lost, including the Main Street Transfer Station and either, or both, of the river-crossing pipelines.

Options are being considered to meet capacity needs beyond those obtained from SIPS. These options could include increased conservation measures, new water supply alternatives (such as backup and emergency wells on the South Grid), and indirect potable reuse. A hybrid alternative composed of new backup/emergency wells for reliability, along with indirect potable reuse, will also be evaluated based upon aquifer recharge through rapid infiltration basins or injection wells, followed by extraction wells for raw drinking water supply.

The indirect potable reuse concept requires advanced treatment to treated wastewater, followed by injection of the water back into the aquifer. Aquifer recharge has the potential to provide JEA with a significant source of fresh water supply for partial recovery to help meet emergency (river-crossing outages) or seasonal peak demands. The additional treatment processes needed to produce water for injection into the aquifer were recently studied and successfully piloted at JEA's Southwest and Buckman Water Reclamation facilities; however, future work remains for full-scale permitting and capacity allocation offset acceptance.