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THE ST. JOHN'S WATER COMPANY WATER SYSTEM IMPROVEMENT PROJECT: USING PVC IN DIFFICULT HDD PROJECTS

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ABSTRACT: A new water transmission line installed for the St. John's Water Company set a new record in February 2008 for the longest single Horizontal Directional Drill (HDD) pull of large diameter thermoplastic pipe with the successful pull-in of 4,400 linear feet (LF) of 24-inch Fusible C-905® pipe under the Stono River near Charleston, SC. The transmission line was installed using HDD techniques in a single pull with no casing, adjacent to an active runway.

The overall project consisted of approximately 64,000 LF of pipe, with over 20,000 LF of piping installed using trenchless construction techniques, including HDD and jack & bore. The 4,400 LF Stono River crossing was the technical showpiece of the project. Project engineering was provided by BP Barber of Charleston, SC. The project was bid as four (4) divisions. RH Moore of Murrells Inlet, SC and Anson Construction of Charleston, SC were prime contractors for Divisions I to III and Division IV, respectively. Bore-Tek of Ladson, SC completed the trenchless work for RH Moore and the Mears Group of Rosebush, MI completed the Stono River crossing for Anson. Pipe fusion support was provided by Underground Solutions, Inc. (UGSI) to all contractors. Fusible PVC™ pipe was used for all HDD applications. Trenchless construction was critical to minimizing damage to the critical habitat along the project route, including wetlands, marshlands, protected trees, and archaeological resources.

This paper illustrates and discusses the many design, permitting, construction challenges and technical issues that were negotiated to successfully accomplish this unique and difficult project. It also details the economic and technical reasons for the trenchless construction methodologies and piping materials chosen and utilized.

1. INTRODUCTION

The St. John's Water Company (SJWC) service area is primarily rural agricultural, with the typical zoning being AGR8 or AGR15, representing a housing density of one (1) residential unit to every eight or fifteen acres. The SJWC also provides water through wholesale purchase agreements to the Towns of Kiawah and Seabrook Islands. SJWC retained BP Barber of Charleston, South Carolina to provide engineering services to assess system demand and capacity issues. As a result, a new 24-inch water transmission line was installed by the SJWC in 2008. The new transmission line provided an alternate water source and alleviated pressure and fire protection concerns. Figure 1 shows the location of John's Island and the extent of the SJWC water service area.

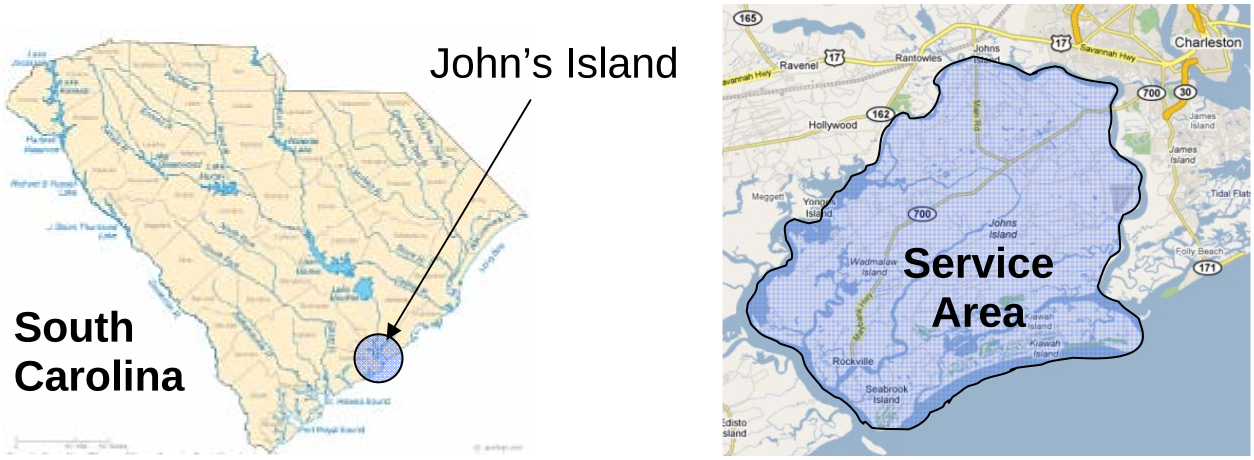

Figure 1. Location of John's Island and the extent of the SJWC service area.

2. PROJECT BACKGROUND

The existing water system was constructed in the 1970's. SJWC is a wholesale purchaser and reseller of potable water for John's Island. Water is purchased from the Charleston Water System, and there are wholesale resell contracts established with Kiawah and Seabrook Islands. Improvements in 1979 to the system included a booster pump station at the supply, new transmission lines across and to John's Island, an elevated water storage tank, metered connections to Kiawah and Seabrook, and distribution lines to provide roughly 6.0 Million Gallons per Day (MGD) of system capacity. In 1985-86 improvements included a major distribution system expansion and a new booster pump station at the elevated tank. A second 24-inch transmission line was added in 1989 increasing supply capacity to 10.0 MGD. In 1996, construction included an additional ground storage facility and booster pump station. The last set of improvements prior to this project were completed in 2001, including an additional ground storage tank, hydro-pneumatic tank, and booster pump station.

In 1979, there were 278,000 Linear Feet (LF) of distribution lines and 0.5 Million Gallons (MG) of water storage capacity. In 2001, there were 600,000 LF of distribution lines and 1.0 MG of total storage capacity (elevated and ground storage). Rapid growth of John's Island and the seasonal demand variability of the resort sea island communities of Kiawah and Seabrook Islands were placing tremendous pressure on the system's ability to meet capacity demands and maintain adequate pressure. The average summer demand is 7.0 MGD, and the winter demand is 2.0 MGD. The July 4th Holiday weekend is the system's peak demand period. System pressure and fire protection were significantly reduced during summer months. As a result, in 1999, the Charleston County Comprehensive Plan identified reduced system pressure and fire protection as major concerns. Figure 2 highlights the system's seasonal variation.

The storage tanks and booster pumps could not keep up with service area and resort community growth. The problems were exacerbated with two-thirds of the water demand located at the coastal extremities of the water system and all transmission sources located in the northern part of the service area. In 2000, a water study prepared by BP Barber for the SJWC identified an urgent need for additional infrastructure to meet system demands.

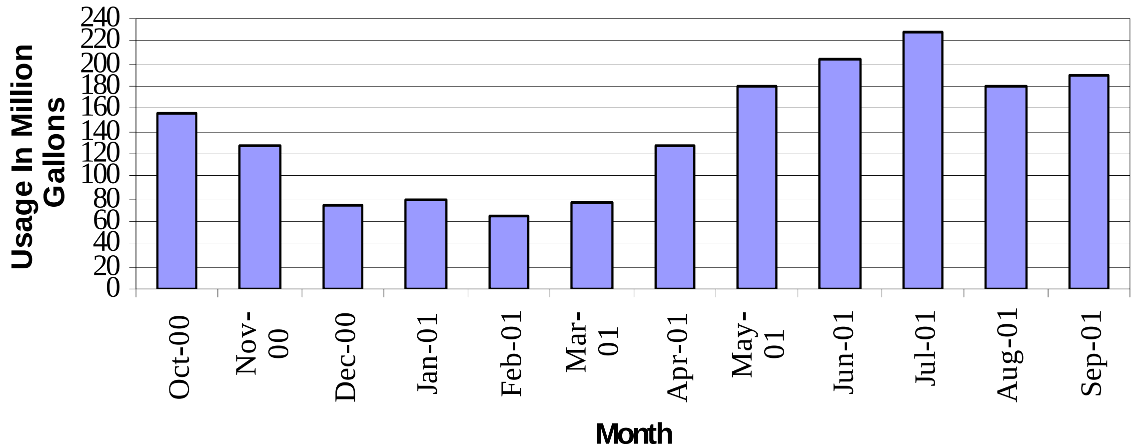

Figure 2. SJWC water usage by month (October, 2000 to September, 2001).

Approximately 32% of the rural customers rely on well water and a 10% increase was projected for each year from 1999 to 2001 for residents requesting water service connections (taps). Table 1 identifies SJWC system demands, based on Berkeley Charleston Dorchester Council of Governments projections through 2031. 2031 represents the capacity build-out date of the SJWC system. The build-out capacity represents the capacity required to meet all future demands, based on allowable zoning densities.

Table 1. SJWC water system demand projections through 2031.

Average Daily Demand (MGD)	**Year 2000**	**Year 2005**	**Year 2010**	**Year 2015**	**Year 2020**	**Year 2031**
Johns Island	2.300	2.956	3.547	3.838	3.838	4.417
Seabrook Island	1.226	2.650	2.650	2.650	2.650	2.650
Wadmalaw Island	0.000	0.000	0.000	0.555	0.762	0.762
Kiawah Island	3.600	3.600	3.600	3.600	3.600	3.600
TOTAL (MGD)	**7.126**	**9.206**	**9.797**	**10.643**	**11.140**	**11.431**

BP Barber worked closely with the SJWC to identify and assess various options to meet future water demands and ensure the availability of adequate system pressure for fire protection. Table 2 identifies the alternatives that were considered.

Following a detailed analysis of the various alternatives considered, including a thorough environmental review, the new 30-inch water transmission line was selected as the most feasible solution. The Stono River crossing location changed several times due to landowner concerns and easement issues. The preliminary cost estimate was $9.5 million and funding was sought through Rural Development. The route was selected to minimize the Stono River crossing distance, easement acquisition, and environmental impacts. The selected route needed to provide capacity to the lower service area and River Road was selected as the best option due to right-of-way (ROW) availability. However, River Road is a designated Scenic Highway and all trees greater than six-inches are protected and cannot be removed or damaged. The initial route prior to completion of design was 72,500 LF. After navigating through a myriad of permitting, environmental, and legal concerns; the final route length was 64,000 LF.

Table 2. Project alternatives analysis.

Alternative Considered	
No Action	
Pros	**Cons**
Inexpensive	Does not address immediate and future capacity and pressure concerns
	Jeopardizes public health and safety
	Creates additional demands on limited and unreliable groundwater source
Reverse Osmosis (RO) Water Treatment Facility	
Pros	**Cons**
Additional water supply attained	High construction and Operation and Maintenance (O&M) costs for limited capacity increase ($16M for 3.0 MGD / $0.8M/YR O&M)
Could be adapted in future for added capacity	Ultimate demand not addressed
	Disposal of RO waste required
	Construction timeframe of 24-30 months
	Intensive permitting
	Extensive site requirements
New Elevated Water Storage Tank	
Pros	**Cons**
Reasonable construction and O&M costs	Even with an additional 3.0 MG storage, system capacity only 11.0 MGD
	With only 7.0 MGD supply available and over 7.0 MGD peak summer demand, tanks would not be able to refill
	Ultimately does not meet system requirements
New 30-inch Water Transmission Line	
Pros	**Cons**
Capable of delivering additional 7.9 MGD	Potential environmental concerns
Satisfies current and future demands	Pipeline length
Reasonable O&M costs	Requires crossing of Stono River
	Private easements required

3. PERMITTING AND LEGAL ISSUES

Early project planning was initiated in 1996, and BP Barber was authorized to begin design work in late 1998. Funding was secured and permitting was well underway when the entire project came to a halt due to legal challenges in 2000.

Due to the perception of the water line being the catalyst for uncontrolled growth on John's Island, there was intense public opposition to the project from the beginning. Reacting to public pressure, the Charleston County Planning Commission refused to issue a Special Exemption permit for the water line. The Coastal Conservation League (CCL) then filed suit against the water line project and the permitting process came to standstill for five years during legal challenges. Figure 3 shows examples of the press generated by the proposed project and ensuing legal challenge. As a result of the legal standstill and the lack of available capacity, the SJWC was required to issue a tap moratorium. The moratorium was issued during the housing boom of the early 2000's. During the tap moratorium, the SJWC issued over 100 letters to developments ranging from 10 to 1000 residential units indicating that water service would not be available until the new water line was installed. The tap moratorium remained in place and was not removed until completion of the waterline project in July, 2008.

Construction costs were increasing as much as 10% per month while awaiting a court decision. Projected costs spiraled upward to $18 million. Finally, the SJWC reached a settlement with the CCL and Charleston County to reduce the nominal inside diameter line size from 30-inches to 24-inches. This reduction corresponded to a capacity reduction of 2 MGD (6MGD to 4MGD, based on a velocity of 2 feet per second).

Figure 3. Newspaper articles during legal challenge.

Figure 4. Topographic location map of the final project route.

Following the compromise between the SJWC and the CCL, BP Barber was able to resume acquisition of the remaining permits. Figure 4 identifies the final project route. All permit applications were required to be revised to reflect the new line size. All permits were finally obtained in 2007 and the project was prepared for bidding. Table 3 identifies the various permits that were obtained for the project. The use of trenchless construction techniques significantly streamlined the permitting process as potential impacts to wetland and critical areas, as well as to protected trees was shown to be minimal.

Table 3. Required permits.

Agency	Permit Reason
South Carolina Department of Health & Environmental Control (SCDHEC)	Permit to Construct; Preliminary Engineering Report
Office of Ocean and Coastal Resource Management (OCRM)	Impacts to Critical Area (tidally influenced areas); Stormwater/Land Disturbance Permit
US Army Corps of Engineers (USACE)	Impacts to Federal Waters
South Carolina Department of Transportation (SCDOT)	Installation of a Utility within a State Highway ROW (Encroachment Permit)
State Budget and Control Board (SBCB)	Easement for a Utility Crossing a State Waterway
Charleston County	Installation of a Utility within a County Highway ROW (Encroachment Permit); Special Exemption Permit
US Department of Agriculture - Rural Development (RD)	Preliminary Engineering Report; Environmental Report

4. BID SETUP AND REALIZATION

The project bid was organized into four (4) divisions, based on unit prices, and each division was bid out separately, but at the same time. Each division represented one particular portion of the total alignment. An addendum was issued during the design process to allow fusible polyvinyl chloride (Fusible PVC™) pipe and steel pipe as alternates to the HDPE pipe that was originally specified, due to overall price concerns. The bids were received by the SJWC on June 19, 2007 at 2:00 PM. Table 4 shows the breakdown of the project by Division and the winning bid amount.

Table 4. Bid Results by Division.

Division	Description	Bid Amount
Division I	36,600 LF	$4.88 M
Division II	5,400 LF (almost all HDD)	$1.79 M
Division III	17,500 LF	$2.48 M
Division IV	4,400 LF (Stono River Crossing)	$1.59 M
	Total	**$10.74 M**

The bid results represented a $1.2 million increase over the initial 2000 estimate. Basically, the legal challenge resulted in paying almost 15% more for 33% less capacity. However, the inclusion of Fusible PVC as an alternate material for all HDD sections of the project provided a significant cost savings to the SJWC. Considering the required pressure class and flow area for the project pipeline, Fusible PVC with its higher tensile strength could utilize a thinner wall, and therefore a smaller nominal pipe size, saving a substantial amount of material and fittings costs in the process. As a result, the bid results were viewed favorably by the SJWC, especially since estimated construction costs were expected to be significantly higher than the original estimate due to material price increases. BP Barber also considered Fusible PVC as a viable alternate bid material because the materials high strength to weight ratio would be well suited to the lengthy Stono River HDD crossing. Division I-III Contracts were awarded to RH Moore of Murrells Inlet, South Carolina, with the Notice to Proceed (NTP) issued on September 10, 2007. The construction period was set as 250 days, with substantial completion required by May 17, 2008. The Division IV Contract was awarded to Anson Construction of Charleston, South Carolina, with a NTP issued on September 4, 2007. Their contract also required substantial completion within 250 days from issuance of the NTP or May 11, 2008. Given the urgency to have the water line operational by the peak July 4th weekend, the contracts included provisions for the assessment of liquidated damages in the amount of $750.00 per day.

RH Moore selected Bore-Tek of Ladson, South Carolina to perform HDD on the shorter land-based bores, primarily under large diameter protected trees and wetlands, in Divisions I-III. Anson Construction chose the Mears Group of Rosebush, Michigan to perform the long Stono River crossing in Division IV. Underground Solutions, Inc. (UGSI) supplied and fused all 20,000(+/-) LF of 24-inch Fusible C-905® pipe used on the project in the trenchless portions. BP Barber was retained by the SJWC to provide contract administration and observation services during construction.

5. TRENCHLESS CONSTRUCTION

Each Division needed to be operational to be able to pressure test and flush the following Division; therefore, the construction sequence required was Division IV, followed by Division III, followed by Division II and finishing with Division I.

Division IV

The longest and most difficult HDD installation on the project was the crossing of the Stono River, which would take roughly 4,400 LF of pipe to complete, including the waterway and large areas of wetlands on either side of the waterway itself. The crossing location was adjacent to the Charleston Executive Airport, which allowed for ample room for fusion, pipe staging layout and required drilling equipment, but also introduced certain constraints due to the active operation of the airport. The Charleston County Aviation Authority approved the use of the airport right of way and set the requirements for construction, such as flagging and limits of work depending on the hours of operation. Most fusion was completed during the day and kept a very tight footprint, minimizing the impact to the operation of the airport. Figure 4 shows the fused pipe on rollers adjacent to the runway awaiting pull-in.

Fusion for the 24-inch DR 18 Fusible C-905 piping for the Stono River crossing was completed by UGSI with a McElroy 1648 fusion machine. Pipe handling and string layout was completed by Anson

Construction. Pipe fusion began on December 5th, 2007 and concluded on January 21st, 2008, with almost three weeks of non-working time included over the holiday season.

Figure 4. Arial view of pipe and fusion layout at Charleston Executive Airport

The pipe was fused into a single, 4,400 foot long string, performed in a straight run parallel Runway 4-27. Once the pipe string was completely fused, Anson pulled pipe on an 800 foot radius to the south (back end of pipe) curving it around the Runway 4 approach to enable the north (front) end of the pipe to be pulled into alignment with the bore exit creating a horizontal S-curve above ground. Pipe rollers, utilizing pillow block bearings, were used to support the pipe and decrease drag for the fusion process, layout, and then pull-in (Figure 6). Figures 5 through 9 identify various components of the Stono River HDD operation.

Figure 5. Pullback reamer and pipe pull-in assembly

Figure 6. Example of pipe rollers used.

Figure 7. Ballasting operation

The pipe was pre-tested on January 24th, 2008 with a 3-lb low-pressure air test following completion of the fusion process. Pipe remained on 1-lb of air pressure until it was moved into position for the actual pull-in operation and was then re-tested with 3 lbs of air on February 12th, 2008 as a final check. Mears utilized a 500,000-lb Mears drill rig to perform the pilot bore, pre-ream, swab passes, and finally, the pipe pullback (Figure 8). The pilot bore took approximately four (4) days to complete for the alignment. Pre-reaming was performed immediately afterward with a 40-inch reamer, going straight from the 9.75-inch pilot bore hole to the 40-inch final cut. The decision to make this one pass leap from pilot bore to finished hole dimensionality was driven by the Cooper Marl formation that the bulk of the drill alignment ran through. The Cooper Marl formation is a structurally stable clay formation. Mears was able to cut and evacuate the soil effectively with the recycling and mixing equipment used. Mears was also able to pre-ream and swab while adding drill string to the pipe side of the bore as they pulled back to the rig side. Even though they were trucking drill stem from the drill side to the pipe side of the alignment, time was saved because it was not necessary to push back for each swab pass. Pre-reaming took a little longer than anticipated at approximately 17 days, due to the direct cut to 40-inch from the pilot bore. Two (2) swab passes were performed following the pre-ream.

Figure 8. Drill rig and operations of rig side of Stono River crossing.

Figure 9. Pullhead and pipe recovery after successful installation.

A standard UGSI recommended pullhead was used for the installation, with the only special modification being a properly sized eyelet to mate properly with the driller's swivel assembly (Figure 5). Pull-in was completed with rollers and the pull-in trench ended up being approximately 120 feet long as the original pilot bore collapsed a length of the shallow area of the drill on the insertion side. On the insertion side, two (2) above ground storage impoundments were constructed. Due to the limited area on the drill side, Mears worked to retrieve as much displaced mud as possible from the pipe side during the pull-in. Approximately 1,800 LF of pipe installation was completed before the mud flow reverted to the drill side. On the drill side, the mud was sent through a reclamation unit to remove any cuttings from the drilling fluid and then pumped to tankage for disposal.

The pipe was ballasted with a water filling operation as it was installed to cut down on the expected buoyancy forces of the pipe and thereby reduce drag during the pull-in operation (Figure 7). A fill line was pulled through the 4,400 foot length of PVC and connected to a low head trash-type diesel pump. Five (5) frac tanks provided an estimated 90,000 to 100,000 gallons of river water for the ballasting exercise. The filling operation was paced to assure that the ballasting water remained in the pipe that had been inserted, but not full enough to spill back into the pipe that was yet to be pulled in.

The pipe pull-in started at 7:55 in the morning on February 15th and lasted until 9:45 PM that same day, when the pipe and pullhead assembly was pulled from the drill rig pit on the east side of the crossing (Figure 9). To the authors of this paper, this represents the longest midrange (>16-inch) thermoplastic pipe HDD installation, performed in a single installation without any other pipe materials or casing pipe utilized. Pullback forces required at the drill rig ranged from approximately 100,000 lbs to 170,000 lbs, with two rods requiring around 250,000 lbs of estimated force. These two rods were through a section of the installation where they had run into many root systems with the reamer near the drill rig side. It is believed that this was the cause for the spike in thrust force required and therefore it would not have affected the pipe's tensile load capacity, only the force to pull the reamer through the area. The 24-inch DR 18 Fusible C-905 pipe carries a safe allowable pull force of approximately 307,000 lbs, which includes a safety factor of 2.5.

Division I-III

Trenchless construction was utilized to maintain the natural character of the selected route along River Road. River Road serves as a primary North-South thoroughfare for John's Island, and made sense as a utility corridor. Limiting the impact of construction on River Road traffic was also a concern.

River Road is designated as a State Scenic Highway and all trees greater than 6-inches diameter at breast height (dbh) must be protected. Charleston County requires protection of all trees greater than 12-inches dbh. The River Road ROW is almost entirely lined with massive oak trees, know as Grand Live Oaks, some even exceeding 96-inches dbh. Trenchless construction techniques made it possible to install the water transmission line in these densely forested areas, without impacting the trees. In addition to avoiding damaging the protected trees, trenchless construction was also utilized to minimize impacts to the numerous wetland and marshland crossings. Almost 16,300 LF of piping installed by trenchless methods were utilized during the construction of Divisions I-III, including fifteen (15) jack & bore installations and 24 HDD installations, representing over 25% of the 60,000 LF of overall piping installed.

The individual HDD installations ranged in length from 300 LF to 1,300 LF. Division II, which started as a single bore of almost a mile of pipe was broken up into smaller sections, as could be more easily configured along the alignment. A total of 700 LF of piping was installed via jack & bore type installations, performed under trees and other obstacles. Two (2) jack & bore type installations were performed for two state roadway crossings that required a casing pipe to be installed. All pipe installation, including open cut trenching, was completed within an extremely tight contract period of 250 days. Figures 10 and 11 show pipe fusion and drilling during the Division I-III work.

Figure 10. Fusion Machine and Fusion Layout. Large tree on left is an example of the project site protected by the trenchless work.

Figure 11. BoreTek's Drill Rig being utilized for the 24" DR 25 Fusible C-905 installation by HDD.

Bore-Tek performed all of the HDD installations for Divisions I through III, with UGSI providing pipe and fusion and R.H. Moore providing pipe handling services. Bore-Tek utilized a DitchWitch® 70 and a DitchWitch® JT8020 Mach1 drill rig (shown in Figure 11) to complete all of the installations of the 24-inch DR 25 Fusible C-905® pipe.

6. PROJECT COMPLETION AND SYSTEM PERFORMANCE

Substantial completion was achieved on May 7, 2008 for Division IV, May 14, 2008 for Division III, June 18, 2008 for Division II and July 3, 2008 for Division I. All four (4) divisions were completed within the allocated contract time and operational approval for the line was received on July 3, 2008, just prior to the SJWC system peak demand weekend of the July 4^{th} holiday, 2008. Significant pressure improvements were immediately realized. Figure 12 shows the general difference in system pressure before and after installation of the water line. The cooler colors (greens) indicate areas of low available pressure, while the hotter colors (reds) indicate areas of high available system pressures.

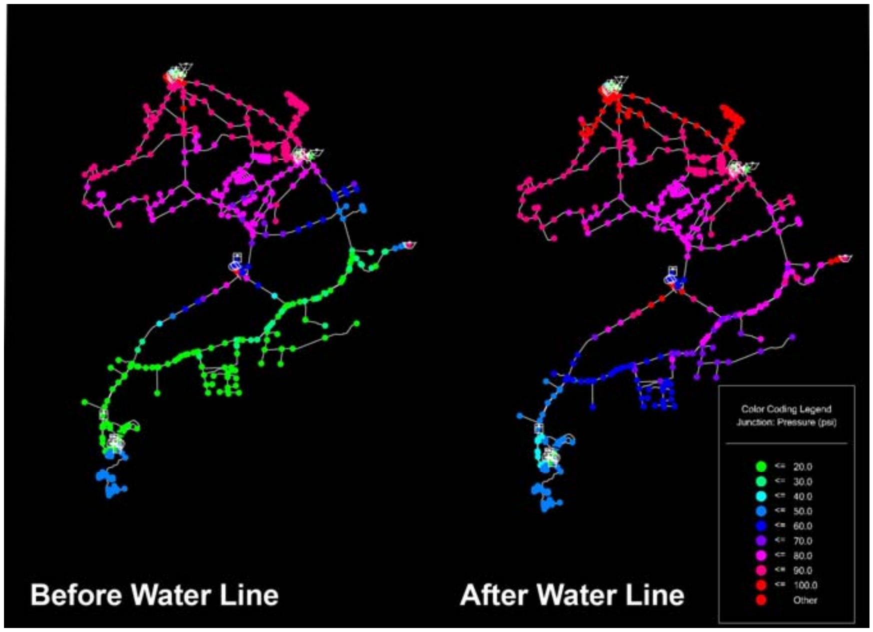

Figure 12. Available system pressure before and after project

The system pressure immediately increased to 65 psi even while delivering 2,800 gpm to Kiawah without requiring booster pumps to come on-line. Booster pumps previously ran 24 hours a day to meet demand; now they are only required during highest peak periods. The previous pressures would only be 35-45 psi, even with the booster pumps running. The SJWC system can now fill storage tanks and meet the peak system demand of the system. The performance of the new system is currently exceeding the Owner's expectations. The new 24-inch water transmission line afforded the SJWC a tremendous amount of operation flexibility previously unavailable.

The trenchless aspects of the installation were a complete success and pivotal to obtaining operational approval prior to the SJWC's peak demand period. HDD, jack & bore technology and new materials of construction, such as Fusible PVC created an economical and workable solution to the construction issues facing the pipeline in those key areas of concern, such as the crossing of the Stono River, and the environmental impacts on River Road.

7. REFERENCES

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