The Environmentally Sensitive Boca Ciega Bay 4,000’ Force Main Replacement: Taming HDD Technology

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1. ABSTRACT

The 40-plus year old 24-in PCCP Boca Ciega Force Main conveys wastewater from a high-density beach area in Madeira Beach, FL to the South Cross Bayou Water Reclamation facility located approximately five miles inland. The pipeline alignment includes two subaqueous crossings, one under the Intracoastal Waterway and the other under Boca Ciega Bay. The aging condition of the PCCP main posed an unacceptable risk to Pinellas County who retained AECOM, the Engineer of Record (EOR) to evaluate alternatives, design and support construction of the replacement of a 5,000 LF portion of the pipeline located under the bay. Previously, the EOR had designed a 2,000 LF replacement force main for the portion of the pipeline under the Intracoastal Waterway.

The challenge was replacing the mile long force main without impacting the environment. The EOR evaluated Horizontal Directional Drilling (HDD) alignment and pipe material alternatives. For the final selected 4,000 LF alignment, 24-in diameter FVPC was specified providing robust strength and a lean bore diameter. Temporary and permanent construction easements were negotiated with property owners for the construction and permanent use. Alignment selection considered available routes, easements and permitting.

Although the originally proposed alignment under Boca Ciega Bay is approximately 1,000 LF less than the existing alignment an additional 620 LF of FVPC via HDD and 2,300 LF of open-cut PVC were required to connect the HDD installation to the existing force main. The original alignment included over 1,700 LF along the Pinellas Trail, a former railroad corridor turned into a public access trail by the Rails to Trails project and another section along heavily traveled Park Street North. The final project design and construction documents were developed by using similar HDD crossings the EOR had designed in the area, including:

- 2,000 LF of 20-inch HDPE crossing at the Intracoastal Waterway (ICW) at Madeira Beach at minus 75 feet to avoid the Tom Stuart Causeway Bridge piles.
- 1,850 LF of 15-inch HDPE crossing of the ICW at Indian Shores with a reverse compound horizontal curve to avoid a property boundary.
- 3,000 LF of 30-inch HDPE water main crossing of the Manatee River at Fort Hamer.
- 3,500 LF of 20-inch HDPE water main crossing of the ICW at Cortez Road.
This paper discusses the alternatives assessment, design and successful construction within the beautiful and strict environmental setting of Boca Ciega, drawing upon lessons learned from these preceding projects.

2. INTRODUCTION

Pinellas County has the sixth largest population in Florida with approximately 970,000 residents, is the second smallest in area and boasts over 600 miles of coastline and eleven barrier islands. The service area is significantly developed composed of commercial, condominiums, apartments and hotels. The Madeira Beach Pump Station/Force main system conveys wastewater generated by the barrier island community to the County’s South Cross Bayou Water reclamation facility, a distance of approximately five miles. The force main is PCCP and consists of approximately 6,900 LF of 20-inch pipe and 19,400 LF of 24-inch pipe. Constructed in the early 1970’s, the alignment includes two subaqueous crossings, a 2,000 LF crossing of the Intracoastal waterway and a 5,000 LF crossing of Boca Ciega Bay. The crossings were originally installed by cut and cover approximately 2.5 feet below the bay bottom in the early 1970s. Figure 1 below illustrates the existing and proposed pipeline alignment under Boca Ciega Bay.

The existing force main is the sole method to convey the collected wastewater from the Madeira Beach area to the County’s treatment facility. As such the County determined that the over 40-year-old force main posed a significant risk in the event of failure at the subaqueous crossings and selected the EOR to design new crossings at both the Intracoastal Waterway and the Boca Ciega Bay crossings. The plan was to install an additional force main at both crossings while retaining the existing pipeline crossing as a redundant backup.

The available as-built drawings from the County showed that the existing force main at Boca Ciega Bay is a 24-inch diameter PCCP manufactured by Interpace Corporation and that it was installed by direct bury in 1973 as further described below. The existing pipe alignment is located in County Right-of-Way until the subaqueous crossing. Along the east and west shorelines, the pipeline is located in 20-foot easements. Along the westside, the easement

![Figure 1 - Existing and Proposed Alignments](image-url)
runs through a Kampgrounds of America (KOA) campground. On the eastside, the easement is located between the Otter Key Condominium and the Bay Area Heart Center and other businesses. The pipeline located in these easements is difficult to access and would cause significant impact to the public should the County need to perform maintenance or repair work.

3. ALIGNMENT ALTERNATIVES AND SELECTION

The main goal of this project was to install a second pipeline crossing of Boca Ciega Bay so the existing 40-year-old crossing could be taken out of service, rehabilitated and eventually act as a redundant crossing. A secondary goal was to develop an alignment that provided the County with better accessibility to the pipeline prior to it crossing under the bay. Taking these goals into account, three alternatives were developed for consideration by the County. Alternative #1 considers a subaqueous crossing alignment parallel to the existing force main. Alternative #2 considers a subaqueous alignment south of the existing force main that includes some open cut installation. Alternative #3 considers a significant amount of open cut installation with the bay crossing being achieved by attaching the proposed pipeline to an existing pedestrian bridge. The alternatives proposed for evaluation and the adjacent parcels are shown below in Figure 2, Site Layout Map with Alternatives.

Alternative #1 was eliminated because HDD could not follow the “S” shaped alignment of the existing pipeline near the west shoreline of the bay. To perform an HDD crossing using this alignment, additional easements and relocation of buildings would be required in the KOA camping area that would require the relocation of existing structures. Alternative #3 was eliminated as it would present a much longer and therefore more costly alignment. In addition, it was determined that the existing Pinellas Trail Bridge crossing Boca Ciega Bay could not support the additional loads that would be imposed by the proposed pipeline. Alternative #2 was determined to be the most feasible alternative. The proposed alignment required the installation of 1,700 LF along the Pinellas trail, a 4,000 LF crossing of Boca Ciega Bay and a 650 LF HDD installation along Park Street, only required the acquisition of two permanent and one construction easements and resulted in the least impact to the public during the construction phase.

Figure 2. Site Layout Map with Alternatives.
4. EASEMENT ACQUISITION

Based on the selected alignment, Pinellas County contacted representatives of KOA and Park Place Medical to discuss the proposed alignment and the need for permanent easements for the new force main. Both KOA and Park Place Medical representatives indicated that the properties would likely be sold or redeveloped in the future and requested that the County minimize any possible additional easement that would dissect the property and thereby affect the sale. Based on these requirements, the proposed alignment was somewhat modified so that the required easements would be located in portions of the respective parcels that could not be developed. Finally, a temporary construction easement was acquired from the Bay Pines Marina along the west side of the Pinellas Trail. This easement was needed for drilling operations.

The existing force main was installed via direct bury from the west side easement through the KOA property in an easterly direction across Boca Ciega Bay to an easement on the east side to the intersection of Park Street and 54th Avenue and continues east along 54th Avenue. The final proposed layout connected the existing force main from its location on the Pinellas Trail near the entrance of the KOA southeast via open cut to the southernmost edge of the KOA property minimizing easement requirements and avoiding dissecting the property. It then crossed Boca Ciega Bay via HDD to an easement along the property boundary between Park Place Medical and a U-HAUL Moving & Storage facility, continued via open cut to Park Street, then ran North via HDD on Park Street to the intersection of Park Street and 54th where it connects to the existing force main before it crosses Park Street. The proposed alignment required temporary and permanent easements, further discussed below. The existing force main and proposed alignment configuration are depicted in Figure 1.

East Side: The Park Place Medical facility offered a large area where temporary construction easements could be acquired to support drilling operations. There was sufficient space available in the surrounding landscaped green area of the Park Place Medical facility to facilitate the staging of the required HDD drill rig, associated support equipment and locate the entry pit for the drill. In addition, for the staging of the individual pipe sections, there was sufficient space to stage six pre-fused pipe sections of approximately 670 feet in length in preparation for the final over 4,100 feet of pipe pull since the connection point on the Trail would be overshot to the Marina property. The 670-foot sections would then be pulled individually and fused as needed during the installation procedure to come to the full length. This was required because it was not possible for the entire length of pipe to be fused along Park Street as it would block both entrances to Park Place Medical. There was some risk associated with starting to pull the pipe, then stopping to butt-fuse the next section (about 45 minutes of down-time) and then re-starting the pulling operation, but it was minimal due to the soil conditions along the recommended alignment. There was also significant available area for the staging of equipment, necessary support vehicles and tanks. A permanent easement 583 feet by 20 feet would also be required on the property. A 430-foot section would be installed along the easement to reach the Park street right-of-way. Easements were negotiated with property owners and are further discussed below.

West Side: Space was much more restricted on this side as there was insufficient space to stage the drill, pipe or required supporting equipment on the Pinellas Trail. However directly west and adjacent to the Trail was Bay Pines Marina. There was a boat storage lot within Bay Pines Marina that could support the exit pit during drilling operations and the required equipment to support the proposed alignment. The storage lot was surrounded by a Mobile Home Park that is part of the Marina on two sides, a boat storage warehouse on a third side and the Trail on its east side. Hence drilling operations would take place from the east side as well as pipe layout, while pulling operations would take place from the west side from the Bay Pines Marina empty lot (see Figure 3). The pipe would be intercepted at the Trail where it would continue north. Appropriate sound attenuation was provided to minimize disturbance to the mobile park residents. A small 65-foot by 20-foot mostly submerged permanent easement would be required on the southernmost edge wetlands of the KOA property which avoided dissecting the property. A temporary construction easement would also be required and is further discussed below.

Pinellas Trail: The installation of the approximately 1,750 feet of force main did not represent a significant problem along the Trail. There appeared to be sufficient space along the east side for the force main to be placed. Pinellas County requested that the Trail remain open during construction of the force main and as such the Contractor would need to take into consideration maintaining safe public access through the Trail during the installation of the force main. The force main could be installed via open cut or via HDD while maintaining access through the Trail; the contractor ended up installing by open cut. The force main was installed by open cut along the Trail.
Park Street: Installation of the approximately 700 feet of proposed force main along Park Street connecting the Bay crossing to the existing force main at the 54th Avenue intersection presented some difficulty due to the number of existing utilities. In addition, there were plans to expand Park Street in the near future with associated new and existing relocated utilities. As such the recommended method of installation was HDD with 24-inch FPVC DR-18. The proposed section of force main was installed at approximately 30 feet below ground taking into consideration existing and proposed future utilities including a 36-inch Reclaimed Water main also installed via HDD. The construction of the connection to the existing force main located in the grass median in the entrance to Otter Key condominiums and two medical facilities would be phased to maintain access at all times.

5. GEOTECHNICAL INVESTIGATION ALONG PROPOSED ALIGNMENT

EOR staff reviewed maps, plans, historic aerial photographs, geologic reports and other project specific information in order to evaluate surface and subsurface conditions along the proposed force main route. Some of the documents reviewed include the following:

- USGS Seminole 3123 NE area Quadrangle Maps History (topographic)
- NOAA Nautical Chart 11412 Tampa Bay and Joseph Sound
- USDA/SCS Soil Survey of Pinellas County, Florida
- Geotechnical Report, developed by MC Squared, Inc. (MC²) in June 2016 based on 6 subaqueous borings, 4 land based borings and 3 hand augers performed to support construction of the force main.

Additionally, site reconnaissance of the proposed pipeline route was performed by EOR staff to assess site conditions. No areas of specific concern with respect to possible poor soil conditions were identified during the site visit; however, some limitations were identified on both land sides and are discussed here subsequently.
Based on the data review, the grade for the land-based work vary approximately between elevation (EL) +13 and +8 feet on the west side and +4 and +7 feet on the east side. The Bay bottom elevations in the Boca Ciega Bay are shallow and vary from around EL -1 to -2 feet MSL.

Geotechnical boring (soil & rock) information presented was collected by the project geotechnical engineer, MC², using a total of eight (8) Standard Penetration Test (SPT) borings along the proposed alignment across the Bay ranging in depth from 40 to 80 feet below the existing ground surface or mud line. Soil samples recovered were visually examined and select samples were used to develop the soil legend using the Unified Soil Classification System. Laboratory testing included natural moisture content tests, percent passing No. 200 sieve, organic content tests and Atterberg Limit Test. Corrosion series testing, should a steel casing be required, and specialized testing such as Mohs Hardness and Abrasiveness of Rock Testing were also performed on selected samples. The data collected was used to provide a general characterization of soil and groundwater conditions along the force main alignment and to generate the HDD boring and installation calculations.

Subsurface conditions were explored via 8 SPT borings at select locations along the alignment. Two of the STP borings were land based near the entry and exit pits and performed to a depth of 40 feet below ground surface (bgs). The remaining 6 STP borings were performed to a depth of 80 feet bgs (below the bay bottom) from a barge mounted drill rig. Six undisturbed Shelby tubes were collected for laboratory testing. In addition, a total of 3 hand auger borings were collected along the Pinellas Trail to obtain soil and groundwater information.

In general, the soils were found to be mostly poorly graded sand with silt to fine sand and clayey fine sands with cemented layers from ground surface to approximately EL -68 to -78. Cementitious non-cohesive soils with high N-values were found at varying depths ranging from EL -10 to -30 in B-1 to B-3 to -36 to -45 in B-4 to B-8. Hand auger borings along the Pinellas Trail, or west side of the alignment, revealed fine sands with silt from ground surface to the termination depth of 6 to 6.5 feet bgs at the groundwater table. The groundwater table was recorded at 3 feet bgs at B-8 (on the east side of the proposed alignment). The seasonal high water table is estimated at 3.5 feet bgs.

In addition, the potentiometric surface in the vicinity of the project is reported as ranging from approximately 0 to +10 feet, NGVD83.

6. EVALUATION OF CROSSING TECHNIQUES

The EOR evaluated the trenchless technology techniques currently available in the marketplace for construction of the proposed 24-inch force main over 4,000 feet in length crossing beneath Boca Ciega Bay. The following four (4) trenchless techniques were considered as potential alternatives.

- Microtunneling,
- Horizontal Auger Boring,
- Horizontal Directional Drilling (HDD), and
- Conventional Tunneling Techniques.

The horizontal auger boring and microtunneling techniques were eliminated as potential construction alternatives due to the practical and experience limitations on the maximum installation length thereby causing need for intermediate shaft construction within the protected Boca Ciega Bay. HDD and conventional tunneling techniques are discussed below:

**Horizontal Directional Drilling (HDD):** The HDD method comprises of a two-stage process. The first stage consists of drilling a small diameter pilot hole along the desired alignment. The pilot hole is excavated using a drill head with a rod stringing for the entire length of the proposed crossing. The pilot hole is then enlarged (reamed) to a larger diameter by attaching a reamer to the drilling rod until the required proposed borehole diameter is obtained. This reaming process can be completed in one step or several steps depending upon the proposed diameter required.
Throughout the reaming process, the hole is kept open (or kept from collapsing) by the use of thick drilling mud to fill the annulus space. The drilling mud is usually a bentonite-based compound.

The final borehole diameter is typically 50% larger than the proposed pipe diameter. Upon completion of the last reaming step, the product pipe is then pulled through hole. The HDD technique can be used in a variety of soil and rock materials.

The HDD technique requires a relatively large staging area on both sides of the operation at the entry point and the exit point of the proposed force main. Preferably, a long section of the pipe should be assembled and pulled in one operation to reduce starts and stops and down time for the pipe welding process during the pipe pull phase.

The HDD method is typically a cost-effective method for pipe installation of diameters up to 48 inches. It is commonly used for pressurized pipelines similar to the proposed force main crossing. It is an ideal method where precision and accuracy of installation is not critical or detrimental to the installed pipe or existing surface and subsurface facilities/utilities. A potential risk of the HDD method is the occurrence of drilling mud seepage creating inadvertent returns or “frac out” through the surrounding soils and rock to the ground surface that may affect existing facilities and/or cause contamination of groundwater and/or surface water. However, based on the obtained soil information, the drill alignment was located at approximately 70+ feet bgs below the Bay mudline in cemented soil and clay layers thereby minimizing the likelihood of “frac-outs”.

Conventional Tunneling Methods: This method involves the use of a tunnel boring machine (TBM) or enlarged microtunnel boring machine with a temporary lining support system consisting of liner plates or pre-cast concrete segments. This method requires man entry into the tunnel during the construction phase. The minimum diameter planned for conventional tunneling was 72 inches. The proposed force main pipe would be installed inside the temporary lined tunnel. A launching pit and receiving pit are required to launch and retrieve the TBM from the ground. In addition, a relatively small staging area is required compared to that of the HDD technique.

This method proved significantly more costly than the HDD alternative and required a longer duration of construction to complete. However, with conventional tunneling, access for pipe maintenance could be available throughout the design life of the pipeline. In addition, other utility pipes or replacement pipes could be installed inside the tunnel in the future.

A comparison between the HDD and conventional tunneling methods for the Boca Ciega Bay crossing is presented in Table 1 below.

Table 1. Comparison of Crossing Technique

<table>
<thead>
<tr>
<th>Comparison Item</th>
<th>HDD</th>
<th>Conventional Tunneling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost per lineal foot</td>
<td>$600 - $800</td>
<td>$8,000 to $15,000</td>
</tr>
<tr>
<td>Staging area requirements</td>
<td>Large area required</td>
<td>Relatively smaller area required</td>
</tr>
<tr>
<td>Risk of mud leak into surface</td>
<td>Yes</td>
<td>Nominal</td>
</tr>
<tr>
<td>Future maintenance, pipe replacement, use of space for other utilities</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Alignment control and accuracy</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Risks from Presence of Karst formation</td>
<td>Potentially Problematic</td>
<td>Less problematic</td>
</tr>
</tbody>
</table>

Based on the aforementioned evaluation, the recommended crossing technique for installing a new pipeline under Boca Ciega Bay was HDD. The next step in the process was to evaluate pipe materials to determine which type was feasible for the installation. Pipe materials evaluated included FPVC, HDPE and Steel.
7. BOREHOLE PIPE STABILITY ANALYSIS

A borehole stability analysis was performed to determine the factor of safety for the borehole drilling conditions using the Delft equation (van Brussel and Hergarden, 1997). Eight soil borings were drilled up to 80 feet bgs to assess subsurface conditions. Bore logs, laboratory testing data, and a geotechnical report were issued by MC² in June 2016 (not included herein). Explorations for nearby projects were also reviewed including borings provided by the Florida Department of Transportation and by geotechnical reports from other URS/AECOM Projects (Tierra, 2014).

An interpreted subsurface profile was developed and three distinct units were interpreted. Soft, loose unconsolidated siliciclastic marine sediments with SPT blow counts less than 25 were observed from the surface to depths that ranged from greater than 40 feet bgs to approximately 15 feet bgs. Hard, partially cemented siliciclastic marine deposits with SPT blow counts above 25 and averaging greater than 50 were observed from 15 feet bgs to greater than 80 feet bgs. A third unit of very firm elastic silt was observed in five borings at elevations greater than EL -72 feet bgs. These same units were also identified in nearby explorations and are consistent with the marine environment. The following soil input properties were used:

Table 2. Soil Properties

<table>
<thead>
<tr>
<th>Soil Parameters</th>
<th>soft sands, silts and clays</th>
<th>partially cemented sediments</th>
<th>elastic silts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Weight¹</td>
<td>115</td>
<td>135</td>
<td>130</td>
</tr>
<tr>
<td>Phi (deg)²</td>
<td>25</td>
<td>35</td>
<td>30</td>
</tr>
<tr>
<td>Cohesion (psf)³</td>
<td>0</td>
<td>0</td>
<td>300</td>
</tr>
<tr>
<td>Poisson ratio⁴</td>
<td>0.8</td>
<td>0.6</td>
<td>0.3</td>
</tr>
<tr>
<td>E - Elastic modulus (psf)²</td>
<td>40320</td>
<td>403200</td>
<td>403200</td>
</tr>
<tr>
<td>G - shear modulus³</td>
<td>11,200</td>
<td>126,000</td>
<td>155,077</td>
</tr>
<tr>
<td>Plastic radius FS⁴</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

1: Properties estimated from bore logs and laboratory data
2: Calculated in accordance with AASHTO using E=8064*N for silts and E=13968*N for sands. Average blow counts for each formation were used.
3: G=E/(2*(1+Poisson’s Ratio))
4: The Delft equation requires a factor of safety for the soil formation. The FS can range from 1.5 to 2. For the formations encountered, a FS of 2 was used due to the variable nature of loose and partially cemented sediments.

Below are a few key points of the bore path geometry used:

- 12 degree entry and exit angle
- Bottom tangent below -70 feet EL
- 3,000-foot bend radius to accommodate steel pipe
- 2% grade on bottom tangent to promote fluid flow
- 30-inch diameter pipe with a 42-inch diameter borehole for HDPE and 24-inch diameter pipe and 36-inch diameter borehole for FPVC

The following are the results of the borehole stability analysis:

In general, when drilling from West to East the borehole stability factor of safety was acceptable (FS>2) from the start of the alignment to approximately station 336+00. The final approximately 500 feet of the drilling may present a challenge to the driller to maintain proper borehole stability. When drilling from East to West the initial 200 feet of the boring would present unstable conditions as well as the final 500 feet. The limiting factor to borehole stability
was the soft sediments found in the upper 40 feet of the exploration boreholes. These soft marine sediments have SPT blow counts that range from 0-25 with an average of approximately 6.

Due to the variable nature of marine sediments and partially cemented sediments, the conditions encountered were expected to vary, possibly significantly from what is presented in the calculations. There is some evidence for fractures and soft zones in the partially cemented sediments shown in the bore logs provided by MC² and therefore conditions were constantly monitored by a qualified driller with experience in similar environments.

8. PIPE STRESS ANALYSIS

The pipe analysis considered a 24-inch (for Steel or Fusible PVC) to 30-inch (For HDPE) transmission force main at a range of pipe thicknesses to be installed using horizontal directional drilling (HDD) in the 4,100-foot-long subaqueous crossing of Boca Ciega Bay. Calculations were performed for Steel, Fusible PVC (FPVC), and HDPE pipes. The purpose of these calculations was to determine the minimum pipe requirements, materials, and pullback conditions to achieve acceptable pipe stresses during pullback. Calculations were performed in accordance with Pipeline Research Council International (PRCI) (2008), Plastic Pipe Institute (PPI) (2008), and ASTM (2005) guidance and considered allowable tensile, bending, and buckling stresses under assumed “favorable” and “adverse” conditions. Calculations utilized the accompanying excel workbooks. Two calculations were performed for each, Steel, PVC and HDPE pipe; a “best estimate” case that follows design and assumes favorable pullback conditions, and an “adverse” case which assumes adverse installation geometry and pullback conditions.

The following parameters were used for steel pipe to calculate the appropriate minimum wall thickness:

- Diameter: 24 inches
- Specified Minimum Yield Strength: 65,000 psi
- Young’s Modulus: 2.9E+07 psi
- Poisson’s Ratio: 0.3
- Coefficient of Thermal Expansion: 6.5E-06 in/in°F

The following parameters were used for FPVC pipe:

- Diameter: 24 inches
- Specified Minimum Yield Strength: 7,000 psi (Reduced in calculations using a factor of safety of 2.5)
- Young’s Modulus: 400,000 psi (Reduced using the formula \( \text{E}_{\text{pvc}} = 2800 \times t^{-0.067} \), where \( t \) is time in minutes. From AASHTO (McGrath and Sagan, 2000))
- Poisson’s Ratio: 0.38
- Specific Gravity: 1.4

The following parameters were used for HDPE pipe:

- Diameter: 30 inches
- Allowable Yield Strength: 1,100 psi
- Young’s Modulus, Short Term: 57,500 psi
- Young’s Modulus, Long Term: 28,200 psi
- Poisson’s Ratio, Short Term: 0.35
- Poisson’s Ratio, Long Term: 0.45
- Specific Gravity: 0.95
The following properties were assumed for HDD installation conditions under the “best estimate” case:

- Drilling Mud Density: 12 lbs/gal (Mud properties may have varied at the discretion of the HDD contractor)
- Hydrokinetic Pressure: 10 psi
- Fresh water was assumed as ballast (sea water may also be used)
- Coefficient of soil friction: 0.25 for “favorable” conditions and 0.5 for “adverse” conditions
- Fluid Drag Coefficient: 0.025 psi for “favorable” conditions and 0.05 psi for “adverse” conditions

The following are the results of the pipe stress analysis:

Under both the “favorable” case and the “adverse” case a steel pipe with the stated specifications and a wall thickness of 0.375 inches would have adequate performance under the anticipated pipe stresses. However, ballasting the pipe during pullback would be required to keep pipe stresses in an acceptable range for the “adverse” case. Ballast in the pipe may need to be used during installation if conditions vary significantly from the “best estimate” case.

A 24-inch FPVC pipe with a dimension ratio (DR) of 18 (the thickest common 24-inch FPVC size) has an acceptable factor of safety (FS) for pullback tensile stresses. The factor of safety came to 1.5 for the “adverse case”. However, the FPVC pipe must remain ballasted during installation and its service life in order to maintain adequate factors of safety against buckling and acceptable deflections. With the pipe fully ballasted, the critical case would be during pullback where deflections up to 5% may be experienced with an allowable deflection of 6% of the pipe’s diameter. The factor of safety against buckling is 3.5.

A 30-inch HDPE pipe with a DR of 7.3 would have adequate performance under the anticipated pipe stresses if the pipe were ballasted during drilling and in long term use. However, the factor of safety for tensile stresses during pullback in the “adverse” case was unacceptable; the factor of safety was 1.1. If adverse conditions were encountered during pullback care must be taken by an experienced driller to limit tensile stresses on the product pipe and the pipe would risk being damaged or lost. Alternative methods of installation, such as intersect technology should also be explored.

9. **RECOMMENDED MATERIAL OF CONSTRUCTION**

Based on the recommended crossing technique of HDD, 30-inch, DR-7.3 HDPE, 24-inch C-905, DR-18 FPVC and a 24-inch Steel pipe with a 0.375-inch wall thickness were retained for further evaluation and HDD calculations. As discussed above, a pipe Stress Analysis using allowable tensile, bending, and buckling stresses under assumed favorable and adverse pullback conditions was performed for the pipe types. Adverse pullback conditions represent poor installation geometry and pullback conditions. Calculations showed that 30-inch DR-7.3 HDPE did not have the required tensile factor of safety during pullback in the “adverse” case scenario and therefore it was not recommended. Note that this was a risk-based decision recognizing HDPE could perform adequately within allowable stresses if the pipe is ballasted and a qualified experienced driller used best practices to limit tensile stresses. Alternative HDD installation methods of HDPE such as intersect technology were not considered due to the increased cost and anticipated overwater access risk factors. DR-18 FPVC and a Steel pipe with a wall thickness of 0.375 inches both performed adequately under favorable and adverse pullback conditions. However, steel pipe is not only more costly than FPVC, but laboratory testing revealed the soils to be corrosive requiring added costs of cathodic protection against corrosion. As such FPVC was recommended and retained for the basis of design, including provisions that FPVC remain ballasted during installation and service life (see Figure 4).
10. PERMITTING REQUIREMENTS

A variety of Federal, State and local permits were required for this project. The permits included are listed and further discussed below.

10.1 Florida Department of Environmental Protection

Pursuant to Chapter 62-604.600, Florida Administrative code (F.A.C.), a Florida Department of Environmental Protection (FDEP) permit was required for the addition of a new force main to the existing wastewater collection and transmission system. A permit application form 62-604.300(8)(a) Notification/Application for Constructing a Domestic Wastewater Collection/Transmission System with the respective fees was completed and submitted to FDEP for review and approval.

10.2 Pinellas County Right of Way Utilization Permit

A Right of Way Utilization Application and Permit from Pinellas County including Maintenance of Traffic (MOT) was anticipated for the proposed work along Park Street North, a Pinellas County Road. MOT plans were developed and included in the design drawings. The Contractor was required to obtain the Right of Way Utilization Permit.

10.3 Federal Permits

A 404 Federal Dredge and Fill Permit from the U.S. Army Corps of Engineers (USACE) required for this project involved a complex permitting process considering the degree of the potential impacts to jurisdictional wetland areas. A Nationwide Permit 12 – Utility Line Activities was required for the proposed pipeline installation since waters of the U.S. could be temporarily impacted by construction. The Nationwide permit required compliance with the General Conditions for Nationwide Permit 12, including the restoration of all impacted wetland areas to preconstruction grade, no adverse impacts to fish or wildlife, use of only clean fill (if needed), no impounding of water or draining of waters of the U.S., and the use of proper sediment and erosion controls during construction.
10.4 State Environmental Resource Permit

An Environmental Resource Permit (ERP), also from the FDEP, was submitted as part of this project. Like the 404 Federal Dredge and Fill Permit, the complexity of the permitting process depends on the degree of the impact to jurisdictional wetland areas. A Noticed General Permit (NGP) was required for the proposed project since wetlands could be impacted during construction. The NGP requires compliance with Chapter 62-341.453, Florida Administrative Code (F.A.C.), including a construction corridor less than 30 feet wide, less than 0.5 acre of wetland impact, no permanent fill in wetlands, no impounding of water, the use of proper sediment and erosion controls, and restoration of impacted wetlands to preconstruction grades.

In addition to the ERP, a National Pollutant Discharge Elimination System (NPDES) permit was required pursuant to 40 CFR Part 122 for point source discharges of stormwater associated with construction of the pipeline. Under FDEP’s delegated authority to administer the NPDES program, operators that have stormwater discharge associated with one acre or more of construction clearing must file for and obtain either coverage under an appropriate generic permit contained in Chapter 62-621, F.A.C. (one to five acres of construction), or an individual permit issued pursuant to Chapter 62-620, F.A.C. (greater than 5 acres of construction). A major component of the NPDES permit is the development of a Stormwater Pollution Prevention Plan (SWPPP). The SWPPP identifies potential sources of pollution that may reasonably be expected to affect the quality of stormwater discharges from the site and discusses good engineering practices that were used to reduce the pollutants. The contractor was required to obtain the NPDES permit.

Chapter 253 Florida Statutes (F.S.) requires authorization from the Board of Trustees of the Internal Improvement Trust Fund (Board) for any activities in, on or over state-owned, sovereign submerged lands (state lands). A public easement was not required in accordance with Chapter 18-21.005, F.A.C. for installation of the utility pipeline across state lands. The force main is processed and recorded by FDEP concurrently with the ERP application. The installation required compliance with Chapter 18-21.004, F.A.C., including minimizing adverse impacts to state lands, not being contrary to the public interest, and the applicant having sufficient upland interest in the adjacent riparian properties.

10.5 Miscellaneous Permits

A Spill Management and Prevention Plan was also developed and implemented during construction of all HDD crossings of wetlands and surface waters. This plan was developed prior to the permitting phase of this project and submitted as part of the ERP application. The Spill Management and Prevention Plan needs to contain monitoring procedures for inadvertent loss or spills of drilling fluids, the types and storage locations of sediment and erosion control materials to be used in the event of a loss or spill of drilling fluids, and procedures for restoring the disturbed areas.

11. PROJECT BID AND AWARD

Bids were received by the County on June 13th, 2017. A total of five responsive Contractors submitted bids for consideration with a sixth non-responsive due to inadequate prequalification information. Bid prices ranged from a high of $8,545,318.00 to a low of $4,747,565.00 submitted by TLC Diversified, Inc. (TLC). The engineer’s estimate provided by EOR was $5,483,775.00.

In reviewing the bids, some differences were noted in the price for the directional drill cost per linear foot of installation of the subaqueous crossing between the bidders. The cost for the directional drill ranged from the lowest $531.00 per linear foot ($/LF) submitted by the lowest bidder, TLC, to a high of $1,122.00/ LF submitted by the highest bidder. The second lowest price for this bid item, $614.88/LF was provided by the second lowest bidder. EOR’s estimate for this bid item was $700.00/LF.

Relevant project experience and qualifications required by Contract documents were requested from the low bidder and reviewed for conformance with project specifications. TLC subcontracted Centerline Directional Drilling Services (Centerline) for the HDD segments of the project. Centerline provided sufficient experience with projects of similar diameters and length to demonstrate the required successful drilling capability to complete the project.
The Florida Department of Business and Professional Regulation’s website was used to verify the status of the bidder’s licenses. TLC and company president Thurston Lamberson had an active Certified General Contractor’s licenses since 1987 with a Construction Business qualification since 2004. Centerline was a Certified Underground Utility and Excavation Contractor. Licenses were current/active with no complaints on file.

Based upon the information provided, and in consideration of Contract requirements, the project was awarded to TLC Diversified, Inc. as the Contractor with Centerline as the HDD Subcontractor for the amount of $4,747,565.00.

12. CONSTRUCTION

This project was a challenge as the record setting HDD subaqueous crossing in Pinellas County and the second longest in the State of Florida of its diameter and kind. Construction lasted approximately nine months from January 3rd, 2018 to Substantial Completion on September 20th with final completion achieved on October 3rd, 2018. To complete the pilot borehole Centerline mobilized two drill rigs, an American Auger DD-440T capable of generating 440,000 lbs of thrust/pullback and a Vermeer inline D330x500 capable of generating 330,000 lbs of thrust/pullback, and performed an intersecting pilot borehole utilizing Sharewell HDD Services and True Gyde software (see Figure 5). By using the intersect method, a smaller rig can be used than with a single crossing. There is logic to sizing the rig so that they are incapable of overstressing the pipe during pullback. The Vermeer rig was then used to perform the multiple reaming passes of 18-inch, 20-inch, 24-inch and 32-inch. The multiple reaming passes of relatively small upsizing increments per pass were used to condition the borehole to minimize abrasions from cemented zones and to ensure that the borehole was well stabilized before pullback. A 28-inch barrel reamer was then used to provide final cleaning before pulling the FPVC pipe. The subaqueous crossing final pullback was completed in 36 hours including 13 intermediate fuses. Maximum pullback forces observed did not exceed 160,000 psi, less than half of the allowable pull force for 24-inch DR18 FPVC. The project also included the additional 620-foot HDD section along Park Street, a busy road, and almost 2,300 feet of open cut force main along the Pinellas Trail and along a permanent easement on Park Place Medical. By carefully considering all of the challenges, TLC Diversified and Centerline Directional Drilling Services, Inc. team planned well and finished the project on time and the owner was very satisfied with the outcome.
The major concern during the HDD operation was a potential frac-out under the protected Boca Ciega Bay during the drilling operation, in particular near the location of the entry pit and the mangrove populated shoreline on the west side of the drill. This coincided with the location of the force main HDD tie-in to open cut within only a narrow section of upland. TLC worked with Centerline, Pinellas County and the EOR to minimize any possible impact to the Bay. In order to prevent a frac-out, the HDD subcontractor, Centerline, installed approximately 40 feet of 30-inch diameter steel conductor casing from grade, extending far enough below the Bay to contain the drilling mud within the casing, protecting against the “path of least resistance” into the Bay shallows near the exit. It worked as intended and the drill was a complete success with no frac-outs experienced (see Figure 6).

![Figure 6. Tail End of FPVC after completing pullback under the Boca Ciega Bay.](image)

An additional challenge was maintaining ingress and egress of the two businesses that had to be open to the public during construction, on the east side of the Bay at Park Place Medical and the KOA Campground on the west side of the bay. TLC successfully achieved this with proper traffic control means and methods, nighttime work for underground pipe installations across their entry/exit driveways and most importantly a competent Project Manager, Superintendent and crew.

Maintaining safe access to the Pinellas Trail during open cut construction also presented a challenge. The popular Pinellas Trail is a main pedestrian and bicycle artery through Pinellas County that provides a safe asphalt path for users to walk, jog and ride their bikes. It also provides a route for many daily commuters who use it to get to and from work. The contract documents required this trail to be kept open during construction with no shut downs. The design included approximately 2,300 feet of force main along the Trail. TLC worked with the County and the EOR to revise the alignment two feet east to eliminate any disturbance to the pavement while maintaining appropriate trench shoring except at crossings.

Finally maintaining the project schedule was extremely important since legal easement agreements had been executed by the County with property owners. TLC completed all easement work on time including restoration to the property owner’s satisfaction. It is the Author’s opinion that TLC and their HDD subcontractor Centerline DD Services, Inc. did an outstanding job on the Boca Ciega Subaqueous Crossing project.
13. SUMMARY

The use of FPVC with HDD provided a cost-effective solution for the installation of the new subaqueous force main crossing of Boca Ciega Bay for Pinellas County, replacing the existing 40-year-old pipeline within the environmentally sensitive Bay. After minimizing the risk in design, informed by performing a detailed geotechnical investigation of the sub-bay soil conditions, selecting the appropriate material of construction at a depth of minus 70 feet below the Bay, evaluating alignments that limited easement acquisition and disruption to businesses and the public and awarding the project to an experienced Contractor that could complete the work, the new 24-inch crossing was installed quickly and under the Engineer’s estimate.

Figure 7. Leading Head of FPVC.

14. REFERENCES


