HDD Used to Install New Force Main under Lake Meade

Tim Marsh, Hampton Roads Sanitation District, Virginia Beach, VA
Brandon Beamon, Michael Baker International, Virginia Beach, VA
Rachel Maupin, Underground Solutions, Inc., Poway, CA

1. ABSTRACT

Hampton Roads Sanitation District (HRSD) was facing an aging infrastructure undersized for continuing population growth within the City of Suffolk, Virginia. In addition to meeting increased demands, HRSD needed to minimize the likelihood of sewage overflows in wet weather conditions, compelling them to increase the capacity, to reduce system pressures and to improve operating conditions of its sewer system.

One pipeline in their Suffolk service area was nearing 50 years in age and at 14-inch and 18-inch diameters, was undersized for the future service requirements. HRSD undertook a two-phase, 26,000-foot force main replacement project to install a new 24-inch pipeline. The new alignment ran along main roads and an abandoned railroad corridor which included a trenchless crossing of Lake Meade. Michael Baker International designed a 3,200-foot horizontal directional drill (HDD) to cross under the lake using a detailed drill geometry with varying vertical and horizontal curves to maneuver through the clayey soils.

The development of the HDD design, material selection, and successful installation is examined in detail. This paper will also focus on the series of events that followed complications during pipe installation and how the driller’s ingenuity recovered the installation.

2. INTRODUCTION AND PROJECT BACKGROUND

Hampton Roads Sanitation District (HRSD) was established in 1940 as a regional wastewater treatment agency to combat the increasingly worsening state of local waters as the area surrounding the Chesapeake Bay in Southeastern Virginia continued to develop. Prior to implementation of any sewer regulations, the standard practice had been to discharge untreated raw sewage into the nearby rivers. When smaller populations had inhabited the area in previous centuries, this method had not presented a serious issue as the lower sewage inflow was more easily diluted. However, as the area became more developed, water pollution became a major concern both for health and business with 10,000 acres of oyster beds condemned by the 1920s.

Since HRSD’s establishment, there has been a drastic change in public opinion on water pollution and a series of federal mandates to correct and protect natural resources. By the 1990s, HRSD had 10 plants running to treat 150 million gallons per day (MGD) of sewage which served 1.4 million residents in a 2,100-square mile area. The district consistently expanded existing plants to meet growing demand, not only caused by increased population, but expansion of the service area with the continued addition of counties and cities to its territory. To date, HRSD serves a population of 1.7 million over 18 counties and cities in a 3,087-square mile area (see Figure 1), with a system capable of treating 249 MGD via 600 miles of interceptor pipelines (16-inch to 72-inch), 109 pump stations and 9 major and 6 smaller treatment plants.
Suffolk, Virginia makes up the largest area of the Hampton Roads region at 432 square miles. Only 20 miles from Norfolk, where the Virginia Port Authority is located, it is highly accessible for exporting and importing products, making it a fitting home for several large companies from SYSCO Foods to Lockheed Martin, ripe for continued growth.

Although the sewer system in Hampton Roads had vastly improved over the previous century and was built up to meet projected demands into the 2000s, HRSD now needed to expand its system for further growth and an extended lifespan. One major force main in the Suffolk service area was nearly 50 years old and undersized for the service requirements at the existing 14-inch and 18-inch diameter sizes. The existing asbestos cement and ductile iron lines were installed in the 1970s, largely along Holland Road, which is one of the main roads through Suffolk. With these lines approaching the end of their design lives, HRSD looked to update the sewer infrastructure to increase capacity for further development in the region. This would also provide the added benefit of minimizing chances of sewage overflows in wet weather conditions.

HRSD undertook a two-phase, 26,000-foot force main replacement project to install a new 24-inch pipeline. Approximately 18,000 feet of this line would be installed as part of Phase 1 and was required to cross active railways and, most significantly, Lake Meade. This water body is owned by the City of Portsmouth and serves as one of its water supply sources for the nearby Lake Kilby Water Treatment Plant (located in Suffolk). The task of designing the proposed main was entrusted to Michael Baker International (Michael Baker).
3. PROJECT DESIGN

Michael Baker began design of the new force main in early May 2012. The population in Suffolk had multiplied by more than eight times since the original installation almost 50 years ago, making a similar installation along Holland Road impractical. Therefore, for the replacement force main, the engineer took advantage of an abandoned railroad corridor, rather than following this same alignment. The project area contained three railroad right-of-ways (ROW); two of these, Norfolk Southern Railroad and CSX Railroad, were still active but the third, Suffolk Railroad ROW, had been abandoned and did not have any tracks on it. The Suffolk ROW was formerly owned by Norfolk Southern but was purchased by the City of Suffolk about a decade prior to this design. Michael Baker saw the corridor as an ideal opportunity to install large runs of pipe with minimal obstacles and a minimized impact to the public (see Figure 2).

![Figure 2. Phase 1 project map.](image)

The required flow capacity of the replacement line was determined by the HRSD Hydraulic Analysis Review Team (HART) and indicated the existing 14-inch and 18-inch force main should be replaced with a 24-inch diameter main. Because the majority of the proposed alignment was within the Suffolk Railroad ROW, most of the pipeline could be installed by open trench methods with tunnel-bored steel encasements required only where the alignment crossed wetlands and the active CSX and Norfolk Southern Railroads. The greatest design challenge was traversing Lake Meade.

The original 14-inch force main spanned Lake Meade by way of the bridge along Holland Road. Michael Baker initially considered a similar design approach for the new 24-inch force main and researched the possibility of an aerial crossing on the existing wooden bridge over Lake Meade along the Suffolk Railroad corridor. Unfortunately, this City-owned structure was a 100+-year-old railroad trestle that had long since been abandoned. Because it was abandoned, the City did not complete regular maintenance on it and, in its remote location, made no sense to bring it under the maintenance requirements of the City. Without a known entity responsible for the state of the trestle, the structural integrity of an aerial crossing was questionable. Also, such a crossing would mean hanging a force main just above a water reservoir and potential leakage of sewage into the water supply was a significant concern. Ultimately, after completing a risk analysis between an aerial and a horizontal directionally drilled (HDD) crossing, Michael Baker and HRSD decided it would be in their best interest to cross Lake Meade via HDD. The geotechnical conditions in the area of Lake Meade were ideal for drilling, consisting of clayey to silty sands (SC-SM) near the
surface and heavy clay (CH) at greater depths. Michael Baker was confident the borehole would hold well with these soil characteristics.

The actual distance across Lake Meade at the location of the abandoned railroad corridor was relatively short with only 300 feet of the alignment under water. However, the road on each side of the trestle was very narrow with steep drop-offs to either side. To allow a large enough work area, the HDD entry and exit points were set a couple hundred feet back from the narrow sections of the corridor, giving a total bore length of approximately 3,200 feet. The bore was designed to have 43 feet of cover from the bottom of Lake Meade to limit the risk of hydraulic fracture. Table 1 details the designed bore geometry. Because there were not any detailed as-built drawings available to confirm the support system under the railroad trestle, a horizontal offset was incorporated into the alignment on the west end of the drill to ensure clearance from any potential batter piles along the lake bed.

Table 1. Designed horizontal directional drill geometry.

<table>
<thead>
<tr>
<th>START COORDINATE</th>
<th>EASTING</th>
<th>NORTHING</th>
<th>STATION ELEVATION (FT)</th>
<th>AZIMUTH</th>
<th>RADIUS (FT)</th>
<th>PLAN LENGTHS (FT)</th>
<th>PATH LENGTHS (FT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENTRY ANGLE @ 8.2°</td>
<td>12,035,575.55</td>
<td>3,431,636.41</td>
<td>141+84.01</td>
<td>38.08</td>
<td>N 80°44’11” E</td>
<td>--</td>
<td>87.04</td>
</tr>
<tr>
<td>VERT CURVE 1</td>
<td>12,035,661.88</td>
<td>3,431,650.49</td>
<td>142+71.48</td>
<td>25.60</td>
<td>N 80°44’11” E</td>
<td>--</td>
<td>2,000</td>
</tr>
<tr>
<td>TANGENT 2</td>
<td>12,035,867.27</td>
<td>3,431,683.99</td>
<td>144+79.59</td>
<td>6.79</td>
<td>N 80°44’11” E</td>
<td>--</td>
<td>143.13</td>
</tr>
<tr>
<td>HORIZ CURVE 1</td>
<td>12,036,008.54</td>
<td>3,431,707.03</td>
<td>146+22.72</td>
<td>1.36</td>
<td>N 80°44’11” E</td>
<td>2,300</td>
<td>--</td>
</tr>
<tr>
<td>TANGENT 3</td>
<td>12,036,270.57</td>
<td>3,431,734.48</td>
<td>148+68.33</td>
<td>-8.64</td>
<td>N 87°18’11” E</td>
<td>--</td>
<td>94.45</td>
</tr>
<tr>
<td>HORIZ CURVE 2</td>
<td>12,036,364.92</td>
<td>3,431,738.92</td>
<td>149+80.78</td>
<td>-12.22</td>
<td>N 87°18’11” E</td>
<td>2,300</td>
<td>--</td>
</tr>
<tr>
<td>TANGENT 4</td>
<td>12,036,625.57</td>
<td>3,431,766.15</td>
<td>152+42.99</td>
<td>-22.17</td>
<td>N 80°46’16” E</td>
<td>--</td>
<td>70.54</td>
</tr>
<tr>
<td>VERT CURVE 2</td>
<td>12,036,695.20</td>
<td>3,431,777.41</td>
<td>153+13.53</td>
<td>-24.84</td>
<td>N 80°46’16” E</td>
<td>2,000</td>
<td>--</td>
</tr>
<tr>
<td>TANGENT 5</td>
<td>12,036,745.48</td>
<td>3,431,785.31</td>
<td>153+62.45</td>
<td>-26.10</td>
<td>N 80°46’16” E</td>
<td>1,464.03</td>
<td>--</td>
</tr>
<tr>
<td>VERT CURVE 3</td>
<td>12,038,162.42</td>
<td>3,432,015.86</td>
<td>168+26.48</td>
<td>-45.77</td>
<td>N 80°46’16” E</td>
<td>2,000</td>
<td>--</td>
</tr>
<tr>
<td>TANGENT 6</td>
<td>12,038,630.94</td>
<td>3,432,091.99</td>
<td>172+74.66</td>
<td>-1.07</td>
<td>N 80°46’16” E</td>
<td>--</td>
<td>119.24</td>
</tr>
<tr>
<td>EXIT ANGLE @ 12.2°</td>
<td>12,038,748.64</td>
<td>3,432,111.11</td>
<td>173+93.90</td>
<td>24.62</td>
<td>N 80°46’16” E</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>SUBTOTAL LENGTH =</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,978.43</td>
<td></td>
</tr>
<tr>
<td>TOTAL LENGTH =</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3,209.45</td>
<td></td>
</tr>
</tbody>
</table>

Due to the length of the HDD, fused joint pipe materials were required to cross the lake, unlike the rest of the alignment which would consist of ductile iron pipe. Specifically, fusible polyvinyl chloride pipe (FPVCP) and high density polyethylene pipe (HDPE) were considered. Michael Baker briefly looked into using steel but decided against it as the site conditions would require a deeper drill path to accommodate the larger bending radii for steel pipe. The sizing and wall thickness of the FPVCP and HDPE materials were determined by HRSD’s set flow area for the main, installation loading conditions, and the final depth of the alignment. Michael Baker designed the HDD crossing using either 24-inch DR 18 FPVCP or 30-inch DR 9 HDPE in order to provide a nominal diameter of 24 inches (see Figure 3).

Figure 3. Cross sections of force main materials considered.

4. PROJECT BIDDING AND AGREEMENTS

HRSD advertised the Holland Road 24-inch Interceptor Force Main – Section A, Phase 1 project on October 18, 2015. The bid schedule itemized the force main with estimated total quantities for each size, excluding the length
across Lake Meade. Each trenchless crossing, by tunneling, boring, or HDD, was broken out as a lump sum item to include the setup, material, and installation. The HDD under the lake was bid with alternative pipe materials, either FPVCP or HDPE, and was left up to the bidding contractor. Measurement and payment for this item was based on successful completion of the HDD installation.

Seven bids were received at the bid opening on November 19, 2015. T.A. Sheets General Contractors, Inc. was awarded the project and elected to install FPVCP under Lake Meade due to its advantage both in borehole size and simplified connections. T.A. Sheets subcontracted the HDD work to Environmental Crossings, Inc. (ECI). In order to shift accountability to the drilling contractor, T.A. Sheets set up a bond on the purchased FPVCP that placed ownership of the pipeline on ECI until it was successfully installed and tested. This gave the driller greater incentive to properly complete the crossing and lifted responsibility from the general contractor for the cost of new pipe and/or the abandonment of a failed installation.

Construction commenced on January 15, 2016 with a contractual project completion date of March 20, 2018.

5. HDD PREPARATION AND INITIAL PULLBACK

Site preparation of the HDD work area started in early 2016 with the clearing of a 200-foot by 155-foot wooded wetland area for drill rig staging on the east end of the bore. Because most of the setup for the HDD took place in the abandoned railroad corridor, there were minimal constraints to staging and pipe layout. Drilling operations were permitted from 7:00 AM to 7:00 PM six days a week, with operations allowed 24/7 once pipe pullback commenced. The only restriction in the area related to the potential discovery of archeological artifacts, as the area was designated as a historic civil war battle ground. Certain areas could not be disturbed and any artifacts found during excavation had to be presented to the Department of Historic Resources.

T.A. Sheets’ construction crew worked to install other sections of the project while ECI drilled the borehole, but their pipe crew was brought in to support the HDD when pipe layout and pullback efforts began. Fusion of the 24-inch FPVCP was completed throughout May 2016 on the west side of the bore. In an effort to more easily maneuver the pipe lengths along the corridor, the pipe was initially fused into approximately 600-foot lengths. Once these shorter lengths were fused, they were repositioned and then joined with intermediate fusions into a single length of over 3,000 feet, laid along the railroad corridor (see Figure 4).

Figure 4. Fusion and layout of 24-inch FPVCP along abandoned Suffolk Railroad corridor.
ECI began staging the drill rig on July 1, 2016 and started drilling the pilot hole a week later (see Figure 5). On July 13, the pilot bit reached the west side of Lake Meade, 6 inches short and 1 foot to the right of the designed exit point, well within the parameters noted in the HDD specification, with the goal to exit within 5 feet along the pipe length and 2.5 feet perpendicular to either side of the pipe. The pilot was followed by a 24-inch ream back to the east side, then a 38-inch ream to the west side, bringing the bore to its final diameter of 38 inches. A 20-inch swab was passed through to clean the drilled hole, then the swab was sent back through with the 38-inch cutter to connect to the 24-inch pipe for pullback, reaching the west end on August 7.

Pullback started at 11:37 AM on August 10 but was stopped for the day to realign the pipe rollers after pulling in only 150 feet. Pullback recommenced at 6:49 AM the next morning. Then, at 9:20 PM, after pulling in 2,800 of the total 3,200 feet, just as the pipe was about to curve vertically up to the borehole exit, progress stopped. Although not officially determined, the general consensus was that the borehole had collapsed. The soils had caved in around the pipe to where it could not be pulled any further, nor could it be pushed back.

6. PIPE RECOVERY AND REINSTALLATION

The drilling contractor had a choice to make; either abandon the installation and drill a new path across the lake or try everything they could think of to dislodge and recover the existing line. ECI chose the latter. The contractor connected a pull-head to the back end of the pipe on the west side. Crews initially tried to pull the pipe out with a 470 excavator, but it would not budge. The 24-inch pipe was dewatered and then attached to a custom-linked train of six excavators including a 470, 350, 328, 300, 220, and 210 (see Figure 6). Steel rods were welded directly to the chassis of the excavators to form the train. Although a valiant effort, this attempt was unsuccessful and broke several 35-ton shackles in the process.

Figure 5. Drill rig setup on east side of Lake Meade.
The next retrieval attempt used a 2nd DD330 drill rig, meaning that there was one drill rig on each side of the alignment. One pulled while the other pushed to provide some additional force out of the borehole, but this was also unsuccessful. Then, the contractor attempted a washover tool, used to try to free the FPVCP. A washover pipe is a technology typically used in the gas/oil industry as a last ditch effort to retrieve items lost in the bore. For the purpose of HDD pipe retrieval, a steel washover tool was manufactured on site to fit around the HDD carrier pipe and through the borehole (see Figure 7). The tool was fixed to a drill rod, allowing it to be pushed through the borehole with the drill rig.

On August 27, the washover tool was connected to the drill rig, placed around the end of the pipe and pushed through the borehole. Bentonite was pumped through the drill rods connected to the tool to wash away cuttings from around the outside of the pipe up to the point of bore collapse until the returns came out at the drill rig. By 1:45 PM on August 28, the washover tool had finally loosened the soil around the pipe and by 3:20 PM the drill rig on the west end began pulling the pipe out of the borehole (on the pipe layout side). Once the pipe was mobile, excavators were attached and pulled both the washover tool and carrier pipe out at one time. Crews worked around the clock to complete the retrieval (see Figure 8).
The salvaged pipe was inspected and evaluated after recovery. After cutting out and re-fusing 90 feet of pipe found to be gouged in the recovery process, the pipe length was ready for reinstallation. The driller decided to take another pass through the bore with a larger cutter. The 38-inch reamer was modified to a 42-inch reamer and installed through the borehole on September 6 and reached the other side by September 11. At 8:25 AM on September 14, pipe pullback began and successfully reached the east side of Lake Meade by 2:40 PM on the same day (see Figure 9).
The FPVCP was hydrostatically pressure tested on September 16. During the test, the pipeline suddenly lost pressure. An external stress or impact load impinged on the pipeline at some point during handling or installation had caused an approximately 12-foot section near the east end of the bored alignment to break. The contractor excavated about 100 feet back along the length of the pipeline to the break point, removed the damaged section, then capped and successfully pressure tested the line on September 19, 2016, holding a pressure of 100 psi for 2 hours. Ductile iron pipe was installed from the cut back end of the HDD pipeline to bring the line up to design grade.

The remainder of the project, including installation of the other 15,000 feet of 24-inch force main and various smaller sizes of force main and water line piping, was completed in February 2018, one month ahead of the contractual deadline for final completion.

7. CONCLUSION

With the completion of Phase 1, HRSD is on its way to having a fully updated sewer system and will be prepared to serve its largest city for years to come. This project was largely successful due to the thorough design by Michael Baker, closely coordinated with HRSD, and the determination of both the general and HDD contractors. Re-alignment of the new force main along the unused Suffolk Railroad ROW allowed the contractor the freedom to use the 30-foot wide corridor as needed without disturbance to residents or overly constrained work areas and hours.

Even though the installation across Lake Meade did not go as planned, it provides a prime example of how creative solutions can save a seemingly failed installation. The driller’s ingenuity prevented the complete abandonment of nearly 3,000 feet of 24-inch pipe. Despite the complications during installation, HRSD was very pleased with the end product.

8. REFERENCES


Michael Baker International (2015) – Contract Documents and Specifications for Holland Road 24-inch Interceptor Force Main Section A – Phase 1, Suffolk, VA.