The Northern California Pipe User's Group
19th Annual Sharing Technologies Seminar

Berkeley, CA
February 17, 2011

www.norcalpug.com

LARGE DIAMETER HDD PROJECT FOR LAVWMA WESTERN TERMINUS

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ABSTRACT: The Livermore-Amador Valley Water Management Agency (LAVWMA) Export Pipeline Facilities Project consists of over 15 miles of 24- to 36-inch inside diameter pipe and carries flows from Dublin to the East Bay Dischargers Authority (EBDA) pipeline in San Leandro. Replacement of the Western Terminus of the pipeline involved installation of 1,200-feet of 42-inch OD HDPE using horizontal directional drilling (HDD).

This paper discusses the design and construction of the Western Terminus HDD Crossing. The project design faced the typical challenges, including the large diameter and length of the HDD crossing, and soft Young Bay Mud soils. The more severe challenges on the project included a significantly accelerated design timeline, work area constraints, numerous environmental restrictions, a very tight construction window, and minimizing disruption to nearby highly vocal residents.

Construction of the pipeline began in late September and tie in to the EBDA pipeline was completed on December 8, 2010 (Substantial completion of the project was awarded Dec. 20th, 2010).

1. INTRODUCTION

The Livermore-Amador Valley Water Management Agency (LAVWMA) pipeline system transports over 30 MGD of treated wastewater effluent from the City of Livermore, the Dublin San Ramon Services District (DSRSD), and the City of Pleasanton to the East Bay Dischargers Authority (EBDA) pipeline, which empties into the San Francisco Bay. The 16 miles of export pipeline from the LAVWMA pump station to the EBDA pipeline was installed in 1979 and ranges in diameter from 24- to 36-inches. The Western Terminus of the export pipeline lies beneath the San Leandro Marsh, a restored wetland area which is habitat to several protected species, including the harvest salt marsh mouse and the clapper rail. The marsh is bounded by a residential development to the east, and the San Francisco Bay to the west, as shown in Figure 1.

Figure 1. Aerial View of the LAVWMA Western Terminus Project Site

In 1998, the LAVWMA system began an expansion that would approximately double the capacity of the system. In conjunction with the expansion, several portions of the original pipeline were determined to require either replacement or rehabilitation. The 1,750-foot Western Terminus replacement project was the last section of the export pipelines to be replaced. The existing Western Terminus was 27 inches in diameter, but due to increased capacity needs, the replacement pipeline was designed as a 36-inch inner diameter (ID) pipeline.

Due to the numerous protected species that live in the marsh, the construction window was limited to September 15 through January 15 for work within and under the Marsh. In addition, work hours were restricted to 7 AM to 6 PM to limit impacts to the nearby residential community. Trenchless construction methods were essential for the majority of the pipeline replacement to reduce the environmental and social impacts from construction. The trenchless construction methods that were considered for installing the 1,200-foot, 36-inch ID pipe across the marsh included microtunneling and horizontal directional drilling (HDD).

Microtunneling 36-inch ID pipe is very common; however, guidance becomes less accurate for small diameter pipe as drive lengths increase beyond 600 feet. Because of environmental restrictions, it was impossible to place an intermediate shaft in the middle of the marsh to reduce drive lengths. In addition, the shafts required for microtunneling would need to be watertight to prevent seepage of groundwater into the shaft which could result in flooding and/or settlement around the shafts. The need for watertight shaft construction methods would further increase the cost and construction schedule. Due to the long drive length, it was also likely that intermediate jacking stations would be required to microtunnel the1,200-foot drive, further increasing risk and cost.

Using HDD to install 1,200 feet of pipe is standard practice, however, the diameter of pipe required for this project is near the upper end of HDD capabilities. Installing large diameter pipelines with HDD requires an annular space with approximately 6-inches of radial overcut to reduce friction during pullback. In soft soils, such as Young Bay Mud, a large HDD bore diameter can collapse and cause delays in construction, increased costs, and possible settlement damage. In addition, the risk of hydrofracture is significantly higher with HDD than with microtunneling. Due to the environmental permitting requirements, drilling fluid hydrofracture risk needed to be aggressively mitigated.

After considering the required length, diameter, construction schedule, risks, estimated cost, and anticipated soil conditions, HDD was selected as the more applicable construction method for the

Western Terminus Replacement Project. Design of the Western Terminus project was awarded to Brown and Caldwell in January of 2010, with geotechnical subconsultant DCM/GeoEngineers, trenchless subconsultant Bennett Trenchless Engineers, and construction manager The Covello Group. Final design was completed in June 2010, only 6 months after notice to proceed. The design timeline of the project was considerably more compressed than typical projects of this size in order for construction of the pipeline to occur during the construction window of 2010.

2. GEOTECHNICAL CONDITIONS

The geotechnical investigation for the entire LAVWMA expansion and rehabilitation project was conducted in 1998 by DCM/Joyal Engineering (now GeoEngineers). There were four borings performed for the Western Terminus portion of the pipeline in addition to four borings that had been previously performed in the area for other projects. Additional borings were planned, however due to environmental permitting restrictions in the marsh, the required permits could not be obtained and the supplemental borings were cancelled. The existing eight borings showed that the soil in the upper 20 feet was predominantly soft to medium stiff fat and organic clays, geologically identified as Young Bay Mud. The upper layer of Young Bay Mud was underlain by a layer of stiff lean clay and medium dense sand, identified as Old Bay Mud. Groundwater levels were within 10 feet of the ground surface.

Young Bay Mud is under-consolidated soft clay, is very compressible, and is susceptible to high settlement and hydrofracture risks. Old Bay Mud is typically normally-consolidated medium stiff to hard clays and medium dense to dense silty sand, and is much less susceptible to settlement and hydrofracture. Therefore, due to the environmental restrictions within the marsh it was imperative to reduce the risks associated with HDD construction by locating the bore in the deeper Old Bay Mud as much as possible.

3. ALIGNMENT

The west side of the crossing was chosen as the entry point for the HDD crossing due to the much larger work area available. Locating the rig on the west side also helped to minimize noise impacts to the nearby residential neighborhood on the east side of the crossing. To site as much of the bore as possible in the more competent Old Bay Mud, the HDD bore alignment used steep entry and exit angles of 16° with approximately 90 feet of straight section before beginning a vertical curve with a bend radius of 1,000 feet. The steep entry and exit angles and the length of the straight tangents were selected to ensure that the bore reached a depth of 25 feet before starting the vertical curves. It was important that this depth be attained to ensure steering response in the stiffer Old Bay Mud. Conductor casing was specified at both the entry and exit to extend through the upper weaker soils into the deeper Old Bay Mud. This geometry resulted in the bore reaching a maximum depth of approximately 70 feet below the ground surface. In addition, a horizontal curve was required to remain largely within the existing LAVWMA easement, as shown in Figure 2.

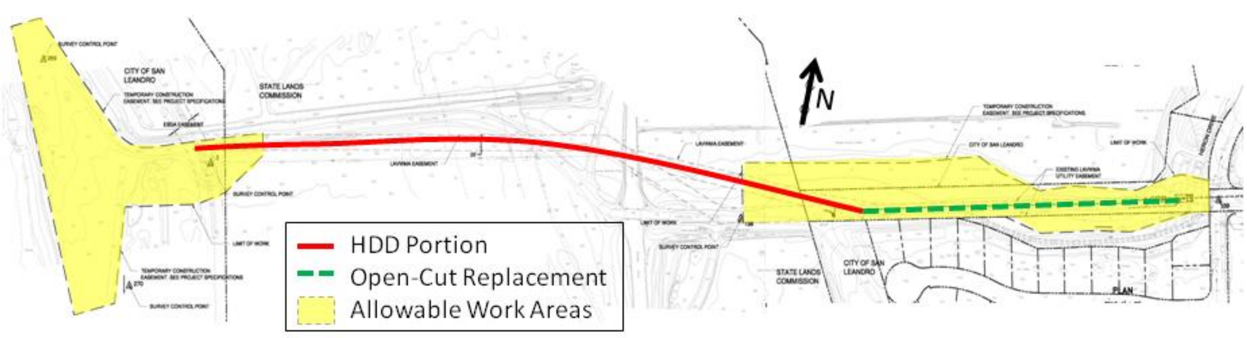

Figure 2. Plan View of the Final HDD Bore Geometry and Allowable Work Areas

Pullback load and pipe stress analyses were performed for this alignment using the ASCE Pipelines Guidelines (ASCE, 2005). Based on the analysis of pullback loads and pipe stresses, HDPE and FPVC pipe materials were determined to be suitable for the project. Steel pipe was not considered due to the corrosive nature of the organic bay soils and the treated effluent, as well as the tight geometry. The 36-inch ID FPVC with the required stiffness class was not available within the short construction schedule, therefore 42-inch OD DR 13.5 and DR 21 (for the open-cut section) HDPE pipe was selected as the carrier pipe.

A detailed hydrofracture evaluation was conducted to help optimize the design to reduce the risk of hydrofracture. Hydrofracture calculations were performed according to the Delft Cavity Expansion Model, (Bennett and Wallin, 2008; Staheli, et. al., 1998; Delft Geotechnics, 1997; Luger and Hergarden, 1988), and were based on the soils described in the Geotechnical Report and assumed drilling fluid properties and means and methods. The hydrofracture analysis results, shown in Figure 3, indicated that there was a heightened risk of hydrofracture near the exit point. Therefore conductor casing was specified at the exit point to reduce risks of drilling fluids escaping the bore, as well as to provide additional bore stability in the soft Young Bay Mud.

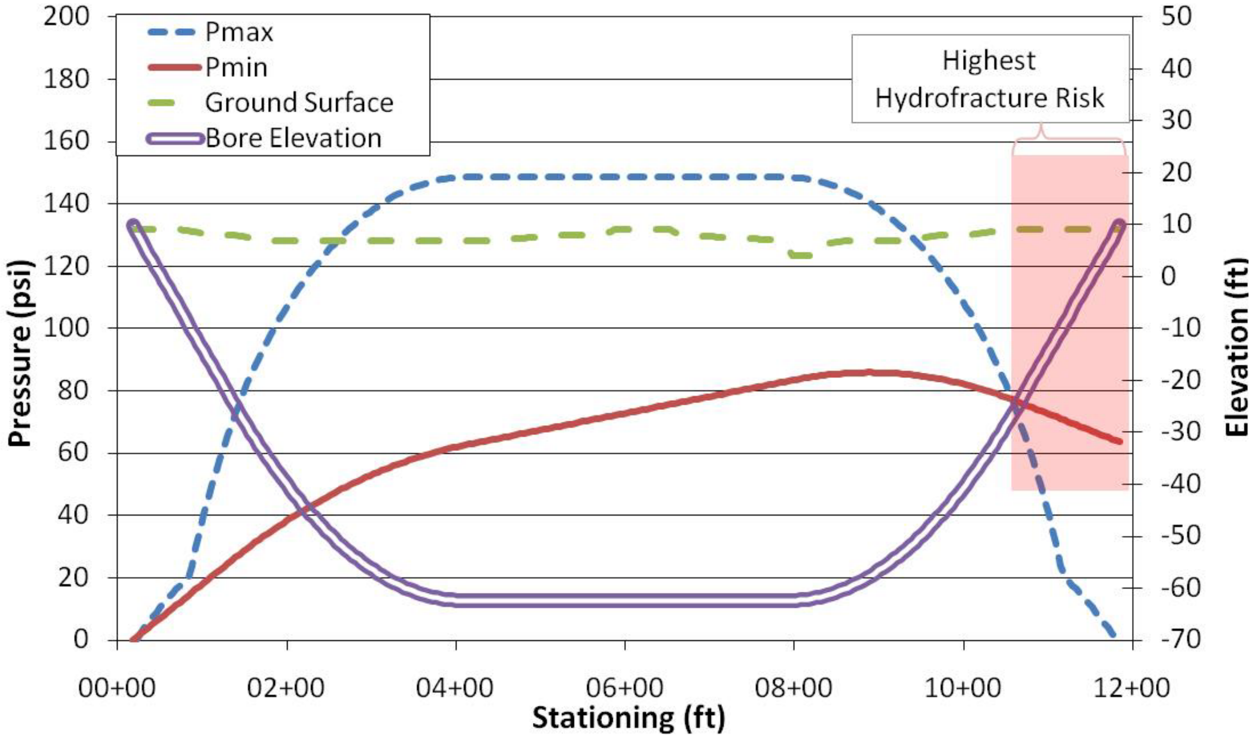

Figure 3. Hydrofracture Analysis Indicated Heightened Risk of Hydrofracture Within 130 Feet of Exit

4. CHALLENGING WORK AREA CONSTRAINTS

The work area at the HDD entry point included a section of an elevated bike path that crossed east/west over the marsh, as shown in Figure 4. The work area needed to include a bike path detour around the site to ensure public safety and uninterrupted access. In addition, the work area had approximately 1 acre of low-lying land that needed to be filled in with either earth fill or timber mats to provide a stable work area and provide access for construction and emergency vehicle traffic. The actual fill thickness varied from zero to as much as 3 feet over the combined area with a total fill volume of approximately

3,000 yd^3. After construction was complete, the permitting agency required that the fill be removed and the site restored to original condition to avoid marsh mouse and clapper rail habitat impacts.

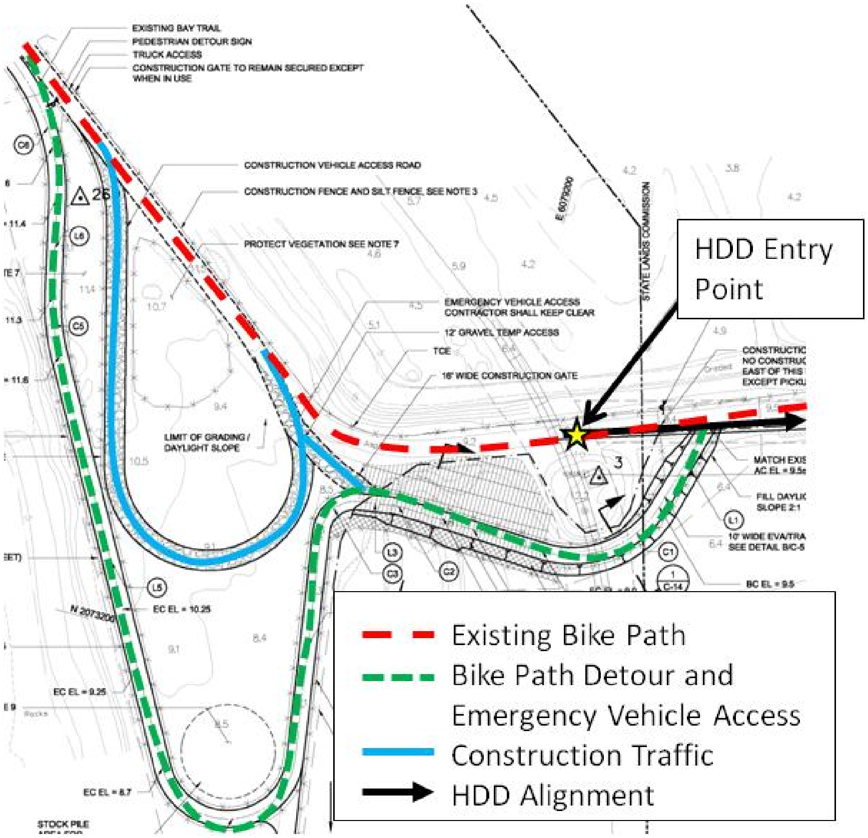

Figure 4. Bike Path Detour and Truck Access Modifications to Work Area on HDD Entry Side

The work area on the eastern end of the alignment was insufficient to allow layout of the full length of fused pipeline without restricting access of residents and traffic. Therefore, to reduce impacts, the pipeline was designed to be fused in two 600-foot segments and staged in the work area and adjacent park. The two segments would then be fused during a 3 hour pause in the pullback operation, slightly increasing the risk of becoming stuck. However, fusing two segments during pullback is relatively common and the risk was considered small.

5. CONSTRUCTION

Bids for the Western Terminus Replacement Project were opened on July 21, 2010. Notice to proceed was provided on August 1, 2010 to the winning team: KJ Woods with The HDD Company as the HDD subcontractor. The contractor began constructing the perimeter environmental exclusionary silt fence on September 9, 2010. Mobilization also included environmental training for all construction personnel and hand clearing wetland and upland plants to minimize disturbance to the salt marsh harvest mouse. Approximately 71 feet of 60-inch (OD x .500”) conductor casing was installed at the entry to prevent hydrofracture and bore collapse.

The contractor used the Tensor Steering Tool System for steering and downhole pressure monitoring. Due to lack of access to the sensitive marsh habitat, a walkover guidance system was not feasible.

The 10-inch pilot bore began on October 8, 2010 and reached the exit point on October 12, 2010. There were approximately 7 hydrofractures which occurred during the first 834 feet of the pilot bore.   The soils at the exit point were more competent than anticipated and the bore hole was showing no signs of collapse. Therefore, because the chance of hydrofracture is greatest during the pilot bore, the contractor submitted a proposal to eliminate the conductor casing on the exit side of the bore and provide a credit to the Owner.

The contractor reamed the bore with a 34 inch reamer and then a 58 inch reamer over the course of 2 weeks. Prior to pullback the first segment of the 42-inch DR 13.5 HDPE was attached to a steel pull head, then attached to the bore hole swabber with a swivel and was staged in the east work area. The bore hole swabber, which is used to stabilize the soil surrounding the bore hole, was then attached to the drill pipe for pullback. After the first segment of HDPE pipe was pulled about 500 feet into the ground , pullback stopped and the second 600-foot segment was fused to the first. The pullback process began on October 28, 2010 and was completed in 19.5 hours, including the 3 hour downtime for fusing the two sections of pipe together. The average rate for HDPE pipe pull was 30 feet in 5 minutes, however, pumping and removal of displaced drilling fluid and bay mud as well as filling the HDPE pipe with water to counteract the buoyancy were the most time consuming parts of the entire process. After the 1,200 feet of HDD pipe and 550 feet of open-cut pipe construction was complete, the contractor tied the new Western Terminus to the EBDA pipeline and the new LAVWMA export pipelines began flowing on December 8, 2010. Demobilization and site restoration were completed on January 14, 2011, one day before the permit expired.

6. SUMMARY AND CONCLUSIONS

There were several challenges encountered in the design and construction of the HDD crossing for the Western Terminus of the LAVWMA Export Pipeline Project. The primary challenge was the accelerated design and construction schedule. The complete schedule from award of design to completion of construction was less than one year. The accelerated schedule was facilitated by the availability of geotechnical data prior to award of design, extensive coordination within the design team and with the Owner, and early and ongoing discussions with HDD contractors. During design the team solicited input and feedback from various HDD contractors to solve the challenges regarding work area constraints, lack of access for installation of a surface coil guidance coil north of the bore, ensuring emergency vehicle access and bike path bypass. The narrow construction window required effective communication between the contractor, designer, and Owner to resolve issues in an efficient manner.

The site geotechnical conditions were challenging for a large diameter HDD installation due to the high risk of settlement, hydrofracture, and bore collapse in the upper layer of weak Young Bay Mud. These difficulties were overcome through the use of conductor casing through the Young Bay Mud to maintain bore stability, locating the majority of the bore within the more competent lower Old Bay Mud, and increasing the depth of cover to reduce the risks of hydrofractures and settlement.

To overcome the issues posed by the high groundwater and weak compressible soils at the HDD entry location, timber mats were installed to provide a stable base for the equipment and construction traffic. Mobilization and demobilization of the timber mats required a significant amount of time from the tight construction schedule, but was necessary to satisfy permit conditions, stabilize the work area, and allow the contractor to operate efficiently.

The successful completion of this project marks the overall completion of the LAVWMA Export Pipeline Project begun over a decade earlier. The project's final link, completed using HDD, also underscores the significant incremental advancements in HDD practice that ensured protection of sensitive species and minimized disruption to nearby residents.

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