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DESIGN BUILD OF A 54" REDUNDANT FORCE MAIN UTILIZING HORIZONTAL DIRECTIONAL DRILLING

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SHORT SUMMARY

The City of Miami Beach owns and operates a 54-inch sanitary sewage PCCP force main (FM) that was built in 1977. In 2012, the City identified structural deficiencies in the PCCP pipe and developed with the local construction and engineering experts the new 54-inch HDPE FM that could be commissioned in one year using Horizontal Directional Drilling (HDD).

KEYWORDS

HDPE, PE4710, PCCP, Force Main, Horizontal Directional Drilling, HDD

ABSTRACT

The City of Miami Beach owns and operates a 54-inch sanitary sewage PCCP force main (FM) that was built in 1977. This FM is the only transmission pipeline for conveying about 22 million gallons per day (MGD) of raw sewage to the wastewater treatment plant. In 2012, the City identified structural deficiencies in the PCCP pipe. Due to the associated risks, the City prioritized the implementation of a new redundant 54-inch HDPE FM that could be commissioned in one year. HDPE was selected due to its low life cycle cost, well-established monolithic fusion features, axial strength to withstand the pullback loads, surge allowance, resistance to corrosion, and due to its highly ductile properties which made HDPE the ideal material for Horizontal Directional Drilling (HDD). In addition, the locally experienced HDD team was crucial in developing this solution.

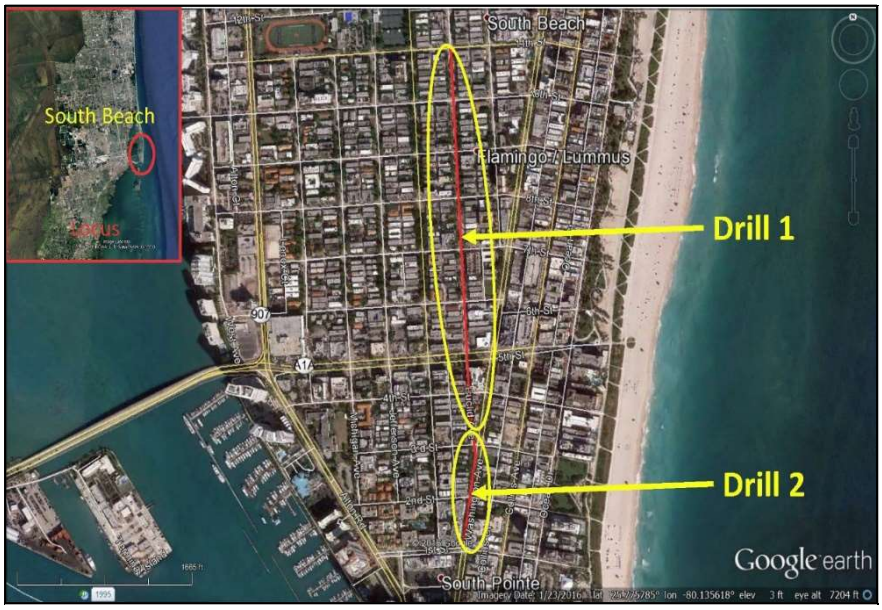
INTRODUCTION

The City of Miami Beach, a thriving community in South Florida that was established in the early 19th century, has been nimble in responding to the infrastructural challenges that have plagued urbanized coastal communities.

Challenges include aging and deteriorating infrastructure, and the immediate and measurable impacts of climate change. The City has embarked on a robust Capital Improvements Program, totaling $750M over the next five years. The City of Miami Beach owns and operates approximately *5,300 linear feet of existing 54-inch sanitary sewage* FM starting at Pump Station (PS) No.1 located at Jefferson Ave and 11th St, and extending westerly along 11th St, southerly along Michigan Ave, then easterly on Commerce Street. *This main is the sole transmission pipeline for conveying approximately 22 Million Gallons per Day (MGD) of raw sewage from the City* to Miami-Dade Water and Sewer Department's (MDWASD's) newly constructed 60-inch FM. This 60-inch FM directs flow to the Virginia Key Central District Wastewater Treatment Plant (CDWWTP) for final treatment.

The existing 54" PCCP FM was constructed in 1977. A condition assessment conducted in February 2012 identified structural deficiencies of this important pipeline. Given the risks associated with a lack of system redundancy, the City prioritized the implementation of a new redundant 54-inch FM that could be commissioned in one year and engaged in an emergency event.

To expedite delivery of the project, and as a means of mitigating owner risks, the City selected a Design- Build Delivery approach.



RISK EVALUATION

With the opportunity to significantly refine the means and methods to realize cost savings, the Project Team embarked on a collaborative effort to evaluate real risks associated with implementing the value-engineered HDD approach. The risk

associated with all aspects of the project were assessed, severity of the risks determined, and a mitigation strategy developed that managed risks to "acceptable". The main risks identified included:

- Limitations in equipment capacity to deliver the required pull back forces and torque for a successful bore and pipe installation.

- Buckling failure of the product pipe if pull forces exceeded maximum allowable for the material.

- Loss of drilling fluid to voids in the coral formation resulting in the inability to clean the bore path or the elevated risk of drill fluid discharge to the ground surface or into adjacent utilities or basements of adjacent structures.

- Inability of maintaining the drill path tolerance within the right-of-way and design depth to prevent buckling due to variability of subsurface conditions and induced magnetic fields created by buried and overhead electrical cables or magnetic interference from overlying metallic utilities.

- Borehole collapse preventing insertion of the carrier pipe due to subsurface conditions that become unstable with excavation of a 66-inch to 70-inch diameter excavation in low Rock Quality Designation (RQD) materials with sand lenses.

- Equipment damage – drill head/cutting tool wear due to abrasive ground; or failure of drill tools from eccentric loading applied by wide variability in formation strength imparting longitudinal rotational loading to cutting tools.

- Limitations in staging available for drill equipment operation (control booth, drill rig, engine, and frac-tanks) and pipe stringing along the project limits.

- Stakeholder complaints relative to dust, noise, and traffic inconvenience.

Communication between all team members was crucial to developing viable and acceptable mitigation approaches for all identified risk. Risk mitigation to address subsurface condition issues included:

- acquiring supplemental geotechnical data from borings supplemented with extensive local experience,

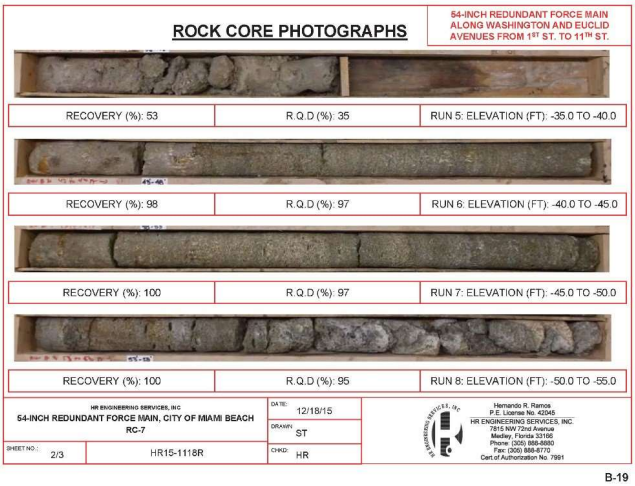
- use of locally experienced HDD staff with state-of-the-art technology,
- reserving high-capacity drill equipment,
- implementing a robust mud management strategy,
- and retaining spare parts on site.

These mitigation strategies were all reviewed, modified, and final actionable measures accepted by the City and their representative to manage the severity and probability of the risks and associated impacts to schedule and cost. Subsequently, the City authorized DMSI to advance the project.

GEOLOGICAL/ SUB-SURFACE CHARACTERIZATION

DMSI expanded on the geotechnical data that was published in the Design Criteria Package (DCP) by initially retaining NV5 to acquire site specific subsurface data and later HR Engineering Services, Inc (HRES). The subsurface conditions described in the HRES report are summarized below:

- An upper limestone layer was found at elevations ranging from -20.4 feet to -25.4 feet, NAVD 88 (North American Vertical Datum of 1988).
- An upper sand layer of loose to medium dense fine sand with traces of limestone lenses and occasional sandstone layers were found at elevations ranging from -25.4 feet to -32 feet, NAVD 88.
- An upper sandstone layer was encountered at elevations ranging from -31.3 feet to -40.0 feet, NAVD 88.



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- A lower sand layer of loose to very dense fine sand with some sandstone lenses layers were found at elevations ranging from -36.9 feet to -48.0 feet, NAVD 88.
- Lower sandstone and coralline limestone layers were found down to the borehole termination depths.

DESIGN CONSIDERATIONS

The final design and selection of the 54-inch HDPE product pipe was based on several considerations that were unique to the City of Miami Beach's geology and the operation of their wastewater systems. Key design and operating criteria included:

- The average operating pressure of the existing wastewater system being 20 psi.
- A peak flow of 60 MGD that had been diminishing over the course of 10 years due to the City's existing rehabilitation that has reduced extraneous inflows.
- Surge allowance of three times the operating pressure based on historical data.
- Axial strength to withstand the pullback loads without causing permanent deformation or buckling.
- Resistant to long term installation loads without risk buckling due to overburden, or borehole collapse imposed loads.

The design process was a team effort focused on risk mitigation and the achievement of Owner requirements for an HDD construction. Specific design features included:

- HDD alignment and locations to provide suitable work areas while managing length and depth.
- Pipe structural design for construction loading.
- Pipe structural design for long-term loading from operation and maintenance, and in-ground loading
- Pipe material to mitigate corrosion

Final Alignment:

It was determined that the 54-inch HDPE pipe will be pulled in two segments: Drill No. 1 and Drill No. 2.

Locations of the drills are shown on the Location Map. Characteristics of each alignment include:

	Drill 1	**Drill 2**
Approximate length	3,100 feet	1,240 feet
Vertical radius	2,100 feet	2,100 feet
Entry Angle	8 degrees	8 degrees
Exit Angle	6 degrees	6 degrees
Horizontal Curve Radius	No Curve	3,000 foot
Invert Elevation	-42 feet	-35 feet

Material Product Selection:

A 54-inch IPS DR-17 bimodal HDPE pipe (PE4710) was chosen for manufacture by Dura-line with technical assistance, pipe fittings and fusion services provided by

ISCO. ISCO's technical support helped to maximize the construction efficiency and minimize the social impact. HDPE was chosen for this project not only because of its low life cycle cost and monolithic features, but also because of its lightweight and ductile properties which makes it the ideal material for the HDD construction method. The pipe fusion on the project was completed utilizing one of ISCO's 2065 MegaMc fusion machines. The 54-inch IPS DR-17 HDPE pipe is manufactured with a minimum wall thickness of 3.18 inches. The product satisfied the required 80-year service life, with its characteristic long-term strength, ductility, and its resistance to corrosion, providing equal and better value as the FRP.

Construction Considerations

Construction planning during design was a critical component to the success of this project. The Contractor was knowledgeable and experienced in managing the construction risk associated with this HDD design. Sufficient work space was a basic requirement for this construction project. It was necessary that the work space selected would be capable of providing enough staging area for the drilling equipment, which would be selected to meet the City's requirements. Path design involved selection of a specific elevation that would have the capacity to confine drill fluid and provide sufficient structural stability to support the 66-to-70-inch diameter excavation of the slurry supported tunnel made by the HDD process. Drill geometry also considered pipe handling to permit safe entry into the prepared hole and to manage pull forces that increase with every bend and bend radius.

The pulling of the pipe through drill fluid was pre-determined to generate enough pressure to fracture the ground and release the drill fluid to the ground surface due to the quantity of drill fluid being displaced rapidly through this large diameter pipe. In order to mitigate this undesirable event, the project planning team developed a solution of constructing relief wells to manage the drill fluid pressure during the pipe installation process.

Equipment Selection:

Calculations indicated that the expected pulling load for a ballasted 54-inch DR 17 HDPE pipe was close to 230,000 pounds of force. A Vermeer D1000x900 Navigator® horizontal directional drill machine was selected which can deliver 1,000,000 pounds of push and pull and deliver up to 92,000 ft-lb of rotational torque.

Alignment Control:
Several methods of tracking/guiding the directional tooling include the traditional walk over system; magnetic guidance system; and the gyroscopic guidance system.

Site Requirements & Staging:
Early project planning addressed required work areas. These areas were negotiated with the City for access and work conditions were developed for their use. Construction required implementation of the planned work within the allowed staging areas with the given conditions. The drill site included the drill, the power unit, control cabin, mud cleaning system along with its independent power unit, materials, and drill rods.

Social Issues & Mitigation:
The task of drilling and pulling such a large pipeline is one that requires a great amount of power. The size and capacity of the drill rig required large engines that produced a large amount of noise and this was a potential problem since the primary drill site was within a residential neighborhood. In order to reduce the effects of noise to the surrounding community, the contractor built a sound wall adjacent to and around the main engine with double plywood, insulation, and acoustic lining.

An additional consideration requiring special attention was the vibration aspect. Drilling can cause vibrations in the geological formation, which can be transferred to nearby structures. A vibration monitoring and mitigation plan was adopted to ensure that the vibrations of the equipment and the drilling activities were kept at a minimum.

CONCLUSION

In summary, the coordination efforts and collaboration between the City of Miami Beach and DMSI with assistance by AECOM, APCTE, Brierley Associates as the HDD and pipe designer, Hard Rock Directional, and Spartan Directional greatly contributed to the success of this project. By advancing this project as a

design-build venture the City was able to leverage the techniques of the contractor and the latest technologies available in the industry, which in turn allowed the 54-inch HDPE force main to be installed at a faster pace than the use of conventional methods. Various mitigation measures such as a mud management and pipe stringing technique allowed for risk reduction and reduced impacts to the surrounding community.

ACKNOWLEDGMENTS

The authors would like to thank the city of Miami Beach for their leadership and vision to protect the community and implement this new redundant 54-inch HDPE Force Main with the full assistance of DMSI, AECOM, APCTE, Brierley Associates, Hard Rock Directional, Dura-Line, ISCO Industries and Spartan Directional who together contributed to the success of this project.