Truck Shots and Over the Hole: Rehabbing a Force Main in West Palm Beach

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The City of West Palm Beach (city) is completing an intensive condition assessment and rehabilitation project to extend the service life of a critical 48-in. force main that carries all of its wastewater to the East Central Regional Water Reclamation Facility (facility). After an internal investigations in 2015 to evaluate the condition of the prestressed concrete cylinder pipe that was installed in the 1970s, the city will complete a $14 million project in late 2017 to install a cured-in-place pipe (CIPP) lining system in the most distressed portions of the force main.

The CIPP lining was installed under two separate and sequential contracts, covering a total length of 12,000 ft. The work was performed under two separate contracts to allow work to begin in the most vulnerable section of the force main as soon as possible. The early start for the first contract also minimized the impacts on a golf course that the force main passed under, allowing the work to be performed during the slower summer season.

As the first phase of work was being bid and construction was beginning, the design of the second phase of construction was being completed. The second contract included more design and permitting challenges to be addressed for road crossings, traffic maintenance, and bypass piping layout, since the force main alignment was within the right of way of a busy Palm Beach County roadway.

The first contractor used a lining installation technique referred to as a "truck shot," which involves delivering sections of the liner, prewetted with epoxy resin, to the jobsite in a refrigerated truck traveling several hours from a remote facility. The second contractor elected to install the liner by setting up the equipment to wet the liner with the epoxy resin at the insertion pit itself, referred to as the "over the hole" method. Both methods are well-established in the industry and can provide equivalent final results. The liner was installed in lengths up to 1,000 ft in a single shot, minimizing the number of insertion pits required to be constructed.

Other special features of the lining installation included the design of the temporary flow bypassing systems, with one contractor using available upstream line pressure to carry the full force main flow through multiple parallel bypass lines, while the second contractor used in-line booster pumps and a fewer number of bypass lines to convey the bypassed flow to the treatment facility.

Installation of the temporary bypass lines involved extensive coordination with the golf course, state and county roadway agencies, and a local drainage district. A relatively new technology for installing bypass lines under a state road was approved for this project by the Florida Department of Transportation as a demonstration test, involving close tolerance horizontal directional drilling to install multiple bypass lines side by side at a relatively shallow depth below the roadway.

An effective community outreach and public information program was successfully employed throughout both construction contracts, including public open houses, mailers, a telephone hotline and project website, and direct personal communications with impacted residents and business owners. The construction contractors were responsible for providing the community outreach and public information services, with coordination and approval by the city, to ensure that the contractors were fully engaged in identifying and mitigating the impacts on the community during construction.

This article provides background on the condition assessment process and findings, with an emphasis on the critical construction issues, innovative approaches, costs, and lessons learned.

Overview of the Water and Wastewater Systems

The city, located on the Atlantic Ocean in south Florida, is the largest in Palm Beach County, with a population of approximately 110,000. The city and other communities in the county are favored destinations for visitors yearround, but especially during the winter months, when people from northern regions come to enjoy the sunshine and warm temperatures.

The city provides wastewater collection and treatment services for a total population of approximately 120,000, consisting of residents on the mainland and the Town of Palm Beach (town), located on the barrier island between the Intracoastal Waterway and the Atlantic Ocean. The wastewater for these two locations, along with wastewater from other communities in the area, is treated at the 70-mil-gal-per-day (mgd) facility. The facility is funded and governed by a board consisting of representatives of the entities it serves: the cities of West Palm Beach, Lake Worth, Riviera Beach, and Palm Beach, as well as Palm Beach County. Three large force mains from the various contributing communities carry wastewater to the facility for treatment; there are no interconnections among these force mains.

The wastewater from the city and the town is conveyed to the facility through a collection system consisting of 400 mi of gravity sewers, 100 mi of force mains, and 124 lift stations. All flows eventually are pumped into a single 48-in. force main, which serves as a manifold collector pipe that eventually discharges at the headworks of the facility. The force main is operated and maintained by the city, but it is jointly owned by the city (77 percent) and the town (23 percent).

The city's public utilities department also operates a 50-mgd water treatment plant, which uses surface water taken from a broad catchment area within the city limits and extends further west toward the Everglades. The 48-in. force main passes through the raw water supply catchment area, highlighting the need for ensuring the reliability and integrity of the force main.

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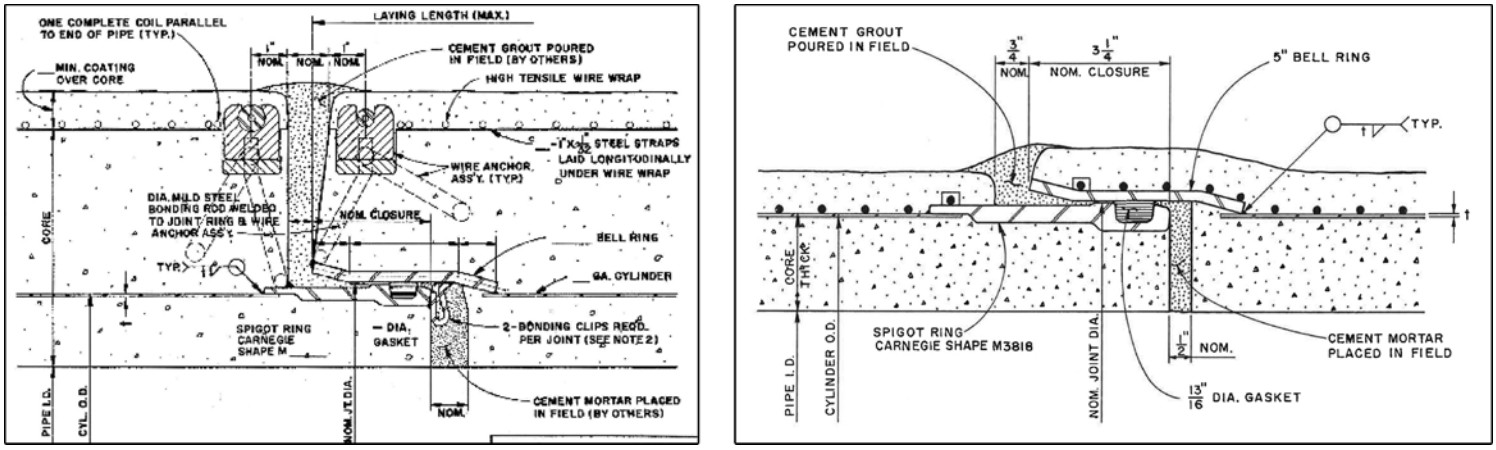

Figure 1. Typical construction of embedded cylinder pipe (left) and lined cylinder pipe (right) joints.

Critical Force Main

The force main that delivers wastewater from the city and the town to the facility is the sole pipeline for carrying flows from the city's service area to the treatment plant, so it must provide continuous and reliable service. The force main is constructed of prestressed concrete cylinder pipe (PCCP), with a total length of approximately 31,000 ft; the force main generally runs from east to west. The pipeline consists of 12,000 ft of 42-in.-diameter and 5,000 ft of 48-in.-diameter lined cylinder pipe (LCP) in the eastern portion of the city (east of I-95) and approximately 14,000 ft of 48-in.-diameter embedded cylinder pipe (ECP) west of I-95 for the rest of the run to the treatment plant. The force main was installed in the mid-1970s under two separate contracts; the contractor for the eastern portion (Contract 1) selected LCP type pipe manufactured by Price Brothers, and the contractor for the western portion (Contract 2) selected ECP type pipe manufactured by Interpace.

The pipeline generally was installed on a flat grade with depth of cover generally ranging from 5 to 10 ft, except where dropped sections, with up to 18 ft of cover, were required to cross under canals and roadways (including I-95). The force main was installed in dedicated easements or within roadway rights of way through a highly developed area. The pipeline passes through a condominium development, crosses a Jack Nicklaus-designed golf course and country club, and runs under a heavily traveled county road. No valves for isolating segments of the line were installed in the 42-in. and 48-in. force main in its original construction.

Recent master plans prepared for the city indicate that the force main will need to convey up to 32 mgd to the facility, although current flows average less than 20 mgd. The 48-in. force main was conservatively sized in its original design and is projected to have adequate capacity to serve the community at build-out.

Typical operating pressures are less than 20 pounds per sq in. (psi). Hydraulic modeling under a variety of flow conditions and lift station start/stop scenarios demonstrated that pressure surges/transients are quite small in magnitude and duration, largely due to the diversity of lift station capacities, connection points, and operating sequences.

Action Plan for Force Main Rehabilitation

The city was well aware of the potentially severe impacts that could result if a major failure of the force main occurred, including:

- Loss of wastewater service for the entire city's service area
- Localized contamination in the vicinity of the pipe failure
- Contamination of the city's primary raw water supply
- Contamination of the Intracoastal Waterway

This knowledge prompted the city's leaders to initiate the condition assessment in the first place, to be followed by decisive steps to mitigate, if required, the impacts of a force main failure, and more importantly, to proactively reduce the likelihood of such a failure.

The steps in the city's action plan are described.

Condition Assessment of the Force Main

The force main has provided reliable service for 40 years, with only a few repairs required during that time; however, the city is well aware of the history of failures of certain types of PCCP pressure mains. In particular, pipes with Class IV prestressing wire are known to be associated with excessive numbers of broken wire wraps; the pipe installed under Contract 2 was manufactured with this type of prestressing wire. The city decided to proactively investigate the condition of the force main and take steps to ensure uninterrupted conveyance of wastewater to the treatment plant for another 40 years and beyond.

Field Investigations

In 2014, the city initiated plans to investigate the condition of the force main through the selection of Jacobs as its engineering consultant to assist in procuring the services of a firm to perform an internal condition assessment, and then develop alternative solutions for rehabilitating the pipeline. To perform the field studies and condition analysis, the city contracted directly with Pure Technologies (Pure), a firm specializing in performing condition assessments for a variety of infrastructure systems.

Field investigations were conducted by Pure in spring 2015. The two elements of the condition assessment consisted of the following:

- Acoustic inspection, using Pure's SmartBall® device, to identify leaks and gas pockets
- Electromagnetic inspection, using Pure's PipeDiver® technology, to locate and quantify broken prestressing wire wraps.

Findings and Recommendations of the Condition Assessment

Key findings of the condition assessment were:

- No indication of leaks was found
- 23 anomalies in the acoustic test results were found that were indicative of entrained gas or slugs of gas at various locations along the length of the force main
- 1,682 pipe segments (total of LCP and ECP types) were inspected electromagnetically
- 169 pipes had measurable broken wire wrap distress, consisting of:
  - 55 pipes with 65-100 broken wire wraps (Category 1 pipes)
  - 31 pipes with 30-64 broken wire wraps (Category 2 pipes)
  - 83 pipes with 5-30 broken wire wraps (Category 3 pipes)

Continued on page 16

Continued from page 15

- 161 (out of the 169 segments) of the distressed pipe segments were 48-in. ECP manufactured by Interpace and installed under Contract 2
- Only eight of the 169 pipes were LCP type (Contract 1 pipe manufactured by Price Brothers) with only five or fewer broken wire wraps per segment
- Approximately 75 percent of the distressed ECP pipe segments were found in the first 50 percent of the 48-in. ECP (Contract 2) length
- Category 1 distressed pipe segments were calculated to have reached or exceeded the yield limit of the pipe design and were recommended by Pure to be rehabilitated in the near future
- Category 2 pipe segments were calculated to have reached approximately one-half the yield limit and were recommended to be re-inspected or rehabilitated within two years
- Category 3 pipes were recommended to be re-inspected in two years to determine if the physical condition and category determination have changed

Engineering Evaluation of Rehabilitation Alternatives

With the publication of the condition assessment report and its conclusion that a significant level of distress had already occurred in the ECP portion of the force main, the city concluded that a rapid and comprehensive rehabilitation approach would be required.

A series of strategy sessions between the city and Jacobs were held to quickly determine the city's best option for addressing the distressed condition of the force main. The outcome of these sessions was a decision to employ a trenchless technology, namely installation of a CIPP lining system for the entire length of the ECP pipeline installed under Contract 2. By rehabilitating the ECP force main, the city addressed all Category 1, 2, and 3 pipe segments at once, while eliminating the need for future periodic inspections and condition assessments of the pipe.

Design of Cured-in-Place Pipe Lining Solution

Preparation of the design documents for installing a CIPP lining system for 12,000 ft of 48-in. ECP type force main began within a few weeks after final release of the condition assessment report. To expedite the rehabilitation work and address the most critical portions of the force main first, the construction was divided into two separate construction contracts, referred to as Phases 1 and 2. The Phase 1 bid package was released first to rehabilitate the portion of the force main with the greatest number of distressed pipe segments. A schematic map of the force main route and rehabilitation contracts is shown in Figure 2.

The CIPP lining system specifications for both phases of construction included the following requirements:

- Liner tube: Glass fiber reinforced felt
- Resin: Vinyl ester
- Test pressure: 55 psi
- Liner thickness: To be determined by CIPP lining system manufacturer
- Depth of soil cover: 8-18 ft (maximum groundwater level at ground surface)
- Design service life: 50 years
- Design standard: American Society for Testing and Materials (ASTM) F1216

The bid documents allowed the bidders to propose the most cost-effective installation methodology to complete the force main lining within the specified parameters. The goal of this approach to formulating the bid documents was to establish the requirements of the completed work, but to also take advantage of the specialty contractors' expertise to find a timely and cost-effective method to meet those requirements. Options available to the bidders included selection of the number and placement of liner insertion pits (and correspondingly the length of each insertion "shot"), as well as the liner preparation method, choosing between the following:

- *Truck shot method*, in which the liner tube for a specific insertion procedure is prewetted with resin at a remote facility, transported to the project site in a refrigerated truck, and then immediately inserted into the force main. The length of a single-liner insertion shot can be limited by the allowable weight of the wetted liner tube that can be carried on the highway.
- *Over the hole method*, in which the dry liner tube is brought to the project site, wetted with resin at the insertion pit location, and then inserted into the force main. The weight restriction for transporting the dry liner without resin is eliminated, potentially allowing longer shots; however, more space at the worksite is required for the additional wetting facilities.

Phase 1 Lining Construction

Phase 1 Contract Overview

Approximately 5,700 ft of 48-in. pipe were lined under the Phase 1 contract, beginning at the eastern end of the Contract 2 ECP pipeline and extending westward to the edge of the right of way of a heavily traveled state road, called Military Trail. The work began in the parking lot of a residential condominium development, passed through the country club and golf course, and paralleled a canal managed by a local improvement district.

Flow Bypassing

Flow bypassing was accomplished using the upstream driving pressure contributed by the multiple lift stations that discharge into the 48-in. force main (rather than using temporary bypass pumps). Specifications for the no-pumping flow bypass sys-

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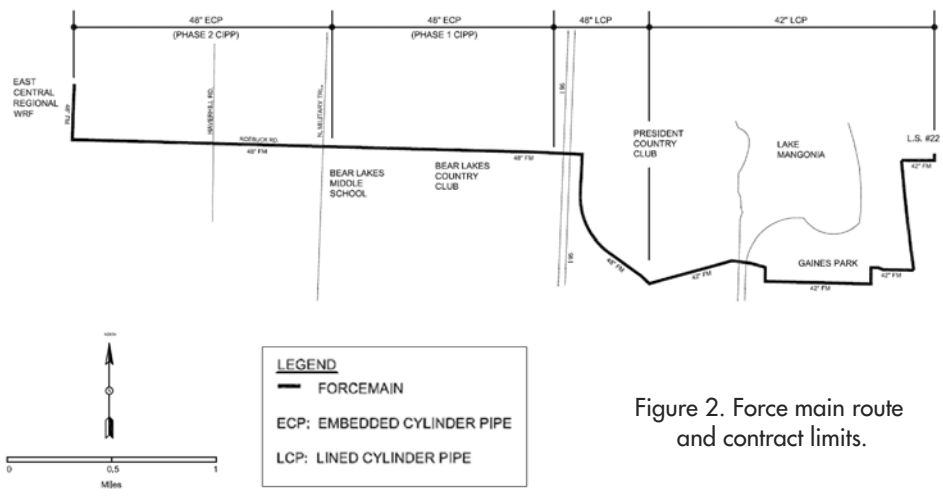

Figure 2. Force main route and contract limits.

Extensive coordination with the Bear Lakes Country Club minimized disruptions to the golf course during lining operations.

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tem included requirements to deliver a peak flow of up to 30 mgd at a maximum allowable pressure drop of 12 psi, with a redundant bypass pipe installed to provide the specified hydraulic capacity and with one bypass pipe out of service.

The contractor elected to use multiple 24-in. high-density polyethylene (HDPE) pipes for the bypass system. To meet the hydraulic requirements, a total of four bypass pipes were installed (three service, one standby). The redundant line was used occasionally when flow in one of the three in-service lines needed to be transferred due to maintenance issues. The city's directive to require firm capacity for the bypass system proved to be a wise choice.

Because the bypass lines needed to be parallel to the force main alignment across from the golf course, the contractor created an access "road" by placing a series of high-strength plastic mats on the grass on which the bypass pipes were placed and construction vehicles drove. Although the turf grass of the golf course was damaged due to the extended period of work, the underlying soil was undisturbed. At the completion of the work, the mats were removed and the golf course used an allowance in the contract to replace the damaged grass within the limited area of the placed mats.

Lining Installation

Although the engineer's concept for the Phase 1 work was based on the use of the over the hole method, due to the relatively open terrain available to set up equipment, the contractor elected to use the truck shot method. This required one additional insertion pit to be constructed due to the shorter allowable length per shot that could be achieved, but the benefits of this method for the Phase 1 contractor outweighed the cost of the additional excavation and insertion procedure. Shot lengths were approximately 900 to 1,000 ft in length.

Regardless of the lining installation method selected, insertion of 48-in. linestops at each end of the project was required to divert flow into the bypass system, while the force main was emptied, cleaned, and lined. The city elected to take advantage of this project to install permanent isolation valves at each linestop to provide a way to stop flow in the event of a future leak in the force main. A typical lining insertion/termination pit detail with a linestop is shown in Figure 3.

Contingency planning and rapid response to unexpected events is required in any project, and the Phase 1 work was no exception. As the first liner tube, wetted with resin at the factory in Alabama, was en route to the town in a refrigerated truck, the resin began to activate unexpectedly before reaching the project site. Once the resin activated, there was no way to reverse the process and prevent the resin from hardening before insertion into the pipe. The truck returned to the factory, the liner tube was discarded, and a fresh tube was loaded with resin and transported successfully to the project for insertion. No further instances of premature resin setting occurred during the project.

Project Cost and Schedule

The total construction cost for the Phase 1 work was approximately $7.1 million for the CIPP lining, flow bypassing, air release valve (ARV) replacement, feeder main reconnections, and 48-in. gate valves.

The original Phase 1 construction contract period was approximately six and a half months, from May through November 2016, but the final completion date was extended two months by a change order. Substantial liquidated damages were established for failure to meet the milestones for completing the work within the golf course, reflecting the potential economic impact on the golf course that would result if construction work hampered play as the busy winter golf season got underway.

The first three months of the contract pe-

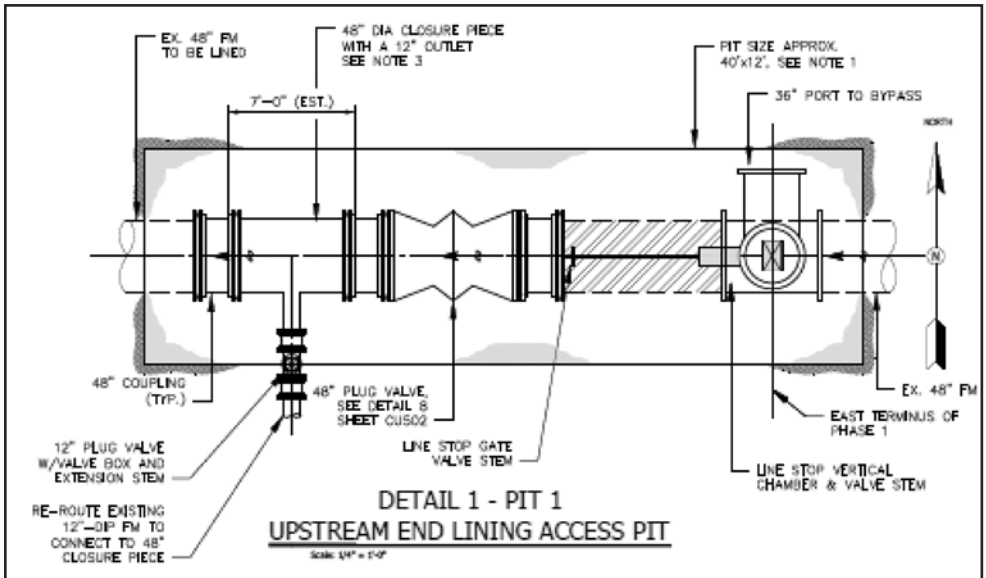

Figure 3. Typical lining insertion pit detail.

Bypass piping and liner insertion pits were located to limit impacts on the property.

The wetted liner tube was positioned vertically over the insertion pit (left) and inverted into the open end of the force main (right).

riod were dedicated to site mobilization and installation of the flow bypass system. Lining activities required another two and a half months from initiation of flow bypassing to return of flow to the force main, and the remainder of the contract period was used for site restoration and cleanup. The critical requirement for completing all work and removal of construction equipment from the golf course prior to the busy winter season was achieved, and no liquidated damages were assessed.

Phase 2 Lining Construction

Phase 2 Contract Overview

Scheduled for completion by fall 2017, approximately 6,500 ft of pipe will be lined, from Military Trail to the entrance to the facility. Nearly the entire length of this portion of the force main to be lined in Phase 2 is directly under the paved roadway of a heavily traveled Palm Beach County road, called Roebuck Road.

A significant portion of Roebuck Road is scheduled to be improved, widened, and repaved by Palm Beach County beginning in early 2018. The city needed to complete the Phase 2 CIPP lining work prior to the beginning of the county's roadway improvement construction to avoid conflicting work activities between the two contracts and to allow final paving of the roadway to be completed after the lining insertion pits were backfilled. The city and county, and their consultants, collaborated extensively during the parallel design efforts to share utility location information, geotechnical data, and traffic planning.

Flow Bypassing

Flow bypassing during bypass operations was specified to be accomplished for the full length of the Phase 2 lining contract limits, requiring linestops only at each end that could be placed in pits outside the paved roadway and active traffic area. The flow bypassing system for Phase 2 required in-line pumping to overcome the pressure drop in the bypass pipes running the 6,500-ft distance between linestops at a peak flow of 30 mgd. Because bypass pumping was specified for Phase 2, the hydraulic constraints to limit pressure drop in the bypass piping required for Phase 1 were not applicable. The contractor was allowed to select and size the pumps and piping to satisfy the flow requirement of 30 mgd with one redundant bypass pipe.

The contractor's engineered bypass system consisted of three 10,500-gal-per minute (gpm) diesel engine pumps, with sound-attenuating enclosures (two service, one standby) and three 24-in. HDPE pipes (two service, one standby). The bypass lines were placed on public road rights of way or on private property, with permission granted by a homeowner's association.

Bypass pumping through three 24-in. HDPE pipes was required to deliver 30 mgd to the treatment plant during lining operations.

Bypassed flows were discharged directly into the headworks structure.

The bypass pipes were routed to discharge directly into the headworks structure at the facility.

A critical work element for completing the bypass system involved road undercrossings for the 24-in. HDPE pipes. The bid documents gave the bidders the option of open-cut or horizontally drilled crossings. The Phase 2 contractor elected to use a relatively new technology referred to as "close tolerance horizontal directional drilling" (CTHDD) to install the bypass piping under two roads where open-cut crossings would be difficult. The CTHDD approach allows a shallower placement of the lines than traditional horizontal directional drilling.

Lining Installation

The lining sequence plan and proposed access excavation pit locations presented in the bid documents were based on using a combination of over the hole lining insertions and truck shot insertions within the paved roadway to limit lane closures and maintain two-way traffic at all times. As with Phase 1, bidding contractors were given the flexibility to select their most cost-effective lining approach, within the constraints of traffic maintenance and overall specification requirements.

The winning contractor based the bid on using the over the hole method for the entire project. The work area layout at each insertion pit and the associated maintenance of traffic (MOT) plan are based on the extended length of facilities and equipment required for this method. The equipment set-up area for each insertion pit is approximately 200 ft long by 24 ft wide, extending along the length of the force main.

Project Cost and Schedule

The Phase 2 contract amount was approximately $7.1 million, with a total contract period of seven and a half months. Due to challenges in obtaining permits, the contract period was extended by five and a half months for final completion in December 2017 in advance of the beginning of the county's roadway project.

Lessons Learned

The design, permitting, and construction of this project highlighted several key lessons:

- The use of so-called "trenchless" technologies for pipeline installation or repair does not mean "impactless." Through the course of design and construction, extensive efforts were made by the city, the engineer, and the contractors to be proactive and open about the work. During construction, one-on-one attention to residents, school officials, and business owners was key to resolving issues as they arose, resulting in a positive and lasting impression on the public.
- Once all systems and preparations were in place, the actual force main lining process was relatively straight-forward. The major project challenges were associated with permitting and installation of the bypass system, as well as developing and implementing the MOT plan.
- Precautions against movement of HDPE pipes should be taken. Extended storage periods of stacked HDPE pipes resulted in shifting of the pipes, causing some pipe segments to fall (with no damage or injury, in this case). Even when fused and placed in service on the ground, thermal expansion caused one of the pipes to flex sufficiently that it slipped down the bank of a canal.
- The CTHDD is a developing technology for trenchless pipe installation that merits consideration when compared with traditional horizontal directional drilling.

References

- "Condition Assessment of PCCP: 42- and 48-inch-Diameter PCCP Force Main, Lift Station 22 to the East Central Water Reclamation Facility." Prepared for the City of West Palm Beach by Pure Technologies U.S. Inc., Sept. 21, 2015.