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HDD Helps Repair Decades-Old Water Main Leak in Fragile Coastal Environment

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ABSTRACT

In the 1990s the water main that connects Siesta Key, Florida to Casey Key began failing in a sensitive wetland between these two barrier islands. The 8-inch cast iron water main was built in the 1970s and was situated almost entirely within an environmentally sensitive bay and marine preserve, making the main inaccessible for repair. To minimize water loss, Sarasota County partially closed valves at both ends of the crossing, but that reduced available pressure and was not a long-term solution. Replacing the main was very important to restore water quality, water pressure and fire-flow reliability on both keys, which were lengthy dead-ends without this 'interconnecting' pipeline between them.

The County considered several repair alternatives, but most had unacceptable environmental ramifications, high construction costs and/or were not acceptable to the adjoining public. In 2012, after years of pursuit, the County obtained the last of the needed land rights and permits to proceed with a horizontal directional drill (HDD) solution that replaced the leaking watermain and minimized impacts on native habitats and species, reduced environmental mitigation requirements, and lessened the effects of construction to the public.

The sub-aqueous crossing was successfully completed using 2,765 feet of 10-inch diameter HDPE pipe installed by HDD. Extensive planning and careful execution were needed to overcome the project's many risks, which included limited access, limited staging, potential for hydro-fracture, species impacts or property damage. Other challenges included avoiding an existing seawall, limiting impacts to the public and obtaining easements from the adjacent property owners.

1. INTRODUCTION

From the perspective of Sarasota County (Owner), they had a progressively degenerating watermain installed across a very inaccessible and sensitive marine environment. To further complicate matters, easements and permits would be required and staging on both ends would be extremely constrained. The County needed to find a cost-effective replacement technology and avoid unnecessary impacts and risks. Horizontal Directional Drill was the chosen technology after consideration of multiple alternatives, but it would require meticulous planning and execution.

2. EVALUATION OF ALIGNMENTS

Alternative Alignment 1

Three alternative alignments were considered to replace the existing 8-inch water main as shown on Figure 1. Alternative alignment 1 considered replacing the water main along its current alignment by pipe bursting. Pipe bursting was considered by a previous study as part of several earlier efforts by the County to replace the leaking

water main[1]. The original alignment was routed approximately 6,000 feet through environmentally sensitive habitat in the Jim Neville Marine Preserve and was located within Little Sarasota Bay for most of its length. Today, an alignment like this would not be permitable if there were other viable alternatives such as HDD. The previous study concluded that pipe bursting would require intermediate staging points at the bends in the existing alignment, and that a barge would be necessary to access the bends with construction equipment[1]. Dewatering would also be necessary at the bends; barging, excavation, and dewatering could all potentially damage the seagrass and mangroves in the area thus triggering a substantial permitting requirement.

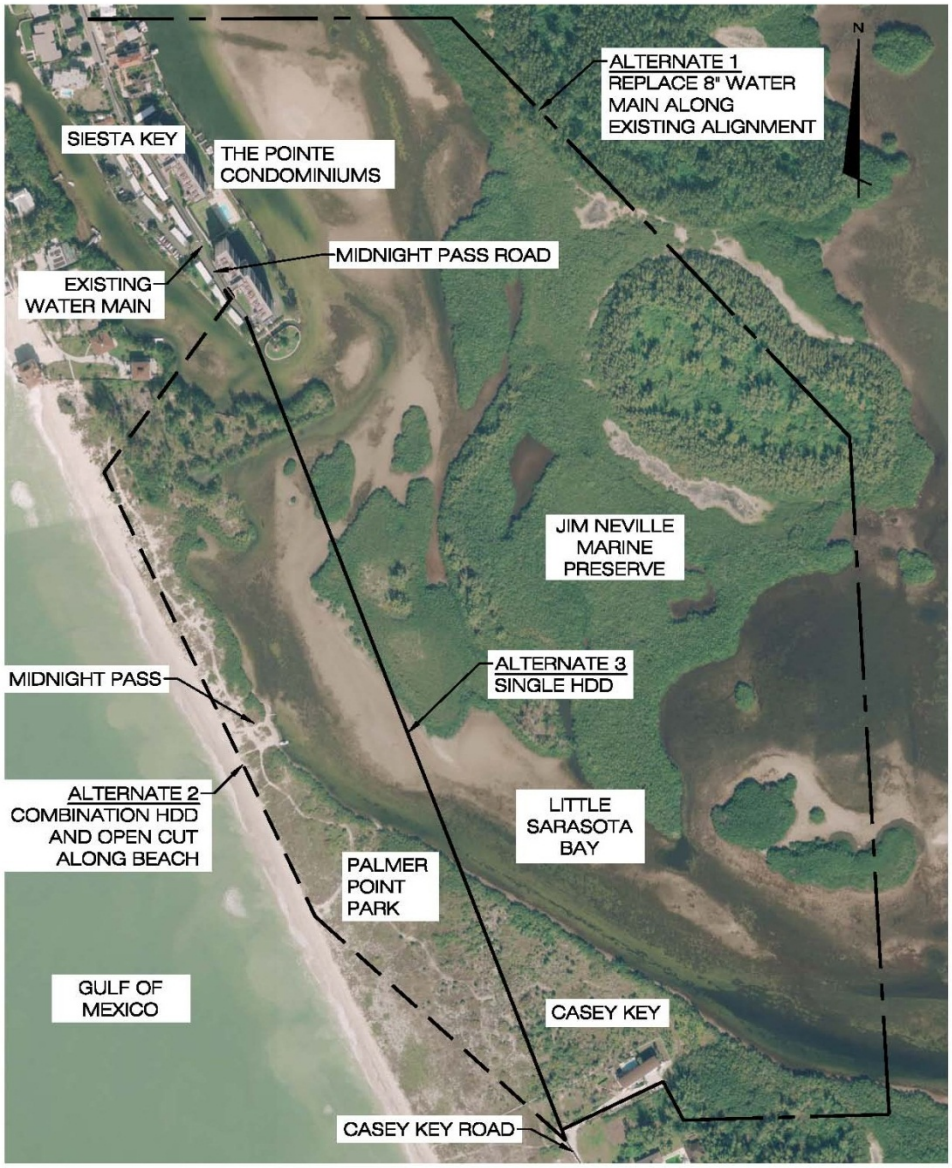

Figure 1. Alternative alignments.[2]

Alternative Alignment 1 was determined to be unfeasible given the potential environmental impacts and permitting requirements. Even if the pipe were able to be replaced along its existing alignment, the new infrastructure would retain all the negative attributes that made the old alignment difficult to maintain and repair.

Alternative Alignment 2

Alternative alignment 2 took the approach of using the beach connectivity between Siesta Key and Casey Key to replace the water main since the nearby beach provides a continuous land route between the two keys. The HDD alignment would start at The Pointe Condominiums located on the southern tip of Siesta Key. The alignment would cross Little Sarasota Bay via an approximately 700-foot HDD to the beach dunes to the southwest. The remaining pipe would be installed along the beach dunes and would consist of a series of open-cut and HDD pipe segments. The overall length of this alternative alignment was approximately 3,300 feet. Midnight Pass, a former pass between Little Sarasota Bay and the Gulf of Mexico, is currently closed by the continuous beach between Siesta Key and Casey Key. Historically, the pass had four different openings along this stretch of beach, dating back to 1949[1]. The pass could potentially reopen again by natural or manmade forces. A concern of this alternative was that the pass may re-open thus exposing the newly installed pipeline.

This alignment could potentially be designed, permitted and constructed, but the uncertainty of the future Midnight Pass opening location with respect to the HDD end points limited its viability by creating the risk of the pass exposing the HDD pipe segments. Additional disadvantages of this alignment were limited construction site access for equipment, environmental impacts, potential habitat impacts, sea turtle construction moratorium, restoration requirements, and water availability.

Alternative Alignment 3

The third alternative alignment sought to minimize environmental impacts by installing approximately 2,700 feet of pipe in a single HDD from the southern terminus of Siesta Key, at the Pointe Condominiums to the cul-de-sac on Casey Key Road. The HDD pipeline would be installed with sufficient depth to avoid damage from potential dredging on Little Sarasota Bay, anchor drag by boat traffic, erosion caused by storm events, and a natural or manmade opening of Midnight Pass. This alternative was determined to be less expensive than either alternatives 1 or 2 because of its more direct route and fewer complications. A majority of the complexities anticipated with the other alternatives, such as construction access, environmental effects, habitat effects, sea turtle construction moratorium, restoration requirements, and water availability, were either reduced or eliminated with this alternative. The environmental effects associated with this alignment were generally limited to a hydro-fracture, which could damage environmentally sensitive areas and native habitat and trigger permit compliance action. Another complication was finding sufficient space for the larger drill rig and support equipment that would be needed for an HDD of this length. On the Casey Key side, the longer HDD would require more room for pipe staging and layout.

Alternative alignment 3 was selected, based on its ability to mitigate the multiple issues associated with alternatives 1 and 2. Permitting by the Florida Department of Environmental Protection (FDEP) regarding this alignment was a critical milestone which allowed the development of construction plans and specifications to proceed. Minimizing impacts of noise, dust, and limited vehicle access to the residents on both Casey Key and Siesta Key would be important to the success of this alignment.

3. PERMITTING

This project had extensive permitting requirements, reflective of the unique and outstanding nature of the area. The northern approach and staging area was contained in uplands within the private property of a densely developed high-rise condominium. An FDEP permit was required for upland activities that may impact wetlands. The crossing itself was under sovereign submerged lands and required a Nationwide Permit from the Army Corps of Engineers. The crossing also required a separate FDEP permit for possible impacts to wetland habitats and a Board of Sarasota County Commissioners land-use variance for crossing the County's Palmer Point Park situated within the route. The southern staging area was seaward of the State Coastal Construction Control Line and the County Gulf Beach Setback Line. These regulatory lines were established to limit losses in the event of catastrophic coastal damage, as is typical from large storms or hurricanes near the gulf coast. To obtain the needed permits, construction impacts would have to be limited to previously built areas and construction activities would have to be kept out of the dune zone and other protected habitats. Had an uncontrolled hydro-fracture or other abnormal event occurred which damaged wetland or beach vegetation, a written clearance to re-commence work would be required from the Army

Corps of Engineer's District Engineer and FDEP. It was believed that such a letter would be difficult to obtain, so great pains were taken to ensure contingencies were planned for, that permit compliance was required by the Contract Documents and due care was taken during construction. If an abnormal event had triggered a shut-down, it was believed it would be very important to be able to demonstrate that every reasonable measure had been taken to ensure permit compliance.

4. EASEMENTS

The proposed pipeline alignment required easements on both Siesta Key and Casey Key. On the Siesta Key end, the alignment took the pipeline through the entrance drive and main corridor of a private condominium. A permanent utility easement was needed from the Condo association for a length of approximately 1,000-LF. Additionally, a temporary construction easement was needed for placement of the HDD maxi-rig, sand separator, drilling products and tools.

On the Casey Key end, access was provided via a narrow and winding partially private maintained road. The properties along this private beach-front road were among the most exclusive in Sarasota County. Fortunately, watermain easements were recorded over 40 years ago. However, residents were very concerned the project may subject them to additional impacts and disruptions. Access along the road, as contained in the easements, was limited and residents were insistent the limited rights be strictly adhered to. There were landscape features and mature vegetation within inches of the road, these features limited the size of trucks and trailers during construction. Creative and effective efforts were taken to avoid damages to these private interests on private property. One example is the 40-ft long drill rods, to be used as trailing rods during the ream, had to be 'pushed' through the bore-hole from the Siesta Key side to the Casey Key side because a tractor-trailer capable of transporting the rods could not be brought down Casey Key road.

Finally, a single permanent easement was required and obtained near the pipe entry pit on the Casey Key side.

5. ENVIRONMENTAL CONSIDERATIONS

The existence of a large, open water body along the proposed alignment was the initial impetus to consider HDD, but that was only the most obvious 'environmental' concern. Upon further investigation and after meetings with personnel in responsible charge of the County Park, Marine Preserve and beach habitat, additional environmental concerns were identified. The HDD alignment crossed multiple distinct and protected eco-systems – seagrass habitat, mangrove habitat and dune vegetation, to name a few. Protected and endangered wildlife were also in the area. This included the endangered Florida manatee, endangered sea-turtles, endangered gopher tortoise and endangered shore birds.

The net effect of these environmental concerns was the project was rife with risk. Any abnormal event or inadvertent damage to these protected habitats or species could severely jeopardize successful completion of the project. Damage to the protected habitats or species could bring an extended regulatory shut-down. While there was no way to positively guarantee abnormal events would be avoided, it was firmly believed the only way to limit their impact was by being able to demonstrate the project team was proactive in identifying risks and had taken all reasonable measures to avoid them. Similar jobs were studied to identify needed footprints for staging and pipe lay-down and to ensure they could be accommodated without impacting the protected areas. Silt fencing was installed to exclude species from the construction zone. Equipment was monitored and spotters were onsite to look for species impacts and indications of losses of drilling fluid or other abnormal events. Lastly, the bid documents were written to require the Contractor to have on file contingency plans for the following possible abnormal events, with the express consent the plan would be followed if one of the events occurred:

- Hydro-fracture of drilling fluids (frac-out)
- Loss of return or circulation of drilling fluids
- Borehole obstructions
- Loss of drill pipe or product
- Product collapse

These efforts were successful as no regulatory excursions or shut-downs occurred. No protected species were harmed during execution of the contract; also, the habitat impact from the two hydro-fractures that occurred resulted in negligible damage. Because of the existence of contingency plans and the emphasis on the importance of regulatory compliance, the appropriate materials were onsite when the two hydro-fractures occurred and everyone from inspectors, equipment operators and site foreman had a very clear idea about how to respond.

6. GEOTECHNICAL CONSIDERATIONS

A geotechnical investigation was performed to examine the subsurface soil conditions for design of the HDD and for reference by the Contractor. Boring data was obtained from another study in the area[1]. Three new borings were obtained as part of this project[3]. The soil was generally characterized as very loose to dense, slightly-silty sand within the first 35 feet of depth, and very loose to very dense silty-sand down to 50 feet deep.

Based on the prevalence of loose soils at shallower depths, the target depth of the HDD was 35 feet. Denser soils with N-Values of 28 or more were targeted to lower the potential of a hydro-fracture. Because of the denser soil, the Contractor was able to operate at a greater mud pressure than would be possible in loose soils.

7. HORIZONTAL DIRECTIONAL DRILL DESIGN

Figure 2 shows the design horizontal and vertical alignment for the HDD. The horizontal alignment was designed to provide the shortest length of pipe to connect the Siesta Key and Casey Key water mains. The entry point was located at the south end of The Pointe Condominiums with the exit point of the HDD at the Casey Key Road cul-de-sac.

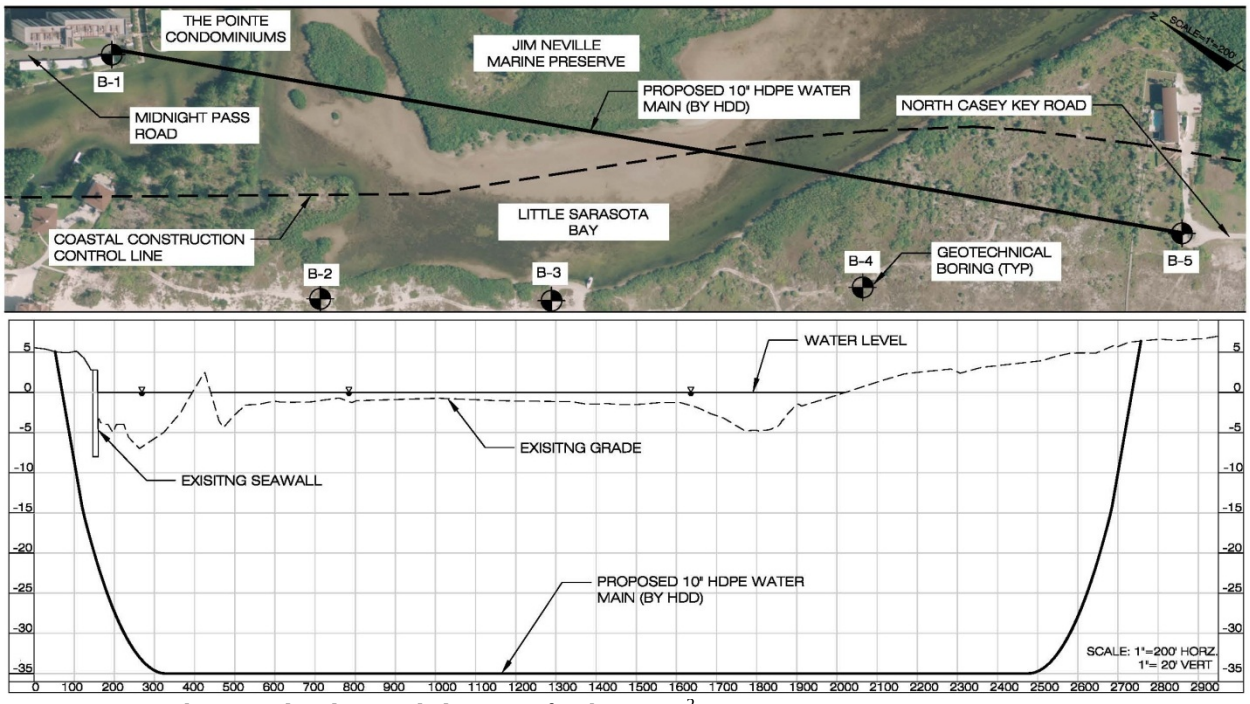

Figure 2. Design horizontal and vertical alignment for the HDD.[2]

The entry angle of the drill and the drill rig setback distance were designed to avoid disturbing the sea wall located at The Pointe Condominiums. The sea wall depth was field verified to be approximately 6 feet below the bay bottom. Based on the limited horizontal distance between the seawall and the south condominium building, as well as the available staging area for the drill rig, an entry angle of 16.5 degrees was specified to provide a minimum clearance of 9 feet between the seawall and the top of the pipe. The maximum depth of 40 feet was based on the geotechnical considerations previously discussed and the desire to avoid exposure from possible shifting sands near the old Midnight Pass. The design alignment characteristics are summarized in Table 1.

Table 1. Alignment Characteristics – Design

Parameter	Value
Pipe Diameter	10-inch
Pipe Material	HDPE
Entry Angle	16.5 degrees
Bend Radius (1st Vertical Curve)	1,000 feet
Maximum depth	40 feet
Length of Straight Section	2,103 feet
Bend Radius (2nd Vertical Curve)	1,200 feet
Exit Angle	13.5 degrees
Total Pipe Length	2,702 feet

The selected pipe material was 10-inch HDPE DR 9, PE4710 pipe. HDPE pipe was selected for this application due to its flexibility, abrasion resistance, and the strength of its fused joint, as well as its capacity to withstand forces during pullback. To reduce the buoyant forces acting on the pipe, and to keep the pullback forces below the allowable pipe stress of 1,100 psi, the pipe was required to be filled with water as it entered the bore hole[4].

8. CONSTRUCTION

Construction commenced in July 2012. To accurately monitor the position of the drill string, the Contractor (Arrow Directional Boring, Inc. of Coral Springs, FL) utilized a gyroscopic steering tool called DrillGuide GST from SlimDril International. The Contractor selected this tool to provide continuous drill-tool tracking which avoids the risk of magnetic interference when drilling in a marine environment and to realize time savings by not having to install a wireline tracking system.

During preparation of the Contractor's bore plan, the Contractor opted to increase the vertical separation of the pipe below the seawall on the north end of the project by increasing the entry angle to 17 degrees and not starting the vertical curve until the drill was beyond the seawall. Since the Contractor was concerned with damaging the seawall, starting the vertical curve after the drill cleared the seawall reduced the upward force on the top of the bore hole during pullback in the area of the seawall. The entry and exit bend radii were also increased to 1,500 feet and 2,000 feet, respectively, to allow more flexibility when making the vertical bends. The result of these modifications was a deeper bore, from the projected 40 feet down to 80 feet. Since the modified profile extended below the 50-ft deep geotechnical borings, the Contractor had to mitigate the risks of drilling in unknown geological conditions. The risks were mitigated in two ways. First, the increase in bend radii allowed the Contractor more leeway when making the vertical bends in unknown geologic conditions. Second, a mud motor was used to construct the 9 5/8-inch pilot hole, since it was unknown if the Contractor would encounter limestone, or other variables, at the increased depth. The as-built alignment characteristics are summarized in Table 2.

Table 2. Alignment Characteristics – As-Built

Parameter	Value
Pipe Diameter	10-inch
Pipe Material	HDPE
Entry Angle	17 degrees
Bend Radius (1st Vertical Curve)	1,500 feet
Maximum depth	80 feet
Length of Straight Section	1,638 feet
Bend Radius (2nd Vertical Curve)	2,000 feet
Exit Angle	13.5 feet
Total Pipe Length	2,765 feet

The Contractor utilized an American Augers DD210 drill rig with a maximum pullback force of 210,000 lbs. This drill rig provided sufficient pullback force given the expected and actual maximum pullback force was about 33,000 lbs. Also onsite were a Tulsa Rig Iron MCS-500 portable bentonite system and other support equipment. The

Contractor carefully monitored pullback forces to ensure the pipe did not exceed its allowable stress, which could cause the pipe to creep or potentially yield. Figure 3 shows the construction site and drill rig location facing south toward the exit location.

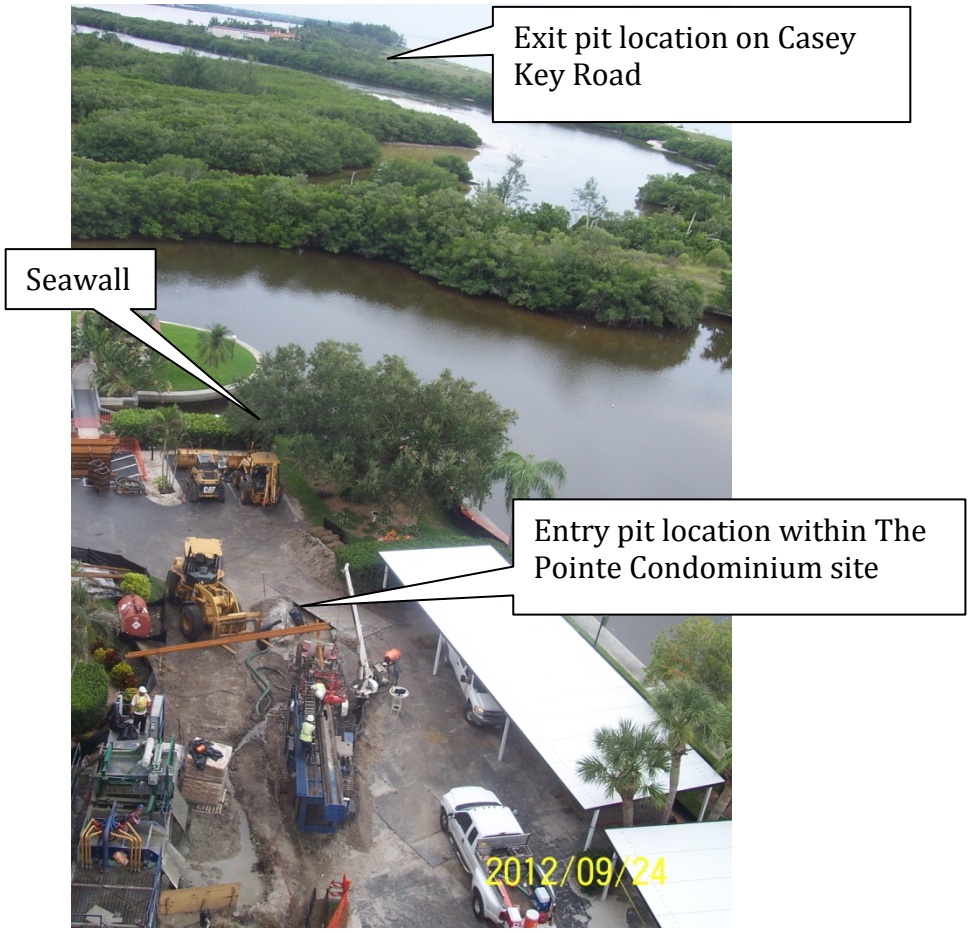

Figure 3. Construction site at the Point Condominiums on Siesta Key looking south to Casey Key.

The pilot hole was enlarged to approximately 16 inches in diameter by pre-reaming the hole with a 16-inch reamer in a single pass. The soils encountered during the pilot drill and reaming process remained silty sand with no limestone encountered.

Two hydro-fractures occurred during the HDD process; one during the pilot drill a few feet away from the exit pit and a second within The Pointe Condominiums near the entry pit. The Contractor immediately implemented containment measures as required in the contingency plans. Both hydro-fractures were controlled by excavating the entry and exit pits to intersect the hydro-fracture location. The hydro-fracture near the exit pit flowed into the adjacent upland beach area with no adverse impacts to habitat, as verified by an environmental scientist. No drilling fluid was observed entering the bay during the HDD process.

To minimize the forces during pullback, the HDPE pipe was pulled in two strings of approximately 1,380 feet. The product pipe could not be assembled into a single length because of layout constraints on Casey Key Road. Figure 4 shows a segment of the pipe layout along Casey Key Road. The two strings required an intermediate pipe fuse during pullback. The intermediate pipe fuse required a stop in the pullback process for about 2 hours. The intermediate weld was a critical point in the pipe installation due to the risk of not being able to re-commence the pullback; also, because peak pullback loads were expected immediately after the 2nd half of the product string was attached. The pullback process proceeded without any complications as a result of the intermediate weld. Each string of HDPE pipe was pressure tested to 105 psi at ground surface to check for the presence of leaks prior to pullback. Following installation, the pipe was pressure tested at 150 psi.

Figure 4. Pipe layout along Casey Key Road.

CONCLUSION

The decision to replace the existing 8-inch cast iron water main with 10-inch HDPE by HDD proved to be a successful methodology to restore the functionality of this critical water infrastructure for Sarasota County. Upon conclusion of the project, fire flow availability almost doubled to at least 840 GPM, as tested on both Keys. Early and frequent coordination with regulatory agencies, affected land-owners and other stake-holders as well as obtaining early regulatory buy-in of the proposed methodology and alignment, proved invaluable to obtaining the necessary permissions. By boring under the environmentally sensitive areas, the project team was able to reduce the construction time, cost, and potential adverse impacts to the environment. Advancement in HDD technology, such as the gyroscopic steering tool used for this project, along with careful planning and execution, provided Sarasota County Utilities with a successful solution to this long-time operational challenge.

REFERENCES

1. Dufresne-Henry, Inc. (2003) – Design Report for Water Main Replacement Between Siesta Key and Casey Key, Sarasota County, Florida

2. Sarasota County (2011) – Aerial Orthophotos

3. Allied Engineering & Testing, Inc. (2010) – Geotechnical Engineering Services Report

4. The Plastics Pipe Institute, Inc. – Handbook of PE Pipe, Second Edition