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Frisco Extends Reuse and Sanitary Sewer Systems Along Busy Commercial Corridor using Horizontal Directional Drilling

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1. ABSTRACT

The City of Frisco, located just north of Dallas, Texas, has experienced a drastic population increase over the past 15 years. The rapid population growth coupled with recent drought conditions and limited overall water resource options posed an increased focus on water conservation efforts. This conservation effort, combined with an overall need for additional infrastructure to support a growing population, has resulted in two projects with major trenchless components to lessen the impact of construction on a fully developed commercial area along on of the City's major thoroughfares.

The first project was for a new reuse pipeline to convey treated wastewater from Stewart Creek West Wastewater Treatment Plant (SCWWWTP). The design included a total of 10,000 feet of 12-inch reuse pipeline and a booster pump station. While most of the pipeline was installed by open trenching within the roadway median, one section of the alignment employed horizontal directional drilling (HDD) methods to bore 2,500 feet of the reuse pipeline under a busy intersection that could not be open cut. Based on the reuse project's success, the City decided to install approximately 4,000 feet of 18-inch and 10,000 feet of 20-inch sanitary sewer force main along a similar alignment to convey raw sewage to the SCWWWTP. The second project required installation of a 2,680-foot portion of the 20-inch force main via HDD. This paper will discuss the benefit that HDD provided and the challenges faced in drilling a compound curvilinear alignment with the encounter of hard rock formations.

2. INTRODUCTION AND PROJECT BACKGROUND

The City of Frisco (City) is located in Collin and Denton counties in Texas, just north of Dallas. It is a part of the growing Dallas-Fort Worth Metroplex. The City is only 25 miles away from Dallas Love Field and Dallas/Fort Worth International Airport. Its strategic location contributes to the City's success as one of the fastest-growing cities in the nation. The rise of significant corporate headquarters and entertainment opportunities, including the Dallas Cowboys, Toyota Soccer Center, Toyota Stadium, and Memorial Stadium attract new residents; thus, continuously increasing the population. Frisco serves as a housing community for many professionals who work in the metroplex. The spark of explosive growth occurred when the northern Dallas-Fort Worth Metroplex suburban development tide reached the northern border of Plano and spilled into Frisco in the 1990s. This marked the beginning of Frisco's tremendous growth into the 2000s. Figure 1 summarizes the City's population growth since 1990.

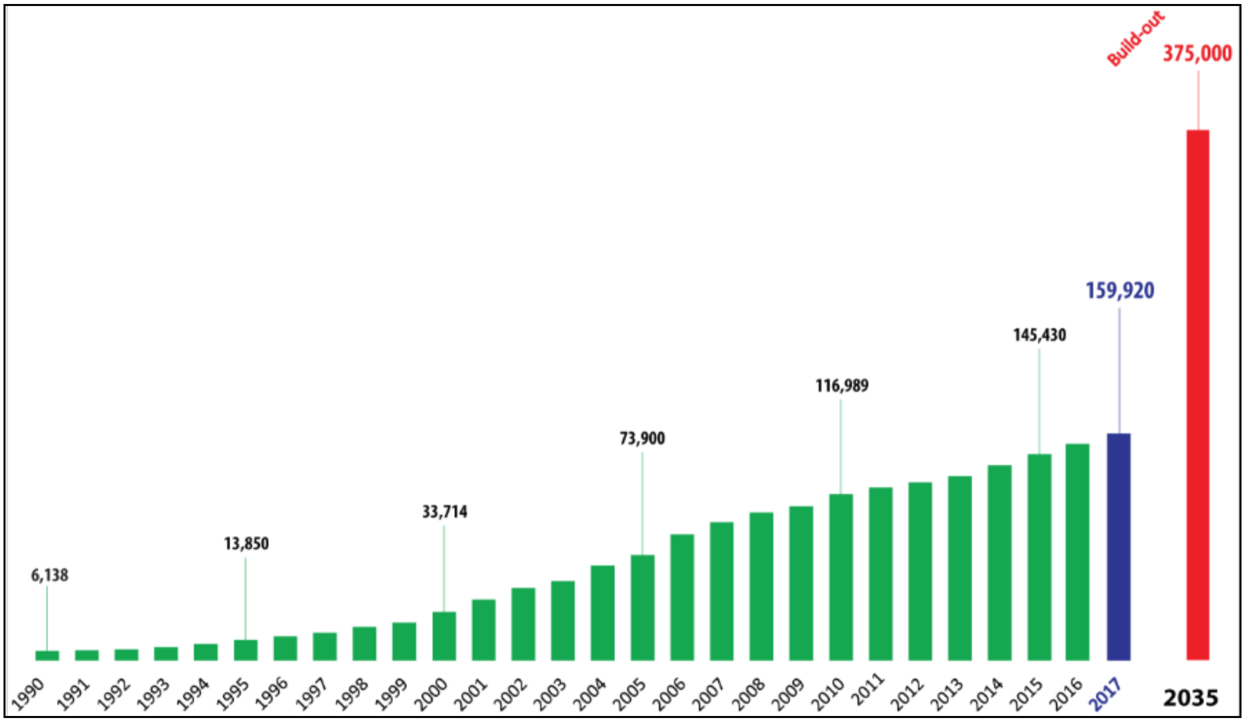

Figure 1. Demographic data from City's website.

With the rapid population growth and previous drought conditions, water conservation efforts became the City's main focus. The City was an early adopter of water conservation through the use of treated effluent water for non-potable uses. In an effort to conserve water resources in high growth areas, the City extended their existing reuse system to utilize treated wastewater for irrigation. The City purchases its treated water from the North Texas Municipal Water District (NTMWD), a regional wholesaler provider. The steep cost of a new water supply and the ever-growing water demand drove Frisco to consider diversifying its water supply portfolio. This was achieved by developing a direct non-potable reclaimed water system for irrigation purposes. The effort came to fruition when the City obtained authorization from the Texas Commission of Environmental Quality to sell and distribute Type 1 reclaimed water in 2002. The early reclaimed water system distributed reclaimed non-potable water to meet the irrigation needs of primarily parks, golf courses, and the Frisco Independent School District. However, the City still felt that the existing reuse system was underdone and looked to add more extensions to the system.

Frisco's reclaimed water system is powered by the Stewart Creek West Wastewater Treatment Plant (SCWWWTP) and the Panther Creek Wastewater Treatment Plant (PCWWTP). Each facility has a reclaimed water pump station that conveys Type 1 reclaimed water into the reclaimed water distribution system, which previously consisted of approximately 70,000 feet of 12-inch to 24-inch pipelines.

The existing system does not include elevated storage. The pressure is maintained through the operation of two pump stations. When the system pressure exceeds the pressure valves' settings, water discharges into either pump station's wet well. The City utilized hydraulic models to develop a weekly irrigation schedule for each reclaimed water customer. The model compared the reclaimed water demands against the available supply from the two treatment plants to make sure that demands were met and sufficient pressure was maintained in the system. Reuse supplies from the SCWWWTP and PCWWTP declined significantly overnight when most landscape irrigation occurred.

With the addition of high-end developments in late 2014, the City was looking to extend their system to serve these new areas. The four new developments were dubbed "The 5-Billion Dollar Mile" and included Wade Park, The Gate, Frisco Station, and The Star. The developments sought to transform 539 acres of land in Frisco and required different levels of irrigation. The Star, which is the new home of Dallas Cowboys headquarters, was the first to break ground. The City retained Freese and Nichols (Engineer) as the consulting engineer for this project. The Engineer met each of the developers to determine the weekly reclaimed water volume required to meet their irrigation needs. The irrigation needs of these developments were projected to increase the average reclaimed water demand to 2.5 million gallons per day (MGD), a 19% jump, and increase the peak reclaimed water demand to 4.3 MGD, a 26% jump. This new improvement design included a total of 10,000 feet of 12-inch reuse pipelines and a booster pump station to raise the overall pressure in the system. Once completed, the new pipeline would convey reclaimed water from SCWWWTP to The Star.

Bringing reclaimed water to the future developments was only one part of the utility service equation. As the growth in the area continues, the need to convey raw wastewater back to the treatment plant would exceed the capacity of the existing infrastructure. As a result, the second project required was the installation of a sanitary sewer force main. The installation of the reuse pipeline was such a success that the City and Engineer decided to employ a similar alignment and installation techniques to install the new sanitary sewer force main. This included 4,000 feet of 18-inch and 10,000 feet of 20-inch sanitary sewer force main to convey raw sewage to the SCWWWTP. The majority of this project was installed via open cut and HDD methodologies.

3. DESIGN REVIEW

The reuse pipeline project design started in November 2014. Time was the main limiting factor for the reuse pipeline project. The developers of The Star required installation of irrigation on the practice fields by Spring 2016 to meet the deadline to install grass for the practice facilities. The short time frame was accomplished by the joint effort between the City, the Engineer, and The Star development. The City acted as the project manager, overseeing fund coordination, the contracting process, and construction. The project was funded by the City of Frisco, with a contribution of 7% of the total project cost by The Star development. The goal was to provide a sustainable infrastructure that could be easily maintained and expanded by the City.

To accommodate the short time frame, the design was broken into three segments. The Engineer utilized the topographic survey data from The Star's engineer for the first 4,800 feet of pipeline. This allowed the reuse design to be completed in 30 days, and enabled the plans to be incorporated into The Star developer's construction plans for installation. The second segment had 1,000 feet of reuse pipeline, which was broken out and included in adjacent roadway improvement projects to better minimize the risk of construction conflicts. The last segment was located within the median of Lebanon Road. The Engineer and the City wanted to keep the disturbance level to the surface minimal. This alignment included a Burlington Northern Santa Fe (BNSF) railroad crossing, several median openings, and a Lebanon Road-Legacy Drive crossing. The Lebanon Road-Legacy Drive crossing was the second busiest intersection in Frisco, with an average traffic volume of 30,000 vehicles per day. The City could not afford to close the intersection for construction. Thus, this alignment incorporated a combination of trenchless methods to alleviate the sensitive surface concerns. For the median openings and BNSF railroad crossing, the Engineer specified dry bore casings. The Lebanon Road-Legacy Drive intersection would be crossed via a 2,500-foot horizontal directional drill (HDD). These methods allowed pipe installations without any lane closures. The Engineer consulted with several local HDD contractors to discuss drilling equipment, pipe layout, preferred alignment, and depth. The design of the reuse line HDD became the basis for the second project's implementation of HDD to install 2,680 feet of 20-inch force main under the same intersection of Lebanon Road and Legacy Drive. The HDD section closely followed the alignment of the installed reuse pipeline.

The Engineer initially considered multiple alignment options for the reuse line connecting the SCWWWTP to the 5-Billion Dollar Mile developments. These alternatives varied in length, cost, schedule, and number of affected properties. Since each option had many similar challenges, all requiring trenchless installation and minimal workspace, the Engineer decided to select the most direct route (Figure 2). The time frame, traffic control, and constructability were the major design considerations. Fortunately, use of HDD in the busiest segment of the alignment minimized most of these challenges. The drilling equipment would be staged within the median, resulting in no lane closures. Furthermore, the contractor would not have to open cut and replace the pavement.

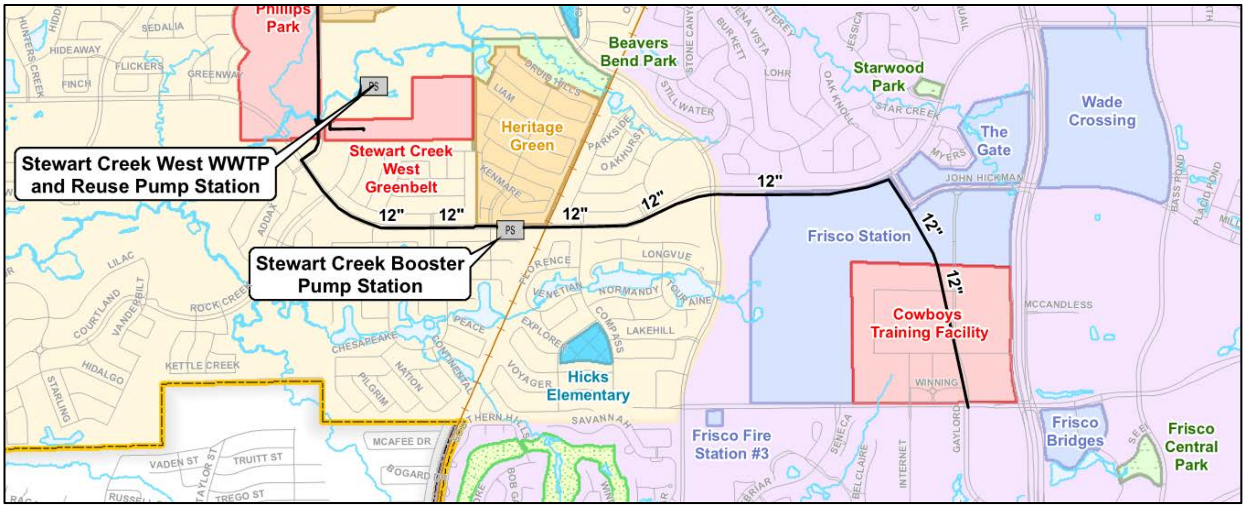

Figure 2. Project vicinity map for reuse pipeline.

Geotechnical reports were obtained to provide necessary subsurface information of the proposed route's soil condition. Three bore holes were made; one at the drill entry point, one at the apex of the drill, and one at the drill exit point. From the investigation, the Engineer learned that the drill path would encounter relatively hard limestone rock formations along the proposed alignment (Table 1 and Figure 3). While rock bores can often be challenging, the drillers actually saw the hard rock formation as an advantage because it would create a more stable borehole, resulting in drill path with a higher safety factor.

Table 1. Generalized subsurface conditions in the area of the proposed alignment.

Nominal Depth, feet bgs		General Description	Detailed Description of Soils/Materials Encountered
Top of Layer	Bottom of Layer		
B-01			
0	20	Fat Clay Lean Clay	Stiff to hard, Fat Clay with Sand (CH) / Lean Clay with Sand (CL) / Fat Clay (CH).
20	30	Weathered Shale	Soft, Weathered Shale.
B-02			
0	1	Fill	Hard, Clayey Sand (SC) / Sandy Lean Clay (CL) Fill.
1	5	Weathered Limestone	Soft to hard, Weathered Limestone.
5	13	Limestone	Very hard, Limestone.
13	45	Shale	Soft, Shale.
B-03			
0	2	Fat Clay	Very stiff, Fat Clay with Sand (CH).
2	7	Weathered Limestone	Hard, Weathered Limestone.
7	30	Limestone	Very hard, Limestone.

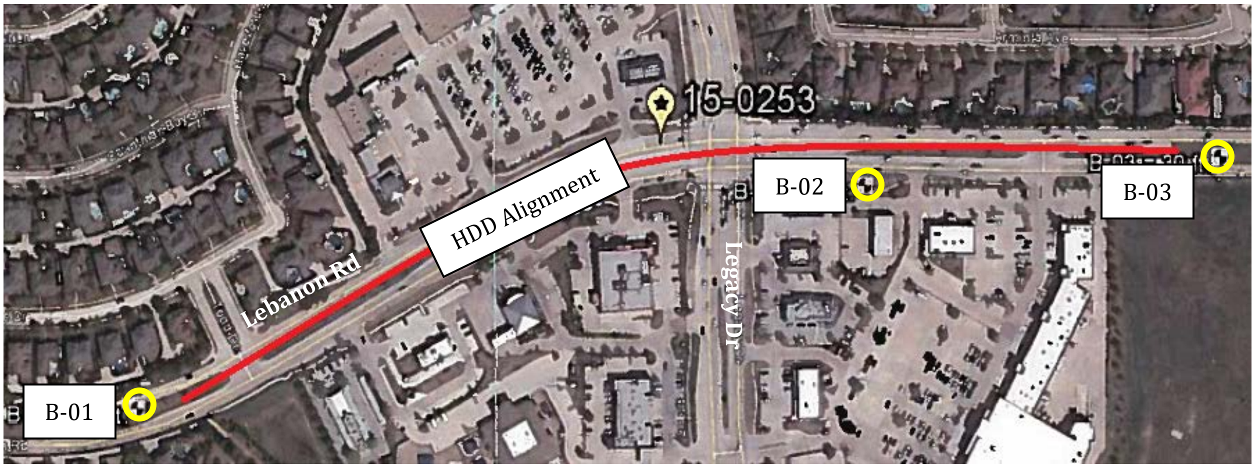

Figure 3. HDD alignment and bore locations.

The Engineer's main concern on the HDD section was the alignment (Figure 3). For both the reuse pipeline and sanitary sewer force main HDDs, the goal was to avoid compounding horizontal and vertical curves. Maintaining slope on horizontal turns was desirable as a compound curvilinear alignment in an HDD puts additional external stresses on the pipe. Additionally, there can be a risk of over-bending the pipe when installed through a compound curve, and the steering required to maintain line and grade is more challenging for the HDD contractor. An alignment without compound curve was achievable during the installation of the reuse pipeline. However, a compound curvilinear alignment was necessary for the sanitary sewer force main due to the alignment of the previously installed reuse pipeline. To avoid disturbing the busy traffic, the work area was limited to only the median. This caused the entry and exit points of the force main drill to be very close to the installed reuse line's. Despite this, the main portion of the proposed force main drill was horizontally separated from the reuse by 20 feet.

The Engineer utilized the City's hydraulic modeling to determine the pipe sizes needed for the reuse line and sanitary sewer force main. The new developments would send raw sewage to and receive reclaimed water from the SCWWWTP. The initial reclaimed water customers of the SCWWWTP are all located within the lower reuse pressure plane, while the new 5-Billion Dollars Mile developments are in the upper reuse pressure plane. The Engineer planned to use a pre-manufactured skid mounted booster pump station to maintain the pressure of the system. The flows within the pipe were projected to range from 15 to 1,580 gallons per minute (gpm). The Engineer chose to place the new booster pump within the median of Lebanon Road near the BNSF railroad. The location had the lowest elevation within the median, allowing for sufficient suction pressure. The selection of 12-inch pipe for the reuse line was based on reclaimed water demand, required flow, losses within the pipe, pumping pressure, and estimated head loss in the system. The required flow and friction losses within the pipe were the more important factors in choosing 20-inch pipe for the force main since the line conveys raw sewage from the lift station to the SCWWWTP. Both the reuse and force main HDD sections required pressure class 235 (DR 18) pipe. The operating pressures of both pipelines are lower than the specified pressure class of the pipe, but DR 18 provided the necessary thickness to ensure the pipes could withstand the external load during installation by HDD.

The project specified fusible polyvinyl chloride pipe (FPVCP) for the HDD section of the reuse line to match the characteristics in the rest of the system, which was made up of PVC pipe. FPVCP is compatible with all PVC piping systems, and it has the additional benefit of a low profile fused joint system. The fused joint system allows the pipes to be fused into a single monolithic length. The low profile fused joint reduces the friction during HDD pipe pull-in making it suitable for long-pull trenchless installations.

Other materials were considered for the HDD sections during the design review, but were ultimately eliminated from the project design. Other restrained joint PVC systems are not suitable for long HDD applications with compound curvilinear alignments. Ductile iron pipe was a feasible option, providing the necessary material strength and compatibility to the existing system; however, ductile iron pipe would require joint restrainers, resulting in larger bore diameter and overall increased project costs. HDPE, another material commonly used in HDD installation, requires specialized adapters to connect to standard fittings. In addition, the HDPE pipe would need to be upsized in order to provide the same inside diameter as the FPVCP option which, in a HDD application, would add to installation cost.

Furthermore, the City does not maintain an inventory of HDPE materials in their system and, therefore, would not have the necessary equipment in the case of a break.

FPVCP was selected for the HDD in the force main system based on the success of the reuse installation in the same area.

The reuse water distribution extension project was advertised in July 2015. Three qualified sealed bids were received on July 28, 2015. Kodiak won the award as the lowest responsible bidder with their bid of $2,550,000. The sanitary sewer force main followed suit two years later, advertising in May 2017. Five sealed bids were received on June 12, 2017. Flow-Line Construction's bid of $6,730,884 won the award as the lowest responsible bidder.

Table 2. Project bid tabulation.

Bidder	Bid Total
Reuse Line	
Kodiak	$ 2,550,000
Quality Excavation	$ 2,893,139
Dickerson	$ 3,244,324
Sanitary Sewer Force Main	
Flow-Line	$ 6,730,884
N. Texas Contracting	$ 7,270,746
SJ Louis	$ 7,856,493
Thalle	$ 7,979,672
John Burns	$ 8,058,943

4. CONSTRUCTION

The initial reuse line construction effort began in September 2015 with site preparation. This included removing street lights and trees, and digging entry and exit pits for the HDD. The project only required minimal traffic control due to the use of trenchless methods. Staging and pipe layout was set up within the median of Lebanon Road. Occasional brief shut-downs on one lane were required for equipment and materials drop-offs.

Kodiak retained Dakota Directional Drilling (Dakota) as their HDD contractor. Dakota mobilized onsite in October of 2015 with a Vermeer 220 x 300 drill rig (Figure 6). That rig was capable of providing a maximum of 240,000 lbs of thrust and 30,000 ft/lbs of torque which was more than enough for the 2,500-foot drill of 12-inch.

Figure 4. FPVCP fusion, individual FPVCP stick being inserted into fusion machine (left); certified fusion technician fusing FPVCP into one continuous length (right).

The contractor began the HDD installation by staging the drilling equipment within the median on the lower elevation side of the drill, on the west side of Lebanon Road's median. This position was chosen to allow for a lesser entry angle for the drill. Furthermore, by drilling from the busier west side of the median, the pipe could be laid out within the median openings of the less developed eastern side of the intersection. This enabled the entire 2,500 feet of FPVCP to be fused (Figure 4) and laid out in one length (Figure 5), allowing for one continuous pull for installation. This is the ideal case scenario for trenchless installation using FPVCP.

Figure 5. The median provided ample layout space [FPVCP fusion and staging (left); FPVCP layout (right)].

Dakota utilized a wire line locating system during the pilot hole drilling operation. The pilot hole was accomplished utilizing a paddle bit to jet the portion of the hole that cut through the clay soil section of the drill; upon encountering the rock, which according to geotechnical data consisted of soft shale, weathered limestone and very hard limestone. Dakota switched tooling to utilize a polycrystalline diamond compact (PDC) drill bit with a mud motor. According to Dakota Directional, “This drill was complex based on the varied geology and location. We had to change tooling to match the material that we were encountering while paying attention to downhole pressures to eliminate the potential for unintended drilling fluid release.”

Figure 6. Vermeer 220x300 drill rig being set up to drill the pilot hole.

After spending 20 days completing the pilot hole, the HDD contractor moved on to the reaming process. A 20-inch PDC hole opener was used to enlarge the pilot hole. This was done in a single pass, as the drill rig that was being utilized had plenty of torque to turn the reamer, even given the rock. The reaming process was slow based on the need to control downhole pressures while making sure that all of the cuttings were removed leaving a clean borehole. The final diameter of the drilled hole would allow for the installation of the 12-inch FPVCP, which had an outside diameter of 13.2 inches. While the process of drilling in rock can be more time consuming and therefore more expensive, the end result is an extremely stable borehole that reduces the risk of issues during pull-in.

After spending 5 weeks drilling the pilot hole, performing reaming pass, and prepping the hole for the pull-in, the actual pipe insertion occurred on November 10, 2015 with the pull-in lasting for approximately 7 hours. During the pull-in the maximum pull force that was utilized was less than 50,000 lbs which is considerably lower than the safe allowable pull force of the pipe and only a fraction of the overall capabilities of the drill rig. The HDD section was pressure tested for 2 hours at 200 psi prior to connection to the rest of the open cut work. The entire system was brought online in February 2016.

The successful installation of the 12-inch reuse line was confirmation that the 20-inch sanitary sewer force main could be installed via HDD in a very similar alignment. After awarding the force main project to Flow-line Construction in the summer of 2017, Dakota was again selected as their HDD contractor for the 2,680-foot 20-inch HDD section.

Similar to the reuse line HDD, the installation began with staging the drilling equipment within the median of the lower elevation west side of Lebanon Road to allow for lesser entry angle. The whole length of the pipe was fused and laid out within the median for one continuous pull.

Dakota mobilized onsite for their second drill in October of 2017 with a Vermeer 100 x 140 drill rig. The drill rig is capable of providing 100,000 lbs of thrust and 14,000 ft/lbs of torque. As with the reuse line, Dakota utilized a wireline guidance system with a paddle bit for the clay soil and a mud motor driven PDC bit for the rock portion of the pilot hole. Based on lessons learned from the first drill, they were able to complete the pilot hole in 10 days.

After completing the pilot hole and initial 12-inch push ream pass in 10 days. Dakota moved up to a 18-inch ream pass which took another six days. When the 18-inch ream pass was completed, Dakota moved their larger 220 x 300 rig onsite to perform the remainder of the reaming and the pull-back. The 24-inch ream pass took approximately 2 weeks and the final 32-inch ream pass required 6 additional days of work. The site constraints limited the speed in which the work could be completed and made the drilling fluid handling more difficult. However, because Dakota did not need to close down traveled lanes during the drilling operation they were not limited to working hours outside of peak travel times.

Once reaming was completed the pipe was put in final position and staged for insertion. Pull-in began around 10 am on Friday, December 15, 2017. In an effort to eliminate the potential for an unintended drilling fluid release, the contractor pulled the pipe in very slowly. The overall pipe insertion took a total of 14-hours and required 2 intermediate fusion joints. While this pace created for an extremely long day, it proved successful in managing downhole pressures during pull-in.

5. CHALLENGES AND LESSONS LEARNED

Installation of linear infrastructure in an already developed corridor provides many challenges. The ability to utilize trenchless installation to mitigate overall impact can be a highly effective way to solve the problem. However, trenchless installation methods, while considered more common today than they were 20 or 30 years ago, still carry risks related to the unknowns that can exist under the ground.

The success of these projects were a result of solid planning, engineering, and execution by all the parties involved. Constant communication between the owner, engineer, and contractor allowed for seamless installations that minimized the overall impact to surrounding businesses and residents.

By thoroughly understanding three key components, two successful HDD projects were installed

1. Alignment – Both alignments were curvilinear in both the horizontal and vertical directions. The ability to make minor alignment adjustments and design the HDD to eliminate compound curves on the reuse line provided a major benefit. While similar adjustment could not eliminate the compound curve on the sanitary sewer alignment, it was identified and analyzed to make sure that overbending of the pipe material would not

be a concern and the HDD contractor paid special attention during the pilot hole boring procedure to make sure they met both proposed line and grade.

2. Geology – Accurate geological and geotechnical data is critical for HDD installation especially when looking at longer HDDs. The ability to properly identify the soil and rock that will be penetrated allows the HDD contractors to appropriately price during bidding and utilize proper tooling when drilling.
3. Site constraints were a major component of this project. The engineer put significant thought into how the project would actually be constructed and built the alignments to allow for HDD equipment setup and pipe string layout.

Successful projects do not happen by mistake and the City of Frisco has been able to install two complex projects through a highly developed commercial corridor in the last couple of years. If the recent past is any indication of future events, they will need to continue this effort to meet future utility demands.

6. REFERENCES

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