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Morgan County Quality Water District – Water Main Flood Damage Repair Project

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ABSTRACT: Starting on September 9th, 2013 a slow-moving cold-front stalled over Colorado clashing with warm humid monsoonal air from the south. This resulted in heavy rain and catastrophic flooding along Colorado's Front Range from Colorado Springs to Fort Collins. The situation intensified on September 11th and 12th with 9-inches recorded on the 11th and as much as 17-inches recorded on the 12th. The flood waters spread 200 miles across a range of 17 counties. Governor John Hickenlooper declared a disaster emergency on September 12th in fourteen counties, including Morgan and Washington Counties, which is northeast of Denver. Morgan County Quality Water District (MCQWD) lost three of its four main water lines that cross the South Platte River when the flood waters passed through. When the flood waters subsided, MCQWD was able to reach and repair one of the damaged lines, but the other two that had been damaged needed to be replaced. Replacing these lines with traditional open-cut construction techniques would have required a very expensive effort to divert the river. Therefore the District turned to trenchless technology and horizontal directional drilling (HDD) to complete these challenging repairs. The HDD installations were 2,400 feet and 2,000 feet long, and included work in a difficult shale formation beneath the river.

1. INTRODUCTION

Morgan County Quality Water District (MCQWD) supplies approximately 2,700 service connections to residents of Morgan County and the surrounding area. MCQWD serves the rural areas of Morgan and Washington counties, including the towns of Snyder, Hillrose, Goodrich, Weldona, Log Lane Village, Orchard, and Jackson Lake State Park. The system currently serves an area in excess of 650 square miles. MCQWD customers receive their water from the Hay Gulch, San Arroyo and Beaver Creek aquifers from eight wells which are appropriated approximately 2,800 acre feet of water per year. On average, the district supplies 60 million gallon of water per month or 2 million gallon per day (MGD). The peak summer demand can increase up to 3.8 MGD.

In early September, 2013, a slow moving cold front combined with humid, monsoonal air from the south, resulting in extremely heavy rain and catastrophic flooding along Colorado's Front Range. When the flood waters reached Morgan County by way of the South Platte River, MCQWD's ability to service a large portion of its customers residing north of the South Platte River was severely hampered (see Figures 1 and 2). The raging waters damaged three of MCQWD's four main water supply lines that provide potable water to residents north of the South Platte River. After the flood waters subsided, the District was able to reach and repair one of the three damaged lines, but the other two could not be repaired and needed to be replaced. Replacing these lines with traditional open-cut construction techniques would require a very expensive effort to divert the river and would also require them to wait for the low-flow season months later after snow melt. Making this effort more complex would be the permits required to divert the river and perform the construction. These permits would be time consuming and difficult to obtain.

The two remaining water lines crossing the South Platte River were incapable of meeting the demand in the service area north of the river. In order to avoid a public health hazard, at least one of the damaged lines needed to be replaced immediately.



Figure 1. Flood waters overtake the established riverbanks in Morgan County, CO.

2. EMERGENCY MAIN REPLACEMENT AT THE NORTH TANK CROSSING

Although MCQWD didn't have extensive experience with trenchless construction methodology, they were aware of how horizontal directional drilling (HDD) worked, some of the projects that had been completed using the method in the Front Range, and the identity of some of the local groups that were intimately involved with the method. Given the urgency of the situation, there was no time for an engineered design and subsequent bid process to secure the new pipe and drilling contractor. MCQWD worked with local sources to identify several experienced HDD contractors that had completed HDD Projects under the South Platte River, as well as experience with boring similar-sized pipe diameters more than 2,000 feet. A meeting was called with HDD Specialists and Global Underground at the proposed North Tank Crossing location to discuss the feasibility of an HDD installation to complete the emergency main replacement.

When planning an HDD installation, identifying and clarifying unknowns is the key to risk reduction. Choosing a location for the HDD crossing was the first of several factors considered. A tie-in point to the existing distribution system north of the river and sufficient laydown room for the new pipe prior to insertion needed to be evaluated. If there is room, it is best to assemble the entire pipeline prior to beginning the pull-back operation. It is also best to align the pipeline so that it limits unnecessary bends as it enters the insertion point. Although it is possible to make intermediate fuses during pull-back, there is an increased risk of the bore-hole collapse, so it is avoided if possible. The final alignment for the North Tank Crossing was just under 2,500 linear feet, or nearly half a mile, and this is a lot of pipe length to lay out in one string prior to pull-back. MCQWD was able to find a location that allowed for a convenient tie-in location for the system, as well as layout the entire pipe alignment in one string in line with the HDD bore requirements.



Figure 2. Flood waters nearly overcome a bridge crossing in Fort Morgan, CO, located in Morgan County.

With a proposed alignment in place, the next unknown to characterize was the geology of the crossing at the depths required. MCQWD knew that several water wells had been drilled in the surrounding area over the years and were able to get copies of the bore logs. The logs showed mostly poorly graded sands & gravels as well as a shale formation at depth. The absence of cobbles or potential cobble bearing formations, and a solid shale formation under the river made the drillers optimistic that the proposed bore was feasible. Further, based upon the geotechnical information available, the drillers agreed that a target-depth that would provide at least 20 feet separation between the bore and the bottom of the river should be adequate to reduce the risk of inadvertent fluid returns during the installation.

Since the new pipe being installed by HDD is literally pulled through a hole underground, the new pipe must be fully restrained to allow tensile loading of the pipe and joints. Traditional pipe materials used include steel, high density polyethylene (HDPE) and Fusible PVC[®] pipe (FPVCP). Most new installations for the MCQWD are bell and spigot PVC pipe conforming to AWWA C900 (AWWA, 2007) or AWWA C905 (AWWA, 2010) standards, so their crews are already accustomed to working with PVC. This made the FPVCP option more attractive than the other two options in terms of future maintenance. MCQWD also ruled out steel pipe due to corrosion issues they've seen in their system and focused on using HDPE or FPVCP.

The project qualified for FEMA funding, so FEMA guidelines applied, meaning specifically that no 'improvements' may be made by the new pipelines. This primarily meant that the new installations needed to closely match the function of the previous installations. The two water mains destroyed by the flood waters were a 12-inch ductile iron pipe and a 10-inch asbestos cement pipe with a total cross-sectional flow area of 194.58 sq-in. (See Table 1). The goal in selecting the replacement pipes would be two-fold; first, they must be capable of being installed for the proposed installations and second, they must be capable of providing a similar but not improved ability to service residents north of the South Platte River.

Table 1 – Flow capacity of existing lines from a cross-sectional area perspective

Pipe Area	Inside Diameter (in.)	Area Calculation (sq. in.)	Area (sq. in.)
N. Tank Crossing	12.45	$(12.45/2)^2 \times \pi$	121.74
Log Lane Crossing	9.63	$(9.63/2)^2 \times \pi$	72.84
Total			194.58

Pipe recommendations for the crossings were based upon the required pressure capacity, the hydraulic capacity in comparison to the previous installations, and the required safe allowable pull force capability.

The required hydraulic capacity for a consistent/comparative replacement of the existing compromised pipe was critical. Relevant to this discussion is the required pressure classification for the replacement pipe. MCQWD indicated that working pressures including surge pressures consistently exceed 200 psi in this portion of the system and therefore would require the replacement pipe material to be rated 250 psi or greater.

- DR14 FPVCP has a maximum pressure capacity of 305 psi with a safety factor of 2.0
- DR7.3 HDPE has a maximum pressure capacity of 250 psi with a safety factor of 2.0

The required safe allowable pull-force based on the soil conditions and distance of the HDD installation was also critical. Global Underground and HDD Specialists indicated they would be most comfortable with a safe allowable pull-force capacity of approximately 100,000 lbs for a 2,500 foot HDD installation. Therefore, considering required flow capacity, pressure capacity and the desired allowable pull-force capacity the pipe recommendations were as follows:

- 12-inch DR14 FPVCP: ID = 11.20-inches, allowable pull force = 101,600 lbs.
- 14-inch DR7.3 HDPE pipe: ID = 9.93-inches, allowable pull force = 94,600 lbs.

Although only the North Tank Crossing was being treated as an emergency replacement, MCQWD wanted to consider the pipe to be used for the second damaged line at Log Lane as well in order to take advantage of the economies of scale that would be realized if they could make a single purchase for all materials needed for the two damaged crossings.

Selecting the 14-inch DR7.3 HDPE for the two line replacements would only provide 154.89 sq. in. of flow area compared with the 194.58 sq. in. flow area that was provided by the original pipelines, a 20 percent reduction. Upsizing the HDPE pipe option to 16-inch in order to achieve the needed flow area was ruled out due to the additional drilling expense for a larger hole. MCQWD therefore selected 12-inch DR14 FPVCP for both crossings. As shown in Table 2, two 12-inch DR14 pipes as the replacement for the lost 12-inch DIP and 10-inch AC pipelines provides 197.04 sq. in., an increase of approximately 1 percent, but most importantly, no decrease.

Table 2 – Flow Capacity of two proposed 12-inch FPVCP pipes in terms of cross-sectional area

Pipe Area	Diameter (in.)	Area Calculation (sq. in.)	Area (sq. in.)
N. Tank Crossing	11.20	$(11.20/2)^2 \times \pi$	98.52
Log Lane Crossing	11.20	$(11.20/2)^2 \times \pi$	98.52
Total			197.04

Now that the alignment and the replacement materials had been selected, the only remaining decision MCQWD needed to make was which HDD Contractor would be given a contract to complete the emergency replacement at the North Tank Crossing. HDD Specialists and Global Underground submitted their estimates and MCQWD selected HDD Specialists.

3. EMERGENCY MAIN REPLACEMENT –CONSTRUCTION REVIEW

Despite the speed with which MCQWD was able to move forward with the emergency main replacement project at the North Tank Crossing, the winter season was well underway by the time HDD Specialists was able to mobilize to the site and begin drilling. Early in the drilling operations, HDD Specialists encountered about 40 feet of loose sands and gravels that were dissipating the mud flow and preventing it from circulating. To solve this problem, a 24-inch steel conductor casing was inserted on the drill rig side of the alignment to allow drilling fluid returns. Later when the

shale formation was reached, a ribbon of hard sandstone was encountered that greatly slowed the drilling operations and eventually overworked the mud motor being used and caused it to fail.

Equipment Problems and harsh winter temperatures aside, HDD Specialists eventually completed the drilling operations with an excellent bore-hole. Initial recommendations from Underground Solutions included ballasting the pipe during pull-back in order to help the pipe sit down in the bore-hole and reduce drag on the top of the pipe through the bore-hole, but the topography of the laydown area with its rolling hills made ballasting the pipeline very difficult (see Figures 3 and 4). Even without the ability to ballast the pipe, HDD Specialists felt confident that they had a very good hole and the strength of the 12-inch DR14 FPVCP was more than sufficient for the task and continued with pull-back operations. Roughly eight hours later the pipe was fully installed and pull forces never exceeded 40,000 lbs compared to the safe allowable pull force for the FPVCP pipe section of 101,600 lbs.



Figure 3. Laydown area for North Tank Crossing showing the staged pipe string alignment.



Figure 4. Front end of pipe string aligned with the insertion point towards the water's edge.

4. LOG LANE CROSSING PIPE REPLACEMENT

Following the successful 2,400 LF emergency HDD installation for the North Tank Crossing, MCQWD now had three of its four water mains serving residents north of the South Platte River. The public health risk was now addressed affording them time to procure the replacement Log Lane Village crossing with a typical design, bid, build method (see Figure 5). While additional time was available, schedule was a factor to complete the work prior to increased demands in the spring that required the Log Lane crossing to be operational. Still, MCQWD was very impressed with the success and ease of the North Tank Crossing HDD installation and chose to repeat an HDD installation for Log Lane. As MCQWD's district engineer, the Farnsworth Group, Inc. (Farnsworth) in Fort Collins, CO was authorized to proceed with design and bid documents. This process followed MCQWD's normal process for construction projects along with additional requirements to qualify for FEMA's reimbursement.



Figure 5. Exposed water main at Log Lane as damaged in the flood, shown after the flood waters had subsided.

The design process followed normal procedures including topographic survey of the crossing that was partially hampered by high South Platte River flows at the time of the survey. From the survey, a new alignment was identified to be off-set from the existing line which accommodated HDD working areas, pipe fusing operations, and tie-ins to the existing waterline (see Figure 6). Farnsworth designed the bore path to be a U-shaped profile with smooth transitions and curves well above the 275 foot minimum allowable bending radius of the 12-inch FPVCP. The profile of the pipeline was designed to maintain a minimum depth below the existing river bottom of 30 feet which resulted in a proposed bore of approximately 1,900 LF. As with the emergency North Tank Crossing, overall project schedule duration was reduced by the use of historical well information for soil conditions in the area. This information revealed similar soil conditions with poorly graded sands and gravels near the surface as well as a shale formation.

With an acceptable alignment selected, design calculations were completed to confirm the 12-inch FPVCP that MCQWD had purchased at the same time as the North Tank Crossing project would withstand the calculated pull force for the design alignment, depth and anticipated soil conditions. These calculations followed ASTM F1962-11 (ASTM, 2011) guidance and was found to provide adequate capacity for the crossing. To complete the design, waterline filling, testing and disinfection factors were considered and incorporated into the tie-in locations.

The bid documents were assembled and the project was advertised for bid. Four contractors submitted proposals for the crossing replacement and MCQWD awarded the contract to Kleven Construction of Tempe, AZ. While Kleven Construction was an experienced HDD contractor, this was their first project that included the use of FPVCP. Kleven Construction mobilized in March of 2014 to begin the Log Lane Crossing.

Unlike the North Tank Crossing, gravel at the surface was not an issue and pilot hole work was completed in relatively short order. As with all HDD applications, accurate pilot hole information is critical to the process and dictates the final alignment of the bore hole and pipe. Accurate steering can be made more difficult with river crossings depending on the technology used. This was the case at Log Lane as during the month of March, river flows required that a section of the bore hole could not be recorded. While Kleven continued with back reaming operations, pilot hole as-built information was being analyzed for conformance with the contract documents. Review by the Farnsworth found a potential area of concern in which the as-built profile deviated from the required profile. This issue appeared to be a "hump" or high point in the profile creating a location of potential increased pull forces during installation and an unplanned high point in the final pipeline. Further investigation found this location to be at the area of missing

information under the high flow sections of the crossing. This information was immediately communicated to the contractor and a meeting was held to review the issue.



Figure 6. Log Lane Village Crossing Plan, shown schematically.

While Klevin Construction understood the concern with the as-built profile, they were confident that a good bore hole existed based on the pull forces experienced during the back reaming process. To ensure an acceptable profile, it was decided that a new as-built of the bore would be performed. This as-built was completed at a time when other work along the South Platte River had diverted the flows to the south portion of the river allowing for as-built information to be recorded in the previously missed section. Immediate review of the new as-built proved that while the profile did gain elevation then flatten, no actual “hump” existed in the profile. Based on this analysis, the bore was approved for pipe installation.

Taking place concurrently with the back reaming and profile review process was the assembly of the 1,900 LF of pipe. Due to the ease of completing the pilot hole and back reaming process, this activity became an item of concern in which the bore hole would be ready for pipe prior to completion of the joining and staging process. To accommodate the shortened schedule, an additional fusion machine was mobilized to the site to increase productivity to complete this task and ensure no delay between completion of the bore hole and pipe installation.

With the cooperation and teamwork between MCQWD, Klevin Construction, Underground Solutions, Inc., who performed the pipe assembly, and Farnsworth, all pieces of the puzzle came together and pull-back operations commenced. The Log Lane crossing pull-back was completed in approximately six hours under minimal pull forces.

5. CONCLUSIONS

As with several water districts in Colorado, the flooding events of September, 2013 caused significant damage to their infrastructure. MCQWD sustained heavy casualties as part of this flooding event that needed to be remediated under an emergency basis. HDD technology proved to be an effective tool to economically and efficiently restore service to customers with limited disturbance to the surrounding environment for MCQWD. Foresight of the District in procuring the materials for both crossings and teamwork between agencies, contractors, suppliers and engineers, proves that having proper communication and a common goal can result in a successful project in both negotiated and hard bid applications.

7. REFERENCES

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