Denver Water Turns to Sliplining to Renew Century-Old Transmission Main

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ABSTRACT

Back in 2011, Denver Water began arranging to have their existing 36-inch cast iron transmission line cement mortar lined (CML) as part of their active rehabilitation program targeting aged metallic lines that had exhibited signs of significant corrosion. The existing 36-inch line was installed in the 1920s and was now approaching 100 years in service. The main runs beneath 29th Avenue near Sheridan Boulevard in an extremely busy area of Wheat Ridge. Due to unanticipated delays in the CML process, originally planned for the fall of 2017, Denver Water engineers investigated the possibility of sliplining the existing 36-inch pipeline with a 30-inch fusible polyvinyl chloride pipe (FPVCP). The age of the pipe, the need to keep the full project on track, and the immediate availability of 30-inch FPVCP helped to fast-track approval and a slipline solution was slated for construction.

Denver Water had regularly used PVC in their system, but only up to 24-inch, making this the largest PVC pressure pipe installation in their system. The FPVCP, even with its reduced inside diameter, would adequately supply the flow demands of that system segment while providing a new non-corrosive asset.

The 30-inch FPVCP was fused and installed through a 1,200-foot segment in one week at the end of March 2018. This paper addresses measures taken to minimize the construction footprint and details the sequence of events that led Denver Water to use a non-standard installation method and introduce the largest PVC segment in Denver Water’s network of potable water pressure pipelines.

INTRODUCTION AND PROJECT BACKGROUND

The City and County of Denver has known countless challenges and moments of ingenuity as advancements in water distribution and storage became required with the growth of the area. Dating back to the 1800s, the South Platte River acted as a major source of water for residents, as it does today, but eventually wells and buckets could not meet the demands of an expanding population. Infrastructure soon developed starting with irrigation ditches, then canals, and some of the first filtration and treatment plants using wood stave pipe distribution systems in the late 1800s. Multiple water companies had emerged as part of this development but eventually collapsed or merged into the Denver Union Water Company (DUWCo) in 1894. The DUWCo built their first water lab in the 1890s, followed by a new filtration plant using slow-sand filters, and a 221-foot dam, Cheesman Reservoir, which eliminated dependence on streamflow and in-town water storage.

In 1918, residents voted to buy the DUWCo, establishing a public agency, known as Denver Water, with a goal to provide a stable water utility separate from city government. It remains separate from the City and County of Denver...
and uses its set water rates to cover costs of operation rather than city taxes. Denver Water continued the water system expansion over the next 100 years. Crossing the continental divide gave Colorado residents to the east, where an overwhelming majority of Coloradans are located, access to water west of the divide in 1935, drastically enlarging Denver’s resources. Now the oldest and largest water utility in Colorado, Denver Water maintains over 3,000 miles of pipelines, 23 pump stations, 30 underground reservoirs, and three potable water treatment plants with capacities ranging from 185 to 280 million gallons per day (MGD) all sourced by the surrounding rivers. The utility serves over 1.4 million people over an area of 335 square miles in Denver and its surrounding counties (see Figure 1).

As part of a continued effort by Denver Water to maintain and upgrade their water system, a contract was set to replace the Ashland reservoirs, located in suburban Wheat Ridge, and rehabilitate the associated infrastructure, “Ashland Reservoir Tank Replacements Contract 14063A-C”.

The Ashland reservoirs were built in the 1890s to store water from the South Platte River. These reservoirs were some of the original water storage locations in Denver, built on the outskirts of the city by the DUWCo, preceding the formation of Denver Water. At the time, water was delivered to the reservoirs through 20 miles of 36-inch wood stave gravity pipelines. When Denver Water was established, they took over this existing infrastructure, eventually replacing the wood stave piping in the 1920s with the current 36-inch cast iron pipe (CIP).

This pipeline, Conduit No. 1, runs along West 29th Avenue to/from the Ashland Reservoirs. In a preemptive approach to maintenance, the 36-inch CIP was cement mortar lined (CML) in the 1960s upstream of Sheridan Boulevard. However, the stretch of CIP from Sheridan Boulevard to Fenton Street, where the line meets the Ashland

Figure 1. Denver Water service area.
Reservoirs, was left unlined. The unlined length (see Figure 2) had not failed or leaked yet but, a century later without protective coating, the interior had severely corroded producing a build-up, tuberculation, that greatly reduced the inside diameter of the line and greatly affected the flow characteristics. Denver Water excavated along the alignment and determined that the pipe exterior was in good condition, structurally suitable for lining. The rehabilitation was added as one of the bid packages in the Ashland Reservoir Tank Replacement project.

![Figure 2. Segment of century-old transmission main to be rehabilitated.](image)

**PROJECT DESIGN**

Construction on other portions of the Ashland Reservoir contract was initiated back in 2013. The original design involved an effort from Denver Water; their design consultants, SDG, Inc. and TST Infrastructure, LLC; and the selected Construction Manager at Risk, Western Summit Constructors, Inc. Initially the design involved CML rehabilitation of the existing CIP, a method that had been used regularly on these older lines in past years. However, when it came time to start on this segment of the project in the summer of 2017, a CML contractor was not available. There are not any CML contractors located locally in Denver; most come from either the east coast or California. With only 1,650 feet of 36-inch and 200 feet of 30-inch CIP to be rehabilitated by CML, the volume of work did not attract contractors that would incur large mobilization costs to do the work. Denver Water considered packaging the work with other CML rehabilitation needed within the system, but no additional work was required at the time.

Therefore, in September 2017, now mid-project, Denver Water initiated a re-design to rehabilitate the line without the standard CML methods. Layout was only constrained by minimal existing utilities along the existing line and maintenance of traffic on 29th Avenue. While not a critical path in the City of Wheat Ridge, 29th Avenue only had one lane in each direction and the City required one lane to be open at all times during construction and both to be open at night. Designs were considered for both a complete replacement with new 36-inch ductile iron pipe (DIP) and sliplining the entirety of the segment with 30-inch fused polyvinyl chloride pipe (FPVCP). For the slipline option, even though PVC had never been used at this large of a diameter within the Denver Water system, FPVCP was solely specified due to their previous experience with the product in other water system installations and rehabilitations in the service area.

The hydraulics team evaluated the allowable head loss in the system to determine appropriate replacement methods, using a C-factor of 150 for PVC and 137 for CML. The required 9.5 MGD peak flow rate could be provided within the bounds of their head loss criteria when considering 30-inch FPVCP sliplining the existing 36-inch CIP. However, a 200-foot segment on the west end of the alignment necked down to 30-inch CIP. This section in its existing condition was violating Denver Water’s head loss criteria. While cleaning and CML application would allow the 30-inch to meet the criteria, it was not enough work to entice a contractor. If it were to be sliplined, only a 24-inch carrier pipe would fit, limiting the flow area beyond what was required. Due to this obstacle, a combination of pipe replacement and sliplining emerged as the most balanced design.
In addition to having a smaller diameter, the western part of the pipeline was deeper than the rest of the alignment (see Figure 3). If replaced with new DIP, it could be installed at more shallow depths and aligned to meet the existing 36-inch CIP on its shallower alignment. Coincidentally, the point where the new pipe would meet the existing pipe in terms of depth, happened to be the point where Denver Water was making a connection to another major conduit. For this tie-in between Conduit No. 1 and Conduit No. 17, additional appurtenances including a blow-off, butterfly valve, and air valves were being installed. This connection, combined with the ability to have a shallower pipe alignment on the western segment, made for an ideal point to start sliplining the remaining two-thirds (1,200 feet) of existing CIP with 30-inch FPVCP.

PROJECT BIDDING

The Ashland Reservoir project was broken into several discrete bid packages in a Construction Manager at Risk (CMAR) bid set-up. With this set-up, a previously selected CMAR takes responsibility for organizing and packaging the designed project such that subcontractors can bid on individual segments of a project, rather than a project in its entirety. This set-up allows specialized contractors to bid on project aspects best suited for their experience and, with multiple contractors awarded parts of the project, it permits multiple segments to be constructed at once by different crews brought together cohesively under the guidance of one CMAR. Western Summit, the CMAR, packaged together the different facets of the project and bid them out individually to subcontractors. The CML of this Conduit No. 1 segment was originally bid under Bid Package 6 but, with the new design, was pulled out and bid as a new package, Bid Package 13.

“Bid Package #13 – Conduit 1 Rehabilitation” advertised on November 13, 2017. The work was bid as a lump sum including the sliplining, new pipe installations, and appurtenances. Two bids were received at the bid opening on December 19, 2017. T. Lowell Construction out of Castle Rock, CO was the low bidder awarded the project.

CONSTRUCTION

T. Lowell Construction mobilized to the site in mid-March 2018 with a substantial completion deadline of May 1, 2018. In preparation for the slipline installation, crews began excavation of the pipe insertion pit on the west end of the alignment at the intersection of 29th Avenue and Depew Street, as well as the exit pit east of Ames Street, before Sheridan Boulevard, from which a winch would pull the pipe through (see Figure 4). No bypassing of the main was required since the line does not feed any customers directly; it only feeds the distribution system which in turn feeds the customers.
Once pits were established on each end of the slipline alignment, it was time to remove the nearly 100 years of tuberculation built up in the 36-inch CIP line. This cleaning process was completed by pulling a tuberculation removal device through the existing pipeline (see Figure 5). Then the pipeline was excavated at three locations and a piece of the existing CIP was cut away on top of the pipe to provide access for a CCTV camera to allow observation of the effectiveness of the cleaning. There was concern that remaining tuberculation could gouge or otherwise damage the FPVCP when it was pulled through. The right side of Figure 5 shows that the removal tool was very effective, and the CCTV inspection confirmed this throughout the length of the cleaning.

Figure 4. Slipline pits [pipe insertion pit on west end of alignment (left); exit pit with winch (right)].

Figure 5. Tuberculation removal [device that was pulled through CIP (left); 36-inch CIP post-cleaning (right)].
To further alleviate concerns, the contractor was required to pull a 25-foot test piece of 30-inch FPVCP through the 1,200-foot length of 36-inch CIP to confirm that the line was clean enough (see Figure 6). A 10% gouge during inspection would result in pipe rejection. The test piece was pulled from the insertion pit at the west end to the exit pit at the east end. The right side of Figure 6 shows that there was minor scoring of the pipe surface, but the defects were less than 1 mm deep and were considered to be acceptable.

![Figure 6. Proof piece pulled through alignment.](image)

At the end of March, the site and existing line were prepared to start sliplining. The 30-inch FPVCP was fused in-pit and sliplined into the host pipe 45 feet at a time, further reducing trenching and the project footprint by eliminating roughly 50% of the necessary trench length required for the pipe to make a full S-curve bending from grade down to invert-depth. The contractor had the option of having the pipe insertion pit on either the east or west end of the alignment. Due to the heavy traffic along Sheridan Boulevard (at the east end of the alignment), the west end was considered more suitable for in-pit fusion and the continual loading of 45-foot pipe lengths into the pit. Traffic was limited to one lane for the duration of construction. The westbound lane was kept open and eastbound traffic was either detoured or guided by flaggers along the westbound lane depending on timing. At night two-way traffic was restored.

Once set-up, the slipline installation was completed much faster than anticipated, taking only half the time allotted. Individual 45-foot pipe lengths were lowered into the insertion pit, fused at invert-depth, then pulled into the existing CIP once cooled (see Figure 7). This process was repeated until the full 1,200-foot length of FPVCP was installed. Denver Water had estimated a week to do the sliplining but it only took three days to fuse and pull 1,200 feet of new PVC line through the CIP, providing a new non-corrosive asset in a fraction of the time compared to standard open trench methods.
Figure 7. In-pit fusion and pull-in sequence.

The open cut ductile iron pipe segments were installed once the slipline was complete. After all connections were made, the entire segment was pressure tested at 150 psi for two hours on April 28, 2018 and then reinstated into Denver Water’s system.

LESSONS LEARNED AND RECOMMENDATIONS

The main lesson learned from this project was the value of sliplining as an alternative rehabilitation method. For an agency with an established CML program in place for large diameters, it can be difficult to deviate from the standard. Denver Water kept an open mind and discovered that sliplining is a viable option where CML is not possible and, in many cases, can be a cost effective and less intrusive approach to typical remove and replace methods.

It is highly recommended that a short ‘proof piece’, as shown in Figure 6, be pulled through the alignment to check for unknown obstructions and potential abrasive areas that weren’t fully cleaned. The successful test pull assured that the host pipe was cleaned well enough that Denver Water and the contractor didn’t have to worry about damage to the FPVCP when the full 1,200 feet was pulled through.

CONCLUSION

Despite an impromptu re-design mid-construction of the Ashland Reservoir project, the rehabilitation of this 36-inch CIP length was considered a great success. Sliplining provided Denver Water a feasible solution when standard rehabilitation methods were no longer an option. Fused pipe assembly within the slipline insertion pit massively minimized the construction footprint in this suburban area and drastically cut down installation time and the associated disruption to residents. Construction on the entire bid package 13 was completed by the required May 1st deadline without issue.
Denver Water was concerned there would be several complaints relating to the partial closure of 29th Avenue and the subsequent detouring because this took place in a residential area and many use 29th Avenue to get home. However, very little negative feedback was received, which Denver Water attributes to the use of FPVCP and Western Summit, the CMAR, for providing ample notice to all in the area prior to start of construction. The City of Wheat Ridge and Denver Water were pleased with the solution and now have an alternative option to the standard CML method in their toolkit for their larger diameter lines in the future.

REFERENCES


