1. ABSTRACT

When the City of Fort Collins (City) Utilities (Utilities) decided they needed to replace an existing 4-inch Cast Iron Pipe (CIP) waterline in College Avenue (State Highway 287) to increase flow capacity, they knew that they would have to get creative in order to reduce impacts to third parties and streamline the construction. Replacing a 90-year old waterline under one of the busiest thoroughfares in the City and replacing an 8-inch sewer line running under a very busy intersection would require extensive coordination and planning. The utility department put this project into their Alternative Project Delivery System (APDS) and put together the APDS team of Engineers (Stantec & Brierley Associates) and Contractors (Connell Resources & Temple Construction) to develop a design and a construction plan that would

- Minimize third party impacts to traffic and pedestrians, local businesses, and Colorado State University
- Share project risks between the City, Design Engineer(s), and Contractors
- Maintain traffic flow - vehicular and pedestrian
- Meet a tight construction schedule
- Reduce pavement replacement costs
- Improve water distribution capacity and increase sewer flow capacity
- Provide a safe work zone

The team, supported by TT Technologies and Underground Solutions, decided to replace the pipe in situ using a combination of Pipe Bursting and Horizontal Directional Drilling (HDD) with Fusible PVC pipe (FPVC) and Certa-Lok® pipe. Pipe Bursting was used where new pipe followed existing pipe alignments and HDD was used to relocate waterline for easier future maintenance and on side streets where there was no existing pipe.
2. **INTRODUCTION**

In the spring of 2013 The Colorado Department of Transportation (CDOT) informed the City of Fort Collins (City) that they would be doing a mill and overlay project during the summer of 2015 on College Avenue (State Highway 287) from Harmony Road at the south end of town to Mulberry Street at the entrance into the downtown area of Fort Collins known as Old Town. College Avenue is the main north-south thoroughfare through Fort Collins passing 10,000’s of vehicles a day. In general when an existing road is improved, it is also important to look at the underground infrastructure to assess whether it will require maintenance or repair in the near future post road improvement so as not to have to cut in to new asphalt right after it has been placed.

Roads and underground infrastructure in the Old Town area date back to the early 1920’s. Parts of Old Town have redeveloped in the past 20-years increasing the demands on this aging infrastructure. The condition of the existing cast iron pipe limited fire flows and created water quality problems. These were some of the reasons the City decided to completely replace this section of waterline in addition to wanting new waterlines under the roadway before CDOT paved College.

![Figure 1: Cast Iron Pipe with holes](image1)

![Figure 2: Tuberculation in existing Cast Iron Pipe](image2)

Two parallel lines extending south from Mulberry Street servicing buildings on the east and west sides of College Avenue were considered for replacement or abandonment.

- from Mulberry Street south to Buckeye Street on the east side of College (4350 LF 4-inch CIP) and
- from Mulberry Street south to Laurel Street on the west side of College (1350 LF 6-inch CIP)
The first questions to be answered were what size of waterline was needed along the route to meet domestic and fire demands and were the two parallel lines required. The City, together with Stantec, modeled the existing and expected development in the area and determined that both lines could be replaced with a single 8-inch line along the east side of College with services connecting across the street to the properties on the west. Additional fire hydrants were also placed along the route to improve coverage and better meet fire code requirements.

3. HOW TO BUILD IT

With that question out of the way, Fort Collins now needed to determine how to build it. The Utilities department has developed a process to design and manage all of their projects called the Alternative Project Delivery System (APDS) that brings together Utilities and other City departments, the Design Engineer(s) and the General Contractor at the outset of the design process to evaluate all aspects of the project from design to construction. Utilities put together the APDS project team of Stantec, Brierley Associates and Connell Resources (Connell) in the summer of 2013.

The APDS system has several advantages over the traditional Design – Bid – Build method of municipal construction projects including:

- Introducing the Contractor at the outset of design rather than weeks before bids are due provides them with a better understanding of project costs, schedules and impacts and thus reduces their risk for the project. In this case, the design process took 7-8 months with regular design progress meetings including the entire APDS team.
- Allowing the Engineer and Contractor to work through the design with means and methods in mind along with the engineering aspects.
- Taking into account other aspects of the project including public outreach, planning for traffic control (crucial for this project) as part of the means and methods and coordinating with other City departments, the project team developed a better understanding of the soft and hard costs and schedule for the project.
• Allows the team to look at alternative methods of construction, such as trenchless installation, with time to look at the pros and cons of each method and without the issues relating to low bids from contractors who might not have the experience with newer technology.
• Eliminates as many unknowns as possible, thus reducing risk to all parties.
• Shares risk between the City, Design Engineer(s), and Contractor.

Survey of field conditions was the first step along with determining the number, size and location of all existing water services along the route. Once the locations of everything where known, the APDS team got together to look at means and methods of construction with consideration for traditional open cut and trenchless methods.

The APDS team looked at traditional open cut methods of replacing the water line but determined that there were a lot of disadvantages. The biggest disadvantage to the open cut method was third party impacts associated with having to shut down the entire north bound (NB) stretch of College Avenue for about one mile from Prospect Road on the south to Mulberry Street on the north. Shutting down the NB stretch of College Avenue would have had significant impacts to vehicular flow along the corridor. The City Streets Department made a very strong argument that this could not be done given the daily vehicular volume along College and the nearest comparable north-south streets being 1-mile east and west of College.

Additionally the open cut method would have required significantly more asphalt replacement versus trenchless installation alternatives. If an open cut method was utilized to install the waterline, Connell Resources estimated 3,100 tons of asphalt would be required to patch the roadway. Approximately 5,800 LF of waterline was installer under roadways with this project utilizing trenchless installation methods reducing the asphalt requirement to 1,300 tons. In addition to more asphalt, there would have also been the additional cost and time associated with replacing curb, gutter and sidewalk given the proximity of the waterline to the curb. Installing the lines using trenchless technology resulted in a small amount of curb, gutter and sidewalk being replaced where new services or fire hydrant installation required it.

Finally, the construction duration for the project would have been significantly longer using open cut methods. It is estimated that waterline (installation only) production along the College portion of the project would have been 60-70 feet per day not including setting up the temporary water or reconnecting services back in (62 working days @ 70 feet per day just to install 4340 LF of waterline). As an example, the waterline installation including temporary water and services tied over from Mulberry to Laurel began on 5/27/14 and was completed on 6/25/14 including two side street installations for a total production (temporary water, pipe installation and testing, services, and patching) of 1800 LF of pipe in 24 days or 75 feet per day. Several more weeks would have been added to this section of the project if open cut methods had been used.

The contractor also replaced an 8-inch sewer main through the Laurel and College intersection, which could have possibly taken a month to complete using open cut methods given the traffic load at that intersection. The 400 LF of 8-inch sewer line was burst up to a 12-inch line with construction only taking a week from start to finish including five deep service tie-ins.

The other issue relating to College Avenue and open cut methods was that there are a mixture of asphalt pavement sections and asphalt over concrete sections in College and there were areas of widely varying thicknesses of asphalt. This posed a problem as current City policy requires that patching pavement thicknesses be the existing pavement thickness plus one inch. This has led to pavement thicknesses in excess of 18-inches where the letter of the law was followed. Also the City has in the past required concrete be replaced in kind extending the project duration due to the time required for concrete placement and curing. This was resolved as a result of the APDS system and is the subject of another discussion.

Based on the project constraints discussed above, the APDS team opted to look at trenchless methods of installing the new waterline and sewer line. Brierley Associates was tasked with determining the subsurface conditions under College to ascertain whether or not they would be suitable for trenchless installation methods. They concluded that the trenchless installation of new pipelines was a suitable method given the existing ground conditions under College Avenue and the adjoining side streets.
Initially, the APDS team looked at pipe bursting for the entire length of the project as it would eliminate the need to change technology mid-stream. The alignment of the existing 4-inch CIP waterline caused the team to rethink this idea. The existing 4-inch CIP was located approximately 3-ft off the eastern curb line of College from Mulberry south to Elizabeth Street (2750 LF). From Elizabeth south to Buckeye Street the waterline moved further out into the middle lanes of College caused by the widening and realignment of College back in the 1950’s. The city preferred that the entire line be closer to the eastern curb line along the entire route for maintenance reasons and so that the two lanes of NB traffic could be maintained during construction. This required creating a new alignment for the waterline south of Elizabeth, which brought Horizontal Direction Drilling (HDD) into the planning discussions.

Figure 4: HDD Pipe Sling

The next task for Brierley Associates was to determine if Pipe Bursting and HDD were both viable options for the project with the limits of the project as follows. Pipe bursting essentially installs a new pipe using the existing pipe as a conduit. Two pits, receiving and pulling, are excavated at the ends of the pipe being replaced. Rods are inserted in the pipe at the receiving pit and pushed to the pulling pit where a pipe bursting head larger than the existing pipe (upsized from 4-inches to 8-inches) is attached to the new pipe and the rods and pipe are pulled back bursting/breaking the old pipe in-situ while filling the resultant cavity with new pipe. The new pipe is then reconnected to the existing services and the exposed areas are backfilled and paved if under roadways. Pipe bursting reduces the amount of excavation required to replace old waterlines and more pipe can be installed per day than using open trench construction methods. Approximately 700 LF was installed in less than 2-hours with the first pipe bursting operation after a little over 1 week of preparation including exposing existing services, installing temporary waterline and connecting the services. As noted earlier in the report the contractor estimated that they would complete approximately 60-70 feet of pipe installation per day using open cut methods or 350-500 feet in a little over a week.

HDD is similar to pipe bursting except that a machine creates a new opening underground for the waterline using an augur and drilling fluids. A pilot hole is initially drilled along the alignment and at the required depth and then the hole is enlarged to accommodate the new pipe by pulling a reamer back through the hole. That and the drilling fluids reduce the pressure required to pull the pipe back through the hole in the final step of the
process. The length of the pull takes into account the allowable pulling forces on the pipe in comparison to the resistive forces generated against the pipe by the soils as well as the size of the pipe. The first HDD operation took about 3 days to set up and execute with 300 LF of pipe being pulled in about 1-hour.

Brierley Associates determined that both trenchless methods were viable in their report (Brierley Associates (2014). They concluded that the soft Lean Clay (CL) at the elevation of the proposed pipe were sufficiently displaceable, based on blow counts to allow for a successful pipe bursting operation. Along with this they noted that the existing depth of the pipe was sufficient to minimize the chance of pavement movement at the surface during bursting operations.

The also concluded based on the existing soils conditions at the southern end of the project that had blow counts in the 4-17 bpf (blows per foot) range were soils that could be excavated using a mud motor, which is used in HDD. Testing determined the unconfined compressive strength of the subsurface to generally range from 1,510 to 5,740 pounds per square foot (psf) near the proposed depth of installation. Therefore from a geotechnical perspective both HDD and pipe bursting were considered suitable methods to install the waterline in College Avenue.

Based on the results of the Brierley Associates report and discussions amongst the APDS team, it was decided that Pipe Bursting and HDD would be used to install the new waterline and sewer line for this project. This project was divided into sections of pipe bursting and HDD installation methods as follows.

- **Pipe Bursting where the existing pipe alignment is being maintained** – waterline from Mulberry to Elizabeth and across the intersection of Laurel and College for both water and sewer lines
- **HDD from Elizabeth south to Buckeye where a new alignment was defined closer to the eastern curb line as required by the City.**
- **HDD several side laterals at crossing streets to provide additional looping to existing waterlines in Remington Street, one block east of College Avenue.**
  - Buckeye – 300 LF
  - Garfield – 300 LF
  - Myrtle – 500 LF
- **100 LF of replacement waterline was installed using pipe bursting at the intersection of Laurel Street and College Avenue.**
- **400 LF of replacement sewer line was installed using pipe bursting at the intersection of Laurel Street and College Avenue.**

The APDS team also verified the pull forces for the HDD portion of the project based on decisions made as to the locations of the pulling and receiving pits in order to determine the type of pipe used in the installation. For the HDD installation and the given lengths of each drill, Brierley Associates determined a maximum pull force of 14 kips or a maximum pulling stress of 978 psi which was significantly lower than the allowable pull strength of 35.7 kips for the Fusible PVC (FPVC) pipe.
Fusible HDPE and Fusible PVC (FPVC) were considered for both portions of the project and it was decided that FPVC would be the pipe used based on the following.

- The City currently uses PVC for all their new waterline and they can use the same fittings whether working with PVC or FPVC

The APDS team also worked out the potential issue of inadvertent drill fluid loss or frack-out with this project by planning to use the service pits installed at the onset of each section of pipe installation with the temporary water service as relief wells, allowing for collection of drill fluids that might be released during the HDD process. This was accomplished as the service pits were excavated at the beginning of each section and the services tied over to a temporary water service. The pits remained open during construction allowing any fluids a point of release that would not spill out onto the road or into a storm sewer system.

Figure 6: HDD Machine at Buckeye Street

4. WHEN TO BUILD IT

The other planning decision made by the APDS team was the timing of the construction. Fort Collins is the home of Colorado State University (CSU) with a student population of 32,000 and growing. CSU fronts on College Avenue and has 3 points of access to their campus off College Avenue within the project limits. With this in mind the City opted to plan for construction during the summer (mid May – mid August) when the majority of students would be gone reducing the amount of traffic on this section of College Avenue. However, this placed a burden on Connell and their subcontractors to be able to install this much waterline and reconnect all the services in this short of a time frame (75 working days). The APDS team worked out the sequencing of the following.

- Installing and connecting temporary water services
- Turning off and isolating individual line sections for replacement
- Installing the new lines and testing
- Reconnecting the service lines and any side laterals
- Patching the service holes and any other excavating areas.
- Other work as needed
- Project clean up
5. INSTALLATION

The final plans worked out the following installation sections and phasing to limit the amount of time in College Avenue by completing a lot of the side street work ahead of the end of the CSU semester (May 15th) and not closing any lanes in College until after the May 15th. Phase 1 included

- Buckeye Street Waterline (HDD) 300 LF
- Edwards Street Waterline (Open Cut) 150 LF
- Garfield Street Waterline (HDD) 300 LF

Construction on the side streets began on 5/5/14 and was completed by 5/23/14 (15 working days). Phase 2 work in College Avenue began after Memorial Day and was phased as follows.

1. Mulberry to Myrtle – Pipe Burst 500 LF Waterline – also included a 500 LF HDD waterline portion on Myrtle Street
2. Myrtle to Laurel – Pipe Burst 700 LF Waterline
3. Laurel and College Intersection – Pipe Burst 100 LF Waterline
4. Laurel to Locust – Pipe Burst 1000LF Waterline
5. Laurel and College Intersection – Pipe Burst 400 LF Sanitary Sewer Line
6. Laurel to Elizabeth – Pipe Burst 400 LF Waterline
7. Elizabeth to Buckeye – HDD in 3 reaches from north to south
   a. Elizabeth to Garfield 500LF Waterline
   b. Garfield to Pitkin 540 LF Waterline
   c. Pitkin to Buckeye 345 LF Waterline
8. Mulberry Street Tie in – 80 LF waterline burst set up and completed in one long night

The lengths of the HDD reaches were based on reasonable drill lengths and logical tie-in places for the side street laterals installed earlier in the project. These locations could also be used as pulling and receiving pits minimizing the number of mobilizations required for each drill (i.e. spin the machine around and drill the other direction).

Water services on the west side of the road were installed using a Grundopit machine supplied by TT Technology. This proved to be quite efficient and kept traffic moving on the south bound side of College with very minimal interruptions. As the project continued the crew was able to complete as many as five services across the road per day.
Additional trenchless work on the project included Pipe Bursting 400 LF of 8-inch sewer up to a 12-inch across the Laurel and College intersection using Certa Lok® pipe and HDD installation of a 12-inch storm sewer under the sidewalk between Edwards and Garfield Street (300 LF) so as to abandon an existing irrigation/storm line that was failing but inaccessible for open cut replacement.

6. TRAFFIC FLOW

Traffic flow was maintained during the installation of the waterline. It was thought that two lanes of NB traffic could be maintained along the entire length of the project. However, when it came down to closing the section from Laurel Street North to Mulberry (2 blocks), it was decided to limit traffic to one lane as this allowed for more efficient movement of construction equipment along this section speeding up the installation. Jersey Barriers were used to line the limits of the construction keeping the construction crew safe. Continuous coordination with City traffic control personnel and their prompt responses were critical to keeping the project moving smoothly. Short term soft closures were scheduled during off peak hours when the pipe had to be pulled into place for either bursting or HDD installation.

From Laurel south only one lane was closed and this did slow down the progress somewhat. In hind sight, the team should have considered additional soft lane closures during certain phases such as flo-filling of excavated holes to allow easier access to those locations reducing the time spent completing these tasks and maintaining adequate traffic flow. This is one of the lessons learned post project that will be included in future trenchless projects.
7. RESULTS

The project succeeded in meeting the demands outlined at the beginning of this paper.

- Project risks and unknowns were identified early in the design stage and planned for,
- Traffic flow was maintained with minimal disruption.
- The construction schedule was maintained even with the additional work that was added to the project
- There was a reduction in cost of asphalt required.
- Services were installed to the west side of the road without having major lane closures in the SB lanes
- There was minimal construction impact to adjoining properties
- Safety was maintained for the construction crew, pedestrian and vehicular traffic.
- Additional waterline capacity was created for the surrounding users as well as increased ability to handle fires with the installation of additional fire hydrants along the route.
- An important piece of sewer line was upsized to handle additional flows coming from recently redeveloped upstream areas.

8. CONCLUSION

The City Fort Collins Utilities was pleased with the results of this project and will continue to make use of trenchless technology as they replace and rehabilitate underground pipes in Old Town and other locations throughout the City. As with every project, lessons were learned including the following:

- Trenchless methods for pipeline replacement are cost effective and can significantly minimize third party impacts and make a project flow smoothly with proper planning.
- With proper planning, trenchless methods can save time for waterline installations.
- Plan for short lane closures to facilitate easier placement of flo-fill in the holes at service and lateral connections as well as sending and receiving pits along the construction route. Backing concrete trucks into the area to place the flo-fill was difficult and time consuming.
- Connecting smaller diameter pipe into large diameter pipe needs to be considered as well since there is a possibility of additional fittings near the connection. We encountered this at the connection between the 4-inch and the 16-inch line in Mulberry. A vertical bend stopped the burst and required open cut and removal.
- We used 40-ft sticks of FPVC on this project and may consider shorter sticks in the future to speed up the pipe transport around the site.
- Reflective flags will be used on the Jersey barriers for future projects to improve visibility and safety of workers and vehicular public.
- Build a more realistic schedule for future trenchless projects based on the results of this project

9. REFERENCES