# THERMALLY FUSED PVC PIPE HELPS ACCELERATE ADOPTION OF TRENCHLESS PIPE INSTALLATION TECHNIQUES IN NORTH AMERICA

**Andrew D. Seidel, Robert Walker**

**Underground Solutions, Inc. 13135 Danielson Street, Suite 201, Poway, CA 92064; Tel. 858-679-9551**
**E-mail aseidel@undergroundsolutions.com**

## ABSTRACT

In North America, trenchless pipe installation methods continue to see rapid adoption growth in municipal markets with 71% of utilities having used trenchless methods in the past 12 months.1 This adoption rate is a function of improving equipment, installation experience and improved materials.

The three most recognized trenchless installation methods for pressure pipe; horizontal directional drilling (HDD), sliplining and pipe-bursting are seeing rapid growth in application. Improvements in methods and materials have stretched the boundaries of these technologies, allowing longer lengths of pipe, larger sizes and an increased range of project constraints to be managed. New pipe joining methodologies for thermoplastic pipe materials and specifically the advent of thermally fused PVC pipe have had the largest impacts on the growth of these installation modes in North American water and wastewater infrastructure.

This paper discusses the fused PVC pipe technology that is enabling trenchless growth and highlights two cases studies where fused PVC was utilized; a 3,800 foot (1,1140m) HDD bore with 24 inch (600mm) and 6 inch (150mm) pipe pulled in simultaneously under a live airport runway in Portland, Oregon and a water utility in Colorado that has installed over 150,000 feet (45,000m) of fused PVC via the pipe-bursting method.

## INTRODUCTION: 3,800 FOOT (1,140M) HDD BORE AND PULL-IN

Portland International Airport (PDX) encompasses over 2,600 acres (10 km2), serving over 15 million travelers annually to domestic and international destinations. It is also home to the 142nd Fighter Wing of the Oregon Air National Guard. A vital element to providing safe aviation service at PDX is the deicing and anti-icing of planes and pavement during periods when air temperatures are below 40 degrees Fahrenheit (4°C).

The Port of Portland (Port) is tasked with capturing and managing fugitive aircraft and pavement deicing and anti-icing chemicals, as well as collecting and treating large volumes of deicing chemical impacted stormwater on-site. The deicing and anti-icing fluids are collected and managed through the existing stormwater management system. The concern with excessive non-toxic deicing fluids in the stormwater is its high biological oxygen demand (BOD). To maintain stormwater discharge compliance with State and Federal regulations, the Port needed to make significant investments in the existing infrastructure to enhance the deicing collection and control system at PDX.

As shown in Figure 1 below, due to the significant restrictions placed upon construction activities at an airport, the enhanced system was located on the western edge of the airport property. However, the existing collection and management system is located in the central and eastern portions of the airport, representing significant design and construction obstacles in order to connect the two systems together.

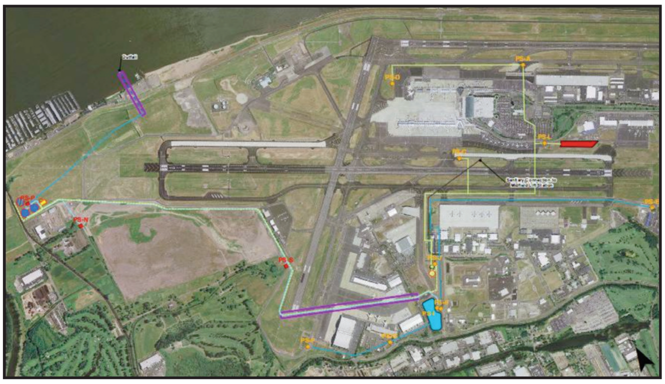

**Figure 1 – Final site plan showing new treatment and conveyance facilities on the western side of the PDX property and the existing facilities in the central and eastern portion of the PDX property.**

## DESIGN AND CONSTRUCTION OF THE AIRFIELD CROSSING

The new portions of the deicing enhancement system were designed on the far west side of the airfield, and the existing system was on the eastern and central areas. These two areas are roughly two miles apart (3.2 km), and the route between them passes through an active runway/taxiway system.. Going around the runway using open cut or direct bury methodology was quickly eliminated as an option due to the distance and quantity of utility piping that would have to be managed. This option would also add significant cost to the project.

Going under the runway/taxiways eliminated the additional pipe cost, however the costs for removing/replacing aircraft-rated pavement greatly outweighed these reduced pipe cost savings. Additionally, the logistics of working on or temporarily closing a runway/taxiway made this option unfeasible.

Another option was a combination of open cutting and "jack and bore" installation methodology under the critical runway and taxiway facilities in the near surface soils, which could be done while the runway/taxiways were operational. Unfortunately, these near surface soils proved to be predominantly loose and unconsolidated, precluding the use of "jack and bore" technology.

After further and exhaustive review of potential options, evaluating potential risks and costs, HDD was advanced as the most cost efficient, viable option. Using historical geotechnical information (Figure 2) a proposed HDD boring plan was developed going under the cargo air operations and just south of the active runway (Figure 3). Due to the poor soils prevalent across the site, the proposed bore trajectory was taken to a depth of at least 75 feet (22.5m), where competent soils were expected. The Port was very wary of HDD installation methodology within the airfield, due to contractor miscalculations on a previous project that resulted in the emergence of a sinkhole adjacent to PDX's south runway. To mitigate this potential risk, this crossing's bore path alignment was carefully selected to provide numerous viable "work arounds" if there were a similar issue that occurred under the cargo area or the very southern end of the active runway.

Further complicating this installation was the fact that two separate pipe sections were required for the crossing. One large primary conveyance, which was for storm water from the airfield collection areas, would require the same 24" (600mm) FPVCP or 30" (760mm) HDPE pipe similar to the outfall installation. The second conveyance, however, was much smaller and required for a concentrate stream pump back to the airfield side. Both 30" (760mm) HDPE and 24" (600mm) FPVCP were considered for this crossing, in the same manner that they were considered for the outfall installation.

Bore depth again dictated minimum critical buckling design requirements, but the extreme length (3,800' or 1,1140m) and bundled pull also required maximizing tensile strength to weight ratio. 24" (600mm) DR18 DIPS FPVCP was chosen specifically due to its strength-to-weight ratio, allowing risk minimization on the bore by giving the driller the highest safe pull force to weight possible to meet any actual required pull force during pullback. The smaller line was also FPVCP, a 6" (150mm) DR14 DIPS cross-section.

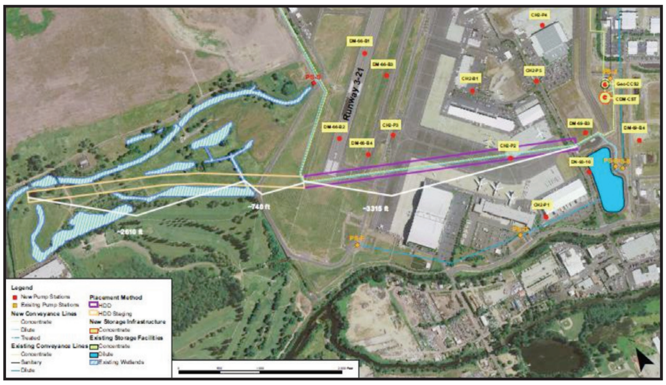

**Figure 2. Proposed Boring Plan for the active airfield crossing (CDM, Geotechnical Data Report, June 2009).**

The joint venture of Northwest Underwater Constructors (NUC) and Kinnan Engineering (Kinnan) was selected to perform the HDD for the airfield crossing. Underground Solutions, Inc. (UGSI) provided the FPVC pipe and fusion services for this crossing. During drilling, Kinnan encountered difficult and complicated drilling conditions. The same soils that precluded "jack and bore" methodology also had to be considered in the initial approach of the drill shot. Kinnan used a steel casing for the first ~120 feet (36m) of the installation to stabilize the bore.

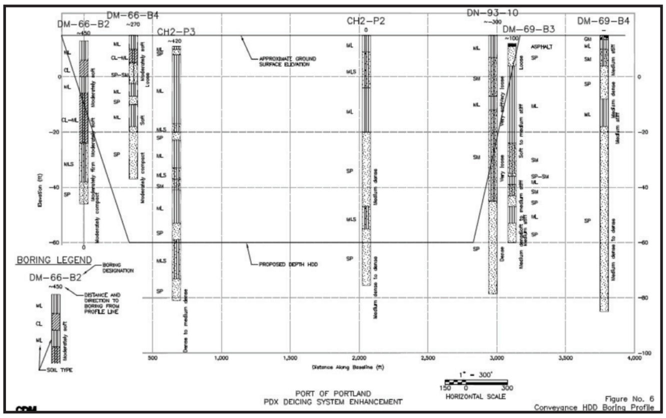


**Figure 3. Results of the Boring Plan along the chosen HDD alignment (Geotechnical Data Report, June 2009),**

The required length of the bore, 3,800 LF (1,140m), was a significant length of pipe to fuse and stage – not only to string out in one length, but to make sure that it lined up with the crossing alignment. The fusion and lay-down area for the fused pipe (Figure 4) presented a major challenge because wetlands and environmentally sensitive areas that could not be disturbed existed in the work area that had to be used. JE Dunn, CDM, The Port of Portland, Kinnan, and UGSI ultimately identified an alternate alignment that did not disturb the wetlands, yet allowed for the full lengths for both 24" (600mm) and 6" (150mm) sections to be laid out.

**Figure 4. Lay-down area for the fused FPVCP sections**

Kinnan custom-fabricated a manifold-style pullhead to separately link the 6 inch (150mm) and 24 inch (600mm) pipes and their individual pullheads simultaneously. Pullback commenced on July 27, 2010, with water ballast in the 24 inch (600mm) pipe to reduce frictional force in the bore. The pull was completed in 13 hours, exerting a maximum pull force of 117,000 pounds (520 kN). A successful pressure test was completed several weeks later.

**Figure 5. Start of Pull into the insertion pit**

Figure 6. Pipe Bundle at Borehole Exit and Casing

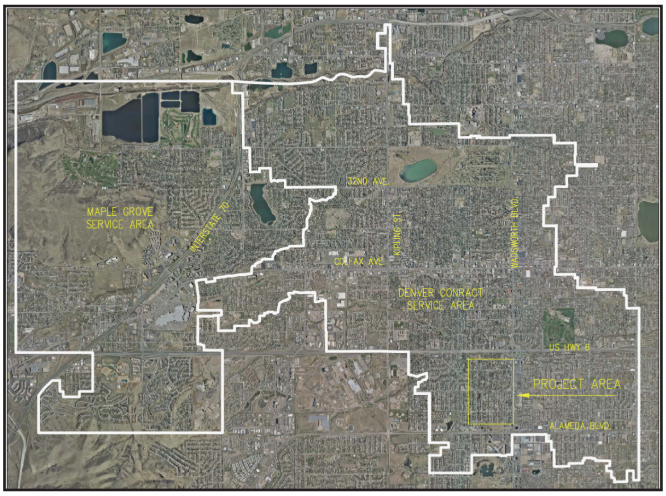


**Figure 7: Service area map with delineation of the service area into the two systems – also shows the project area for 2010.**

## INTRODUCTION: 37,000 FEET (11,100M) OF PIPE-BURSTING REHABILITATION

The Consolidated Mutual Water Company (Consolidated) distributes approximately 4 billion gallons (15 million m3) of water annually to about 90,000 residents in Lakewood, Wheat Ridge, and unincorporated portions of central Jefferson County, Colorado. Treated water is delivered through 380 miles (1638 km) of pipelines and 21,100 tap connections over a service area of approximately 27 square miles (70 km2). Consolidated, through a distribution contract with Denver Water (Denver), purchases approximately 70% of the total treated water it distributes annually. The other 30% of water is supplied by Consolidated's own Maple Grove Water Treatment Facility from water rights acquired over the past 85 years. Consolidated still follows the original pattern of the early cooperatives that it was created from - ownership by the water users it serves. It is presently operating under the provisions of the Colorado Nonprofit Corporation Act, accepted by action of the stockholders in 1969. As stock holders, the rate payers and water users of Consolidated's system have a vested interest in the system and its success.

Consolidated's distribution system dates back as far as 1926 when the original company was formed from four smaller, well-based systems. Through decades of additions, expansions, and reorganizations, Consolidated has remained committed to providing the highest quality water to its stock holders through a reliable distribution system. Since the mid-50's, they have budgeted money annually for water main replacement and upgrades of other aging infrastructure (Consolidated Mutual Water Company, 2010). Consolidated has historically used the open-cut installation process in its water main replacement program. As the cost of open-cut installation continued to rise, including paved street restoration, Consolidated began evaluating alternative methods for water main replacement. The primary focus of such an initiative being to lower the cost per linear foot (meter) of line being replaced – as long as the methods were suitable and met the requirements of Consolidated and Denver's standards.

Over the years Consolidated has brought all of the elements of water system maintenance, construction and design, into its organization. All engineering design, maintenance and construction are self-performed by company employees. The replacement program that was in place for undersized or ineffective water mains in the system was to be performed by Consolidated's crews and it was important that any alternative methods to improve the system were capable of being delivered by Consolidated's staff.

## REHABILITATION AND/OR REPLACEMENT NEEDS

Consolidated was facing the same aging infrastructure problem that many other utilities face, namely large sections of their system that needed to be replaced. These sections contained large amounts of undersized 4" (100mm) and 6" (150mm) cast iron pipe. The piping had served the system well over the years in these sections of the system, however due to large numbers of breaks, water quality issues and restricted flows in some areas due to tubercles and pipe size, it was becoming an ever-increasing concern.

**Figure 8. Typical water main in areas to be replaced, both outside and inside pipe showing tubercles.**

In early 2009, money was budgeted for a large-scale pipe replacement program that would begin in 2010, the goal of which was to replace the undersized and insufficient piping in those areas where required by dig and replace methodology. The total budget for 2010 was approximately \$2.4 million USD ( R22.8 million), which was intended to replace approximately 24,000 LF (7,200m) of existing piping. It was also during this time period that Consolidated started to investigate other methods of waterline rehabilitation compared to the daunting open cut, dig and replace program that was outlined.

After hearing about pipe bursting as a pipe rehabilitation and replacement method, Consolidated began evaluating and testing a variety of equipment, piping products, and procedural methods using pipe bursting technology. Consolidated decided to proceed with a pipe bursting program to replace 23,000 LF (6,900m) of water pipelines, beginning in April 2010, in a service area with antiquated and undersized lines. Consolidated selected Fusible PVC™ pipe (FPVCP) as the replacement pipe based on its corrosion resistance, ease of connection, and its ability to upsize old cast iron distribution lines while minimizing soil displacement due to its smaller pipe OD versus other pipe options. Additionally, the other pipe material evaluated and determined to be feasible was high density polyethylene pipe (HDPE), however, Denver would not allow it to be used. While Consolidated runs their own program, maintains and constructs their own water system, and functions as a fully autonomous utility, the use of Denver water carries with it a stipulation of following all of Denver's rules, regulations and requirements including following their engineering standards for all materials and methods. This required that any alternative pipe replacement or rehabilitation methods that Consolidated decided to use had to get a variance approval from Denver. Based on Denver's use of FPVCP pipe in the past, they allowed Consolidated to use FPVCP as part of a pipe bursting program, after reviewing their variance request.

In February 2010, Consolidated sent two employees to be trained and certified to fuse FPVCP. Consolidated also purchased fusion equipment from McElroy Manufacturing and pipe bursting equipment from TT Technologies, Inc. Consolidated enlisted the technical assistance of a contractor with experience using the same means and methods on another large-scale, potable water pipe burst program completed in the Kansas City, MO area using FPVCP. Wiedenmann & Godfrey Construction, Inc., located in Belton, MO, provided initial support and consultation when the project began.

## PIPE BURSTING AS BOTH A REHABILITATION AND REPLACEMENT METHOD

Under the 'trenchless' moniker come many varied forms of pipeline rehabilitation and replacement methods, all with various strengths and weaknesses depending on the many variables associated with the system, pipe materials and specific attributes of a given project scenario. It can be argued that most trenchless pipe installation methods fall into one of two global categories, those that 'rehabilitate' a pipeline, and those that 'replace' a pipeline. They all share the common goal of reducing excavation as much as possible; however, there are distinct differences between the two in relation to how a 'new' pipeline is created in relation to the existing one. Rehabilitation methods, by broad definition, utilize the existing pipe that has reached the end of its useful design life. This means that whatever method is employed, whether it is Cured-in-Place-Piping (CIPP), liner installations, or others, the original host pipe is maintained and the existing utility corridor is re-used. The solution provided is not the installation of a 'new' pipeline; it is the extension of the existing pipeline's design life. Replacement, on the other hand, includes those methods, like horizontal directional drilling, that provide an entirely new pipeline installation with the opportunity to upsize the pipe. Replacement requires that a new pipeline installation be made, that is independent of existing line, and does not rely on the existing line for any of the new pipeline's intended design life.

Some trenchless methods sit on the line between these two broad definitions, methods such as sliplining, tight fit liners, and pipe bursting. Of these methods that have aspects that make them a rehabilitation method and aspects that assure that they are in fact a replacement method as well, pipe bursting is unique. Pipe bursting provides an entirely new pipeline, sized according to design needs and not entirely limited by existing project conditions, but is installed utilizing the same utility corridor and original host pipe of the pipeline it is replacing. It is both a viable replacement method, with a brand new wholly replaced pipeline, and a utility corridor rehabilitation method, using the existing pipeline as the template for installation and final alignment.

The use of the pipe bursting as a potable water system rehabilitation and replacement technique has been recognized for some time, but has just recently seen a major rise in application. As pipe bursting equipment and suitable pipe replacement products have evolved and flourished, so too has the use of the technology and the required expertise in the construction sector has responded to this need.

### *Pipe bursting equipment for potable water installations*

Static pipe bursting has long been recognized as a viable form of pipe bursting and potable water pipe rehabilitation (U.S. Water Standards AWWA M28, 2001). Today, static pipe bursting has come to the forefront of trenchless methods in North America. During the static bursting process specially designed bladed rollers are pulled through an existing line by a hydraulically powered bursting unit. As the bladed rollers are pulled through, they split the host pipe. An expander attached to the rollers forces the fragmented pipe into the surrounding soil while simultaneously pulling in the new pipe (see Figure 9).

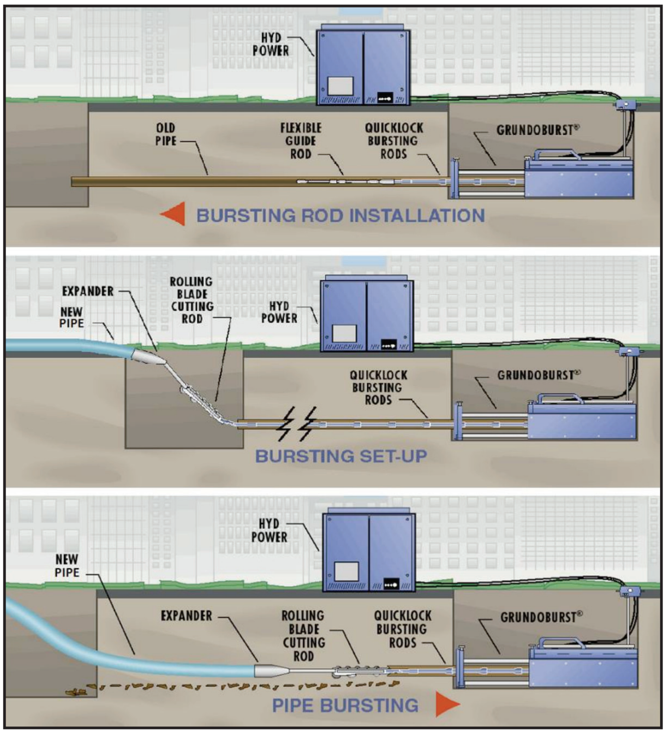


**Figure 9. The static pipe bursting process illustrated.**

Patented "Quicklock" bursting rods are linked together which speeds the installation process as well as the breakdown procedure. The rods can be quickly removed one at a time at the exit pit as bursting is in operation. The advantages of static bursting over the other prevalent form of pipe bursting which is pneumatic bursting is that it allows for the use of many product pipe materials, and additionally does not require air hoses that feed the pneumatic process to be run down the new product pipe, alleviating concerns about contamination for potable water use.

Advances in the equipment technology, including more powerful units with smaller footprints, have sped the increase of its use in the potable water pipeline rehabilitation market.

***Pipe products for use in potable water pipe bursting:***

As the equipment for pipe bursting has evolved, so too have the pipe products that can be employed with it. HDPE pipe was the original product used in North America when pipe bursting was first advocated as a method to replace existing cast iron natural gas distribution lines, back in the early 1980's in New Jersey. This pipe material has also seen crossover use in the water and wastewater markets as well, mainly due to its low-profile, non-mechanical, high tensile capacity thermally butt-fused joint, which is perfect for installation by trenchless methodologies, including pipe bursting. HDPE, in practice however, is historically not a common, standardized waterworks piping material, save for a select few water utilities. This has created a void for other materials to fill when it comes to trenchless piping products in the water market. Filling this void are a number of restrained joint products utilizing the more traditional piping materials for the North American water industry, including Polyvinylchloride (PVC) and ductile iron pipe. One material that has combined both of these trends is FPVCP, which takes the very popular and common waterworks piping material of PVC and couples it with the low-profile, non-mechanical, high tensile capacity of the thermally butt-fused joint.

## CONSOLIDATED'S PIPEBURSTING PROGRAM, 2010

Early in 2010, Consolidated started to narrow its focus on pipe bursting as a viable alternative for pipe system replacement and rehabilitation. Research into the method and its successes, as well as its limitations were showing that it could be viable for a long term pipe system replacement tool in many areas of their system. Just how useful it would be became the question, and after certainty was attained that this method would meet the physical and operational requirements of the system, the only way to answer that question was with money – namely, will this method be cost effective, in addition to providing the socio-political benefits of a 'trenchless' construction methodology for the shareholders of the system?

By all accounts, the numbers that Consolidated came up with showed that it would be beneficial. Not only should the replacement method save construction time in neighborhoods, limit excavation in the street and right of way (ROW), and limit the impacts of these activities to individual shareholders, the numbers were showing a significant cost savings – almost 50% compared to the normal dig and replace construction methods normally utilized. As the pieces of the program began to fall into place, two areas defined themselves as critical for Consolidated to make sure that it would be a success and that their numbers would be justified. The first was the pipe joining and fabrication and the second was the actual equipment, labor and efficiency associated with the pipe bursting process.

**Figure 10. Pipe bursting a 4 inch (100mm) cast iron water main and upsizing to 6 inch (150mm) FPVCP.**

FPVCP pipe joining, which is a thermally fused joining process requires that technicians undergo an initial three day training course and then annual requalification to perform the joining process. It also requires the use of a pipe fusion machine, rated for the sizes of pipe to be used in the joining process. Consolidated needed to decide how to handle these two items, and per the long term goal of the process and rehabilitation program, decided to bring these items in house. This meant the purchase of a fusion machine and training of Consolidated's employees in the process. Both of these items would add to the initial cost of the program.

The pipe bursting process also required the use of special equipment. The installation technique relies on a hydraulically actuated pulling device to fracture the existing pipe into fragments, push them into the surrounding soil, and simultaneously pull in the new product pipe. The process is also coupled with the hardware of the bursting 'train' and pipe attachment assembly. This special tooling connects to the pulling system of the equipment, assures that the existing pipe is sufficiently fractured and displaced, and finally expands the created annulus of the utility corridor to allow the trailing insertion of the new product pipe (see Figure 10). All of this equipment would need to be acquired as well, and this too would add to the initial cost of the program.

Before this process takes place, activities include excavating pulling and insertion pits, removing service taps from the existing line, setting up temporary water services and supply, and decommissioning the existing utility. After this process takes place, activities include tie-ins to the existing system, tapping of the line for water services and other work associated with commissioning the new line. All of these are typical processes and well within the equipment and working knowledge of Consolidated's skilled labor.

The final and arguably the most important piece of the puzzle for Consolidated was the efficiency of the work process. In order to assure that they could meet the production and budgetary goals created for the program, they would need to maximize the efficiency of the process. Not only would they need to make sure that the procedure of the installation worked fluidly from the temporary water system installation to the final commissioning of the new line, they also had to try and make it into a template that could be repeated over and over again, street to street, making the process as efficient as possible.

The following table illustrates how a typical street block of waterline would be rehabilitated in regards to activities and relative timing. Total time for work on a given block is 8 working days:

**Table 1: Walkthrough of typical completion of one block (~1300 LF – 390m).**

| Day No. | Day | Activity | Description |
|---|---|---|---|
| 1 | Wednesday | Fuse Pipe - 1 | Pipe length of FPVCP is created, one half of the required block length (~680 LF – 204m)) |
| 2 | Thursday | Temporary Water | Temporary Service System Installed Pipe is set down. Services are disconnected from the existing water main, the temporary service is initiated, and the existing water main is removed from service. |

| | | | |
|---|---|---|---|
| | | Fuse Pipe - 2 | Pipe length of FPVCP is created, one half of the required block length (~680 LF – 204m) |
| 3 | Friday | Prepare Existing Water Main | Cut, plug and otherwise prepare existing water main for bursting activities. |
| 4 | Monday | Prepare for Pipe Bursting Activity | Dig pull pits and insertion pits - set plates and bursting equipment. |
| 5 | Tuesday | Pipe Burst Activity | Pull 680 LF (204m) of pipe into existing main through pipe bursting activity (one half of block). Line connections are made into rest of piping system. |
| 6 | Wednesday | Pipe Burst Activity | Pull 680 LF (204m) of pipe into existing main through pipe bursting activity (other half of block). Line connections are made into rest of piping system including mid-block connections, hydrants, etc. |
| 7 | Thursday | Commission and Testing of new water main | New water line is hydrostatically tested, health tested, and then biologically tested. |
| 8 | Friday | Reconnection of New Waterline, Surface Rehab | After line clears testing, services are reconnected, temporary services and system are removed, excavations are back filled, and surface patching is completed. Water Pipe on block is completely replaced. |

## PIPEBURSTING EFFICIENCIES ATTAINED

The overall program started in earnest on April 26, 2010, and was completed on September 10, 2010. Through the course of their pipe bursting work, Consolidated gained tremendous efficiency with the process. This not only resulted in a large amount of replaced pipe, it also meant that the total cost to do so on a linear foot basis dropped as well. By focusing on each step of the process as it related to time efficiency, Consolidated streamlined their pipe bursting operations. They installed what amounted to a 12 month open cut dig and replace program in a little over 4 months.

Ultimately, the optimization that had the most impact on the work was in the overall process schedule itself. Consolidated quickly dialed in the needed steps and the appropriate timing of those steps to assure that any one aspect of the overall procedure was not inhibiting or slowing down any other aspect. As in Table 1 portrays, when Consolidated moved the process through a city block, they were there for approximately 8 days. Essentially, they were in front of a given customer for 8 days in one fashion or another. By overlapping activities, they were also working on the next block as the previous one was being completed – so, instead of finishing a block every two weeks, they were actually finishing one every week.

The process starts with pipe fusion, so the fusion crew works ahead of the balance of the installation crews in relation to the activity located on each block. With one block's worth of pipe fused ahead of the installation schedule, the 'pump is primed' to roll the program at the pace of a block a week, re-commissioning a block on every Friday.

**Figure 11. Final restoration in areas of pipe bursting. Asphalt patches shown in relation to rest of street.**

There are several keys to the successful implementation of a rolling schedule such as this one for a pipe bursting program. First and foremost, one needs skilled and ambitious workers that can meet the rigors of the schedule while delivering a high quality work product. Secondly, while the steps of the process could be stacked to maximize efficiency of the process with respect to time, the key to staying on that time schedule is the successful completion of each of those steps without cutting corners or omitting the routine aspects of the process.

## FINAL COST COMPARISSON

The original budget, based on a dig and replace program was priced at ~$2.4 million dollars (R22.8illion) for 2010 for Consolidated. This utilized historic dig and replace metrics of previous projects to quantify expected labor, time, and equipment needs. Then these values were coupled with expected rate structures for 2010 to arrive at the total budget estimate.

**Table 2: Expected dig and replace dollars (use R9.5 for each USD) based on past project experience (sampling of 6 inch-150mm projects)**

| | Previous Dig and Replace Projects - 2010 Projected dollars | | | | |
|---|---|---|---|---|---|
| | Orchard Rd. | 26th Place | 33rd Ave. | 32nd & Tabor | |
| Length of Pipe (feet) | 1128 | 542 | 2213 | 710 | |
| Diameter (inch) | 6 | 6 | 6 | 6 | |
| Select Cost Items | | | | | Averages |
| Labor and Overhead | $ 27,460 | $ 15,550 | $ 64,350 | $ 22,190 | $ 28.21 |
| Road Cut Repairs | $ 37,760 | $ 17,850 | $ 45,500 | $ 21,870 | $ 26.78 |
| | | | | | |
| Total | $ 102,170 | $ 62,750 | $ 224,710 | $ 69,810 | |
| **Total per linear foot** | **$ 90.58** | **$ 115.77** | **$ 101.54** | **$ 98.32** | **$ 100.03** |

When Consolidated looked at the possibility of a pipe bursting program, saving money, but keeping a quality product was a major component of the possible benefits of using the technology. It was estimated that the money savings would come from two major areas, one was the reduced cost of asphalt resurfacing and the second was the reduced time for installation required and the labor associated with it. Examining these two items, with the rolling schedule as described, showed that the entire slate of pipe intended for replacement could be installed in less than half the time and with a massively reduced surface rehabilitation budget, which indicated a possible savings of approximately ~$1.3 million USD (R12.35 million). Based on these cost differences, along with the reduced impact to their shareholders and water users, Consolidated decided to proceed with the program. They utilized the cost differential to offset the purchase of the new pipe bursting and fusion equipment required for the program.

**Table 3. Actual Pipe Bursting dollars (use R9.5 for each USD) based on 2010 program (sampling of 6 inch-150mm projects).**

| | Actual Pipe Bursting Costs - 2010 Program Results | | | | |
|---|---|---|---|---|---|
| | Allison St. | Brentwood St. | W. 4th Ave. | W. 1st Pl. | |
| Length of Pipe (feet) | 1160 | 1320 | 2800 | 840 | |
| Diameter (inch) | 6 | 6 | 6 | 6 | |
| Select Cost Items | | | | | Averages |
| Labor and Overhead | $ 29,780 | $ 25,560 | $ 65,270 | $ 17,050 | $ 22.49 |
| Road Cut Repairs | $ 3,320 | $ 3,830 | $ 12,420 | $ 3,830 | $ 3.82 |
| | | | | | |
| Total | $ 58,830 | $ 59,860 | $ 143,510 | $ 52,160 | |
| **Total per linear foot** | **$ 50.72** | **$ 45.35** | **$ 51.25** | **$ 62.10** | **$ 51.37** |

Actual dollars have borne out what was originally thought to be the case by Consolidated. Pipe bursting has saved them approximately 50 percent on costs, while at the same time has reduced impact to their rate payers in the form of construction hassle and surface restoration. In the end, the goal of an improved water system has been met with the pipe bursting program, while at the same time saving time and money for all of the stakeholders involved in the process.

By 2013, Consolidated has replaced over 150,000 feet (45,000m) of cast iron water main by pipe-bursting with fused PVC pipe.

## REFERENCES

1. Underground Construction, February 2013 – "Municipal Survey"