Pacific Northwest Trenchless Review

2017

Trenchless Symposium

January 11-12

SeaTac, Washington

KAMLOOPS AUGERING & BORING LTD.
SINCE 1979

HORIZONTAL BORING & TUNNELING
GUIDED BORING & MICRO TUNNELING
PIPE RAMMING & DIRECTIONAL DRILLING


WORLD'S LARGEST AUGER BORING MACHINE


LARGE DOWN HOLE HAMMERS FOR BOULDERS AND ROCK


WORLD'S LARGEST PIPE RAMMER


WORLD'S LARGEST PILOT TUBE TUNNEL

THERE IS NO SUBSTITUTE FOR EXPERIENCE

WITH WELL OVER 100 YEARS OF COMBINED MANAGEMENT EXPERIENCE TOGETHER WITH THE LARGEST MODERN FLEET OF EQUIPMENT IN THE NORTHWEST MAKES US YOUR BEST PARTNER FOR TRENCHLESS CONSTRUCTION.

— MALCOLM BACHAND PRES.

BUS: 250.573.7814 FAX: 250.573.7815
CELL: 250.371.1252 EMAIL: KAMAUG@TELUS.NET

Pacific Northwest Trenchless Review

WINTER 2017

Featured...

HDD Project 09

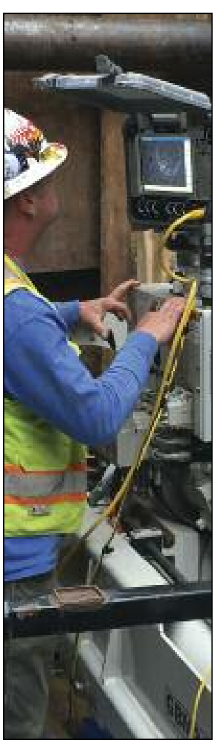
A contractor worked through site constraints, environmentally sensitive areas, and strict permitting conditions

Auger Bore 14

A 313-foot-long steel casing was installed under a highway for installation of a water transmission line in Washington

Pipe Bursting 18

A host of technical challenges added to budgetary challenges involved in an Oregon sewer project



Also...

COVER PHOTO: Staheli Trenchless Consultants

Published by:

PTR COMMUNICATIONS INC.

Unit 1 – 73 Fontaine Crescent
Winnipeg, Manitoba
Canada R2J 2H7

President

Elaine Chouinard

204.255.6524

elaine.ptrcom@mts.net

Editor

Mike Stimpson

807.346.0510

ptrcommike@gmail.com

Advertising Sales

Tracy Dufresne

204.837.9176

tracy.ptrcomm@gmail.com

Layout & Design

Jim Schmidt

Lunch Pail Productions

PTR Communications Inc.
Unit 1 - 73 Fontaine Cres.,
Winnipeg, Manitoba
Canada R2J 2H7

Printed in Canada 11/16

Symposium in January

Chris Sivesind - *Chair, NASTT PNW Chapter*

I am writing this final chair message with much excitement and anticipation for the future of the North American Society for Trenchless Technology's Pacific Northwest Chapter. We have seen a lot of change in leadership on the board the last couple of years, and have a lot of interest from people to join the board and volunteer time for upcoming events. I really like the new leaders that will be in place going forward, as they will continue educating the great Pacific Northwest in all aspects of trenchless technology.

As we look forward to 2017, my time as chair will be ending and Brendan O'Sullivan will take over as chair in January. Brendan will be a great leader for the group, and I expect we will see growth in membership and events under his guidance. In addition to Brendan, we have identified two or three additional professionals in the industry who will take a more active role on the board and/or in planning the future growth of the PNW Chapter of NASTT.

On January 11-12, at the Cedarbrook Lodge in SeaTac, we will hold our bi-annual Trenchless Symposium featuring one day of exhibitors and presenters followed by a second day that will feature an eight-hour short course on "Trenchless Construction—New Installations." This is a wonderful course that will give owners, engineers and interested contractors an overview of the many trenchless methodologies that can be used in various applications. For more information on the symposium and registration, visit www.pnwnastt.org.

> "We have all the ingredients for success and innovation in the Pacific Northwest"

Thank you to everyone who has supported the PNW Chapter over the last couple of years. This has been a truly rewarding experience for me. We live and work in such a beautiful region of the country, and it is so nice to see in the PNW that we always seem willing to try new methods, push the limitations of existing methods, and overall really set the bar for the rest of the country in relation to the trenchless installation, repair and rehabilitation of underground infrastructure.

The Pacific Northwest is a highly innovative market, and I hope this continues for years to come. We have all the ingredients for success and innovation in the PNW: owners willing to try new methods, as well as industry-educated engineers and contractors that are both talented and very experienced.

I look forward to seeing you and a couple hundred of your closest friends at both the Trenchless Symposium at the Cedarbrook Lodge in January and the NASTT No-Dig national convention in Washington, D.C., in April. No-Dig will also host the International Society for Trenchless Technology's annual event. Having the International event in combination with No-Dig should make this a marquee event and a great opportunity to learn more about both domestic and international trenchless technologies.

Thank you again to the current board and membership in the Pacific Northwest for your guidance and support over the last two-plus years..

Regards,

Chris Sivesind

Chair, NASTT PNW Chapter

A Promising Future

Dr. Kimberlie Staheli - *Chair, NASTT*

Greetings, Pacific Northwest Chapter members! NASTT is having another great year, and I'm excited for our future during the remainder of my term as Chair of the Board of Directors and beyond. As I'm sure you know, NASTT's 2016 No-Dig Show in Dallas was a huge success with a sold-out exhibit hall and excellent attendance.

NASTT could not reach this level of excellence without dedicated and selfless volunteers at the national level and within our 11 regional chapters. I would like to personally thank the following Pacific Northwest Chapter members who served on NASTT's 2016 No-Dig Show Program Committee and gave their time and expertise to review each and every abstract to ensure that the No-Dig Show delivers a program with the highest quality technical content and excellent educational presentations: Dan Buonadonna, Jack Burnam, Steve Donovan, Michelle Macauley, Laura Wetter and Dina Worthen.

I would also like to extend a special thank-you to Dan Buonadonna and Dina Worthen for serving as Session Leaders, providing peer review and comments for technical papers within a session that falls within their expertise. This contribution is vital to the quality of the Show, and we acknowledge the enormous amount of time you expended in a devoted effort to ensure NASTT's No-Dig show is unsurpassed.

The upcoming 2017 Pacific Northwest Trenchless Symposium in SeaTac, Washington, at the Cedarbrook Lodge promises to deliver another great educational opportunity, presenting the leading edge of trenchless. The first day will feature NASTT's New Installation Methods Good Practices Course, and the second day will focus on presentations with case studies and projects in the Pacific Northwest. There will also be an exhibit to offer a great opportunity to network with local vendors and contractors. I hope you will make it a top priority to join us on January 11 and 12 for an outstanding event.

During our strategic planning efforts, the Board of Directors identified goals of engaging larger groups of trenchless professionals to participate in the many volunteer opportunities provided by NASTT. These opportunities prove to be very satisfying and rewarding. NASTT has a wide variety of ways to participate that allow involvement at any level. If you are interested in more information, please visit our website at nastt.org/volunteer. There you can view our committees and learn more about these great ways to stay involved with the trenchless community. Please consider becoming a volunteer – we would love to have you get more involved.

NASTT has a very promising future, and we're thrilled to have the Pacific Northwest Chapter as part of our organization. Thank you again for your support and dedication to NASTT and the trenchless technology industry.

Sincerely,
Dr. Kimberlie Staheli
Chair, NASTT

NASTT Pacific Northwest Chapter
Board of Directors

Chair
Chris Sivesind
Akkerman
Seattle, Washington
(507) 567-2261
csivesind@akkerman.com

Secretary
Brandon Simonds
Trenchless Construction Services LLC
Arlington, Washington
bs@trenchlessconstruction.com

Director
Vacant

Vice Chair
Brendan O'Sullivan
Murray, Smith & Associates Inc.
Portland, Oregon
Brendan.O'Sullivan@msa-ep.com

Treasurer
Matthew Pease
Pease Consulting, LLC
Portland, Oregon
matt@mattpeaseconsulting.com

Immediate Past Chair
Erik Waligorski
Stantec Consulting
Bellevue, Washington
erik.waligorski@stantec.com

NASTT Events

January 11-12, 2017

Pacific Northwest
Trenchless Symposium
Cedarbrook Lodge
SeaTac, Washington
Information: pnwnastt.org

April 9, 2017

NASTT's Introduction to Trenchless Technology – New Installations
Gaylord National Convention Center
Washington, D.C.
Information: nastt.org/training/events/

April 9, 2017

NASTT's Introduction to Trenchless Technology – Rehabilitation
Gaylord National Convention Center
Washington, D.C.
Information: nastt.org/training/events/

April 9-13, 2017

NASTT's 2017 No-Dig Show & ISTT's 35th International No-Dig
Gaylord National Convention Center
Washington, D.C.
Information: nodigshow.com

April 12, 2017

NASTT's Gas Good Practices Course
Gaylord National Convention Center
Washington, D.C.
Information: nastt.org/training/events/

April 12-13, 2017

NASTT's HDD Good Practices Course
Gaylord National Convention Center
Washington, D.C.
Information: nastt.org/training/events/

April 12-13, 2017

NASTT's Laterals Good Practices Course
Gaylord National Convention Center
Washington, D.C.
Information: nastt.org/training/events/

April 12-13, 2017

NASTT's CIPP Good Practices Course
Gaylord National Convention Center
Washington, D.C.
Information: nastt.org/training/events/

April 12-13, 2017

NASTT's New Installation Methods Good Practices Course
Gaylord National Convention Center
Washington, D.C.
Information: nastt.org/training/events/

April 12-13, 2017

NASTT's Pipe Bursting Good Practices Course
Gaylord National Convention Center
Washington, D.C.
Information: nastt.org/training/events/

April 12-13, 2017

NASTT's HDD Good Practices Course
Gaylord National Convention Center
Washington, D.C.
Information: nastt.org/training/events/

March 25-29, 2018

NASTT's 2018 No-Dig Show
Palm Springs Convention Center
Palm Springs, California
Information: nodigshow.com

Dual HDD River Crossing: Challenges & Lessons Learned

(Presented at NASTT's 2016 No-Dig Show – Dallas, Texas)

Brendan O'Sullivan, P.E.
Murray, Smith & Associates, Inc.

Kimberlie Staheli, Ph.D., P.E.
Staheli Trenchless Consultants

Brent Gruber, P.E.
Murray, Smith & Associates, Inc.

Joel Staheli
Staheli Trenchless Consultants

Barry Lovingood, P.E.
Clark Public Utilities

Clark Public Utilities (CPU) is a regional water and electricity provider located in southwest Washington. CPU is currently developing the Paradise Point Water Supply System, a regional groundwater supply project designed to meet the demand for water from growing communities in northern Clark County. The water source is a well field with a build-out capacity of 10,000 gallons per minute located at the confluence of the East Fork and the North Fork of the Lewis River. The well field has no connection to their existing system, and CPU proposed to cross the river with two parallel horizontal directional drill (HDD) crossings from the well field on the west bank of the river to Paradise Point State Park on the east side of the river.

The Phase 1 Raw Water Transmission Main project included final design and

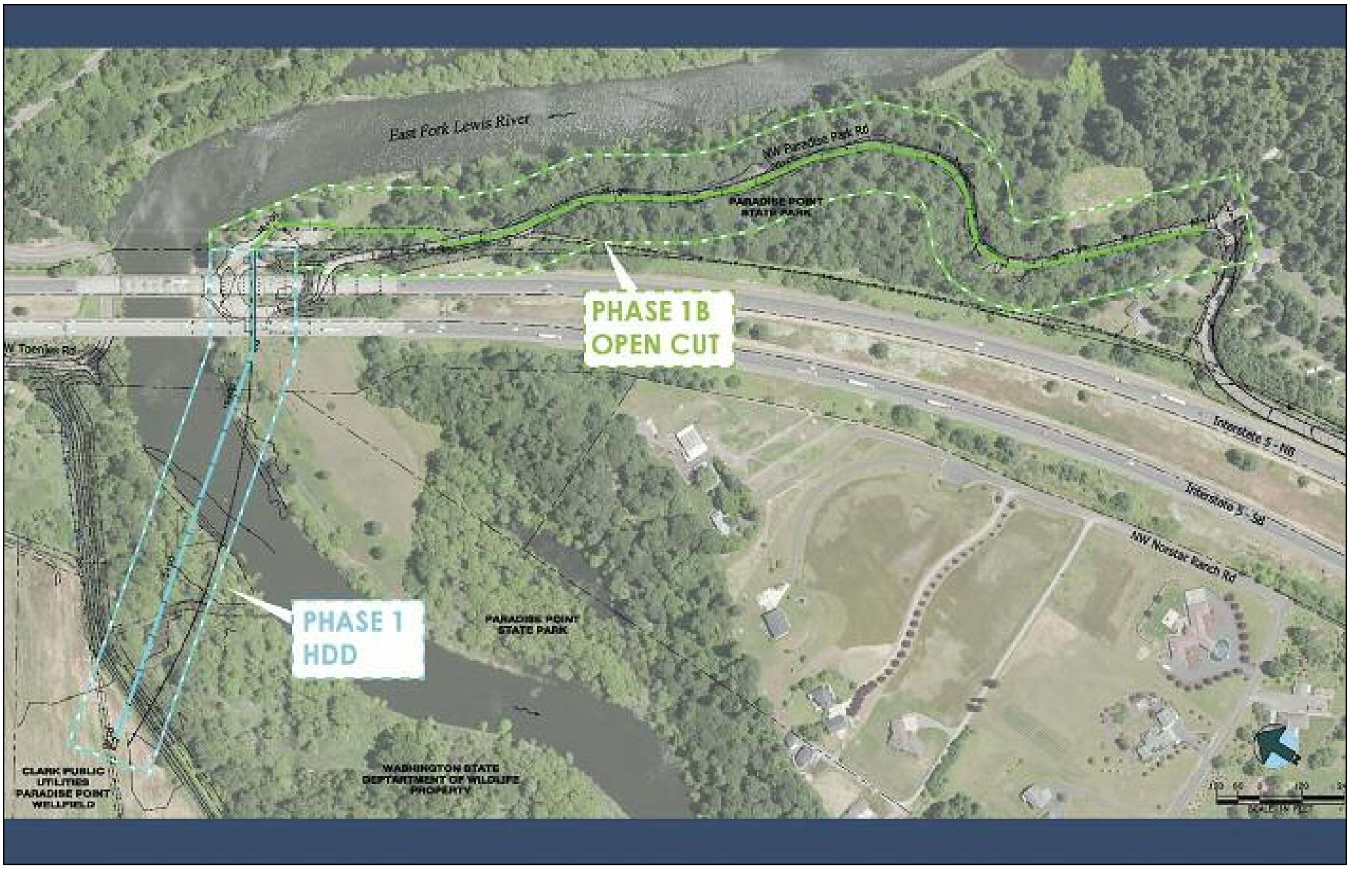


Figure 1. Project Site Location

HDD installation of approximately 1,200 feet of 24-inch-diameter raw water transmission main and a 20-inch-diameter casing pipe for the bundled pullback of an 8-inch-diameter Water Treatment Plant (WTP) backwash pipeline and communication conduits. The design team elected to install a casing pipe rather than perform a bundled pullback of the backwash line and conduits to eliminate the risk of losing one or more of the conduits during pullback. Pipeline installation will continue south from the HDD termination an additional 3,300 feet, utilizing open-cut construction across land owned by the Washington State Department of Transportation and Paradise Point State Park, as shown in Figure 1.

HYDRAULICS, PIPE SIZING, & PIPE MATERIAL

Based on the build-out flows for the well field and WTP operations, CPU engineering staff determined the pipe diameters for the raw water pipeline and the backwash pipeline to be 24 inches and 8 inches, respectively. A pipe material evaluation was performed to determine the most cost-effective pipe materials that were compatible for the proposed installation methods and the pipeline design pressure criteria. The pipe material evaluation included a transient analysis and analysis of soil resistivity.

The transient analysis was performed without surge protection during emergency shutdown of all pumps. The analysis assumed HDPE piping for the river crossing and ductile iron piping for the remainder of the alignment. The transient analysis indicated maximum surge pressures greater than 450 pounds per square inch and minimum pressures below -14 psi causing column separation and potential pipe cavitation. Combination surge critical, vacuum relief-air inlet and air release valves were recommended along the pipe alignment as required to mitigate the transient pressures.

Based upon the pipe material evaluation, the design team recommended that CPU bid both fusible PVC DR 18 and HDPE DR 9 pipe for the HDD portion of the project to increase competitive bids. Ultimately, HDPE was used for the installation of both HDD crossings.

PERMITTING

One of the most challenging aspects of the project was the permitting process and designing the pipeline to meet the conditions imposed by the permitting agencies. Eight permits were obtained for the construction of Phase 1, issued by various federal, state, and county agencies. Due to the site layout restrictions, the HDD rigs and staging areas were located in wetland areas. The wetlands proved to be the most challenging conditions to permit, combined with the necessary Joint Aquatic Resources Permit Application (JARPA) for the

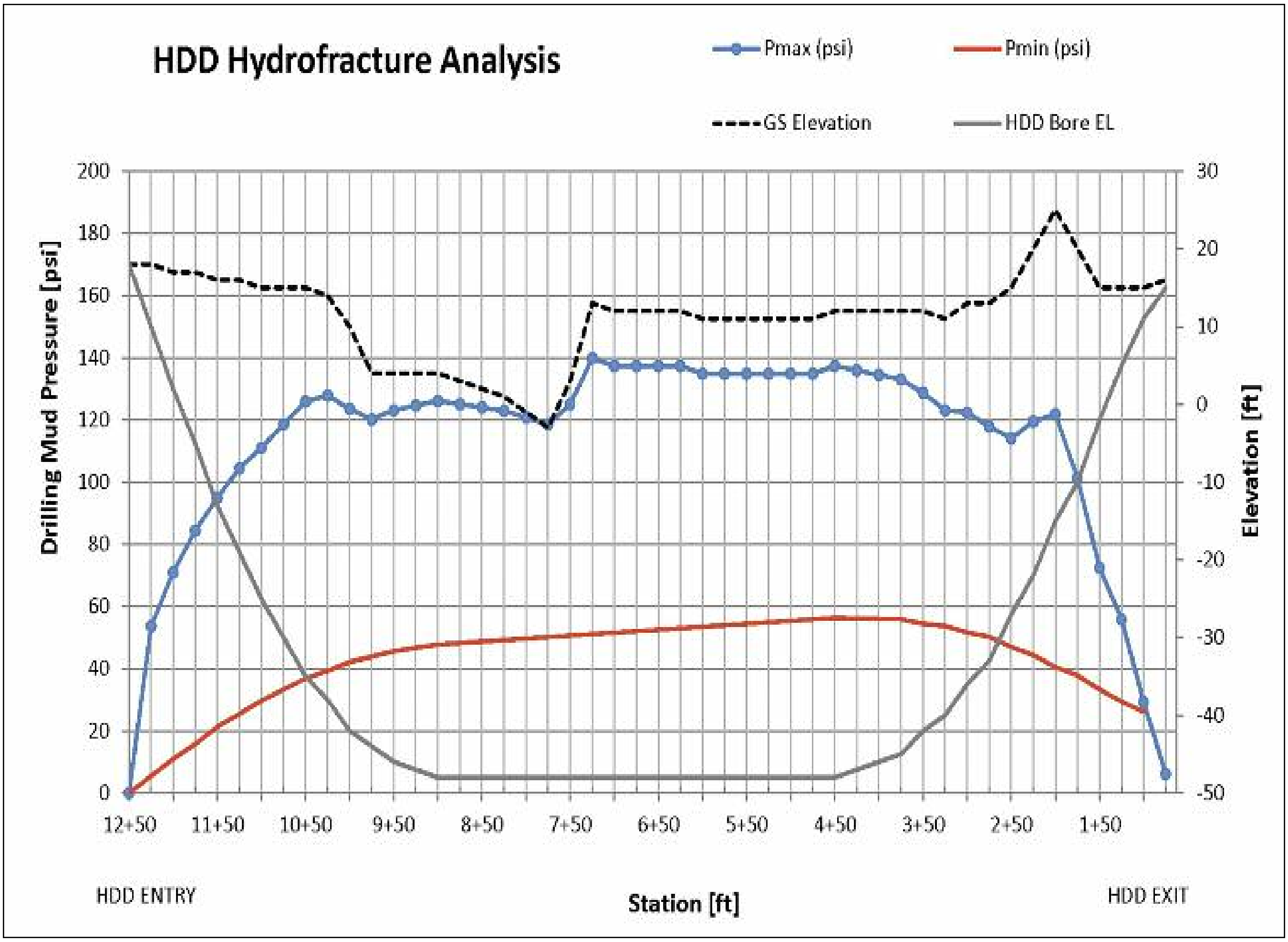


Figure 2. HDD Hydrofracture Analysis

river crossing, which defined an allowable HDD work window for a salmon-bearing stream. The JARPA permit work window provided minimal overlap with the allowable work start date established by State Parks to minimize impacts to park users, forcing the Contractor to complete work during a two-month window (July-August 2015).

GEOTECHNICAL CONDITIONS

To determine subsurface conditions in the project area, a mud rotary drill collected vertical information to a depth of approximately 100 feet. This boring was completed on the southern bank of the East Fork in the vicinity of the proposed entry point of both drills. The boring encountered approximately 35 feet of very loose to loose silty sand/sand with silt, underlain by medium dense to dense silty sand/sand with silt to the maximum depth explored. This boring was compared to previously completed studies for the Paradise Point Well Field on the west side of the river. It was found to be in good agreement with the main difference between the west and east sides of the river, being the transition to the denser material was approximately 15 feet deeper on the west side than on the east side of the river.

The medium dense to dense sands and silts encountered below EL -19 (eastern side) to -34 feet (western side) were highly suited to pipeline installation using HDD as they are highly stable and easily transportable by the drilling fluid, resulting in a stable borehole with minimal risk of settlement, hydrofracture, or borehole collapse. The near-surface very loose to loose sands and silts are less desirable, but still considered feasible for HDD construction. The lower-strength material is more prone to borehole collapse, settlement, and/or hydrofracture near the entry and exit points where depth of cover is low. To mitigate steering difficulties associated with soft soils, the bore was designed to enter the medium dense to dense material as soon as possible and to stay within this unit while beneath the river.

In the near-surface soils, it was prudent to assume that some minor borehole collapse would occur in the vicinity of the entry and exit points. This was planned for and addressed by specification to ensure that the Contractor had appropriate materials on site to clean up or mitigate any settlement or hydrofracture which might occur.

HDD DESIGN

A preliminary profile was developed based on the geotechnical information and the relative suitability of the soils. The majority of both bores were located within medium dense to dense soils. To enter into these soils rapidly, the bore entry was established at an angle of 16 degrees, transitioning after approximately 100 feet of straight section into a curve with a 1,000-foot bend radius. The base elevation of both bores is approximately 50 feet below the deepest portion of the river, and the flat section of the bore traversed beneath the river before beginning the curve back to the surface where it was designed to curve upward on a 1,000-foot bend radius to exit at an angle of 14 degrees. This resulted in a total bore length for each bore of approximately 1,150 feet.

A hydrofracture analysis was performed based on the soil and fluid mechanical properties and the cavity expansion theory (Luger and Hergarden, 1988). The model was developed to establish the maximum allowable pressure that can be applied to a given soil without exceeding the confining stresses in the soil allowing a cavity to expand. At a maximum pressure, a fracture occurs in the soil and the drilling fluid escapes from the expanded cavity.

Figure 2 shows locations along the proposed alignment where hydrofracture has a high likelihood of occurrence due to pressures created during the pilot bore. Where the blue and red lines are in close proximity to each other, the factor of safety (FOS) against hydrofracture is low, and where the red line rises above the blue line, the FOS is less than 1.0, and hydrofracture is expected to occur. hydrofracture

	Rate	Duration
Bore 1 – 20-inch HDPE, DR9		
Pilot Bore	380 feet/day	3 days
Reaming		
Stage 1 – 24-inch diameter	392 feet/day	3 days
Stage 2 – 36-inch diameter	470 feet/day	3 days
Pullback	142 feet/hour	8 hours
Bore 2 – 24-inch HDPE, DR9		
Pilot Bore	380 feet/day	3 days
Reaming		
Stage 1 – 24-inch diameter	588 feet/day	2 days
Stage 2 – 36-inch diameter	383 feet/day	3 days
Pullback	103 feet/hour	11 hours

Table 1. Bore Summary

HDD CONSTRUCTION

The contractor used a Universal 250 x 400 drill rig with 20-foot drill pipe for the construction of the pilot bores. The bores were guided by a gyro guidance system. The first challenge the Contractor had to overcome was the calibration of the gyro, which proved to be difficult on the initial pilot bore. After several attempts on the rig, the gyro was calibrated on the surface and the bore path was resurveyed to ensure that the gyro was calibrated correctly.

The pilot bore and reaming process for both bores were performed in the same manner to achieve a final bore opening of 36 inches in diameter. A jet assembly with a 9-7/8-inch-diameter mill tooth bit, with a 2-degree bend in the down hole assembly that measured approximately 20 feet was used for the pilot bore. Stage 1 of the reaming operation utilized a 24-inch-diameter reamer and Stage 2 utilized a 36-inch-diameter fly cutter (open-design clay reamer) and the 24-inch Stage 1 reamer as a centralizer. Immediately following completion of the 36-inch ream pass, the 24-inch reamer was repurposed and pulled back thru as a swab pass in preparation for pipe pullback.

Some of the challenges experience during both bores included minor hydrofractures at the exit locations, and brief (20- to 30-minute) shutdowns during pullback to allow the mud plant to "catch up" with the drilling fluid displaced from the bore hole.

Other challenges arose during the second pilot bore. At approximately 70 feet, drilling fluid escaped very close to the work area, and the Contractor attempted to use Poly Swell to heal the bore; however, the Poly Swell clogged the gyro, which took the remainder of the day to clear. Approximately 500 feet into the bore, the north seek on the gyro failed. The Contractor elected to remove several drill pipes until the gyro numbers matched the calculated numbers, then re-drilled without incident.

CONCLUSIONS

With challenging site constraints, environmentally sensitive areas, and strict permitting conditions, this project required open and transparent communication between CPU, the engineers, and the Contractor. This project was a success because of the ability of all parties to communicate constantly and clearly during construction. The designers addressed key concerns of the permitting agencies, such as avoiding hydrofracture in the wetlands, predicting hydrofracture near the entry and exit, protecting the river with proper depth of bores. By doing so, the designers were able to design to these critical permitting conditions, allowing the HDD process to be successful.

REFERENCES

- *Apex (2010) Paradise Point Water Transmission Main. Geotechnical Evaluation. La Center, WA.*

- *Bennett, R. and K. Wallin, 2008. Step-By-Step Evaluation of Hydrofracture Risks for HDD Projects, North American Society for Trenchless Technology, Proceedings of 2008 No-Dig Conference, Dallas, Texas.*

- *Luger, H.J., and A.M. Hergarden, 1988. Directional Drilling in Soft Soil: Influence of Mud Pressures, International Society of Trenchless Technology, Proceedings of 1988 No-Dig Conference.*

- *Staheli, K., Price, C., and L. Wetter, 2010. Effectiveness of Hydrofracture Prediction of HDD Design, North American Society for Trenchless Technology, Proceedings of 2010 No-Dig Conference, Chicago, Illinois.*

Auger Bore Challenges Under a State Highway

Michelle L. Macauley
Jacobs Engineering

Robert Metcalfe
GeoEngineers

Eric McArthur
UW Bothell

(Presented at NASTT's 2016 No-Dig Show – Dallas, Texas)

This trenchless project was part of a larger campus expansion and involved crossing a state highway near Bothell, Washington. For the crossing, a 313-foot-long, 30-inch-diameter steel casing was installed under State Highway 522 (SR 522). The steel casing was installed to allow for installation of a 16-inch HDPE water transmission main.

DESIGN CONSIDERATIONS

To facilitate permitting and avoid impacts to SR 522, the locations of the launch and reception shafts (and the length of the crossing) were set outside the Washington State Department of Transportation (WSDOT) right-of-way. An additional constraint on the south side was the Burke Gilman Trail, a heavily used bike and pedestrian trail along the Sammamish Slough. The crossing had to be at least as long as the right-of-way was wide, with the launch pit beyond the toe of the highway embankment. But the launch pit work area could not impact the trail, which needed to remain in use during construction. Additionally, the depth of the steel casing was vertically constrained by trying to maintain as much cover as possible under the highway yet avoid a 24-inch sewer pipe crossing near the launch pit (Figure 1). To have as much cover as possible, the alignment was virtually on the sewer pipe. Near the north end, the depth of cover was about eight feet.

Two geotechnical borings were advanced on either side of the

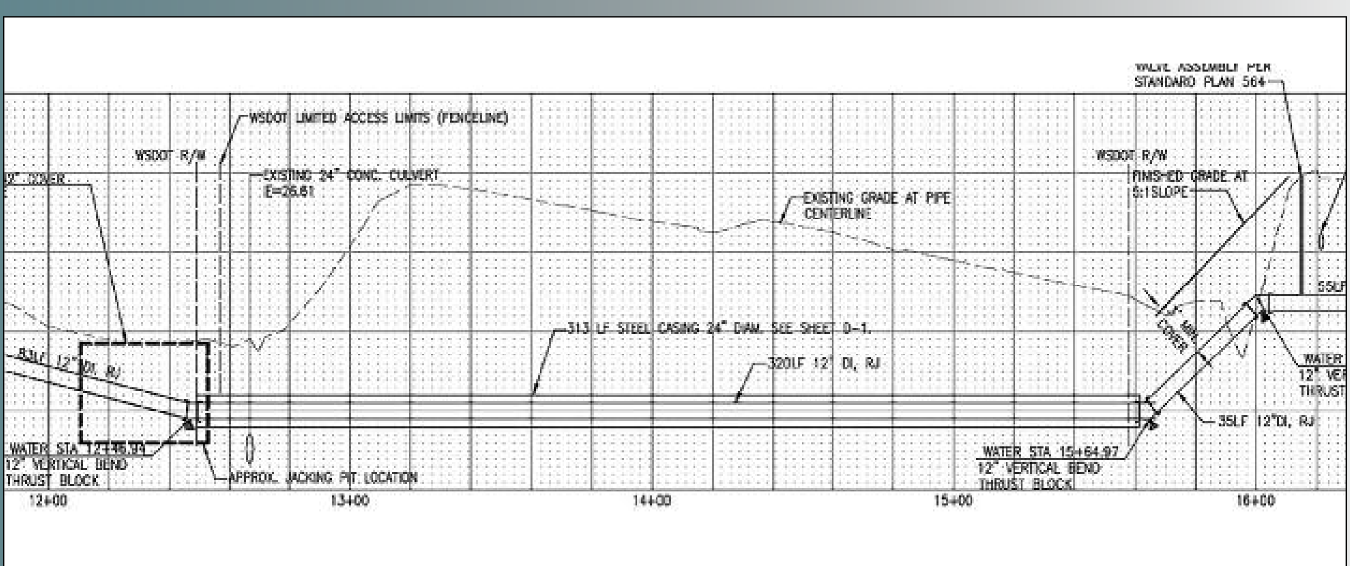


Figure 1. Crossing Route

Figure 2. Looking south at the launch pit, trail in background

crossing to evaluate the soil and groundwater conditions. The borings indicated the soils were very dense glacial till consisting of silty sand with gravel and cobbles. The groundwater conditions were of some concern because of the proximity of the Sammamish Slough southeast of the launch pit. However, the geotechnical borings indicated perched groundwater on the north side and not perched water on the south.

An added challenge during construction was that the contractor elected to upsize the casing to a 30-inch-diameter casing (from the specified minimum 24-inch-diameter casing). While ultimately this proved to be a very fortunate change, it reduced the minimum depth of cover by about six inches at the north end.

> "GEOTECHNICAL BORINGS WERE ADVANCED ON EITHER SIDE OF THE CROSSING"

CONSTRUCTION

Construction started in August 2014 with the construction of the launch pit. The launch pit was constructed about 10 feet south of the toe of the embankment. The soils excavated for the launch pit were consistent with what we anticipated. The glacial till was very dense and stood near vertical with minimal support at the face. As shown in Figure 2, the launch site was very constrained, with both the Burke Gilman Trail immediately behind the silt fence (shown in the photo) and an active low-voltage power line about 15 feet from the rear of the launch pit.

The contractor set up the auger bore equipment in the launch shaft and elected to use a steerable auger bore. The steerable auger bore with all flaps closed is shown in Figure 3 before it was set on-line and grade. At the face of the excavation, the glacial till soil is standing vertical.

Figure 3. Front steer-guided auger bore (pre-launch)

The front steer auger bore set-up was a unique addition to the equipment that the contractor selected for this crossing. As shown in Figure 4, the front portion of the equipment necks down inside the first 10 feet. This necking down of the inside of the lead casing helps funnel material into the following casings and provides a close fit for the auger flights within the steerable portion.

The front steer-guided auger bore uses hydraulically controlled flaps (or doors) located within the lead section to push the head in the direction it should go. The hydraulics are controlled from within the pit by the driller. As the bore progresses, the driller is able to control the fluid pressure applied to each flap. If very soft soil is encountered, the pressure needed to extend the flap decreases significantly. The driller is also able to monitor the relative location of the head to the starting location of the head by using a Dutch water level.

As the auger bore began, the soil coming out of the auger was as anticipated: silty sandy gravel with cobbles. About 40 feet in, a piece of one of the wings of the cutting head broke and came back in the spoils. Concurrent with this, there was an increase in the water content of the spoils. But we were able to continue excavating. As we continued, more pieces of metal started coming back in the spoils and the amount of water increased slightly. After stopping to re-confirm from the design drawing that we were not near any known utilities, we continued excavating. As additional pieces of metal came back in the spoils, it became increasingly obvious that we were augering through a piece of corrugated metal culvert.

Upon closer inspection, the spoils consisted of both native glacial till and pea gravel. While the fact that we were essentially boring through an old utility was disconcerting, we made relatively good progress. Later it was confirmed that there were no active utilities. Excavation continued along the planned line and grade until we were about 290 feet from the end of the crossing. At that point we had only about 25 feet to go and were across the mainlines of the highway.

At 295 feet, the driller noted a change in the pressures on the hydraulic panels at leading edge. He had not changed any of the pressure settings, yet the panels on the top of the machine indicated less resistance. Additionally, he noted an increase

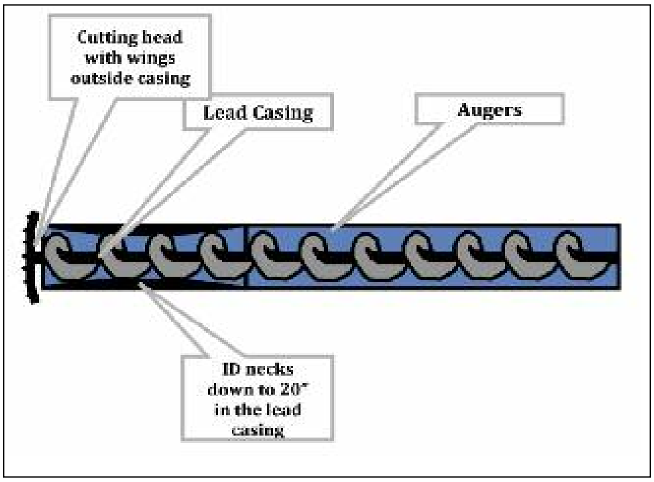


Figure 4. Schematic of inside of front steer–guided auger

in the torque required to turn the augers.

When he pulled the augers back, the flights were difficult to extract and he was worried that the face had been flooded. Further manipulations of the auger flights (turning, removing, re-inserting and turning again) confirmed that there was something at the face. After removing all the augers and sending a person in to look at the face, the driller confirmed that the face of the auger bore was packed with 2-4-inch quarry spalls. After some discussion it was decided to run the augers a few feet inside the leading edge of the casing to remove the quarry spalls and slowly push forward.

The driller reinserted the auger flight and started rotating the augers to remove the quarry spalls from inside the casing. Once removed, he slowly pushed forward on the casing while continuing to rotate the augers within the casing. In the span of three feet, the front of the cutting head rose almost seven inches and the pressure on the top flap dropped to almost nothing.

Immediately, the contractor stopped all equipment and ran to the other side of the crossing to look at the ground surface. The roadway had experienced about one foot of heave.

Fortunately the heave was contained to the two north-most lanes of the freeway, which were two off-ramps. The two main lines were not impacted. After implementation of emergency closure of the two off-ramps, the contractor began digging down to the front of the auger bore casing to determine what caused the sudden rise in grade.

After excavating down to the front of the casing, it was discovered that under about a foot of base course and four feet of structural fill there was a layer of geotextile over a few feet of four- to six-inch quarry spalls over two- to four-inch quarry spalls over glacial till. The bottom of the leading edge of the casing was on the glacial till and the face of the casing was full of quarry spalls.

A vactor truck was used to remove quarry spalls from in front of the cutting head. Once the quarry spalls were removed, a backhoe was use to push down on the top of the steering head as the casing was pushed forward from the jacking pit. For the last 23 feet, the casing was welded on in the jacking pit and pushed forward through an open excavation and through the last portion of unexcavated soil before the reception pit.

Upon evaluation of the soils in the excavation where the casing heaved the road, we concluded that the casing likely encountered an old ditch line filled with quarry spalls and covered with geotextile. It is postulated that during a previous highway expansion the ditch was filled in with quarry spalls, covered with geotextile and filled over.

Construction in a built-up urban environment poses unique challenges. Even with as-built information, historical photos and geotechnical borings, there will often be unexpected conditions. For this project, a local contractor with considerable experience and capabilities was instrumental in mobilizing the resources needed to complete the project.

REFERENCES

- *GeoEngineers, December 5, 2014, Geotechnical Engineering Services, SR522 Water and Sewer Repair, UW Phase 3 Building, Bothell, Washington.*

Tough Lessons Learned and Applied: Difficult Pipe Bursting in Gresham, Oregon

Jeremy Provenzola
City of Gresham

Andrew Thorne
City of Gresham

(Presented at NASTT's 2016 No-Dig Show – Dallas, Texas)

The City of Gresham is a community of just over 100,000 people sitting immediately east of Portland, Oregon. The service area for the wastewater infrastructure is approximately 22 square miles comprising seven distinct drainage areas. Approximately 300 miles of sanitary sewer mains and eight pump stations convey the City's sewer flows to a single treatment plant which discharges directly to the Columbia River.

Each of Gresham's seven drainage basins are served by a collection of sewer trunks and interceptors. A primary trunk in the East Basin has been recognized for several years as operating over its designed capacity. Furthermore, future build-out of the East Basin would contribute significant additional loading to the

already undersized trunk. Aware of the existing issues with the trunk, the City funded a Capital Improvement Plan (CIP) budget to perform a modest upsizing of the trunk.

However, in the process of updating the Wastewater Master Plan in 2012, it was discovered that capacity concerns had been significantly underestimated. Of the eight nodes designated a Risk Level 1, five were found along the East Basin. Additionally, the East Basin accounted for 13 of 36 Risk Level 2 nodes across all seven basins. Both risk levels call for immediate system improvements. The East Basin trunk was already more undersized than initially thought, and would be required to accommodate higher future flows than initially planned, and sooner than previously projected. It was obvious that the City's modest CIP budget for a trunk upgrade would need to be stretched much further than when it was initially adopted.

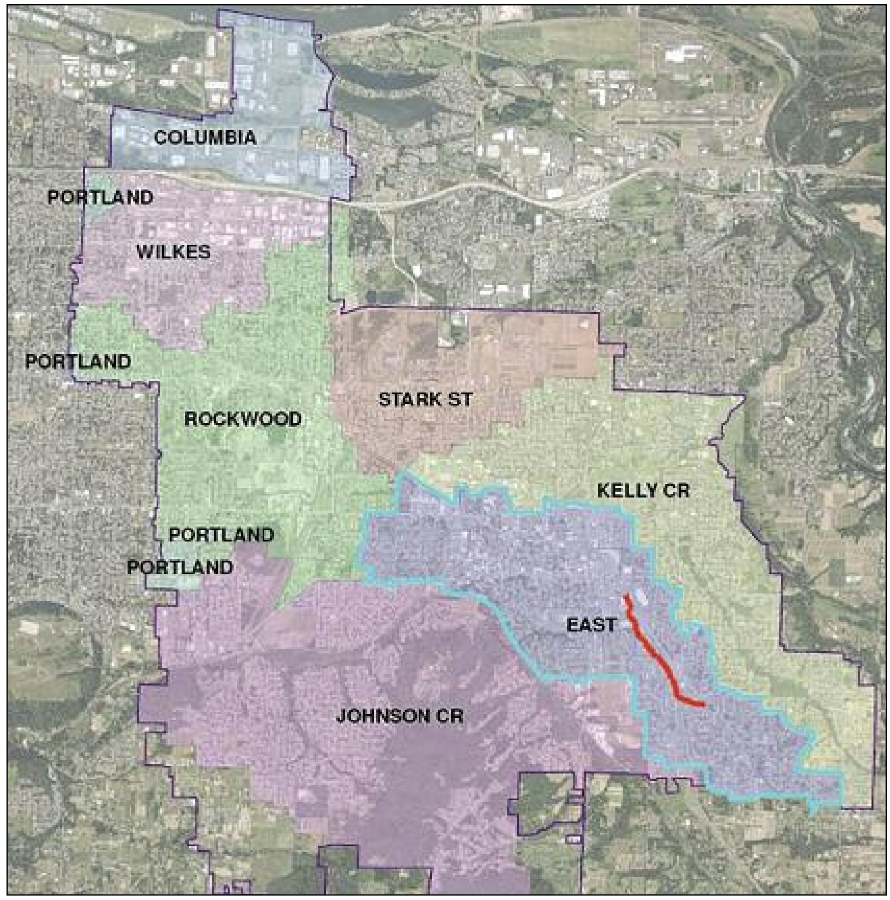


Figure 1 – Gresham's seven drainage basins and two additional plan districts

CHALLENGES

Adding to the budgetary challenges was a host of technical challenges that culminated in what was anticipated to be a difficult project to troubleshoot, design, and build.

PIPE SIZE AND METHODOLOGY: What was initially planned as a nominal size upgrade of one or two pipes quickly grew to an upgrade of three or four pipes. Whereas the City staff had considerable experience with a variety of trenchless technologies, the required upgrade presented a distinct challenge when compared to "routine" projects. The project was initially planned as a pipe bursting project, but City staff met with a handful of local contractors and trenchless consultants to discuss other potential technology options for the project. (See Table 1.) Ultimately it was agreed that although the circumstances would be difficult, pipe bursting was still the ideal solution moving forward. In order to mitigate the challenge of the upsize, it was decided to pursue the maximum reasonable increase in capacity while at the same time focusing aggressive efforts to minimize upstream inflow and infiltration (I&I) throughout the basin. The result of this decision meant that the design would implement a combination of upgrades including: 18-inch concrete to 24-inch HDPE, 15-inch concrete to 22-inch HDPE, and 12-inch concrete to 20-inch HDPE. Adding to the difficulty was that the depth of the existing pipe ranged from 8 to 30 feet deep.

EXISTING UTILITIES: Although existing utilities present a challenge on any excavation project, the challenge was more acute for this project both due to the critical nature of the proximate utilities and the degree of material displacement resulting from the pipe bursting. In one case the existing sewer lay approximately one foot below a 112-inch storm culvert and inches below the 50-inch Bull Run Conduit, the primary water source for the majority of the Portland metropolitan area. Many of these conflicts would be resolved with a combination of potholing and excavation to expose, observe, and alleviate displacement.

LOCATION: The alignment for the East Basin trunk weaves through private lots and crosses major arterials and a highway. Some of the lots are commercial whereas many of them are high-density residential, each posing unique challenges and a varied mix of stakeholders. One complex is a small apartment building owned locally whereas many of the larger complexes are held by out-of-state

Technology	Pros	Cons
Pipe Bursting	Small excavation footprint, familiar construction practice, lower relative cost, limited bypass times, lower permitting requirements	Required upsize pushes limits of technology, alignment remains near creek
Open Cut	No limit on upsize	Higher permit requirements, difficult creek crossings and protection of assets, road closure required, many utility conflicts, high cost
Pipe Reaming	Small excavation footprint, large upsize possible, lower permitting requirement	Higher cost, high risk of frack out in wetland or creek, risk of collapse, possible difficulty with PVC
Sewer Realignment	New alignment can avoid conflicts with wetlands, building and creeks, possibility of moving trunk to public ROW	Extremely high cost, challenges with rerouting existing services and connections
Pipe Burst w/ Auger Bore for Headspace	Potentially very large pipe bursting upsize possible, reduce/eliminate potential for heave	Longer bypass required than standard pipe burst, higher cost than pipe burst, potentially unnecessary

Table 1 – Brief overview of technology decision making process

interests that are difficult to engage. In addition to parking lots, wooded areas, and building corners, the pipe alignment crosses creeks, wetlands, and ponds. Managing these environmentally sensitive areas increased the challenge of access, staging, layout, impact, and restoration. It also introduced the challenge of balancing environmental permit requirements with the schedule, limited budget, and other stakeholder interests.

PHASE 1: LESSONS LEARNED

In deciding how best to tackle over a mile of trunk upgrade through such difficult and varying conditions, it was decided to break the project into smaller phases. The available funding was sufficient to cover two phases but the remaining work would need to be run through the CIP process to secure additional funding. Taking all factors into consideration, delineation for Phase 1 quickly became evident. Starting at the most downstream portion of the troubled trunk, the first phase would cover the 18-inch concrete pipe and a little bit of the 15-inch concrete pipe. Recognizing that the different property types would present unique challenges, the first phase would include all of the commercial properties while only impacting a single apartment complex. Furthermore, the upstream terminal provided what seemed to be an ideal pivot point where one phase could end and the next phase could begin, essentially impacting only one isolated location twice. Finally, Phase 1 appeared to be situated in such a way that it could be constructed entirely without impacting the environmentally sensitive areas, thereby postponing the need for permitting.

EASEMENT ACQUISITION: Given the complexity of the project, different facets of the project were assigned to different members of the team. Specifically, one member was assigned the responsibility of acquiring construction easements from the property owners. Although forcing the contractor to proactively engage the correct stakeholders in a timely fashion was difficult, the situation would have been much easier to manage had the City secured the appropriate layouts for construction easements. Unsurprisingly, through an unfortunate communication error between City staff, the easement language implied that the duration of construction for each property would only be two weeks whereas in reality it would take significantly longer to get through each property.

PERMITS: As stated earlier, Phase 1 was laid out in such a way that suggested the need for environmental permitting could be avoided. Several hundred feet of the alignment lay under wetlands and ponds but there was one point in the middle of this stretch that was tantalizingly untouched by such restrictive labels. In theory, the project would be set up such that this point could be accessed and excavated as a receiving pit from both directions without impacting the sensitive areas surrounding it. Initially the city had considered pursuing a Joint Permit Application but the process seemed increasingly onerous, slow, and costly once there was a perceived means to avoid it. In hindsight, constant battling with the contractor to confine their work-

Figure 2 – Example of custom burst head breaking

space and the heightened difficulty of constrained access was not necessarily worth the tradeoff. The impact and quantities would have been so low that our permitting requirements would have been easy to manage.

INNOVATION: Recognizing the host of difficulties on the project, City staff made it clear from the beginning that there was a willingness to support innovative solutions. This approach left the door open for different and perhaps more innovative equipment and methodologies. The intent was that this would encourage the contractor to think outside-the-box while troubleshooting, while providing greater flexibility than usual. The advantage to the City would be the potential for breakthroughs as the project progressed to later phases. Among some of the innovations that the contractor incorporated into the project was a custom-fabricated winch for the bursting process. This led to the design of a custom-fabricated bursting head. The concept behind the design was to build a modular head that could be used on multiple pipe sizes. The design included an array of bolts aligned parallel to the alignment. The first instance in which this bursting head failed was immediately after the head's entry into a receiving pit. While other work was being performed, the contractor and the fabricator revised the head design and incorporated a handful of tweaks. Unfortunately, during the next pull, the head broke before entering the receiving pit. Although the break did not occur in a sensitive area, the depth of the pipe was such that the contractor was still required to use engineered shoring for the retrieval, which added additional time. Not only does such a setback affect the schedule, but it also requires continuous sewage bypass, which exposes both parties to a higher degree of liability. In fact, there was a minor failure of the bypass system during this time which, fortunately, did not spill sewage on the surface as it was confined to the insertion pit. Nevertheless, this spill did require a self-report to Oregon DEQ. Caught in the City's effort to support an innovative approach, the contractor was informed that they would not be penalized for the schedule delay but they would of course be bearing the costs of retrieval. Despite additional enhancements, the burst head failed a third time during the contractor's next burst. Due to the depth and other complicating fac-

Figure 3 – Custom built winch in operation

tors, the contractor lost another three weeks retrieving and then completing the pull. Although the City stands behind its decision to support innovative solutions, the compromise in this particular instance came at the expense of the tenants who were affected by the elongated impact to their premises.

UTILITIES: Existing utilities on site offered a couple of important learning opportunities for City staff. The first was a lesson in communication and assumptions when dealing with contractors or consultants. A portion of the 18-inch concrete line to be upsized beneath a major road crossing was determined to be in a casing to protect the 50-inch Bull Run Conduit which crossed above it. Initially, the contractor was expected to perform an exploratory pit to determine if it was possible to burst the pipe in the casing. Due to the depth, location compared to the roadway and the proximity to a 112-inch storm culvert, it was determined that simply changing the alignment and boring a new crossing would be a more cost-effective option. A large bore pit had been excavated and boring had begun when, through a miscommunication, the Bull Run Conduit had not been potholed to ensure the bore would have adequate clearance. Boring was stopped immediately, and the conduit was potholed along the alignment of the bore. Once it was determined that the bore would not be able to avoid the conduit, the bore was abandoned immediately. Ultimately, the City ended up bearing a significant portion of the cost of the abandoned bore attempt.

Additionally, there was a conflict with unexpected sanitary connections at the manholes. Survey had been performed by a team of City staff that had been acquired in a transfer from the county. These surveyors had little to no experience working with subsurface utilities and were evidently not sufficiently trained or equipped to properly diagnose the internal workings of a manhole. Since these connections were not noted in the bid documents, a change order was required to manage these connections. Management of the connections includes bypass, reconnection and any repair to the lines. The cost of the change order was very high relative to the work being done.

PHASE 2: LESSONS APPLIED

Immediately after completion of Phase 1 of the East Basin Trunk Repair, the City began early design and engineering for Phase 2. The length of Phase 2 was predetermined by budgetary constraints and included upsizing the trunk through the band of apartment complexes upstream of Phase 1. The City decided that some professional assistance would be helpful to prepare for the second phase of this project. Two firms were selected to be involved in this project – one to assist in permit acquisition, determine construction footprints and address sequencing; the other to assist with easement acquisition. Using the skills of both firms and the City's experience with the first phase, several of the lessons learned from the first phase were applied to Phase 2. The end result was a successful second phase of the project.

EASEMENT ACQUISITION: While Phase 1 had difficulty acquiring the proper easements to perform pipe bursting operations, the challenge facing Phase 2 easements was determining the available space to be used for construction. In all three apartment complexes affected by this project, space in proximity to the trunk alignment was at a premium. The goal of the City with regard to easements was to obtain enough area to complete the project with as little impact to the apartment parking as possible. An engineering firm with extensive experience in the field of pipe bursting was valuable in determining the project area required for each burst. Insertion pits, layout areas, bypass routes, construction areas and staging were all determined by the design firm. These layouts were utilized to create the easement acquisition documents. To further ensure involvement and understanding of owners and property managers, City staff, design firm staff, and easement acquisition staff performed walkthroughs with as many property representatives as were available. The walkthroughs greatly streamlined the acquisition of temporary construction easements for this project. It also appears that this early involvement helped improve relationships with the involved parties as work proceeded.

PERMITS: Phase 1 was designed to have no permit requirements, but it proved to be a difficult task ensuring the contractor worked only within the 'safe zone.' Phase 2 could not be accomplished using this method; permits were required. The design and permitting firm performed the leg work necessary to submit a request for General Authorization. The authorization was acquired in a timely manner and did not hold up the bid date. Hiring a professional with experience in the permit application allowed the City to perform other parts of the design and engineering work for the project instead of spending time navigating the permit process and, in theory, eliminated the risk of 'novice mistakes' holding up the permitting process. With the design layout in place for the contractor, the work was all performed within the permit requirements. The majority of the excavation was performed outside of wetland areas, most of the bypass routing and layout also remained outside of the wetland, and the contractor's erosion control held throughout the project. The site even held up remarkably well during a 100-year rain event near the completion of the project.

INNOVATION: Although the innovation of the contractor in Phase 1 caused sizeable project delays, the City felt that there was still value in the ingenuity and experience of contractors in the area and did not wish to stifle this in the contract. Specifications were tightened up in order to make sure equipment met industry standards, but the only thing abnormal added to the specifications was a Certificate of Rapport. This certificate would ensure that any contractor hiring a subcontractor to perform the bursting could show a familiar and compatible working history with that subcontractor. The City also changed some specifications that had previously been perceived as not being static-friendly, thus stimulating more interest from static bursting contractors as an acceptable method for this phase. Due in part to these changes, the contract was awarded to a general contractor whose subcontractor operated static bursting equipment. The equipment utilized a chain being pulled by a hydraulic rig. The equipment performed very well in the soil conditions and no emergency retrievals were required. The only difficulty seen by this bursting method was weak soil buckling under the pulling force of the rig. This was remedied with some driven piles that offered more resistance for the pull rig. A major risk was averted during Phase 2 compared to Phase 1 since there was no bypass pumping running over night or over the weekend. Temporary connections were in place at the end of each work day. The other advantage of the static burst was that it allowed us to eliminate a section of open cut since percussive force on a nearby foundation would not be an issue.

UTILITIES: The easiest implementation of a learned lesson for Phase 2 was inspection by City crews to locate all sewer connections at manholes and make sure they were included in the bid documents. This was done by making physical entries into each manhole to positively identify all connections. Since these laterals were known by the contractor before construction, they were prepared to bypass and reconnect the laterals which produced a cost savings for the City. In regard to utility crossings, the city was very clear that crossings and potential conflicts would be potholed by the contractor before construction. There were no utility crossings on the scale of the Bull Run Conduit, but ensuring potholing was performed did prove useful in Phase 2. Potholing a waterline crossing for the open cut portion of the job revealed that the attached fire line was installed with unrestrained joints. Instead of risking the private water system of the apartment complex that may have been entirely unrestrained, a simple alignment adjustment allowed us to limit the risk at the waterline crossing. This project only damaged one utility that could have been potholed and protected; an un-located private storm line.

	Phase 1	Phase 2
Feet Installed:	2,060	1,800
Construction Bid:	$799,000	$818,000
Overages:	17%	5%
Construction Cost:	$934,830	$858,900
Consulting:	$0	$107,000
Total Cost/Foot:	**$454**	**$537**

Table 2 – Cost comparisons between phases

SUMMARY

At this point, the East Basin Trunk Upgrade project has offered the City of Gresham a rare opportunity to test different contract and project management approaches under similar construction conditions. In this environment the City was able to apply lessons learned from the first phase to the second and use two distinct management approaches. Future phases of this project will experience their own unique challenges, but with the knowledge and experiences of the first two phases there is a much larger likelihood of success. A cost comparison is a reasonable but difficult measure between the first and second phase of this project. The difficulty of comparison stems from the different nature of the contracts (i.e. different pipe sizes, different constraints and different bursting methods, etc.). A reasonable comparison could however be made between contract overages. Phase 1 of the project was over 17% higher than the contracted amount whereas Phase 2 was only 5% higher than the contracted amount. A major difference between the overage of Phase 2 compared with Phase 1 is that the overages of Phase 2 were mostly City initiated changes (i.e. design mods while Phase 1 overages were mostly contractor initiated). A major advantage of City initiated changes was they were not made in a time sensitive environment which gave the City more leverage to negotiate costs or explore other design options.

Construction and project management of Phase 2 certainly went much smoother than it did for Phase 1, it would be fair to therefore assume that this was the more successful project; however, the actual values suggest such an assertion is not so simple.

The final cost per foot wound up being dramatically lower for the first phase. It should be clear that this is still a difficult comparison to make given the many distinctions between the two phases. Most notably, the second phase included permitting and the preliminary work associated with that effort whereas the first did not; however, the first included larger and much deeper pipes and more significant traffic control which at least partially mitigate that disparity. The point is that despite so much difficulty, there was still an evident economic benefit in the unconventional approach to Phase 1. This is not to say all the costs for the different approaches have been captured, such as the economic impact to businesses along the Phase 1 alignment, or the non-monetary costs, such as the hardships and difficult experiences of certain tenants. However, under the circumstances, it would be difficult to assert that a different, more thorough approach would have been used for Phase 1 in hindsight. Keep in mind that the mindset behind the Phase 1 approach was intended to be higher-risk/higher-reward given the budgetary constraints and it would appear that the City achieved that intended reward by sacrificing a high degree of thoroughness and relying heavily on an ability to manage a project competently under looser conditions.

What this case study offers for other agencies is a rare look into the distinct management styles of two comparable jobs and the benefits and disadvantages of each approach. Ultimately, it comes down to recognizing the risks at hand, acknowledging the risks that can or should be either accepted or mitigated, and managing those risks moving forward.

Preventing CIPP Mishaps with QA Process Implementation

Thomas Porzio, P.E.
JACOBS Engineering Group

There has been tremendous growth in the CIPP industry and a dearth of experience to go around. The key to improving overall quality and reducing costly mistakes will be a combination of installers redoubling their efforts to strictly follow manufacturer procedures and the owners' having quality assurance practices in place. This paper will focus on quality assurance practices that the owner can employ. An understanding of each subprocess is necessary to achieve quality installations.

Subprocess	Wrinkles, fins, folds (WFF)	Lifts	Blisters	Short Liner	Thin Liner	Low Test Values	Leaks
Pipe Measurement	X			X	X		
Materials Selection/Order	X	X	X	X	X	X	X
Wet-Out	X	X	X	X	X	X	X
Handling/Installation	X	X		X	X	X	X
Cure		X	X			X	X
Materials Sampling & Testing					X	X	

Table 1. Subprocess Influence on Potential Defects

PROCESS

After manufacturing of the liner and resin in factories, the remainder of the CIPP manufacturing process can be defined as the six subprocesses in Table 1. The efficiency of each subprocess defines the level of quality of each CIPP produced. When there are mistakes in a subprocess, shortfalls in quality can result in the defects shown. Note that each of the defects can be influenced by one or a combination of the subprocesses. Each of these subprocesses will be discussed in greater detail in the following sections.

Pipe measurement affects quality in three defect categories. The two obvious factors regarding host pipe measurement are diameter and length, with a result of too much or too little liner potentially resulting in serious problems. An example of breakdowns in the host pipe measurement process: The diameter of a segmented clay tile pipe was shown on a map to be 60 inches, recorded by a CCTV subcontractor as 58 inches, and installed as 60 inches. The results were large wrinkles, fins and folds (WFF) as shown in Figure 1. Investigation found some resin void areas within some of the WFF and other quality issues related to the excessively large liner. The host pipe was later determined to be 55 inches in diameter, not 60.

Lesson 1is not to be "fooled" by map dimensions. An accurate pipe measurement and robust communication process is essential to ordering the right size liner. This process should include procedures by which the pipes are physically measured, forms for recording the measurements, and a chain-of-custody system with checks and double checks. Once the

Figure 1. Significant WFF (wrinkles, fins and folds)

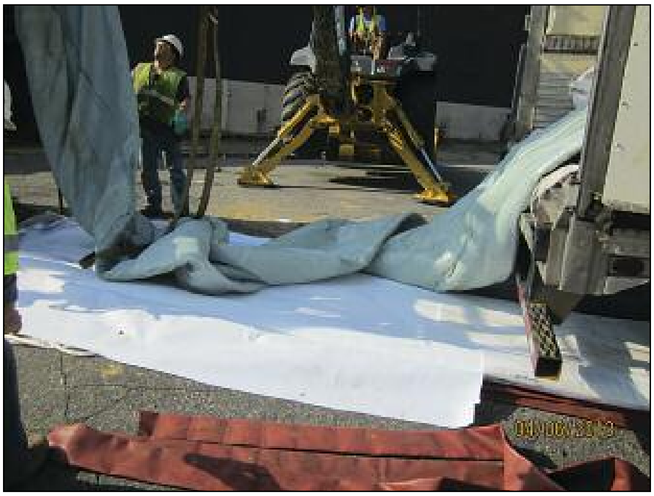


Figure 2. Liner handled with backhoe and sling

Figure 3. Severe WFF in poorly handled liner

liner is on site, the ID and length of the host pipe must be remeasured by the installation crew. This critical last step must be executed, because actually installing the wrong size of liner is where the really high costs happen. If dimensions of the delivered liner don't match the crew's measurements, the liner should not be installed! The measurement and communication process should be defined in the specifications and strictly managed by the quality inspection team to assist the contractor in getting it right.

The quality of each CIPP starts with materials selected for wet-out and installation. Although this statement appears obvious, it's surprising how often the wrong decisions are made. As shown in Table 1, materials selection and liner order affect quality in every defect category. Several of the key factors to consider for materials selection are (1) site-specific conditions (host pipe size, material, configuration, I/I, etc.), (2) resin and catalyst type, (3) type and size of CIPP liner, (4) installation process (water, steam, UV), and most importantly (4) assignment of the well-equipped, well trained installation crew to bring it all together.

Liner handling and installation affects quality in a majority of the defect categories (Table 1). Liner handling includes many aspects of wet-out, loading of the liner into the refrigerated truck, unloading it on site, and control of the inversion head and inversion rate. Two key items associated with installation of the liner are lifting & conveying and surface protection. Figure 2 shows a liner being lifted with a sling and backhoe. Backhoes do not have the range of motion required to properly move the liners, and slings cinch and ball-up the liner. This type of liner handling can result in excessive stretching of the liner, tearing of flame bonds between felt layers, WFF (wrinkles, fins and folds) and potential rope burns through the coating.

The CIPP in Figure 3 (handled and installed in the same way by the same crew as in Figure 2) wound up with severe WFF which were cut out prior to relining the pipe. Using motorized rollers or conveyors and a spreader bar to handle liners reduces and more evenly distributes stress on the liner (and stress on the crew). Cutting or scraping of the liner can result from exposure to rough surfaces or sharp edges as shown in Figure 4. Note that while some of the sharp edges are covered with felt, some sharp edges are exposed to the liner, and the liner is being dragged on the ground.

Protection of the liner and its coating from damage is critically important. Damage to the coating can result in localized resin washout during installation or leakage through the finished CIPP. Liner handling equipment should be fabricated to eliminate sharp edges. The installation crews should place barriers such as dry felt between rough surfaces and sharp edges to minimize potential for damaging the coating and inner layers. And lastly, the crew should inspect the liner for damage as it approaches the final insertion point and make any field repairs necessary.

As noted in Table 1, the cure affects quality in four defect categories. Regarding curing, there are two ends of the spectrum. One is not getting the correct amount of heat where it needs to be, and the other is too much heat. One instance of not getting enough heat resulted in a lift in the liner. The cure record showed low interface temperatures and circulation problems, but the lift was not present hours after the cure ended. It was only evident three days later. Many lifts do not give us this red flag of questions raised during cure, with lifts being found even after the interface readings appear adequate. Had the liner been immediately repressurized and reheated, the lift may have been repaired. It's also possible that taking interface readings at more locations may have identified an incomplete cure before it was abundantly apparent to

Figure 4. Liner and coating exposed to rough surfaces and sharp edges

all on Day 3.

Allowing the liner to get too hot can result in resin-void pathways being created in the laminate wall and blisters (the two not necessarily being related). Selection of the type of cure and better control of the combination of input temperature and circulation reduces the possibility and level of blistering. Additionally, selection of higher heat-resistant coatings significantly reduces the possibility of blistering.

MANUFACTURING IN THE FIELD

There's nothing new about the problems noted above or the lessons learned, so why do these costly mistakes still happen more often than they should? Part of the answer is that CIPP is actually manufactured in the field, far from a controlled factory-like environment. The liner and resin components are separately manufactured in factories that have highly controlled atmospheres with few variations in the manufacturing process. There can be deficiencies in delivered product, but these are relatively few and far between. The resin and the liner come together for the first time in the wet-out facility, which is a warehouse type atmosphere that is pretty well controlled but with more variables affecting the process as compared to the factory environment. The wet-out and liner delivery can sometimes result in product

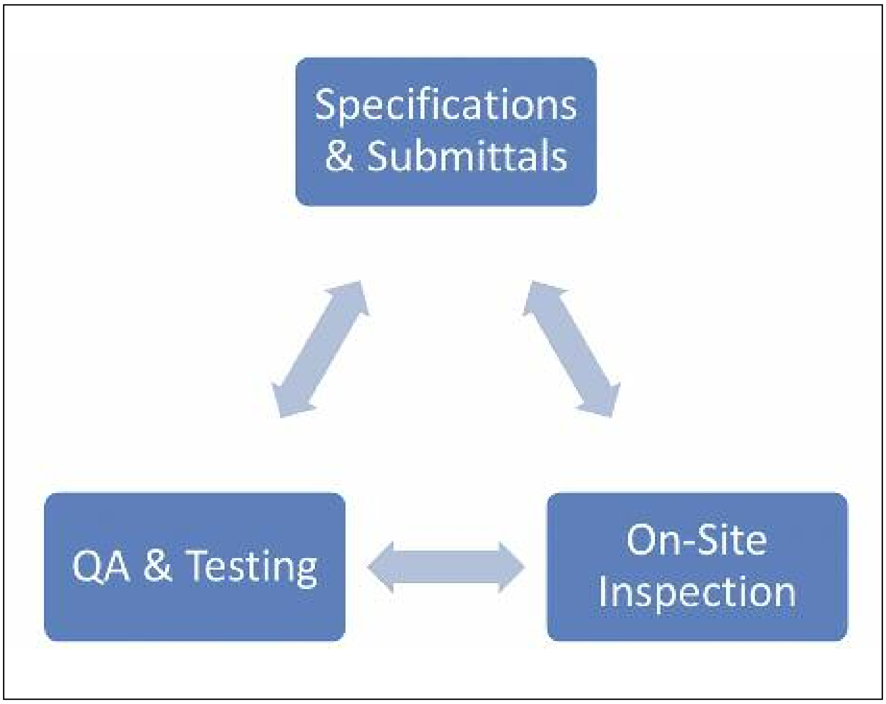


Figure 5. Quality Process Components

deficiencies, and at a higher rate than with the liner and resin that come from factories. The wet-out liners are installed in the field where there is very limited control of a relatively large number of variations in site conditions, including weather, access to manholes, and groundwater infiltration, as well as host pipe materials, shape, size, etc.

In addition to the wet-out process some of the key variables influenced or controlled by the contractor during installation include:

- Installation method (water, steam, UV);
- Liner handling equipment and practices;
- ype and quality of liner installation equipment; and
- Level of training and support of installation crews.

Because the CIPP is manufactured in the field and subject to such a large number of variables, there is much greater risk of deficiencies occurring. Therefore, it's especially critical to have processes in place to reduce or eliminate problems.

QUALITY DELIVERY PROCESS

The overall solution is a robust quality definition and assurance process. The three aspects of the process are interrelated and interdependent, and they work best when there is collaboration among owners, engineers, manufacturers and contractors.

The specifications must be project and scope specific, and written with input from all parties to ensure the document thoroughly communicates quality requirements to be delivered by qualified contractors (especially qualified crews). Once the project has started up and is being executed, the submittals process should be used as a final check to ensure (1) the contractor understood the specifications and has a plan to deliver according to defined expectations and (2) that results are being achieved in the field.

Because CIPP is manufactured in the field, the QA/QC processes in the field should be as robust as those applied in the factory and wet-out settings. Table 2 outlines the key actions recommended for each of the CIPP delivery subprocesses that support the quality process.

SUMMARY

Having a robust quality assurance process in place – implementation of project-specific specifications/submittals, onsite inspection, and QA/Testing – results in meeting expectations and providing higher-quality CIPP results. While there is opportunity for improvement in all components of the quality process, the

Subprocess	Specified Submittal Requirements	Onsite Inspection	Quality Assurance & Testing
Pipe Measurement	Pipe measurement procedure and forms	Periodic review of pipe measurement procedure; Check delivered dimensions prior to installation.	Review measurement form and related data prior to approval to deliver materials.
Materials Selection/Order	Resin and tube materials information.	Verify that specified materials and materials size (length, diameter, thickness) are delivered.	Review final video and all field records to verify delivery of specified product.
Wet-Out	Wet-out form and chain of custody from wetout to delivery at installation site.	Wet-out log serves as delivery ticket.	Check wetout log for proper materials (resin, tube coating, etc.).
Tube Handling/Installation	Project-specific tube handling procedures.	Photos and notes record observations that proper procedures are followed.	Review field notes, site photos and final video to verify procedures were followed.
Cure	Cure schedules approved by resin and tube manufacturers.	Photos and notes record location of thermocouples and heat-up, hold and cool-down temperatures and durations.	Review inversion log and digital logs to verify that the cure procedure was followed.
Materials Sampling & Testing	Type of samples and frequency of testing.	Observe location and method of sample taking.	Review materials property test results.

Table 2. CIPP Subprocesses Related to Quality Process Components

process too often receives less attention after the initial specifications/submittals phase. All phases are both critical and interdependent in delivery of high-quality CIPP; however, the key aspect of the QA/QC process that brings it all together is field inspection by individuals with experience in the nuances of CIPP installation.

REFERENCES

- *Kampbell, E., et al. (2011) – Quality Assurance and Quality Control Practices for Rehabilitation of Sewer and Water Mains, U.S. Environmental Protection Agency*
- *Muenchmeyer, G.P. (2007) – A Higher Level of Quality & Testing for CIPP Installations is a Reality, North American Society for Trenchless Technology (NASTT), 2007 No-Dig Conference & Exhibition*
- *Porzio, T. (2014) - Coatings and Cures – Is the CIPP Watertight?, North American Society for Trenchless Technology (NASTT), 2014 No-Dig Conference & Exhibition*
- *Shelton, J.W. (2012) – Cured in Place Liner Defects – Three Studies of Installed Liner Performance Quality, North American Society for Trenchless Technology (NASTT), No-Dig Show 2012*

The Rock Drill Adapter Solution

Laura Anderson
Director of Marketing
Akkerman Inc.

In late April, Brotherton Pipeline, Inc. (BPL) of Gold Hill, Oregon, embarked on what was expected to be the first of three routine guided auger boring installations. The contractor requested a field technician for the initial drive to provide crew training on their GBM 240A guided boring system and target visibility on extended runs. Through adversity, they ended up learning a whole lot more than they anticipated, and as an additional benefit took part in the longest run to date for the Rock Drill Adapter and drill bit tooling.

The SL38-300 project, owned by SoCalGas, is located in Bakersfield, California, and BPL is trenchless subcontractor to Snelson Companies, Inc. of Sedro Woolley, Washington.

The alignment was 400 linear feet at a flat grade, 10 feet below an irrigation canal and 20 feet below surface level. Two future runs will lengthen the gas line from an open-cut extension under Highway 99 to meet an in-road drive at a SoCalGas facility. The soil conditions were noted as compacted sands with some variability and blow counts around 20. The three 12-inch-diameter casing runs totaled 1,070 linear feet. For completion, eight-inch-diameter gas line will be pulled in as the casing is removed and the general contractor will finish with grouting.

Right out of the gate with the pilot tube installation, initial jacking pressures rose to 70 tons with rotational pressures at 3,500 psi, indicating that the geology was in fact much denser than expected. As a first course of action the contractor pulled back the pilot tubes and replaced the 45-degree steering head with the bullet steer-

ing head, designed to aggressively displace high blow count ground conditions. Unfortunately the change provided no relief to jacking and rotational pressures.

Next, the polymer-based lubrication was substituted for a bentonite mixture with a higher gel strength and suspension agents to prevent absorption.

At 258 linear feet into the bore the pilot tube string started to bow, jacking pressures rose to 75 tons, and the steering head was deflected downward, causing the operator to lose sight of the target. The crew pulled back a few feet of pilot tubes, increased the volume of lubrication, and made another attempt at advancement to little avail.

Shortly thereafter, the steering head reacted as though it had encountered an obstacle and further jacking was not possible. Luckily, the bore had progressed beyond the edge of the canal structure in an area with surface accessibility. The next morning a hydrovac service arrived and drilled down to the area of incidence, which surprisingly revealed no obvious obstruction.

BPL's project superintendent, John Kelly, realized that the project was at a crossroads. An open trench at this depth would have required a great deal of soil displacement. Furthermore, it was not likely that the landowner would permit an open trench and even if they did, there would not have been enough clearance around the perimeter for a shaft without encroaching on the irrigation canal.

At this point, the Akkerman field technician shared examples of past successes with the new Rock Drill Adapter using a Tri-Hawk® drill bit and offered it as a possible solution to the dilemma.

The inaugural pilot tube rock bore took place in September 2015 in Australia. To date, subsequent runs up to 225 feet have been achieved in soft rock in North America. The technology is based on directional drilling tooling for hard ground conditions yet the guidance and pilot tube installation processes are the same. Even though the tooling is designed for rock density which has been tested to up 10,000 psi, thus far it had not been used in ground conditions less than 6,000 psi. Furthermore, the tooling's lengthiest run to date was nearly half of this length.

Despite these circumstances, Kelly remarked, "We had nothing to lose. It was something that the field technician suggested and we agreed to give it a shot since we had no alternative." BPL received permission for its use from the general contractor and the tooling was expedited for delivery the following morning.

The Rock Drill assembly was launched into the existing bore path early the next morning. Given that over half of the bore was already hollowed out, the first length of the install went relatively quickly, and few steering corrections were necessary.

Steering with the Rock Drill Adapter is managed differently than when advancing a pilot tube string with a steering head, although the means and method for guidance control is identical. The LED target, located just behind the drill bit, was visible and its position was assessed by the operator on the monitor to guide steering corrections.

Consistent low pressure was maintained for jacking control while the operator slowly advanced and rotated the tooling from the 10 to 2 or 4 to 8 o'clock positions for upward or downward movement. Advancement of the drill head was maintained in a clockwise motion to prevent the pilot tubes from unthreading. This progression continued until the entire installation was completed at the end of the shift.

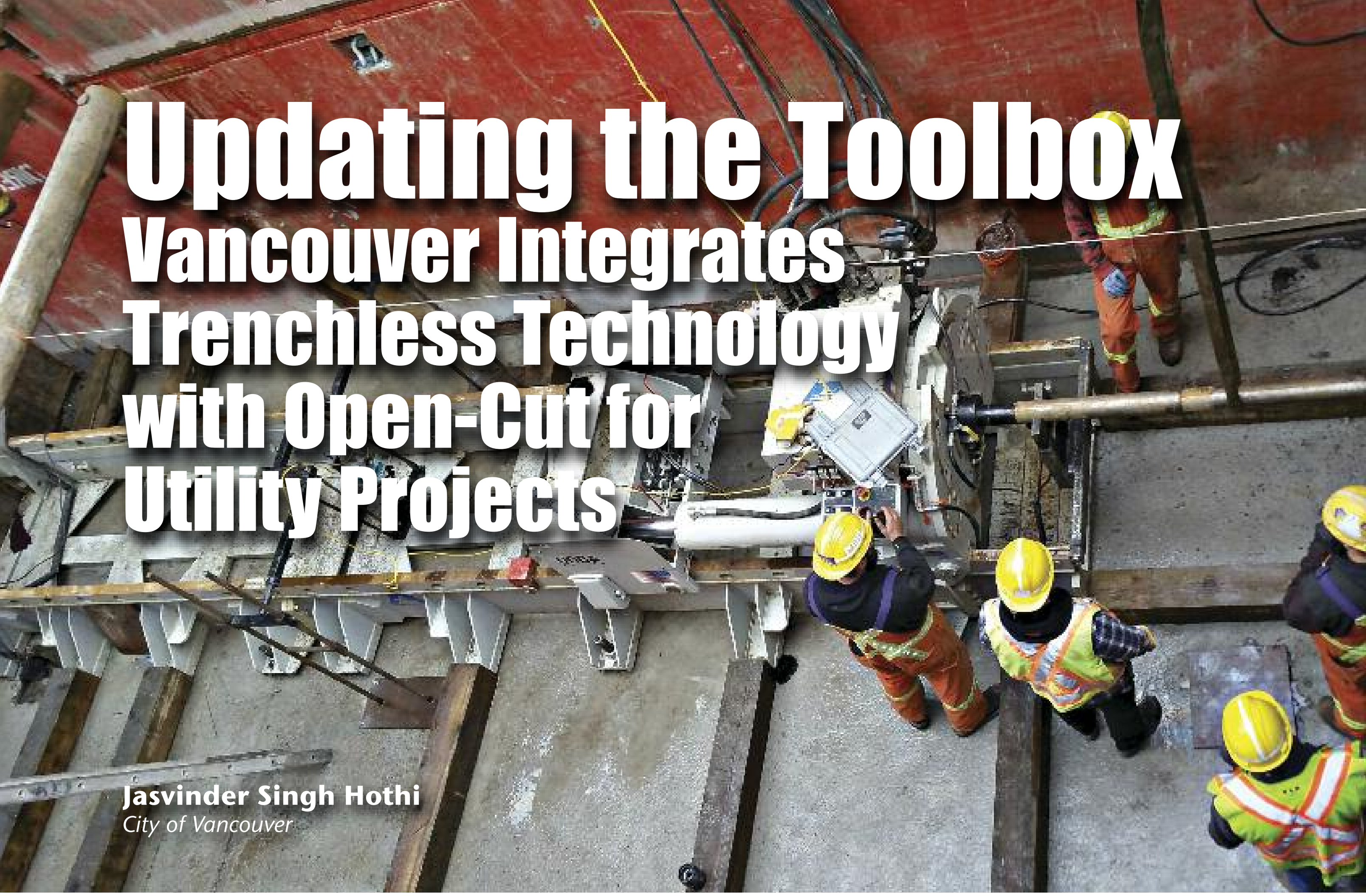
Although the Rock Drill Adapter was used a bit outside of its intended wheelhouse, it turned out to be the right tool for the job.

Kelly commented: "BPL, Snelson and SoCalGas were all very pleased with the alignment's success. We were basically at a dead end. You can't auger bore 12-inch casing that far and be accurate. We requested a field technician to provide training and hopefully bore assurance, and that's what we got."

Construction on subsequent 450- and 220-linear-foot runs began in May and the contractor installed them with guided auger boring methods. Even if they couldn't, BPL was able to proceed with confidence knowing that they have tooling choices to overcome nearly any challenge.

Updating the Toolbox

Vancouver Integrates Trenchless Technology with Open-Cut for Utility Projects



Jasvinder Singh Hothi
City of Vancouver

Over recent years, Vancouver, British Columbia, has experienced a rapid increase in population and urban densification. The City of Vancouver strives to maintain existing sewer systems and construct new systems, and has had to adapt operations to meet new pressures and demands – including internal demands from the City's own Traffic Management group, and external demands from the public and other local stakeholders.

The City of Vancouver's Sewer Operations branch, led by David Lundberg, is one of the most unique public sector construction organizations in Canada. The department works collaboratively and draws expertise from an internal design team – in the Sewers and Drainage Design branch – that facilitates all design and project management relating to the City's sewers infrastructure. A team of more than 240 employees works to construct, replace and maintain approximately 2,000 kilometers of storm and sanitary pipe. The volume and type of work that the department completes makes it similar to some of the largest design-build construction firms in western North America.

In addition to installing more than 1,200 storm and sanitary lateral connections to new homes each year, Vancouver's Sewer Operations branch has a goal to replace one percent of the City's existing combined sewer system annually. The goal is in support of the Province of British Columbia's environmental goal to replace all combined sewer systems with separated sewer and storm drain systems on all buildings by the year 2050. The Sewer Separation Program will stop untreated sewage overflows from entering Vancouver's waterways and the Pacific Ocean.

The majority of the City's sewer infrastructure work has traditionally been completed using open-cut construction methods. In and around 2011, City crews did complete several traditional pipe bursting jobs, but due to the types of projects the infrastructure team was taking on at that moment, continued use of trenchless methods could not be maintained and drifted back to the traditional open-cut methods.

While the City's construction and connection crews are proficient in these methods, there has been an increasing demand for a less disruptive and more efficient solution. To address this need, in May 2015 the department added trenchless technology into its operations and successfully used it in four major trenchless construction projects: Alma Street Separation Project; Telus Gardens Lateral Connection, utilizing horizontal direction-

The Canadian City of Vancouver added trenchless technologies to its sewer operations construction toolbox in 2015.

al drilling (HDD); three guided boring machine (GBM) lateral connections at East 41st Avenue and Inverness Street; and one of two Granville Street crossings, using large-diameter pilot tube guided boring.

Alma Street Separation Project

The Alma Street Separation Project was a major sewer separation project completed by the City of Vancouver in 2015. The project included four of the City's engineering departments: the Project Management Office, Streets Design, Street Operations and Sewer Operations.

Along with open-cut installation, a portion of this project was identified for completion by directionally drilling two sewer pipes from West 13th Avenue to Alma Street through a park at a grade of more than 15 percent.

After completing the excavation of the launch and receiving pits at more than five meters in depth, the installation of the two new sewer pipes was completed in just four days with minimal impact to the park. The total length of the project was 104 meters of 10-inch high-density polyethylene (HDPE) sanitary main and 104 meters of 15-inch HDPE storm main.

The success of this project is directly related to the outstanding collaboration between the City's Sewer Operations and Sewers Design teams, particularly during the critical pre-planning stage of the project. When considering low-impact and more carbon-neutral techniques, the Alma Street Separation Project highlighted how instrumental the pre-planning stage for is for success.

Telus Gardens Lateral Connection

At 1 million square feet of office, retail and residential space in downtown Vancouver, Telus Gardens is one of the largest developments Vancouver has seen in recent years. The storm drain and sanitary connection for Telus Gardens is located under one of the City's busiest intersections – Robson Street and Richards Street.

The Robson and Richards intersection experiences particularly high pedestrian, vehicular and public transit traffic. After careful consideration and preconstruction planning, the City's Sewer Operations branch resolved to directional drill a 300-

millimeter and a 375-millimeter storm and sanitary connection across five lanes of traffic, 44 meters, at a grade of 2 percent.

Due to the high traffic volumes, there were significant challenges in placing the HDD machine above ground to drill both pipes. The decision was made to lower the drilling machine into the launch pit, and drill from inside the shored trench. The same was done when the HDPE pipe was fused and pulled back into the launch pit.

The duration of the project took four weeks from start to finish, and was completed on time and on budget without disruption to traffic, public transit or local businesses.

41st and Inverness

A four-person crew from the City's Sewer Operations branch prepared for the installation of three residential sewer connections located on a dedicated disaster response route and one of the busiest east/west arterials in Vancouver. After analyzing the costs of previous connections on the same route using open-cut construction methods, it was determined that utilizing a pilot tube guided boring machine (GBM) to install the new connections offered cost and productivity efficiencies.

The three-step pilot tube method is in keeping with Sewer Operations' construction goals: safety, efficiency and sustainability. The GBM is also ideally suited for the construction scope of work for lateral connections for new homes.

City crew members were trained on a 308 Akkerman pilot tube GBM machine, which was then mobilized for the new connections located at 41st and Inverness. This technology was a first for the Sewer Operations crew, and it was a steep learning curve. However, the crew learned quickly, building efficiencies with each crossing.

After the pilot tubes were pushed through to the exit pit, 14-inch augers were installed inside the casing pipe and pushed across. After the completion of the casing pipe, a 4-inch sanitary PVC pipe and a 6-inch storm PVC pipe were installed as the carrier pipes and the annular space was filled with Cell-Crete non-shrink grout. Each lateral connection was a 15-meter bore at a 12-foot depth to the invert.

The crew completed the work two days ahead of schedule. Due to the success of this project, the Akkerman 308 GBM is currently being used for new lateral connections and small mainline sewer line installations.

Granville Street Crossings

Serving as a disaster response route, a connector to the Vancouver International Airport and a major public transit route, Granville Street is a major north/south arterial road for Vancouver. Due to the potential for significant transportation and emergency services disruption, the decision was made to use trenchless technology for the major sewer line crossing located on Granville Street at 33rd Avenue and 29th Avenue.

Tunneling sewer mainlines with an Akkerman 4800 tunneling machine was another first for the City's Sewer Operations crews. A five-person crew excavated the launch and exit pits, and successfully set up the GBM machine with ease. However, it was immediately apparent that the crossings would be a challenge.

The crossings consisted of a 36-inch non-weld steel casing with a 675-millimeter fiberglass pipe as the carrier, and a 16-inch non-weld casing fitted with a 250-millimeter PVC carrier. The 4800 GBM was also the right machine to integrate into Sewer Operations' construction methods. The pilot tubes crossed six lanes of traffic and boulevards (over 45 meters) at a grade of 0.55 percent.

After the initial auguring across the intersection, a 36-inch Powered Cutting Head was attached and pushed across the intersection with the 36-inch casing.

Once casing pipes were pushed through, the fiberglass pipe was slipped in as the carrier pipe on skids and grouting of the annular space was done. Despite minor setbacks due to unforeseen ground

QUICK FACTS

Construction, Connections & Maintenance

- 4 mainline crews (heavy civil) replacing old storm & sanitary infrastructure
- Up to 2 trenchless crews, when required to meet project needs
- 10 connections crews installing residential & commercial connections
- 13 maintenance crews maintaining all lateral connections, storm & sewer mains, and 5 pump stations

Equipment

- 22 tandem dump trucks
- 9 case backhoes
- 3 excavators
- 1 front-end loader
- 5 hydro vacs

Administration

- 20 supervisory & administrative staff
- Approx. 240 employees in total

conditions. Even though bore logs and the geotechnical report showed ideal ground conditions for the pilot tube method, large isolated pockets of cobbles and loose sand were encountered along with large rocks. However, the crew persevered and successfully completed both crossings.

Due to the success of this project, the Akkerman 4800 GBM is currently being used for new mainline sewer line installations.

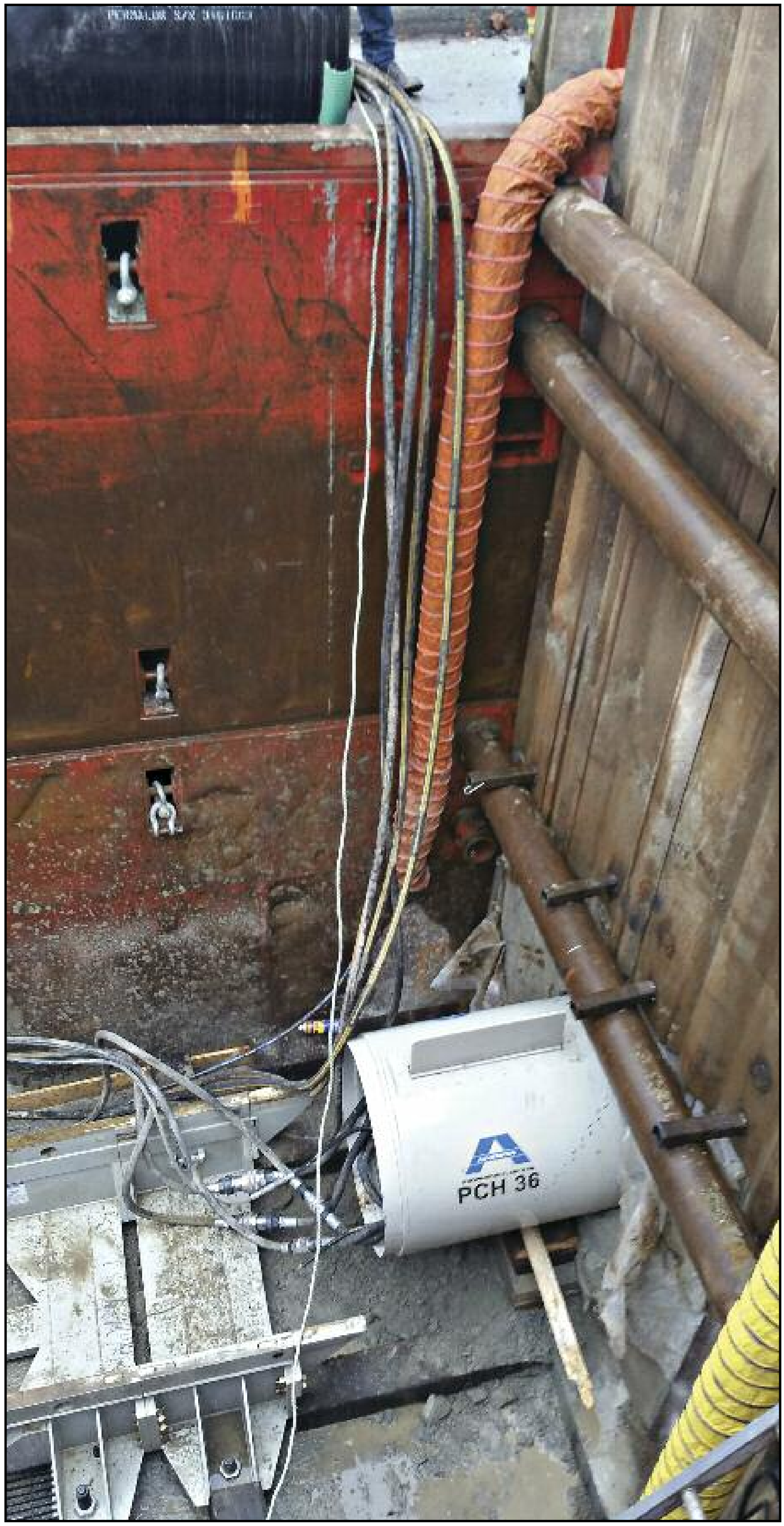
The Future

In the spring of 2016, the City of Vancouver's Sewers Design and Operations teams will embark on a major crossing over 90 meters in length located at one of the busiest intersections in the City – Burrard Street and West Broadway. Sewer Operations is also planning a large sliplining project on South West Marine Drive and is considering the further development of the cured-in-place pipe (CIPP) program.

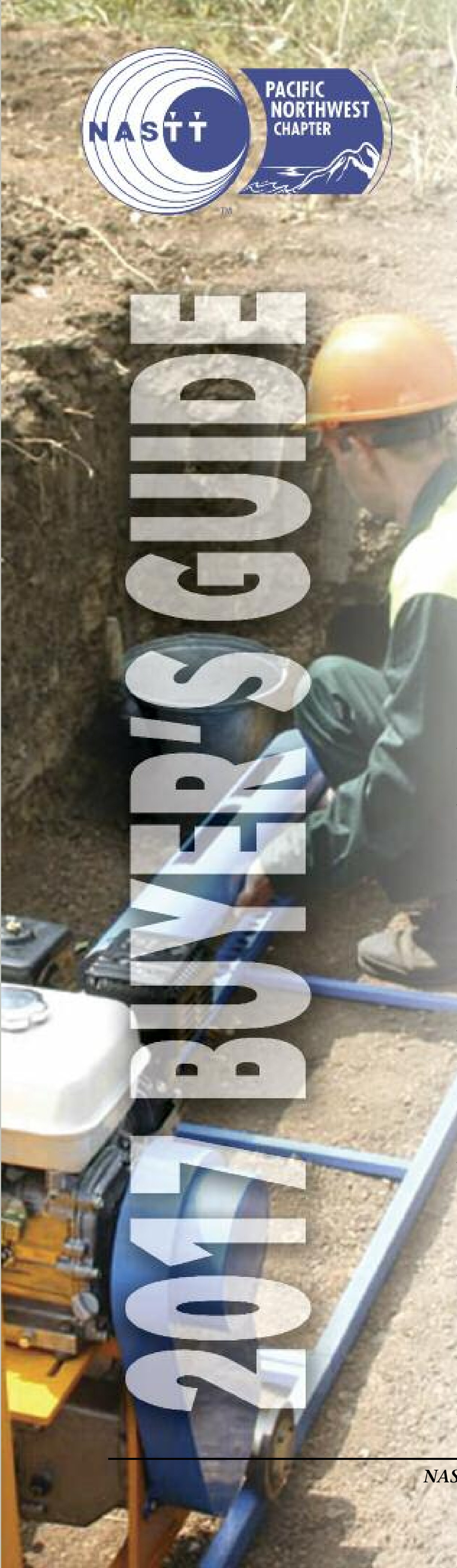
As the City of Vancouver continues to embark on infrastructure upgrades, the City's Design-Build Construction Team is integrating advanced technology, such as HDD and the pilot tube GBM System and trenchless technology methods, to limit construction impacts to the public and stakeholders, and to generate cost efficiencies in installing long-term piping systems.

By using trenchless technology in the years to come, the City of Vancouver's Sewers Design and Operations branches will make significant contributions toward the reduction of Greenhouse gases, helping Vancouver meet its goal of becoming the greenest city by the year 2020.

Originally published in Trenchless Technology Canada, April 2016.



Trenchless technology was used for the major sewer line crossing located on Granville Street at 33rd Avenue and 29th Avenue.



By Category

Asset Management
Pipeline Inspection & Condition Analysis Corporation (PICA)

Auger Boring
Kamloops Augering & Boring Ltd.

Condition Assessment
Pipeline Inspection & Condition Analysis Corporation (PICA)

Engineering Design
Murray, Smith & Associates, Inc.
Stephl Engineering LLC

General Consulting
Murray, Smith & Associates, Inc.
Staheli Trenchless Consultants

Horizontal Directional Drilling
Baroid Industrial Drilling Products
The HDD Company
Michels Corporation

Inspection & Evaluation
Murray, Smith & Associates, Inc.
Pipeline Inspection & Condition Analysis Corporation (PICA)
Stephl Engineering LLC

Manhole Rehabilitation
AP/M Permaform

Microtunneling Service
Akkerman
Michels Corporation

Pipe Jacking
Akkerman
Kamloops Augering & Boring Ltd.
Michels Corporation

Pipe Ramming
Kamloops Augering & Boring Ltd.

Pipe Relining
AP/M Permaform
Try Tek Machine Works, Inc.

Pipeline Inspection
Pipeline Inspection & Condition Analysis Corporation (PICA)

Sewer Rehabilitation
AP/M Permaform
Michels Corporation
Murray, Smith & Associates, Inc.
Stephl Engineering LLC

Tunnel Boring Equipment
Akkerman

Tunnel – Large Diameter
Michels Corporation

Video Inspection
Pipeline Inspection & Condition Analysis Corporation (PICA)

Water Well
Baroid Industrial Drilling Products

By Company Name

Akkerman
58256 266th Street, Brownsdale, MN 55918
www.akkerman.com
Contact: Akkerman Sales
sales@akkerman.com
1-800-533-0386
Akkerman develops, manufactures and supports pipe jacking and tunnelling equipment and accurately installs a variety of underground infrastructure.

AP/M Permaform
PO Box 555, Johnston, IA 50131
www.permaform.net
Contact: Linda Keairns
info@permaform.net
1-800-662-6465
AP/M Permaform® offers CentriPipe® and Permacast® for rehabilitation of deteriorated manholes, pipe and similar structures. CONmicSHIELD® prevents MIC in concrete sanitary sewers.

Baroid Industrial Drilling Products
3000 N Sam Houston Parkway E., Houston, TX 77032
www.baroididp.com
Contact: Customer Service
idp@halliburton.com
1-800-735-6075
The Original Drilling Fluids Company

The HDD Company
#215-3161 Cameron Park Drive,
Cameron Park, CA 95682
www.hddcompany.com
Contact: Neil Swope
nswope@hddcompany.com
530-676-5705
Providing trenchless solutions for all sizes of pipeline and utility installation projects.

Kamloops Augering & Boring Ltd.
10085 Dallas Drive, Kamloops, BC, Canada V2C 6T4
www.kamloopsaugering.com
Contact: Malcolm Bachand
kamaug@telus.net
250-573-7814
There is No Substitute for Experience

Michels Corporation
www.michels.us
Contact: Ben Nelson
bnelson@michels.us
A diversified infrastructure and utility contractor self-performing construction throughout North America and abroad with licenses in over 50 states.

Murray, Smith & Associates, Inc.
888 SW 5th Ave, Suite 1170, Portland, OR 97204
www.msa-ep.com
Contact: Brendan O'Sullivan
Brendan.O'Sullivan@msa-ep.com
503-225-9010
Consulting civil engineering firm specializing in public/municipal infrastructure planning, design, and project delivery in the fields of water, wastewater, stormwater, and transportation.

2017 BUYER'S GUIDE

Pipeline Inspection & Condition Analysis Corporation (PICA)
4909 75 Ave NW, Edmonton, AB, Canada T6B 2S3
www.picacorp.com
Contact: Dave Russell
info@picacorp.com
1-800-661-0127
"Good Decisions Start with Good Information." Our technology can "see" through liners, scales and tubercles to detect areas of concern.

Staheli Trenchless Consultants
5405 196th St. SW, Lynnwood, WA 98036
www.stahelitrenchless.com
425-205-4930
Offering innovative solutions to trenchless challenges through risk mediation, trenchless design, forensic analysis and construction inspection.

Stephl Engineering LLC
3900 Arctic Blvd. Ste. 204, Anchorage, AK 99503
www.stephlengineering.com
Contact: Matt Stephl
mattstephl@stephleng.com
907-562-1468
Alaska's trenchless technology engineering specialists since 1996, with services including engineering of Cured In Place Pipe Lining, Horizontal Directional Drilling, Pipe Inspection & Sliplining.

TRY TEK Machine Works, Inc.
www.trytek.com
trytek@trytek.com
717-428-1477
Since 1985, providing worldwide quality manufacturing, including lateral cutters for reinstating relined pipe, CIPP liner inversion units and air routers.

APRIL 10, 2017 | 5:30 PM - 7:30 PM | WASHINGTON, D.C.

NASTT'S 16TH ANNUAL EDUCATIONAL FUND AUCTION AND RECEPTION

The Annual Educational Fund Auction helps raise money for very worthy causes. Since 2002, NASTT has raised nearly $930,000 and used those funds in support of our many educational initiatives. Due to your generosity, NASTT is able to provide targeted trenchless training courses to the industry, publish trenchless resources manuals and sponsor university students' attendance at NASTT's No-Dig Shows, as well as award scholarships.

In conjunction with NASTT's No-Dig Show

EXCITING AUCTION ITEMS

Come to the auction and bid on great items like trips, tickets, electronics, industry items and more!

HAWAIIAN VACATION RAFFLE

The winner of this raffle will receive a dream Hawaiian vacation, a $5,000 value! Tickets are $25 or five for $100 with a maximum of 1,000 tickets being sold. Don't miss out – preorder your tickets by visiting nastt.org/auction.

Need not be present to win.

COSTUME CONTEST

Dress like your favorite super hero for the auction's Sixth Annual Costume Contest! Prizes will be awarded- don't miss out!

Raffle generously sponsored by Vermeer

50/50 RAFFLE

A great way to win some cash for yourself and help out our student chapters! The winning ticket will be drawn immediately following the live auction and you must be present to win. The winner splits the cash pot with the students.

Auction Reception sponsored by

INTERPLASTIC

Ditch Witch
ditchwitch.com

FOR MORE INFORMATION ABOUT THE AUCTION VISIT:

NASTT.ORG/AUCTION

NASTT ™

Index to Advertisers

PLEASE SUPPORT THE ADVERTISERS WHO HAVE MADE THIS PUBLICATION POSSIBLE

PICA

Pipeline Inspection and Condition Analysis Corp.

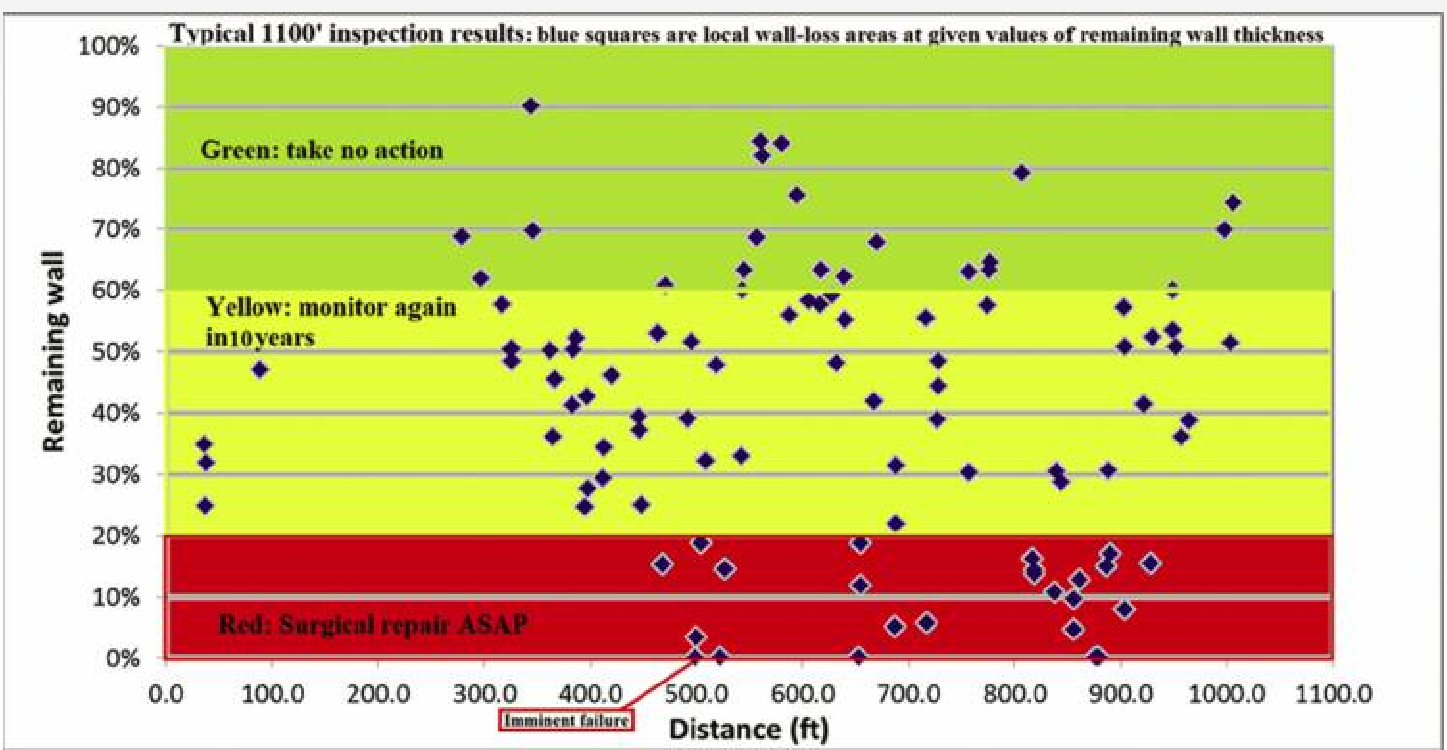
WANT TO KNOW THE EXACT CONDITION OF YOUR MAINS?

- Exact axial location of local areas of corrosion
- Remaining wall thickness, every 1/8″ of the full length
- Clock location of defects

Over 3,000,000 ft. of pipelines inspected across North America since 2009.

Asset Managers who need to know how much of their system needs surgical repair, rehabilitation, or replacement, (and how much is in good shape), call PICA.

Extend the life of your pipelines and stretch your capital budgets.



Good Decisions Start with Good Information

1-800-661-0127 www.picacorp.com