PACIFIC NORTHWEST CHAPTER NASTT

Pacific Northwest Trenchless Review

2013

Innovation

Vertical Shaft Machine Used for First Time in North America

Also Inside:

Willamette River Crossing by HDD

Fast-Track Project at Juneau Airport

No-Dig Show Comes to California

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NORTH AMERICAN SOCIETY *FOR* TRENCHLESS TECHNOLOGY

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NASTT is your link to thousands of local, national and international trenchless professionals and industry leaders. Whether your business is engineering, public works and utilities, underground construction, or equipment manufacturing, NASTT is the definitive resource for the trenchless industry and the application of trenchless methods for the public benefit.

Continuing Education

NASTT's Good Practices courses offer members a range of trenchless topics to choose from and the opportunity to earn valuable Continuing Education Units (CEUs) for their participation in class work held in various locations.

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The annual NASTT No-Dig Show brings together the trenchless industry to make important connections at vibrant locations throughout North America. Also get involved in your Regional Chapter and make key contacts, while staying informed about issues within your own region.

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Members receive discounted pricing on these NASTT publications: *No-Dig Show Conference Proceedings, HDD Good Practices Guidelines* and the *NASTT Pipe Bursting Good Practices Guidelines Manuals*. Enjoy complimentary subscriptions to the industry's leading trade magazines, including *NASTT's Trenchless Today.*

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From educational resources to training tools and more, NASTT members have access to a wealth of valuable information and networking opportunities.

Membership benefits include:

- Members-only discounts
- Complimentary access to online reference tools and publications
- Subscriptions to industry trade magazines
- Leadership opportunities
- Involvement in your regional chapter
- And much more! *Our members often join for one reason, only to discover the value of many others.*

Joining is easy. Visit our website at www.nastt.org/join or call 315-409-7552 for membership details.

The Show!

The annual NASTT No-Dig Show is the largest trenchless technology event in North America, offering an impressive collection of quality papers, an exhibition hall with more than 135 trenchless companies displaying their products and services, a series of specialized training courses, and many entertaining networking events and special awards. *Mark your calendars for NASTT's 2013 No-Dig Show, March 3-7 in Sacramento, California!*

www.nodigshow.com

www.nastt.org

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PNW TRENCHLESS REVIEW

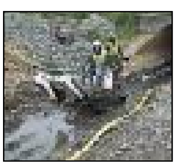
PACIFIC NORTHWEST CHAPTER NASTT

WINTER 2013

Featured...

Pioneering

Case Study



In Alaska

Also...

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Message From the Chair

Erik Waligorski

As I write this message and think back over the past two years, I'm struck by what an honor it has been to represent the Pacific Northwest Chapter of NASTT as your Chairman. This coming January, I will hand the reins to a new Chairman, and I can't help but be excited about the future of our young chapter. I find that it doesn't take much effort to find amazing trenchless projects, Owners, Contractors, or Consultants within the limits of our region, and I believe that the future of trenchless in the Pacific Northwest is very bright with new and exciting projects being formulated every month.

2012 has been another great year for the PNW Chapter. The Chapter was very well represented at the national No-Dig Show in Nashville this past March with many exciting projects being presented. We were also able to develop and launch our new Chapter website (www.pnwnastt.org). We are very excited about the website and our ability to highlight upcoming events and recent projects, and provide contact information for local industry professionals. We welcome input from our members on projects and publications to help populate the website. I want to thank Chris Price with Staheli Trenchless Consultants for taking the lead on the development of the website.

We are very excited to announce that we will be hosting our bi-annual Pacific Northwest Trenchless Symposium again this coming January 23 and 24 at the Cedar Brooke Lodge in SeaTac, Washington. We have had amazing success in bringing together local trenchless experts and vendors to present the latest in technology and projects to our members at past symposiums, and we expect this upcoming symposium to be equally amazing.

One change to the symposium schedule this year will be the addition of a PNW Chapter meeting. We welcome and encourage participation in the chapter and would like to see the number of active members continue to grow as we work to increase the reach and involvement of trenchless technology in the Pacific Northwest. As with past symposiums, we will again be offering an eight-hour NASTT Good Practices Short Course, with this symposium's topic being "New Installations." Our very own Kim Staheli will be teaching the course.

I want to again say it has been an honor to serve as the Chairman of the PNW Chapter of NASTT, and I look forward to all of the upcoming events in and near our region. I hope that I have the chance to see and meet many of you at both our upcoming Symposium and the 2013 No-Dig Show in Sacramento. This will be the closest the national No-Dig conference has come to the Pacific Northwest for many years, and I highly recommend taking advantage of the opportunity. Please feel free to contact me for information at ewaligorski@rothhill.com or call: (425) 289-7320.

Best Regards,

Erik Waligorski
Chair, NASTT PNW Chapter

Greetings from NASTT

Mike Willmets - NASTT Executive Director

True to form, NASTT is diligently working to prepare for the much anticipated return to the West Coast for the 2013 No-Dig Show. In just a few short months, our annual trenchless showcase will be on the coast — March 3-7 at the Sacramento Convention Center in sunny California.

Sacramento is the perfect location for NASTT's No-Dig Show to return to the West Coast, after a six-year hiatus. The Sacramento area has been home to a tremendous amount of trenchless work over the years and recently completed an extensive, long-term trenchless program. The Sacramento Convention Center offers our attendees and exhibitors a fantastic venue in the heart of downtown Sacramento. I know that many Pacific Northwest Chapter members are also working above and beyond to help make this conference successful, and I appreciate that more than I can express.

There were many exciting developments that came out of NASTT's 2013 No-Dig Show Program Committee and Board of Directors meetings held in Sacramento this past July. Planning for the 2013 show is well under way as work started immediately following the incredible success of NASTT's 2012 No-Dig Show in Nashville. The Program Committee is building off that fantastic momentum with fresh ideas for the growth of the world's best trenchless conference. Get ready for the Flower Child theme at the Education Fund Auction!

The Program Committee is truly blessed to be building what is shaping up to be another record-setting technical program. Hosted by 2013 Program Committee Chair Kim Staheli, the committee reviewed what can only be described as an overwhelming number of high-quality abstracts. Our technical program sets the standard by which other conferences hope to achieve, and the competition to have a paper selected for these sessions is fierce. Tough decisions were made to ensure that the best of the best technical papers were chosen for presentation at the 2013 No-Dig Show, and I'm sure that they all will be enthusiastically received. Congratulations to the many successful authors!

One of the most highly anticipated events at the 2013 No-Dig Show is the induction of the second NASTT Hall of Fame class. This is already my favorite event of our No-Dig Show experience. I am so proud to announce that the NASTT Board of Directors has again selected an outstanding group of trenchless trailblazers to honor at the Sacramento No-Dig Show.

The members of the 2013 NASTT Trenchless Hall of Fame Class are: Insituform founder and inventor of the CIPP process, the late Eric Wood (1935–1994); trenchless author and engineering expert, Dr. David Bennett of Bennett Trenchless Engineers; and Ditch Witch founder and machinery developer Ed Malzahn. I want to note that having David Bennett inducted into the Hall of Fame in Sacramento is incredibly fitting as he and his trenchless specialty firm are based in the Sacramento area. You'll definitely want to be there when this inspiring group is honored during the Gala Awards Dinner on March 5 at the Sacramento Memorial Auditorium.

This also leads me to congratulate all the members of the Pacific Northwest Chapter for your continuing efforts to expand trenchless technology industry in your region. A successful society such as NASTT is only as strong and vital as its grassroots Regional Chapters. Thank you for diligently delivering the trenchless message and for making our volunteer Society that much stronger.

Finally, I am extremely pleased to tell you that NASTT kicked off our first-ever Trenchless Webinar Series this year, and the response was more than we could have ever hoped for. More than 1,200 attendees participated in the first three sessions of the four-part "Introduction to Trenchless Technology" webinar series, which focuses on rehabilitation and new installation methods. What an impressive new education vehicle for NASTT to reach a huge hungry-for-trenchless audience — all at no cost to attendees who don't even leave their office to take part. I sincerely want to thank our Communications and Training Manager, Michelle Hill, for her role in making this webinar series a reality.

NASTT has many great things on the horizon in the months to come, and I enthusiastically look forward to working with the Pacific Northwest Chapter to make them happen!

You're Invited to the NASTT No-Dig Show

Kim Staheli
No-Dig Program Chair

Kevin Nagle
No-Dig Program Vice-Chair

Dear Trenchless Colleagues:

We are calling the 2013 No-Dig Show "The Great Trenchless Gold Rush!" – and what an apt description for this fabulous event as attendees, sponsors, students and exhibitors will face a "Gold Rush" of trenchless information at the only conference in North America that focuses solely on trenchless technology!

We are thrilled to return the No-Dig Show to the West Coast, and Sacramento offers the perfect setting to promote and celebrate our exciting industry. We officially invite you to join us and the global trenchless community at NASTT's 22nd annual No-Dig Show, March 3-7 at the beautiful Sacramento Convention Center!

Trenchless technology continues to grow throughout North America, as municipalities and cities look for cost-effective and non-disruptive solutions to their infrastructure challenges. Sacramento is a city rich with trenchless experience, having just completed an extensive, long-term trenchless program.

The volunteer members of the Program Committee have worked tirelessly during the past year to offer you an extensive educational program that overflows with opportunities to learn everything about trenchless technology and is packed with outstanding cutting-edge trenchless advances in the technical sessions. In addition, there is no better place to network with your peers and talk with vendors offering the latest technology and products — a true "Trenchless Gold Rush"!

NASTT is committed to trenchless education, and our No-Dig program is full of the best the industry can offer. Our Technical Program — the "gold" standard of technical programs – begins on Monday, featuring 150 high-quality, peer-reviewed, non-commercial papers in a six-track schedule. And there's more: Our pre- and post-conference courses feature topics on the gamut of trenchless applications, including pipe bursting, HDD, laterals and CIPP.

Networking and interacting with our trenchless professionals, educators and experts is a key component of our No-Dig Show, and we have several excellent events where you can kick back or kick up your heels! Monday begins and ends with two fantastic networking events. The day begins with our "Kickoff Breakfast" and ends with NASTT's fundraising social event of year, the Educational Auction and Reception. Not only is the Auction a great time where you can network over drinks and appetizers, but it's also a wonderful opportunity for you to give back to the industry by bidding on amazing items. The Auction helps NASTT support the future of the industry by raising money for its educational initiatives. Since 2002, NASTT has raised more than $500,000 for the fund. You don't want to miss this event!

One of the highlights of any No-Dig is our Gala Awards Dinner, held on Tuesday evening. Here, NASTT gathers for an evening of incredible food, awards and live entertainment. NASTT will formally recognize the recipients of the Chairman's Award for Outstanding Lifetime Service, the Trent Ralston Award for Young Trenchless Achievement and the Joseph L. Abbott, Jr. Innovative Product Awards. The highlight of the evening will be the induction of the second class to NASTT's Hall of Fame.

The 2013 No-Dig Show ends Wednesday with our annual Closing Luncheon, where we will also draw the winning "golden" ticket for our second annual vacation raffle. This year's raffle will send the winner on an all-expenses-paid vacation to the Caribbean, so we hope you have your tickets! Purchase your tickets today at www.nodigshow.com for your chance to win some fun in the sun! All proceeds benefit NASTT's Educational Fund. This cool raffle is made possible through the generous donation of Vermeer Corp.

All of these events will take place at the gorgeous Sacramento Convention Center Exhibit Hall, located in the heart of downtown Sacramento. Our host hotels are just a few steps away from the Convention Center at the Hyatt Regency Sacramento and Sheraton Grand Sacramento Hotel. Call today to make your reservations at the group discounted rate. Save $100 on your full conference fee when you register before Feb. 8.

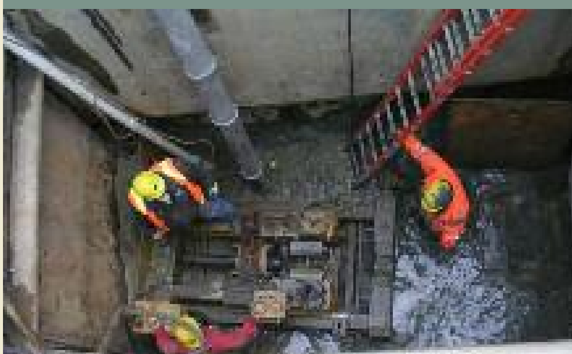
We can't wait to see you in Sacramento!

The Biennial

Pacific Northwest Trenchless Symposium

Wednesday-Thursday, January 23-24, 2013

Cedarbrook Lodge, SeaTac, Washington





Registration options include an informative technical program, product/service exhibit area, and NASTT New Installations Short Course.

Presented by the

PACIFIC NORTHWEST CHAPTER NASTT

All the benefits of a national conference with a convenient local setting!

The PNW Trenchless Symposium and Good Practices Short Course

NASTT New Installation Methods Good Practices Short Course - Wednesday January 23, 2013

The New Installation Methods Course addresses trenchless methods commonly used to install new pipe and casing. These methods include: (1) auger boring; (2) pipe ramming; (3) pipe jacking; and (4) the pilot tube method. Examples and case studies will be presented to assist attendees in determining which method is preferable to use under various project conditions and requirements.

Course Includes:

- The limitations and advantages of each method discussed
- The steps you need to follow "to know the underground"
- The history, sizes, equipment options and process of excavating through different ground types
- Grade and alignment control and guidance
- Installation and jacking forces and ways to reduce these forces
- The best method to use through actual case studies, which are used to illustrate what can go wrong if the project is not designed for success
- Continuing Education Units (CEUs) for all participants

PNW Trenchless Symposium - Thursday January 24, 2013

A full day of presentations detailing local trenchless highlights in construction, design, and academic research.

Planned topics include:

- Vertical Shaft Machine case history
- Pipe Ramming case history
- HDD construction case history
- and case histories on other trenchless methods

Register Online At:

www.regonline.com/2013pnwnasttsymposium

Prices:

Short Course only	$300
Symposium only	$200
Short Course + Symposium	$500
Exhibitors*	$500

*includes 8'x10' space with table and power supply, registration for the symposium for one person and company recognition in the program

For all questions please contact Christopher Price at chris@stahelitrenchless.com or 425.205.4930

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First Use of Vertical Shaft Machine Technology in North America

John Fowler
Project Principal, James W. Fowler Co.

Vertical shaft machine (VSM) technology was first developed in Germany by tunnel technology company Herrenknecht AG. Relatively new to the construction industry, this equipment has been used in Europe and the Middle East for the last seven years. The VSM technology is similar in concept to a microtunnel boring machine, except that the excavation is completed vertically rather than horizontally. James W. Fowler Co. (JWF) is the first contractor to bring this innovative new method of shaft construction to North America on the Ballard Siphon Replacement (Ballard) project for King County's Wastewater Treatment Division (County) in Seattle.

BALLARD PROJECT OVERVIEW

The Ballard project helps the County improve the reliability of an aging sewer system and control combined sewer overflows during periods of heavy rain. The project calls for slip lining of existing twin 36-inch-diameter cable-wrapped wood stave sewer pipelines installed in 1935 in the lake bed sediments of the Lake Washington Ship Canal near Salmon Bay. A new siphon pipeline will also be constructed via trenchless methods that will provide additional capacity to accommodate future growth in the area.

The project requires JWF to build two vertical shafts on either side of the Ship Canal for the earth pressure balance tunneling machine. The south shaft for launch of the machine is located in the Interbay neighborhood and the north shaft where the machine will be received is in the Ballard neighborhood. The launch shaft needed to be deep enough to install a tunnel 60 feet below the Ship Canal.

The Ballard project award was delayed nearly 18 months due to an extended protest by the second-place bidder. JWF investigated various shaft construction methods to help offset these delays and eventually proposed the use of VSM to construct the south shaft. This innovative construction method offered the additional benefits of allowing the shaft to be shored using caissons at an extended depth while addressing the challenges associated with the high water table. To ensure material supply was to the quality standards required and delivered in timely manner, JWF fabricated and stored the bolted gasketed concrete segments at an off-site facility specifically for the Ballard south shaft and tunnel.

The project team for the Ballard project included King County, JWF, Tetra Tech, Landau Associates, Jacobs Associates, Staheli Trenchless Consultants and Brierley Associates.

VSM TECHNOLOGY

Herrenknecht's VSM was designed to work in Europe's dense urban areas with a small footprint and in difficult soil conditions

A guide wall for the Herrenknecht VSM is prepared at the Ballard project's south site.

with high groundwater tables. This description perfectly fit the conditions at the south shaft area, which is located in an industrial parking lot with high traffic and a limited project area. The soil conditions included loose sand, silty sand, medium-stiff sandy clay, medium-dense silty fine to medium sands with gravel, very dense granular and hard cohesive materials, and very stiff to hard clay containing very small sand-filled slickensides. Additionally, groundwater was encountered approximately 16 feet below the surface.

JWF chose the VSM10000 model, which was designed for the type of soils and groundwater anticipated on the project. The machine consists of a sinking unit and shaft boring machine. A horizontal rotary grinder is located on the end of a telescoping road header boom connected to the shaft boring machine. The VSM10000 has a maximum cutting diameter of 36.4 feet and on the Ballard south shaft the outer diameter was 32.2 feet and the inner diameter was 29.5 feet.

Shaft construction began with the excavation of an area the diameter of the shaft. The first four segments were fitted with a cutting shoe to ease the sinking process, and then lifted into place in the excavated area by crane to create the first concrete ring wall. Four additional sets of rings were added to the first ring, causing the first two rings to sink into the ground. The VSM was set into place, and then anchored via winches and cables to the third and fifth rings. Slurry lines to carry the excavated material to the separation plant and return the water to the shaft were installed along with the energy supply unit. Excess material was pumped hydraulically to a soil separation unit on the surface which removed the soil and sediment and recycled the water back into the shaft. The VSM operated on public electricity, so no noisy generators disturbed the nearby residents or businesses. At this point, the machine was calibrated and tested.

Excavation of the shaft using the pivoting cutting arm began, with an operator on the surface controlling the VSM remotely. Additional rings were added to the shaft as the VSM continued to remove material below the lowest ring. To balance the groundwater pressure, the shaft was flooded as it was excavated. When the shaft reached the correct depth, the VSM over-excavated the depth and diameter to create an inverted “champagne cork” shape. At this point, the VSM was removed from the shaft and a tremie pour of 450 cubic yards of concrete created the bottom shaft plug capable of resisting the hydrostatic uplift, which is a concern in deep shafts. Only after the structural invert slab at the bottom of the shaft had fully cured and the caisson annular space was grouted was the shaft dewatered.

BENEFITS OF VSM TECHNOLOGY

The most significant value of utilizing VSM technology on the Ballard project was the time savings. The north shaft was constructed using a traditional secant method and involved approximately four months to shore and excavate the 100-foot-deep opening. Conversely, the VSM-constructed south shaft required approximately five weeks to shore and excavate the 157-foot-deep shaft in challenging soil conditions and with significant groundwater pressure. This time saving was significant,

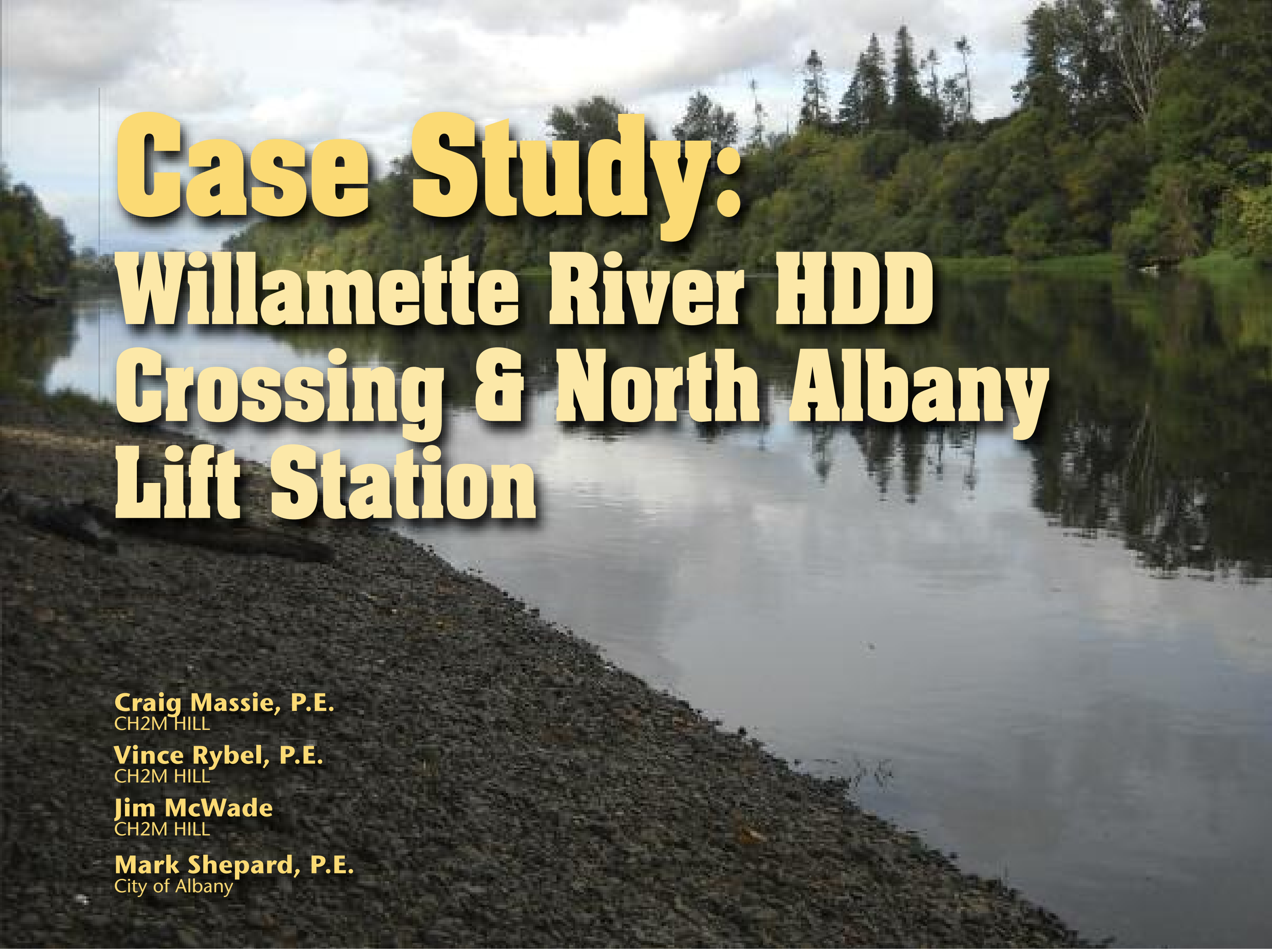
The Herrenknecht VSM is set into the shaft at the Ballard project’s south site.

especially considering the Ballard project was JWF's first use of the technology.

Another significant advantage of this method is its ability to deal with obstructions during the excavation process. At one point during excavation, JWF crews encountered difficult excavation of an unknown obstruction that was estimated to be in excess of four feet in diameter. The crews efficiently mined past the difficult area with no significant impacts to time or cost in less than four hours. During the entire excavation process, the winches and cables that helped to correctly position the machine during excavation ensured the finished structure was precisely vertical, which prevented issues throughout the remainder of the construction process.

The Herrenknecht VSM technology's first use in North America was a success. It was an effective and efficient method for constructing the south shaft on the Ballard project.

With a VSM, excavation is completed vertically rather than horizontally.



Case Study:
Willamette River HDD Crossing & North Albany Lift Station

Craig Massie, P.E.
CH2M HILL
Vince Rybel, P.E.
CH2M HILL
Jim McWade
CH2M HILL
Mark Shepard, P.E.
City of Albany

Since 2007, the City of Albany has invested more than $80 million in improving its municipal sewer collection system and water reclamation facility (WRF), which discharges highly treated effluent into the Willamette River. This investment is a result of more stringent Oregon Department of Environmental Quality total maximum daily load waste allocations, steadily increasing population within the service area, and the need to eliminate sanitary sewer overflows. The Albany-Millersburg water treatment plant serves a population of more than 50,000 residents, and its location in the Central Willamette Valley makes it home to a number of agricultural and food processing industries that rely upon the City's sewer collection system.

In the early 1990s, the City of Albany incorporated the area north of the Willamette River and across the river from the WRF known as North Albany. Already at a population of 6,500, this area is projected to have significant residential growth. The anticipated growth, combined with recently discovered hydraulic deficiencies in the riverfront interceptor, motivated the City to seek a solution to increase service capacity while managing capacity limitations in the downtown core served by the riverfront interceptor.

Beginning in 2008, CH2M HILL developed and evaluated alternatives and assisted the City in selecting to install more than 4,000 feet of 18-inch PVC and 20-inch HDPE forcemain within the Willamette River greenway, obtain easements across local farm property, and construct a 1,720-foot horizontal directional drilling (HDD) crossing under the Willamette River to connect the North Albany Lift Station (NALS) to the WRF. The NALS was also upgraded from 4.5 million gallons per day (mgd) to 6.5 mgd pumping capacity. Construction was completed in 2009 and the system was successfully commissioned in December of the same year.

Significant time constraints for the project were imposed by deadlines contained in a Stipulated Final Order outlining that the City had to eliminate sanitary sewer overflows by December 31, 2009. With design beginning in May of 2008, the City elected to implement the construction manager/general contractor (CM/GC) alternative delivery method, shaving two months off a typical design-bid-build schedule. Under this delivery model, the contractor and designer began working together at the 30 percent

Construction in the North Albany Lift Station project was completed in 2009

design phase. This saved time by eliminating the process of hiring a contractor after design was complete, and it allowed the contractor and designer to recognize issues early on rather than discovering issues during construction.

DEVELOPING ALTERNATIVES ANALYSIS

The alternatives analysis phase of the project included six potential alignments that were analyzed for the following:

- Cost
- Constructability
- Environmental impacts
- Traffic operations and control needs
- Maintenance access
- Reliability
- Right–of–way and easement needs

One option included not only an HDD river crossing but also an HDD undercrossing of a privately owned golf course. This route was technically feasible and would have been the shortest overall, but was not pursued due to anticipated challenges in obtaining easements and the fact that lower-cost options existed.

CH2M HILL's geotechnical engineering experience in the Willamette Valley and specific experience in Albany provided a good understanding of potential challenges of deep excavations required for part of the work, and in the potential feasibility of trenchless methods for crossing under the river. The City had minimal experience with trenchless technologies, which was limited to cured-in-place pipe and pipe-bursting pipeline rehabilitation.

The main factors leading to the selection of an HDD forcemain river crossing in lieu of a forcemain mounted on the U.S. Highway 20 Bridge were maintenance access and reliability. Despite the inability to access a deep river undercrossing, the HDD crossing was cost-competitive and more reliable in terms of long-term maintenance, access challenges, worker safety, and sewage spill risk.

The CM/GC, C&M Construction from Sherwood, Oregon, and major subcontractor, The HDD Company (who constructed the river crossing) from Cameron Park, California, worked closely with CH2M HILL and the City to complete the design and provide value engineering input from a construction perspective. For example, C&M Construction selected their equipment size such that the shortest pipeline route could be constructed with minimal impact to the Willamette Greenway, saving more than $500,000 of pipeline construction and potential restoration costs associated with other routes proposed.

GEOTECHNICAL CONDITIONS

The project site geotechnical conditions are dominated by high seasonal groundwater, expansive soils, and little-known subsurface conditions. Constraints on the construction season included high water potential along the entire pipeline route, which limited accessibility, and the timing of commercial agricultural activities for the portion of the alignment located within an active grass seed farm.

This alignment was known to have mostly favorable subsurface conditions. Some fill materials existed at the entry point near the water reclamation facility overlying Willamette Silt, Linn Gravel, and Calapooia Clay formations. The Calapooia formation is a stiff clay-like silt, bordering on siltstone, and easily could contain frac-out pressures below the river.

The project experienced very few and low-cost change orders, none associated with HDD

Most of the bore and the entire alignment under the river was in this formation. The entry point geometry inside the plant site was very tight. Nearby utilities had to be missed and the entry point was selected after considering several constructability options. Some loose gravel fill and steep slopes near entry raised some frac-out concerns during design, which were realized during construction. Because of a severe drop-off in front of the rig (which created a lack of cover), the contractor set about 50 feet of 48-inch steel casing, on grade, beginning at the entry point. Even with the work to mitigate the possibility, a frac-out occurred at the end of the casing. The material release slowed over time and was ultimately contained, and the fluids were pumped back to the mud tank with no ill effects. The exit side was open farmland, ideal for economical pipe staging.

TECHNICAL CHALLENGES

An American Augers DD660 performed the directional drilling. On the first attempt to pull the pipe, a fuse in the pulling head failed as the front of the pipe was traveling through a severe gravel layer, on the exit side. The crew had to pull the pipe back out the exit side and re-condition the hole, yet was successful on the second attempt. The open-cut portion of the work was constructed between June and September 2009 and, because of harvest delays and threatening rain, the HDD portion was constructed during a four-week window in October 2009.

The project budget was $4.49 million, including the pump station improvements. The project experienced very few and low-cost change orders, none associated with the pipeline or HDD. The CM/GC approach is credited with saving the project more than $500,000, primarily by optimal pipeline route selection.

Jordan Creek Culvert Repair

Successful Slip Lining of a Large-Diameter Culvert under an Airport Taxiway

Brian Gastrock, P.E.
Stephl Engineering LLC

The City and Borough of Juneau (CBJ) is located in the panhandle of southeastern Alaska approximately 900 air miles north of Seattle and 600 air miles southeast of Anchorage. Similar to many Alaskan communities, CBJ is isolated in that the only access is via either airplane or boat – no roads are accessible to this capital city of approximately 31,000.

This beautiful capital city is host to a vibrant tourism influx in summer and also dependent on government, mining, and fishing industries to provide jobs for residents. As such, Juneau International Airport is essential infrastructure for CBJ.

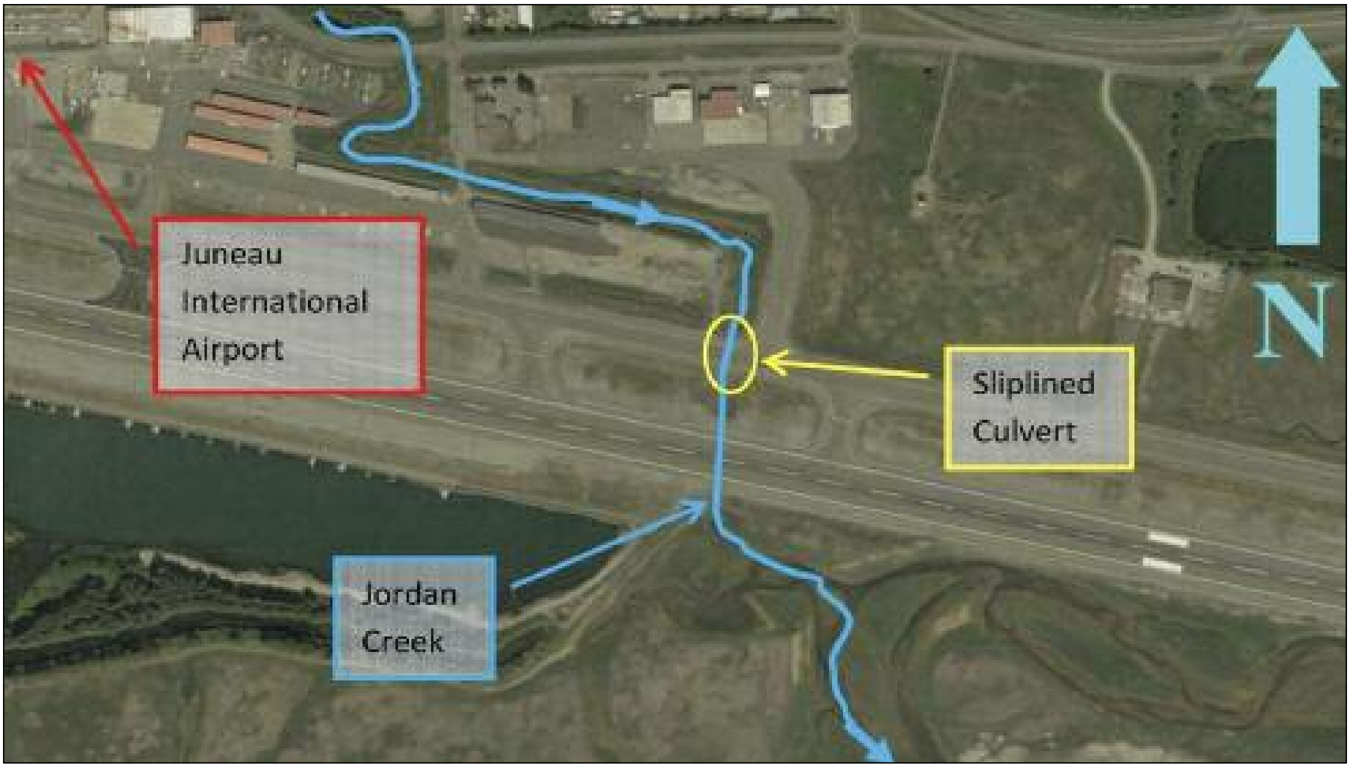
The community recently completed the first phase of a multi-million-dollar safety improvement project for the city-owned airport. During the first phase of the construction project, the 96-inch corrugated metal pipe (CMP) culvert located under Taxiway A was found to have moderate to severe corrosion and require immediate repair.

The culvert conveys Jordan Creek from the north side of the airport property, under the taxiway and runway, to the south side of the airport property which is ocean tidelands. The creek averages between 15 and 20 cubic feet per second (CFS), with the two-year storm exceeding 80 CFS. The taxiway culvert is approximately 220 feet long with an invert elevation at approximately 12 feet mean sea level. The creek and culvert are subjected to ocean tides

Due to the severity of the corrosion and the culvert being located under an active taxiway for large commercial aircraft, CBJ began discussions with the Contractor, Alaska Interstate Construction (AIC), to develop a short-term solution to remove accumulated gravel and repair corroded portions of the culvert.

The airport is undergoing phased construction improvements and expects the culvert to be improved or relocated in the next several years; therefore, CBJ was interested in a short-term repair. After various alternatives were discussed, CBJ issued a change order to slip line the existing 96-inch CMP with a new 84-inch corrugated aluminum pipe (CAP). The final decision was to slip line 120 feet of the culvert centered under the taxiway – 60 feet each side of the taxiway centerline, which was the area with the most severe corrosion. The decision to slip line a portion of the corroding pipe with CAP was made for several reasons:

- Relatively short lead time – the decision to repair was made in spring 2012, with repair desired before salmon spawning in August. The 84-inch CAP would be available within the accelerated schedule.
- Proven structural capacity – the 84-inch CAP is lightweight yet capable of withstanding the design loads of a loaded Boeing 737 aircraft.
- Corrosion resistance – the 84-inch CAP



Aerial view of project site (photo courtesy Google Earth)

would improve the culvert's corrosion resistance.

- Short-term repair – the culvert may be either replaced or relocated during future construction phases at the airport within the next several years. The repair was intended for a short-term design life (less than 10 years) and not for long-term use at the airport.

Once the change order to slip line the culvert was issued, AIC assembled a team of subcontractors to provide engineering design, grouting, and material procurement for the repair. Stephl Engineering, a local Alaskan business, was brought to the team for their trenchless engineering design and construction expertise. Mobile Concrete and Grout of Alaska (MCGA) provided annular space grouting for the project. The 84-inch CAP was purchased through Contech Engineered Solutions.

FAST-TRACK DESIGN

Stephl Engineering, MCGA, and Contech personnel met with AIC on site in May of 2012 to evaluate the feasibility of slip lining the culvert under the taxiway. A subsequent site visit by Stephl Engineering in June probed the gravel in the bottom of the pipe to attempt to confirm the host pipe was in acceptable condition (round and not deformed) to accept the new pipe.

Following the site visits, the project team determined that slip lining the culvert was achievable and Stephl Engineering began compiling a design package using all members of the project team for the culvert repair. The package included a plan and profile drawing of the site, load bearing calculations, grouting specifications and procedures, flotation calculations, bulkhead design, CAP shop drawings, a bypass pumping plan for Jordan Creek, a dewatering plan, and pipe-bracing design. The original project permits were amended for the slip-line project, which helped expedite the construction project.

PREPARATION, INSTALLATION

Once the design package was submitted and approved by CBJ and the proper agencies, the 84-inch CAP was manufactured in 40-foot lengths, and then shipped to Juneau via barge. While the CAP was being manufactured and shipped, AIC began preparations for installation by cleaning the host pipe in mid-July. The Contractor used small excavators and sweeping equipment to clean the pipe. AIC discovered that the existing CMP had baffles every 20 feet inside the host pipe, which impeded proper cleaning and gravel removal to prepare the pipe for the CAP slip line. Additional work was required to remove the baffles before being able to use the excavators and sweeping equipment.

The cleaning effort was timed around the tides instead of inflating the large-diameter rented plug to hold back the tidal water. Working without the inflatable plug in place allowed AIC to use equipment and machinery to remove the baffles and remove the gravel. The cleaning efforts removed approximately 50 cubic yards of gravel from the host pipe.

Cleaning the culvert pipe at Juneau International Airport's Taxiway A

Once the cleaning was finished, the inflatable plug was placed at the downstream end of the culvert, holding back the tidal water. However, AIC soon learned that a significant amount of groundwater continued to infiltrate the host pipe. The Contractor used a hydrophobic water-activated grout to reduce the volume of water infiltrating in the invert of the host pipe. AIC used activated oakum soaked with the two-part hydrophobic grout, packing the oakum into the holes in the host pipe where the groundwater activated the resin.

When the groundwater was felt to be under control, AIC then constructed skid rails in the host pipe to slide the new CAP into place. The skid rails were constructed from 4x4 lumber, set in the bottom of the host pipe. The new 84-inch CAP was installed in the host pipe using an excavator with a sling to place the new culvert, and a mini-loader to push the culvert into place.

After the culvert was in place, the Contractor installed the internal bands at the two joints and constructed the bulkheads at each end of the new culvert. The bulkheads were constructed using a non-shrink cement grout with two-inch grout ports at designed elevations to accommodate the three grout lifts.

Once the bulkheads were constructed, AIC placed screw jacks in the culvert to brace the CAP during the annular space grouting procedure. The screw jacks were braced against the bottom of the CAP, through two-inch access ports in the crown of the CAP. The screw jacks had limited reach with the length of the all-thread screw at the top of the jacks. This required that the bottom of the CAP be raised approximately two inches above the design elevation. This did not affect the desired flow characteristics of Jordan Creek, but did affect the grouting procedure.

ANNULAR SPACE GROUTING

The grouting plan prescribed three equal lifts to be placed in the annular space. Each lift would be approximately 18 cubic yards, or two truckloads. The grout was required to have a minimum 500 psi compressive strength and be flowable from one end of the slip-line length to the other. The grout specified was developed by Pacific International Grout Co. and has a density of between 55 and 65 pounds per cubic foot. The low-density grout reduced the buoyancy forces, allowing for fewer lifts, while the high flowability allowed for reduced injection port connections. The three grout lifts was expected to take three days – one for each lift.

The first lift of 18 cubic yards was placed as anticipated. Because of the screw jacks requiring the CAP to be high-

Annular space grouting after slip lining er than designed, the first lift did not envelope as much of the CAP as anticipated during the design. This caused the second lift's grout to separate the CAP from the first grout lift, which caused the second lift to create higher-than-designed buoyancy force during the grout lift. The screw jacks began creaking during the grouting operation, so it was decided to stop the second lift after nine cubic yards of grout was placed. The grout was given another night to set.

The designer, who was on-site for consultation during the grouting procedure, determined that to reduce the buoyancy force, the CAP needed to be weighted during the grouting procedure. The following day, the Contractor placed sand bags at either end of the CAP to a depth of approximately 20 inches. The bottom 20 inches of the CAP was filled with water to help weigh down the CAP, helping counteract the buoyancy force of the annular space grout. The second lift grouting commenced and approximately 18 cubic yards of grout were placed on the third day.

The grouting was canceled on the fourth and fifth days due to a rain storm increasing the flows in Jordan Creek. The increased flows in Jordan Creek exceeded the capacity of the bypass pumps. The inflatable plug was removed and the creek flows were allowed to flow through the new culvert.

After the rains subsided and the bypass pumps were able to maintain the creek flows, the plug was re-inflated and the screw jacks were removed. Once the screw jacks were removed, the final grout lift was placed, requiring approximately 13.5 cubic yards of grout. The total volume of grout placed was approximately 62.5 cubic yards.

CONCLUSION

Determining the existing culvert was severely corroded during the construction project prompted the airport to perform an emergency repair. The short-term repair needed to be completed within the current construction season and the use of a readily available pipe allowed CBJ to complete the repair of the culvert under the taxiway. The repair will allow for continued use of the taxiway until future phases of the safety improvement project upgrade the Jordan Creek culvert.

While the project was successful, the construction methods required field modifications during installation. The buoyancy forces need to be re-evaluated during construction if the elevations of the new pipe are field-modified, as the uplift force may exceed the allowable forces for the bracing system. Having an experienced design engineer and grout specialist on-site during the construction phase can pay dividends for the final product. For this project, slip lining was a viable alternative that saved CBJ from excavating through the airport's main taxiway.

Tulalip Tribes & City of Everett Bring Regional Water to the Pacific Northwest with Massive HDD Project

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INTRODUCTION

The Tulalip Water Pipeline is a 7.6-mile-long water transmission pipeline made up of 36-inch and 48-inch-diameter welded steel pipe intended to support the mutual water supply needs of the Tulalip Tribes and the City of Everett (Figure 1). The design of the pipeline, which includes five individual trenchless crossings made up of almost 12,000 linear feet of 36-inch-diameter steel pipe installed via HDD, was highlighted in the previous issue of this publication. This article describes the construction of three of the five trenchless crossings.

THE SEGMENT 5N HDD CROSSING

The Segment 5N HDD Crossing is 2,760 feet in length, and is parallel to and located just west of an Interstate freeway (Interstate 5) bridge over Ebey Slough. The primary risks associated with the Ebey Slough Crossing were settlement of a freeway off ramp, hydrofracture near the exit location, and pipe binding during pullback. To mitigate the risk of settlement of the off ramp and hydrofracture, the installation of a conductor casing at the entry location was required by the contract documents. To mitigate the risk of pipe binding and increased forces during pipe pullback, the pipe was designed to be pulled back in one continuous pull. However, this proved to be difficult to accommodate during design due to the length of the pipe and the site constraints.

Southeast Directional Drilling (SEDD), the HDD subcontractor on the project, used an American Augers DD-625 drill rig to construct the boreholes. The drill rig was originally capable of 625,000 pounds of pullback force, but SEDD modified it to provide 800,000 pounds of pullback force. SEDD is responsible for all of the HDD work on the project that has been awarded to date. The general contractor, Don Kelly Construction, the prime Contractor, is responsible for assembly of the steel pipe, which was specified with a minimum wall thickness of 0.625 inches and fusion-bonded epoxy lining and coating.

Construction of the pilot bore took approximately six days, with an average rate of advance of 456 feet per day. There were no inadvertent returns (i.e., frac-outs) while drilling the pilot borehole. During the submittal process, the Contractor was required to submit the minimum borehole pressure that was necessary to construct the pilot bore and the maximum or limiting pressure that would cause a frac-out at the surface. Figure 2 shows the Contractor's minimum and maximum calculated drilling fluid pressures in addition to the actual borehole pressures that were continually measured during drilling.

It is interesting to note that the actual borehole pressure exceeded the calculated limiting pressure at many locations along the alignment. However, at every location where a pressure spike occurred, a corresponding pressure drop occurred as well, due to the drill rig operator who was constantly monitoring borehole pressure. When a pressure "spike" occurred, the drill rig operator would immediately turn off the drilling fluid pumps, which resulted in the pressure drops seen in Figure 2. Since the driller did not allow the drilling fluid to continue to pump at

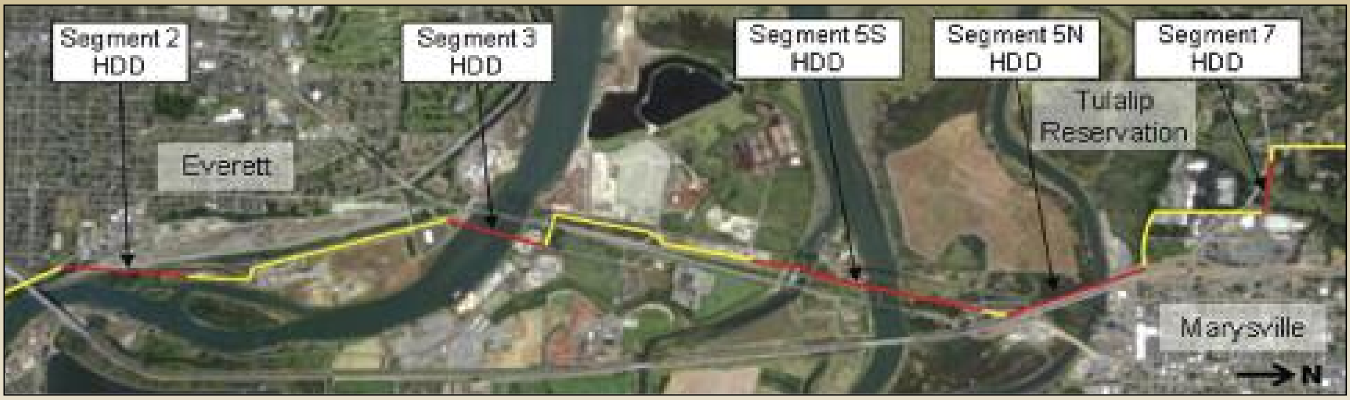

Figure 1. HDD Bore Locations relative to adjacent Open-cut Pipeline

the high pressure, it is hypothesized that this may be the reason that frac-outs were not observed at the ground surface.

The Contractor completed reaming operations in approximately two weeks using a 36-inch fly cutter, a 48-inch hole opener, and a 48-inch barrel reamer. The average reaming rate was 554 feet per day.

The Contractor was allowed to close a roadway for 24 hours while they pulled the product pipe from the layout area into the borehole. The contract allowed the pullback to occur only over the weekend of September 11. This proved to be very restrictive and required very close coordination between the HDD contractor and the General Contractor.

It took approximately six hours to move the product pipe from the assembly location to the borehole exit point. Once the product pipe was lined up with the borehole, pullback began and continued through the night of September 11. Once 2,360 feet of product pipe was pulled into the borehole and the tail end had crossed the road, the roadway was re-opened, meeting the road-closure restriction. However, the drill rig blew a seal on one of its hydraulic motors, which resulted in 3-1/2 hours of downtime for repair. The drilling crew did an amazing job of fixing the hydraulic motor seal at the site; however, following the downtime the drill rig could not get the product pipe moving again. After several hours of attempting to get the pipe moving, the Contractor elected to leave the site for eight hours (many of the crew had been on site for over 36 hours at this time) and reconvene the next day and attempt to get the pipe moving again with pipe ramming equipment.

The next day, a TT Technologies Taurus pneumatic hammer was attached to the tail end of the product pipe and a ram assist was attempted to get the pipe moving. The hammer was fitted with two air compressors allowing 4.2 million pounds of ramming force. While ramming, the drill rig applied approximately 500,000 pounds of pull force on the product pipe. After approximately five minutes of pipe ramming, the product pipe started moving and the pull force applied by the drill rig dropped back down to the 200,000-pound range – the level where the pull force had been prior to the downtime.

THE SEGMENT 5S HDD CROSSING

Segment 5S has the longest HDD crossing within the Tulalip Water Pipeline project with a total length of 3,680 feet. This crossing passes under two sloughs (Union and Steamboat sloughs) and the southbound lanes of a State highway (SR 529), and incorporates two horizontal curves to avoid bridge pilings.

The primary HDD risks associated with the Segment 5S HDD crossing stem from the near-surface soft soils that are identified as marsh deposits containing peat. These soft soils do not provide the strength required to contain drilling fluids and prevent frac-outs. The soft near-surface soils also do not provide the resistance necessary to steer a drill bit and maintain line and grade tolerances.

The risk of drilling fluids entering the sloughs due to frac-out was less of a concern for Steamboat Slough due to the increased set-back from the slough. Frac-outs that could occur between the entry point and Union Slough could be contained at the surface with erosion and sedimentation controls (to protect the wetlands). As such, a conductor casing was not specified at the entry location, although the contract did not preclude the Contractor from using a conductor casing.

Construction of the Segment 5S borehole began after the completion of the Segment 5N borehole and pullback of the product pipe. The same American Augers DD-625 drill rig was used for the construction of the Segment 5S borehole. The Contractor elected not to use a conductor casing at the entry location and, as expected, experienced a significant amount of frac-out at this location as the estuarine deposits did not have the strength to prevent the drilling fluids from escaping to the surface. Due to the loss of drilling fluids into the formation, the Contractor elected to install approximately 145 feet of 16-inch-diameter wash-over casing while drilling the pilot borehole.

The Contractor completed the pilot borehole in 12 days, with an average drilling rate of 356 feet per day. Similar to the Segment 5N HDD crossing, the Contractor submitted the estimated minimum borehole pressure (necessary to drill and maintain the borehole) as well as the limiting pressure that would cause frac-out. Figure 3 depicts the minimum, limiting, and actual borehole drilling fluid pressure during drilling of the Segment 5S pilot borehole.

Interestingly, frac-out occurred on this segment at three distinct locations as shown on Figure 3, but not where the borehole pressure momentarily exceeded the limiting pressure. Rather, frac-out occurred where the ground cover was

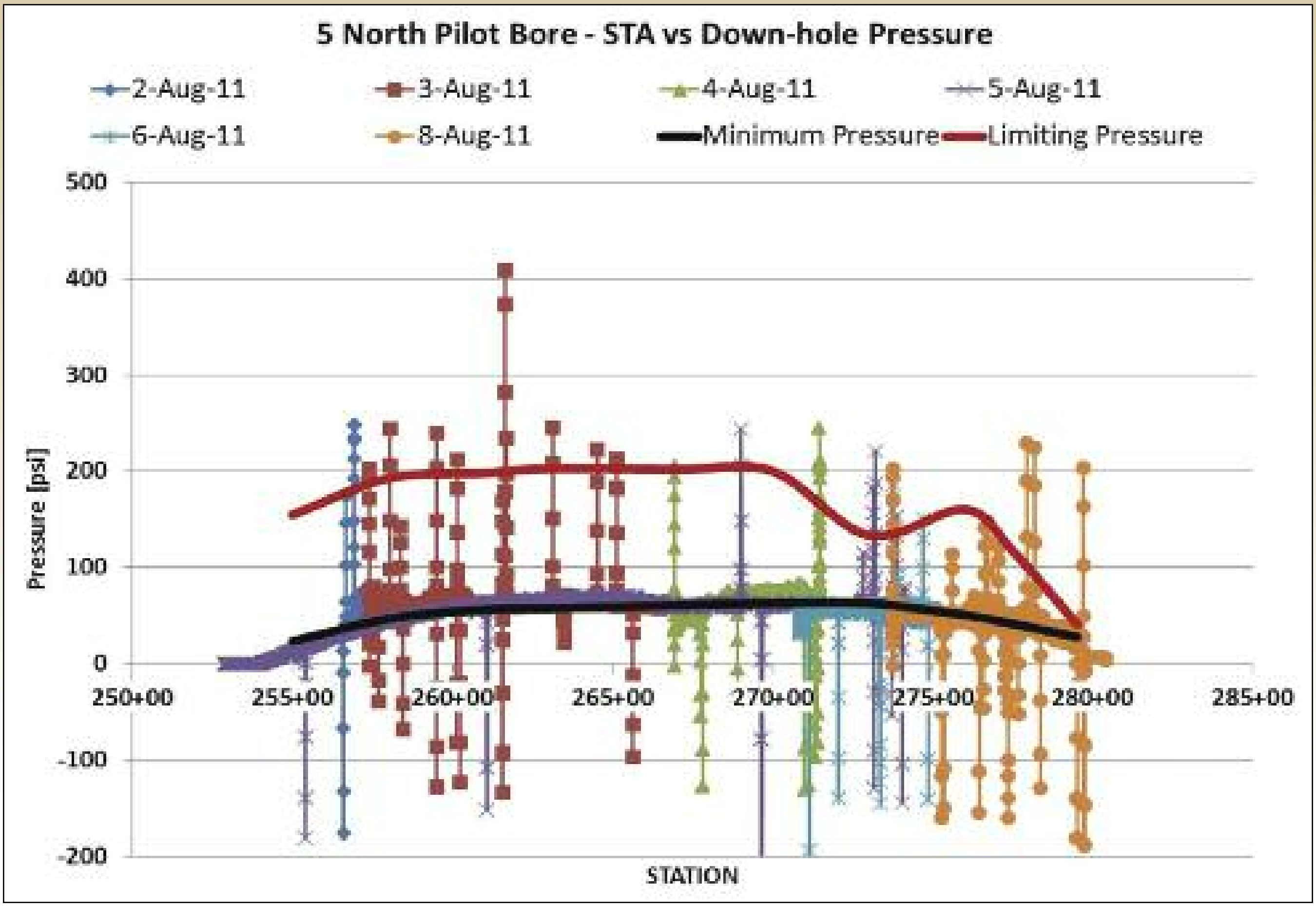

Figure 2. Measured Annular Pressure and Estimated Minimum and Limiting Annular Pressure for Segment 5N

shallow and the borehole pressure was near the calculated minimum borehole pressure. At these locations, if the frac-out is analyzed using the Delft equation (Staheli, et al. 2010) and the radius of the plastic zone is back-calculated by setting the limiting pressure to the pressure at which frac-out occurred, we find that the radius of the plastic zone is approximately three times the borehole radius.

For this segment, the Contractor elected to ream the pilot borehole in a single pass using a 36-inch scorpion reamer followed by a 48-inch scorpion ball reamer. This reaming assembly proved to exacerbate frac-out at the areas where the frac-out had previously occurred when drilling the pilot borehole. Although the borehole pressures were not measured during the forward reaming operations, it is likely that the massive increase in borehole diameter in a single pass induced significant borehole pressures that resulted in frac-out at the surface. Reaming operations were completed in eight days, with an average rate of 472 feet per day.

On the day of the product pipe pullback, it took several hours to move the product pipe in line with the borehole; however, once pullback of the product pipe commenced, it was completed without incident in just under 13 hours.

THE SEGMENT 7 HDD CROSSING

The Segment 7 HDD crossing is 1,287 feet long and traverses beneath a tidally influenced creek (Quil Ceda Creek) and wetlands. The primary HDD risks identified for the crossing include potential frac-out in the soft estuarine deposits, difficulty maintaining line and grade near the entry and exit locations due to soft soils, and overhead constraints (power lines) during pullback near the exit. Conductor casings were not required at this HDD crossing because the set-back distance from the creek was sufficient to allow drilling fluid clean up in shallow areas prior to crossing the creek.

Drilling of the pilot borehole took two days, averaging 628 feet per day. Frac-out occurred (while drilling the pilot borehole) at three main locations. Figure 4 shows the actual pilot borehole pressures, the minimum calculated borehole pressure required to create and maintain the pilot borehole, and the estimated limiting borehole pressure at which frac-out would occur.

The three main frac-out locations did not correlate with locations at which borehole pressure spikes occurred in the data recording. However, it should be noted that the frac-outs were not necessarily discovered when the drilling head was at the location that was in concert with a frac-out location. For example, one frac-out was discovered when the drill head was well beyond the location.

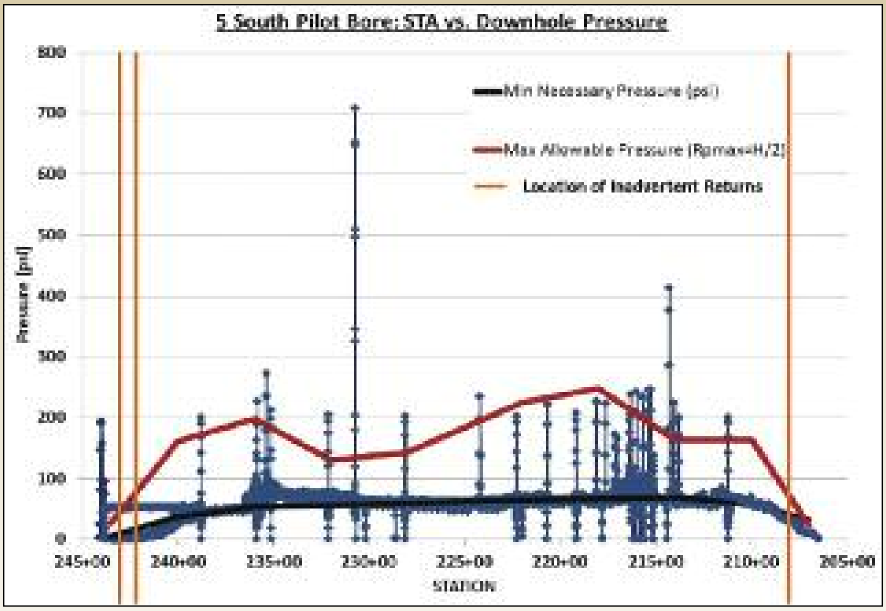

Figure 3. Measured Annular Pressure and Estimated Minimum and Limiting Annular Pressure for Segment 5S

Therefore, the over-pressurization of the borehole could have been caused by borehole collapse. A pressure sensor in the borehole would have measured the borehole pressure, but the frac-out would have manifested at the area along the borehole that was the weakest, not necessarily at the location of the drill bit.

As with the Segment 5S HDD crossing, the Contractor again elected to ream the borehole to the desired 48 inches in diameter in a single pass. Reaming was completed in three days, and averaged 235 feet per day. During the reaming process, several more frac-out locations manifested. In the soft soils, it was tremendously difficult to maintain a stable borehole and maintain drilling fluid flow back to the drill. As a result, the drilling fluid escaped at many locations including into Quil Ceda Creek.

Once the borehole was reamed, the Contractor was put on hold because product pipe pullback was not allowed during weekdays in order to minimize traffic disruption. Product pipe pullback operations commenced on the Wednesday before Thanksgiving and was completed in less than five hours without incident.

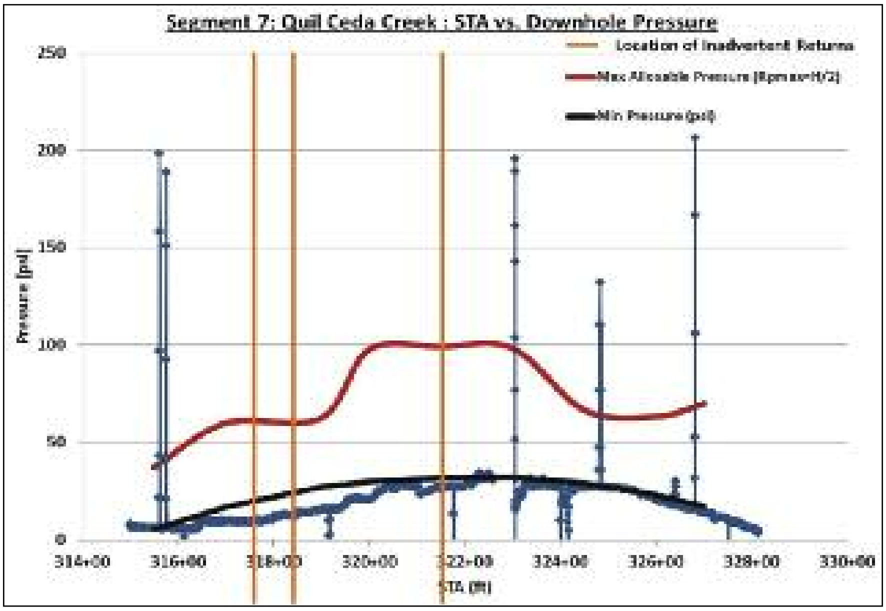

Figure 4. Measured Annular Pressure and Estimated Minimum and Limiting Annular Pressure for Segment 7

CURRENT STATUS OF SEGMENTS 3 & 2

Segment 3 was successfully completed in the spring of 2012 and included 2,000 feet of 36-inch diameter steel pipeline installation beneath the Snohomish River.

Segment 2, when constructed, will include an HDD installation of approximately 2,040 feet of 36-inch-diameter steel pipe underneath a city street and a BNSF Railroad yard. Final design is expected to begin in 2012, but construction has not yet been scheduled.

CONCLUSION

At the time this article was written in late 2012, the four HDD crossings that have been completed to date will allow the pipeline to be placed into service in an interim operation condition. Although not without challenges, the project has proven to be a success largely due to successful planning, design, management, and teamwork. There have been a tremendous number of people who have collaborated and worked tirelessly to ensure the success of the project and continue to strive to provide value to the Owner. Through diligent planning, design, and construction management, trenchless technologies can continue to be used for the successful installation of challenging pipelines.

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Frozen Soil Rescue Shaft Beneath An Interstate Off-Ramp

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ABSTRACT

Ground freezing was used to successfully rescue a project involving the installation of a 36-inch-diameter water line for the Tulalip Tribes near Marysville, Washington. Horizontal direction drilling techniques for the waterline were successful until the pipe and pull string got hung up on the lead edge of a previously installed 60-inch-diameter steel conductor casing during the pullback process. Access to the stuck pipe was limited because it was 65 feet deep directly under an active off-ramp for Interstate 5 (I-5). SoilFreeze and Southeast Directional Drilling utilized frozen soil to create a stable, eight-foot-diameter inclined access shaft down to the rescue point. At the bottom of the sloped shaft, a large open cavity, roughly 10 to 12 feet in size, was excavated to allow workers access to the product pipe. The water line was successfully completed without disrupting traffic and having met the requirements of the owner and the many involved agencies.

The Tulalip Water Pipeline project consisted of the installation of a 7.5-mile-long water transmission pipeline from the City of Everett to the Tulalip Tribes Reservation to provide long-term water supply to the Tribes. The project was broken into eight segments. The general contractor for Segment 5 was Don Kelly Construction (DKC), who subcontracted with Southeast Directional Drilling (SEDD) to complete the horizontal directional drilling (HDD) required in the high-water slough area.

Segment 5N consisted of a 2,800-foot-long HDD that roughly paralleled the west side of I-5 extending beneath Union Slough. The project required that a 240-foot-long 60 inch-diameter steel conductor casing first be installed beneath the I-5 off-ramp for SR529 to protect the off-ramp during HDD operations. During the pullback/reaming process, the drill string became hung up on the lead edge of the conductor pipe. The location where the drill string became stuck is directly beneath the off-ramp, approximately 65 feet below the pavement surface.

The soil conditions at the site consisted of embankment fill (silty sand and gravel) overlying alluvial deposits (loose to medium-dense silty sand). Tidally influenced groundwater was near the natural ground surface near the base of the embankment. Wetlands surrounded the rescue shaft site.

Early attempts to free the drill string from the ground surface failed. The best remaining option was to excavate down to the lead edge of the conductor casing and expose the product pipe via a rescue shaft. This approach required significant shoring and groundwater control due to the loose alluvial soils and high groundwater. After an exhaustive review, the selected method for the rescue shaft was ground freezing. SoilFreeze, a Seattle-based ground-freezing contractor, was retained by SEDD to design and create a frozen soil shaft that provided stable and watertight access to the rescue point at the end of the product pipe.

FROZEN SOIL SHORING APPROACH

The geometry on this project was quite challenging given its proximity to the state-controlled roadways and surrounding wetlands. Traffic along the Interstate and off-ramp could not to be impacted in any way. This restriction eliminated the possibility of a vertical shaft that extended from the ground surface down to the rescue point. Instead, SoilFreeze designed an inclined shaft that extended below the off-ramp from the west side of the roadway embankment, perpendicular to the conductor casing, to the rescue point. Then, because the soil at depth consisted of saturated, silty sand, a shaft “bottom” was built by extending a freeze wall down from the east side of the exit ramp to intersect the shaft below the rescue point. Figures 1 and 2 show a plan view and

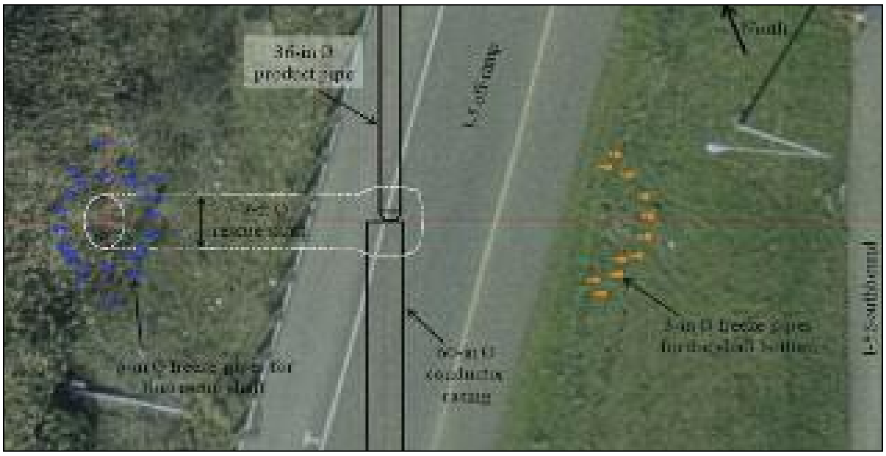

Figure 1. Plan View

cross-section of the area and the location of the shoring elements. The inclined shaft and bottom cutoff wall resulted in a complex three-dimensional solution that was made even more difficult by the sloping and non-uniform ground surface and the waterline that was inclined at 10 degrees from horizontal.

Finite element modeling, including thermal and structural analysis, was used to design the frozen soil shoring. Great care, excellent ground surface survey control, and a considerable amount of trigonometry were used to lay out the freeze pipe locations on the ground surface so that they were spaced close enough to freeze the ground in a reasonable timeframe without hitting each other or the product pipeline during installation.

Due to the Interstate off-ramp being located between the east and west systems, separate chillers and generators were operated at each location. The west system consisted of the access shaft and included 22 freeze pipes installed at 45 degrees into the side of the roadway embankment (See Figure 2). These pipes generally extended beyond the rescue point to a depth of 75 to 80 feet below the ground surface except in the vicinity of the conductor casing and the product pipe. The east system consisted of the shaft bottom and included 13 freeze pipes installed at 60 degrees (from horizontal) to a depth of 80 feet below the ground surface. Calcium chloride brine chilled to about 18 degrees Fahrenheit was circulated through each of the pipes, freezing a solid zone of soil for the shaft.

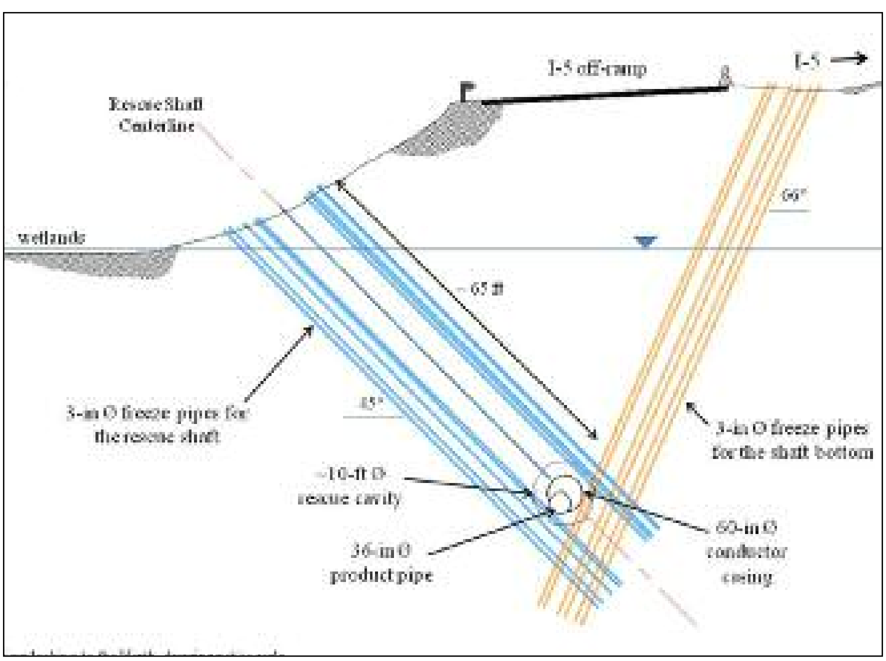

Figure 2. Area Cross-section

Installation of the freeze pipes was completed by DBM, an experienced drilling subcontractor. The pipes on the east side were installed first to create the bottom wall, and then the pipes from the west were installed for the shaft.

One of the biggest challenges during installation was verification of the freeze pipe location and alignment. On the east side, this was easily accomplished using a downhole survey probe. However, the pipes on the west side were at too flat an angle for this probe and a different methodology was required. SoilFreeze engineers created a small trolley equipped with a mini surveying prism (peanut) that fit into the empty three-inch freeze pipe. The trolley was then lowered down the pipe and successfully surveyed using a conventional total station instrument.

FREEZING PERFORMANCE

The frozen soil stabilization worked very well. Freezing took about five weeks to complete, at which time excavation began at both the rescue shaft and from inside the conductor casing. The excavation in the casing consisted of cleaning out the material in the casing down to the rescue point. The excavation for the rescue shaft was completed by Engineering & Construction Innovations, Inc. (ECI). It was begun by constructing a concrete portal with eight-foot-diameter (ID) steel liner plates that was surveyed into place to establish the correct alignment.

A concrete portal with steel liner plates was constructed and put into place.

Excavation was completed using high-pressure water wands and pneumatic chipping guns.

The contractor elected to use the steel liner plates to aid in entering and exiting the steep shaft, to protect the frozen soil from thermal erosion as work progressed down the shaft, and to help maintain the alignment of the shaft. Ground support and groundwater cutoff, however, was provided entirely by the frozen soil shoring. Excavation was completed using primarily high-pressure water wands and pneumatic chipping guns. The frozen soils remained stable during the entire excavation, and no signs of seepage were observed. The air temperature differential between the cool air at the base of the shaft and the warm ambient air resulted in condensation on the liner of the upper portion of the shaft. The condensation then collected and flowed back to the base of the excavation and re-froze, creating an ice layer that occasionally had to be chipped out and removed.

The end of the conductor casing and the product pipe were encountered almost exactly in the middle of the excavation. The product pipe was exposed and the shaft was expanded to a cavity that was roughly 12 feet wide, 10 feet deep, and nine feet high. The steel liner plates did not extend into the frozen cavity. Instead, insulated tarps were nailed directly onto the frozen soil to protect the soils against thermal erosion. The cavity remained open for approximately two to three weeks while the product pipe was repaired and completed. The repair process included heat-generating activities such as the use of a cutting torch to remove portions of the conductor casing and the drill string, welding the butt straps onto the product pipe, and heating the pipe for application of the protective coating.

Through all the repair activities, the frozen soils remained frozen with a typical temperature of 20 to 25 F on the face of the cavity. After the pipeline was successfully completed and coated, the frozen cavity was backfilled with pea gravel and the shaft was filled with grout.

One of the concerns at the beginning of the project was the stability of the frozen soil shaft and the impact that the frozen soil would have on the surrounding soils, most notably the Interstate off-ramp overlying the rescue point. During excavation, points were established inside the shaft to measure any deflection that occurred while the excavation progressed. Shaft deflections never exceeded 1/8 inch. In addition, survey of settlement points on the ground surface indicated ground settlement of less than 1/8 inch throughout excavation and repair activities.

Directional Drilling In Mukilteo -

Lessons Learned from an HDD with 330 Feet of Elevation Difference

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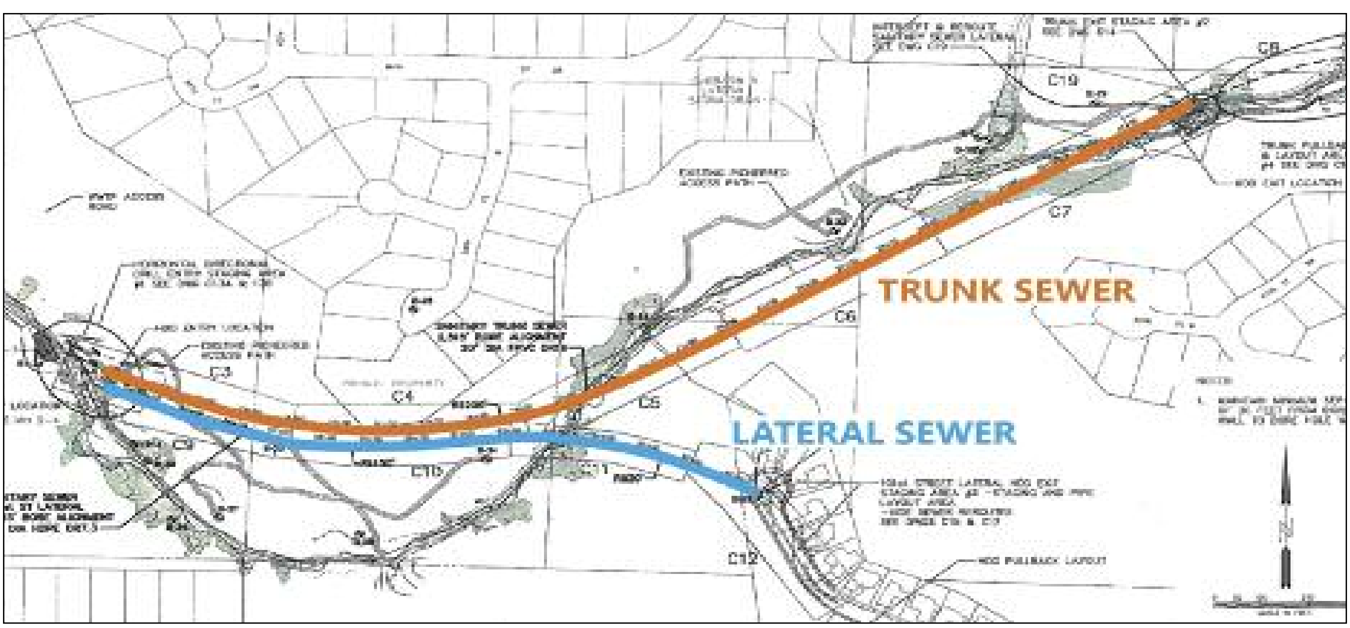
Mukilteo Water and Wastewater District

In August of 1999, Mukilteo Water and Wastewater District (District) conducted an evaluation of a deteriorating sanitary sewer trunk line within the Big Gulch, a steep-sided coastal ravine located just south of Mukilteo, Washington. The existing trunk sewer was an unrestrained bell-and-spigot concrete pipeline approximately 8,650 feet in length which was constructed in 1970 to convey wastewater to the District's sewage treatment plant on the shores of Puget Sound. Since the construction of the sewer main, increased flow in Big Gulch Creek had led to incision of the ravine and undermining of the sewer trunk line at several locations. The 1999 evaluation ultimately recommended replacement of the sewer and suggested that the Big Gulch Sewer Repair Project be divided into four segments for design and construction. Segment 3, the focus of this paper, included the construction of both a new trunk sewer and a lateral sewer installed via horizontal directional drilling (HDD). The two drills are shown in plan view in Figure 1.

The replacement trunk sewer consisted of approximately 2,600 linear feet of 20-inch (nominal diameter) fusible polyvinylchloride pipe installed via HDD. The vertical elevation difference between the HDD entry and exit points was approximately 140 feet. The alignment was designed on a 1,200-foot horizontal bend radius and utilized a 1,500-foot vertical bend radius.

The proposed lateral sewer consisted of approximately 1,500 linear feet of 12-inch (nominal diameter) high-density



Plan view of the two sewer alignments

Temporary shoring at the entry location

Excess mud flows out of the spoils pit

polyethylene (HDPE) pipe installed via HDD. The vertical elevation difference between the HDD entry and exit points was approximately 280 feet. The alignment was designed with compound curves containing an 1,150-foot and a 920-foot horizontal bend radius in conjunction with an 800-foot vertical bend radius.

GEOTECHICAL CONDITIONS

The geologic investigation conducted for Segment 3 included 20 borings taken between August 2007 and January 2008, and determined that subsurface conditions in the project area generally consisted of colluvial (landslide) and alluvial (stream) deposits underlain by glacial lacustrine deposits. The distinct density difference between the landslide deposits, which generally consisted of very soft to stiff silt and clay with variable sand and gravel content, and the underlying glacial lacustrine deposits, which consisted of very stiff to hard silt and clay, led to significant concerns about slope stability at the HDD entry point. These concerns were reinforced by the prominent head scarps and colluvial masses observed throughout the project area, indicating both recent and prehistoric landslide events in the Big Gulch ranging from hundreds to thousands of years old.

In order to negate this risk, conductor casings were specified on both drills to bridge the bore into the more competent glacial lacustrine deposits. Eighty and 100 feet of 36-inch and 20-inch conductor casings were specified for the trunk and lateral sewers, respectively. Additionally, temporary shoring piles and steel plates were used to stabilize the slope at the HDD entry points in order to restrict potential movement of the slope toe while expanding the available contractor work area.

TRUNK SEWER – PILOT BORE

Construction of the trunk sewer began in May of 2009 with the installation of the 80-foot 36-inch conductor casing. Having elected to install the casing via pipe ramming, the Contractor ran into difficulty at 48 feet when the casing advancement slowed to approximately one inch every 10 to 12 minutes. After hammering for almost two hours with no movement, the Contractor elected to halt the installation at 52 feet due to concerns about damaging the leading edge of the casing.

The pilot bore for the trunk line began in June, with 300 feet of drill pipe advanced on the first day of drilling. For excavation the Contractor elected to use a downhole mud motor, a high-pressure and high-volume tool that is commonly used for rock drilling. This quickly proved to be problematic, as hydrofracture on the slope above the bore centerline 200 feet into the alignment was discovered on the second day of drilling, likely from excessive downhole fluid pressure. As the pilot bore advanced, excessive volumes of spoils coming out of the mud pit began to clog the screens on the slurry plant and to overtop the spoil containment area beyond the defined boundaries of the construction work limits adjacent to a creek. Repeated attempts to remove the drill string and re-drill the hole resulted in higher and higher mud volumes coming out of the mud pit, and significant flooding of the work area with mud and spoils. Despite these complications, the Contractor elected to keep trying to advance the bore beyond the 310-foot mark using the original mud motor. Within the first eight days, the Contractor had re-drilled the same approximately 120-foot section of the alignment 12 times and had excavated several times the anticipated soil volume of the bore.

This continued over-excavation had a dramatic impact on the ninth day as three trees suddenly fell into a large sinkhole that developed on the surface more than 50 feet above the alignment. At this point, the Contractor elected to switch to a more traditional slanted head bit, with which 1,160 feet of the pilot bore was successfully drilled. Hard ground prompted the Contractor to switch to a different mud motor after three days of progress. One

31-inch forward reamer

with less volume output was selected in order to restrict mud flow. After a few episodes of tripping and re-drilling, the Contractor successfully finished the 2,600-foot pilot bore after a combined 14 days of drilling.

TRUNK SEWER – REAMING, PULLBACK

Reaming started in the third week of June with a 31-inch forward reamer. A problem was encountered almost immediately when the Contractor could not advance the reamer beyond the edge of the 36-inch conductor casing. It seemed probable that the edge of the casing had partially collapsed upon installation due to the repeated blows with the pneumatic ramming hammer. A crew member was sent into the 36-inch casing with a cutting torch to remove a portion of the collapsed section, and returned with a 1-foot-by-1-foot section of the leading edge. At this point the Contractor was successful at advancing the reamer past the end of the conductor casing.

After successful completion of the reaming pass, the Contractor prepared the bore for pullback. The pipe was successfully pulled back in approximately 10 hours, which included one intermediate connection of two pipeline sections.

LATERAL SEWER – PILOT BORE

Construction of the lateral sewer started in the last week of August. The 20-inch conductor casing had been installed prior to the start of the drill, but it was determined upon advancing the drill pipe out to the end of the casing that the leading edge had been damaged, presumably during installation. Given the difficulties experienced on the trunk sewer installation due to the damaged end, the Contractor elected to ram out the 20-inch casing and replace it with 75 feet of 24-inch casing. After the new casing installation was completed, a plan was developed to drill a pilot hole about 250 feet and then ream out the hole to an approximately 18-inch diameter for the installation of 18-inch washover casing. This installation was quickly performed, ending with 240 feet of 18-inch casing.

LATERAL SEWER – REAMING, PULLBACK

The lateral sewer was reamed from entry to exit to within 100 feet of the exit location. The reamer was then pulled back to the rig and taken to the exit side where the Contractor then pulled ream from the exit side back towards the rig approximately 100 feet while installing the 18-inch washover casing simultaneously behind the reamer until the reamed holes were within 20 feet of being "connected." The pipe was successfully pulled in about eight hours, which included an intermediate fuse of two pipeline sections.

This challenging project, which pushed the limits of the current technology, was ultimately successful because of the efforts of a diligent HDD Contractor, a vigilant and fair CM and inspection staff, and a forthright and understanding project owner.

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Challenges & Successes of Open-Shield Pipe Jacking in a Congested Neighborhood

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The Madison Valley area of Seattle has a history of major flood events due to the area's steep watershed flowing into Lake Washington east of the city's downtown. The natural drainage route was cut off in the early 1900s when the Madison Street Trestle was replaced with sluiced fill from the surrounding hillside, effectively blocking the natural water course. The sewage and storm water system, built in the 1970s, was designed for a 25-year storm and proved inadequate to convey flows generated by extreme storm events, resulting in chronic

Figure 1. Overview of the Madison Valley Project Area in Seattle, Washington

Figure 2. Locations of the Borings for the Alignment Study

flooding of the area. The impacts of flooding resulted in numerous damage claims, a $2.5-million settlement to affected homeowners, and a $2.8M settlement when a local resident became trapped and drowned in her flooded basement in a December 2006 storm.

To alleviate local flooding and attenuate peak storm water flows, Phase II of the Madison Valley Long Term Solution, Northwest Diversion and Washington Park Storage Project was implemented. Storm water and/or combined sewer flows from the western slope of the Madison Valley drainage basin are diverted to a two-million-gallon storm water storage area consisting of both an above-ground retention berm and a below-ground partially buried storage tank.

PREDESIGN AND ROUTE IDENTIFICATION

During the preliminary design of the project, an extensive geotechnical investigation was conducted to explore multiple alignment alternatives. Seattle Public Utilities (SPU) used their in-house geotechnical division to perform the investigation and develop the geotechnical report for the project.

The geotechnical investigation revealed that the overall geology of the site consisted of a thick lacustrine layer that was primarily stiff to hard silt. This layer had very low permeability with perched groundwater. An alluvial channel was identified through the middle of the project that had previously served as the primary drainage for the Madison Valley area prior to development. Alluvial outwash was discovered in this area consisting of medium-dense silty sand with gravel and the potential for cobbles and boulders. Groundwater was seasonally present within this unit. In addition, a buried trestle was located along with a timber road that was abandoned and contained within the fill material.

The alignment was chosen to avoid the fill and alluvial outwash as much as possible while maintaining gravity flows to the storage tank site. During the pre-design, the necessary pipe-flow diameter was determined to be 48 inches and SPU chose ductile iron for the conveyance pipe.

TRENCHLESS ALTERNATIVES

After selecting the preferred alignment, a feasibility study was conducted to identify the trenchless technologies that would be carried forward for further evaluation. The technologies considered were microtunneling, pilot tube auger boring, and open-shield pipe jacking. Horizontal directional drilling was discounted due to the pipe and grade requirements. The 48-inch ID pipe required an oversized casing for the trenchless construction. To compare the trenchless alternatives, a "base case" of jacking 60-inch steel was evaluated.

Early in the feasibility study, pilot tube technology was deemed high-risk due to the presence of hard over-consolidated silts with blow counts too high for advancement of the pilot tubes. Auger boring was feasible in the soil conditions but could not provide the accuracy necessary to maintain the grade requirements to

Figure 3. Alignment and Shaft Layout for Madison Valley Project

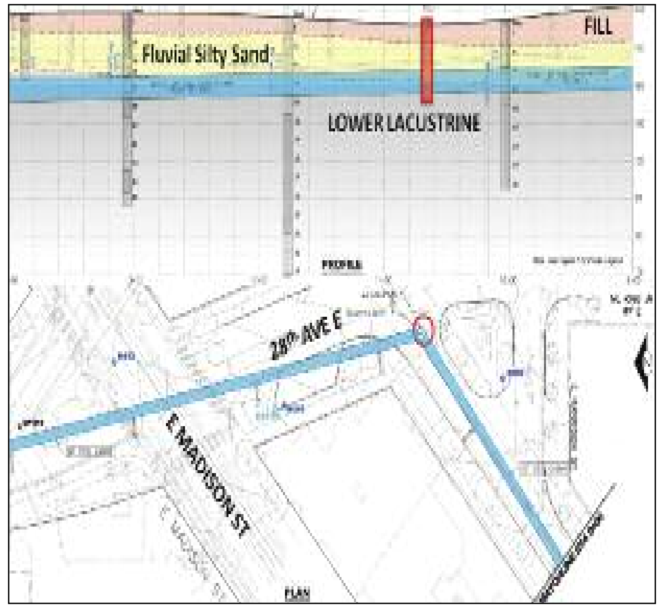

Figure 4. Cross Section of Soils along Madison Alignment

guarantee gravity flows in the pipeline.

Both microtunneling and open-shield pipe jacking were carried forward into a detailed evaluation for final selection of the preferred trenchless method. Figure 3 shows the final alignment for either microtunneling or open-shield pipe jacking.

Geotechnical conditions were the primary factor for determining the preferred trenchless method. Microtunneling was favorable in the alluvial soils where groundwater was seasonally present and where soils were potentially unstable; however, these soils were only present along the Arthur and Madison drives comprising approximately 25% of the alignment. In addition, the alluvial soils had the highest chance for encountering cobbles and boulders which are more problematic to microtunneling than to open-shield pipe jacking, where access to the face is possible for removal of obstructions. Open-shield pipe jacking was ideal for the lacustrine soils that comprised 75% of the alignment but could have stability issues beneath Madison Street – the street with the most traffic flow on the project.

Figure 4 shows the geotechnical cross-section beneath Madison Street, which was the area of greatest concern for both trenchless methods. This alignment was of particular concern for open-shield pipe jacking due to the potential instability of the alluvial outwash and the groundwater, and for microtunneling due to the potential of encountering cobbles and/or boulders.

A risk matrix was developed to identify the various risks associated with each technology along the preferred alignment. The risks were refined by identifying the potential impacts (costs) of each risk. They were then quantified by determining the likelihood that each risk would occur and then multiplying the likelihood of occurrence by the impact cost. This exercise allowed the design team to systematically characterize the trenchless risks based on the nuances of each technology and then choose the trenchless method that provided the lowest overall risk profile for the project. It was also a valuable tool to allow the owner to clearly understand the range of risks for each trenchless method. Working with the engineer, the owner identified project risks that were deemed "acceptable" and those which were not. Acceptable risks were carried through the project and appropriately budgeted for in the project contingency. Risks that were not deemed acceptable were specifically eliminated through design.

Evaluation of the risk matrix led to the selection of open-shield pipe jacking as the preferred trenchless method. For the area where this method posed increased risk, the owner decided to pursue the permits necessary to allow dewatering across Madison Street and Arthur Street should it be required to ensure face stability. In addition, the owner wanted to specify a trenchless method that allowed access to the face of the machine if an obstruction was encountered under East Madison Street in order to reduce the chance of excavating from the ground surface.

SITE CONSTRAINTS

Madison Valley is an older affluent community of Seattle with narrow neighborhood streets and an active business community. Noise and local access were of critical concern for the businesses and homeowners adjacent to the shafts. Among the businesses most sensitive to construction impacts were a psychiatry practice, a local kindergarten, and small offices. Efforts were made by the engineer during design and by the contractor during construction

Figure 5. 60-inch Diameter Open Shield Pipe Jacking Machine Used on the Project

to mitigate construction noise and reduce impacts to the community. By communicating early on in the design process, business owners were provided the opportunity to voice concerns, and the design team had the time necessary to respond with educational efforts to manage expectations allowing the design to proceed without delay. The contractor positioned equipment and performed on-site outreach to build rapport with the neighbors and reduce overall project impacts during construction.

CONSTRUCTION OF THE TUNNELS

The soils along the vast majority of the alignment proved to be consistent with the Geotechnical Baseline Report, which identified both upper and lower lacustrine deposits. Both lacustrine units proved ideal for open-shield pipe jacking as they were excavated; the face stood vertically and allowed a consistent and stable annular space with low jacking forces.

Fill ranged from very loose to medium-dense silty sand and stiff sandy silt, and was present near the surface along the majority of the alignment. An abandoned trestle which had been sluiced-in with surrounding material in the early 1900s (Aspect GDM, 2009) was a concern during design. The tunnel alignment was positioned to decrease the likelihood of excavating through the remnants of the old trestle and during tunneling there was no indication that the trestle was ever encountered.

CONCLUSION

Choosing the most appropriate trenchless method can be the most critical decision the design team makes for a trenchless project. Careful analysis of the available geotechnical data, site constraints, cost, risks (including the associated impacts), and how all of these factors influence one another is not only challenging, but crucial for a successful project. The decision to select one technology over another on this project was ultimately influenced by a balanced risk approach to geotechnical impacts and having the engineer work side by side with the owner to

Figure 6. Constrained Jacking Shaft Site Overlooked by Adjacent Homes

develop an understanding of how trenchless risks can be mitigated. Open-shield pipe jacking was chosen as the tunneling installation method and it proved to be the best fit for the ground conditions and the overall project constraints. The contractor was able to perform the work with expediency and successfully completed the nearly 2,500 feet of casing installation.

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I-15 Project: Extensive Small-Diameter Pipe Jacking in Utah

Laura Anderson
Akkerman

The Interstate 15 (I-15) CORE Corridor Expansion Project, owned by the Utah Department of Transportation (UDOT) in Provo City, Utah, is home to one of the largest amounts of concentrated small-diameter pipe jacking crossing in one location. Minger Construction, Inc., of Chanhassen, Minnesota, simultaneously jacked 18- to 72-inch ID pipes with a guided boring machine (GBM) system and several tunnel boring machines (TBM) for a total of 14,587 linear feet in shallow depth of cover and varying geology.

The I-15 CORE project encompasses 24 miles of reconstruction including the addition of lanes, extending an express lane, redesigning 10 freeway interchanges, and replacing 55 bridges. In one of the fastest growing counties in the nation and the second most densely populated county in Utah, the I-15 CORE project is essential to meet the needs of the aging infrastructure in Utah County and is projected to meet transportation demands through 2030. The I-15 CORE is bond funded and has a total budget of $1.725 billion.

The full timeline of the project, from design to completion, is January 2010 to December 2012. Forty-eight drives of pipe jacking linear footage were installed between June 2010 and May 2011. Minger Construction did not install pipelines in the summer of 2011 due to traffic phasing and conflicts with other portions of the project. They resumed work in September 2011 and finished in January 2012, completing the final 15 bores.

The design-build consortium of contractors, Provo River Constructors (PRC), consists of many contractors in the local, state and national levels. Ames Construction Company Inc. of Salt Lake City selected subcontractor Minger Construction to perform the storm sewer pipe jacking installation work.

Initial project discussions and design plans estimated that more than 100 trenchless borings would be necessary. After further design revisions, that number was brought down to 60-plus and has manifested into a final quantity of 63 drives. Due to shallow depth of cover and in order to keep costs low, the residual bores were redesigned as open-cut pipelines. The majority of the 63 bores consist of highway cross culverts and storm drainage tunnels, with about 5% of the bores for utilities. Old culverts and storm drainage tunnels were abandoned and PRC filled the retired lines with grout. About 85% of the new installations were parallel to the abandoned tunnels.

The project owner did not specify that trenchless methods must be used in the original bid package. Due to the design-build nature, emphasis was placed on innovation, optimized costs and adhering to the timeline. All pipe-jacking work had to be completed while other highway, expressway, interchange and bridge work was conducted and live freeway traffic was moving.

Minger Construction completed all pipe-jacking drives with a GBM system and several sized TBMs. Additional equipment used with the GBM system included a cutter head with integral swivel, three sizes of power cutter heads (PCH) upsizing tools, along with a power pack and dirt bucket. The TBMs were launched with an all-in-one pump unit, yoke, skid, haul unit configuration and intermediate jacking stations to distribute the thrust load on longer drives with harder ground conditions. Most of the pipe-jacking equipment was purchased or leased by the contractor from manufacturer Akkerman.

The reinforced concrete pipe (RCP) used was specially manufactured by Old Castle Precast in sizes 18-, 24-, 30-, 36-, 48-, 60- and 72-inch ID. The smallest pipe was 18 inches ID with a mere 2.5-inch wall thickness, yet responded well under 150 tons of jacking pressure. The RCP sizes 18- through 28-inch ID were in eight-foot segments. The RCP in the 60- and 72-inch ID sizes were 12-foot sections. The combined length of RCP installed with both pipe-jacking systems was 12,599 l.f., with an additional 1,730 l.f. in extension lengths.

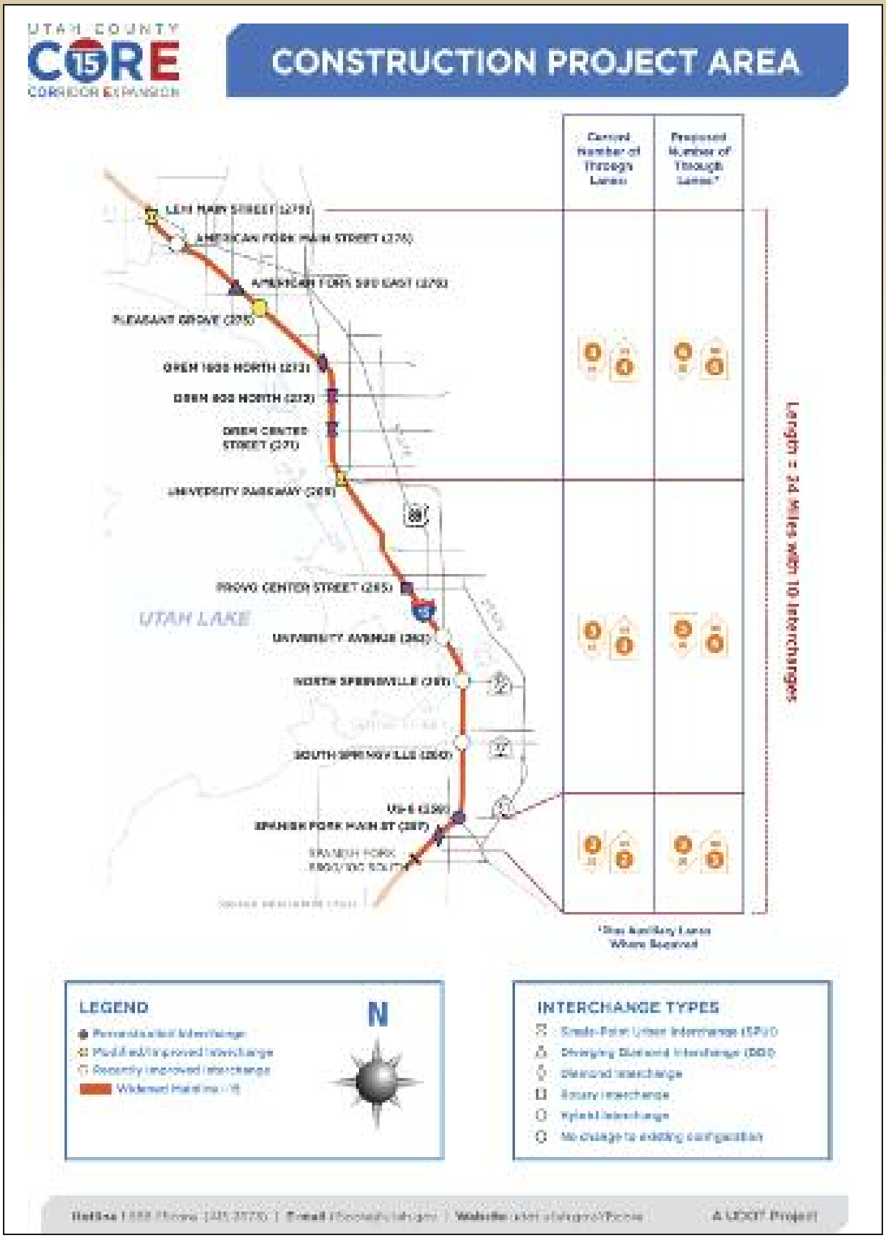
There were 10 drives where steel casing pipe, acquired from various manufacturers, was used in 24- to 48-inch ID sizes. The steel casing pipe installed with a TBM, was in 20-foot lengths. The steel casing pipe installed with the GBM method was cut into 10-foot lengths and welded at each joint. The total length of steel casing pipe installed on this project was 1,988 l.f. with an additional 690 l.f. in extension lengths on these bores.

A GBM jacking frame with a 200-ton thrust capacity was used for diameters ranging from 18 to 36 inches ID and totaled 6,542 l.f. in 29 drives. A PCH upsizing tool, in three sizes, was used in conjunction with the GBM jacking frame to increase the final bore diameter to match the final product pipe. The longest GBM drive on this project was 456 l.f. of 24-inch ID RCP.

The all-in-one Akkerman 5000 Series pipe-jacking system and five sizes of TBMs were used to complete 34 drives ranging in size from 36 to 72 inches ID and totaled 8,045 l.f. The longest TBM drive on this project was completed with the TBM 360 and installed 432 l.f. of 36-inch ID RCP.

Paramount to the performance of the equipment was the need for accurate line and grade due to a shallow depth of cover. Since most of the bores were replacement culverts and storm drainage tunnels, contractors had to work within the existing infrastructure. The drive with the shallowest cover rested six inches below the roadway and averaged six feet for the whole project. The deepest drive was 30 feet below ground surface, and Minger crew members immediately pressure grouted it upon its completion.

Minger reported a 95% up-time on all pipe-jacking equipment. When faced with the simultaneous demands, one GBM and one TBM crew would average two to three GBM bores and two TBM bores per month. When necessary, the crew would work a double shift or all day. Minger reported their best installation with the GBM system was 18 eight-foot sections of 24-inch ID RCP in 10 hours, or 144 feet. Their best production rate with a TBM 480 was 13 eight-foot sections, or 104 feet, of 48-inch RCP in 10 hours.



The soil conditions on the drives ranged dramatically. It included slag which had been transported as fill into the area from a nearby steel mill in the 1950s when the highway was originally constructed. Minger found that each of the five construction areas had distinctive soil properties laden with anything from slag rock, iron deposits, large cobblestones, undocumented obstacles including concrete, asphalt and concrete slag along with pipe, storm and irrigation lines, iron, and galvanized steel culverts to very wet geology where the water table was encountered just one foot below the ground.

One of the contractor's largest hurdles was refiguring shaft locations due to traffic pattern or project construction changes. This presented many difficult choices in terms of obtaining pipe, moving equipment, maintaining crew safety, optimizing distance from other concurrent I-15 CORE construction and contending with live traffic. The trench boxes needed to be large enough to accommodate the equipment, eight- to 20-foot-length pipe sections, and enough above-ground surface space for the pipe jacking ancillary equipment. Changes to drive lengths and sizes had to be relayed to the pipe manufacturer so that the appropriate amount of pipe was delivered in time for the bore launch.

The composition in the area with slag and fill material was chock-full of undocumented obstacles and large, naturally occurring cobbles. The obstacles included stumps, iron ore deposits 12-plus inches in diameter, concrete bases from former light posts, storm and irrigation lines, concrete pipe, asphalt chunks, steel culverts and concreted slag. The GBM could not be used in this area because the pilot tubes could not penetrate or displace these objects. Three small-diameter drives, originally intended for the GBM system, had to be changed to TBM system drives. Minger had to hand mine at the front of the cutter head to remove the obstacles from the face of the bore. In addition, this area contained pockets of loosely compacted gravel, which would funnel down into the cutter face. In these cases, Minger pressure grouted the outside of the pipe string to reduce the potential of forming voids.

Minger Construction jacked 18- to 72-inch ID pipes with a guided boring machine system and several tunnel boring machines.

During the winter months, colder temperatures would cause the high-pressure jetting water and bentonite lubrication fluid to freeze. To overcome this, Minger placed frost blankets over the jetting and lubrication pumps. They also created a tarped frame and ran a propane heater inside the shaft to keep fluids warm. At night they either ran the propane heater or removed the pump unit from the launch shaft and stored it in the job-site trailer.

On the I-15 Corridor Expansion Project, Minger Construction installed an unprecedented amount of trenchless construction linear footage in one concentrated area. Although several of the original crossings were eliminated due to value engineering and shallow cover, Minger was able to install a sizeable number of new highway culverts, storm drainage and utility crossings via pipe jacking. While faced with challenging soil conditions, concurrent construction strains, shallow depth of cover and other stressors, Minger gained a vast amount of expertise on their equipment's capabilities and is now able to tackle similar projects with a high level of assurance. The UDOT and Provo-area residents can also enjoy the benefits of quality infrastructure for many years to come.

Microtunneling Compressed Air Interventions in Challenging Ground Conditions

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Compressed Air Interventions (CAI) are not uncommon in conventional tunneling. Used for machine inspection, maintenance or repair, the intervention is a useful tool that allows tunneling to continue without the undue delays of other alternatives. However, when microtunneling in challenging ground conditions is involved, the CAI takes on much different risk and safety considerations. This was the case in the Balch Consolidation Conduit Shafts and Pipelines project (Balch) for the City of Portland's Bureau of Environmental Services (City).

THE BALCH PROJECT

In its continuing efforts to control combined sewer overflows into the Willamette River, in 1994 the City entered into an Amended Stipulation and Final Order administered by the Oregon Department of Environmental Quality (DEQ). The order required the City to control combined sewer overflows into the river by December 1, 2011. Balch was one of the final steps in meeting this mandated deadline. More than 8,000 feet of pipeline would carry combined sewage and stormwater runoff from Portland's industrial neighborhood northwest of downtown to the Columbia Boulevard Wastewater Treatment Plant on the east side of the river.

The area is known for challenging soil conditions, as evidenced on prior tunneling projects. Balch proved no different, with the geotechnical baseline report indicating a combination of gravel alluvium, sand, Troutdale formation (gravel, cobbles and boulders in lightly cemented sandy silt), open-network gravel with cobbles, mixed face conditions, and zero blow count silts. The project site also included a former lake filled in with a variety of soft lake sediments, sand, sluiced gravel and wooden railroad trestles and a former landfill with contaminated media along the pipeline alignment.

Early in the design phase of the Balch project, the City made a decision to pursue an alternative form of contracting rather than traditional design-bid-build procurement. This determination was based on two key factors: the necessity to meet the DEQ deadline by procuring long-lead-time equipment such as the microtunnel boring machine (MTBM), and to reduce the City's risk by having qualifications as part of the selection criteria. The Construction Manager/General Contractor procurement also created an additional benefit of developing a partnership mentality for the project where the typical contentiousness was removed and replaced with a genuine attitude of all the project participants working together for the best outcome for the project. James W. Fowler Co. (JWF) was chosen as the preferred contractor and entered into a Pre-Construction Services Agreement (PSA) with the City at the 30% Design phase and eventually a construction agreement when the design was complete.

The Balch team included the City, JWF,

Kennedy/Jenks Consultants, Staheli Trenchless Consultants, Jacobs Associates, and Shannon & Wilson, Inc.

PROJECT CHALLENGES

The scope of work for the Balch project included five microtunnel drives and six launch and/or reception shafts at depths from 20 to 75 feet below the surface. Based upon the geotechnical conditions, ground modifications were recommended for break-in and break-out of the shafts and along the alignment of one microtunnel drive. With the close proximity of the Willamette River, the groundwater would fluctuate seasonally, ranging from 10 to 15 feet below the surface, with typical groundwater pressure of approximately 1.2 bar. Dewatering methods to address the significant water were identified, keeping in mind the contaminated media known to be in the vicinity.

Approximately 900 feet into the final 1,700-foot drive, the MTBM hit an unknown object and would not continue mining. Eventually, after performing a CAI at the face of the machine, it was determined that the cutter head and crusher chamber had sustained damage that would need to be repaired before tunneling could be resumed. JWF ultimately performed 248 Compressed Air Worker (CAW) entries over 65 days to make the necessary repairs to allow continuation of the drive and timely completion of the project.

COMPRESSED AIR INTERVENTIONS

As previously mentioned, CAI are utilized to remove obstacles, replace tools or inspect the tunnel machine. It's typically a three-phase process: phase one involves preparing the tunnel face, the machine and the personnel; phase two involves performing the work; and the final phase is the decompression process.

Preparing the tunnel face for a CAI is a technically challenging process and the key component to ensuring the safety of personnel and the project. An air bubble is created outside the face of the machine to prevent an inflow of groundwater and to guarantee face stability during the intervention process. The bubble is monitored continuously from the surface during the process, with a redundant power and air supply available in the event of system failure. Additionally, the CAWs that will be performing work in the crushing chamber must be acclimated to the conditions they will encounter using an air lock installed on the tunnel machine behind the crushing chamber. The workers enter the air lock, the door is secured and the application of compressed air pressure based upon a face stability calculation begins.

Performing any activities within the crushing chamber requires the personnel to be properly trained to perform the tasks in a tightly constrained area. This includes entering the crushing chamber through a door 16 inches high by 19 inches wide. Once inside the crushing chamber, which is approximately the size of an average-size person, the work can begin. Challenging in normal circumstances, lifting heavy objects such as tools, cutter discs, or rocks can be much more difficult for a person 75 feet underground and in the crushing chamber of a microtunnel boring machine. If repairs such as welding are required, the physical constraints and awkward positions make efficient repairs nearly impossible.

After the inspection or maintenance is complete, the CAWs must complete the decompression process by entering the air lock, closing and securing the doors, and allowing the air pressure to return to normal. Only after this process is complete is the air bubble outside of the machine face allowed to dissipate and tunneling can resume.

BALCH COMPRESSED AIR INTERVENTIONS

As previously mentioned, the Balch project required CAI on the final drive of the project. When the obstruction was encountered on the final drive, the project team determined the most efficient method of investigating the type of obstruction and the amount of damage the tunnel machine had sustained was to perform a CAI. JWF understood that this was an extremely complex and potentially dangerous operation. Creating and maintaining the air bubble with minimal ground support, an extremely constrained work environment, keeping the pipe string moving during the intervention so that it would continue to remain fluid, and the working restrictions at the jacking shaft all added to the difficulty of the process.

The soil conditions when the mining was halted resulted in the most challenging aspect of the intervention process. The open graded gravels did not allow a working air bubble to be established or maintained. By sealing the voids with a variety of ground improvement methods, JWF was able to achieve the proper conditions for maintaining the proper air bubble. Throughout the time period that the interventions were performed, the ground conditions and the air bubble were monitored 24 hours a day to ensure the bubble maintained the proper pressure.

CAWs familiar with compressed air situations were brought in to perform the repair and maintenance to the damaged cutter head and crushing chamber. While comfortable with this situation, they were not always familiar with the repairs to be performed. Continuous communication with the surface and the array of 17 required support personnel allowed the work to be completed successfully. Additional challenges involved the City's inspectors, who were not allowed into the crushing chamber for both safety and logistical reasons. They had to rely on photographs of the conditions to approve the process.

While compressed air interventions can be a very useful tool to inspect, maintain or repair a microtunnel boring machine, they are not without risk, especially when challenging ground conditions are involved.

Constructing Twin 24-inch Force Mains in a Highly Sensitive Environment Utilizing HDD

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AECOM

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Clean Water Services

Nick Michels
Mears HDD

Clean Water Services is a water resources management utility and special service district with more than 520,000 customers in Washington County, Oregon. The boundaries of the district are shown in Figure 1.

To accommodate expansion and associated regional economic growth, Clean Water Services is committed to providing the wastewater infrastructure required for the Dawson Creek Basin service area. This commitment recently led to the design and construction of a new 25 MGD pump station and twin 24-inch force mains within the sensitive environmental corridor of Rock Creek in Hillsboro, Oregon. The District hired Carollo Engineers out of Portland and Staheli Trenchless Consultants out of Seattle to design the Dawson Creek force mains and provide trenchless consultation.

Trenchless alternatives were considered from the beginning of the design in order to reduce environmental impact, disturbance, and restoration, and to minimize environmental permitting requirements. After considering geotechnical data, alignment constraints, and available technologies, it was determined HDD was the most favorable trenchless alternative for the pipe installation beneath Rock Creek.

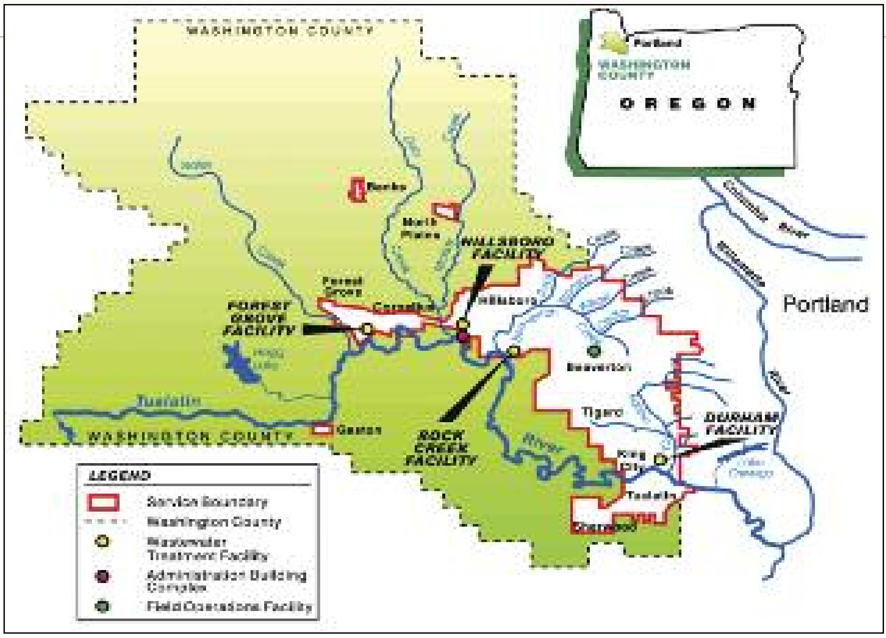

Figure 1. Clean Water Services District Service Area

DESIGN

To eliminate the need for excavation within wetlands and to reduce environmental impacts, the HDD alignment needed to extend from the existing roadway on the north side of Rock Creek to an existing cul-de-sac in the south. To prevent the bore alignment from crossing under any existing structure, the alignment included three horizontal curves at a 1,000-foot bend radius. Initially, the bores were planned to be side-by-side; however, due to soft soils that existed near the ground surface, it was determined that a separation distance of 40 feet was needed to minimize the potential for cross-contamination of drilling fluid between the bores. To maintain that separation and to avoid crossing under existing structures required bore radii of less than 1,000 feet – considered too small for the size of rig that would be required to install the pipelines.

It was then decided to stack the bores vertically, allowing each bore to maintain a minimum bend radius of 1,000 feet while avoiding existing structures and maintaining a separation distance of 40 feet. Stacking the bores provided the additional benefit of restricting construction within a narrower easement, thereby reducing project costs.

The design included a 35-foot clearance from the bottom of Rock Creek to the top of the upper bore and 35 feet of separation between the HDD pipeline and an existing 72-inch gravity sewer.

The pipeline was sized for hydraulics as 24-inch ductile iron pipe size HDPE. Structural and installation load calculations determined that DR 11 was sufficient for external and pullback loads.

CONSTRUCTION

The project, competitively bid using a pre-qualification process, was awarded to Emery and Sons General Contractors with Mears as the HDD subcontractor. During the submittal process, Mears proposed deepening the upper bore to further protect against inadvertent returns to the ground surface. However, Mears did not propose moving the lower bore. Instead, they proposed decreasing the separation distance of the two bores.

To offset the risk of having two bores within close vertical proximity, the Contractor elected to first drill the upper bore and then run the guidance tracking wire through the installed upper bore product pipe. They would then track the lower bore with the cable that was located in the upper bore pipe. This would increase the accuracy of the tracking equipment (which becomes less accurate with depth) and ensure that adequate separation of the bores was maintained by steering the lower bore from the previously installed pipe.

The Owner required Mears to submit calculations showing that the proposed reduced clearance would not generate downhole drilling fluid pressures high enough to cause cross-contamination between the bores. The Contractor provided the requested calculations and was willing to accept the risk of drilling fluid communication between the two bores. With this commitment, the Owner allowed the Contractor to proceed with the newly proposed bore profile layout.

The layout room at the entry and exit points for the bores was very constrained. Figure 2 shows the drill rig set up in a linear fashion to allow keeping one lane of the roadway open to traffic during construction while maintaining access to multiple driveways. The Contractor elected to survey points prior to mobilization and to sequence the mobilization of the equipment in order to fit all of the necessary equipment in the long but narrow work area that also included overhead power. Careful planning of the rig-side layout allowed savings of both time and resources since the Contractor was able to quickly remobilize to set up for the second bore.

The exit site, located on a narrow cul-de-sac, posed further challenges with traffic control and community relations. To maintain access to houses on both sides of the narrow neighborhood street, the work area essentially quartered the road by taking half the road width for construction down the centerline, and leaving access lanes for the residences on either side, as shown in Figure 3.

Figure 2. Narrow Entry Site Work Area

Figure 3. 24-inch HDPE Pipe Layout Along Center of Roadway

Figure 4. Centralizers Inserted into the Conductor Casing

The Contractor utilized a system of bolt-together centralizer casings as shown in Figure 4 that were inserted into the entry conductor casing to center the alignment during the pilot bore and provide support for the drill pipe during reaming.

DRILLING

The upper pilot bore was drilled first. The length of the upper bore was 1,630 feet and was constructed in four days, averaging 410 feet per day.

An inadvertent return occurred at approximately 1,350 feet from the entry location while drilling the pilot bore. It is possible that at this location the soil properties differed greatly from those assumed in the calculation, or that a pre-existing weakened zone allowed the inadvertent return of mud to the ground surface. Through careful response planning and quick action by the Contractor, the drilling mud was contained and did not reach wetlands or water bodies.

For the reaming, the Contractor elected to ream the bore in two phases, reaming to a final diameter of 36 inches.

The total duration of pullback was twelve hours, with five hours and 10 minutes spent making three HDPE pipe fuses. The Contractor also utilized a buoyancy control water volume table to coordinate between entry and exit personnel for adding the volume of water required per length of pipe pulled to reduce installation forces. This procedure was performed for both the upper and the lower bores and assured that pullback would not outrun the addition of the required buoyancy control water.

The lower bore was drilled after completion of the upper bore. For tracking purposes, a wireline was placed within the completed upper bore and used to steer the lower bore. The length of the lower bore was 1,940 feet and was constructed in five days, averaging 388 feet per day.

While drilling the lower pilot bore, the maximum drilling fluid pressures were established based on the location of the upper bore. Consequently, the actual drilling pressures were very close to exceeding the maximum allowable pressures at several locations. Comparing the actual pressures versus the limiting pressures based on the ground surface, the actual pressures are significantly lower than the maximum pressures with the exception of the location near 1,400 feet just uphill from Rock Creek. Although the actual pressures approached the limiting pressures for both the upper bore and the ground surface at this location, no inadvertent returns were seen on either the pilot or the reaming operations during the construction of the lower bore.

CONCLUSION

For Clean Water Services, the use of HDD for the installation of the Dawson Creek Force Main pipelines was tremendously successful. Utilizing trenchless technologies allowed the project to be completed in an efficient and expedient manner and allowed the pipeline to be installed with minimum disturbance to sensitive wetlands and beneath Rock Creek while avoiding utility conflicts. Through collaborative efforts with the Owner, Designer, trenchless specialty consultant and Contractor, project costs, schedule duration and impacts to the public were reduced while safety, quality and project value were enhanced.

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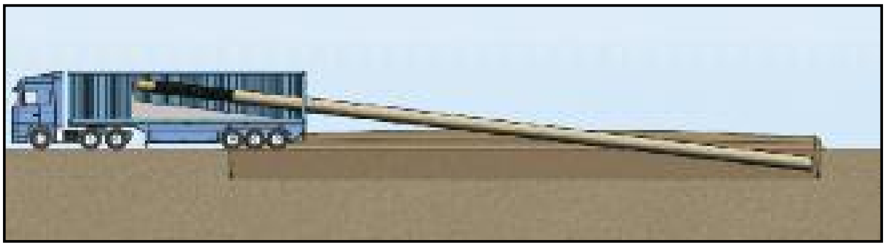
A Transforming Concept: On-Site Manufactured Joint-Free Pipe

Mo Ehsani, Ph.D., P.E., S.E.
President, PipeMedic, LLC

Mo Ehsani, President of PipeMedic, has developed a pipe that can be manufactured on-site to almost any length.

To overcome shortcomings associated with conventionally manufactured pipe, PipeMedic has developed a new non-metallic pipe that can be manufactured on-site in virtually unlimited length, thus eliminating all joints. This new product, InfinitPipe, possesses the two primary attributes required for good pipe: a) sufficient strength and stiffness so they can be handled and resist gravity loads safely, and b) adequate strength to resist the internal fluid pressure. Furthermore, it does so economically with a reliable product.



InfinitPipe can be installed in an easy process.

The shortcomings of conventionally manufactured pipe are well known. Construction requires fairly complex manufacturing facilities. As a result, pipes are constructed in short segments and shipped to the job site, where they are joined together. The outcome is a pipeline with joints every 20 feet or so. These joints are a potential source of leaks, which can inflict significant loss of revenue as well as harm to the environment. For larger-diameter pipes, the transportation costs from the plant to the job site could add significant expense to the project.

Now, here's how PipeMedic's InfinitPipe addresses the shortcomings. Similar to the construction of an I-beam, the wall of this pipe is made up of a lightweight core that is covered with carbon or glass Fiber Reinforced Polymer (FRP) materials as the skin. The carbon fabric is used on the interior surface of the pipe to resist internal hoop and thrust loads. Additional layer(s) of glass or carbon FRP will be used as the outer skin of the pipe. As an example, if we consider the stiffness of a 1/8-inch-thick carbon FRP as unity, when the same amount of FRP is sandwiched between a 3/8-inch-thick honeycomb, making the total thickness a half-inch, the stiffness of the panel is increased by 37 times while there is only a 9% increase in weight.

The constituent materials for the construction of this pipe are lightweight and can be packaged in compact fashion for ease of transportation to site. A full-size container, for example, may carry enough fabric and resin to construct thousands of feet of pipe. Prior to the construction of the pipe, a trench will be cut for placement.

A 20-foot-long mandrel having the same diameter as the pipe to be manufactured is mounted on a trailer that can move along the trench. The steps of the construction can be summarized as follows; the choice of carbon or glass fabric and the number of layers is a function of the design and loading requirements for the project:

a) A bond-breaker layer is applied to the outer surface of the mandrel.
b) A roll of carbon or glass fabric is saturated with epoxy resin using the on-board saturating machine and it is wrapped once or twice around a 20-foot length of the mandrel.
c) A honeycomb panel is wrapped around the mandrel.
d) Additional layer(s) of glass or carbon fabric saturated with epoxy resin is wrapped around the mandrel
e) The epoxy resin will start to harden in about an hour in ambient temperature; a slight heating of the mandrel can reduce this time to 20-30 minutes.
f) The mandrel is partially collapsed, and the finished pipe is mostly slipped off the mandrel, leaving about two feet of it on the mandrel.
g) Steps b) through f) are repeated to build a continuous joint-free pipe.
h) The finished pipe is lowered in the trench as the trailer travels along the trench.

A crew of five can easily manufacture and place 150 feet of a 24-inch pipe in an eight-hour shift. Automation of this process is planned and it will significantly reduce manufacturing time. This construction technique allows for easy modification to the pipe. For example, if a portion of the pipeline is going to be subjected to traffic loads, that region can be constructed with more layers of fabric or a thicker honeycomb to provide additional stiffness for the pipe; such stronger sections offer a seamless transition to the remaining portion of the pipe.

InfinitPipe is subject to several pending patent applications.

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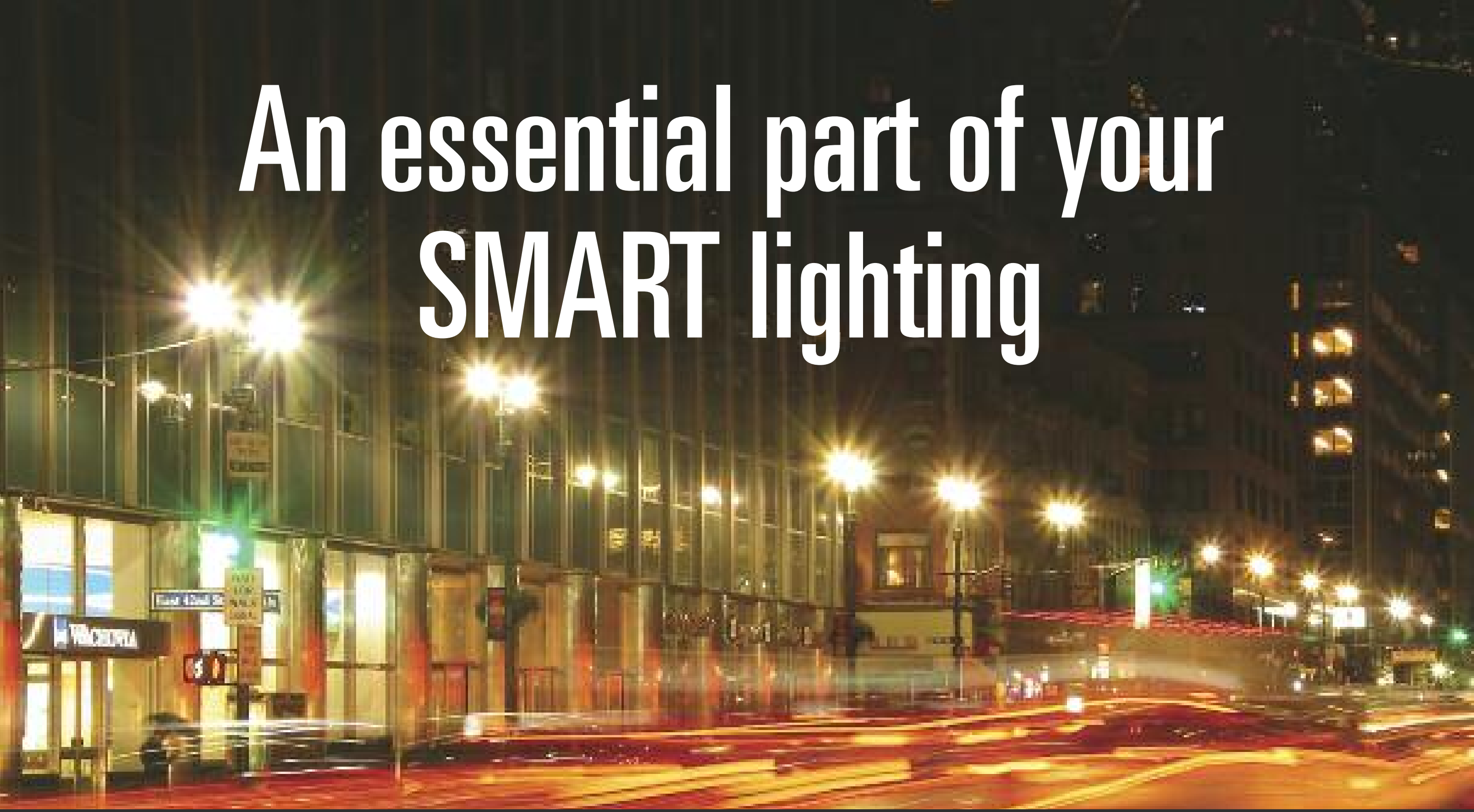

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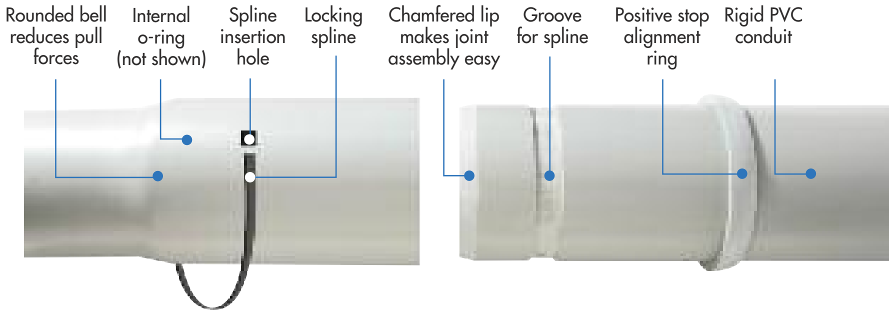

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