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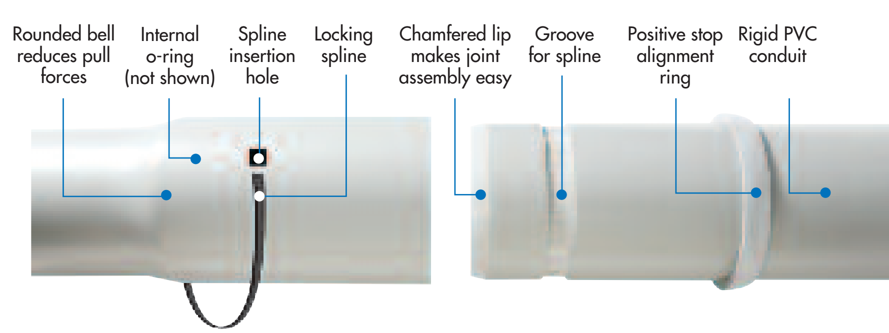

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PNW TRENCHLESS REVIEW

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Message From the Chair

Erik Waligorski

Oh, how time flies! Welcome to the second edition of the Pacific Northwest Trenchless Review. It seems like only yesterday that I was reading the inaugural edition and reveling in the amazing projects being completed in the Pacific Northwest. Based on the success of our first edition, we are again pleased to share with you local highlights in the trenchless arena. Thank you to all trenchless professionals and advertisers who have dedicated their time to making this magazine a success, and a special thank-you to past chair Laura Wetter for leading the Trenchless Review effort for a second year!

2011 was an exciting year for the PNW Chapter of NASTT. It all began in February with our 2011 Trenchless Symposium held in SeaTac, Washington, at the Cedarbrook Lodge. The two-day symposium was a great success with 25 people attending the NASTT Good Practices Short Course on Cured-in-Place-Pipe (CIPP) and an additional 84 attendees at the presentation portion of the symposium, along with nine exhibitors. The symposium drew attendees from Washington, Oregon, Alaska and British Columbia. The PNW Trenchless Symposium has proven to be an excellent educational opportunity for public service managers, engineers, inspectors, and contractors who are new to the trenchless world, and it is a great way for our members to network with other local professionals involved in the industry. Be sure to keep your eye out for our next trenchless symposium, tentatively scheduled for 2013.

We are also pleased to see that two PNW Chapter projects have been recognized by the October 2011 Trenchless Technology magazine. Both the WWTP Outfall Extension for the City of Gig Harbor, Washington, and the Portsmouth Force Main Segment 1 for the City of Portland, Oregon, received Honorable Mention for new install projects of the year. Congratulations to those teams.

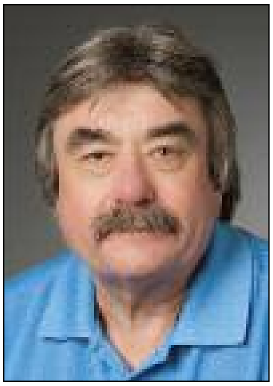
I look forward to another banner year for the Pacific Northwest Chapter, and we welcome new members to join us. Watch for future chapter activities, including the development of a chapter website. I hope to see many of our fellow PNW Chapter members at the No Dig Conference in Nashville this March. Please feel free to contact me for information at ewaligorski@rothhill.com or (425) 289-7320.

Best Regards,

Erik Waligorski
Chair, NASTT PNW Chapter

Moving Forward in 2012

George Ragula



2012 is here and I know the Pacific Northwest Chapter is as eager as I am to get to work to promote the trenchless industry!

The hard work of your Chapter leadership and membership continues to produce success as you take on new challenges to advance trenchless technology as the first choice of municipalities and utility owners addressing their infrastructure needs. Great strides have been made, but there is still much to do. I'm glad I have another year as NASTT Chairman to see this effort through.

The Regional Chapters of NASTT are key to expanding the acceptance and usage of trenchless technology at the local level. Through the diligent efforts of the Pacific Northwest Chapter, great strides have been made over the last year in your region through local outreach, such as the Chapter's Symposium last February, which also included a NASTT Good Practices course.

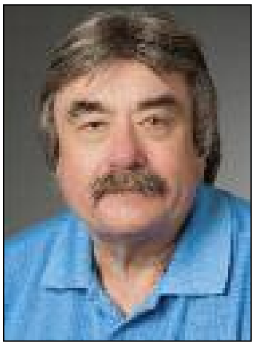
I want to thank the Chapter Board of Directors as it energizes your efforts to promote and educate the benefits of trenchless technology: We appreciated the dedication and good work of Chair Erik Waligorski, Vice Chair Chris Price, Secretary Chris Sivesind, Treasurer Matt Pease and Board Member Brian Gastrock!

As you are aware, NASTT's No-Dig Conference and Exhibition will be held March 11-15, in Nashville, at the Gaylord Opryland Hotel and Convention Center. The Program Committee has developed an exciting and well-rounded program — from its peer-reviewed technical program to the Educational Auction to the Gala Dinner — and I hope that you can join me and your fellow NASTT members at this event. For more information, visit www.nodigshow.com.

2011flew by and you made significant progress to advance our message with the municipalities and utility owners. I look forward to working with you as we move forward together in 2012.

George Ragula
Chair, NASTT

Trenchless Takes Center Stage in Nashville



George Ragula
No-Dig Program Chair

Kim Staheli
No-Dig Program Vice-Chair

Dear Trenchless Professionals,

Nashville, home of country music's hottest stars, will host the industry's premier trenchless technology event in North America – NASTT's No-Dig Show, the hottest ticket in town. We invite you to join us March 11-15 at the beautiful and well-appointed Gaylord Opryland Hotel.

Our 21st annual conference marks the third return of No-Dig to Nashville, rousing a sense of nostalgia for many. When we first met here a decade ago, some would say that it was a turning point, a sort of renaissance for the organization and the industry itself. The 2001 event sparked a renewed interest in trenchless technology as a viable method to repair/replace underground systems while minimizing surface disruption.

Since 2001, No-Dig has nearly doubled in size, keeping pace with the rapid growth of our industry. Cutting-edge technologies are continually being developed and introduced to the marketplace. Each year brings new products, new services and new players. Projects are continuously pushing the boundaries of what can be achieved with trenchless technologies. Our conference creates a unique opportunity for you to see, hear and interact with leaders in the industry who drive the trenchless marketplace today.

We have 155 technical papers in the conference program packed with timely topics and useful information that you can put to use right away. The papers and presenters are of the highest quality, making for an excellent technical program. We are pleased to announce the addition of a sixth track to the paper schedule, offering you even more educational opportunities!

That's not all! The trenchless education provided at the No-Dig show is unmatched. You can choose to attend one of our pre- and post-conference courses on HDD, pipebursting, laterals, new installation methods and CIPP lining. New this year, we're offering an expanded one-day "Introduction to Trenchless Technology" course on Sunday, March 11, with the latest advances in trenchless techniques.

Benefit from the in-depth sessions and courses offered at No-Dig in more ways than one. For every 10 hours you attend, you receive one continuing education unit to advance your professional career.

The overall No-Dig program is focused on one objective: helping you maximize your investment in trenchless technologies, services and applications. Owners, utilities and municipalities can immediately benefit. You will learn how to replace/repair and install pipelines with minimal excavation while reducing the impact to your surroundings. You will find that trenchless technology is not only the least disruptive option, but oftentimes is the most cost-effective. The technical sessions and exhibitions are designed to provide you with information you need to make the best possible decisions.

Starting with Monday's Opening Kick-off Breakfast, you'll have plenty of opportunities to network with your industry peers throughout the week. We also invite you to support our annual Education Fund Auction by donating or bidding on amazing items to help raise funds for NASTT's educational initiatives. This year's Auction promises to be truly exciting with a country-western theme and costume dress-up. Also new this year, NASTT will unveil its Trenchless Technology Hall of Fame awards at the Tuesday evening Gala Awards Dinner. Stay tuned for more details!

Please mark your calendars for March 11-15 in Nashville, where we hope you will join us as "Trenchless Takes Center Stage." We look forward to seeing you in attendance. For conference updates and information, be sure to visit our website at www.nodigshow.com.

Sincerely,
George Ragula
Kim Staheli

NASTT Pacific Northwest Chapter
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IN MEMORIAM: PADDY RYAN O'TOOLE
JUNE 29, 1958 – JULY 16, 2011

NASTT extends our deepest sympathies to the family and friends of Paddy Ryan O'Toole, founder and President of PTR Communications. After a courageous battle with cancer, Paddy passed away peacefully on Saturday, July 16, with his family and trusty dog Tessa close by his side.

For Paddy, publishing was more than mere work – it was his passion and higher purpose. He took great delight and satisfaction from carefully producing magazines for many of the NASTT Chapters with the highest written and artistic quality possible.

Paddy was forever attentive to the interests of the NASTT community and was a notable proponent and friend of the trenchless technology industry. He worked relentlessly at raising the profile and helping to further the cause of numerous NASTT Chapters. Very simply, Paddy LOVED trenchless! The magazines were his "love made visible."

For those who knew him professionally and personally, Paddy was a great humanitarian with a deep love for the written word. He was a vastly talented writer, gifted musician and remarkably astute businessman. Charming, intelligent and a witty conversationalist, Paddy was always ready with a practical joke or funny play on words.

On behalf of NASTT and all the Regional Chapters, we thank Paddy for his significant contribution to the trenchless technology industry.

Mike Willmets
Executive Director, NASTT

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Balch Consolidation Conduit

Installing Pipelines with Microtunneling while Successfully Avoiding Claims – A Case History Illustrating the Value of Using Alternative Contracting Methods

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In 1994, the City of Portland's Bureau of Environmental Services (BES) entered into an Amended Stipulation and Final Order (ASFO) administered by the Oregon Department of Environmental Quality. The ASFO requires that the City construct facilities to control 42 combined sewer outfalls to the Willamette River to a level commensurate with four winter overflows annually and one summer overflow every three years. Control of 16 outfalls along the west side of the Willamette River was completed by December 2006, and full control to the stipulated level is required by December 1, 2011. The Balch Consolidation Conduit, a key component to the BES Combined Sewer Overflow (CSO) Management Program, had to be in place and operational by the December 1, 2011 deadline to meet requirements of the ASFO.

The Balch Consolidation Conduit (BCC) Project will convey combined sewer over-

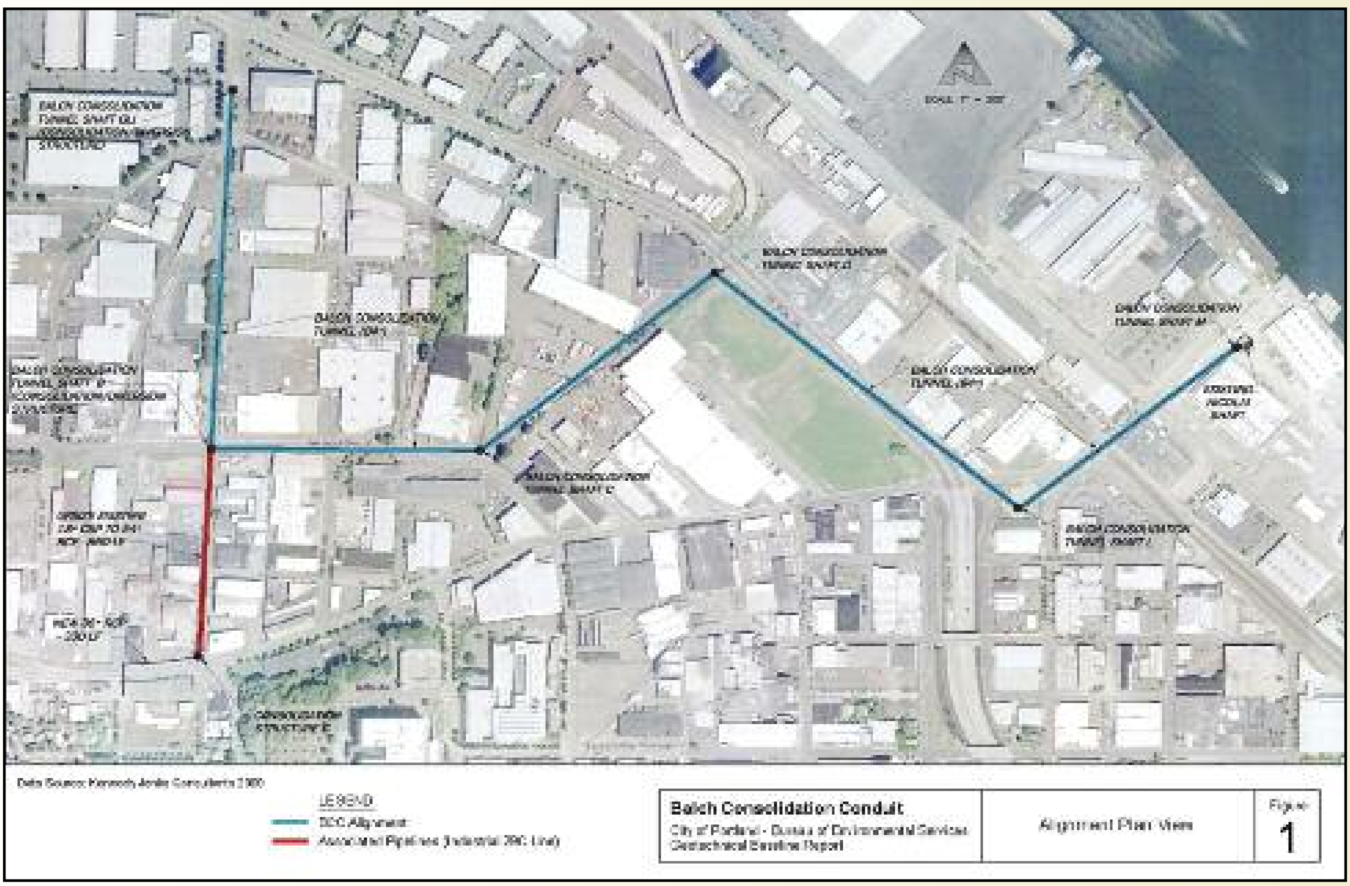

Figure 1. Balch Consolidation Conduit – Alignment Plan

flows from the Balch Drainage Basin in northwest Portland. The area is bounded by the Willamette River to the north and the Tualatin Mountains to the south. The project includes 6,900 feet of 84-inch reinforced concrete pipe (RCP) microtunneling in five drives and 950 feet of 54-inch RCP microtunneling in a single drive. The 84-inch-diameter sewer main will convey up to 390 cubic feet per second (cfs) of combined sewage from the Balch Basin to the existing Nicolai drop shaft and into the West Side Combined Sewer Overflow tunnel, completed in 2006. The project configuration is shown graphically in Figure 1.

CONTRACTING METHOD

The central focus of any microtunnel design is the geotechnical conditions. On the BCC project, the Design Team was presented with a wide array of soils ranging from very soft clays and silts to very dense open-graded gravels and a possible interface with the Troutdale formation, known to have cemented layers containing cobbles or boulders. Additionally, a section of the alignment passed through an abandoned landfill anticipated to contain objects not conducive to microtunneling, such as logs, boulders, industrial debris and other potential obstructions.

Due to the variability of the subsurface conditions, a well conceived and managed approach to construction contractor procurement was important. This included a responsible level of risk-sharing between the Contractor and City. During the time period from December 2007 to January 2008, BES representatives evaluated various methods for contractor selection and project execution. In mid-January 2008, BES decided to pursue a qualifications-based competitive proposal selection process and a Cost Reimbursable Fixed Fee (CRFF) form of contract for project construction.

As part of the Competitive Proposal Process, BES issued a Request for Qualifications to which a number of contractors responded. After evaluation of the qualifications, three contractors were asked to prepare a proposal which would evaluate the project and develop specific solutions to some of the project challenges, including the very soft soils and very aggressive open-graded gravels. The Contractor was ultimately selected following an intense evaluation of the proposals by BES and the Design Team.

Upon contractor selection through the Competitive Proposal Process, the Contractor and City entered into a Pre-Construction Services Agreement. During this preconstruction period, the Contractor participated in the project's final design and an Estimated Reimbursable Cost (ERC) was negotiated between the Contractor and City. The construction contract also was negotiated between the City and Contractor, with the Contractor compensation based on the ERC and Fixed Fee.

This form of contract and process allowed or facilitated the following:

- Ability to develop an equitable risk-sharing approach and method between the Contractor and City.
- Contractor selection occurring concurrently with design, thus reducing overall project schedule requirements.
- Contractor participation in the final design process and decision-making relative to materials and equipment selection, construction means and methods (particularly for shafts), and construction schedule/sequencing.
- Early procurement of long lead time equipment and materials (particularly microtunneling machine).
- A cooperative working relationship among Contractor, design team and BES during design and construction.
- Ability to work concurrently on inter-related elements of work including value engineering, constructability review, evaluation of risk, and development of estimated reimbursable cost.

PROJECT RISKS ADDRESSED DURING DESIGN

Project risks were identified during the design phase in a BCC Risk Workshop held with BES, the Contractor and the Design Team. The risk workshop identified risks with project construction along with frequency, probability and magnitude of occurrence. Design actions were taken and decisions made to minimize these risks while also establishing appropriate levels of construction allowances to provide for any remaining risks. Some of the project risks include ground modification, contaminated media handling, dewatering, ground settlement and permit/easement acquisition. These risks and mitigation measures are described in the following sections.

Due to the presence of highly variable soft soils, an extended zone of microtunnel break-out ground modification was recommended around Shaft B, and for the microtunnel drive between B and GLI. The modified zone extended for a distance of 60 feet in the direction towards Shaft GLI. Along the drive from GLI to B, ground modification was recommended in the form of grout column panels for support of the microtunneling machine. The recommended panel spacing was 15 feet clear space between each panel. This spacing was based upon the machine proposed for the BCC project that included a secondary steering joint and an air-lock cylinder. In addition, ground modification was necessary for successful break-in/break-out (BI/BO) at all BCC shafts. Other segments of the microtunneling, such as from Shaft L to Shaft M, and from Shaft L to Shaft D, traversed through abrasive, open-graded gravels and cobbles. At the conclusion of each drive, the project team evaluated the machine face and made modifications based on materials to be encountered.

A program was implemented to facilitate the efficient construction of the BCC Project and properly manage contaminated media encountered during construction. The Contaminated Media Management Plan (CMMP) identified the processes and procedures used in the handling of contaminated media (soil and groundwater) encountered during construction. The CMMP was submitted to the Oregon Department of Environmental

Provided by Portland Bureau of Environmental Services	Provided by Contractor
Street Opening/Utility Permits	Utility services connections
Railroad Crossing/Encroachment and Easement Permits	NPDES Construction Stormwater Permit
Greenway Permit/Land Use Approval	Discharge Permits
Non-park use permits	Excavation Disposal Permits
Urban Forestry approval/Tree permits	Noise Variance Permit
Clearing permit	Permits for pumping water from the Willamette River
	Building, site grading, and demolition permits related to construction staging areas
	Contaminated media disposal

Table 1. Division of Responsibilities for Permits/Approvals

Quality (DEQ) to obtain agency concurrence that contaminated media would be handled in a manner that was protective of human health and the environment and did not exacerbate existing environmental conditions.

Dewatering methods and issues were identified and coordinated among BES, the Contractor, the Design team and DEQ, along with the possible effects of dewatering on existing groundwater contamination. Based on the results of those discussions, field and office activities were initiated to characterize the lateral extent of a known groundwater plume that exists in the vicinity of Shaft B. This groundwater contamination plume is related to historical releases on private properties, located southwest of the Shaft B location. Those subject private property sites were under evaluation by others. Additional field and office evaluation by the BCC Project team was undertaken to determine the effects of various dewatering methods and withdrawal rates of potential groundwater plume migration.

An overall settlement monitoring program was prepared with respect to baseline determinations, monitor spacing, frequency of recording, information to be recorded, and lead entity for conducting the program. Surface and utility settlement estimates were prepared. The BES Materials Testing Lab managed the settlement monitoring program with PBOT survey assistance. This work was conducted in coordination with building video survey and project public involvement staff.

To facilitate the timely acquisition of permits, responsibilities were divided into those which could be undertaken by BES and the design team during design, versus those that were more related to means and methods and to be undertaken by the contractor. This division of responsibility is shown in Table 1.

In addition, five temporary construction easements, six permanent tunnel easements, four permanent shaft easements and three permanent sewer easements were acquired for completion of the work. Early coordination with affected property owners enabled construction activities to proceed as scheduled.

Goals/Objectives	Means
Comply with the mandated Amended Stipulated and Final Order (ASFO) administered by the DEQ.	Provide design drawings and specifications for CSO control using 84-inch tunnel and consolidation/diversion structures.
Have the Balch Consolidation Conduit in place and operational by the December 2011 deadline to meet requirements of ASFO.	Use an alternate form of Contract Method to allow concurrent design and constructability reviews, and also to initiate equipment procurement for long lead time items. including microtunnel boring machine (MTBM).
Provide subsurface characterization with respect to geologic units, soil properties and chemical characteristics.	Prepare thorough Geotechnical and Environmental Data Report.
Identify means by which risks will be shared for microtunneling construction work.	Prepare Geotechnical Baseline Report. Conduct detailed risk analysis, risk workshop, prepare and implement mitigation plans.
Minimize environmental risk and ensure worker health and safety.	Prepare and implement a Contaminated Media Management Plan.
Ensure collaboration and coordination among multiple project disciplines and affected businesses.	Use a single Balch Consolidation Conduit Project Office within the project area for design, construction and public interaction.

Table 2. Summary of Project Goals and Objectives

CONCLUSION

The alternative contracting method chosen by Portland BES allowed the owner, design team and contractor to work collaboratively during the preconstruction/final design phase to meet the project objectives and implement cost-saving measures while concurrently addressing project technical, constructability, budgetary, and schedule risks. Table 2 summarizes key project goals and objectives along with the means used to meet those goals and minimize project risks.

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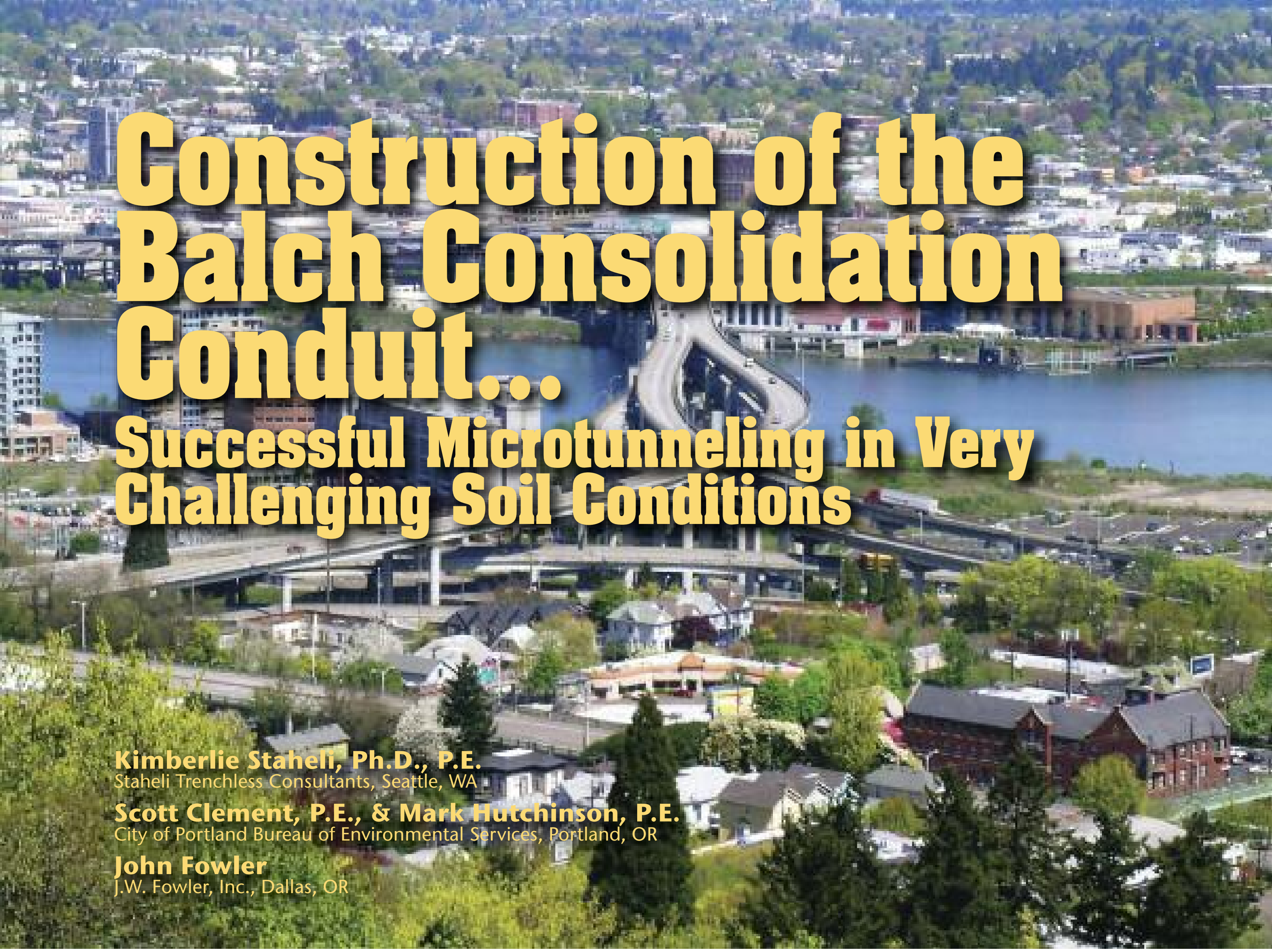

Construction of the Balch Consolidation Conduit…

Successful Microtunneling in Very Challenging Soil Conditions

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

Scott Clement, P.E., & Mark Hutchinson, P.E.
City of Portland Bureau of Environmental Services, Portland, OR

John Fowler
J.W. Fowler, Inc., Dallas, OR

The Bureau of Environmental Services (BES) in Portland, Oregon, provides sewer and storm water collection services for the City of Portland and surrounding areas. The Balch Consolidation Conduit Project was the final piece in a massive combined sewer overflow (CSO) program. A detailed description of the project background and the unique contracting method can be found in the preceding article by Moore et al.

The trenchless portion of the project included 6,800 feet of 84-inch microtunneling that was installed in five drives. It also contained a single drive of 54-inch microtunneling. All pipe installed by microtunneling was reinforced concrete jacking pipe.

CONSTRUCTION

In large part due to the identification and mitigation of risks through proactive design by the collective team of BES, the Contractor, and the Design Team, two of the first three of the attempted microtunneling drives on the BCC Project were constructed without any significant issues. (Since this article was written, all six drives have been successfully constructed.) The authors have chosen to focus this article on the drive that presented serious challenges during construction. It is the strong belief of the authors that this drive would not have been successful without the collaborative relationship between BES, the Design Team and the Contractor generated by the fixed-fee-plus-reimbursable-cost contract.

Anticipated Geotechnical Conditions

The microtunnel drive from Shafts C to D was 1,293 feet in length and ranged in depth from 53 to 63 feet. The geotechnical conditions along the alignment were extremely complex and required numerous borings to characterize the soils at the depth of the alignment. These soils included gravel alluvium, sand, Troutdale formation (gravel, cobbles and boulders in a lightly cemented sandy silt) and open-network gravel with cobbles, as well as mixed-face conditions at the unit transitions. Figure 1 shows a profile of the anticipated geotechnical conditions.

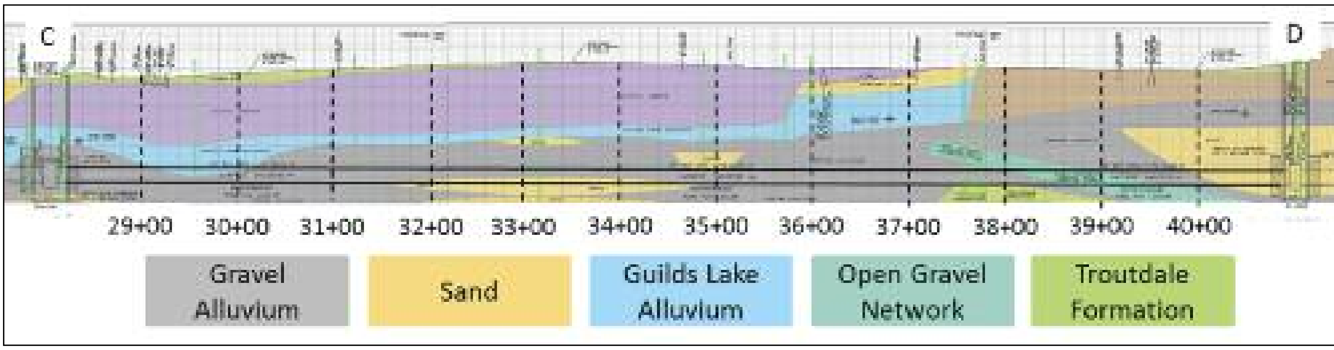

Figure 1: Cross Section of Drive C to D showing Soil Units by Color

Construction Challenges

The machine was launched in August 2010, into gravel alluvium as expected. Machine parameters, excavation rates and performance were all excellent. As expected, the material had an increase in sand content approximately 350 feet into the drive, consistent with the geotechnical report. However, unlike the expected conditions, the sandy gravel/gravelly sand was not as dense as expected, as was evidenced by lower torque and face pressure readings (as compared to the first 350 feet of the drive). In fact, face pressure readings were indicative of medium-dense soils, as opposed to the dense soils that had been encountered on other parts of the project.

At 459 feet into the drive, the machine encountered a very hard object at its base. The object was hard enough to cause the machine to roll 13 degrees. The machine was then shut off as a safety precaution. The cutterhead was rotated in the opposite direction, but would stall when it came up on the hard object. With manipulations of the steering cylinders, the telescopic cylinders, and counter-rotation of the head, the machine was able to be freed of the object. However, as the machine passed over the object, it went into a significant negative pitch and gained grade over a very short distance.

While working to move past the object, the sounds from the machine and the material recovered from the slurry separation plant indicated that the object was geotechnical in nature and likely consisted of a boulder or a "ledge" of the Troutdale formation that was encountered earlier in the alignment than expected. Either of these things could have caused the machine to behave in the fashion observed.

With the fixed-fee-plus-reimbursable-cost contract, BES, the Contractor, and the Design Team were able to meet and discuss the options moving forward. Due to the efforts to get past the object, there was a significant "hump" in the pipe that was less than desirable for the gravity flow sewer. There was the option of digging up the machine because, by luck, the machine was not under a critical structure when the object was encountered. However, digging up the machine would cost over $1 million and would have involved excavation through the abandoned landfill. BES ran hydraulic models and determined that the grade deviations in the system were not large enough to adversely impact the hydraulic conveyance requirements of the tunnel. As a result, it was decided to move forward with the microtunnel and to try to drive the machine to a new design grade, as modified by the Design Team.

However, this proved to be easier said than done. When tunneling resumed, the entire team assumed that through standard methods of adjusting the steering cylinders and advance rates, the machine would regain pitch, effectively leveling out, and operations would continue as before the object was encountered. This, however, was not the case. When tunneling forward, the machine did not recover pitch and continued to tunnel forward with an extreme negative pitch. At some points, the back of the machine was 14 inches higher than the front of the machine. This induced plowing through the soils, significantly increasing the jacking forces.

In addition, the "hump" that had been put into the pipeline after encountering the object was extremely sharp and stressed the pipe joints beyond a state of equilibrium. As a result, when jacking continued, the axial loads that were put into each joint across the "hump" were distributed through adjacent pipes, mak-

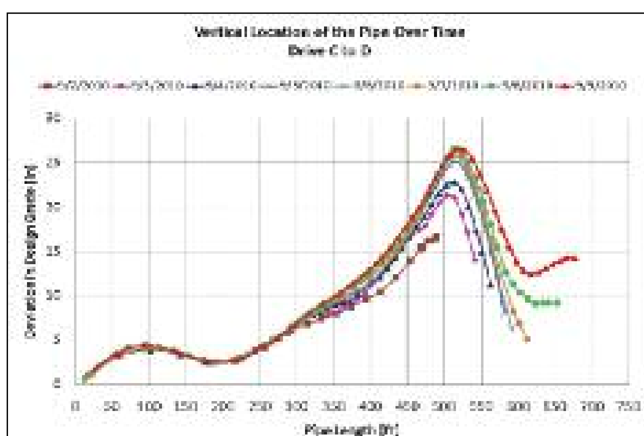

Figure 2. Length v. Deviation from Design Grade over Time (9/2/2010 to 9/9/2010)

ing the "hump" higher and wider with each push. Essentially, the pipe was moving both vertically and laterally in the ground to distribute the concentration of jacking forces through the pipe string. Figure 2 shows the as-built survey of the pipeline as it was taken after each 10-foot pipe was jacked.

When looking at Figure 2, it is interesting to note that the object was encountered at 459 feet. As a result of encountering the object, the vertical deviation of the pipeline from design grade was approximately 14 inches. Moving past the object, the machine "crested" as if moving over a speed bump, resulting in a sharp curve in the pipeline as can be seen in Figure 2 on 9/3/2010. At that time, the deviation in grade had risen to 21 inches. Each day a single 10-foot piece of pipe was jacked and a complete as-built survey of the pipe was conducted to record the location of the pipeline. Although the head of the machine and the first pipe section was trending back toward design line and grade, the reaming pipes continued to move vertically upward and toward the machine. This action distributed the jacking force more evenly throughout the "hump." From September 2 to September 9, the crest of the vertical deviation of the pipe at 459 feet into the drive moved from 14 inches to 27 inches. In addition, the peak of the "hump" in the pipeline shifted from 459 feet in the drive to 518 feet.

As the drive continued, the machine advanced with a negative pitch for approximately 600 feet. Although maximum steering inputs were applied to the machine in the lower steering cylinders, the machine would not respond, or would only respond very slightly, throughout the zone from 459 to 600 feet. However, at 600 feet the machine began to respond to the steering input. Due to the very aggressive steering input on the bottom steering cylinders, the machine immediately began to rise, resulting in counter-steering. The result of this was a second "hump" in the alignment as seen in Figure 3.

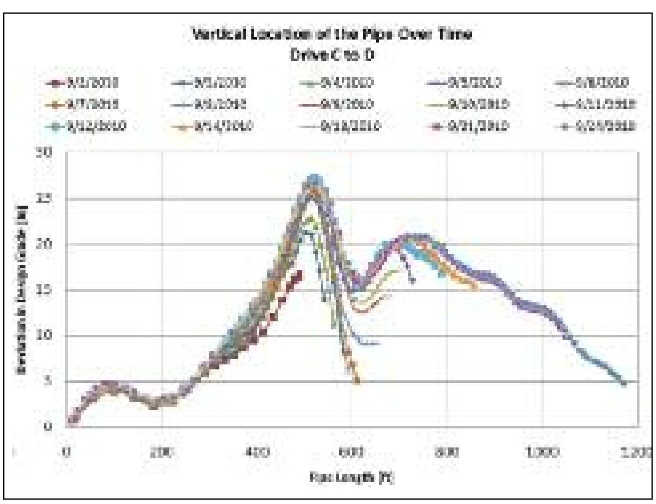

Figure 3. Length v. Deviation from Design Grade over Time (9/2/2010 to 9/24/2010)

Perhaps the most interesting thing about Figure 3 is the documentation of the total amount that the pipe was able to move after installation. For example, at 600 feet into the drive on 9/7/2010, the pipeline was only 5 inches out of vertical alignment but ended up being 16 inches out of vertical alignment. This vertical shift underground with approximately 60 feet of earth cover on a 101.5-inch outer-diameter concrete pipe is very rare and happens only under very unique circumstances.

One might assume that the soils in this region were very soft to allow the movement of the pipe; however this was not the case. The pipe was moving under a tremendous amount of jacking force that was acting on an angle due to the misalignment of the pipes due to the vertical deviation. Figure 4 shows the jacking forces throughout the entire drive. It is apparent that the jacking forces markedly increased when the object was encountered, and continued to rise at an increased rate (as compared to before the object was encountered) until the machine was well beyond the alignment deviations. When examining Figure 4, one should note that the lower jacking forces (between 200 and 300 tons) that can be seen at the bottom of the graph from 500 feet to the end of the drive are forces from the telescopic jacking station. This station was located just behind the head. When the object was encountered, the telescopic jacking station was used to push the head forward and to excavate. The main jacks and intermediate jacking stations were then used to propel the pipe forward.

When the pipe was being pushed over the main grade deviation area, it was necessary to use the intermediate jacking station (IJS) because the main jack, at 1,200 tons, did not have enough force to propel the entire pipe string. This is because a tremendous amount of the force was being used to move the pipeline vertically and horizontally toward the machine, rather than to propel the pipe along the design alignment. At times when the IJS was advancing over the first "hump," the maximum extension on the IJS was one inch when the hydraulic cylinders were at the maximum pressure. At that point, there was much concern that the pipe was going to get stuck due to the excessive jacking thrust requirement.

At the end of the drive, it can be seen that although the face pressure and excavation forces were eliminated from the total jacking force by independently using the telescopic station to excavate, jacking forces were still spiking at the main jacks at 1380 tons. This was right at the maximum force available from the jacking frame and the beyond the design limit of the jacking shaft. However, the drive was completed successfully at close to the original construction budget.

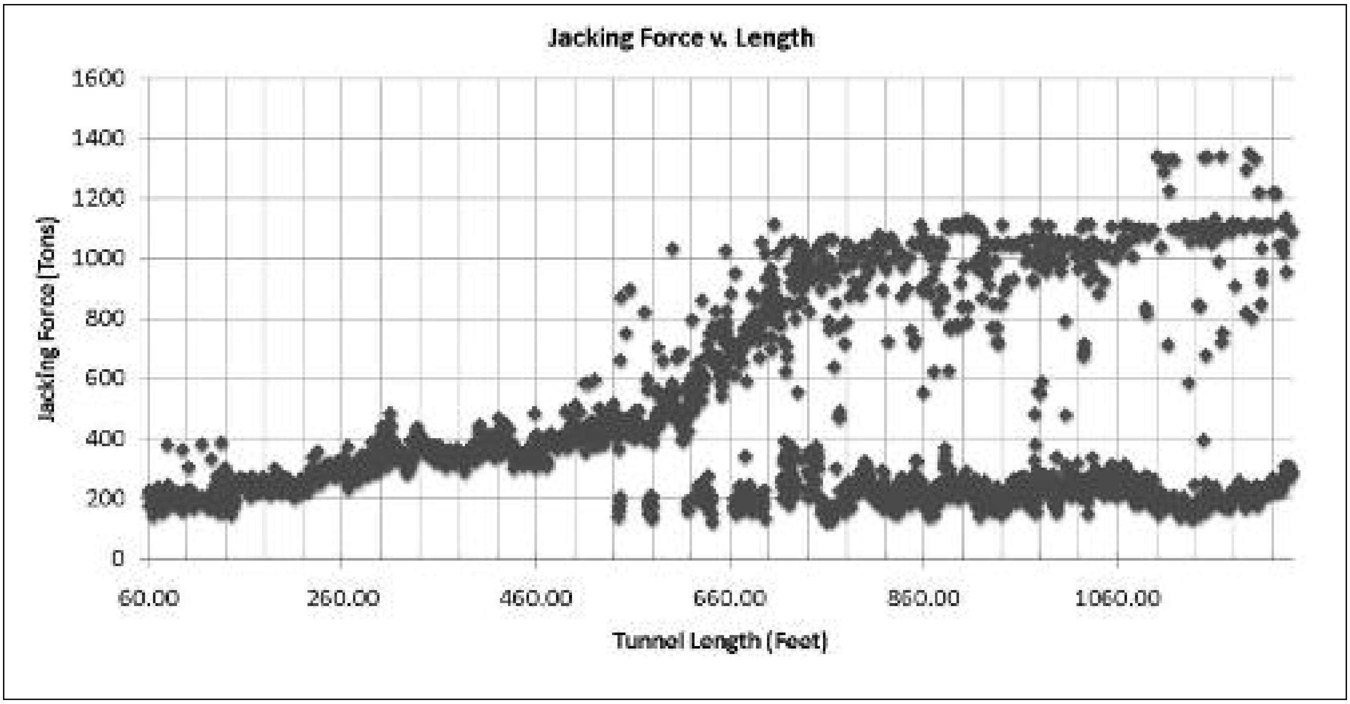

Figure 4. Length v. Jacking Forces for Drive C to D

CONCLUSION

The Balch Consolidation Conduit Project had many challenges that required a team effort to overcome. The alternative contracting method chosen by Portland BES allowed the Owner, Design Team and Contractor to work collaboratively during the pre-construction/final design phase to meet the project goals and objectives, while concurrently addressing project technical, constructability, budgetary and schedule risks.

On the drive from C to D, the Owner, Design Team and Contractor working together allowed for a positive outcome to a highly challenging issue. On most design-bid-build projects when obstructions are encountered, shafts fail, settlement occurs, etc., the Contractor quickly moves into the "who pays" mode while the Owner moves into the "whose fault" mode of discussion. The positioning by the Owner and the Contractor often takes precedence over solving the problem. Meanwhile, precious time is expended, which typically equates to increased change-order or claim costs (due to standby or the time to fix the issue) in the long run.

Had we been using a design-bid-build contract, when the obstruction was encountered, the Contractor certainly would have filed a potential change order based on a differing site condition. At that point, the Contractor likely would have wanted to dig up the machine to "prove" to the Owner that a large obstruction had been encountered that had forced the machine off of line and grade.

By using the alternative contracting mechanism, both teams move very quickly into solving the problem with little discussion about fault or who pays because it is already understood that the Owner will pay. There is always some positioning as the traditional Owners and Contractors fall back into their old habits of blaming first and solving the problems second. However, within short order the team will work together to find the lowest-cost solution to the problem that is in the best interest of the project and work together in a collaborative partnership.

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Under Sandy Boulevard

Value Engineering Trenchless Solution for Rehabilitation of Trunk Sewer in Portland

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In June 2008, a video inspection was made of Halsey Combined Trunk Sewer in northeast Portland, Oregon. This trunk sewer runs approximately 35 feet beneath NE 60th Avenue and passes underneath Sandy Boulevard, a busy arterial. The video inspection revealed longitudinal cracks in the pipe at 10, 12 and 2 o'clock throughout the entire length from Klickitat Street down to Brazee Street, with ovality of 10-25% in some areas. NE 60th Avenue is only 23 feet wide curb-to-curb; therefore, open-cut replacement was not an acceptable option. The other problem with the trunk sewer was its existing lateral connections to the surrounding properties, made through deep vertical risers. Most of these deep vertical connection risers were found to have settled and dropped into the trunk sewer.

The sewer system in this area clearly showed signs of catastrophic failure, and so a project to restore the sewer was initiated in 2009. Consulting firms including Brown and Caldwell and Staheli Trenchless Consultants were hired to provide engineering services, and assisted in shaping the design and specifications for the contract package. The project was advertised for bid in April of 2010 with an engineer's estimate of $4.9 million which included installation of 2,144 feet of new 36-inch RCP parallel to the existing sewer via microtunneling. JW Fowler of Dallas, Oregon, was declared the lowest responsible bidder with a bid of $3.7 million.

VALUE ENGINEERING

Before beginning the microtunneling portion of the project, the Contractor proposed to use an alternate method to rehabilitate the old sewer. Although the entire pipeline section was found to have longitudinal cracks, laser profiling of the existing pipe performed by Pro-Pipe indicated that only 600 feet of the 2,100-foot section had visible ovality issues.

The Contractor believed that if allowed to reduce the diameter of pipe from 36 to 31 inches, they could install 31-inch pipe to rehabilitate the entire 2,100 feet of deteriorated pipe via sliplining. They proposed to line the section which did not have ovality issues with 31-inch ID PVC Vylon pipe. In the section of the pipe with ovality issues, they proposed to use 31-inch ceramic epoxy-coated Permalok pipe. The Contractor's sliplining proposal demonstrated a net cost saving of $241,584 for the City.

THE DECISION TO CHANGE

The Contractor's value engineering proposal was given full consideration by the City. The proposal appeared to ensure quick rehabilitation of the deteriorated pipe, which was very desirable considering the urgency to fix the sewer. However, switching from the specified microtunneling option to sliplining of the existing 36-inch pipe with 31-inch pipe was a major change with several implications for the City. An informal committee was formed in order to evaluate the Contractor's proposal and address whether the reduced diameter and proposed pipe material met the City's requirements.

The first question of whether the reduced diameter of the trunk sewer was adequate was directed to our designer, who checked with hydraulic modelers to find out the possible effects on flow by reducing pipeline diameter. It was determined that due to

Existing deteriorated 36-inch sewer pipe recent changes in flow characteristics in the basin (primarily due to separation of storm sewer from sanitary sewer), the reduced diameter of 31 inches was adequate for the City's needs.

The second issue dealt with the pipe material proposed by the Contractor. Since the proposed PVC Vylon pipe is not an approved pipe for use in the City of Portland sewer system, we needed to ensure that the pipe had a good track record. After talking with many city officials throughout the Northwest, we came to the conclusion that the pipe has a good track record as far as its use and performance as sliplining pipe is concerned. It is important to note that every city official we contacted about Vylon PVC pipe emphasized good grouting of the annular space, and pointed out that grouting is the most critical aspect of the slipline process. They recommended that the grouting be done by experienced professionals and that the grouting pressure must be sufficient to fill the annular space without causing collapse of the pipeline.

31-inch ID PVC Vylon pipe

A final meeting with all committee members who reviewed the Contractor's proposal was held in late November 2010. It was unanimously agreed in the meeting to accept the Contractor's proposal and subsequent cost savings. One significant factor that influenced the decision was the fact that recent open-cut excavation for a separate portion of the project had revealed several 12-foot-diameter boulders in a gravelly soil matrix. This discovery was thought to present serious challenges to the microtunneling method originally specified in the contract.

Once it was agreed by all involved that sliplining using 31-inch Vylon PVC pipe and 31-inch Permalock pipe would be acceptable, a change order was issued authorizing the Contractor to change the method of installation from microtunneling to sliplining.

EXECUTION

Preparation for sliplining commenced with the installation of five 35-foot-deep shafts using engineered slide rail-shoring. Before any actual sliplining began, a tapered steel pipe of 32-inch OD was pulled from Stanton Street to Brazee Street as a pilot to check for any obstacles within the existing pipe. The pilot reached the shaft at Brazee without any problems, and 1,000 feet of Vylon PVC pipe was installed in live flow in just two days.

The Contractor then installed 660 feet of Permalok steel pipe from Stanton to Siskiyou. Since the existing pipe in this area had 10-25% ovality, the pipe was installed using 650 tons of jacking force. The last section of 547 feet from Siskiyou to NE Klickitat was completed with PVC Vylon pipe.

Preparation to fill the annular space with grout took several weeks. Bulkheads and grout ports were installed and a sewer bypass system was put in operation. Grouting was done in five separate sections at an average calculated 9 psi pressure. The annular space between the sliplined pipe and the existing deteriorated pipe was completely filled with grout.

To complete the project, manholes ranging between 72 and 144 inches in diameter were installed in all five shafts.

SUCCESS

The approach that was utilized to perform this complex and time-critical rehabilitation included strong partnership with the Contractor, consultants, other City of Portland Bureaus and the local community. Before the start of construction, a full one-day partnering meeting was held to discuss important issues in design, construction, inspection, safety and public outreach, and to create mutual understanding of the issues to build a team consensus. This was targeted to alleviate chances of dispute and disagreement during execution.

The successful implementation of the project was owed largely to the excellent Public Outreach Program launched jointly by City Public Outreach staff, City Inspectors and the Contractor's site representative. Public meetings held in the project area prior to the start of construction were attended by many local residents. Representatives from the City and the Contractor answered many questions about schedule, service laterals and what to expect during the construction.

Additionally, unlike many other projects, the designer played a very important supporting role during construction of this project. When the Contractor's value engineering proposal to slipline the existing pipe was accepted by the City, the original construction plans had to be revised and reissued showing changes that occurred as a result of the new proposal, which was accomplished promptly by the designer.

By end of July 2011, the project was completed and closed out. Construction management and inspection expenses on this project remained below 6% of the total cost, which is an achievement by itself. The case history of this project is an example of how professionals can work together to creatively and effectively get highly deteriorated pipe rehabilitated in the shortest possible time period. The approach could be used as a model by other cities and communities in similar situations.

PVC Vylon pipe being installed

The Direct Pipe Method:

Tried & tested, many times

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When using the Direct Pipe® method, the Herrenknecht Pipe Thruster operates as a thrust unit – comparable with the jacking frame used for pipe jacking. Developed as an auxiliary tool for the pullback of the pipe in the HDD-method, it was presented for the first time at the Hannover Fair in spring 2006.

The Pipe Thruster embraces the prefabricated and laid-out pipeline and pushes it into the ground at thrusts of five meters each. The requisite bore hole is excavated by a slurry microtunnelling machine (AVN) which is arranged at the front of the pipeline. The soil excavated by the cutterhead at the tunnel face is mixed with the slurry in the excavation chamber and then pumped through the entire pipeline to the se¬paration plant using a slurry pump integrated inside the machine. Apart from transporting off the excavated material, the slurry also provides support at the tunnel face. After treatment in the separation plant, it is conveyed back into the circuit via a feed line.

In terms of its general function, the machine is very similar to a conventional microtunnelling machine, with one difference being its length. In order to ensure the requisite curve motion of the machine and subsequent pipeline in culverts, it features two to three back-up pipes. Considering that all of the individual back-up pipe connections feature articulated tensile couplings, optimum control of the machine is ensured. Another advantage is that in an emergency, the machine and pipeline can be extracted along with the Pipe Thruster.

Just like the microtunnelling method, prior to launch the machine is positioned at the requisite access angle on a launch rail in front of the launch seal which is protecting against ingress of groundwater and soil. This is followed by welding the pipeline (mounted on rollers behind the launch pit) with the conical section of the machine at the rear. The clamping unit of the Pipe Thruster embraces the pipeline and thrusts it into the ground along with the machine.

The current maximum pipeline diameter which can be clamped is 60-inch (OD = 1,524 mm). The forces to be anchored depend on the pipeline access angle and the maximum thrust or retraction force to be applied. Horizontal forces applied can be absorbed by lateral support profiles mounted in the shaft while deep sheet pile or bore pile walls can be used for the vertical forces.

In the course of the Direct Pipe development process outlined below, the individual process components have been permanently improved and adapted to changing demands. For example, an innovative launch rail is to be used as of 2011 in setting up the machine in the launch pit. In the Direct Pipe method, this is part of the Pipe Thruster. It should be possible to save two to three days during setup using this hydraulic height- and angle-adjustable support.

Pilot project at a Rhine River crossing in Worms, 2007

PILOT PROJECT IN WORMS

With the aid of a Pipe Thruster (HK500PT) and an AVN1000 Direct Pipe machine, it was possible to successfully install a 464-meter steel pipeline under the Rhine in 2007. The steel pipe was intended to serve as a protective pipe for a water line and various protective cable pipes at a later stage. As the lack of space prevented the 48-inch pipe (OD = 1,219 mm) from being installed in one piece, it was laid in sections of approximately 90 meters. The fact that the pipeline was pushed with only 80 tons into the small target pit in Worms port within only 13 days shows that the friction arising during the Direct Pipe method is very low although no lubrication was applied along the entire length of the pipeline. This advantage has meanwhile also been displayed in the form of relatively low thrust forces required within the framework of various other projects.

As the Worms project involved a bare, uncoated steel pipe, it remained to be seen whether coated product pipes such as gas or oil pipelines could also be clamped and thrust by the Pipe Thruster without any damage being incurred. In a lab-quality test in the Herrenknecht AG workshop in Schwanau, initial evidence was provided in collaboration with a German gas supplier. Tests with a PE coating (polyethylene) and a GfK coating (GfK on PE) indicated that no damage is incurred to the coating when full clamping force is applied by the clamping unit and maximum thrust by the two large hydraulic cylinders.

SECOND PROJECT, SUMMER 2009

The next step in the development of the Direct Pipe history was to install a 280-meter brine outlet pipeline for the construction of the Jemgum natural gas storage facility at the Rysumer Nacken near Emden. A PE-coated 48-inch steel pipe (OD = 1,219 mm) in which a DN900 GfK pipe was subsequently inserted was installed here for a North German energy supplier by means of the Direct Pipe method.

During project planning, the direct trenchless advance of GfK product pipes in the partially soft tidal flats of the Ems estuary was not regarded as possible. The steel pipe required as a casing pipe could not be laid out in the water due to prevailing currents, so advance was necessary from land. However, owing to the tight spatial conditions, the pipe could only be installed in sections of 36 meters, which would have posed a risk of the bore hole collapsing if the HDD-method had been applied along with the welding associated with this process.

At advance speeds of up to 25 centimetres per minute, it was possible to install a 36-meter pipe within only four hours. A coupling process generally involves one to two shifts.

Crossing the Hartelkanaal in Rotterdam's Europoort, 2010

While tunnelling through sand, silt and in some cases clay, unanticipated old banking reinforcements made of wood and water stones were also driven through. Obstacles crushed by the mixed-soil cutterhead and cone crusher were pumped to the surface through the slurry line. As the invert line ended in an insertion structure in the Ems, the machine was to be recovered in there. The requisite accuracy was easily achieved by the surveying system deployed.

The conclusion drawn by the client after successful realization of this project was that the Direct Pipe method was the only practical method for this project and that it represents a good alternative for product pipe intersections with large-volume steel pipes.

INSTALLATION OF GAS PIPELINES

The next phase of development undergone by the Direct Pipe method – direct installation of product pipes – was preceded by another lab-quality load test conducted on the pipeline coating. Confirmation was given to a Dutch gas supplier planning realization of one of his projects using the Direct Pipe method that the Pipe Thruster would not cause any damage to the polypropylene (PP) coating.

Following successful testing, a total of five projects were realized in the Netherlands in 2010. Crossings of between 360 and 540 meters in length bypassing obstacles such as archaeological sites, smaller rivers and a railway line formed part of the approximately 500-kilometer North-South Route intended for transporting gas throughout the Netherlands in the future. This first-time installation of gas pipelines in the Netherlands represented yet another milestone in the history of the Direct Pipe method.

The most unusual of these five projects was the 540-meter crossing of the very deep and busy Hartelkanaal in Rotterdam's Europoort in summer 2010. What made this project so different was the requisite course depth of 30 meters under the ground surface and the ensuing very steep access and exit angles of 10 degrees and 12 degrees respectively. (Three to five degrees had been the standard to date.) The altitude to be overcome necessitated the application of a slurry pump within the pipeline (in addition to the one at the end of the machine). In geology comprising sand and silt, September 2010 saw the entire pipeline being installed successively in 10 sections of 54 meters each over a period of two weeks.

The NSTT (Netherlands Society for Trenchless Technology) awarded the client and construction company the 2010 No-Dig Award for successful realization of the project using this alternative installation method. This No-Dig Award was the second of its kind with the first award presented in Moscow in 2008 by the ISTT (International Society for Trenchless Technology). The innovative process was also nominated for the Hermes Award at the Hannover Fair in 2008. And the Direct Pipe method received the IPLOCA New Technologies Award in San Francisco in 2009.

Another milestone was achieved during the last two of the five Dutch projects (both over 500 meters long) involving first-time crossing of a railway embankment using the Direct Pipe method. The overburden under the railway tracks on the Zwolle-Almelo line totaled 15 meters. The 48-inch gas pipeline was thrust in one single piece and inserted into the target pit together with the machine with only 150 tons of thrust force. Advance rates of up to 124 meters were achieved in a shift lasting approximately 10 hours.

DEBUT IN THE USA

The Direct Pipe method celebrated its successful premiere in the United States in August 2010. Unlike the 48-inch pipelines already installed in Germany and the Netherlands, the three gas pipeline crossings realized in Florida only involved diameters of 30 and 36 inches (OD = 762 and 914 mm). The drive lengths of 119 to 226 meters were therefore correspondingly shorter. Considering the lack of space, the AVN machines used for these very small diameters could not be fitted with a hydraulic power pack, which meant that the drive length is currently limited to about 250 meters for pipeline diameters which are smaller than 40 inches.

One particular feature of the first American Direct Pipe project is its alignment. Unlike previous alignments, the pipeline under Highway 70 not only had to be installed with a vertical curve (R = 914 m) but with a horizontal one (R = 1,828 m), too. The navigation system featuring a gyroscope and electronic water leveling system kept the machine on the specified space curve. After only three days of tunnelling (in three shifts of 12 hours each), the site team had installed the 215-meter gas pipeline in one go. The HK500PT Pipe Thruster used required average thrust forces of 15 tons (maximum 28 tons).

In early 2011, the Direct Pipe machine including a 36-inch pipeline was extracted for the first time using the Pipe Thruster in the third project performed in the U.S. After tunnelling through 102 meters, the machine was recovered to the surface with the aid of the Pipe Thruster together with the pipeline, the cutterhead replaced and reinserted into the bore hole – all within a single day. During the pullback process, the bore hole was filled with bentonite to prevent it from collapsing. The cutterhead required changing after encountering an unexpected rock formation which could not be passed through without disc cutters. The remaining 124 meters were then installed over a period of three days.

As indicated by all projects realized since Worms, the Direct Pipe method allows fast installation speeds. This has made the process a technically practical alternative to HDD and microtunnelling. The improved installation reliability in difficult soil – compared to HDD – as well as the economic advantage over conventional pipe jacking translate into considerable competitiveness on the part of this method.

The fact that in the past it has always been possible to overcome invariably new challenges is already an indication that the limits of the process will shift increasingly from one year to the next, making areas of application ever more obvious – something which was difficult to assess in the early days. It will therefore remain exciting for observers and especiallyfor those wishing to use the Direct Pipe method.

Alternative Procurement Options for Small-Diameter Trenchless Projects

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The construction industry as a whole is innovating with the use of Design-Build, General Contractor/Construction Manager (GC/CM), best value, integrated project delivery and other alternative procurement methods. Small-diameter trenchless projects (i.e., less than 100 inches OD), by contrast, continue to be procured in Washington State almost entirely on the basis of the traditional low-bid process. Why is this?

This article examines options available for use of alternative procurement for small-diameter trenchless projects, primarily from the standpoint of Washington State law. The benefits of alternative procurement – i.e., enhanced likelihood of success, cost savings, reduced risk exposure, faster construction and decreased claims incentive – can be attained by using existing options under state law.

BACKGROUND

The success of a small-diameter trenchless tunnel project, especially in the geotechnical conditions of the Pacific Northwest, depends on various factors. First, success is often highly dependent on the equipment selected to tunnel the alignment and on how well the contractor manages soil and groundwater behavior during tunneling. Other factors that impact project success include a clear characterization of ground conditions, contractor motivation and incentives to succeed, the potential for obstructions, and realistic design.

Given the complexity of small-diameter tunneling in the dense, abrasive glacial soils of the Northwest, it is surprising that project sponsors (water and wastewater utilities) have largely ignored alternative procurement options.[1] By contrast, large-diameter tunnel projects in the Northwest (most notably the Seattle waterfront SR 99 Viaduct tunnel) have been built or will be built on Design-Build. In addition, the City of Portland has micro-tunneled the vast majority of its recent CSO expansion under a negotiated procurement process. Another illustration is the City of Calgary's flexible tender approach.[2]

This current underutilization of alternative procurement for small-diameter trenchless projects in the Northwest may be due to two factors. First, many public owners and their consultants have the misapprehension that there is only one way to procure such projects – the traditional low-bid process. Second, incumbent tunneling companies do not appear to have innovated. As a result, the small-diameter trenchless market is lagging behind the construction market generally in its failure to exploit the benefits associated with alternative procurement, such as greater cost certainty and enhanced likelihood of project success.

THREE OPTIONS

Under current law, any public owner in Washington has at least three significant options that all promise a better likelihood of satisfactory outcome compared to the prevailing low-bid procurement process. As things stand today, Washington law permits three alternatives to be utilized under the proper circumstances: Design-Build, GC/CM and Supplemental Bidder Responsibility Criteria to determine bidder qualifications in an otherwise traditional lump sum procurement.

This article explores the availability (and pros and cons) in each of these three options, starting with Design-Build. These are only general guidelines, and are not meant to displace the specific analysis one would conduct for any particular project's conditions.

DESIGN-BUILD

Only an elite handful of public owners in Washington currently have automatic, built-in Design-Build authority, principally WSDOT. This fact has caused some public owners to believe that Design-Build is categorically off limits to them. This is incorrect.

Every public owner – from the smallest water district to the largest city – has the statutory right to use a Design-Build for a particular project with approval of the Capital Projects Advisory Review Board (CPARB), a state board created to provide evaluation of capital project construction processes. On application, CPARB must determine whether the applicant and its project meet certain requirements, principally:

- Whether Design-Build will provide a "substantial fiscal benefit" or where use of the traditional lump sum process to the low bidder "is not practical for meeting desired quality standards or delivery schedules";
- Whether the agency has assembled a qualified team to carry out the process; and
- Whether the proposed project meets certain other statutory requirements. (See RCW 39.10.280.)

In addition, under current law, the total project cost must exceed $10 million and one of the following three factors must exist:

- The design or construction activity or technology is highly specialized and Design-Build is critical to developing the construction methodology; or
- The project design is repetitive in nature; or
- Regular interaction or feedback with end user is not critical for effective facility design. (See RCW 39.10.300.)

The statute also provides flexibility to use Design-Build where total project cost is between $2 million and $10 million (RCW 39.10.300(5)).

If CPARB approves the application for use of Design-Build, the public agency must provide for reasonable budget contingencies of at least 5% of the anticipated contract, employ staff or consultants with expertise on previous comparable projects, and include alternative dispute resolution procedures. It also may provide incentive payments to contractors for early completion, cost savings or other similar goals (RCW 39.10.320).

After securing permission to use Design-Build, the agency awards the contract through a competitive process by first soliciting proposals (request for qualifications identifying evaluation factors). Typically, the agency will short-list a panel of finalists. The statute specifically allows for use of a best and final proposal (BAFP) process as well (RCW 39.10.330(4)(a)). The owner may negotiate with the firm submitting the highest-scored proposal.

From the standpoint of the agency/owner, some advantages of Design-Build for trenchless projects include (1) a more complete transfer of risk; (2) early involvement by the design-builder in soils investigation and machine selection; (3) the allowance of incentive payments; and (4) the presumed elimination of subcontracting risks.

Potential disadvantages include (1) loss of owner control over final design; (2) continued need for development of bridging documents to specify desired performance; (3) current lack of market awareness and sophistication regarding use of Design-Build in small-diameter tunneling; and (4) the possibility of claims in the event of project failure regardless of best efforts to avert them.

CONTRACTOR/MANAGER

As with Design-Build, every project owner has the option of obtaining CPARB authorization to use GC/CM for any trenchless project, provided the project meets the statutory criteria. Under these criteria, as with Design-Build, the applicant must first demonstrate that "a substantial fiscal benefit" will be achieved or that use of the traditional low-bid process "is not practical for meeting desired quality standards or schedules" (RCW 39.10.280(2)). In addition, the applicant must prove at least one of the following factors:

- Project implementation involves complex scheduling, phasing or coordination;
- Project involves construction of an occupied facility that must continue to operate during construction;
- Involvement by the GC/CM during design is "critical to the success of the project";
- Project encompasses complex or technical work environment; or
- Project requires specialized work on a building of historic significance.

The first, third and fourth factors would seem to be a relatively easy fit for most small-diameter trenchless projects. Examples of GC/CM and Design-Build applications can be downloaded from CPARB's website.[3]

Selection of the GC/CM must happen early in the design life of the project, typically in advance of schematic plans. Unlike Design-Build, the owner in a GC/CM context retains design responsibility. The selected GC/CM brings constructability, equipment, feasibility and general know-how to the table to work side-by-side with the owner and its design consultants. After selecting finalists based on qualifications, the owner receives sealed bids from the finalists for its Fee and General Conditions. The actual cost of construction (referred to as the Maximum Allowable Construction Cost or MACC) is negotiated when the design is 90% complete or more.

Advantages to GC/CM include (1) bringing the GC/CM in early for constructability, design development and general know-how, (2) use of incentive payments and (3) reliance on the GC/CM for subcontractor selection and management.

Under existing law, potential disadvantages start with the fact that the GC/CM may be prohibited from bidding on trenchless subcontract work itself. This is not necessarily the case, however, because with careful project planning the GC/CM can either bid on the trenchless work if the value of that work does not exceed 30% of the MACC or can self-perform all or part of the trenchless work if the project is structured appropriately. RCW 39.10.390. As with Design-Build, while one also cannot fully negate the risk of claims, the intent of GC/CM is to make the selected contractor prevent claims through upfront feasibility and constructability review.

BIDDER RESPONSIBILITY

On the scale of options, use of supplemental responsibility criteria under RCW 39.04.350 is the most conservative and/or least innovative option. Under this option, procurement is still obtained under the old-fashioned design-bid-build, low-bid process. The main difference is use of criteria to determine bidder responsibility. Bidders not meeting the criteria cannot be awarded the Contract– the statute states bidders "must" meet the standards, which means the owner cannot waive enforcement of the criteria once they are in the bid invitation.

The supplemental criteria statute (RCW 39.04.250), enacted in 2007, provides owners with a flexible tool to enhance the likelihood of project success. Specifically, and importantly, the statute permits use of any "relevant" criteria.

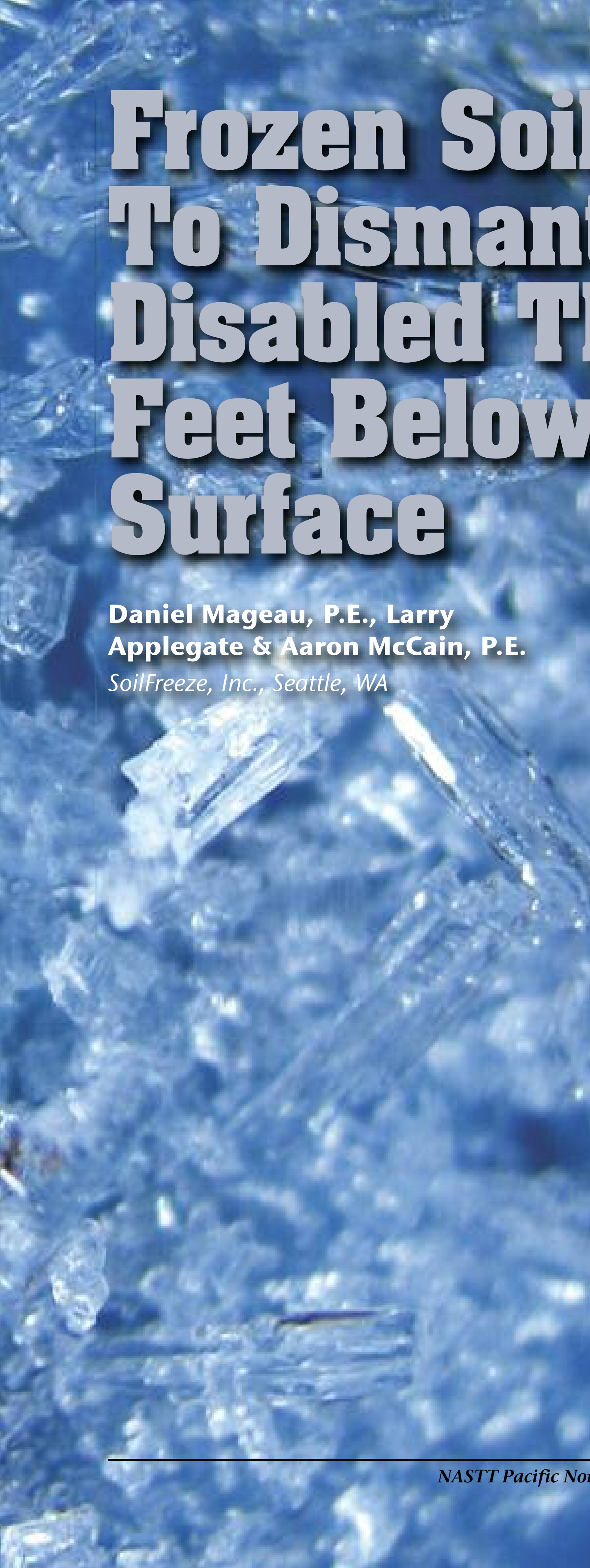
To date, the statute has been largely underutilized in trenchless projects. This is because many owners and consultants, if they use this option at all, have used relatively narrow criteria, such as previous similar experience. The statute itself provides a much broader option to require submission of any "relevant" information. Presumably, that means (for example) the owner could require submission with the bid of specific equipment proposed by the bidder. Owners and their consultants should be more innovative in use of this statutory tool, given the Legislature's intent to provide a mechanism for enhancing the likelihood of project success.

CONCLUSION

The road ahead for use of procurement alternatives in small-diameter trenchless projects is unclear. The Legislature has set the stage for potential use of innovative methods, and will likely loosen the reins more in the future. Whether these methods are actually used to their full benefit in the trenchless market depends on choices and decisions by owners and their consultants – as well as the tunneling industry's ability to evolve and innovate to put project success ahead of other considerations.

NOTES:

1. At the same time, many in the industry believe that this prevailing process, by focusing on low price rather than aligned incentives for project success, contributes to opportunistic claims based on alleged Differing Site Conditions, and therefore desire to have options other than this low-bid system.
2. D. Strayer, G. Kozhushner, City of Calgary Uses Flexible Tender Approach for Tunnel Project, NASTT No Dig Show 2009, Toronto, Ontario, Canada, Paper F-4-01 (1,650 mm diameter).
3. See http://www.ga.wa.gov/cparb/index.html



Frozen Soil Shoring To Dismantle A Disabled TBM 315 Feet Below Ground Surface

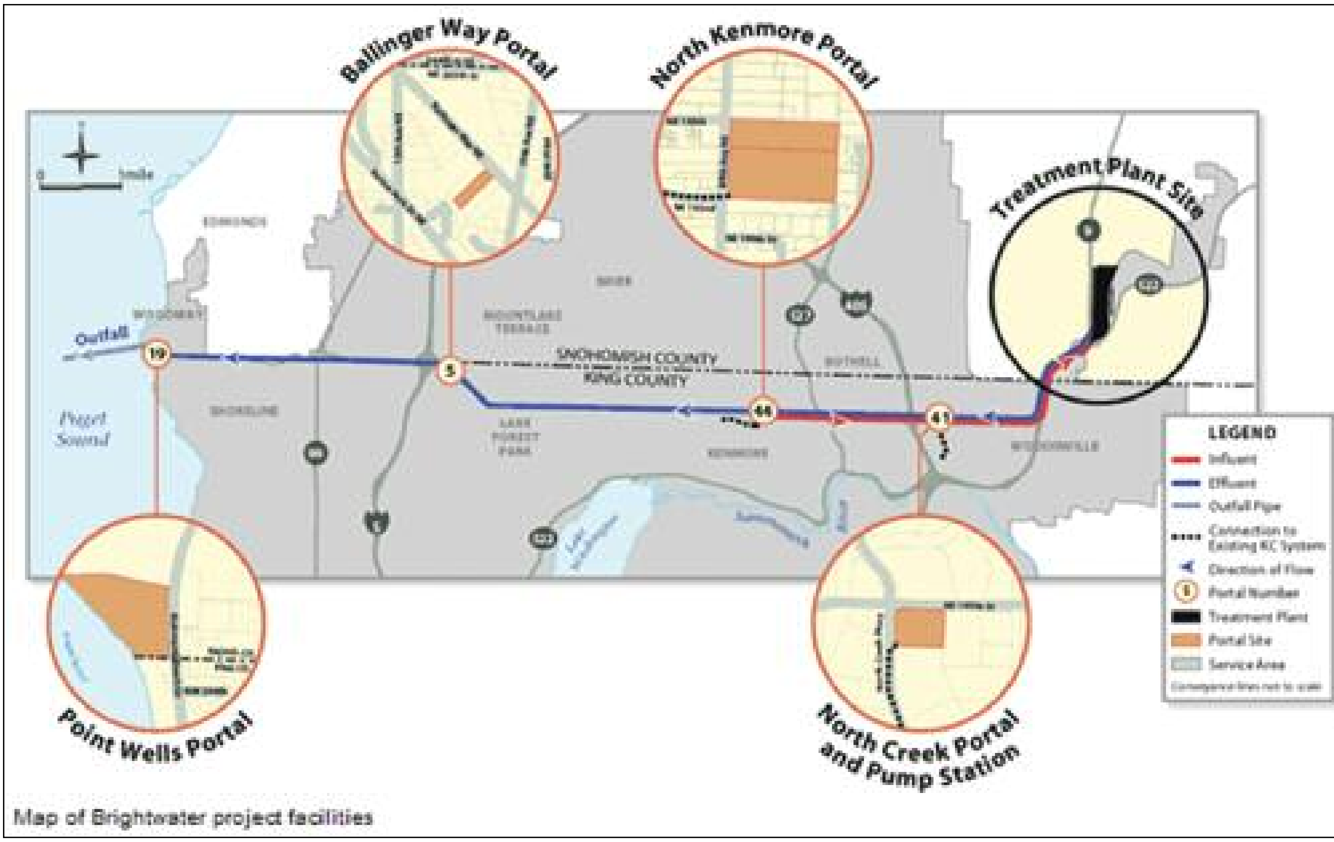
Daniel Mageau, P.E., Larry Applegate & Aaron McCain, P.E.

SoilFreeze, Inc., Seattle, WA

The Brightwater Wastewater Conveyance Project consists of four separate tunnels (designated BT1 through BT4) to deliver waste water from a new treatment facility to an outfall line into Puget Sound just north of Seattle, Washington. Figure 1 shows the overall project plan.

Three of the long tunnels, each two to four miles long, were completed with normal tunneling problems. The fourth tunnel, BT3 operated by VPFK (Vinci), experienced severe wear of the cutter head about halfway through the four-mile alignment and mining was discontinued. The machine was 315 feet below ground surface and 170 feet below groundwater at this point.

To complete this fourth tunnel, the project team led by King County (the owner) retained Jay Dee Coluccio (JDC) to mine the remaining two miles coming from the other direction (from west to east) with the same TBM that they used to successfully complete the BT4 segment. The BT3 machine was 17.5 feet in diameter, while the BT4 machine diameter was 15.5 feet. The idea was to dismantle the BT3 machine entirely, leaving only the 17.5-foot steel shell as the tunnel liner, and to have JDC mine the slightly smaller BT4 machine into the empty BT3 shell. The BT4 machine would then be dismantled out the other end, leaving its shell as the final tunnel liner.



Map of Brightwater project facilities

Figure 1. Plan for Brightwater Wastewater Conveyance Project

The primary issue related to this approach was dismantling the BT3 machine and cutter face under 170 feet of groundwater pressure in a safe manner while managing the risks. The biggest risk was a catastrophic flooding of the tunnel with water and sand. The selected method for protection against this event was ground freezing.

SoilFreeze, a Seattle-based ground freezing contractor, was retained by the Jay Dee Coluccio to design and create a frozen soil zone around the end of the disabled BT3 machine to allow workers to safely remove all of the interior parts of the TBM, include all the pumps, hoses, walls, motors, gears and the cutter face itself. The frozen zone was also extended out more than 30 feet from the BT3 face to also allow the BT4 machine to be encased in frozen soil during the final portions of mining into the BT3 shell.

FROZEN SOIL SHORING APPROACH

For more than 100 years, frozen soil shoring has been used around the world to stabilize wet, loose ground during construction. It is virtually impermeable and very strong and stable. Freezing works in almost any soil type: gravel, sand, silt, clay and even peat. Thus, ground freezing was expected to be an ideal solution for cutting off groundwater and stabilizing the sensitive sands at the cutter face.

For this project, a solid block of frozen soil was needed around the top, bottom, sides and front of the stuck TBM. Any unfrozen zone remaining could create a passageway for water inflow, and at five bars of pressure this could be disastrous. To accomplish this type of block freezing, we designed a system that included 35 freeze pipes drilled from the street surface to a depth of 330 feet (15 feet below the bottom of the machine).

Calcium chloride brine chilled to about 15 F was circulated through each of these pipes. Drilling 330 feet in variable soils was difficult but DBM, the drilling subcontractor, completed this task with great precision. The average horizontal deviation of the freeze pipes was about three feet at 330 feet in depth (<1%). Because we could not install freeze pipes beneath the TBM from the ground surface, we also installed four freeze pipes through the bottom of the TBM at an angle using a small drill rig inside the TBM.

The depth of BT3 machine, the location beneath a narrow residential street, and the deficient electrical capacity in the area increased the difficulties of the ground freezing project. We designed a special type of freeze pipe for this project, referred to as "zone freeze pipe," to reduce the amount of heat extraction from the upper 280 feet where freezing was not necessary. This resulted in a more effective freeze system for the lower 50 feet where freezing was needed. It also allowed us to reduce the number of chillers and electricity required to freeze the ground.

The four short, angled freeze pipes below the bottom of the TBM were installed in drill holes using a small drill rig inside the TBM shell. Besides drilling under 5 bars of hydrostatic pressure, a key difficulty with this approach was delivering chilled brine to pipe that are inside a tunnel 300+ feet below ground surface. We elected to deliver brine to these pipe using brine lines from the ground surface. To accomplish this, we first needed to freeze a wide, stable zone of frozen soil around the side of the TBM shield so that we could safely cut a small access square out of the 2-inch-thick steel shield. This allowed us to tap into an open freeze pipe (#16) installed adjacent to the shell and run a pair of 1.5-inch brine lines from the ground surface down into the BT3 tunnel – without flooding the tunnel.

Angled freeze pipes below the bottom of the TBM were installed in drill holes using a small drill rig inside the TBM shell.

FREEZING PERFORMANCE

The frozen soil stabilization worked very well. The first challenge was freezing for the tap-in to freeze pipe #16 to provide brine to the four freeze pipe below the TBM. To accelerate the contractor's schedule, we supplemented the brine freeze system by flowing liquid nitrogen inside pipe #16 (after the brine and brine lines were removed). The cutting of the shield and insertion of the supply/return brine lines to the pipe inside the TBM went smoothly with virtually no water or soil inflow.

During the freezedown process, our temperature devices embedded in the freeze zone areas indicated that the rate of freezing was slower than expected. During freeze pipe installation over 800 cubic yards of drill mud and bentonite grout was pumped into

Inside portions of a TBM are removed.

the ground to fill voids that had formed around the end of the TBM. This material has significantly higher moisture content than the surrounding native soils. Higher moisture in the soil requires more energy and time to freeze. To meet the contractor's schedule, we modified our freeze system halfway through the installation process so that all of the chilled brine was circulating through only the critical pipes along the face and sides of the TBM. This created a very cold and stable frozen soil zone near the cutter face to allow the contractor to start dismantling the insides of the TBM using hot torches on time.

Prior to the removal of the final watertight bulkhead wall located about 15 feet from the face, we relied primarily on temperature strings in the ground near the TBM to verify that all the soil was, in fact, frozen solid. The final watertight bulkhead wall was then removed and the workers inside the TBM were from then on protected from water and soil intrusion by the frozen soil shoring. For the next few weeks they removed the rest of the inside portions of the TBM one piece at a time using cutting torches, which produced a massive amount of heat. We monitored the soil temperatures outside the TBM throughout this month-long process to verify that the soil remained frozen, which it did. Figure 2 shows the last part of the dismantling process when most of the cutter face had been removed and frozen soil is exposed at the face.

After all of the inside portions of the BT3 machine were removed, the Contractor pumped concrete into the final 15-foot section of the shell to provide a stable medium for mining. The BT4 machine, which had been waiting just outside the frozen soil zone, then mined through the 30 feet of frozen material and into the concrete-filled end of BT3 – with no water or soil inflow.

CIPP Sewer Rehabilitation Saves Millions

Erik Waligorski, P.E.
Principal, Roth Hill, LLC

Southwest Suburban Sewer District has been serving the cities of Burien, Normandy Park, Seattle, Des Moines and SeaTac, as well as portions of King County, for the past 65 years. The District was established in 1945 for the purpose of operating and maintaining the sewer infrastructure installed by the federal government during World War II which encompassed approximately 900 acres. Today, the District maintains over 288 miles of sewer pipelines and operates two wastewater treatment plants. The Salmon Creek treatment plant began operation in 1957 and the Miller Creek treatment plant in 1967. Most of the District's existing pipelines were installed in the mid-1950s and consist of eight- to 15-inch-diameter concrete pipe.

Like many other jurisdictions in the Pacific Northwest, many of the District's sewer facilities have reached the end of their design life and are in need of replacement or rehabilitation. In 2006, the District began a sewer replacement program geared towards the rehabilitation or replacement of some of the first sewer lines installed by the District. The District obtained approximately $4.6 million, including local match, from the Washington State Public Works Trust Fund. The ultimate goal of the project identified by the District was to replace approximately 32,000 feet of existing sewer mains in the Chelsea Park neighborhood located in Burien.

PRELIMINARY ENGINEERING

To begin their replacement program, the District identified an initial project consisting of the replacement of 16,000 feet of sewer, which the District hoped would use half of the $4.6 million allocated to the program. The District, using its own closed-circuit television (CCTV) equipment and crews, began conducting preliminary CCTV inspections in preparation for the replacement program. The CCTV inspections were provided to the District's roster of engineers as part of a Request for Proposal (RFP) process. As one of the roster's engineering firms, Roth Hill, LLC conducted an initial review of the CCTV inspections and suggested that the District could use cured-in-place pipe (CIPP) technology to rehabilitate the entire 32,000 feet of sewers for roughly half of the initial $4.6-million funding.

After being selected to design the Chelsea Park project, Roth Hill completed a detailed analysis of the existing sewer system using the CCTV inspections. The goals of the detailed analysis were to determine the feasibility for CIPP liner installation and identify existing defects within the system that would not allow for CIPP rehabilitation.

Roth Hill, LLC, was selected to design the Chelsea Park sewer rehabilitation project.

The defects identified during the preliminary engineering analysis were divided into three color-coded categories. Existing defects such as root intrusions, minor sags and protruding stubs were put in the green category, which meant that they could be fixed or were not severe enough to prevent CIPP rehabilitation. Defects such as collapsed pipes, major sags or large cavities were put in the red category, which meant that they required excavation before the CIPP rehabilitation could occur.

The third category was yellow, which meant the engineer recommended further District staff review. District staff was asked to determine if the sags in this category were within acceptable limits based on the existing flows. Other yellow conditions consisted of inconclusive CCTV inspections due to excessive debris or grease that required a second CCTV inspection after cleaning. The culmination of the preliminary engineering investigation recommended spot repair locations where the pipe needed to be repaired prior to CIPP rehabilitation. Once repaired, the entire pipe, including the repaired location, was lined during the CIPP phase of the project.

SPOT REPAIR & REHABILITATION

A multi-phased construction project delivery method was developed to complete the rehabilitation project. Instead of having a single contract that required both the open-cut repair of the sewer line and the CIPP liner installation, the open-cut repair and sewer line rehabilitation were split into two separate contracts. By splitting the construction methods into separate contracts, the District ensured that only those contractors who were experienced with CIPP rehabilitation would bid on the rehabilitation project. Likewise, the contractors who were familiar with open-cut work would not need to concern themselves with the liner installation work.

The open-cut repair contract consisted of the repair or replacement work that was required based on the preliminary engineering CCTV analysis. Generally, the contractors bidding on the open-cut repair project were local contractors familiar with the District and the local road and land use agency requirements. That meant these contractors understood the risks and requirements for constructing the project in the area and did not need to inflate their bids to cover those factors.

Once the spot repair project had been designed and put out for bid, and the contractor was selected, the District was able to complete the rehabilitation project design and bid that phase of the work. The CIPP rehabilitation contract was designed to require the contractor provide an increased level of inspection and buyoff of the CIPP feasibility prior to the liner installation. To accomplish this, the contract required the CIPP contractor to perform a pre-installation cleaning and inspection of the existing sewer to identify any locations they believed could not be successfully rehabilitated using CIPP technology.

District staff also reviewed the pre-installation inspection and were required to sign off on the contractor's assessment of the existing condition. By having both contractor and staff review and approve the CIPP feasibility, the District was able to take advantage of the contractor's CIPP experience prior to beginning the actual construction, and the District had time to modify the contract if required.

Liner installation (above) and open-cut repair for the Chelsea Park sewer rehabilitation project were split into two separate contracts.

Once CIPP installation was complete, the contractor was required to conduct a post-installation inspection. As with pre-installation, post-installation inspection review was required and approved by both the contractor and District staff. Tracking of the pre-installation and post-installation inspections was accomplished using a tracking template developed by Roth Hill based on similar tracking templates previously used by the City of Tacoma. The tracking template consisted of three separate sets of data: General Infrastructure Information, Pre-Installation Inspection Data, and Post-Installation Inspection Data. The General Infrastructure Information contained all of the known information for the existing sewer such as size, material, and depth. It also provided space for the contractor to identify the shot number, proposed liner thickness, and proposed date of installation. The Pre- and Post-Installation Inspection Data records allowed space for the contractor and the District to review and make comments on the cleaning and liner installation. The tracking template was transmitted electronically between the District, the engineer, and the contractor during construction.

MULTI-PHASED CONSTRUCTION

One of the issues encountered during construction was that the CCTV records compiled by the District were anywhere from two to four years old. It was understood that by using the old CCTV inspection videos for the preliminary engineering, additional problem areas would likely be found during the pre-installation inspection performed by the rehabilitation contractor.

The initial Phase I spot repair contract for the Chelsea Park project consisted of the replacement of 272 feet of 10-inch-diameter pipe and 590 feet of eight-inch-diameter pipe in 12 locations within the project area. While this work was being completed, the District bid the Phase II rehabilitation project, which consisted of the rehabilitation of 32,600 feet of existing sewer lines.

As expected, during the pre-installation inspection work for the rehabilitation contract, the contractor identified eight additional locations requiring excavation. These locations were packaged into a Phase III spot repair contract which was completed in time for the Phase II contractor to rehabilitate those lines at the end of their contract.

In total, the first three phases of the

Chelsea Park project replaced or rehabilitated approximately 33,800 feet of existing sewer lines for a total project cost of $2,059,100. Having been successful in meeting the goal of rehabilitating the initial Chelsea Park neighborhood using only half of the available funding, the District was able to expand their rehabilitation program to include a Phase IV spot repair and Phase V rehabilitation project which was able to rehabilitate an additional 29,680 feet of existing sewer. This additional 29,680 feet of sewer rehabilitation cost the District another $1,403,600 in total project cost. The District used the remaining funding to complete a Phase VI repair project in preparation for future CIPP rehabilitation projects.

In summary, by utilizing CIPP rehabilitation technology, the District successfully rehabilitated approximately 63,480 feet of sewer lines for $3,462,700 total project cost. This equates to roughly $55/foot for a new sewer line with at least a 50-year design life. It is estimated that this project saved the District in excess of $5 million over conventional cut-and-cover construction.

Rehabilitation of more than 63,400 feet of sewer lines was achieved at a total cost of less than $3.5 million.

Over Or Under: Geotechnical Considerations for Pipeline Levee Crossings

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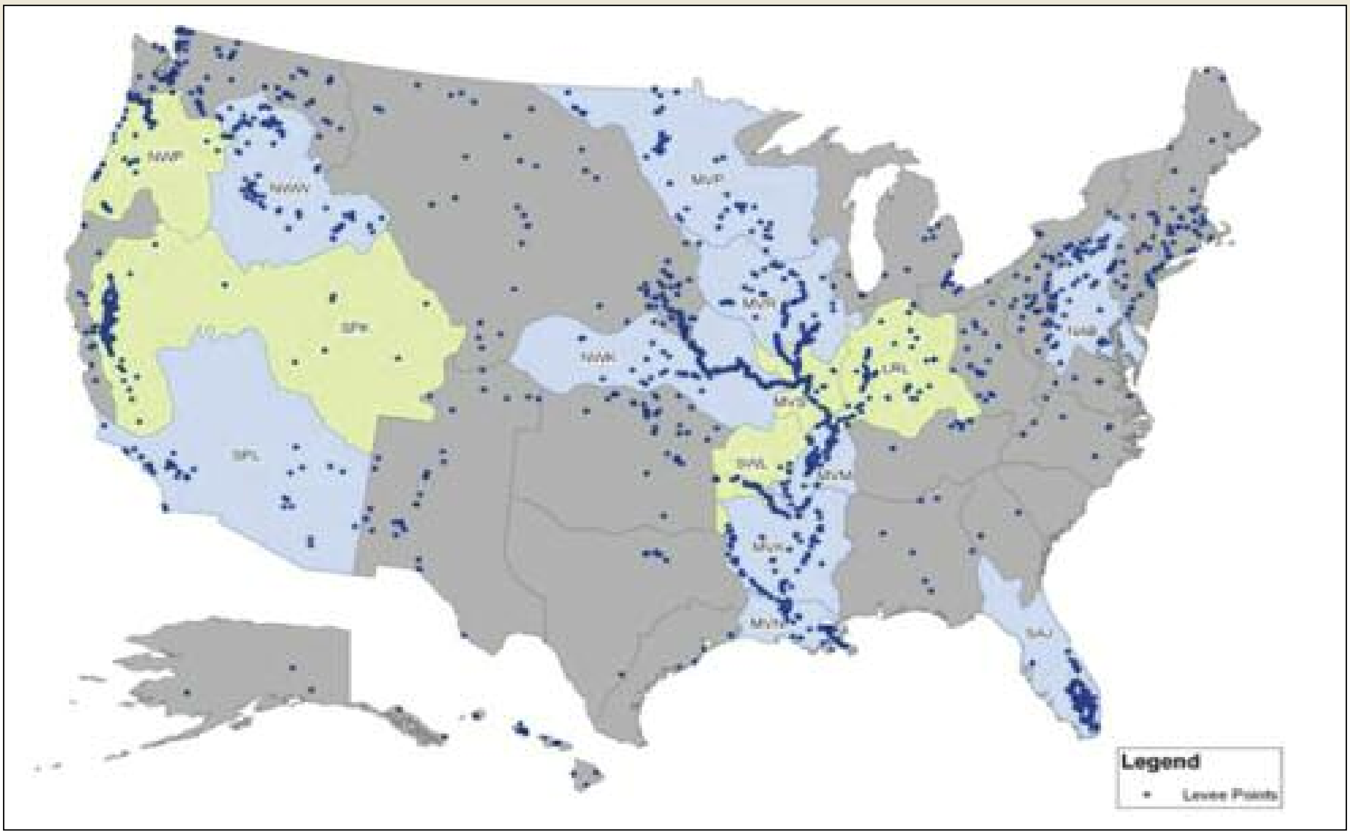


Map of Levee Locations in U.S., From "Status of the National Levee Database" presented by Timothy Pangburn, PE, D.WRE, USACE to the National Committee on Levee Safety 10-7-08.

Levees are a critical piece of the nation's infrastructure. With the memory of the damage caused by Hurricane Katrina hanging as a dark shadow, every pipeline levee crossing project undergoes intense scrutiny. Moreover, with tens of thousands of miles of levees in the United States, the condition of many of the levees is unknown. (See Figure 1.)

When a new pipeline needs to cross a levee, it is important to protect and maintain the integrity of this life-saving infrastructure. Because pipeline crossings occur in different states with different geology and different levee governing districts, these seemingly similar pipeline projects may have different approaches.

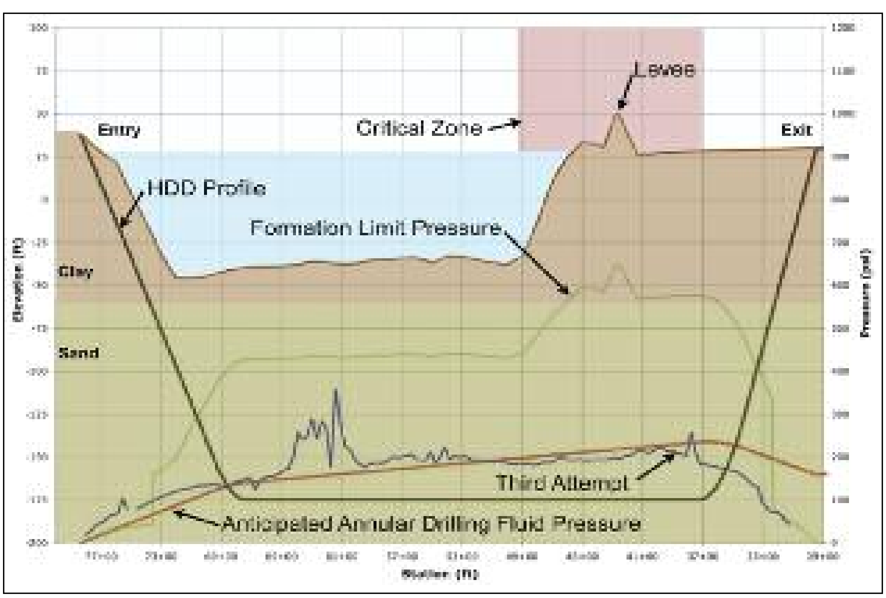
Some local levee districts choose to route new pipelines up and over levees primarily based on precedent and a lack of experience with installation of a new pipeline by horizontal directional drilling (HDD). Others may be concerned about creation of seepage paths by drilling fluid pressure and fracture potential through the critical zone beneath the levee. Yet other local levee districts choose to have new pipelines installed by HDD because they need free access to maintain the levees, know the levees have been settling and understand placing a pipeline on the levee creates a conflict that must always be worked around. Regardless of the method directed by the levee district, it is of paramount importance to investigate the subsurface soil conditions so appropriate geotechnical design considerations can be made for the pipeline crossing.

MAKING A LEVEE-CROSSING DECISION

One of the first considerations for a pipeline levee crossing is reviewing future levee maintenance as outlined on the USACE levee district's improvement construction plans to determine if the pipeline crossing has a potential future conflict. The following early planning steps should be taken:

- Collect available agency data and design information for the existing levee.
- Collect a broad coverage of geotechnical, topographic and environmental surveys that might even extend beyond the standard right-of-way limits.
- Confirm design flood water levels for the levee to use in calculations.

Pipeline owners may have the chance to contribute to crossing-design options, but the reality is they will be working with an agency-prescribed crossing method that must simply be complied with. To facilitate regulatory agency review of designs, pipeline engineers should show all their work. Appendices filled with data plots and selected profiles used for analyses add clarity.



Mississippi River HDD Crossing

GOING OVER THE LEVEE

The first step for going over the top begins with computing the factor of safety for global sliding stability. This establishes the starting point in determining whether the existing levee is sufficient prior to modification for a pipeline crossing. The results will determine if modifications to the levee will impact flood protection.

The over option involves either 1) putting the pipe in a conventional pipe trench on the levee surface or 2) protecting the pipeline with a cover of a protective blast blanket. The protective "blanket" or cover over the top can consist of a simple earthen berm or hardened cover to allow for traffic access or erosion and scour. The earthen berm pipeline cover adds more load on the existing levee, which must be evaluated for the impacts on consolidation settlement and slope stability. Under-seepage must also be evaluated.

GOING THROUGH THE LEVEE

Crossing a levee by going through it via secure sheet-pile T-Wall system is increasingly rare. Current guidelines for T-Wall crossing designs are mandated by the USACE. T-Walls should only be considered for secondary level protection systems and not mainline flood protection for active channel waterways. If the T-Wall is built in a newly constructed levee section, then the settlement and the surrounding embankment will be a significant influence to address.

A governing agency will almost always provide recommendations and directions on when to employ a T-Wall design, and it will take unusual circumstances for a through-the-levee system to be considered. The pipeline owner crossing the regulated levee should not promote this as their initial crossing configuration design.

GOING UNDER THE LEVEE

Having a thorough understanding of the surface and subsurface conditions for a potential HDD under a regulated levee are important in determining the suitability for an under-the-levee crossing. A subsurface exploration program should be developed to evaluate the soil and groundwater conditions along the HDD. The design alignment for an HDD should consider the type and consistency of the soil and groundwater conditions.

Hydraulic fracture describes the case in which the annular downhole drilling fluid pressure exceeds the overburden stress and shear strength of the soil surrounding a drill path resulting in plastic deformation of the drilled hole. Hydraulic fracture typically occurs when the drill path passes through relatively weak cohesive soils with low shear strength. Inadvertent returns occur when drilling fluid emerges at the ground surface or any other undesirable location.

Even within high-strength soil, potential construction problems can occur if the construction practices are not appropriate for the soil conditions. For a successful HDD installation, the drilling fluid properties, drilling fluid flow rates, and drilling penetration rates must be aligned to keep the drilling fluid pressures below the limit pressure of the surrounding soil formation.

Changes in one of these components can affect the others and ultimately affect the annular pressures measured downhole. For example, if inappropriate drilling fluid properties for the soil conditions reduce the ability to carry cuttings through the annulus of the drilled hole. The cuttings falling out of suspension may plug the hole resulting in increased downhole pressures.

MISSISSIPPI RIVER HDD

Targeting high-strength soil and using proper construction techniques aided in a successful HDD installation under a regulated Mississippi River levee near Baton Rouge, Louisiana.

The subsurface conditions consisted of soft to very stiff clay to approximately 100 feet. Dense to very dense sand, sand with silt and silty sand were encountered below 100 feet. See Figure 3.

The USACE expressed concerns of levee disturbance from annular fluid pressures while completing the HDD pilot hole, and the potential impact the installation may have on the levee system. The USACE requested a site-specific hydraulic fracture and inadvertent returns evaluation of the proposed HDD crossing below the levee.

Because the dense to very dense sand below 100 feet was higher strength than the overlying clay, the HDD design targeted the sand when crossing under the levee. The results of the hydraulic fracture and inadvertent returns model indicated a low potential for hydraulic fracture and inadvertent returns under the levee. However, the HDD contractor's construction procedures are critical to the success of HDD crossings. If the contractor operates with inadequate pump volumes, improper drilling fluid properties, or excessive rates of penetration, the annulus may become blocked with drill cuttings.

A critical zone was established by the permit under the levee where the drilling fluid pressures must be limited. The boundary of the critical zone was 300 feet on either side of the levee toe and the pressure limit within the critical zone was 300 psi.

The initial portion of the pilot hole beneath the river had penetration rates and drilling fluid properties generally within an acceptable range. However, as the jetting approached the critical zone, the penetration rates were relatively high and continuous drilling fluid returns were not maintained. As a result, the annular drilling fluid pressures were greater than the anticipated drilling fluid pressures and the formation limit pressure.

An initial attempt to reduce the annular pressure was made by partially tripping out the jetting assembly. However, drilling fluid returns were not re-established and the annular pressures again exceeded the limit pressure.

After the second attempt was unsuccessful, the jetting assembly was fully tripped out to re-establish drilling fluids. Once full drilling fluid returns were re-established, the penetration rates were reduced to maintain continuous drilling fluid returns to entry and the drilling fluid properties were adjusted for the soil conditions.

During the third attempt, the downhole annular pressures were within the acceptable range until about 1,200 feet from entry when the drilling fluid pressures increased significantly. Tests of the drilling fluid indicated an increase of solids in solution, which increased the drilling fluid pressure. As a result, the crew began circulating drilling fluid through the hole to sweep the higher density, cuttings-laden drilling fluid out of the hole.

Once the drilling fluid properties were back to within acceptable parameters, drilling fluid returns were more easily maintained and the pilot hole progressed through the critical zone within the pressure limits prescribed by the USACE. While traversing through the critical zone, the drilling penetration was maintained at a moderate rate to maintain drilling fluid returns to entry. The drilling fluid properties were also managed to allow for successfully completing the entire 4,900-foot pilot hole.

CONCLUSION

Pipelines will continue to cross flood protection levees. Agencies and locations have different design and construction requirements. Pipeline levee crossing design is essentially a combination of both prescriptive USACE design procedures and application of innovative construction techniques.

Crossings over levees must follow a formulaic design that meets agency requirements. HDD crossings require close coordination and definition of drilling fluid properties. During construction, downhole pressure monitoring can protect levee integrity.

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Oregon's Hard Rock Record-Breaker

Robbins Small Boring Unit Achieves Milestone with Minimal Environmental Impact

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The Robbins Company, Kent, WA

Tom Lawler
Clean Water Services, Hillsboro, OR

Jim Gonzales
Gonzales Boring & Tunneling, North Plains, OR

With the completion of a 600-foot-long crossing in December 2009, contractor Gonzales Boring & Tunneling completed a new distance record. The project marked the longest bore using a Robbins Small Boring Unit (SBU-A), a type of cutterhead mounted with disc cutters for excavating hard rock and mixed ground.

"Preparation, a qualified crew, and the right cutting head matched to the right auger boring machine made for a successful crossing," said Jim Gonzales, President of Gonzales Boring & Tunneling.

The local contractor's result capped a series of limit-pushing projects across the U.S., including a 544 foot-long auger bore using a 36-inch SBU-A in Clermont County, Ohio. A third record-breaking bore in the 54-inch-diameter range was accomplished in Louisville, Kentucky, where a contractor excavated a 352-foot-long highway crossing.

The crossing in Tigard, Oregon, had all the right variables to achieve record-breaking status. Gonzales Boring & Tunneling needed a solution for three gravity sewer crossings 230, 600 and 320 feet long near an environmentally sensitive area.

Gonzales Boring & Tunneling completed a new distance record using a Robbins Small Boring Unit.

PROJECT BACKGROUND

The Oregon crossings formed part of the Locust Street Sanitary Trunk Upgrade

Completed in December 2009, the 600-foot bore in Tigard, Oregon, was a record for hard rock auger projects using disc cutters.

Project, which involved upsizing about 1.1 miles of existing eight-inch-diameter sewer lines. The new, larger-diameter pipelines, for owner Clean Water Services, were completed to accommodate future needs of the City of Portland.

Much of the gravity sewer line (4,678 feet) was installed using open trench techniques by general contractor Northwest Earthmovers, Inc. However, a section of the older line ran almost entirely along Ash Creek, a sensitive environmental corridor. To avoid environmental impacts to the stream, Clean Water Services opted to instead build a parallel system some distance away, though this alternative required trenchless construction in a residential area.

Three crossings were needed below properties, between houses, and beneath an active Oregon Military Department facility. The owner deemed open cut an unattractive option because it would impede access and could potentially disrupt daily activities at the military site. "Deep trenching would have been the only option in the area. Geologic conditions at the surface would have required excavation into solid bedrock 30 feet below," said Tom Lawler, Project Manager for Clean Water Services.

The crossings were initially designed as a pilot tube microtunneling project using vitrified clay pipe. However, meetings between Gonzales, other local contractors, and Clean Water Services resulted in the contract being opened up to other trenchless methods, including hard rock auger boring using a Robbins SBU-A cutterhead.

"The owner has saved over one million dollars on the trenchless section alone over their original cost estimates for pilot tube microtunneling. Because the owner listened to the construction community, they saved both time and money, and kept the dollars local," said Gonzales.

The new method also addressed the strict requirements of the gravity sewer crossings, which were constrained to a maximum 1.5% grade. "Given the strict grade requirements, SBU technology offered the best solution to avoid negative impacts to military activities and maintain residential access," said Lawler.

THE SBU-A: HOW IT WORKS

The Robbins SBU-A is a type of hard rock and mixed ground cutting head mounted with disc cutters and used in conjunction with an auger boring machine (ABM). The SBU-A, available in diameters from 24 to 72 inches, consists of a circular cutterhead mounted with single-disc cutters capable of excavating rock from 4,000 to over 25,000 psi UCS. For excavation, the SBU-A is welded to the lead steel casing. The ABM provides both torque and thrust to the cutting head, while a full-face auger is used for spoil removal.

In hard rock, disc cutters penetrate the rock face and create a "crush zone" through which fractures propagate. Material is then chipped from the face into openings in the cutterhead called muck buckets, which transfer the material to the auger. In mixed geology operation of the machine is the same, though the cutterhead may be fitted with a combination of tungsten carbide insert cutters, disc cutters, and drag bits to excavate the ground.

CROSSING EXCAVATION

After completing an initial 230-foot crossing in clay and basalt, Gonzales launched the 60-inch-diameter SBU-A on its second bore (600 feet in length) on October 28, 2009. The disc cutterhead was used with a 72-inch ABM and steel casing. Rock conditions on the second crossing consisted of basalt at various rock strengths from 7,000 to 17,000 psi UCS. Crews monitored line and grade, and were able to maintain advance at about 40 feet per 10-hour shift.

A contractor-designed steering system guided the SBU-A to within one-hundredth-of-an-inch design grade. Despite the mixed ground conditions, no disc cutters required changing after 820 total feet of boring.

The record-setting crossing was completed in early December 2009 with praise from all involved. "Access limitations, environmental concerns, regulatory permitting and public impact are serious considerations in an urban environment, and SBU technology is a great option for these conditions," said Lawler.

FACTORS IN PROJECT'S FAVOR

"The truth is that a record-breaking project is determined by many variables," said Chris Sivesind, Robbins SBU Sales Manager - Western U.S. "This project had a number of factors in its favor: quality equipment, consistent geology, and most importantly an experienced crew."

A five-inch hex auger is an ABM improvement developed within the last 15 years to allow for long-distance bores at high ABM horsepower and high torque. Other design improvements include improved steering accuracy, which allows for more precise installation of casings using a pilot tube boring system or hydraulic steering system.

In addition, the tool steel used for SBU disc cutters allows for excavation of a wide variety of ground types with fewer cutter changes and less downtime. "Towards the end of the 600 ft bore, they were utilizing only 15% of the machine's thrust capability," said Sivesind of the Oregon crossings. "The relatively low force given the distance was a result of the bore path being fairly straight, and the SBU gage cutters effectively maximizing overcut throughout the entire crossing."

The Robbins Small Boring Unit (SBU-A) is capable of excavating mixed ground and hard rock up to 25,000 psi UCS.

Whatever the ground conditions may be, consistent geology, such as the basalt encountered on the Oregon bores, seems to be a contributing factor for record-breaking projects. "Uniform geology, without a lot of fractures or clay seams, allows for longer and more accurate bores as well as optimum cutterhead utilization," said Sivesind.

However, ground that is too hard or too soft can hinder progress. Very soft rock less than 3,000 psi UCS can clog the cutterhead, requiring slowed rotation and advance, particularly if groundwater makes the cutting face sticky. Very hard rock of 36,000 psi UCS or more requires higher thrust loading on the disc cutters, and can also slow progress and increase cutter changes. Extremely hard rock conditions often need larger diameter cutters of up to 14 inches, which allow for the higher thrust loads required to cut hard rock.

Contractor experience with multiple successful bores, as well as willingness to evaluate and manage risk, is critical to completing a record-breaking project. Most record-breaking jobs are a direct result of the contractor's experience with multiple ABM and SBU projects at various diameters.

Ultimately, quality support and contractor willingness to attempt long crossings may have been the highest predictor of success for the Oregon crossings. Jim Gonzales began the project with over 25 years of experience in trenchless boring, and felt that the field service provided was invaluable. "The technology worked very well for both crossings," he observed. "The field service support we received was unmatched, and we hope to receive similar support for future jobs in hard rock."

Multiple factors allowed the Robbins SBU-A to achieve a longer distance, including consistent geology and contractor experience.

HDD Construction Begins on Tulalip Water Pipeline Project

Daniel R. Williams, PE
MWH Americas, Bellevue, WA

INTRODUCTION

The Tulalip Water Pipeline is a 7.6-mile-long water transmission pipeline made up of 36- and 48-inch-diameter welded steel pipe. When complete, it will cross underneath a railroad yard and a major river delta, so the design includes the following five individual trenchless crossings made up of almost 12,000 lineal feet of 36-inch-diameter, 5/8-inch-thick steel pipe:

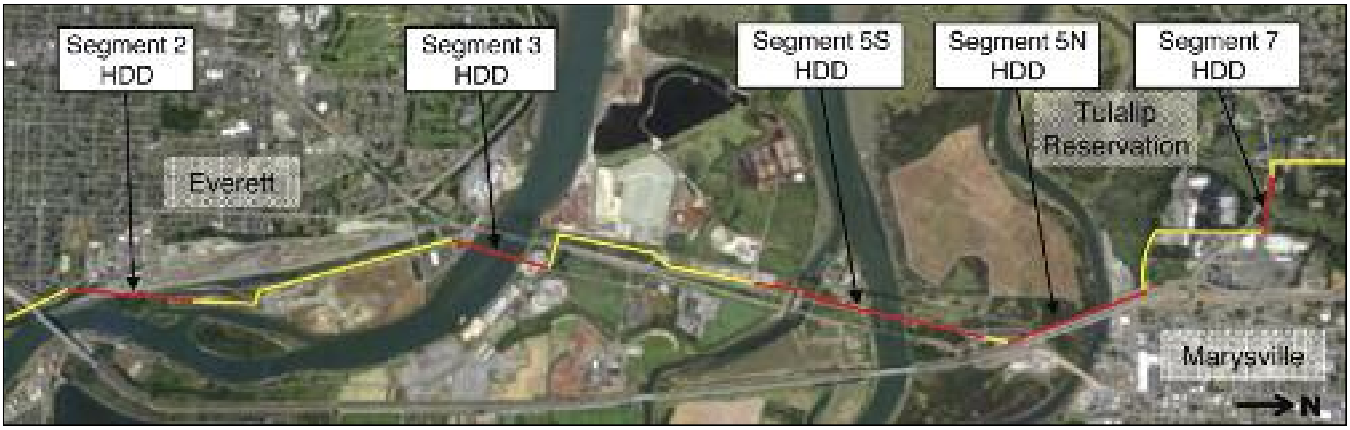
- Segment 2 – BNSF Railroad Yard Crossing – 2,040 feet
- Segment 3 – Snohomish River Crossing – 2,000 feet
- Segment 5S – Union and Steamboat Slough Crossing – 3,680 feet
- Segment 5N – Ebey Slough and BNSF Crossing – 2,760 feet
- Segment 7 – Quil Ceda Creek Crossing – 1,200 feet

Pipe installation at the trenchless crossings will utilize horizontal directional drilling (HDD) technology to avoid impacts to railroads, waterways, and adjoining wetlands. HDD was chosen as the preferred trenchless technology based on the suitability of the geotechnical conditions, the reduced environmental footprint, and the relatively rapid speed of construction.

BACKGROUND

The City of Everett, Washington, is located approximately 25 miles north of Seattle on the shores of Puget Sound and has a population of approximately 104,000. The City is a large regional water purveyor. It owns and operates two surface water reservoirs, a water treatment plant, and a regional water supply system that, collectively, can deliver over 100 million gallons of water each day to primarily municipal customers throughout southwest Snohomish County.

The 35-square-mile Tulalip Indian Reservation is also located on the shores of Puget Sound, just north of Everett and west of Marysville. The Tulalip Tribes have a growing population of about 4,000 members. Approximately 3,000 members reside within reservation boundaries (along with about 7,600 non-members).



The Tulalip Tribes have long been concerned about the capacity of the groundwater aquifer that serves the central and western portion of the Reservation, and now it is feared that Reservation demands for City of Everett water (supplied through the City of Marysville's system) will soon exceed the supply allocation. As a result, the Tulalip Tribes and the City of Everett created a joint board, called the Tulalip-Everett Joint Water Pipeline Board, to design a water transmission pipeline called the Tulalip Water Pipeline to serve the long-term needs of the Reservation (and a portion of the City of Everett called Smith Island) and to support water supply needs.

The Tulalip Water Pipeline Project will ensure a permanent, long-term, 36-million-gallons-per–day potable water supply that will meet Reservation demands over the next 50 to 100 years.

DESIGN TEAM

The Tulalip-Everett Joint Water Pipeline Board entered into a professional services agreement with MWH on June 8, 2007, to develop a pre-design and, upon completion of the pre-design, amended the agreement on January 1, 2009, to include final design services, which included the development of construction bid documents. Parametrix and Staheli Trenchless Consultants were primary subconsultants to MWH during pre-design and design. Other team members retained by MWH for pre-design and design services included the following companies:

- GeoEngineers conducted geotechnical subsurface investigations and prepared geotechnical design and data reports.
- Dowl HKM surveyed proposed alignments, developed topographic maps (i.e., base maps), and prepared legal descriptions.

An American Augers DD-625 drill rig was used in Segment 5N of the Tulalip pipeline HDD project.

- Northwest Corrosion Engineering designed an induced current cathodic protection system.
- Northwest Archaeological Associates identified cultural and historical resources.

A 240-foot-long conductor casing was installed as part of Segment 5N of the Tulalip project.

Pullback work in the 3,600-foot Segment 5S began in November 2011.

CONSTRUCTION TEAM

The Tulalip Tribes entered into a professional services agreement with Parametrix on February 9, 2011, to provide construction management services during construction of four of the five trenchless crossings (i.e., Segments 3, 5S, 5N, and 7). Under this agreement, MWH and Staheli Trenchless Consultants are primary subconsultants to Parametrix. The Tulalip Tribes are currently contracted with Don Kelly Construction of Bozemen, Montana, for $26.5M to build Segments 3, 5S, 5N, and 7. The primary subcontractors/suppliers to Don Kelly Construction are:

- Southeast Directional Drilling of Casa Grande, Arizona, is currently performing the HDD work.
- Reece Trucking and Excavating of Marysville, Washington, is currently installing the open cut portions of the pipeline.
- Northwest Pipe Company of Portland, Oregon, is supplying the steel pipe.

STATUS OF HDD WORK

Segment 5N. This $6.3M segment includes a 2,760-foot-long HDD crossing of Ebey Slough. Underground work began with the installation of a 240-foot-long, 60-inch-diameter conductor casing, which was installed by pipe-ramming technology in July 2011. The pilot bore and subsequent borehole reaming work was completed in August 2011. Pullback of the 36-inch-diameter steel carrier pipe began on September 11, 2011, as required by the bid documents (to minimize the impacts to an Interstate 5 interchange on the Tulalip Reservation). The overall pullback operation was successful; but the carrier pipe became "caught" on the conductor casing and the Driller was unable to complete the last 240 feet of the pullback operation. The Contractor has submitted a plan to excavate and expose the end of the casing and connect the end of the carrier pipe to another section of carrier pipe that will be installed through the casing from grade. The work necessary to complete the carrier pipe installation is expected to begin in the spring of 2012.

Segment 5S. This $7.8M segment includes a 3,680-foot-long HDD crossing of State Route 529 and the Union and Steamboat sloughs. The alignment includes two 3,600-foot-radius horizontal curves. The pilot bore and subsequent bore-hole reaming work was performed in October 2011. Pullback of the 36-inch-diameter steel carrier pipe began on the afternoon of November 6, 2011, and was completed the next morning at 3 a.m. in just less than 13 hours.

Pullback of the 36-inch-diameter carrier pipe on Segment 5S.

Segment 7. This $2.0M segment includes a 1,200-foot-long HDD crossing of QuilCeda Creek on the Tulalip Reservation. The pilot bore and subsequent borehole reaming work was performed in November 2011. Pullback of the 36-inch-diameter steel carrier pipe began at 4:00 p.m. on November 23, 2011, and was completed that evening by 7:30 p.m.

Segment 3. This $4.3M segment, when constructed in the spring 2012, will include an HDD installation of 2,000 feet of 36-inch-diameter steel pipe underneath the Snohomish River. Southeast Directional Drilling is under contract with Don Kelly Construction to perform the HDD work on this Segment.

Segment 2. This segment, 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. A pipeline alignment assessment was completed in 2011. Final design is expected to begin in 2012, but construction has not yet been scheduled.

CONCLUSION

Construction of the Tulalip Water Pipeline through a sensitive river delta with minimal impacts to railroads, waterways, and wetlands would not be possible without trenchless technology. The Tulalip Water Pipeline Project, when complete, is expected to be another HDD success story.

The Missing Link

PipeMedic Laminate Links High-Pressure Gas Pipes

Mo Ehsani, PhD, PE, SE
President, PipeMedic, LLC

The earlier manufactured gas contained hydrocarbon fluids. In design of gas mains ranging between six and 30 inches in diameter, two- to three-feet-wide drip pots were frequently installed to collect these solutions that would be periodically siphoned. Today's manufactured gas has no condensation and thus there is no need for the drip pots. As utility companies renew gas mains with cured-in-place (CIP) liners, these weak liners cannot bridge the gap created by abandoned drip pots. There are occasional abandoned T connections that also introduce similar problems.

In many cases, these drip pots or abandoned Ts are in hard-to-reach places where open-trench repair techniques are not viable. The challenge, then, is to create a structurally strong pipe that would span across that gap and provide support for the CIP liner. The ideal product must also be suitable for trenchless installation from entry points that may be several hundred feet away. Providing a structural link across the opening caused by drip pots was literally and figuratively the missing link to successful lining of these pipes.

BACKGROUND

The development of PipeMedic™ started in 2008. These laminates are constructed with one or more layers of carbon or glass fabric saturated with resin and pressed together to form a very thin laminate sheet. The laminates are supplied in rolls four feet wide by 150 feet long that can be easily cut to any size in the field. With a thickness of about 0.02 inches, the laminates are flexible enough to be coiled for insertion into pipes as small as four inches in diameter. The tensile strength of the PipeMedic ranges between 60,000 and 145,000 psi.

In 2009, QuakeWrap, Inc. showcased one its newly developed PipeMedic laminates at aTrenchless Technology Road Show in New Jersey. The product caught the attention of attendees from Public Service Electric and Gas Co. (PSE&G) who were seeking a solution for bridging the gap across abandoned drip pots in their gas mains. Once it was determined that the product was an ideal candidate for this application, a demonstration was set up to assess the suitability of the proposed repair.

The high strength of the laminates in two orthogonal directions allows them to resist both hoop and longitudinal stresses that would develop under such applications. Furthermore, PipeMedic laminates incorporate a thin glass veil on both surfaces; this allows it to be directly positioned against the steel pipe surface without worrying about the galvanic corrosion that could result by allowing carbon fabric and steel to come in contact with each other.

TEST AND INSTALLATION

To ensure the feasibility of this concept, a demonstration was set up at Progressive Pipeline Management (PPM) facility in New Jersey. It was successful, affirming that PipeMedic could be used to bridge the gap in a drip pot. The major steps for installation were:

1. Applying adhesive to the PipeMedic laminate.
2. Rolling the laminate onto an inflatable bladder.
3. Inserting the bladder into the pipe.
4. Inflating the bladder to expand the laminate, thus simulating a drip pot gap.
5. PipeMedic laminate section bridging a 24-inch gap, and curing.

The first installation of PipeMedic was in a 16-inch pipe in Paterson, N.J. The installation was some 200 feet from the access pit. A closed circuit camera was used to locate the exact location of the drip pot, and the installation followed the steps described in the demonstration proj-

PipeMedic laminate is installed onto an inflatable bladder.

Workers insert a PipeMedic-laminated bladder into a pipe.

ect. Once the PipeMedic™ was properly installed, the entire pipe was lined with Starline-2000. The final CCTV inspection verified that the pipeline was succesfully repaired; the thin PipeMedic™ laminate was hardly visible once the Starline liner was in place.

The many unique features of this application resulted in the the project receiving the 2011 Trenchless Technology Rehab Project of the Year Award.

ACKNOWLEDGEMENT

The PipeMedic laminates and method of repair of pipes described in this paper are subject to pending U.S. and international patents by PipeMedic, LLC. Support of the PPM staff in testing and field installation is greatly appreciated. Funding of the testing program was provided by PSE&G.

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TESTING AT GTI

Before the laminate could be used on this pipeline renewal job, the material's strength and stiffness and its suitability for such an application had to be tested and confirmed.

The Gas Technology Institute (GTI) was selected by PSE&G to develop a test protocol that would satisfy the requirements of ASTM F2207 and manage the overall testing program of using the PipeMedic laminates for rehabilitation of gas pipelines. GTI's work included providing and installing the necessary instrumentation, overseeing and conducting the testing, analyzing the test data and presenting the results of this work in the form of a final report with appropriate recommendations (Farrag 2011).

Testing was performed at PPM's facility in New Jersey by PPM personnel working jointly with representatives from PSE&G and GTI. The testing program included testing steel pipe sections in six-, 12- and 16-inch diameters. Each test section included a 24-inch free-standing laminate section which extended an additional 12 inches into each side of the pipe. The laminate-steel system was lined with CIPP, capped at both ends, thrust-restrained and connected to a hydraulic pressure system to apply controlled test pressures.

All pipe sections were tested under hydrostatic pressure that was increased every two hours by 50 psi up to the maximum pressure of 250 psi, more than four times the pipeline's maximum allowable operating pressure. The measured strains in PipeMedic were about one-third the ultimate values, indicating that the system could have resisted pressures as high as 750 psi.

The test results demonstrated that the liner-composite sections could withstand the applied pressure without leakage.

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