SOME THINGS YOU SHOULD NEVER SEE.

YOUR UNDERGROUND PROJECT IS ONE OF THOSE THINGS.

IT SHOULD BE A JOB DONE RIGHT THE FIRST TIME. DONE WHEN IT'S SUPPOSED TO BE. OUT OF SIGHT, PERFORMING LIKE IT OUGHT TO.

VISIT WWW.CHNIX.COM OR CALL 801-479-9000
FEATURED...

Three Phases
HDD and guided auger boring were employed in a three-part installation project in Boulder County, Colorado

Pilot Tube
There are three basic approaches to pilot tube installation, starting with precise installation of the pilot tube

Sliplining
More than 3,100 linear feet of Hobas FRPM pipe was used in a recent sewer renovation project in Denver

Also...

Message from the Chapter Chair 4
Message from NASTT 5
Board of Directors 6
Pipe Penetrating Radar: Developing Predictive Models 25
UV-Cured CIPP Lining 30
Horizontal Directional Drilling in Colorado 33
Regional Buyer’s Guide 39
NASTT Calendar: Upcoming Events 42
Index to Advertisers 43

COVER PHOTO: various sources
Welcome, everyone, to another issue of Rocky Mountain Trenchless Journal! I am excited for the future as we look back on another successful conference and begin the 2019 construction season.

As I reflect on the past several years while having the great privilege to serve on the board of directors for the North American Society for Trenchless Technology’s Rocky Mountain chapter, I begin to realize just how fast time flies and how quickly our industry moves. It seems our members, volunteers, and board members cannot seem to catch a breath. More projects are hitting the streets, and new and innovative approaches for new construction as well as rehabilitation are popping up into existence to meet the continuous demand. From top to bottom, the industry faces labor shortages combined with the challenge of training a new and evolving workforce.

Yet, as we fight our way through the fog, one cannot help but be grateful for the opportunities this country and our industry pose. As a good mentor once told me, “It’s a good problem to have too much work rather than not enough.”

Growth is happening for RMNASTT, too. We have added Nebraska, Kansas, North Dakota, and South Dakota to our territory. With the new additions, the chapter is reaching out to those new states for champions to spearhead local representation not only on the board but also for local chapter events and even possibly a regional conference or two down the road.

Our goal is to further education in trenchless technologies into areas where people have neglected or limited access. We strive for member and volunteer participation at both the local and national level with hopes we can make a difference.

It is not all work and no play, however. We have lots of fun as well! Clay shoots and field trips to active construction sites are a few of the things we do in addition to our annual regional conference. Please reach out to us if you are considering a desire to volunteer.

Please visit nastt.org/volunteer or contact any of the chapter board members through our website at www.rm nastt.org.

Lastly, as we go back to the explosion of work that awaits us all and look forward to the No-Dig Show (March 17-21 in Chicago, with the 2020 edition set for April 5-9 in Denver) and our next regional conference, I want to take a moment to thank a few people and organizations who help make a difference.

“Thank you” to Stephanie Nix, our chapter’s Treasurer. Stephanie, owner of Claude H. Nix Construction in Ogden, Utah, has been the glue of this organization, without whom we would all fall apart.

I am also grateful for the contributions of Benny Siljenberg, our Vice Chair. As VP of Lithos Engineering in Lakewood, Colorado, Benny takes RMNASTT, his business, and tunnels very seriously. Benny, I can’t thank you enough for covering for me all this time!

Swirvine Nyrienda, RMNASTT’s Secretary and 2018 Conference Chair, is also principal engineer at the City of Aurora. He is always on and provides incredible and intelligent insight to our group.

My thanks also go to the rest of our board of directors – you certainly know who you are – as well as PTR Communications, NASTT, and all of our volunteers.

Lastly, on behalf of the entire board of directors, I would like to thank you, the membership, and our great sponsors. Keep driving forward, be innovative and be excited! We live in great times and have great times ahead.

Chris Larson, Chair
NASTT Rocky Mountain Chapter
Hello, RMNASTT Members! As 2019 begins and progresses we’re looking forward to the continued growth of the trenchless industry and our Society. NASTT’s 2018 No-Dig Show in Palm Springs was very successful on all accounts. The exhibit hall featured close to 190 exhibitors and we welcomed over 2,000 attendees from all over the world, who came to experience the world-class technical sessions and networking events that our Show is known for. NASTT’s 17th annual Educational Fund Auction was, once again, the trenchless social event of the year and we raised nearly $100,000 for our educational programs. Thank you, all, for your generous support.

NASTT exists because of the dedication and support of our volunteers and our 11 regional chapters. Plans are now underway for the 2019 No-Dig Show at the Donald E. Stephens Convention Centre in metropolitan Chicago. It is an exciting time for the Rocky Mountain Chapter because Chapter member Joe Lane of Aegion is also serving as the 2019 Program Committee Vice Chair. This is a huge undertaking, and I know that Joe is up to the task!

Our No-Dig Show Program Committee members volunteer their time and industry knowledge to peer-review the 2019 abstracts. These committee members ensure that the technical presentations are up to the standards we are known for. Thank you to the Rocky Mountain Chapter members who have volunteered for this important task this year: Annalee Collins, Robin Dornfest, Chris Knott, Joe Lane, Jeff Maier, Jon Nix and Swirvine Nyirenda.

The North American Society for Trenchless Technology aims to provide innovative and beneficial initiatives to our members. To do that, we need involvement and feedback from our professional peers. If you are interested in more information, please visit our website at nastt.org/volunteer. There you can view our committees and learn more about these great ways to stay active with the trenchless community and have your voice heard.

Our continued growth relies on the grassroots involvement of our regional chapter advocates. Thank you again for your support and dedication to NASTT and the trenchless technology industry.
Chris Larson - Chair

Chris Larson is a vice president of C&L Water Solutions, Inc. out of Littleton, Colorado. He has been immersed in the trenchless field with particular focuses in sliplining, pipe bursting, UV CIPP, lateral rehabilitation, and manhole rehabilitation. He contributes to the advancement of quality-focused applications of trenchless technologies for unique and challenging project applications.

Benny Siljenberg - Co-Chair

Benny Siljenberg, P.E., MBA, is a founder and vice president of Lithos Engineering. His experience in both design and construction management allows him to understand what projects require from beginning to end. Benny’s career has focused on underground design and construction projects, primarily in Colorado, affording him an in-depth understanding of the different ground conditions around the state. Benny’s enthusiastic approach to his work brings energy to his project teams and accompanies his vast underground technical expertise. This unique combination proves to be a valuable resource on underground engineering and construction projects.

Stephanie Nix-Thomas - Treasurer

Stephanie Nix is president of Claude H. Nix Construction Co. in Ogden, Utah. Since 2002, the company has been committed to expanding the choices of underground utility owners for quality installations and rehabilitation of their pipelines. Her particular focus is in jack and bore (GBM, ABM, TBM), pipebursting, pipe ramming, and sliplining. She is committed to advancing trenchless technologies and believes that NASTT is one of the best educational resources.

Swirvine Nyirenda - Secretary

Swirvine Nyirenda is a Principal Engineer for the City of Aurora’s water department. In this capacity he is responsible for providing strategic planning and guidance to the utility in the areas of wastewater and storm water. With a background in the planning, designing, construction and evaluation of stormwater and waste water infrastructure, Nyirenda has a particular passion for the application of trenchless technologies as a viable solution to project challenges whenever appropriate. He is an active member of NASTT and strongly believes that the trenchless industry will continue to grow as NASTT facilitates its education and information exchange programs.
The City of Lafayette installed a new water line along Baseline and Arapahoe Road in Boulder County, Colorado. The new pipeline was constructed by open-cut and trenchless methods. Five trenchless crossings were necessary to cross critical infrastructure and features. Risk management was an objective in preparing the construction documents, which included a geotechnical data report, geotechnical baseline report and project-specific specifications. Areas along the alignment had narrow rights-of-way, heavy traffic, many utility crossings, ground surface constraints and variable soils creating unique installation challenges. These and other challenges led the design team to include directional drilling and guided auger boring as an integral part of the project.

The project consisted of developing a solution to improve distribution system resiliency and redundancy and providing capacity for a high-growth area in the eastern side of Lafayette. The City has an existing distribution system serving the east side, but a lot of it is aging asbestos concrete pipe and insufficiently sized for future demands.
Various alignments were considered with an initial study. An alignment along Baseline Road was decided even though there were various challenges with right-of-way width and obstructions. Trenchless construction techniques were a fundamental consideration as the design team was developing an alignment along a major arterial road. The project consisted of a 24- to 30-inch-diameter water line approximately 13,000 feet in length. Five trenchless crossings were necessary to cross critical infrastructure and features. The project was conducted in three phases, and construction was completed in July 2018.

Phase I included work in two separate sections: 1) along the south side of Baseline Road, east of the Orange Zone water tank and 2) crossing Indian Peaks Trail west and through Indian Peaks Golf Course. It included horizontal directional drilling (HDD) of approximately 600 LF of 24-inch HDPE under the golf course.

Phase II connected the sections from Phase I along Baseline Road and from the golf course east to State Highway 42 (95th Street) using open-cut and trenchless operations. Phase II consisted of a guided auger bore of approximately 100 LF of 48-inch steel casing under BNSF Railroad, an HDD of approximately 800 LF of 30-inch HDPE watermain, and a guided auger bore of approximately 120 LF of 30-inch steel casing pipe underneath 95th Street.

Phase III included 24-inch pipe installation from the intersection of 95th Street and State Highway 7 (Arapahoe Road) east one mile. It comprised open-cut methods and an 80-LF auger boring underneath Arapahoe Road with a 36-inch steel casing.

**GEOTECHNICAL CONDITIONS**

A geotechnical investigation was conducted to evaluate the subsurface conditions with respect to the construction of the pipeline. In addition, a geotechnical laboratory testing program was undertaken to assist in classification of soil and bedrock samples and assessment of applicable engineering properties of soil and bedrock. Twenty-three test borings were drilled, and temporary observation wells were installed in seven of the borings along the pipeline segments to permit the measurement of stabilized groundwater levels. Fill, fine and coarse alluvium, residuum and bedrock were encountered in the proposed areas of construction. The fill consisted of medium stiff to stiff sandy lean clay and lean clay. The fine alluvium comprised very soft to hard sandy lean clay, lean clay, fat clay and silty clay. Coarse alluvium encountered consisted of very loose to very dense well graded sand, poorly graded sand, clayey sand, poorly graded sand with clay, poorly graded sand with clay and gravel and silty sand. The Laramie Formation and Fox Hills Sandstone were composed of claystone, sandstone, and lignite.

The notable risk management strategies for the trenchless portions of the project included a geotechnical baseline report (GBR), a geotechnical data report (GDR) and project-specific specifications. A geotechnical engineering report was also created for the open-cut portions of the project.

A GBR establishes a baseline of geologic conditions to be encountered during construction. A well-defined, project-specific GBR can reduce time-consuming and costly litigation related to what constitutes a differing site condition. The GBR for this project was in general accordance with an ASCE document entitled “Geotechnical Baseline Reports for Underground Construction, Guideline and Practices” (2007). The GBR included groundwater inflows, ground behavior, cobbles and boulders, stickiness, tunnel lining, and shaft and tunnel construction recommendations.

Specifications carefully tailored to the project requirements and GBR are essential for successful project completion and risk management. The following specifications for trenchless applications were created for this project:

- Tunnel Excavation and Initial Support
- Horizontal Directional Drilling
• Shaft Excavation and Support
• Contact Grouting
• Tunnel Pipe Installation
• Geotechnical Instrumentation and Monitoring

**DESIGN CONSIDERATIONS**

Numerous existing utilities with heavy traffic areas complicated construction of the water line. Horizontal and vertical alignments were adjusted due to easements or the presence of atypical existing utility locations. The project team dealt with public relations regarding maintaining access for bikers, vehicles, businesses, homeowners, etc. Environmental concerns included drainage, observing animal behavior, and topsoil and vegetation conditions. Phase III of the project dealt with maintaining water services to businesses and residences with complicated shutdowns.

The specified boring methods were selected due to technical and cost considerations including the ground conditions. Guided auger boring was utilized for two of the trenchless crossings; the steerable method allowed for better control of the grade. HDD was applied for the golf course crossing and for the alignment south of Baseline Road due to easement constraints.

Very soft and very loose alluvium were encountered within the tunnel horizon for the BNSF crossing. In some instances, it was not possible to record a standard penetration value due to the sampler advancing under the weight of the hammer before any blows were applied. It is difficult to maintain grade when tunneling in soft ground; therefore, steerable methods were used in conjunction with the auger boring machine.

In the event of a carrier pipe rupture, the property owners, BNSF and Colorado Department of Transportation, required the tunneled sections of the carrier pipe to be encased to protect the property. The two-pass method was specified for three of the trenchless crossings. The two-pass installation involved jacking of a larger-diameter steel casing and later installing the carrier pipe within the casing pipe.

**CONSTRUCTION**

**Phase I – HDD Under Golf Course**

The crossing consisted of 24-inch HDPE DR17 pipe installed by HDD. The pilot hole followed the staked alignment except near the entry side due to curve/easement issues. Three reaming passes were completed. Spoils from the recycler consisted of silty sand, clay, and sand throughout the drilling operation. The exit pit was excavated in the “rough” of the golf course, which allowed the golf course to remain open during construction. Due to limited staging areas, two sections of pipe were placed along the temporary construction access road during pulling operations to be fused together mid-pull.

**Phase II – Guided Auger Boring Under Railroad**

Steerable auger boring methods consisting of a 48-inch guiding head was utilized to install the trenchless crossing under a railroad.

The project’s first phase included HDD under Indian Peaks Golf Course.
Observed ground conditions consisted of clayey sand, sandy lean clay, fat clay and weathered claystone. The bore was level with slight deviation along the horizontal alignment. The crossing underneath the railroad encountered two deep fiber optic lines ceasing tunneling activity. The crossing was supposed to be 111 LF with a 30-inch HDPE carrier pipe, but the carrier pipe was later changed to a 24-inch PVC for ease of installation in limited easement areas. The auger was destroyed by the 6-inch steel conduit near the proposed carrier pipe invert. The carrier pipe had to be raised to clear the utility. The carrier pipe was installed using redwood skids. The shortened bore led to the placement of the receiving shaft within BNSF right-of-way and extending the open-cut portion. The railroad was cooperative and approved these changes quickly.

Based on conventional locates, the design drawings showed utility crossings within the proximity of the BNSF crossing. The existence of the 6-inch steel conduit at 18 feet was not expected. Two lines at the same plan location is unusual and would not reasonably be expected in that area. Even with the unexpected conditions, the boring and carrier pipe were installed adequately for service.

Phase II – HDD with Limited Easements
The 30-inch HDPE installed with HDD methods south of Baseline Road dealt with several issues causing substantial time delays. Four reaming passes were completed. Excavation encountered mixed face of fill, alluvium and bedrock creating a difficult combination for HDD installation. Drill fluid was lost from the borehole and appeared at the ground surface (inadvertent drill fluid return) in a few locations requiring cleanup. Due to mechanical drill rig issues during pullback, a portion of the HDPE had to be removed and reinstalled.

Coupling the HDPE to the PVC was a challenge with this pipeline. For the 24-inch line, a butt-fused flange adapter was used on the HDPE and coupled directly to the restrained PVC. For the 30-inch-diameter, the development of the coupling was iterative and ended with the HDPE pipe being restrained with a 10 CY thrust wall and a restrained transition coupling between the PVC and HDPE. The thrust wall was designed to withstand over 60,000 lb. of longitudinal force caused by differential shrinkage due to temperature and pressure.

Phase II – Guided Auger Boring Under 95th Street
Guided auger boring methods were utilized, which consisted of an on-target guided steering system welded onto a piece of 30-inch steel casing. The alignment was shifted prior to excavation due to close proximity of the existing utilities. Soft material was present near the launching shaft, causing the machine to veer down and slightly left of centerline. By the end of excavation, the machine was positioned slightly left and high in relation to the design line and grade. Observed muck consisted of poorly graded sand, clayey sand, and weathered claystone. The receiving pit had several utilities, complicating excavation and pipe connections.
Phase III – Auger Boring Under Arapahoe Road

The tunnel consisted of a 24-inch-diameter PVC installed in a 36-inch-diameter steel casing. A 2-inch steel pipe was also installed on top of the steel casing to create opportunities for future utilities to cross the highway without additional boring. The geology of the site within the tunnel horizon was a mixed-face consisting of fine and coarse alluvium. The spoils from the tunneling operations consisted of sandy lean clay and clayey sand. Groundwater was not encountered during tunneling operations, creating stable ground conditions at the face of the auger boring machine. Thanks to stiff ground conditions, a small-diameter tunnel, and a short tunneling length, the trenchless crossing was completed with minimal deviations in line and grade, on time, and on budget.

CONCLUSIONS

There were numerous challenges associated with this project and several lessons learned. A conventional open-cut method was not an option for portions of this project. Trenchless methods were used due to limited easement areas, difficult roadway and railroad crossings, and the need to limit disturbance to surface features. To mitigate risks associated with the tunnels, a GBR and project-specific specifications were included in the bid documents.

Portions of the alignment encountered unmarked or unclaimed utilities during construction; therefore, before starting the fourth tunnel (95th Street), utilities were potholed and confirmed with the owners before boring commenced. Restrained joints for transitioning between pipe materials were included in the later phases based on the lessons learned in the earlier phases.

Throughout design, there was collaborative work environment between the owner and engineering team. Having the team collaborate during the construction phases allowed for value engineering, constructability reviews, and construction cost evaluation. Guided auger boring, auger boring and HDD allowed for successful installation of the water line. All phases of this project have been constructed and are fully operational.
2019 NASTT SPEAKEASY

EDUCATIONAL FUND AUCTION

NASTT'S 18TH ANNUAL EDUCATIONAL FUND SPEAKEASY AUCTION & RECEPTION

Join us in a Chicago Speakeasy! The Annual Educational Fund Auction helps raise money for very worthy causes. Since 2002, NASTT has raised nearly $1.1 Million and used those funds in support of our many educational initiatives. Due to your generosity, NASTT is able to provide targeted trenchless training courses to the industry, publish trenchless resources manuals and sponsor university students’ attendance at NASTT’s No-Dig Shows, as well as award scholarships.

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

HAWAIIAN VACATION RAFFLE
The winner of this raffle will receive a dream Hawaiian vacation, a $5,000 value! Tickets are $25 or five for $100 with a maximum of 1,000 tickets being sold.

COSTUME CONTEST
Show us your style! Speakeasy style that is! Come dressed in 1920s gangster or flapper attire at the auction's Eighth Annual Costume Contest! Prizes will be awarded- don’t miss out!

50/50 RAFFLE
A great way to win some cash for yourself and help out our student chapters! The winning ticket will be drawn immediately following the live auction and you must be present to win. The winner splits the cash pot with the students.

FOR MORE INFORMATION VISIT NASTT.ORG/NO-DIG-SHOW/AUCTION
Minimal community disruption, low equipment costs and pinpoint accuracy are the three most common reasons for using the Pilot Tube Method (PTM) of guided boring. But just as each project is unique, so too are the engineer’s or contractor’s reasons for selecting this method. PTM is practical in weak soils and at greater depths, contractors can effectively avoid existing utilities and install sanitary sewer lines below the water table. Those are all compelling reasons the method is being adopted by engineers and contractors alike.

The technique originated in Japan and Europe three decades ago as a way to install 4- and 6-inch gravity flow house connections. First introduced in the United States in 1995, it has steadily grown in popularity and expanded to widespread adoption for installation of gravity sewer mains.

Initial applications of the process in the U.S. were conservative, with a range of 4-inch- to 12-inch-diameter pipes with single drive lengths limited to 250 feet. After more than two decades of experience in the U.S., the technology is now used to install pipes of up to 48-inch outside diameter with common drive lengths ranging from 350 to 400 linear feet. Single drives of up to 580 LF have been completed successfully using PTM. Accuracy to within a quarter-inch in line and grade are frequently achieved on drive lengths of 500 linear feet. Improved optical guidance systems and hydraulics in the jacking frames have made larger diameters and longer drive lengths practical.

As popular as the method has become in some areas, there are still large parts of the country where the technique is a bit of a mystery.

THE METHOD EXPLAINED

There are effectively three approaches to pilot tube installation: the two-step method, the three-step method, and the modified three-step method utilizing a powered head. In all approaches, the first step is the same. The following steps are typically controlled by the final product pipe diameter, soil conditions and the tunnel contractor’s equipment.

The Pilot Tube Method relies on the guidance system, adopting the use of an
LED target, digital theodolite, monitor screen and a "real time," camera-based accurate guidance system (see Figures A and B). The video camera, mounted above the theodolite, transmits the image of the battery-powered LED-illuminated target located in the steering head to the monitor which is visible to the operator. The straight line indicated by the center of the target designates the direction and path the slant-faced steering head will follow.

Hollow steel pilot tubes which fasten to each other via a threaded hex connection are available as a double- or single-wall tube depending on the manufacturer. On some double-walled tube systems, the inner tube will rotate with the steering head during advancement for torque reduction. On other double-walled systems, a bentonite lubricant may be pumped through the annular cavity between the tubes to the steering head to assist with soil friction. These pilot tubes range in length from 30 inches to 2 meters, depending on size of jacking frame and shaft diameter.

A slant-faced steering head (similar to that of a directional drill) houses the LED-illuminated target. Steering heads of different degrees of angle are available for various types of ground conditions. During the installation process the ground is displaced by the steering head/pilot tube and directed on line and grade by rotation during advancement. Once Step 1 of the installation is complete, a survey can be performed on the pilot tube at the reception shaft to verify line and grade accuracy of the initial survey and setup. If a survey or setup error is found, the pilot tubes can be retracted and reinstalled to achieve the desired line and grade before proceeding to the second step of the installation.

**STEP ONE**

The first step in all the Pilot Tube installation methods is the precise installation of the pilot tube on line and grade. The hollow stem of the pilot tube provides an optical path for the theodolite to display the head position and steering orientation. This step establishes the center line of the new installation as the remaining step(s) will follow the path of the pilot tube.

Once Step 1 is complete, the theodolite and monitor guidance system may be removed from the jacking pit as they are no longer required.

**STEP TWO IN 3-STEP METHOD**

The second step (in the 3-step and 3-step modified methods) is to follow the path of the pilot tube with a reaming head, which is sized to the outside diameter of the final product pipe. The front of the reaming head fastens to the last pilot tube installed in the same manner the pilot tubes fasten to each other. Following the reaming head are auger casings of the same diameter as the head transporting the spoil to the jacking shaft for removal. The spoil can be removed by a
muck bucket or vacuum truck depending on the soil type and contractors’ preferences. This step is complete when the reamer and auger casings reach the reception shaft and all spoil is removed.

**STEP TWO IN 2-STEP METHOD**

The second step (the final step in the 2-step method) is to follow the path of the pilot tube with the reaming head advanced by the final product pipe. This reaming head funnels the excavated material into auger casings coupled together inside the product pipe and conveyed through to the jacking shaft for removal. These auger casings are then retracted from the inside of the carrier pipe via the jacking shaft. This method has an advantage to contractors as they are able to install multiple sizes of sewer lines while utilizing the same set of auger casings. The disadvantage to this 2-step system is the decreased diameter auger casings will limit the maximum diameter of excavatable cobbles and hardened material. When the 2-step method is utilized, the pipes are set into the jacking frame with the auger casings inside. The auger casings are attached to the reamer (if it is the first pipe to be installed) or previous casing for spoil transport. The product pipe carries the axial load required for advancement and is equal in diameter to the reamer.

Different types of reaming heads are available for a variety of displaceable soil conditions as well as heads capable of controlling
flow when working as much as 10 to possibly 15 feet below the water table (ultimately depending on the soil type). A swivel is required connecting the pilot tube to the reaming head when a rotating cutter head is used for harder ground.

STEP THREE

The third step (final step in the 3-step method) is to replace the auger casings with the final product pipe. The reaming head and auger casings are advanced into the reception shaft and removed as the product pipes are installed. There is no spoil to be removed in this step as the product pipe has the same outside diameter as the auger casings.

The third step (final step in the 3-step modified method) is to install a powered cutter or reaming head behind the auger casings, which is advanced by the product pipe. This method is the newest innovation to the Pilot Tube Methods. These hydraulically driven heads increase the bore to match the larger product pipe diameter. The excavated spoil around the previously installed auger casings is discharged via the reception shaft by reversing the auger direction. This step is complete when the powered cutter head reaches the reception shaft.

PIPE MATERIAL

For most installations, vitrified clay jacking pipe (VCP-J) is preferred because of its unmatched axial strength and lifecycle benefits. During the service life of the installation, the natural properties of VCP make it uniquely suited to the high-sulfur, highly abrasive and highly demanding environment of a sanitary sewer. VCP also provides expanded maintenance options allowing for much more aggressive cleaning techniques to provide a better long-term value to municipalities.

Contact the National Clay Pipe Institute at 262-742-2904 for educational presentations on the Pilot Tube Method and vitrified clay jacking pipe.
The cities of Omaha, Nebraska, and Portland, Oregon, have been employing the Pilot Tube Method (PTM) for over 10 years. Both cities come back to this method repeatedly, in part because of successful track records.

In Portland, Project Hemlock and Project Outfall 33 were completed in 2016. The Pilot Tube Method was chosen for Hemlock to allow for installation in a very tight right-of-way between residences. The need to relocalate overhead utilities if an open trench were created was also a factor for designers to consider. Nine hundred linear feet of 12-inch-diameter VCP was installed from one 9-foot shaft in three different drives. The first two drives created a straight-line installation down the alleyways, between the homes. The jacking frame was then turned at a 90-degree angle to the other two drives to tunnel under an existing garden that included 100-year-old rose bushes. In addition to preserving the highly prized garden, using the trenchless method allowed homeowners daily access to their homes and left the area utilities undisturbed.

Project Outfall 33 was in a heavily traveled downtown area that serves both vehicle and foot traffic. New sanitary sewer mains were recently installed in the dense urban area. PTM installation’s much smaller footprint meant much of the traffic could be maintained while the project progressed on roughly the same timetable that an open trench would have required. The weak soils in the area also meant an open trench would have compromised the integrity of streets and sidewalks. In weak soils, such as the soils generally found in the Portland area, PTM is one part of ensuring a safer workplace for installers.

The City of Omaha is in the midst of a sewer separation program; currently in its 12th year, the program has faced many challenges. The Pilot Tube Method has been critical to its progress. One of the consistent challenges the program faces is dealing with very weak soils.

Omaha’s Nicholas Street project involved installing nearly 5,000 linear feet of 24-inch-diameter VCP at a depth of 40 feet. In this case, the combination of weak soils and great depths meant this would have been a difficult project for most other installation methods. The ability to safely install sewer lines at these depths frequently enables designers to eliminate lift stations.
A 9-foot shaft made trenchless installation in this tight Portland alleyway practical.
In a recent major sewer renovation, Metro Wastewater Reclamation Districts in Denver used over 3,100 linear feet of 48-inch, 54-inch and 66-inch Hobas Centrifugally Cast FRPM pipes for renovation of PAR-1250 in downtown area. Sliplining was selected since the businesses and traffic, both foot and vehicle, would not allow setting up noisy bypass pumping and curing systems for CIPP rehab.

Albuquerque Underground Inc. (AUI) was the successful contractor, and with over 20 years of sewer rehab experience with Hobas pipes, the project was done on time and budget. The longest portion of the project was 2,097 LF of 66-inch CCFRPM that had to be pushed inside a 72-inch reinforced concrete pipe (RCP). Furthermore, 615 LF of 48-inch and 454 LF of 54-inch CCFRPM were used in two smaller reaches.

This paper will provide an overview of the project design, methods and materials selection, logistics and construction of deep shafts in a very congested urban business district in the heart of Denver. The combination of CIPP and slipline methods provided a cost-competitive, efficient and least disruptive option for this critical piece of wet infrastructure and could be used as an example for future projects. Denver continues to design several projects based on PAR-1250.

Denver Metro has used trenchless methods for years for renovating large-diameter sewers in the area. The first large-size pipe sliplining was for 1,600 LF of an above-ground influent brick-lined RCP line in the WWTP more than 10 years ago using Hobas CCFRPM product. This is probably the only above-ground slipline in North America as well. Following that project, several other agencies in the area also have used fiberglass pipes in their trenchless rehab projects successfully.

When the PAR-1250 project came up in the priority list, Denver Metro staff considered a variety of options to minimize impact on the busy downtown Denver area. It was decided that a combination of CIPP for the smaller sizes and sliplining for the larger diameters would be the best combination to minimize the cost and social impact in the business district. The interceptor also crosses under South Platte River (Cherry Creek), and bypass pumping to perform CIPP would require placing the HDPE pipes and lift pumps on and/or near the Millennial Bridge at 16th Street. This would essentially make the bridge unusable for traffic for about 4-5 weeks.

BIDS AND COST

The entire project was bid in September 2015 with an overall project low bid of $6,700,000 by Insituform. The scope of slipline with liner sizes of 2,097 LF of 66-inch, 454 LF of 54-inch and 615 LF 48-inch was $2,066,000. Albuquerque Underground Inc. (AUI) was awarded the contract in October 2015 and was able to mobilize immediately.

ALIGNMENT AND LOCATIONS

AUI had completed over 40 sliplining projects in its roughly 25-year history prior to this bid. The project managers were able to locate the access pits in the least complicated locations to allow for day time work as well as night time, if needed. The Delgany

Bijan Khamanian
Hobas Pipe

Michael Rocco
Albuquerque Underground Inc. (AUI)
Figure 1. Delgany Interceptor Along 16th Street

Figure 2. Multi Size Delgany Interceptor at Cherry Creek
Interceptor alignment along 16th Street (Figure 1) included all 66-inch FRPM within 72-inch host pipe. It was determined to have these done from two manholes, as there was a grade drop in the midpoint of the reach in a flow measuring manhole. Typically, the mid-point manhole would be removed and made into an access pit, but this was not an option at this location.

The second phase of the project posed the most difficult part of the installation along Delgany Street and across the Cherry Creek river, connecting the Cherry Creek Interceptor to Delgany Interceptors. Furthermore, the pipe size changed in midstream to 60-inch and then 54-inch RCP. The 58-inch Delgany Interceptor is running parallel to the 42-inch Delgany Common Interceptor right where the high-rise buildings are located. The construction of an access shaft had to be done without major vibration or noise, in compliance of the local ordinance and to avoid any claims from the local businesses and residential towers (Figure 3).

INTERCEPTOR CONDITION

It became apparent that the RCP was essentially at the last leg of its life. The cut and removed top sections of the pipe showed massive deterioration, along with missing reinforcements anywhere from 40 to 100%
(Figure 4). With number of buildings that were built already and a few others on the way, this created somewhat of an anxiety as the construction activities near this sort of infrastructure asset in the past has resulted in collapse of sewers.

SERVICE LIFE
As Denver and other urban areas are getting more and more congested, repair, rehab and replacement of assets are becoming more cost-prohibitive. The owners are looking for solutions that are able to provide service life beyond the 50 years of traditional pipe materials. One of the selection points for using fiberglass pipe is the long-term service life of such products. The ASTM D3262 Type 1, Liner 2 and Grade 3 fiberglass reinforced polymer mortar pipes are required to pass a long-term corrosion test per ASTM D3681 using 1N Sulfuric Acid in 10,000 hours. This simulates the septic conditions that exist in all collection systems. The requirements are for FRPM pipe to be able to handle 5% deflected conditions and offer a minimum 50-year service life under this strain corrosion testing.

As part of the specifications, the Denver Metro required products that exceed the above specifications, so the slipline pipe could be deflected no more than 2%. At this level of deflection, the liner would be rated to over hundreds of thousands of years of service, which was a desirable feature to have. Hobas testing shows that even at 8% deflection, the pipe would last 1,000 years.
SLIPLINING PROCESS

There was a substantial amount of flow in the system. When the sewer was exposed, it showed 60% full flows for the majority of daytime measurements. There were excessive amounts of solids and debris as well that extended the scope of cleaning. However, once that was accomplished, the flows dropped to less than 30% full (Figure 5).

AUI did not use a pull winch; instead, they opted to use the excavator as a jacking machine to lower the pipe and slipline in place. With clean host and relatively high flows, the buoyancy factor helped reduce the jacking loads so the actual sliplining of each reach finished within a 10-hour shift (Figure 6).

AUI was able to get assistance in engineering for the grouting process to make the pipe less buoyant and prevent flotation in the process. All pipes were grouted with correct mix and strength to provide a fully enclosed system.

CONCLUSION

Extensive experience on the part of the contractor and suppliers can be an asset in any project. Careful planning and having experienced project managers and field crew can make the project a success story under very difficult conditions. Denver Metro was able to take delivery of a brand new interceptor which ratepayers won’t have to spend any more money rehabilitating for at least 500 years.
Pipe Penetrating Radar: Developing Predictive Models for Effective Asset Management

Csaba Ékes, PhD, PGeo.
SewerVUE Technology Corp.

Pipe-penetrating radar (PPR) is the high-frequency application of ground-penetrating radar technology that is deployed from inside a pipe. PPR is an advanced pipeline condition assessment method for non-ferrous water and wastewater pipelines. Compared to qualitative inspection methods such as CCTV, PPR provides comprehensive, quantitative data. PPR measures wall corrosion and degradation, as well as rebar cover in reinforced concrete pipes. PPR can also detect voids developing outside the pipe.
This paper outlines the benefits of PPR as a condition assessment method and asset management tool. Two recent projects will be used to illustrate these benefits. The first project involves the deployment of PPR sensors on the newly designed Asbestos Cement Pipe Scanner (ACPS), surveying a length of 10-inch sewer main in Surrey, British Columbia, Canada. The second project was a PPR survey of a number of large-diameter pipelines in Melbourne, Australia.

OVERVIEW OF PPR

PPR is the use of high-frequency ground-penetrating radar (GPR) from the inside of a pipe (Figure 1). GPR systems transmit EM waves at different frequencies based on the desired outcome. Lower frequencies will achieve deeper subsurface penetration, while higher frequencies will not penetrate as far, but can create a higher resolution image. (Daniels, 2004) High resolution GPR antennas (2.6 GHz – 500 MHz) typically achieve 23 to 118 inches penetration.

PPR uses this technology to gather detailed data on the present condition of...
water and wastewater pipelines. By collecting GPR data from inside the pipe, PPR can provide information on remaining pipe wall thickness, rebar cover, or the presence and locations of voids developing on the outside of the pipe (Ékes et al., 2011).

PPR is presently deployed on either of two platforms: the Surveyor robot, or the ACPS. Where it is safe and feasible to do so, manned entry is an additional option. In the case of the Surveyor, two lines of PPR data are collected in one run, from any two clock positions between 9 o’clock and 3 o’clock. The Surveyor’s current PPR antennae transmit at 1.6 GHz or 2.3 GHz. This setup results in signal penetration of up to 36 inches, with accuracy to 0.3 inches. The robot also collects CCTV and LiDAR data to correlate with the PPR scans. The ACPS carries one or more PPR antennae and is used to inspect smaller-diameter pipelines (8 to 18 inches).

PPR data interpretation is a critical step if meaningful information is to be drawn from the survey. Proprietary software is used to apply different correction, filter, and gain functions to the PPR data. This processing enhances anomalies and allows for clearer interpretation of the results. Proper interpretation of PPR data is enhanced by the construction of a good three-dimensional display. Anomalies or points of interest are far easier to locate on a three-dimensional data set compared to a two-dimensional set. The final PPR data interpretation is superimposed over actual depth profiles versus distance.

To collect data for pipeline condition assessment, PPR sensors must be carried along the length of the pipe section that is to be surveyed, with the sensors remaining coupled to the walls for the duration of the survey. In very large-diameter pipes it is possible to collect PPR data via a man-entry operation. In smaller pipes, or in pipes where man-entry methods would be too unsafe, PPR sensors are mounted to one of two remotely operated vehicles: either the ACPS or the Surveyor.

The ACPS is a remote-operated vehicle used in AC pipes with diameters as small as 8 inches (Figure 2). The ACPS also features a CCTV camera, for visual correlation with the PPR results. The Surveyor is a tracked ROV. It is the first commercially available multi-sensor inspection robot to use both visual and quantitative technologies in underground pipeline condition assessment. It can be adjusted to scan pipes with diameters between 21 and 60 inches. In addition to

Figure 3. ACPS on-site in Surrey, B.C.
carrying two PPR sensors, the Surveyor also carries LiDAR and a CCTV camera that collects visuals for correlation with the sensor data.

**ASBESTOS CEMENT PIPE SCANNER**

Much of North America’s water and wastewater infrastructure exists in the form of asbestos cement (AC) pipes. Between 1940 and 1970, more than 600,000 miles of AC pipe was laid in North American municipalities. Data has shown that AC pipe has a lifetime of 60-70 years on average. As a result, tens of thousands of miles of AC pipe in North America is nearing the end of their expected life (Hu et al., 2013).

With such a large volume of AC pipe nearing the end of their useful life, predictive asset management becomes essential for municipalities. Waiting for catastrophic failure is neither desirable nor economical. Such failures can cause service disruption and environmental damage, and can be extremely costly to fix. However, replacing pipes too early is an inefficient use of resources.

AC pipes are vulnerable to deterioration by acidic, sulphate, and microbiological attack. They can also suffer deterioration due to corrosive groundwater. Traditional inspection methods such as CCTV cannot detect the presence of groundwater corrosion. To address this, more comprehensive measurements are required. The ACPS was developed with this challenge in mind.

The Harbourgreene line in Surrey, B.C., is an AC pipe that was installed in 1972. Currently there are no known corrosion issues; the initial inspection will serve as a baseline. The pipe is inspected regularly using traditional CCTV. The City has partnered with SewerVUE Technology to conduct a high-frequency PPR survey to inspect sections of the Harbourgreene Line in order to obtain structural condition information (Figure 3). This project’s PPR survey was completed using high-frequency antennae while the pipe remained in service. Two-dimensional line data were collected on the invert of the pipe. The high antenna frequency provided good quality data and signal penetration to allow analysis to a depth of 12 inches from the inside pipe wall surface. In Phase 1 of the project, 196.9 feet of PPR data were collected from the Harbourgreene line with supplementary CCTV.

Wall thickness was interpreted to be in the 1.77-inch range with little variation over the inspected length. Interpreted results at
the end of Phase 1 concluded no significant structural issues on the inspected sections of the pipe.

**4TH-GENERATION SURVEYOR**

PPR can be used to gather quantitative data from any pipe made of non-ferrous material (concrete, RCP, AC, RP, PVC, HDPE, brick, etc.). In this case study, PPR was used to inspect a number of pipelines in Melbourne, Australia. Four lines were surveyed, with CCTV, LiDAR, and PPR data being collected. The Surveyor robot was deployed for this project (Figure 4). The utility owner had very little knowledge about the construction or current condition of these pipes.

A 4,255.3-foot section of the Mordialloc Main Sewer was inspected first. This section was reinforced concrete pipe, with a diameter of 30 inches. Access was from a single deployment point near the middle of the surveyed section. CCTV footage showed widespread surface damage that was consistent with chemical attack on the inner surfaces of the pipe wall. A small hole was located 109.6 feet downstream from the access point. Some circumferential fracturing was also seen 136.2 feet downstream. LiDAR results showed a small but consistent degree of deformation along the crown of the pipe. PPR data revealed average rebar cover in the line to be between 1.38 and 2.36 inches.

A section of the Hobsons Bay Main 24-inch line was surveyed next. From one access point, 1,876.6 feet was inspected in the upstream direction. The survey began 45.3 feet from the access point, where the RCP section of the pipe started. This pipe also showed damage that appeared to be the result of chemical attack. PPR data showed the areas with thinner rebar cover, however rebar cover always exceeded 0.59 inches.

The Caulfield Intercepting Sewer is a 37.5-inch RCP line. The survey inspected a 3,920.6-foot section, using a single access point near the centre of the section. Generally, the survey showed the line to be in good condition. The most significant discovery from the inspection was a section where the pipe increased in diameter to 43.3 inches, which was unknown to the utility owner. PPR data revealed an area 262.5 feet downstream of the deployment site where the rebar was quite close to the pipe wall.

The Maribyrnong Main Sewer was the final inspected line. This line was built from RCP, and had a diameter of 29.9 inches. Two different sections of the line were inspected, in each case using an access point near the middle of the section. The inner pipe walls were covered in attached deposits, and the invert of the pipe had frequent patches of gravel and other sediment. CCTV footage from the survey showed significant surface damage, with sections of visible reinforcement. Much of the pipe wall was not visible due to the attached deposits. The PPR data from this section showed little rebar cover along the whole length of the survey.

**SUMMARY AND CONCLUSION**

Examples from the two projects outlined in this paper demonstrate the benefits of PPR in condition assessment projects. The nature of PPR data allows for the creation of accurate predictive models about the remaining useful life of pipes. This is especially true when PPR is supplemented with data from other condition assessment techniques, such as CCTV or LiDAR.

Data gathered from the ACPS survey in Surrey demonstrates that PPR is very useful in the assessment of small-diameter AC pipes. PPR has already been shown to be effective at surveying larger AC pipes, but this survey demonstrated that the technology could be adapted for smaller pipes, which represent a significant portion of the decaying AC pipe infrastructure in North America.

Information collected from the four sewer lines in Melbourne is a prime example of PPR as an effective asset management tool. In these cases, the utility owner had very little information about the current condition of the lines. Following the PPR survey, they could make informed decisions about which of the lines needed immediate attention, and which lines could afford to have maintenance deferred to a later date.

PPR is an invaluable tool for assessing the current condition of non-ferrous pipelines. Supplemented with data from other survey methods such as LiDAR and CCTV, PPR can be used to generate comprehensive data about the current conditions of pipe. This information forms a strong basis for creation of accurate predictive models that allow utility owners to make efficient asset management plans. The cost of a PPR survey pales in comparison to the costs that could be incurred if a line suffers catastrophic failure, or if a serviceable line is replaced too soon. Funding is often limited, so cost-effective asset management methods are essential for municipalities and other owners of underground pipeline infrastructure.

**REFERENCES**

UV-Cured CIPP Lining –
The Future of Pipeline Rehabiliation is Bright

Jeff Maier
C&L Water Solutions, Inc.

Cured-in-place pipe (CIPP) lining is one of the most commonly utilized trenchless methods for the rehabilitation of sewer and storm water pipelines. With the invention of CIPP lining in 1971, a methodology to repair existing pipeline infrastructure with minimal disruption was realized, providing a new fully structural pipe within a pipe at a fraction of the time and cost of typical open-cut excavation and replacement.

CIPP liner systems consist of a resin-saturated carrier tube, either unreinforced felt or reinforced fiberglass, impregnated in most cases with polyester or vinyl ester resins. Liners are inverted or winched into place within a host pipe and cured using thermal (steam or hot water) or ultraviolet light (UV) methods. Continued refinements to the resin systems, liner manufacturing and installation processes have allowed CIPP lining to become one of the most versatile and proven pipeline rehabilitation technologies available. The emergence of UV-cured lining, in particular, is a good example of how the CIPP lining process has improved and continues to evolve as a technology.

The development of UV-cured CIPP lining has brought forth many benefits and advantages, providing owners with a high-quality lining system that addresses specific needs such as infiltration control, stringent QA/QC requirements and improved structural strengths, while incorporating sustainable and environmentally responsible manufacturing and installation processes.

Compared to traditional felt CIPP lining, UV-cured CIPP offers a higher-strength, fiberglass-reinforced lining system that is cured using UV light rather than using steam or boiling water. The polymerization process is photo-initiated using light energy rather than thermally initiated. It features an impermeable outer membrane that serves to both contain the styrenated resins as well as prevent outside ground water from adversely affecting the curing process, with the resins protected from emulsification and dilution issues. UV-cured CIPP lining, due to its reinforced fiberglass-and-resin composite construction, allows for significantly thinner liner design thicknesses to be utilized, providing improved flow characteristics and less inner-diameter constriction of the pipeline compared to traditional felt lining systems.

The design approach for CIPP, both UV and felt lining, utilizes criteria described in ASTM F1216, which provides well-defined structural design methodology based on a number of factors including liner material properties, installation depths, groundwater levels, soil conditions and consideration of live loads. Because of the reinforcement matrix used within the UV-CIPP carrier tube, less shrinkage is realized compared to unreinforced CIPP materials, which provides a tighter fit to the host pipe and reduced water jacketing effects. By design, CIPP lin-
UV-cured CIPP lining offers many benefits and advantages.
thermal liner cure that uses steam or hot water methods.

When the liner is positioned within the pipe, the liner is inflated using air pressure and then a train apparatus carrying the UV light system is inserted. Prior to curing, a pre-inspection video is taken using an integrated CCTV camera located on the front of the UV light train to ensure that the liner is positioned properly and that there are no issues. This extra inspection step, prior to turning on the UV lights, provides a distinct quality control advantage compared to other lining methods, and results in fewer wrinkles, fins or other potential defects.

Once started, curing typically takes a fraction of the time of required for steam and hot water methods, and provides a highly accurate and consistent final lining product that is documented throughout the process. Thermal sensors on the light train monitor the curing process and detect any heat sinks that may require additional energy to ensure proper cure, and through this computer-controlled process, the UV light train speeds up or slows down accordingly. Once completed, there is no cooling-down period or concerns related to disposal or treatment of styrene-contaminated curing water, which is a common issue with curing via steam or hot water.

Over the past decade, UV-cured CIPP production and installation has more than doubled in the North American market. Within the Rocky Mountain region, UV-cured CIPP lining has become a preferred solution for rehabilitation of sanitary and storm sewer pipelines where infiltration and wet pipe conditions are prevalent, and when higher-strength liner solutions are required. Because the styrenated resins are contained within the protective outer bladder layer, the lining system provides a viable alternative in environmentally sensitive areas and where styrene odors need to be minimized.

Although glass-reinforced liner material production costs are somewhat higher compared to unreinforced felt liners, efficiencies realized during the installation process and shorter cure times can result in cost savings, often allowing UV-cured CIPP to be directly competitive with traditional CIPP liner systems.

As this technology becomes more readily available throughout North America, an increasing number of utility owners are taking notice. With more qualified contractors now offering UV-cured CIPP lining as an option, and more liners being produced in North America instead of being shipped over from Europe, pricing and availability continue to improve. The future is bright for UV-cured CIPP lining, with significant growth and increased presence in the pipeline rehabilitation market projected to continue.
As the population and infrastructure needs of the Colorado Front Range urban corridor rapidly grow, horizontal directional drilling (HDD) continues to expand as a trusted method to install pressurized underground utilities. Numerous HDD projects are completed with little to no design and construction planning, placing significant risk on the Owner. Varying opinions regarding the thoroughness of HDD design, quantifying and analyzing HDD project risk exist, specifically for installations of smaller diameter (smaller than 8-in) and shorter length (low hundreds of feet). It should be noted, the four projects presented had, in the opinion of the author, an appropriate level of care relative to industry standard throughout design and construction. As the rate and number of HDD installations continues to rise, so should the Engineers’, Owners’, and Contractors’ knowledge and ability to deliver HDD projects. This article will focus on four recent case studies of HDD installations across Colorado (Table 1).

Various engineering, contracting, and installation alternatives and techniques were utilized to successfully complete the four crossings. Lessons learned during design, bidding, and construction of these four projects are specifically from the trenchless Engineers’ perspective and are intended to further the HDD engineering practice. An appropriate subsurface investigation, HDD design, collaboration and communication between the Owner, Engineer, and Contractor during design and construction are cornerstones to delivering a successful HDD project. The following is not intended to thoroughly guide the design or construction process or present a compressive list of conceivable issues on similar projects, but rather introduce and discuss several intricacies encountered that could benefit future HDD project teams.

<table>
<thead>
<tr>
<th>Location (Colorado)</th>
<th>Utility</th>
<th>Crossing</th>
<th>Diameter (in.)</th>
<th>HDD Length(^1) (ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crook</td>
<td>Water</td>
<td>Interstate 76</td>
<td>24</td>
<td>430</td>
</tr>
<tr>
<td>Fort Collins</td>
<td>Water</td>
<td>Irrigation Ditch</td>
<td>8</td>
<td>240</td>
</tr>
<tr>
<td>Loveland</td>
<td>Water</td>
<td>Highway 34 and Existing Utilities</td>
<td>20</td>
<td>790</td>
</tr>
<tr>
<td>Chatfield State Park</td>
<td>Water</td>
<td>Plum Creek</td>
<td>16</td>
<td>2,440</td>
</tr>
</tbody>
</table>

\(^1\) Horizontal carrier pipe plan length, not actual HDD drilling length

Table 1. Case History Summary
SUBSURFACE INVESTIGATION

An appropriate subsurface investigation should be completed for all HDD projects with project constraints that have a risk of inadvertent fluid returns (IFR) – a.k.a. “frac-out” – overstressing the HDD-installed pipe, or if other damage to existing infrastructure exists.

The four projects all incorporated a minimum of two geotechnical borings near the crossing extents where exploration access was relatively easy. Central borings were drilled on the Loveland and Chatfield State Park projects based on site access, alignment length, and pipe diameter. The criticality and spacing of central boring(s) were discussed with the project team, including Contractors experienced with HDD installations. The risk of variable subsurface conditions relative to successful project completion can necessitate a central borings. Boring offsets from the constructed alignment is critical to reducing the risk of IFR through a backfilled geotechnical boring; in general, we recommend a minimum offset of 50 feet from the proposed alignment for geotechnical borings.

During the Chatfield State Park project, a previous subsurface investigation for a parallel utility conducted a geotechnical boring near the centerline of the original HDD alignment, but was not abandoned in a manner to prevent IFR, for example with grout. To avoid the risk of an IFR through the existing, un-grouted borehole into an environmentally sensitive area, a compound curve was incorporated into the HDD alignment as shown in Figure 1.

Available options exist for when and how to complete the subsurface investigation during a projects lifespan. For the projects completed in Crook and Loveland, the design team recognized the likelihood of an HDD installation early in the project and investigations were completed prior to bidding construction. Owners of these projects recognized the benefit of design dollars being spent to accurately characterize materials along the proposed alignments. The Owner for the Fort Collins project identified existing, recent geotechnical data from an auxiliary project along the same alignment as the HDD, offset by approximately 50 feet. The Engineer and Owner were comfortable performing calculations based on the existing geotechnical data due to the thoroughness of collected data, subsurface conditions identified, scope of the HDD installation, and risk of IFR versus project cost and schedule. Bid documents for the Chatfield State Park project required the Contractor perform a unique subsurface investigation for the HDD alignment in tandem with design calculations for pipe stress and IFR. In all scenarios other than the Fort Collins project, the trenchless Engineer performing design calculations also
conducted the geotechnical investigation.

Ultimately, HDD projects benefit from subsurface investigations completed by geotechnical firms knowledgeable in HDD design and construction. While this is not always selected by the Owner, the subsurface investigation completed for the HDD should consider boring spacing, sampling intervals, an appropriate laboratory testing program, and boring logs detailed enough for pipe stress and IFR calculations to appropriately analyze construction related risk. As project schedules allow, the Owner could consider shifting design dollars and requiring the HDD contractor to complete a supplemental geotechnical investigation specifically for the HDD alignment if project delivery requires HDD design by the Contractor. Trenchless Engineers should not hesitate to request and search for existing geotechnical information from near the proposed site prior to planning and executing a subsurface investigation program.

**HDD DESIGN**

Although fairly typical in pipeline design drawings, an HDD design is not a simple “HDD Installation” note between two points on an engineering plan set. Rather, two major design categories commonly exist for HDD projects: risk of inadvertent fluid return (IFR) and pipe stress. To complete a thorough analysis of an HDD drill path the Engineer should have and/or consider:

- **Accurate survey along the centerline of the proposed HDD alignment**
- **Understanding of drilling equipment and materials and steps required to complete the installation**
- **Pothole data of existing utilities to be crossed**
- **Understanding of subsurface conditions relative to HDD construction.**

HDD designs are commonly an iterative process between a selected drill path geometry and IFR calculations. If a selected drill path is not deep enough beneath a ditch, for example, the profile must be extended deeper, increasing cover and effective stress in turn reducing IFR risk. Drill path geometry must account for limitations in selected equipment and Contractor preferences. As an example, drill rigs have specific range of entry angle ranges and different pipe types and thicknesses accommodate different allowable bending radii. Normalized drill path geometries for the four highlighted projected are shown in Figure 2.

Topography, pipe size and specifications, and subsurface conditions all contributed to the development of the drill path profiles in Figure 2. We encourage the HDD designer to understand the project and
Contractor developed constraints before initiating profile development. After constraints are vetted, the profile can be qualified through design calculations as discussed. The project completed near Crook incorporated an extension of the drill path profile away from the I-76 right-of-way in order to achieve the minimum determined cover under the roadway surface and sufficient equipment layout on the entry side of the alignment. The project completed in Fort Collins was essentially a “belly shot” incorporating minimal straight-line entry, bottom, and exit segments in order to achieve the necessary cover under the irrigation ditch and fit the alignment within a relatively short distance.

Design calculations are commonly deferred to the Contractor and/or Contractor-selected trenchless Engineer due to the lack of the ability of the project Engineer to complete the specialty work, the significance of constructability, and limitations and specifics of Contractor-selected drilling equipment. The projects completed in Crook and Chatfield State Park deferred HDD design to the Contractor and provided entry and exit locations for the HDD alignments. Contrary to typical HDD design delivery, the projects completed in Fort
Collins and Loveland were designed by the trenchless Engineer prior to bidding the project. Design assumptions were confirmed by the selected Contractors upon being awarded the project.

**CONSTRUCTION**

Equipment and pipe string layout, drilling fluid management, site coordination, and construction observation are several considerations in constructing a successful HDD project.

Equipment and pipe string layout and coordination with other site activities are best initially considered during design to prevent constructability issues. Tie-in locations on either end of the alignment should consider both timing, depth, and Contractor coordination. While equipment traffic for HDD installations is relatively minimal, site coordination should allow and consider some back and forth movement between entry and exit locations.

Even on HDD projects with significant design effort, IFRs are still a risk due to uncertainty in subsurface conditions, variability in installation techniques, etc. The Contractor should be prepared to deal with an IFR; immediate identification and action are keys to successfully managing an IFR.

The project completed in Loveland, had multiple IFRs during the pilot bore, reaming, and final product pipe pull in as shown in Figure 3. Immediate action was taken to contain lost drilling fluids within straw waddles, and a vac truck was required in the

---

Figure 4. Walkover Tracking System Across Highway 34 in Loveland
as those outlined in the preceding sections, the following considerations are recommended to help achieve a successful HDD installation:

• Thorough, specific subsurface investigation by a qualified Engineer experienced in HDD design or input from the Trenchless Engineer on the scope of the geotechnical investigation and laboratory testing.

• Site specific design calculations confirming drilling fluid and pipe stress factor-of-safeties for the selected drill path considering the selected HDD Contractor’s construction related preferences.

• An HDD specification in the Contract Documents requiring the appropriate amount of care based on the scope and risk of the subject project.

• Consideration and discussion of HDD specific construction components during the entire project lifespan.

• Although not unique to HDD installations: consistent and effective communication with all effected project team members including at least the Owner, Trenchless Engineer, and HDD Contractor.

In our experience, HDD Contractors are willing to discuss a specific proposed installation even prior to being awarded the project. Several unique and somewhat complicated steps are necessary for HDD installations, and an understanding by the trenchless engineer of those steps and how they can affect the design and construction is important to ensure successful project delivery. Ultimately, the level of care and effort on HDD installations should be weighed based on project complexity and Owner acceptable risk and it is the Engineer’s and selected HDD Contractor’s duty to help the Owner in understanding and quantifying those risks.
## By Category

### Auger Boring
- BTrenchless
- Claude H. Nix Construction Co.
- Horizontal Boring & Tunneling Co.
- Kilduff Underground Engineering, Inc.

### CIPP Tube
- C & L Water Solutions, Inc.

### Construction Management
- Kilduff Underground Engineering, Inc.

### Engineering Design
- Kilduff Underground Engineering, Inc.
- Lithos Engineering

### Geotechnical
- Kilduff Underground Engineering, Inc.

### Grouting
- C & L Water Solutions, Inc.
- Claude H. Nix Construction Co.
- Lithos Engineering

### Guided Boring/Pilot Tube
- Akkerman Inc.

### Horizontal Directional Drilling
- Claude H. Nix Construction Co.
- Horizontal Boring & Tunneling Co.
- Kilduff Underground Engineering, Inc.

### Hydro Excavation
- Claude H. Nix Construction Co.
- Pro-Pipe

### Inspection & Evaluation
- Claude H. Nix Construction Co.
- Pro-Pipe

### Joint Repair
- Claude H. Nix Construction Co.

### Lateral Rehabilitation
- C & L Water Solutions, Inc.
- Claude H. Nix Construction Co.
- Pro-Pipe

### Manhole Rehabilitation
- AP/M Permaform
- C & L Water Solutions, Inc.
- Sunbelt Rentals

### Microtunneling Services
- BTrenchless
- Kilduff Underground Engineering, Inc.

### Microtunneling Systems & Equipment
- Akkerman Inc.
- Kilduff Underground Engineering, Inc.

### Pipe
- Claude H. Nix Construction Co.
- Underground Solutions

### Pipe Bursting & Splitting
- Claude H. Nix Construction Co.
- TT Technologies

### Pipe Cleaning
- Claude H. Nix Construction Co.
- Doetsch Environmental Services, Inc.
- Pro-Pipe

### Pipe Jacking
- Akkerman Inc.
- BTrenchless
- Claude H. Nix Construction Co.
- Horizontal Boring & Tunneling Co.
- Kilduff Underground Engineering, Inc.

### Pipe Ramming
- BTrenchless
- Claude H. Nix Construction Co.
- Horizontal Boring & Tunneling Co.
- Kilduff Underground Engineering, Inc.

### Pipe Relining
- AP/M Permaform
- Claude H. Nix Construction Co.
- Sunbelt Rentals

### Pipe, Valves & Fittings
- RepMasters, Inc.

### Sewer Rehabilitation
- AP/M Permaform
- Claude H. Nix Construction Co.
- IPEX USA LLC
- Kilduff Underground Engineering, Inc.
- Pro-Pipe
- Sunbelt Rentals

### Slippining
- Akkerman, Inc.
- BTrenchless
- Claude H. Nix Construction Co.

### Soil Stabilization
- Kilduff Underground Engineering, Inc.

### Spot/Point Repair
- Claude H. Nix Construction Co.
- Pro-Pipe

### Trenching
- BTrenchless
- Kilduff Underground Engineering, Inc.
- Sunbelt Rentals

### Tunnel – Large Diameter
- BTrenchless
- Claude H. Nix Construction Co.
- Horizontal Boring & Tunneling Co.
- Kilduff Underground Engineering, Inc.
- Lithos Engineering

### Tunnel Boring Equipment
- Akkerman Inc.
- Kilduff Underground Engineering, Inc.

### Utility Locating
- Claude H. Nix Construction Co.
- Kilduff Underground Engineering, Inc.
- Pro-Pipe

### Vacuum Excavating
- BTrenchless
- Claude H. Nix Construction Co.
- Pro-Pipe

### Video Inspection
- Claude H. Nix Construction Co.
- Pro-Pipe
**Horizontal Boring & Tunneling Co.**
505 S River Ave., PO Box 429, Exeter, NE 68351
www.hbttrenchless.com
Contact: Brent Moore
horizontalboring@hbttrenchless.com
402-266-5347

Horizontal Boring & Tunneling Co. is a progressive company with over 35 years of experience that specializes in various methods of trenchless construction.

---

**IPEX USA LLC**
10100 Rodney Street, Pineville, NC 28134
www.ipexna.com
Contact: Rob Hershman
rob.hershman@ipexamericacom
812-319-6098

NovaForm PVC Liner for Sanitary Sewer and Storm Pipe Trenchless Rehabilitation.

---

**Claude H. Nix Construction Co.**
1893 E. Skyline Dr. #203, Ogden, UT 84403
www.chnix.com
Contact: Stephanie Nix-Thomas
801-479-9000

Precision. Underground.

---

**Kilduff Underground Engineering, Inc.**
535 16th Street, Suite 620, Denver, CO 80202
www.kilduffunderground.com
Contact: Todd Kilduff
tkilduff@kilduffunderground.com
303-732-3692

KUE is a geotechnical design firm specializing in underground design.

---

**Doetsch Environmental Services, Inc.**
21221 Mullin Avenue, Warren, MI 48089
www.doetschenv.com
Contact: Joe Schotthoefer
joe@doetschenv.com
586-755-2090

Over a century of sewer cleaning experience, offering solutions for large-diameter, long-reach, difficult-access and impossible cleaning tasks. Download our free app!

---

**Akkerman Inc.**
58256 266th Street, Brownsdale, MN 55918
www.akkerman.com
Contact: Chris Sivesind
csivesind@akkerman.com
800-533-0386

Manufacturer of Guided Boring, Microtunneling, Pipe Jacking, Sliplining and Tunneling systems for 4-in. to 14-ft. pipe diameters and a wide range of ground conditions.

---

**C & L Water Solutions, Inc.**
12249 Mead Way, Littleton, CO 80125
www.clwsi.com
Contact: Tracy Stenger
tracye@clwsi.com
303-791-2521

C & L is a Colorado- and Utah-based contractor specializing in trenchless technology to provide the best solution for the client’s trenchless needs.

---

**AP/M PERMAFORM**
PO Box 555, Johnston, IA 50131
www.permaform.net
Contact: Linda Keaııns
lkeaııns@permamıform.net
800-662-6465

AP/M Permaform’s CentriPipe® and Permacast® enable trenchless repair of manholes, pipe and underground structures. CONmicSHIELD® prevents MIC in sanitary sewers.

---

**B Trenchless**
9855 Emporia St., Henderson, CO 80640
www.btrenchless.com
Contact: Chris Knott / Dave Emm
chris.knott@btrenchless.com or dave.emm@btrenchless.com
303-286-0202

BTrenchless capabilities include auger bores, pipe ramming, sliplining, pipebursting, pipe jacking - tunnel boring machine (TBM) and microtunnels (MTBM).

---

**By Company Name**
Lithos Engineering
Lakewood and Fort Collins, CO
www.LithosEng.com
Contact: Benny Stijljenberg, PE
Benny@LithosEng.com
720-316-3079
Lithos’ trenchless experience for new installations will reduce your risk on underground construction projects while offering innovative solutions.

Pro-Pipe
11750 Depew Court, Broomfield, CO 80020
www.pro-pipe.com
Contact: Steve Jeziorski
steven.jeziorski@pro-pipe.com
303-515-0106
Pro-Pipe provides: Panorama: 360 Digital Scanning, 2D/3D LIDAR/Sonar Profiling, CCTV, Pipeline Cleaning, Rehabilitation of Mains/Laterals, Cross Bore Prevention and GIS Data Integration.

RepMasters, Inc.
1400 East 69th Ave., Denver, CO 80229
www.repmasters.com
Contact: Jon Davis
jdavis@repmasters.com
702-490-2734
Representing the high quality products in Waterworks/Utility & Underground Supply in the Rocky Mountain Region for the past 30 years.

Sunbelt Rentals
2341 Deerfield Drive, Fort Mill, SC 29715
www.sunbeltrentals.com
Contact: Mary Catherine Perryman
mc.perryman@sunbeltrentals.com
803-578-6672
Sunbelt Rentals is one of the largest equipment rental companies in North America with a network of more than 800 locations.

TT Technologies
2020 East New York St., Aurora, IL 60502
www.tttechnologies.com
info@tttechnologies.com
1-800-533-2078
Worldwide leader in trenchless tools and equipment, with over 50 years of service and support behind every tool.

Underground Solutions Inc.
1315 Danielson St., Suite 201, Poway, CA 92064
www.undergroundsolutions.com
Contact: Bo Botteicher
bbotteicher@aegion.com
724-353-3000
Underground Solutions, Inc. provides infrastructure technologies for water, sewer and conduit applications. UGST’s Fusible PVC® pipe products, as well as ServiceGuard® Composite Pipe and TerraBrite® CR pipe, represent the most innovative approach to pipeline installation and rehabilitation in the past decade.
<table>
<thead>
<tr>
<th>Date</th>
<th>Event Description</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>March 17, 2019</td>
<td>NASTT's Introduction to Trenchless Technology – Rehabilitation</td>
<td>Donald E. Stephens Convention Center, Chicago, Illinois</td>
</tr>
<tr>
<td>March 17, 2019</td>
<td>NASTT's Introduction to Trenchless Technology – New Installations</td>
<td>Donald E. Stephens Convention Center, Chicago, Illinois</td>
</tr>
<tr>
<td>March 17, 2019</td>
<td>NASTT's Grouting Good Practices Course</td>
<td>Donald E. Stephens Convention Center, Chicago, Illinois</td>
</tr>
<tr>
<td>March 17-21, 2019</td>
<td>NASTT’s 2019 No-Dig Show</td>
<td>Donald E. Stephens Convention Center, Chicago, Illinois</td>
</tr>
<tr>
<td>March 20, 2019</td>
<td>NASTT’s Gas Good Practices Course</td>
<td>Donald E. Stephens Convention Center, Chicago, Illinois</td>
</tr>
<tr>
<td>March 20-21, 2019</td>
<td>NASTT’s Pipe Bursting Good Practices Course</td>
<td>Donald E. Stephens Convention Center, Chicago, Illinois</td>
</tr>
<tr>
<td>March 20-21, 2019</td>
<td>NASTT’s New Installation Methods Good Practices Course</td>
<td>Donald E. Stephens Convention Center, Chicago, Illinois</td>
</tr>
<tr>
<td>March 20-21, 2019</td>
<td>NASTT’s CIPP Good Practices Course</td>
<td>Donald E. Stephens Convention Center, Chicago, Illinois</td>
</tr>
<tr>
<td>May 6-8, 2019</td>
<td>2019 Trenchless Technology Road Show</td>
<td>Vancouver, Canada</td>
</tr>
<tr>
<td>June 6-12, 2019</td>
<td>AWWA ACE19</td>
<td>Denver, Colorado</td>
</tr>
<tr>
<td>September 26, 2019</td>
<td>World Trenchless Day</td>
<td>Information: worldtrenchlessday.org</td>
</tr>
<tr>
<td>October 28-30, 2019</td>
<td>No-Dig North 2019</td>
<td>Telus Convention Centre, Calgary, Canada</td>
</tr>
</tbody>
</table>

For more information and the latest course offerings, visit [nastt.org/training/events](http://nastt.org/training/events)
## INDEX TO ADVERTISERS

<table>
<thead>
<tr>
<th>Company Name</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Akkerman Inc.</td>
<td>17</td>
</tr>
<tr>
<td>AP/M Permaform</td>
<td>5</td>
</tr>
<tr>
<td>BT Construction Inc/BTrenchless</td>
<td>18</td>
</tr>
<tr>
<td>Claude H. Nix Construction/Jasco, Inc.</td>
<td>IFC</td>
</tr>
<tr>
<td>C &amp; L Water Solutions Inc.</td>
<td>32</td>
</tr>
<tr>
<td>Doetsch Environmental Services</td>
<td>18</td>
</tr>
<tr>
<td>Horizontal Boring &amp; Tunneling Co.</td>
<td>42</td>
</tr>
<tr>
<td>IPEX USA LLC</td>
<td>38</td>
</tr>
<tr>
<td>Kilduff Underground Engineering Inc.</td>
<td>23</td>
</tr>
<tr>
<td>Lithos Engineering</td>
<td>23</td>
</tr>
<tr>
<td>Pro-Pipe</td>
<td>35</td>
</tr>
<tr>
<td>RepMasters Inc.</td>
<td>17</td>
</tr>
<tr>
<td>Sunbelt Rentals</td>
<td>23</td>
</tr>
<tr>
<td>TT Technologies</td>
<td>38</td>
</tr>
<tr>
<td>Underground Solutions</td>
<td>16</td>
</tr>
</tbody>
</table>

Please support the advertisers who have made this publication possible

---

**Let us help GROW your Association's profile, prestige & profitability...**

with a professional, full color communication vehicle that makes a profit for you!

Our team has 70 years experience in top-quality...

- Publishing • Editorial Duties
- On-Staff Writers • Advertising Sales
- Ad and Magazine Design/Layout

---

PTR Communications Inc.

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

204.255.6524 elaine@ptrcommunications.com

- Grow Your Membership • Increase Conference Attendance • Forge New Vendor Partners • Build Your Image •
The North American Society for Trenchless Technology (NASTT) is now accepting abstracts for its 2020 No-Dig Show in Denver, Colorado at the Colorado Convention Center on April 5-9, 2020. Prospective authors are invited to submit a 250-word abstract outlining the scope of their paper and the principal points of benefit to the trenchless industry. The abstracts must be submitted electronically at NASTT’s website by June 30, 2019: nastt.org/no-dig-show.

Abstracts from the following subject areas are of interest to the No-Dig Show Program Committee:

**Potable Water and Pressure Systems**
- Pipeline Inspection, Locating, and Condition Assessment
- Pipe Rehabilitation
- Pipe Bursting
- Emerging Technologies
- Case Studies

**Wastewater, Storm water, and Non-pressure Systems**
- Advanced Pipeline Condition Assessment
- I&I and Leak Detection
- Pipeline and Laterals Rehabilitation
- Pipeline Inspection, Locating, and Condition Assessment
- Cured-in-Place Pipe Lining
- Slip lining
- Pipe Bursting
- Spray Applied Linings
- Grouting
- Manhole Rehabilitation
- Case Studies

**Energy Pipeline Systems**
- Pipeline Inspection, Locating, and Condition Assessment
- Aging System Rehabilitation
- New Trenchless Installation
- Standards and Regulations

**Trenchless Research and Development**
- University and Industry Initiatives
- Education and Training

**Industry Issues**
- Subsurface Utility Engineering
- Submittal Requirements and Quality Assurance/Quality Control
- Project Budgeting and Prioritization
- Funding for “Green” Technologies
- Selection Criteria for Contractors
- Social Costs and Impacts
- Carbon Footprint Reduction
- Sustainable Construction Practices
- Industry Trends, Issues and Concerns
- Differing Site Condition Claims

**New Installations – Tunneling, Boring and Pipe Ramming**
- New Concepts or Trenchless Equipment, Materials and Methods
- New Applications for Boring Techniques (Auger Boring and Pipe Ramming)
- Pilot Tube Boring (Tunneling)
- Case Studies

**Horizontal Directional Drilling (HDD)**
- New Concepts and Applications for Horizontal Directional Drilling Equipment, Materials and Methods
- Case Studies

**Microtunneling**
- New Concepts and Applications for Microtunneling Equipment, Materials and Methods
- Case Studies

Questions? Please contact:
Michelle Hill | NASTT Program Director
E: mhill@nastt.org | P: 888-993-9935

For more information visit nodigshow.com