2022

TRENCHLESS SANS TRANCHÉE Journal

THE OFFICIAL PUBLICATION OF THE NORTH AMERICAN SOCIETY FOR TRENCHLESS TECHNOLOGY
Great Lakes, St. Lawrence & Atlantic Chapter | Chapitre des Grands-Lacs, du Saint-Laurent et de l'Atlantique

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ON THE COVER:
View of the CN Tower and Rogers Center from across Lake Ontario.

TRENCHLESS SANS TRANCHÉE Journal

2022

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David Crowder, *GLSLA Chapter Chair*

No-Dig North an Unprecedented Success

My name is David Crowder; I'm the new chair for the GLSLA Chapter. We continue to celebrate a record-breaking and very successful No-Dig North Show back in October of this year.

In Toronto we shattered all previous records with 818 people in attendance. Our GLSLA chapter along with the Northwest and BC Chapters worked together for the past year to make this show a success.

It was great to see industry colleagues and friends to share knowledge and experience we have gained over the past several years. I would like to congratulate and thank all the dedicated volunteers involved on the planning committee, program committee, Benjamin Media, and NASTT.

> We now look forward to seeing everyone at No-Dig 2023 next October 2023 in Edmonton.

We now look forward to seeing everyone at No-Dig 2023 next October 2023 in Edmonton.

Please watch out for the call for abstracts in early 2023, to get your submissions in to share your project experience with our industry. For more information on the show please visit *www.nodignorth.ca*.

This is our latest GLSLA magazine filled with great project and industry articles. For more information on GLSLA, our events magazine and our training sessions or to contact us if you wish to publish an article in our magazine, please visit our website at *www.glsla.ca*.

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David Crowder, *président de la section GLSLA*

No-Dig North un succès sans précédent

Je m'appelle David Crowder et je suis le nouveau président de la section GLSLA.

Nous sommes encore dans l'esprit du succès sans précédent du salon No-Dig North qui a eu lieu en octobre dernier. À Toronto, nous avons pulvérisé tous les records, grâce à la participation de 818 personnes. La section GLSLA et celles du Nord-Ouest et de la Colombie-Britannique ont uni leurs efforts pendant un an pour parvenir à ce résultat.

Quel plaisir de rencontrer amis et collègues pour discuter des connaissances et de l'expérience acquises depuis quelques années. Je tiens d'ailleurs à féliciter et à remercier tous les bénévoles dévoués qui sont membres du comité de planification et du comité de programme, ainsi que Benjamin Media et la North American Society for Trenchless Technology (NASTT).

Nous espérons maintenant vous revoir tous à l'occasion du No-Dig 2023, en octobre prochain, à Edmonton.

Ne manquez pas l'appel à communications, au début de 2023!

N'hésitez pas à envoyer vos propositions : l'industrie veut connaître votre expérience. Consultez la page *www.nodignorth.ca* : vous trouverez tous les renseignements sur le salon à venir.

Vous avez sous les yeux le dernier magazine en date de la section GLSLA. Il est riche en articles sur l'industrie et ses projets extraordinaires. Pour en savoir davantage sur la section GLSLA, les activités, votre magazine et les formations, ou pour proposer un article, rendez-vous sur notre site Web, à l'adresse *www.glsla.ca*.

Alan Goodman, *NASTT Chair*

In Person Events are Back and Better Than Ever

It feels like we are embarking on a fresh start now that restrictions are lifting across North America. We are excited as we look forward to the future! We're riding high on the successes of the NASTT 2022 No-Dig Show held earlier this year in Minneapolis and the 2022 No-Dig North conference held in Toronto in October. No-Dig North hosted over 800 attendees and a SOLD-OUT exhibit floor! The trenchless industry is ready to be back in person with networking and education leading the way.

Be sure to mark your calendars and save the date for the NASTT 2023 No-Dig Show in Portland, OR, April 30 – May 4. The city of Portland is a perfect location for our industry to come together to celebrate and educate with the theme, *Green Above, Green Below*. It is important that our industry is a steward of our precious natural resources, and we welcome the opportunity to provide a forum to learn about the latest in innovative trenchless products and services. Learn more at *www.nastt.org/no-dig-show*.

If you or your company has attended a NASTT Conference (National or Regional) you may leave that conference wondering how you could get more involved. I ask that you consider getting engaged in one of the many NASTT committees that focus on a wide variety of topics. They cover everything from Publications Committee, Good Practice Course Committee, No Dig Planning Committee and many others for you to consider. With education as our goal and striving to provide valuable, accessible learning tools to our community, one of the things of which we are most proud at NASTT is that we have been able to grow. In keeping with our mission of education and training, we are offering our Good Practices Courses in a live, virtual format throughout the year. For the latest information on all upcoming events, visit our website at *www.nastt.org/training/events*.

For more information on our organization, committees, and member benefits, visit our website at nastt.org and please feel free to contact us at *info@nastt.org*.

We look forward to seeing you at a regional or national conference or training event soon!

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Alan Goodman, *président, NASTT*

De retour en personne, et mieux que jamais!

On dirait un nouveau départ, maintenant que les restrictions ont été levées dans toute l'Amérique du Nord. Et l'avenir a de quoi nous réjouir. Le succès du salon No-Dig de la NASTT qui a eu lieu un peu plus tôt à Minneapolis et du congrès No-Dig North de 2022 à Toronto, en octobre, nous a mis le vent en poupe. No-Dig North a accueilli plus de 800 personnes et le salon des exposants affichait complet! L'industrie du sans-tranchées est prête à reprendre ses activités en personne, et le réseautage ainsi que la formation sont en bonne position au programme.

Mettez à votre agenda le No-Dig Show de la NASTT, qui aura lieu du 30 avril au 4 mai 2023 à Portland, en Orégon. La ville de Portland est l'endroit idéal pour cette nouvelle occasion de célébrer et d'apprendre, sous le thème *Green Above, Green Below* [vert en surface et vert sous terre]. Il importe en effet que notre industrie prenne soin de nos précieuses ressources naturelles, et nous sommes ravis de cette tribune qui nous permettra de découvrir des produits et des services novateurs. Vous en saurez plus ici : *www.nastt.org/no-dig-show*.

Si vous ou votre entreprise avez participé à un congrès national ou régional de la NASTT, il vous est peut-être venu à l'idée que vous pouviez vous engager davantage. Pourquoi ne pas siéger à l'un des nombreux comités de la NASTT, qui traitent de sujets divers, des publications aux pratiques exemplaires en passant par la planification, et beaucoup d'autres encore? La formation étant une priorité, nous nous efforçons de doter notre communauté d'outils d'apprentissage efficaces et accessibles. La NASTT est particulièrement fière de poursuivre sa croissance, et fidèles à sa mission de formation, nous offrons dorénavant nos cours sur les pratiques exemplaires sous forme virtuelle en direct pendant toute l'année. Vous trouverez les informations les plus à jour et la liste des activités à venir sur notre site Web, à l'adresse *www.nastt.org/training/events*.

Et pour en savoir davantage sur notre organisation, nos comités et les avantages offerts aux membres, visitez notre site à l'adresse nastt.org. Surtout, n'hésitez pas à communiquer avec nous, à l'adresse *info@nastt.org*.

Au plaisir de vous voir bientôt, à un congrès régional, au congrès national ou à une formation!

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2022 NO-DIG NORTH TORONTO CONFERENCE *Recap*

The third annual No-Dig North conference was held in Toronto, ON at the Beanfield Centre from October 17-19, 2022 and saw over 800 attendees take in a full schedule of technical presentations, industry educational sessions, and vendors talking shop in a bustling Exhibit Hall. The three-day event featured full days of presentations which covered a wide range of industry topics including Horizontal Directional Drilling (HDD), Cured-In-Place Pipe (CIPP) and Spray-In-Place Pipe (SIPP) rehabilitation methods, and more. There was plenty of time for socializing and networking as well, which is always a highlight at these in-person events.

Canadian Project of the Year awards were handed out, with two of the three award winners coming from the GLSLA; GHD Ltd. won under the New Installation category for its York Durham Sewer System Forcemain Twinning project, and Robinson Consultants Inc. won under the Rehabilitation category for its Stamford Interceptor Phase II Trunk Sewer Rehabilitation project in the Niagara Region. A third winning project was submitted from the U.K., detailing a fascinating new method for mapping out tight and inaccessible underground sewer systems. You can read all about that project in detail on page 14.

There were two recipients awarded the Chapter Chair's Award for Distinguished Service, an award that "recognizes trenchless professionals that have provided both NASTT and the trenchless industry with meritorious, prominent and long-standing service". Derek Potvin of Robinson Consultants Inc. and Gerald Bauer from Stantec were both presented with the award at the conference, as they move on from the NASTT GLSLA board after many years of dedicated service.

A huge thank you to all of the presenters, vendors, and to all who attended this year's conference. We look forward to seeing everybody again at the 2023 No-Dig North conference, set to take place at the Edmonton Convention Centre in Edmonton, AB on October 23-25, 2023.

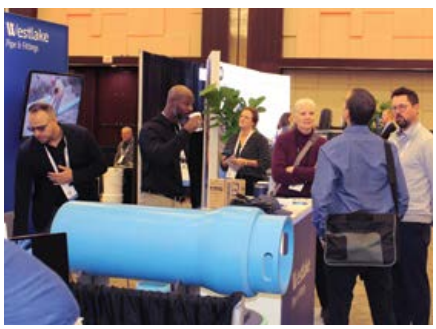
David Crowder gives a welcoming address to the conference at the Kick-off Breakfast.

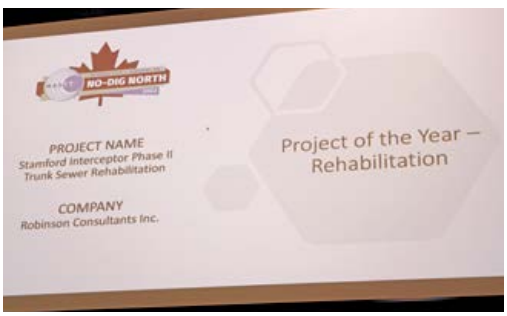
Keynote Speaker Lou Di Gironimo

GHD Ltd. won Project of the Year – New Installation for the York Durham Sewer System Forcemain Twinning project.

Robinson Consultants Inc. won Project of the Year – Rehabilitation for Stamford Interceptor Phase II Trunk Sewer Rehabilitation project.

Derek Potvin of Robinson Consultants Inc. and Gerald Bauer from Stantec were both presented with the Chapter Chair's Award for Distinguished Service, as they move on from the NASTT GLSLA board after many years of dedicated service.





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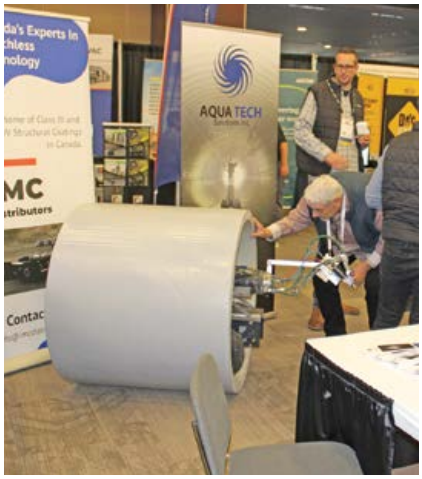
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The No-Dig Show is owned by the North American Society for Trenchless Technology (NASTT), a not-for-profit educational and technical society established in 1990 to promote trenchless technology for the public benefit. For more information about NASTT, visit our website at nastt.org.

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NASTT'S 2022 NO-DIG NORTH SHOW • TORONTO, ONTARIO, OCTOBER 17-19, 2022

THE MACHINES ARE TAKING OVER!

Adapting Drones for Advanced, Safer Sewer Surveys in the UK

Steve Mason, Caledonia Water Alliance, Scotland, UK • Thomas Philliben, Aegion Environmental Techniques, Scotland, UK
Jack Hutton, Good Friday Robotics, Ireland & UK • Shauna Herron, Aegion Environmental Techniques, Scotland, UK

PROJECT OVERVIEW

A significant number of sewers in the United Kingdom have not been able to be surveyed using any traditional methods of CCTV or Man-Entry Survey and, as a result, UK Water Companies have little to no information on their current condition. This may be in large diameter sewers where the pipe invert is too uneven or narrow for a traditional CCTV crawler unit to travel, where there is too little flow to undertake a float survey and where conditions are too hazardous for a man-entry walkthrough. Quite often, costly extensive cleaning is required just to enable a survey.

Scottish Water (SW) challenged Caledonia Water Alliance (CWA) and their partners Environmental Techniques (ET) and Good Friday Robotics to find an innovative solution to achieve surveys in these challenging sewers. Good Friday Robotics adapted drone technology that could fulfil this purpose and include additional technologies that could improve the data we collect during a survey. The Proof of Concept (POC) requirements were high quality footage (4K resolution achievable) and adequate lighting for large diameter sewers (up to 3m). In addition, we also included a LiDAR module for the capability of 3D mapping out the sewers and implemented Artificial Intelligence (AI) software to digitally code the condition of the sewer based on the information from the survey.

INTRODUCTION

Scottish Water (SW) have ownership of a significant number of critical sewers throughout Scotland for which there is limited information on the current condition of the assets. These assets tend to be on main streets within city centres, or adjacent to motorways and railway lines, meaning extensive traffic management needs to be planned and costed before even an initial look into the manholes can take place.

Within the current SR21 Scottish Water Framework, Caledonia Water Alliance (CWA) and Environmental Techniques (ET) have been working together to define programmes to gather as much good quality, relevant information on the condition of these high consequence sewers. These programmes look at various surveying methods that can be tailored for each

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situation in order to attempt to complete a CCTV survey of the asset. These include CCTV crawler cameras, float surveys, push rod camera, pole cameras and man-entry walkthroughs. These techniques are generally successful for surveying 80% of the sewers. The remaining assets present a myriad of difficulties including uneven inverts, high and fast flows, offset manholes, limited access points, heavy

Figure 1. An example of a cascading sewer in Edinburgh. These cannot be surveyed using float/crawler systems and would be treacherous to survey using Man-Entry Walkthrough.

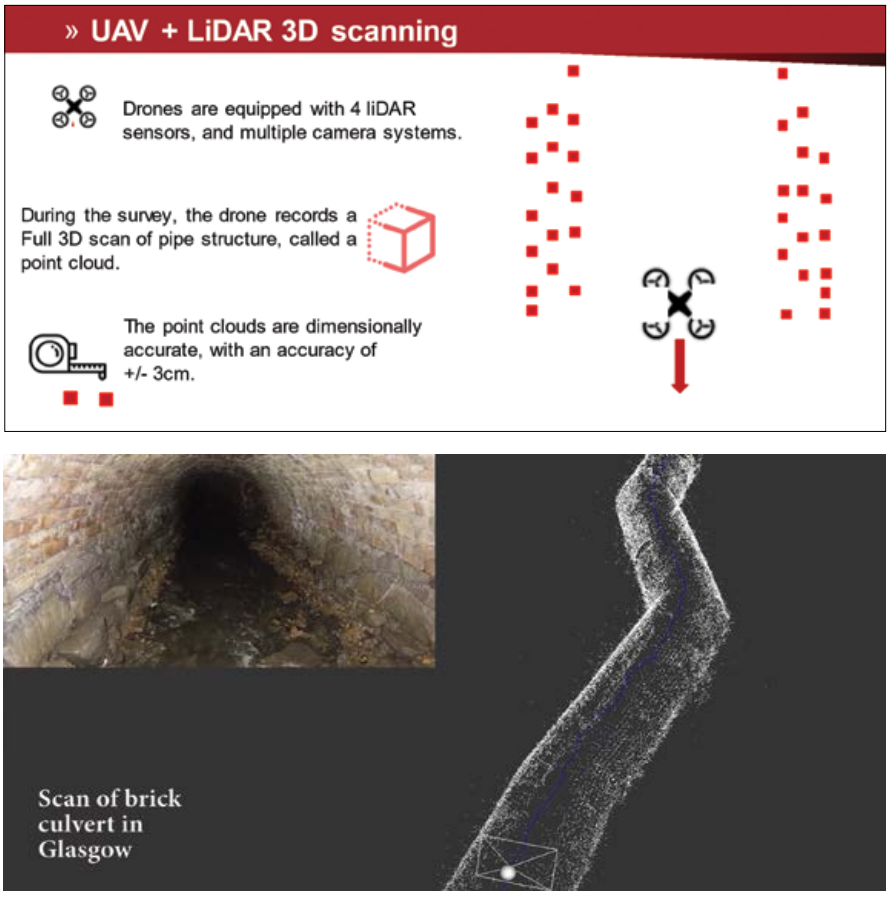

Figure 2. LiDAR 3D dimensionally accurate modelling of a brick culvert in Glasgow.

debris, toxic atmospheres, etc. as illustrated in **Figure 1**. These assets usually fall outside the scope of the Framework and are left unsurveyed. Focused collaboration between CWA and ET aimed to identify potential solutions for achieving surveys in these difficult assets.

THE ENGINEERED SOLUTION

CWA and ET had previously considered the idea of Unmanned Aerial Vehicles (UAVs) but there wasn't a readily available solution on the market that fulfilled the need. Good Friday Robotics were approached to adapt drone technology that could fulfil this purpose and include additional technologies that could improve the data we collect during a survey. Good Friday Robotics are a robotics company based in Northern Ireland that develop UAVs and robotic systems for specific, specialized tasks. The Proof-of-Concept (POC) requirements were high quality footage (4K resolution achievable) and adequate lighting for large diameter sewers (up to 3m).

There are a number of aspects to the development and approval stages. The first is testing the drones in the sewer and understanding the capabilities and limitations of the system, for example what distances we could cover using current battery technologies, what was the minimum pipe size that could be surveyed, which CWA and ET are currently undertaking on live SW projects. The next is ensuring that footage meets the SW Framework Specifications and that matches, or exceeds, what current CCTV systems can provide. By increasing the speed of travel through the sewer, the drone can survey longer lengths of sewers on the same battery charge. Existing specifications dictate speeds for traditional CCTV crawler systems which can often miss defects or bounce around if the speed is too fast. However, the advancements in technology with the drone (strong lighting, high resolution footage, stable flight, and high frame rate) mean these issues are negligible with the higher speeds and the existing specifications will need to be re-evaluated.

In addition, a LiDAR module for the capability of 3D mapping out the sewers as shown in **Figure 2**, and Machine Vision Artificial Intelligence (AI) software, to digitally code the condition of the sewer based on the information from the survey, were also implemented.

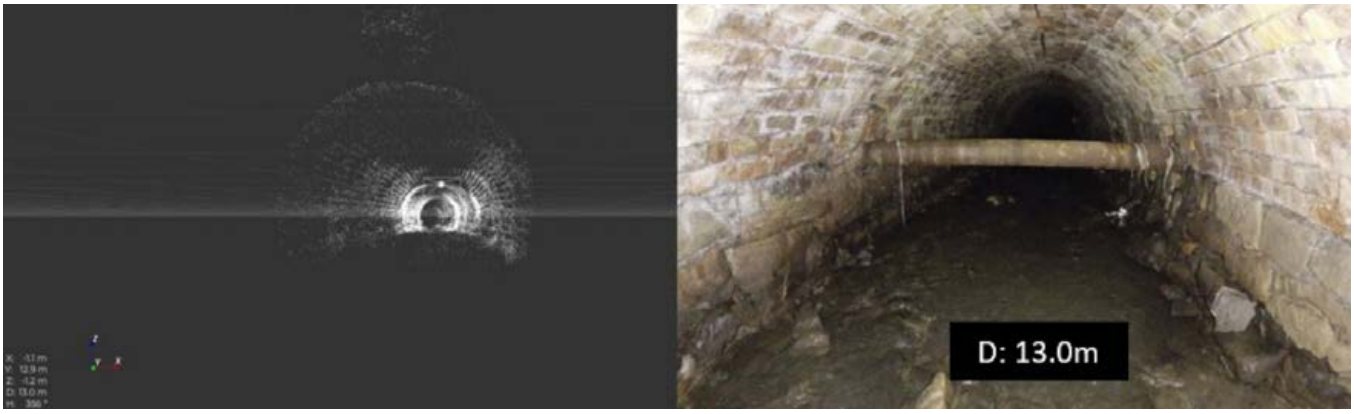

Figure 3. LiDAR 3D dimensionally accurate modelling on the left with corresponding footage on the right.

Figure 3 shows a side-by-side image of a drone survey, showing the LiDAR information on the left and the live video footage on the right. LiDAR, which stands for Light Detection and Ranging, uses pulses from a laser to collect measurements and the computer software creates a 3D cloud map of these points. The output model can be interrogated for to determine dimensions, distances, displacements, size of obstructions, diameters of connections as shown in **Figure 4**. The model can also be placed on topographic surveys to show the location of the sewer in relation to ground level features. The 3D scan can be geotagged, to show the exact geolocation of the pipe and exact geolocation of defects or points of interest.

IMPLEMENTING MACHINE VISION LEARNING (AI)

Machine Vision Learning (AI) aims to replace the repetitive, mundane tasks done by humans with a computer system. The computer system learns from thousands of examples of human

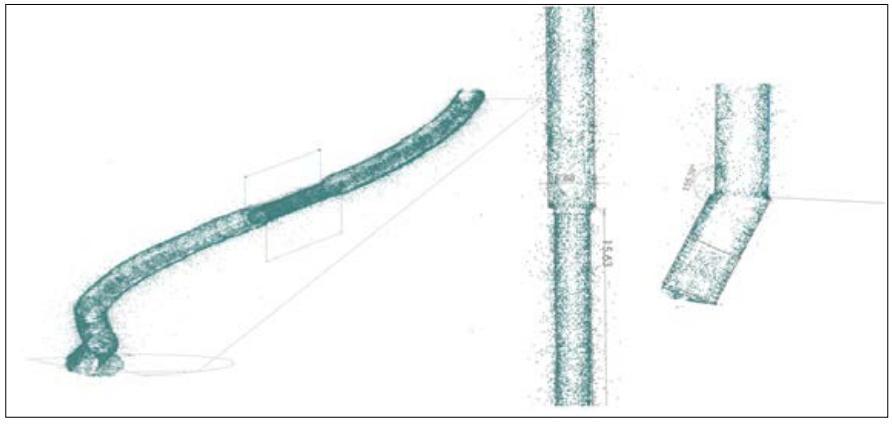

Figure 4. LiDAR 3D dimensionally accurate modelling of pipeline with significant change of dimension and direction.

The LiDAR 3D scan can be analysed and used to accurately measure;

• lengths	• connection orientation	• connection sizes
• diameter changes	• diameters	• missing bricks
• angle changes	• deformity	
• size of defects	• line deviations	

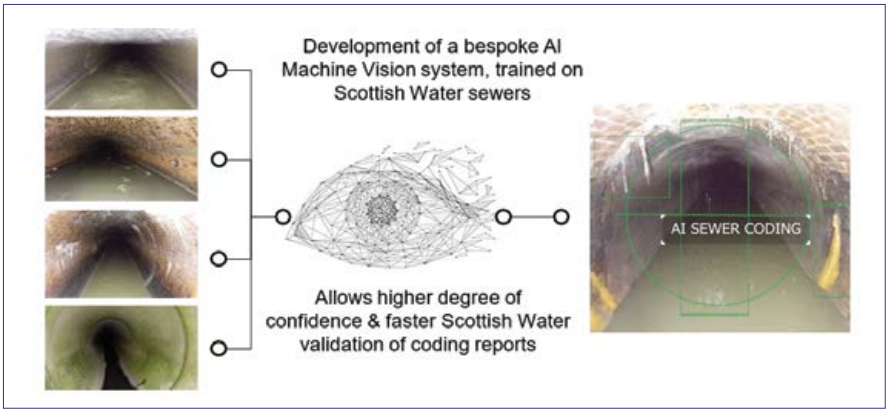

Figure 5. Machine Vision Coding (AI) developed specifically for Scottish Water sewers.

input until it is able to recognize patterns and complete the work itself as shown in **Figure 5**. With SW's assistance, CWA and ET are testing the AI on surveys already undertaken and coded from previous surveys completed on their assets. The video information is passed through the system along with the manual coded data and used to teach, and compare, the AI. The benefits of this system will be improved productivity as CCTV surveyors will have to spend less time coding their work and improved data quality. Once a drone survey is complete, the AI system will automatically code the inputted data and produce a WinCan report which will grade the structural and serviceability condition of the pipe. This will remove variances which are a result of different operators coding the footage and will produce an unbiased, repeatable report for that asset.

CONCLUSION

Where CCTV crawlers are not suitable, man-entry walkthroughs are often undertaken to visually assess culverts and large sewers. In order to be carried out safely, these can often involve nine-person crews, including specially trained rescue team members, as shown in **Figure 6**. The reduced number of operatives and vehicles required on site for a drone survey, as shown in **Figure 7** usually two or three operatives and one vehicle, results in a much smaller carbon footprint which will assist Scottish Water in meeting their Carbon Net Zero Targets by 2040.

The significant benefit of a drone survey compared with a Man-Entry Walkthrough is the improvement of health and safety. Whilst sewers are ventilated, gases monitored and breathing apparatus/ escape sets are provided to survey crews, there remains inherent risks with operatives being in a confined space. The drone survey removes the need for operatives to be in a confined space or travel along the sewers and therefore the survey can be undertaken with a higher certainty of safety for all employees.

> *"The drone survey removes the need for operatives to be in a confined space or travel along the sewers and therefore the survey can be undertaken with a higher certainty of safety for all employees.*

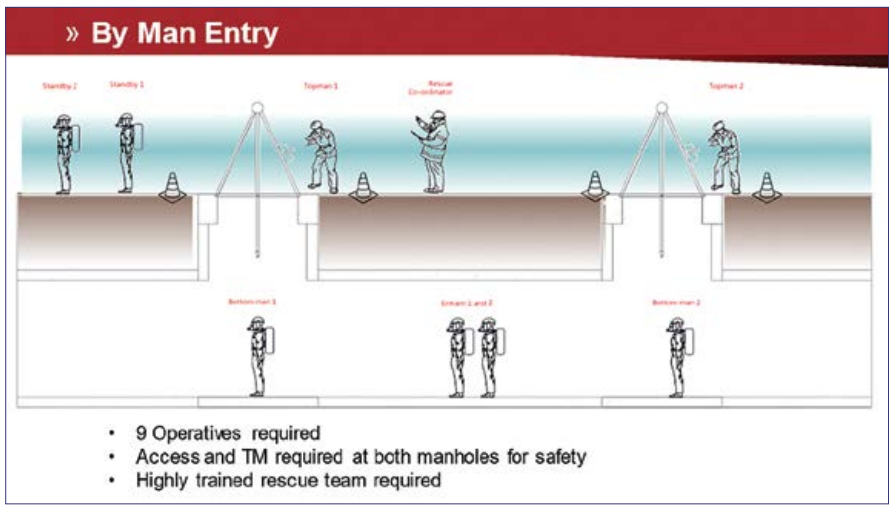

Figure 6. Traditional Man-Entry Walkthrough Surveys require 9+ Operatives

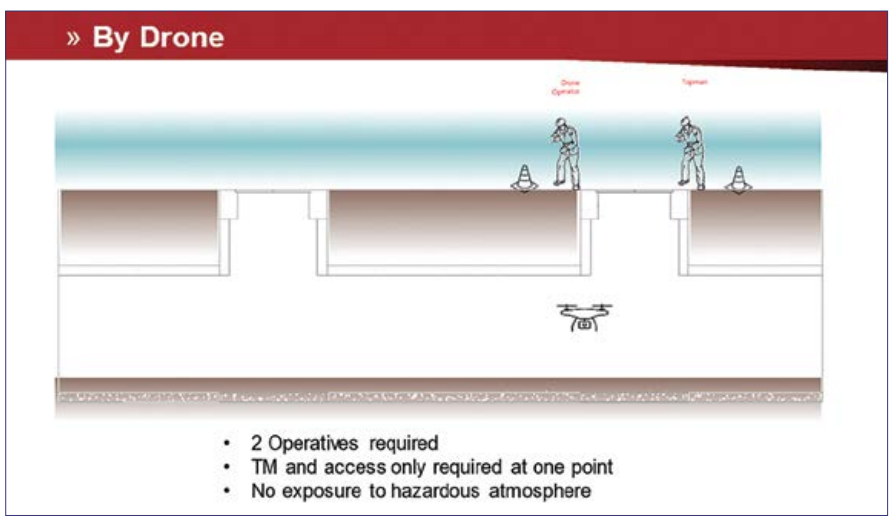

Figure 7. Drone Sewer Surveys require only two Operatives.

As the drone flies near the top of the sewer, it isn't restricted by uneven inverts, narrow channels, debris, high flows, etc. This allows us to complete surveys on more critical assets than solely using the traditional techniques.

Caledonia Water Alliance (CWA), Environmental Techniques (ET), and Good Friday Robotics partnered to develop a drone solution that was a custom-built system to meet the specification. The drones are currently being trialled on SW Framework projects which not only allows the drones to be developed and tested but is also able to deliver instant results as it aids in surveying difficult assets in Glasgow and Edinburgh city centers.

The key benefits are;

- **Safer.** Reduced time in confined spaces – lowers the risk to operatives as the drone can be flown in from the ground surface with no need for operatives to enter into manholes.
- **Practicality.** Improved likelihood of completion of surveys – as the drone flies near the top of the sewer, it isn't restricted by uneven inverts, narrow channels, debris, high flows, etc. This allows us to complete surveys on more critical assets than solely using the traditional techniques.
- **Sustainable.** Reduced carbon footprint – The reduced number of operatives and vehicles required on site makes the drone survey have a much smaller carbon footprint which will assist Scottish Water in meeting their Carbon Net Zero Targets. Drone surveys can be completed safely with 2- and 3-men crews compared to 9 for a safe man-entry walkthrough, as well as reducing the need for jetting and flow control.
- **Development of Machine Vision (AI) coding** – WinCan reports detailing structural and serviceability condition grades can be completed automatically, improve productivity and reliability of results.
- **High-definition footage** – The drone records 4K footage of the sewers with effective LED lighting. The higher elevation of the drone camera in the sewer also allows a high level of detail to be observable even when there is a lot of debris in the line.
- **LiDAR 3D cloud mapping** – In addition to recording high quality video footage of the assets, the drone is also equipped with a LiDAR scanner that produces a 3D map of the asset. The map can then be interrogated using 3D software to measure dimensions, levels of debris, deformations and connections.

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Seattle Public Utilities Pump Station 043 Emergency Force Main Repair, Hiram M. Chittenden Locks (the Ballard Locks) in Seattle, WA.

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North American Record NPS 12 Intersect HDD with Five Horizontal Curves

Hernan Castedo, Enbridge (formerly of UniversalPegasus International), Oakville, Ontario
Jim Murphy, UniversalPegasus International, Calgary, Alberta
Peter Liang, UniversalPegasus International, Calgary, Alberta
Mohtashim Qazi, Imperial Oil, Toronto, Ontario
Trevor Miles, UniversalPegasus International, Calgary, Alberta

PROJECT OVERVIEW

This paper concerns a North American record NPS 12 Horizontal Directional Drill (HDD) installation with a total length of 3,531 meters constructed in 2021. Not only is the drill length a record for this pipe size, but this crossing alignment includes five horizontal curves along with the normal two vertical curves.

Imperial's Waterdown to Finch project is located within multiple jurisdictions throughout the Greater Toronto and Hamilton Area (GTHA) in southern Ontario. This new pipeline will replace in-kind 62.5km of the Sarnia Products Pipeline (SPPL) from Imperial's Waterdown Station in Hamilton to its Finch Terminal in Toronto. A total of 35 HDD crossings were designed into this project with seven crossings at well over 1,000 meters long. The pipeline begins in a rural setting and quickly enters the built-up urban areas of the Greater Toronto Area. Most of the crossings are within an existing utility corridor near and/or parallel to residential developments, commercial buildings, viaducts, 400-series highways, and power lines. Subway tunnels, railways, and concrete sewer lines with diameters as large as three meters were crossed at multiple locations.

This paper will discuss the design and construction challenges of this HDD crossing, as well as the risk mitigations built into the design and construction. The design challenges included: geotechnical conditions, crossing length, intersect near profile mid-point, five horizontal curves, design radius, narrow Right of Way, detailed hydro-fracture analysis, buoyancy control, pipe pull-force capacity, pipe stress capacity, and final reaming size. Construction challenges included: managing drilling fluid properties, calibration and monitoring of rig pull load, steering accuracy, and pipe pullback in three sections.

INTRODUCTION

The Waterdown to Finch Project is proactively replacing 62.5 kilometers of Imperial's 323.9 mm diameter Sarnia Products Pipeline (SPPL) from Imperial's Waterdown Station in Hamilton to its Finch Terminal in Toronto. The SPPL provides products used by households and businesses across the Greater Toronto and Hamilton Area. This includes a significant portion of jet fuel for Toronto Pearson International Airport, as well as gasoline and diesel fuel that keeps people, goods and services moving throughout the region.

The Waterdown to Finch portion of the SPPL begins in a rural setting in Hamilton and quickly enters the built-up urban areas of Burlington, Oakville, Mississauga, and Toronto. Most of the crossings are located within Hydro One Networks Inc's (HONI) high voltage electric utility corridor near and/or parallel to residential developments, commercial buildings, viaducts, 400-series highways and power lines. Tunneled subways, railways, and large diameter concrete sewer lines were crossed at multiple locations. Due to the nature of the Right of Way, multiple HDD crossings were designed with bends that incorporated short horizontal curves to complete the installation. These curves were designed with the typical radius used on the project (500m). The bends varied from

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Figure 1. Overview of Waterdown to Finch Pipeline route.

0.4 degrees to 20 degrees. In addition, the pipeline alignment closely parallels Imperial's two existing pipelines and an additional six foreign pipelines at various points along the alignment. In fact, one of the main criteria for the routing decision making was that the pipeline alignment had to be maintained in the existing easement as much as possible.

UniversalPegasus International (UPI) was retained to provide engineering design and construction support services for the project in 2017. Pipeline engineering and project management was provided by UPI's Houston office while the major trenchless group in Calgary carried out the design of the HDDs. A total of 35 HDD crossings were designed into this pipeline project with seven crossings at over 1000 meters in length and with two of these exceeding 2000 meters. The total length of the HDD crossings designed is 28 kilometers, which is about 45% of the total length of the pipeline. **Figure 1** provides an overview of the Waterdown to Finch pipeline route and the relative location of the subject Hidden Lake HDD.

The Hidden Lake HDD crossing is one of the 35 HDD crossings on the Project, located from kilometer post (KP) 4.0 to KP 7.5. This crossing was designed at a length of 3,531 meters with five horizontal curves and two vertical curves. This is believed to be a North American record for both length and number of horizontal curves on an NPS 12 HDD installation.

It was recognized early on that the Project would require the extensive use of HDD. With this in mind, understanding the geological and geotechnical setting was paramount. The geotechnical program for the Project was substantial, taking over two years to complete with over 150 geotechnical boreholes drilled.

Almost all of the HDD crossings were drilled into bedrock, including 99% of Hidden Lake's bore path. Particular to the Hidden Lake crossing was the presence of known and/or potential Karst zones. Karst is a distinctive topography that forms from the dissolving action of water on soluble carbonate-rich bedrock. In addition to caves and sinkholes, Karst features include pitted rock, rills, grikes, fissures, runnels, voids, shafts, springs and disappearing streams (note the name of the golf course we were crossing – "Hidden Lake"). Based on readily available Karst mapping for the region, this crossing is situated in areas of known and potential Karst or bedrock susceptible to Karst processes. Lake Medad, in close proximity to the crossing, may also be a Karst feature. Because of this, the investigation was focused on identifying the limits of the Karst susceptible bedrock, identifying any evidence of Karst (e.g., water returns during bedrock coring, rock core recovery, rock porosity, cavities, dissolutions) and identifying the preferred profile of the HDD to avoid the potential Karst zones wherever possible. Once the initial investigation identified shale bedrock beneath the overlying Karst susceptible rocks such as dolomite limestone, additional boreholes were drilled along the entry and exit tangents, where the pipeline would be installed within the dolostone, intent on intersecting the Karstic features if present. The concerns associated with Karst features include the loss of drilling fluid during the HDD process which, depending on local regulations, could mean the drilling would have to stop and the installation could not be completed. The other concern was that the pipeline could be installed within a current or future Karst feature, resulting in an unknown length of unsupported pipe which would add unknown bending moments and stresses to the pipeline. Ultimately, identifying these areas allowed the HDD contractor and mud engineers to better prepare for the scenarios associated with drilling through Karst zones.

The crossing was also located across the Niagara Escarpment that runs predominantly east–west from New York state through Ontario and into Michigan state. It reflects the interface between hard

dolostone bedrock to the west and soft shale bedrock to the east. Due to unequal erosion forces, the escarpment reflects a significant change in topography.

HDD DESIGN

A total of seven boreholes were advanced along the crossing alignment, as shown in **Figure 2**. The fieldwork for the investigation was carried out between November 2018 and October 2019 and on May 19 and 20, 2020. The overburden was drilled using mud rotary drilling technique and was sampled using Standard Penetration Testing (SPTs). The underlying bedrock was cored (HQ or NQ sizes) in all the boreholes. Four boreholes are located on the east side of the crossing and show the depth of the overburden to be about 1.0 meters to 4.5 meters. Three boreholes are located on the west side of the crossing near the entry point and show the depth of the overburden to be about 1.5 meters to 15.0 meters. One borehole was located near the HDD exit point (on the east end) and bedrock was encountered at approximate 4.5 meters below grade.

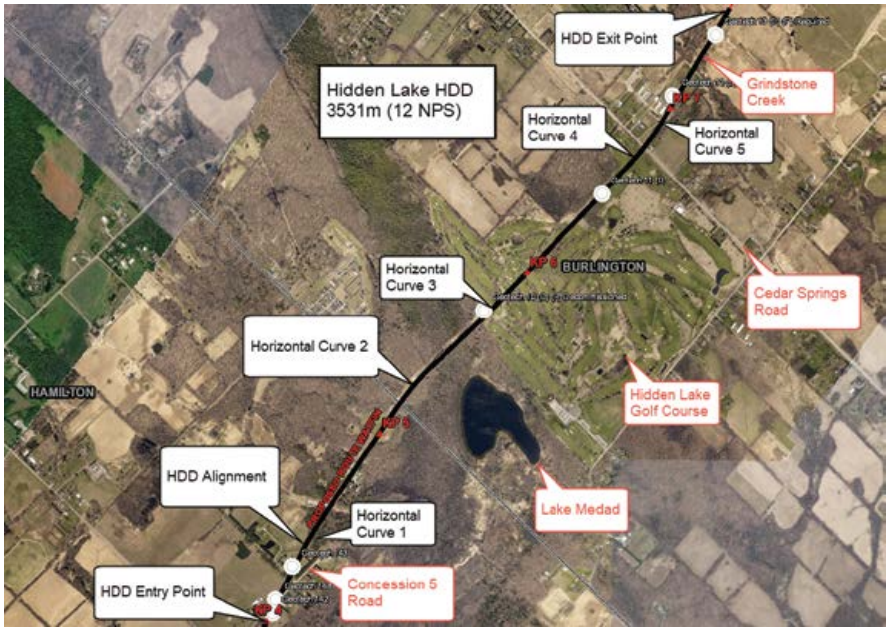

Figure 2. Hidden Lake Crossing Map.

The crossing is an area of 'potential' and 'known' Karst as noted above. The rate of water-return during rock coring ranged from 0% to 90%. The 0% return was related to boreholes BH10 and BH143 and was likely due to the presence of significant Karst conditions. Boreholes BH10 and BH143 encountered fissures/voids (possible conduits) in the upper zone of the dolostone bedrock extending to inferred depths of five meters to six meters below grade. Karst conditions can lead to significant loss of drilling fluid during the HDD. If significant Karst conditions are encountered that cannot be mitigated, a redesign of the HDD would be required.

As noted above, the drill path along the HDD profile is 3,531 meters in length. The pipe crosses Grindstone Creek at a depth of about 53 meters below the creek. This design profile has an entry angle of 14-degrees and an exit angle of 14-degrees. An entry casing was designed to penetrate the top layer of sand with gravel. The west side was designated as the entry side on the drawing because it is 25.7 meters lower than the east end, ensuring that the majority of the drilling fluid will flow back to the entry (west) side during reaming. The pullback string was placed on the east side of the crossing due to the limited available workspace for the 3.5 kilometers of product pipe.

HISTORY OF THE HIDDEN LAKE GOLF CLUB HDD CROSSING

The design for the Hidden Lake HDD crossing began in January 2018. The initial design crossed under the Hidden Lake Golf Course at a length of 1,525 meters.

In May 2019, this crossing was combined with the Grindstone Creek HDD on the east end of the crossing to address landowner concerns. This included Cedar Springs Rd as noted on **Figure 2** and lengthened the crossing to 1,919 meters.

Due to environmental and archeological concerns west of the golf course and near Lake Medad, multiple options to extend the crossing to the west were prepared for discussion. To finalize the extent of the crossing on the west end, three additional boreholes were drilled (see **Figure 2** for Geotech 142, 143 and 148) to establish bedrock levels and the length of casing that might be required at that end. The entry point was ultimately confirmed on the south side of the Concession 5 Road at about KP 4.0. This resulted in a final design length of 3,531 meters with the five horizontal bends and the two required vertical curves.

It was determined that several additional design elements had to be considered for this length of HDD. The typical design radius on the project for NPS 12 pipe is 500 meters. To keep the pull force as low as possible, it was decided that it would be prudent to increase the radius to 1000 meter. A review of the alignment at the bends determined that additional easement area would be necessary to ensure the pipe stayed within the easement. In July 2019, a small amount of extra easement was designed at three horizontal bends in the alignment. **Figure 3** shows a typical easement design at one of the bends.

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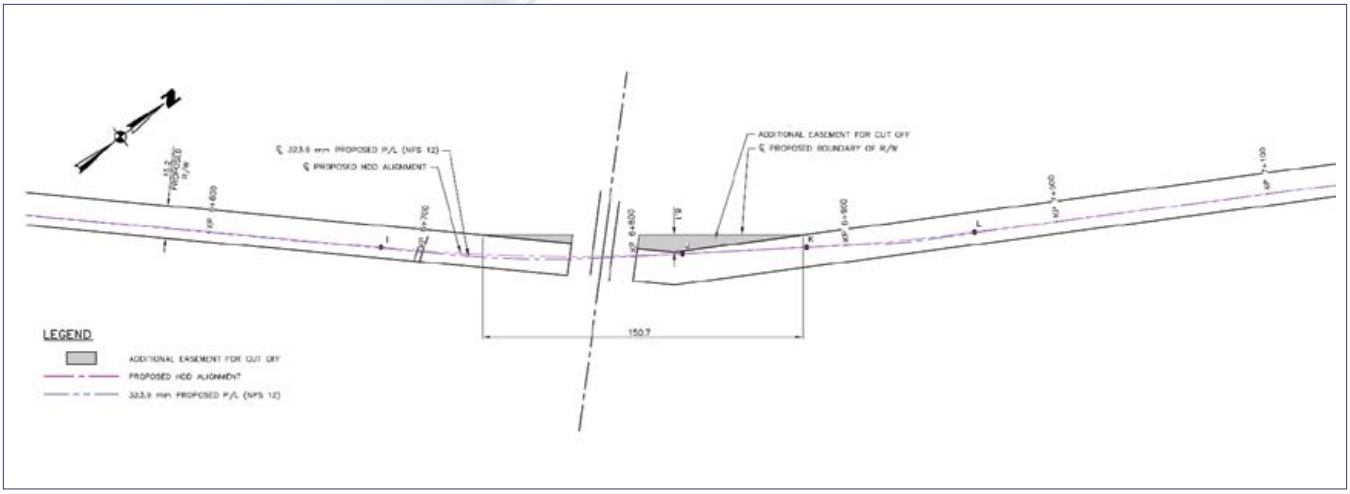

Figure 3. Example of additional easement for horizontal curves 4 and 5.

Three long pipe sections were designed which would require two welds to be carried out during the pipe pull back. The total length of the crossing required the design to include an intersect. The intersect zone was designed in a straight section of the alignment near the middle of the crossing. The majority of the crossing profile was at a single elevation such that the intersect could have been done at a number of locations.

UPI completed hydrofracture evaluations for this crossing to determine the appropriate depth of cover for the HDD installation. The hydrofracture evaluations were in accordance with the Delft Geotechnics Method outlined in Appendix B of the Army Corps of Engineers 1998 Technical Report CPAR-GL-98-1 (Installation of Pipelines Beneath Levees Using Horizontal Directional Drilling). This method is used to estimate the maximum annular pressure allowed based on the strength of the geotechnical formation above an HDD borehole during an HDD operation.

The Bingham Plastic rheological model was used to determine the minimum required annular pressure that ensures drilling fluid can flow back to the HDD entry. The minimum required annular pressure for an HDD installation is governed by the drilling fluid density, viscosity, yield point, flow, hole size, drill pipe size, and installation length and depth. As the crossing was drilled from both ends, two annular pressure curves were created starting at both ends and meeting at about the point of intersect. The annular pressure curves for the intersect pilot hole drilling is shown in **Figure 4**. The area between the two blue lines of Min Required Annular Pressure and +25% Min Required Annular Pressure is a proposed annular

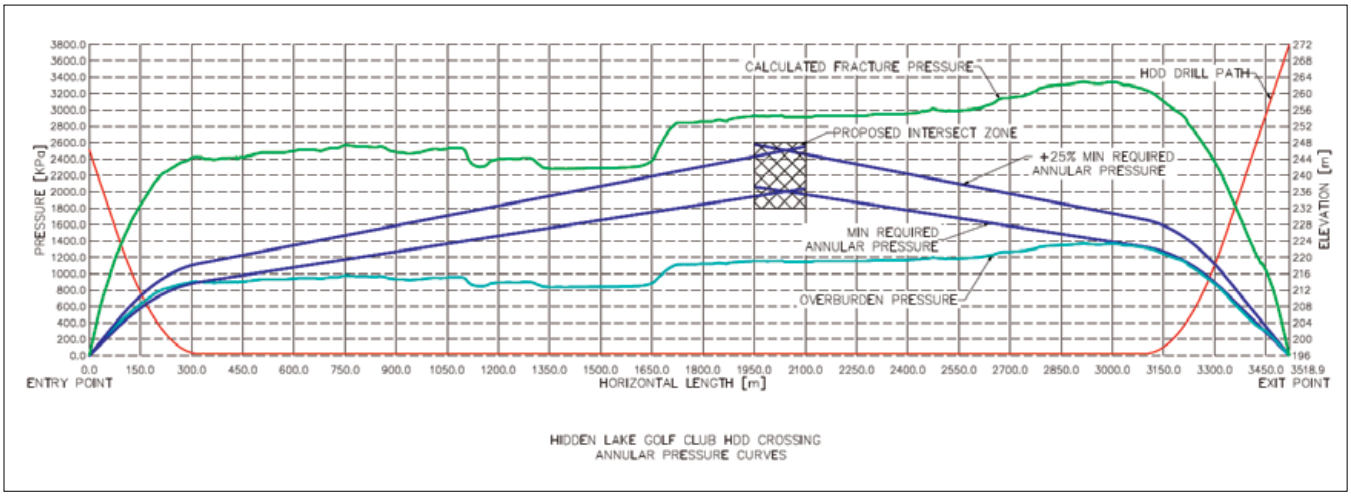

Figure 4. Hidden Lake Golf Club HDD Crossing Intersect Annular Pressure Evaluation.

pressure working zone that is lower than the Calculated Fracture Pressure (green line). Therefore, the depth of cover for the HDD installation was appropriate.

The pull load and stress calculations are based on PRCI PR-227-144507 E01 (2015) – Installation of Pipelines by Horizontal Directional Drilling, an Engineering Design Guide, dated September 2015. Normally, operating conditions govern a design of an HDD pipeline. However, in a long crossing such as the Hidden Lake HDD, and especially for a 12-inch diameter pipe, installation stresses will govern the design.

BUOYANCY CONTROL CONSIDERATION

In HDD design, buoyancy control is normally achieved on large diameter pipeline installations by adding water into the pipe. For the NPS 12 pipeline, this type of buoyancy control is not typically considered effective. Due to the length of the pipe (3,531m), 99% of the drill path through bedrock, and high number of curves (7) in this HDD, it was important to minimize the pulling load during the pullback process and reduce the risk of coating and pipe damage. Therefore, methods to achieve neutral pipe weight needed to be considered.

For large diameter trenchless pipeline installations (typically NPS 30 and greater), buoyancy control methods generally entail filling the product pipe with water or inserting a water-filled plastic pipe inside the product pipe during installation. This is not effective in small diameter pipelines such as the NPS 12 pipeline. UniversalPegasus recommended to adjust the drilling fluid density to achieve an effective pipe weight close to zero. When the drilling fluid density is 69.4 lb/ft^3 (1,112 kg/m^3), the effective pipe weight is about zero (neutral) and the friction between the pipe and the hole will be minimized, leading to a reduction in the required pull force and ensuring the coating is undamaged. After discussions with both a drilling fluid specialist and an HDD contractor, the range of the drilling fluid density was recommended to be 71.4 lb/ft^3 +/- 2.0 lb/ft^3 (1,112 – 1,175 kg/m^3) during pipe pull.

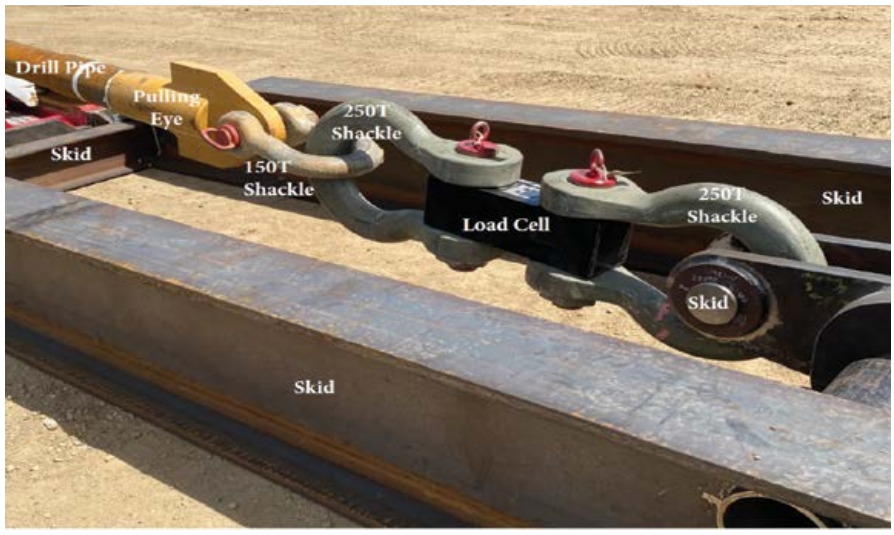

Figure 5. Components for the Rig Load Calibration.

CONSTRUCTION

The execution plan for the crossing was submitted by the HDD contractor and accepted by Imperial on May 7, 2021. The plan called for an 840,000 lbs rig on the entry and an 840,000 lbs rig on exit. Both sides planned to use a gyro steering tool supplied by Brownline GST Guidance System. As this HDD was going to be 99% in shale bedrock, 8-inch mud motors were planned with 12¼-inch TCI tri cone bits.

The entry side pilot hole was started on May 15, 2021; the exit side pilot hole was started on May 20, 2021. After 25 days, the successful intersect occurred at 1,800 meters from entry and the entry rig pushed out to exit side. Normally for long HDDs with large diameter pipe the accuracy of the drill rig is of no consequence; however, for 12-inch product pipe we wanted to be absolutely certain that the accuracy of the pull force reading on the drill rig was sufficiently accurate for this size of pipe. It was specified that if the rig had not recently been calibrated, then the drill rig that would be pulling in the pipe would need calibration. The HDD contractor set up a calibration arrangement in their yard and performed the calibration using a Model #: MSI7300RF load cell. This was performed in accordance with ASTM E4 C39 on June 23, 2021, under the supervision of an engineering consultant who wrote calibration report for Imperial. The conclusion of the report was that the maximum deviation from the conversion chart used on site was about 400 lbs which was determined to be acceptable by Imperial and the Hidden Lake HDD installation. **Figure 5** shows the components used for the rig load calibration.

The HDD contractor encountered steering issues during the drilling of the pilot hole on the entry side on May 22, 2021 and could not maintain the consistent steering accuracy. When the vertical deviation reached four meters below design profile, the pilot hole was stopped for consultation with the engineers. After a check of the pipe installation and operation stresses, a four-meter deeper drill was acceptable from the standpoint of the pipe stress. A revised HDD profile with a bottom tangent four meters lower was proposed by the HDD contractor and was accepted by Imperial.

The pilot hole diameter is 12.25 inches for this project. For the pipe size of NPS 12, a final reamed hole size of 18 inches is commonly used. The contractor used 7 5/8-inch drill pipe with 6 5/8-inch FH connections which puts the drill collars at 9 inches diameter and the torque forces were expected to be around 120,000 lbs.

Table 1. Hidden Lake Golf Club HDD Swab Pass – Drilling Fluid Densities

			Average Drilling Fluid Density at cleaning system (kg/m^3)	Average Drilling Fluid Density at mud pit (kg/m^3)
1	Jul. 27 to 29	Swab Pass #1	1,153	1,211
2	Jul. 29 to 31	Swab Pass #2	1,167	1,186
3	Aug. 3 to 5	Swab Pass #3	1,119	1,165
Drilling Fluid Density Required During Pipe Pull:				1,112 - 1,175 kg/m^3

The HDD contractor recommended a final ream size of 26 inches to further reduce the potential pull force. Concerns with potentially overstressing the pipe during operation were resolved with additional analysis of the static operational stress. The extra effort for mud management also had to be considered with the larger hole due to increased volumes of cuttings and drilling mud required for construction. After careful review this final reamed hole size of 26 inches was approved by Imperial, ultimately the successful execution of the crossing proved that the decision to upsize the hole was the right one.

Reaming began on June 18, 2021, from the entry side. The HDD contractor installed a 26 inches TCI reamer on the entry side drill rig to provide torsional forces and mud pumping while the exit side drill rig provided tensile forces to the reamer. Due to the length of drill stem in the hole, the contractor employed some exit side torsional force during the reaming operation. This had to be closely monitored by the exit side rig to ensure that they did not twist off the tooling downhole. On June 25, 2021, the contractor decided to trip the reamer out and inspect it due to low rate of penetration (ROP). After inspecting the 26-inch reamer, it was confirmed to be in good condition. In order to attempt to increase the ROP it was decided to use a 24-inch milltooth reamer. ROP was significantly improved as a result of this change and this reamer was used for the remainder of the crossing.

As part of the execution plan, three swab passes were proposed in order to condition the drilling fluid and to achieve the required drilling fluid density. The drilling fluid densities for both the sending down hole and on return into the pit were measured during the swab passes. These drilling fluid densities are listed in **Table 1**. The average drilling fluid density sent down hole was 1153 kg/m^3. The average drilling fluid density returned into the pit was 1,211 kg/m^3. The drilling fluid densities (1119 kg/m^3 and 1169 kg/m^3) during the third swab pass met the requirement specified for the drilling fluid density range, so the pullback began after the third swab pass. A 22 inch TCI reamer was used for the three swab passes. **Table 1** shows the drilling fluid densities.

"After reviewing the HDD profile and the geotechnical conditions with 99% of the HDD drill path in bedrock, the project team determined that three pullback sections could be completed with little risk of overstressing the pipe during pull back."

Further complicating the execution of the pull back was that the 3,531 meters had to be split into three sections, each greater than a kilometer in length. Ideally there would have been adequate workspace to accommodate a single string for the entire pullback. However, in this case a single string was not feasible due to perpendicular roadway crossings. After reviewing the HDD profile and the geotechnical conditions with 99% of the HDD drill path in bedrock, the project team determined that three pullback sections could be completed with little risk of overstressing the pipe during pull back.

The pipe pull started on August 5, 2021, at 9:18 a.m. using a 20-inch TCI reamer. The maximum pull load calculated is 185,000lb when drilling fluid density is 1,175kg/m^3. The actual maximum pull

Figure 6. Hidden Lake Golf Club HDD Entry Side.

Figure 7. Hidden Lake Golf Club HDD Pipe Pull.

load during pipe pull was 140,000 lb. The actual maximum pull load is lower than calculated as this load does not take into account the 3,500 meters of drill steel in the borehole. The installation of the NPS 12 HDD pipeline was completed successfully on August 6, 2021, at 4:59 pm. The maximum pull force that was allowed during the pipe pull was 585,000 lbs which ensured that the pipe would never be overstressed in case the pipe became tight in the borehole. Prior to exceeding this preauthorized limit, permission from the team was required and would have required a review of the exact conditions that were present.

Figure 6 shows the HDD entry side. **Figure 7** shows the HDD exit side. The completion of the NPS 12 HDD pipeline installation is shown in **Figure 8**.

CONCLUSIONS AND RECOMMENDATIONS

The Hidden Lake crossing was not originally anticipated to be such a significant drill in the overall execution of the Waterdown to Finch Project. However, as the crossing evolved, there was a need to increase the length of the crossing as a result of multiple factors. The increased length and multiple horizontal curves resulted in additional risks that were required to be managed throughout the design and execution phases of the crossing. The careful planning and anticipation of issues by the project team contributed to the successful completion of the project. Critical to this success was the support and engagement from the client, Imperial. Through enhanced collaboration and engagement with all of the stakeholders, including the HDD contractors, the project team was able to work issues jointly through to resolution ultimately leading to a near flawless completion of not just the longest, but one of the most complex HDDs in North America.

> "The careful planning and anticipation of issues by the project team contributed to the successful completion of the project. Critical to this success was the support and engagement from the client."

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PRCI PR-277-144507-R0, 2015 Installation of Pipeline by Horizontal Directional Drilling, An Engineering Design Guide.

D. Bennett and S. T. Ariaratnam, S. (2017) – Horizontal Directional Drilling Good Practices Guidelines, North American Society for Trenchless Technology (NASTT), Fourth Edition.

Figure 8. Completion of NPS 12 HDD pipeline installation

Robbins Single Shield
Completes Canada's Largest Outfall
TBM bored at record rates below Lake Ontario

The 3.5 km (2.2 mi) long Ashbridges Bay Outfall Tunnel is Canada's largest outfall and connects to 50 risers in Lake Ontario.

On March 3, 2022, a 7.95m (26.1 ft) diameter Robbins Single Shield TBM completed a record-setting run below Lake Ontario. The machine, for the Southland/Astaldi JV, bored 3.5km (2.2mi) in sedimentary rock for the Ashbridges Bay Outfall in Toronto, Ontario, Canada.

The machine launched in March 2021 from an 85m (280ft) deep, 16m (53ft) diameter shaft and began its bore in predominantly shale, with limestone, siltstone and sandstone. During its excavation, the TBM and its experienced crew bored a city-wide record of 30 rings in one day, or about 47m (154ft) of advance. The machine and crew surpassed a previous best day of 21 rings at a project with similar specifications. "We are proud to have completed another successful tunnel with Robbins and greatly appreciate their field service support," said Joe Savage, Project Manager for Southland.

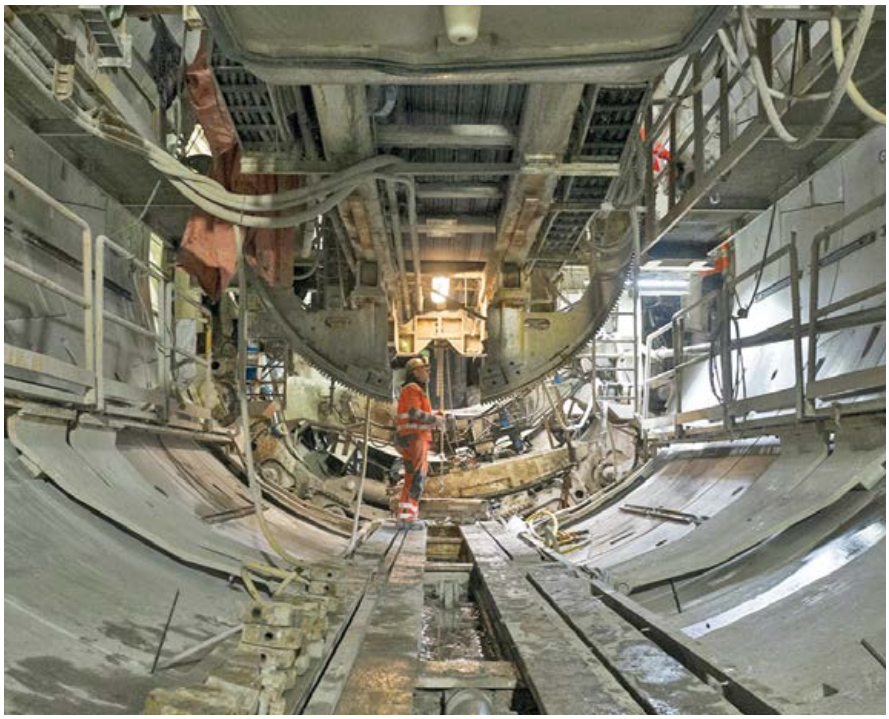
"This is a wonderful type of geology for our machines. During the entire excavation, a total of seven cutters were changed. The wear behavior is incredible, between 2mm and 5mm, and everyone is amazed by the cutter performance," said Alfredo Garrido of Robbins Field Service.

The crew had been operating the machine in two shifts of 12 hours from Monday to Friday. A Robbins continuous conveyor system including vertical conveyor transported muck behind the machine. "Every 25 machine cycles, it was necessary to stop the excavation to probe drill hole in front of the cutterhead to check for possible water. This drilling was done basically every day, stopping the machine for a few hours, but it was very necessary," said Garrido.

The Ashbridges Bay Outfall won accolades from the Tunnelling Association of Canada (TAC) in late 2021 for its all-remote machine acceptance, the first of its kind, enacted due to the COVID-19 pandemic.

The last kilometer of tunnel, bored below a series of 50 risers under Lake Ontario, was challenging but ultimately successful. "The team really worked together to overcome some tough ground conditions and high water inflows in the tunnel," said Savage.

The success of the TBM is just one cause for celebration. The project won accolades from the Tunnelling Association of Canada (TAC) in late 2021 for its all-remote machine acceptance enacted due to the COVID-19 pandemic. The machine acceptance, the first of its kind, enabled communication and confirmation



During tunneling in predominantly shale, the Robbins TBM and its crew bored a city-wide record of 30 rings in one day, or about 47 m (154 ft) of advance.

THE NEWS IN BRIEF

- On March 3, 2022, a 7.95 m (26.1 ft) diameter Robbins Single Shield TBM completed boring at the Ashbridges Bay Outfall Tunnel in Toronto, Ontario, Canada.
- The machine launched in March 2021 from an 85m (280 ft) deep, 16m (53 ft) diameter shaft and began its bore in predominantly shale, with limestone, siltstone and sandstone.
- During its excavation, the TBM and its crew bored a city-wide record of 30 rings in one day, or about 47 m (154 ft) of advance.
- The project won accolades from the Tunnelling Association of Canada (TAC) in late 2021 for its all-remote machine acceptance, the first of its kind, enacted due to the COVID-19 pandemic.

> "It was a challenge for all the people involved due the pandemic travel restrictions; however, due to good planning and communication we were able to go through the Acceptance Test successfully."

between the machine's assembly location in Mexico, suppliers in the U.S. and those involved in Canada. "It was a challenge for all the people involved due the pandemic travel restrictions; however, due to good planning and communication we were able to go through the Acceptance Test successfully. I think this might become quite common in the near future," said Robbins Project Manager Javier Alcala.

The completed outfall will connect to the 50 in-lake risers to enable efficient dispersion of treated effluent over a wide area of the lake, making it the largest outfall in the country. The project for the City of Toronto will improve the city's shoreline and Lake Ontario's water quality by replacing a 70-year-old existing outfall.

Robbins, Southland, and other personnel celebrate the completion of tunneling at the Ashbridges Bay Outfall Tunnel in early March 2022.

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