2021

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

SELECTION OF MICROTUNNELLING FOR SEWER CROSSING UNDER LAKE SHORE BOULEVARD IN TORONTO

PM #40065075

NASTT GLSLA CHAPTER

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- CIPP Material Systems & Installation Methodologies to Overcome Sewer Line Rehab Challenges in Ottawa

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ON THE COVER: Humber Bay Arch Bridge south of Lake Shore Boulevard West, in west Toronto.

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Journal
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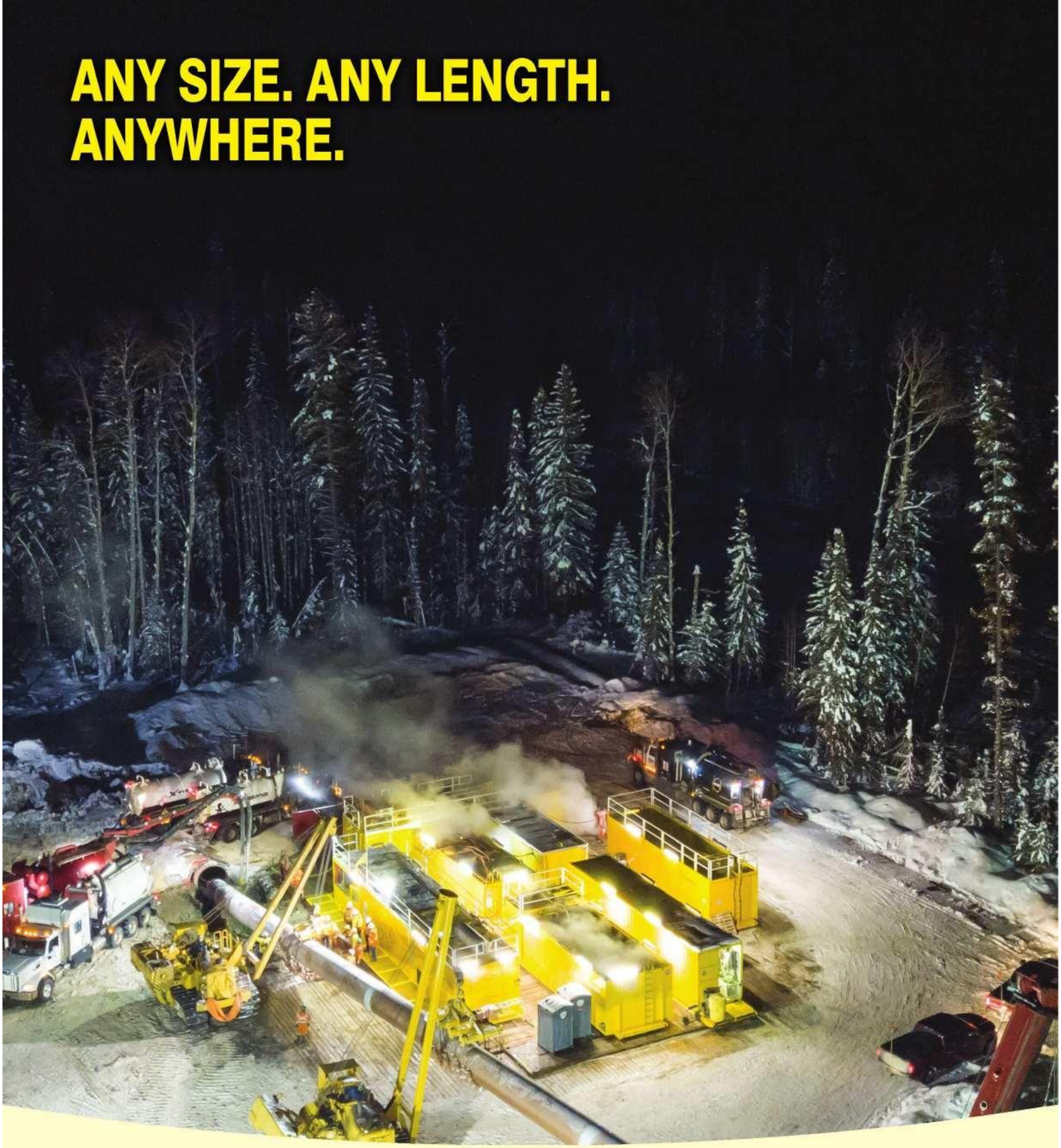
ANY SIZE. ANY LENGTH.
ANYWHERE.

Kevin Bainbridge, *GLSLA Chapter Chair*

Providing Value to Our Members

While the world continues to pivot around the pandemic, the trenchless industry continues to grow and enhance services in the infrastructure industry. The GLSLA board of directors and member volunteers are continuing to work to provide value to our members through training, publications, and the No-Dig North Show. GLSLA continues to support NASTT initiatives in adjusting traditional training course, seminars, and conference to keep the trenchless momentum in the infrastructure industry.

The three Canadian chapters of NASTT (Northwest, GLSLA, and BC) were very excited to see the industry response to the 2021 No-Dig North show in Vancouver on November 8–10 with almost 500 attendees. It was great to see industry colleagues and friends to share knowledge and experiences we have gained over the past several years. I would like to congratulate and thank all the volunteers involved, on the Planning Committee, Program Committee, Benjamin Media, and NASTT. The success of the show is a tribute to all your dedication and effort.

Planning for No-Dig North 2022, in Toronto on October 17–19, is well under way with plans to include a suite of NASTT training course in addition to the full program of high-quality peer reviewed paper presentations. Please watch out for the call for abstracts in early 2022, to get your submissions in to share your project experiences with the industry. For more information on the show, please visit *www.nodignorth.ca*. Looking forward to seeing everyone there!

We hope you enjoy this latest GLSLA *Trenchless Journal* magazine filled with great project and industry articles. For more information on GLSLA, our events, this 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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Valoriser l'association

Tandis que le monde continue de tourner autour de la pandémie, l'industrie sans tranchées poursuit sa croissance et continue d'améliorer les services d'infrastructure. Le conseil d'administration de la section GLSLA et les membres bénévoles continuent quant à eux de valoriser l'association au moyen de formations, de publications et du salon No-Dig North. Enfin, la GLSLA continue d'épauler la NASTT en adaptant les cours, séminaires et conférences traditionnels pour entretenir le dynamisme de l'industrie.

Les trois sections canadiennes de la NASTT (Northwest, GLSLA et C.-B.) ont été enchantées de la réponse de l'industrie au salon No-Dig North de 2021, qui a eu lieu à Vancouver du 8 au 10 novembre et a attiré près de 500 personnes. Il était de bon de voir collègues et amis partager les connaissances et l'expérience acquises depuis quelques années. Je tiens à féliciter et à remercier tous les bénévoles du comité de planification et du comité des programmes, ainsi que Benjamin Media et la NASTT. Ce succès est un tribut à votre dévouement et à vos efforts.

La planification du salon No-Dig North de 2022, qui se déroulera du 17 au 19 octobre, va bon train. Il est question d'ajouter une série de cours de la NASTT à toute la gamme des exposés révisés des pairs de haut niveau. Ne manquez pas l'appel à résumés au début de 2022, si vous voulez participer et faire part de votre expérience à vos collègues de l'industrie. Pour en savoir davantage salon, veuillez consulter le site Web du salon, à l'adresse *www.nodignorth.ca*. Nous espérons vous y voir tous!

Souhaitons, pour conclure, que ce tout nouveau numéro du GLSLA *Trenchless Journal* de la section GLSLA, riche d'articles sur les grands chantiers et sur l'industrie, saura vous plaire. Pour en savoir davantage sur la section, nos activités, ce magazine et nos sessions de formation, ou si vous souhaitez publier un article dans le magazine, veuillez consulter notre site Web, à l'adresse *www.glsla.ca*.

Our Chapter Members & Volunteers Are Crucial

We are a resilient industry!

The trenchless industry grows stronger every year. Even in the pandemic our membership and regional chapters are moving forward to educate the public. It's amazing when you look back at what we have done in 2021. We had an in-person and virtual No-Dig Conference in Orlando this past March, leading the industry in safely meeting face to face once again. Our regional chapters held their fall conferences and networking events all over North America. And, of course, November 8–10 was No-Dig North in Vancouver, BC!

We are so excited that No-Dig North was back again this year and the NASTT Canadian chapters worked together to host the conference. It is a must-attend event for underground infrastructure professionals. The show consisted of two days of technical paper presentations and industry exhibits in the trenchless technology field. There were also multiple networking opportunities to see those industry colleagues you've missed over the last two years and make new connections as well. The value of networking with NASTT members and industry folks is truly priceless. Our members and volunteers are innovative and creative thinkers, always looking for ways to improve technology and infrastructure and protect our environment.

NASTT's mission and vision are "to continuously improve infrastructure management through trenchless technology" and "to be the premier resource for knowledge, education, and training in trenchless technology." 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 even during uncertainty we have been able to grow. Recently, we welcomed our latest regional chapter to the NASTT family and completed our representation of the entirety of North America. NASTT is so excited to announce that we now have our first chapter in Mexico!

Looking ahead, we are currently planning the NASTT 2022 No-Dig Show to be held in Minneapolis, Minnesota, next spring – April 10–14. We are anticipating more than 2,000 attendees and more than 200 exhibitors. There are many new features we plan to roll out, including enhanced educational forums, more networking opportunities, and expanded exhibit hall time. Our industry is constantly growing in innovative ways and the No-Dig Show is representative of our industry. We are excited to bring new value and educational experiences to you in April. Visit *nodigshow.com* for all the latest details and to register or exhibit today.

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!

Nos membres et nos bénévoles sont essentiels

Quelle résilience!

L'industrie du sans-tranchées est de plus en plus robuste. Même en pandémie, nos membres et nos sections régionales privilégient l'information. Notre action en 2021 a été étonnante. Nous nous sommes réunis en personne et par voie électronique à l'occasion du congrès No-Dig d'Orlando en mars dernier, comme de véritables précurseurs du retour – en sécurité – aux réunions en personne. Les sections régionales se sont réunies pour leurs congrès d'automne et diverses activités de réseautage dans toute l'Amérique du Nord. Et n'oublions pas le No-Dig North du 8 au 10 novembre à Vancouver, en Colombie-Britannique.

Quel plaisir de nous retrouver encore cette année pour ce No-Dig North, préparé par l'ensemble des sections canadiennes de la NASTT. Le salon est un incontournable pour tous les professionnels de l'infrastructure souterraine. Ce sont deux jours de présentations techniques et d'exposition qui mettent en valeur la technologie sans tranchées. Les possibilités de réseautage se sont multipliées et nous ont permis de revoir ces collègues qui nous manquaient depuis deux ans, mais aussi de nouer de nouvelles relations. Ces liens sont tout simplement inestimables. Nos membres et nos bénévoles rivalisent d'imagination et sont constamment à l'affût de nouveaux moyens d'améliorer la technologie et l'infrastructure tout en protégeant l'environnement.

La NASTT a pour mission « d'améliorer constamment la gestion de l'infrastructure grâce à la technologie sans tranchées » et veut « être la principale source de connaissances, d'information et de formation » en la matière. Notre objectif étant d'informer, nous nous efforçons de fournir à notre communauté des outils d'apprentissage utiles et accessibles. Nous sommes donc particulièrement

fiers de notre croissance continue, même en ces temps incertains. Récemment, en effet, nous avons accueilli une nouvelle section régionale, grâce à laquelle la NASST est représentée dans toute l'Amérique du Nord. Nous avons l'immense plaisir d'annoncer notre première section… au Mexique!

Nous sommes déjà à planifier le No-Dig Show de 2022, qui aura lieu du 10 au 14 avril à Minneapolis, au Minnesota. Nous attendons plus de 2000 participants et plus de 200 exposants. Et que dire de toutes ces nouveautés en préparation : tribunes de formation améliorées, nouvelles occasions de réseautage et temps d'exposition accru. Notre industrie innove sans cesse et le No-Dig Show reflète ces innovations. Nous sommes emballés à l'idée de vous offrir en avril prochain une indubitable valeur ajoutée et de nouvelles possibilités de formation. Rendez-vous sur le site *nodigshow.com* pour avoir un avant-goût de ce qui vous attend et pour vous inscrire dès maintenant comme participant ou exposant.

Pour en savoir davantage sur notre organisation, nos comités et les avantages de l'adhésion, visitez notre site Web, à l'adresse *nastt.org*, et n'hésitez pas à nous écrire, à l'adresse *info@nastt.org*.

Il nous tarde de vous rencontrer, en congrès ou en formation!

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NO-DIG NORTH

2021 Recap

The 2021 No-Dig North show was held in Vancouver with great success on November 8–10, with almost 500 attendees and 70 exhibitors. After an extended period of time apart, it was great to see folks from the industry again in person and have the opportunity to reconnect with everyone. While there were some obvious differences this year than at previous No-Dig events, the show had the same great energy that it always has. A big draw to the show is the networking, which just can't be accomplished to the same degree online, and it was wonderful to talk shop and share insights in person rather than through a screen.

Another big draw is, of course, the technical presentations and industry expert panels. This year there were more than 75 technical presentations on topics including condition assessment, pipeline and maintenance hole rehabilitation, various new construction trenchless methods including microtunnelling, horizontal directional drilling (HDD), and auger boring, as well as new and emerging trenchless technologies. There were also multiple expert panel discussions featuring leading industry experts from across North America.

The 2022 No-Dig North show will be held in Toronto October 17–19, at the Exhibition Place. We look forward to seeing everyone there!

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MINIMIZING SOCIAL IMPACTS: SELECTION OF MICROTUNNELLING FOR A 2,400 MM SEWER CROSSING UNDER LAKE SHORE BOULEVARD IN TORONTO, ON

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ABSTRACT

The City of Toronto is embarking on a project for a new Integrated Pumping Station (IPS) that will replace the existing M&T pumping stations which are near the end of their operational life. New sewer extensions will be required to convey flow to the IPS. One of the sewer extensions is the High Level Interceptor (HLI) Extension, a 2.4 meter finished diameter gravity sewer that will convey flows from the existing HLI sewer located on the north side of Lake Shore Boulevard East to the IPS located on the south side of Lake Shore Boulevard East. Lake Shore Boulevard East is a major arterial road in Toronto with two travelled lanes in each direction. The depth of the sewer is approximately 9 meters and was constructed using a slurry microtunnel boring machine to provide active face pressure, mitigate ground loss, and to prevent disruptions to traffic on Lake Shore Boulevard East. The microtunnel crossing is approximately 65 meters in length and was successfully completed in February 2021. This article discusses: 1) Selection of microtunnelling technology to mitigate geotechnical risk; 2) Site conditions and their impact on design including the limited site area at the existing wastewater treatment plant and multiple utility crossings including a vital gas main and large diameter storm sewer; and 3) Selection of the microtunnel alignment to mitigate construction risk and social impacts while optimizing constructability.

INTRODUCTION

The Ashbridges Bay Wastewater Treatment Plant (ABTP) is the City of Toronto's largest of four wastewater treatment plants and is the second-largest wastewater treatment plant in Canada after Montreal's Jean-R. Marcotte Facility. The ABTP is currently served by the M&T pumping stations which forward approximately 70% of the inflow to the treatment plant and serve more than 1.6 million residents. The M&T pumping stations, constructed in 1911 and 1970 respectively, are reaching the end of their operational life and are to be decommissioned upon completion of construction of the Integrated Pumping Station (IPS). In addition to flow conveyed through the M&T pumping stations, two gravity conduits carry flow directly from the Coxwell Sanitary Trunk Sewer (STS) to the ABTP headworks. The City of Toronto (the City) is currently implementing a project to allow bypass of the Coxwell STS and to provide Wet Weather Flow (WWF) storage. The project is referred to as the Don River and Central Waterfront (DR&CW) program.

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To accommodate flow from the DR&CW program a new WWF pumping station (Integrated Pumping Station) is to be constructed at the ABTP in the northeast corner of the ABTP site. The City's objective for the IPS project is to provide an operationally robust, reliable solution that is fit to meet long-term City servicing requirements. The City has also required that the Coxwell STS be integrated into the IPS delivery system to optimize flow transfer to the ABTP headworks. The City's requirement for this project is to construct the IPS with a risk mitigation approach to manage the City's risks during construction and ensure that the IPS has a high degree of operability for Operations and Maintenance (O&M) staff.

Black & Veatch is responsible for conceptual design, preliminary design, detailed design, and contract administration of the IPS project. The project was split into three construction contracts: the site preparation contract (Construction Contract 1), the tunnelling and excavation contract (Construction Contract 2), and the pump house, build-out and commissioning contract (Construction Contract 3). Substantial performance of Construction Contract 1 (CC1) was achieved in October 2019 and Construction Contract 2 (CC2) began shortly thereafter. Detailed design for Construction Contract 3 (CC3) is currently underway and is expected to be completed in 2022. Construction of CC3 is expected to begin in Q4 of 2023 and be completed by the year 2032.

The scope of work for IPS CC2 includes the following construction activities:

- Completion of shaft excavation and concrete lining works for two Pump Station Screen Building shafts, the MTI/LLI Conduit Diversion Shaft, and a microtunnel reception shaft provided for construction of the HLI Extension;
- Completion of rock tunnel excavation and lining for the MTI/LLI Extension, the Coxwell Bypass Connection Tunnel and the WWF and MTI/LLI interconnection tunnels between the Screen Building and future Pump House;
- Completion of soft ground microtunnelling for the HLI Extension (2.4 m diameter soft ground microtunnel with a length of 65 m and a depth of 9 m below grade underneath Lake Shore Boulevard East [LSB East]).

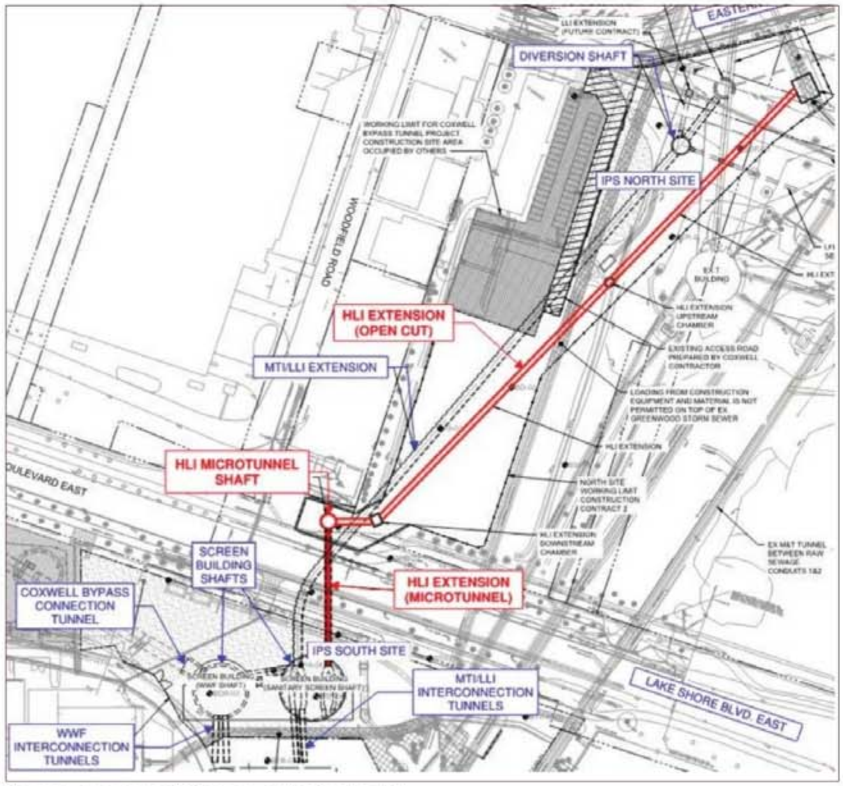

Figure 1. Overview of IPS Construction Contract 2.

Figure 1 shows an aerial overview of the work that will take place under CC2.

This article discusses the design of the HLI Extension microtunnel with a focus on construction risk mitigation and mitigation of social impacts.

DESIGN

The HLI Extension is a new 2.4 meter nominal diameter sewer conduit with an approximate total length of 340 meters that will divert flows from the existing M&T Pumping Station, located south of Eastern Avenue, to the new Screen Building HLI wet well on the south side of LSB East. The LSB East crossing is approximately 65 meters in length and is located at a depth of approximately 9 meters below grade.

This section provides a summary of the detailed design activities that were completed for the HLI Extension trenchless crossing:

- Review and assessment of geotechnical conditions;
- Selection of trenchless method based on risk, local market application and cost;
- Selection of alignment and shaft location based on risk, constructability, social impacts, and cost.

Geotechnical Conditions

During detailed design, under the direction of Black & Veatch, a geotechnical and hydrogeological investigation was carried out by Thurber Engineering Ltd. (Thurber). According to the Geotechnical Data Report (GDR) prepared by Thurber in April 2017, the subsurface conditions in Ashbridges Park (north of LSB East) and Ashbridges Bay Treatment Plant (south of LSB East) generally consist of the following:

- A layer of very soft to very stiff fill extending to depths of 2 to 9 meters in a loose to compact condition. The composition of the fill ranged from silty clay to gravelly sand and contained debris consisting of bricks, concrete, asphalt, glass, and organic material;
- South of LSB East a layer of cohesionless deposits consisting of sandy silt, silty sand, and sand was encountered below the fill with a thickness ranging from 1.5 to 5.0 meters;
- In all boreholes a layer of silty clay ranging in thickness from 2.1 to 10.7 meters was encountered below the fill or the cohesionless soil layer. The consistency of the silty clay to clayey silt varied from very soft to very stiff;

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- Plastic glacial till extending to the Georgian Bay Formation shale bedrock was encountered in some boreholes and consisted of a matrix of silty clay with trace sand and trace gravel with a very soft to very stiff consistency. The thickness of the plastic till layer ranged from 2.3 m to 5.1 m;
- The Georgian Bay Formation consists of fresh to slightly weathered, fine grained, very thinly to thickly bedded, weak to medium strong shale with occasional interbeds of slightly harder limestone. Typically, the top 1 m to 3 m of bedrock is more fractured and weathered, then transitions to more intact rock at depth. The soil/rock interface generally occurs at depths of 12 to 18 meters below grade;
- The groundwater levels measured during the geotechnical and hydrogeological investigation ranged from 3.3 m to 5.8 m below the existing grade within the overburden soils.

Selection of Trenchless Method

Open cut construction was not feasible for this crossing for two main reasons. The first is that open cut construction would have required long-term closures of LSB East. LSB East is a major arterial road in Toronto with two travelled lanes in each direction and is the major connector between Toronto's east-end neighbourhoods and downtown Toronto. LSB East experiences high traffic volumes daily especially during rush hour. It was not feasible to close all or a portion of LSB East long-term as this would have been very disruptive to residents commuting between east end neighbourhoods and downtown Toronto.

Another reason open cut construction was not feasible for this crossing was because the HLI Extension crosses below several major utilities including a high-voltage duct bank and a vital gas main. It would not have been practical to relocate these utilities around the work area. Supporting them in place and excavating around them would have required extensive coordination with the utility owners and may not have been possible. In addition, the risk of damaging or impacting the utilities would have been high in an open cut scenario. Therefore, it was decided that the HLI Extension crossing would be installed using trenchless methods. The selection of a trenchless method of construction required consideration of the depth of the tunnel alignment, the size of the conduit,

> **"THE M&T PUMPING STATIONS, CONSTRUCTED IN 1911 AND 1970 RESPECTIVELY, ARE REACHING THE END OF THEIR OPERATIONAL LIFE AND ARE TO BE DECOMMISSIONED UPON COMPLETION OF CONSTRUCTION OF THE INTEGRATED PUMPING STATION (IPS).**

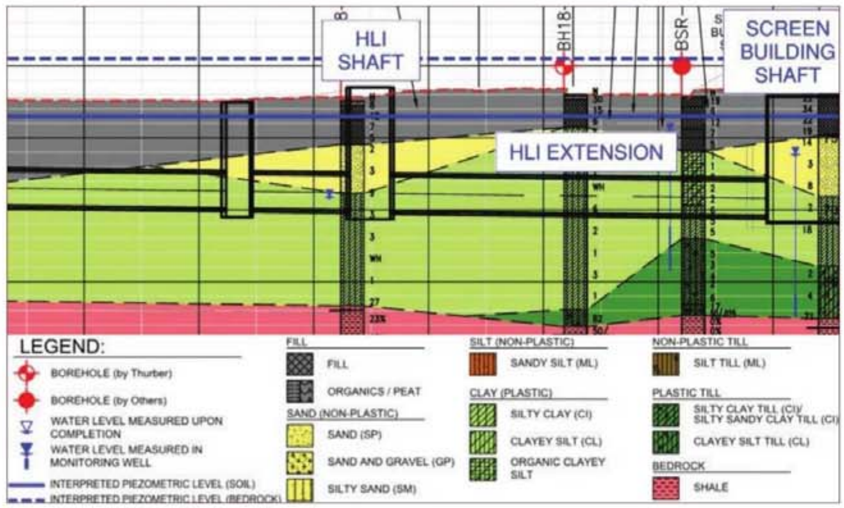

Figure 2. 2-D Subsurface Profile for HLI Extension Crossing of LSB East (Thurber, 2017).

the geotechnical conditions anticipated, the depth of the water table, and the risks associated with the technique.

The HLI Extension crossing was anticipated to be excavated through an initial full face of very soft to stiff, but generally very soft to firm plastic clay consisting of silty clay and clayey silt to organic clayey silt materials. Sand, sandy silt and silt seams, peat, trace shell fragments and rootlets were expected within the plastic clay unit. The conditions were then expected to transition to a mixed face condition consisting of interchanging layers of very loose to compact non-plastic silty sand to sand to firm cohesive silty clay fill materials and plastic clay deposits of generally very soft to firm silty clay, clayey silt to organic clayey silt materials. Figure 2 shows the 2-D Subsurface Profile of the HLI Extension based on the geotechnical investigation. The soil was expected to exhibit flowing behaviour in an unsupported vertical face; this classification was done according to Tunnelman's Ground Classification (Heuer, 1974). Due to the expected flowing behavior, Black & Veatch recommended a tunnel system that continuously supports the soil during excavation.

The following trenchless methods were evaluated for the crossing: pipe ramming, open face tunnelling and microtunnelling.

Pipe Ramming

Pipe ramming involves using pneumatic percussive blows to drive a steel casing pipe through the ground. Once the casing pipe has been installed, a carrier pipe is installed within the casing. Pipe ramming is well suited for short crossings in homogeneous, cohesive soils. Because the crossing was anticipated to be constructed in heterogeneous soils (a mixture of sand, clayey silt, and silty

clay), pipe ramming would not have been suitable for the crossing. The casing pipe could have easily deviated from its alignment if there was a sudden change in the consistency of the soil or if there was a zone of very loose, flowing soil. In addition, because flowing ground was expected there was a risk that the soil could flow through the pipe and into the shaft resulting in ground loss and surface settlement. For these reasons pipe ramming was not considered for the HLI Extension crossing.

Open Face Tunnelling

Open face tunnelling involves advancing a digger shield through the soil by pushing off an assembled tunnel liner product such as liner plates or by jacking the pipe behind the shield from the launch shaft. The digger shield provides protection for workers as they excavate the soil within the shield. Sand baffles may be used at the face of the digger shield to increase the stability of the face. Open face tunnelling is only viable if the face of the tunnel is stable. For the HLI Extension crossing, stabilizing the face would require advanced dewatering and ground improvement ahead of the digger shield. Extensive dewatering had the potential to induce ground settlement beneath LSB East. Surface settlement on LSB East would not have been tolerated due to the potential for significant third-party impacts. LSB East is a major arterial road in Toronto and any lane reductions or lane closures on LSB East would significantly affect traffic. In addition, due to the flowing ground behavior of the soil it was likely that frequent ground improvement would have been required ahead of the digger shield. This would have likely resulted in very slow advance rates and increased costs. If ground improvement would have been inadequate there was a risk of ground loss and settlement. Due to these risks, the use of open face tunnelling was not recommended for this crossing.

Microtunnelling

To mitigate the potential for surface settlement and to continuously support the vertical face of excavation during completion of the crossing, microtunnelling was recommended as the trenchless method. Microtunnelling is a steerable trenchless method that provides pressure at the excavation face to mitigate ground loss and uses remotely controlled pipe jacking to install pipe. The pipe is installed within the shaft and pushed behind the microtunnel boring machine (MTBM). Microtunnelling is well suited to deal with the anticipated challenges of tunnelling in saturated sands and gravel conditions and situations where the water table is high. Microtunnelling allows the operator to stabilize the cutting face by adjusting the face pressure and rate of excavation to counterbalance and equalize the in-situ ground pressure at the face of excavation. The risk of ground loss and surface settlement is therefore low.

A comparison of open face tunnelling and microtunnelling is provided in Table 1.

Table 1. Comparison of Open Face Tunnelling and Microtunnelling

TRENCHLESS METHOD	ABILITY TO ACHIEVE TOLERANCES	SUITABILITY FOR SUBSURFACE CONDITIONS	MITIGATION OF GROUND LOSS AND POTENTIAL DAMAGE	TYPICAL LOCAL MARKET APPLICATION
Open Face Tunnelling	✓ (with frequent surveying)	✓ (with ground improvement)		
Microtunnelling	✓	✓	✓	✓
Note: ✓ Satisfies Requirement				

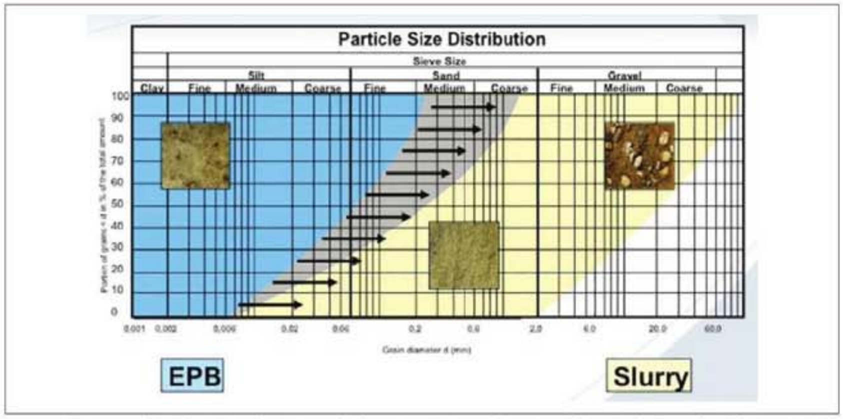

Figure 3. Range of Application for EPB and Slurry TBMs Based on Particle Size (Herrenknecht, M., 2001).

Advantages of microtunnelling include:

- Very high accuracies for line and grade: A laser guidance system is placed within the MTBM to accurately control the line and grade of the pipe. This ensures that the pipe will reach the reception shaft at the design elevation and will be able to convey the design flows.
- Low risk of ground settlement and heave: An equalized pressure system is continuously maintained at the face of the MTBM. The face pressure and advance rate can be adjusted to suit minor changes in ground conditions.
- One-pass technique: There is no need for a casing pipe because the pipe that is jacked behind the machine is the product pipe.
- Local market application: Microtunnelling is frequently used in the Greater Toronto Area and local contractors are capable of installing pipe diameters of 2,400 mm.
- Dewatering is not required because the excavation face is pressurized. Soil and groundwater pressures are equalized with the face pressure.
- Man-entry is not required: Unlike open face tunnelling, workers are rarely required to enter the tunnel because the MTBM is remotely operated.

One potential limitation of microtunnelling was identified: The concurrent process of excavation and lining in the microtunnel operation prevents installation of piles below the invert of the pipe within the finished tunnel. There is a risk of long-term settlement of the pipe if the pipe is not installed on piles. The feasibility of using ground improvement methods beneath the pipe in lieu of piles was assessed. It was determined that the

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completion of ground improvement methods such as jet grouting beneath the pipe prior to microtunnelling would change the soil composition and create non-homogeneous ground conditions which could negatively affect the ability of the MTBM to advance through the soil. In addition, mobilization of ground improvement equipment on LSB East was not recommended due to potential impacts to traffic, the risk of damaging existing utilities, and the risk of causing surface heave. A risk assessment was conducted and it was determined that the risk of long-term settlement of the pipe was minimal and the risk limited to applications where adjacent and currently unforeseen dewatering operations lowered the groundwater table and consolidated soil beneath the pipe (below a depth of 9 meters). To mitigate the risk of this low-risk settlement event, Black & Veatch included notes in the contract documents that prohibit lowering of the groundwater table below the base of the pipe after installation of the pipe.

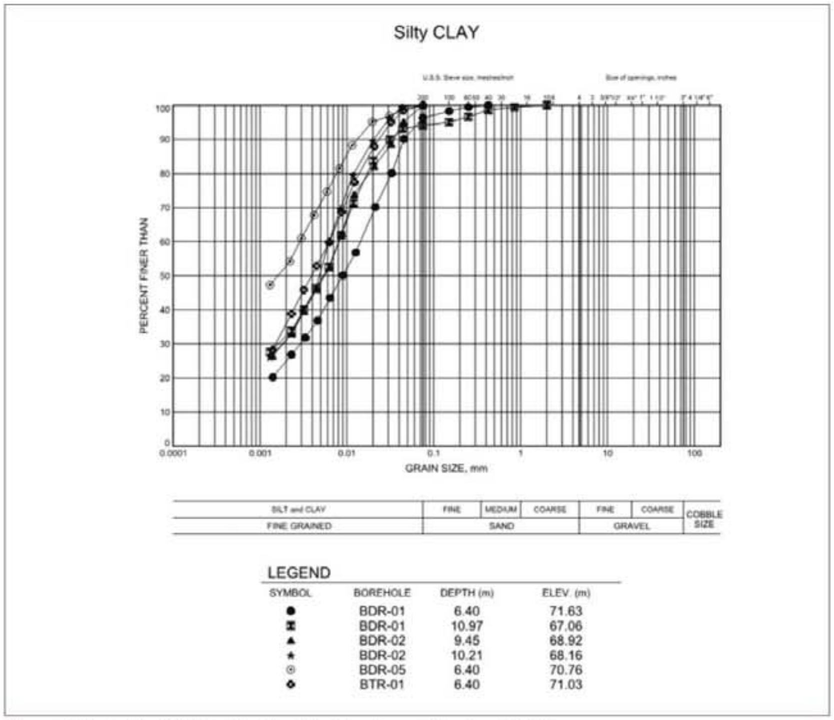

Figure 4. Grain Size Distribution for Silty Clay Layer (Thurber, 2017).

Selection of Microtunnel Boring Machine

There are two types of microtunnel boring machines which provide a pressurized excavation chamber for soft ground soil excavation: slurry MTBMs and Earth Pressure Balance (EPB) MTBMs. In order to determine which type of machine would be better suited for excavation of the HLI Extension crossing, the following factors were considered: subsurface conditions, local contractor experience, and site restrictions.

In general, EPB machines are better suited for fine-grained cohesive soils and slurry machines are better suited for non-cohesive coarse-grained soils, although both machines can successfully be used for most soft ground conditions. See Figure 3 for the general range of application for EPB and slurry machines.

The grain size distributions of the soil types present at the site were examined as part of the geotechnical investigation. At the tunnel design elevation, the soils were expected to be primarily fine-grained and cohesive. See Figure 4 for the grain size distribution of the silty clay layer. After comparing the grain size distribution of the silty clay layer to Figure 3, it appeared that an EPB machine would be better suited for the type of soil at the tunnel elevation. If a slurry machine was used in cohesive material, there was a risk that the machine could become clogged.

Obstructions such as cobbles and boulders were expected within the overburden deposits at the project site. With an EPB machine, obstructions must pass through the openings in the face of the MTBM and then through the screw conveyor of the machine. If an irregularly shaped obstruction larger than the diameter of the screw conveyer enters the excavation chamber, there is a possibility of the obstruction jamming the screw conveyor intake. With a slurry machine, cobbles and boulders are crushed by a rock crusher prior to being transferred to the slurry mucking system.

In terms of site restrictions, slurry machines require a larger footprint on the surface for the separation plant. The design team determined that there was enough space on both the north and south sites to accommodate a slurry separation plant.

Local contractors in the Greater Toronto Area are experienced with microtunnelling and many contractors own slurry TBMs. Based on local market conditions at the time of the assessment, it was expected that an EPB microtunnelling machine would need to be purchased specifically for the project. This would be less cost-effective than using a slurry machine that would already be available locally. In addition, at the time of the assessment, local contractors did not have experience with EPB machines for microtunnelling and there would likely be a learning curve in using these machines. This could make it more difficult for contractors to successfully complete the project.

Although EPB machines are generally better suited for fine-grained, cohesive soils, a slurry machine would also be effective in stabilizing the excavation face. Therefore, a slurry machine was recommended for this crossing. Anti-clay additives or bentonite conditioning could be used to mitigate the risk of the slurry machine becoming plugged in cohesive soils. The challenges and risks involved with using a slurry TBM were communicated in the project Geotechnical Baseline Report (GBR) and discussed with local contractors prior to construction, to ensure appropriate risk-mitigating measures such as using appropriate soil stabilization products, altering the advance rate, and appropriate instrumentation and settlement motoring were in place.

Identification of Risk, Constructability & Social Impacts

The final step in the design process was to select the alignment for the microtunnel drive. Construction risk, constructability issues, social impacts, and cost were assessed.

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The following risks were identified for the crossing:

1. Risk of striking the Woodfield Road Storm Sewer pile caps: The Woodfield Road Storm Sewer, located on the south side of LSB East, was relocated during CC1 and was constructed on piles. The HLI microtunnel crosses below the relocated Woodfield Road Storm Sewer. Sufficient clearance between the pile caps and the HLI microtunnel was required to mitigate the risk of striking the pile caps which could damage the structure and impede progress for the microtunnel crossing. This would result in additional costs and schedule delays.

2. Risk of schedule delay to relocate the 300 mm Enbridge gas main on north side of LSB East: There is a 300 mm diameter vital gas main that runs east-west along the north side of LSB East. The permitting and approval process to relocate a vital gas main is typically a very lengthy process. It was preferable to avoid relocating the gas main to mitigate the risk of delaying the project schedule. The HLI Shaft needed to be located at least 600 mm away from the gas main as per Enbridge clearance requirements.

3. Risk of impacting the hydraulic performance of the system: The HLI Extension had to enter the Screen Building perpendicular to the screen inlet structure for a length of at least 5 pipe diameters (12 meters) from the screen inlet. The hydraulic calculations and physical modelling were performed using these criteria. Modifications to the entry angle of the HLI Extension had the potential to affect the hydraulic performance of the overall system.

4. Risk of schedule delay to obtain approval from Toronto Transportation Services: Contractor access to the HLI Shaft compound was required from either LSB East or Eastern Avenue. Toronto Transportation Services (TTS) had to approve the Contractor access route. LSB East experiences heavy traffic during rush hour. There was a risk that TTS would not allow the contractor to access the HLI Shaft compound from LSB East due to the potential traffic impacts. If TTS refused to provide approval, the HLI Extension alignment would need to be revised which could result in schedule delays and additional costs.

5. Risk of future pipe settlement caused by dewatering: As discussed in earlier, because the concurrent process of excavation and lining in the microtunnel operation prevents installation of piles below the invert of the pipe within the finished tunnel, there is a risk of long-term settlement of the pipe caused by future dewatering. The use of ground improvement methods to mitigate the risk was assessed but was not recommended due to potential impacts to the microtunnelling operation, potential impacts to traffic, the risk of damaging existing utilities, and the risk of causing surface heave. To mitigate the risk of future pipe settlement, the contract documents prohibited lowering the groundwater table below the base of the pipe after installation of the pipe.

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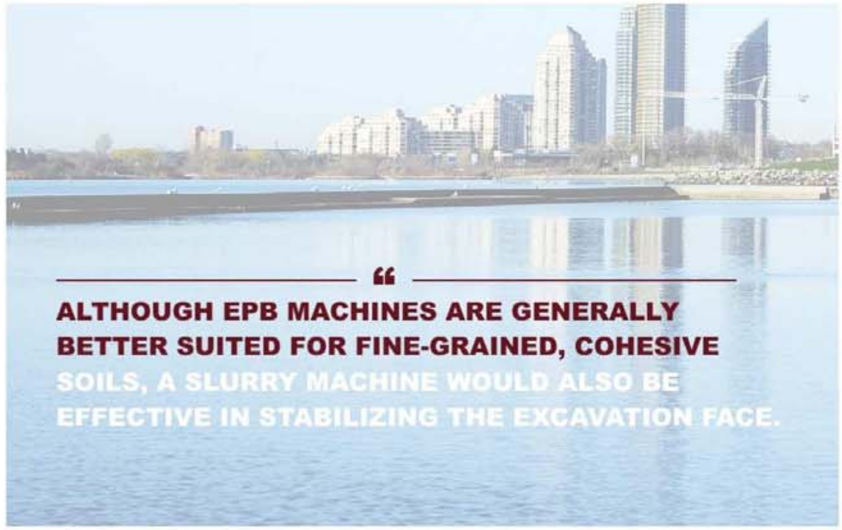
The following constructability issues were identified for the HLI microtunnel crossing:

1. Constructability of curved microtunnels: Following a market analysis, the smallest curve radius the design team identified as constructed locally and for a 2.4 m diameter microtunnel was 500 m. At the time of the assessment, the design team identified a 2.4 m diameter microtunnel with a 250 m turning radius planned for a project in the United Kingdom. The work in the United Kingdom was proposed in more favourable soils conditions. To mitigate the risk of the contractor not being able to complete the microtunnel crossing within the specified tolerances, a straight microtunnel drive or a curved drive with a minimum radius of 500 m was recommended.
2. Limited site area at ABTP: The IPS South Site is located at ABTP, a live wastewater treatment plant. There was limited area on the site for construction and impacts to the operation of the treatment plant would not be tolerated. The design team had to ensure there was enough site area for the microtunnelling operation including the slurry separation equipment, control container, crane, and laydown area.

The following social impacts were considered:

1. Traffic impacts on LSB East.: LSB East is a major arterial road that experiences heavy traffic especially during the two rush-hour periods. There could be significant effects on traffic if trucks were permitted to access the site from LSB East. It was recommended to provide access to the HLI Shaft from Eastern Avenue and not LSB, in order to mitigate traffic impacts on LSB East.
2. Impacts to the Martin Goodman Trail: The Martin Goodman Trail is a multi-purpose recreational trail that links the east end of Toronto to the downtown core. The trail is used by cyclists, pedestrians, skateboarders, and other users. Many cyclists use the trail on their daily commute to the downtown core. It was critical to minimize impacts to the trail.



“ ALTHOUGH EPB MACHINES ARE GENERALLY BETTER SUITED FOR FINE-GRAINED, COHESIVE SOILS, A SLURRY MACHINE WOULD ALSO BE EFFECTIVE IN STABILIZING THE EXCAVATION FACE.

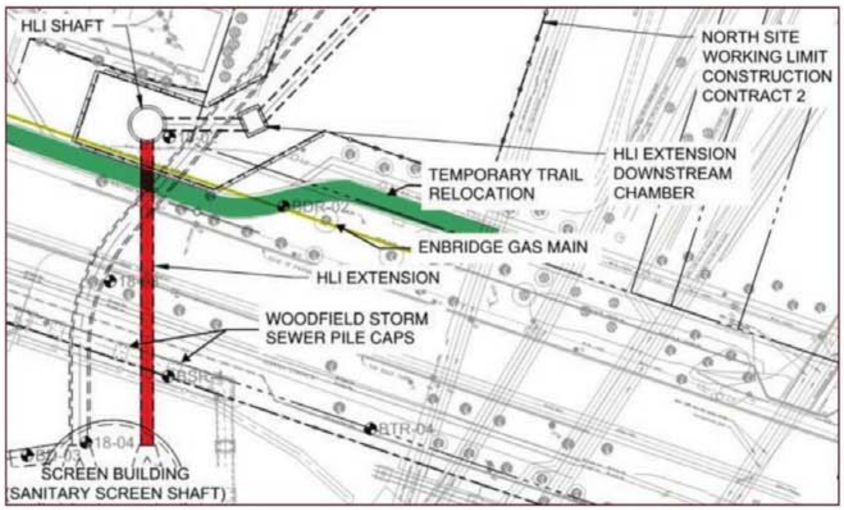


Figure 5. Alternative 1 – Launch from Screen Building Shaft with Reception Shaft Located in Boulevard.

Identification and Evaluation of Alignment Alternatives

Four alternatives were identified for the microtunnel alignment and were evaluated based on risk, constructability, social impacts, and cost:

Alternative 1: Launch the microtunnel from the Screen Building shaft to a reception shaft in the boulevard north of LSB East. Construct the rest of the HLI Extension using open cut construction with a bend and additional access chamber. Figure 5 shows the alignment for Alternative 1 in red.

The advantages of Alternative 1 included:

- Clearance from the Woodfield Road Storm Sewer piles was maximized (2.2 m clearance);
- Relocation of the 300 mm gas main was not required;
- HLI Extension flow was perpendicular to the screen inlet;
- Curved microtunnel was not required;
- Truck access from LSB East was not required;
- The shaft footprint in Ashbridges Park was reduced.

The disadvantage of Alternative 1 was that it required an additional bend including an access chamber for the open cut portion of the alignment. There was an additional cost associated with the access chamber. Alternative 1 also required relocating the Martin Goodman Trail and sidewalk on the north side of LSB East. The estimated cost of Alternative 1 was $5.3 million.

Table 2. Evaluation of HLI Extension Alignment Alternatives Against Cost, Constructability, Social Impacts, and Risk.

Alternative	Risk of striking Woodfield pile caps	Risk of schedule delay due to Enbridge permitting	Risk of impacting hydraulic performance	Risk of traffic impacts on LSB East and TTS delay	Constructability issues with curved microtunnel	Risk of ground loss during hand mining	Cost[1]
1							$5.3M
2		X		X			$5.9M
3	X					X	$5.4M
4	X		X		X		$5.1M

Note 1: Preliminary cost estimate included a 30% contingency. Cost of Alternative 3 did not include cost of ground improvement for hand mining.

Alternative 2: Two microtunnel drives (one from the Screen Building to a reception shaft in the boulevard, and a second from the rugby field to the same reception shaft). Figure 6 shows the alignment for Alternative 2.

The advantages of Alternative 2 included:

- Clearance from the Woodfield Road Storm Sewer piles was maximized (2.2 m clearance);
- HLI Extension flow was perpendicular to the screen inlet;
- Curved microtunnel was not required.

The disadvantages of Alternative 2 included:

- Truck access from LSB East was required;
- Potential schedule delays associated with completion of a traffic study and coordination with Toronto Transportation Services;
- Relocation of the 300 mm gas main was required.

Obtaining approval from Enbridge to relocate a vital gas main would present a significant risk of delay to the project schedule. In addition, access from LSB East would require completion of a traffic study to analyze the potential impacts to traffic on LSB East as a result of this new site access. Following completion of the study, consultation with and approval from Toronto Transportation Services would be required to provide access to the compound from LSB East. This could result in schedule delays and additional costs if the alignment needed to be revised.

The estimated cost of Alternative 2 was $5.9 million.

Alternative 3: Launch the microtunnel from the rugby field and enter the Screen Building at an angle; hand mine or open cut a 14 m long connection to the screen inlet. Figure 7 shows the alignment for Alternative 3.

The advantages of Alternative 3 included:

- Relocation of the 300 mm gas main was not required;
- Curved microtunnel was not required;
- Truck access from LSB East was not required.

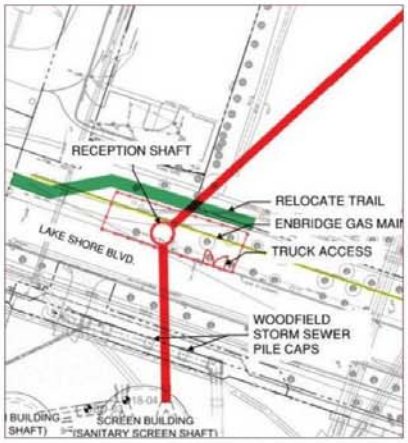


Figure 6. Alternative 2 – Two Microtunnel Drives to a Common Reception Shaft.

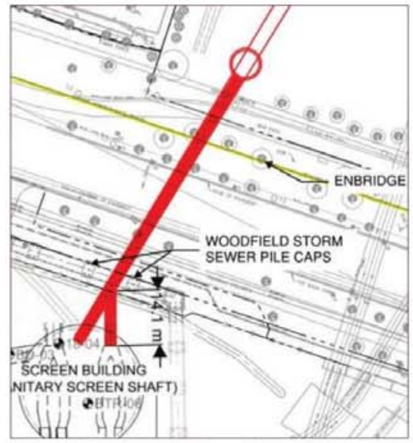


Figure 7. Alternative 3 – Launch Microtunnel from the Rugby Field at an Angle; Hand Mine or Open Cut 14 m Section Perpendicular to Screen Inlet.

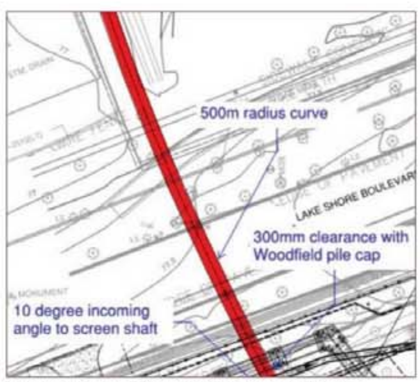


Figure 8. Curved Microtunnel with a Turning Radius of 500 m Entering the Screen Shaft at a 10-degree Angle.

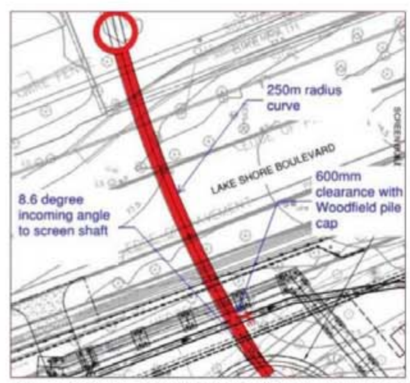


Figure 9. Curved Microtunnel with a Turning Radius of 250 m Entering the Screen Shaft at an Angle of 8.6 Degrees.

The disadvantages of Alternative 3 were as follows:

- The microtunnel would only have approximately 600 mm of clearance from the Woodfield Road Storm Sewer pile cap. It was recommended to maintain at least 1 m of clearance from the pile cap to mitigate the risk of striking the pile cap and impacting the Woodfield Road Storm Sewer;

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- This alternative would require hand mining or an open cut excavation to install the section of pipe that would be perpendicular to the screen inlet. The microtunnel pipe would need to be broken into to make the connection. Hand mining and open cut excavations would require extensive dewatering or expensive ground improvement below the Woodfield Road Storm Sewer, the Screen Building, the electrical duct bank, and the watermain. There was also a risk of ground loss in the loose fill and soft silty clay soils, especially for a hand-mined connection.
- Cost increase associated with ground improvement and hand-mined connection to screen building.

The estimated cost of Alternative 3 was $5.4 million.

Alternative 4: Curved microtunnel incoming at slight angle to the Screen Building. An incoming angle of less than 10 degrees was not anticipated to have an impact on the hydraulic performance of the system. Figures 8 and 9 on page 20 show the alignments for Alternative 4.

The advantages of Alternative 4 included:

- Relocation of the 300 mm gas main was not required;
- Truck access from LSB East was not required.

The disadvantage of Alternative 4 was as follows:

- A curved microtunnel was required. At the time of the assessment, local contractors did not have experience constructing a 2.4 m diameter microtunnel with a turning radius less than 500 m. There was a risk that the contractor would not be able to achieve the specified tolerances or complete the drive successfully due to lack of experience with a turning radius less than 500 m. If a curve with a 500 m turning radius was used, the clearance to the Woodfield Road Storm Sewer pile cap would only be 300 mm. It was recommended to provide at least 1 m of clearance to mitigate the risk of striking the pile cap and impacting the Woodfield Road Storm Sewer.

Selection of Alignment

Each alternative was evaluated against cost, constructability, social impacts, and risk. See Table 2 on page 20 for the results of the evaluation.

Figure 10. Microtunnel Setup for the HLI Extension in the Screen Building Shaft.

Based on the comparison of the alternatives in Table 1, Alternative 1 was the recommended alternative because it was the only alternative that sufficiently mitigated risk and addressed constructability issues and social impacts. Alternative 4 was estimated to be approximately $200,000 less expensive to construct than Alternative 1, but Alternative 4 did not sufficiently mitigate risk, constructability, and social impacts. The Alternative 1 alignment had an additional bend which required an access chamber. There was an additional cost associated with the access chamber (approximately $35,000) but the cost was negligible compared to the cost of the HLI Extension as a whole. From a City Operations perspective, an additional bend may have been undesirable; however, after consultation with the City, it was agreed that the addition of the access chamber would allow City Operations staff to access all sections of the sewer in a safe manner. From a hydraulic modelling perspective, the additional bend did not have a significant effect on the performance of the system. With Alternative 1 the microtunnel drive would be from the Screen Building shaft to a reception shaft north of LSB East. A separate launch shaft was not required for the microtunnel crossing since the Screen Building shaft was large enough to accommodate the jacking frame, thrust block, and other launching equipment. This optimized the site area available on the South Site and allowed for a smaller shaft footprint on the North Site (the locations of the South Site and North Site are shown on Figure 1) since no ancillary equipment would be required for the reception shaft. The reduced shaft footprint on the North Site mitigated the overall impact to the recreational trail and to park users. With Alternative 1, the Martin Goodman Trail and sidewalk on the north side of LSB East needed to be temporarily or permanently relocated depending on City requirements. Through consultation with Toronto Transportation Services and Toronto Parks, Forestry & Recreation, it was agreed that the trail and sidewalk would be relocated temporarily and restored upon completion of the microtunnel drive and construction of the HLI Shaft.

CONSTRUCTION

Construction of the HLI Extension microtunnel crossing was completed between January 26 and February 2, 2021 (a total of six working days). Figure 10 is a photograph of the microtunnel setup in the

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Screen Building shaft. A total of 16 pipes were installed for the crossing. Prior to construction, STRABAG Inc., the General Contractor for IPS CC2, requested that the microtunnel pipe diameter be increased from 2,400 mm to 2,500 mm internal diameter because the 2,400 mm pipe size was not readily available at the time. Black & Veatch reviewed the implications of this change and concluded that the hydraulic impacts due to this change were minimal and the City accepted the change. The microtunnel work was completed by Ward & Burke, STRABAG Inc.'s microtunnelling subcontractor, using a Herrenknecht AVN2500 microtunnel boring machine. The crossing was successful in achieving the risk mitigation desired: the slurry MTBM was successful in mitigation of ground loss, control of ground movement, and excavating through mixed face soil conditions; the crossing was completed on line and grade; there were no adverse impacts to third party utilities; site space was sufficient for operation; and there were no major impacts to the Martin Goodman Trail or to traffic on LSB East. Settlement monitoring on LSB East was conducted daily during the microtunnel operations to monitor potential settlement of the pavement surface. Weekly settlement monitoring was conducted for 12 weeks after microtunnelling was completed. No adverse impacts to the road surface were observed during or after the microtunnel operation.

CONCLUSIONS

When designing a trenchless crossing of a major arterial road in an urban area, the following criteria should be considered:

- Constructability including selection of trenchless method based on geotechnical conditions, assessment of the local trenchless market, site area available, and consideration of utility clearances.
- Social impacts including impacts to recreational trail users and impacts to traffic.
- Construction risk including the risk of utility strikes, schedule delay, and ground loss.
- Lifecycle cost including capital cost of construction and long-term operation and maintenance.

It is recommended to evaluate alternatives against all four criteria to ensure that the selected design mitigates risk to the owner, ensures optimal operability of the system, and mitigates negative impacts to the public.

REFERENCES

Herrenknecht, M. (2001) – Mixschilde – Sicherer Vortrieb in vielschichtigen Boden, Technische Unterlagen Herrenknecht AG Schwanau.

Heuer, R. E. (1974) – Important ground parameters in soft ground tunneling, Subsurface exploration for underground excavation and heavy construction, American Society of Civil Engineers, New York.

Thurber Engineering Ltd. (2018) – Geotechnical Data Report V4, Ashbridges Bay Treatment Plant Integrated Pumping Station Phase 2 Geotechnical and Hydrogeological Investigation, Canada.

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BROAD IMPLEMENTATION OF CIPP MATERIAL SYSTEMS & INSTALLATION METHODOLOGIES TO OVERCOME SEWER LINE REHABILITATION CHALLENGES IN OTTAWA

Kyle Peori, Clean Water Works Inc., Ottawa, ON

ABOUT THE PROJECT

City of Ottawa Contract CP0001048 was a municipal trenchless sewer CIPP lining rehabilitation program covering over 1,500 m of sanitary, combined, and storm sewers; ranging in diameters from 225 mm to 1,800 mm, in a dense urban setting in the nation's capital, completed over a schedule encompassing all four seasons.

The contract documents allowed for the design and construction of CIPP systems employing a variety of liner-resin systems and installation and curing methodologies including hot water, steam, and UV. Clean Water Works (CWW) opted to employ all three methods of CIPP lining over the project, optimizing the advantages, and minimizing the disadvantages, of each method based on a qualitative risk assessment for each sewer condition, location, and use.

This project presented numerous atypical technical challenges that required broad and complex methods of site preparation such as: open-cut excavation through bedrock, an in-water set-up requiring swamp-mats, and a shallow installation that required a structural scaffold build to achieve the necessary head for a water inversion installation. The technical challenges also necessitated four unique CIPP material system solutions, utilizing multiple design standards. These included felt liner with non-VOC resin, felt liner with filled polyester resin, a two-component combination pull-in and inversion felt tube with filled polyester resin, and hybrid fibreglass reinforced felt liner with neat polyester resin.

This article provides an overview on one of the CIPP lining methods (hybrid reinforced liner and neat polyester resin); it also reviews the qualitative risk assessment variables used to select each material system and design standard, details the atypical site preparation challenges and solutions, and presents the lessons learned from the project.

INTRODUCTION

The city of Ottawa has one of the country's largest geographical areas at 2,778 km^2. In comparison, Toronto's land area is 630 km^2 and Vancouver is 115 km^2.

The sewers in Ottawa date back to 1875, and today the waste collection system consist of 2,846 km of sanitary sewers, 108 km of combined sewers, and over 92,000 manholes. The storm system consists of more than 2,700 km of sewers, and due to the large rural area there are over 1,200 km of municipal drains and more than 6000 culverts.

In January 2001, the City of Ottawa amalgamated with 11 area municipalities including the Regional Municipality of Ottawa-Carleton. This new city adopted hundreds of km of collector and interceptor sewers from the former Municipality and thousands of rural sewers and culverts. Like many municipalities, the new city was now challenged with the task of not only maintaining its existing aging infrastructure, but now had the added responsibility of maintain and repairing its newly acquired underground infrastructure.

It was at this time that the City's rehabilitation platform shifted significantly from a normal high-production centralized rehabilitation program to a program that consists of projects with exceptional rehabilitation challenges, for which unique solutions are essential. Due to the varying scope and complexity, each site is treated and managed as a project within a project.

The City of Toronto and Montreal and other municipalities, for example, typically

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release CIPP rehabilitation programs in the range of 5 to 20 km with sewers of smaller diameters, and generally in the same wards or geographical areas of the city. Sewers with larger diameters such as collector sewers, trunk sewers, or outfalls are usually tendered separately. Integrated projects requiring a substantial amount of civil work or having significant bypass requirements are also tendered separately. The City of Ottawa contract combined all of the above.

Below are some of the project specifics from the 2017 City of Ottawa Trenchless Sewer Lining Program – this article will elaborate on the sites and outline in more details the risks, challenges, solutions, and lessons learned from each location.

- Pipe sizes ranging from 225 mm to 1,800 mm
- Bypass ranging from 10 l/s to 240 l/s
- Use of felt liners, reinforced fiberglass hybrid liners, UV liners
- Use of non-VOC resin, filled polyester resin, and neat polyester resin
- Use of inversion liners, pull-in liners, and inverted stay-in-place calibration liners
- Steam cure, water cure, and UV cure
- Rehabilitation of local residential sanitary sewers, sanitary collector sewers, small and large diameter culverts
- Work performed over all four seasons
- Manhole modifications and installation
- Access roads and swamp mats
- Styrene cure water treatment on site
- Styrene odour mitigation
- Lengthy buried by-pass piping
- Collector roads and highway on-ramp locations

NON CIRCULAR CIPP DESIGN

SITE DETAILS

- Existing pipeline was 1,250 mm x 1,150 mm non-circular arch. Tunneled in rock and cast in place reinforced concrete
- Constructed in 1972
- Two sections 161 m, 163 m with a maximum depth of 7.5 m to invert
- Pipeline located under residential transit route and dedicated transit-only route
  - o Existing maintenance holes were square structures excavated into bed rock and cast in place with the top 2 m being 800 mm x 800 mm
- Tender flow: 27 l/s
- On-site measured flow: over 100 l/s

CHALLENGES AND RISKS

- Residential location prescribed this installation to be non-VOC resin
  - o Diameter and depth, and pipeline geometry in combination prevented use of non-VOC resin: These tubes wouldn't fit in a reefer let alone be transported to site

Figure 1. Key Site Location.

- Pipeline geometry prevented use of ASTM F1216 design standard
- Maintenance holes in rock too small for water inversion
- Higher than anticipated flows
- Large volume of CIPP process water requiring on-site treatment
- Dedicated transit route traversing discharge route
- Continuous 36-hour operations (set up, install, cure, cool down, V3 CCTV inspection)

SITE-SPECIFIC SOLUTIONS

- Installation: the size and length and depth of the CIPP liner forced a water inversion, hot water cure methodology.
- Non-VOC resin and residential setting: A secondary risk assessment conducted collectively by the Contractor, Contract Administrator, Owner, and City Councilor on the pipeline determined no connection to residences on the trunk sewer and no near proximity connection to local sanitary pipelines. This significantly reduced stakeholder-associated odour risk to an acceptable level and permitted use of styrenated resin.
- Introduction of styrenated resin facilitated evaluation of multiple design methodologies suitable for the non-circular arch geometry. Between ASTM, ASTEE, and WRc, ASTEE was selected as the suitable option See table 4 on page 28.
- The installed liners – 47,000 lbs and 49,000 lbs.
- Maintenance holes: to minimize install requirements, we selected to install both shots from the middle maintenance hole of the trunk sewer run. Rock excavation was completed to a depth of over 2 m where the existing structure opened up to a suitable internal diameter and rebuilt with precast 1,200 mm square sections.
- Bypass: Two active and one back-up 6" critically silenced trash pump with 1,400' of 12" direct-bury HDPE through a neighbourbood to maintain road function and access to private driveways with 800 m of 12" overland Bauer discharge line.
- Large volume of CIPP process water required on-site treatment. Treatment involved twin carbon filters, on-site testing, and sanitary discharge.

DESIGN CONSIDERATIONS

Contract Special Provision F4107 specifies that ASTM F1216-07a design equations must be used to determine the CIPP liner thickness. Therefore, at time of tender contractors were expected to design based on the standard design approach using ASTM F1216-07a.

ASTM F1216-07a provides four designs equations in Appendix X.1 which are limited to circular pipes as note X1.3 suggests. This ASTM F1216-07a is not a suitable design method for the arch sewer on Keyworth Avenue. The need for a non-standard design for construction is justified by the pipe profile.

Figure 2. Existing Pipe Profile.

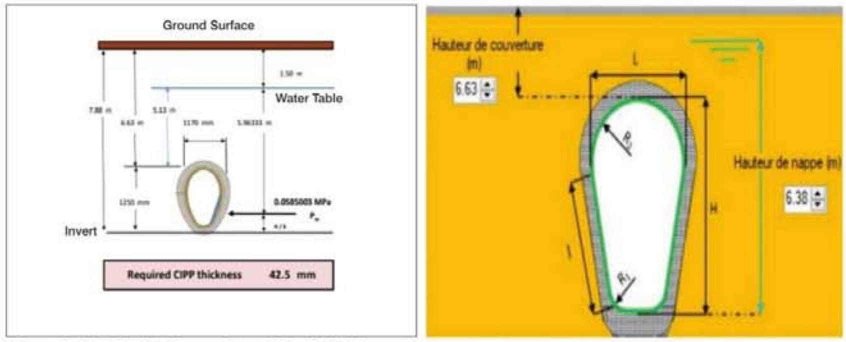

Figure 3. Pipe Profile Comparison (WRc/ASTEE).

Research shows that in the case of similar non-circular profiles the critical portion can be either the "straight" section between the invert and springing or at the crown and invert. (Reference: WRC "Water Research Center" SRM Manual, Vol.2 Chap. 5 – page 5.)

It is important and necessary to apply a design method that considers the critical "straight" sections of the pipe profile. In the case of the arch pipe on Keyworth, the critical "straight" section was confirmed via CCTV inspection. Currently, there is no widely accepted standard for designing non-circular CIPP liners in North America. The most recent version of ASTM F1216 (16) still does not consider non-circular liner designs.

CWW is currently sponsoring and participating in a research project under Dr. Ian Moore at Queen's University to address certain design limitations of ASTM F1216 in regards to non-circular liners. Dr. Moore contributed to a liner design method recently published via ASCE. This method is expected to become an important reference in future non-circular liner design but this method was not yet available at the time of construction.

Alternatively, standards originating from Europe exist and have been accepted on a case-by-case approach in the Canadian CIPP industry. Such accepted design methods are published in the UK (WRc SRM), France (ASTEE- *Scientific and Technical Association for Water and the Environment; est. 1905*) 3R2014-v2), and Germany (ATV-M 127-2).

The German method has mostly been integrated in proprietary software owned by material suppliers. CWW has access to such a design alternative only when a UV liner is considered, as both leading UV liner manufacturers used by CWW originate from Germany. CWW has considered the UV liner option for Keyworth like the ones installed

on other sites on this contract.

Although the much lower required thickness is very attractive, the need to pull this type of liner in place would require extensive modifications to the existing manhole structures for construction access in this case due to the liner size. Since the sewer pipes to be lined on Keyworth are almost 7 m deep in bedrock, the excavation costs would add significantly to the costs. The UV option has been studied but is not presented forward by CWW in this technical proposal because of the anticipated impact to the budget.

Fortunately, WRc and ASTEE design methods are public. CWW developed a non-circular design template in 2012 based on WRc Sewerage Renovation Manual (SRM) equations. Additional considerations were added to hydraulic loading equations to verify for deformation and shallow conditions under live loads. This design method has been used by CWW on an average of 15 km of egg-shaped sewer rehabilitation annually since. CWW has also recently acquired and studied the ASTEE design software which allows for the design of non-circular CIPP liners of various profiles.

The ASTEE design method is the most appropriate for the arch profile of the sewer to be lined on Keyworth as it considers the arch profile specifically. Unfortunately, because of the relatively low CIPP properties of the non-VOC (non-styrene) CIPP liner specified on Keyworth, ASTEE does not produce a CIPP liner thickness for this option. No results are shown when the profile is considered along with the properties of this liner type. This is not an option.

Tables 1, 2, 3, and 4 illustrate the various designs evaluated for the purpose of determining a suitable liner and corresponding thickness. Each selected design platform is evaluated by using the different material properties and constant contract specific design criteria, to establish which design and which material is suitable for rehabilitation.

Table 1. ASTM 12607a design method – specified materials – circular design

Liner Type	Design Method	Liner Finished Thickness	Comment
Non-VOC resin + felt tube, per specifications	3% ovality 4.2% ovality	35.1 mm 37.6 mm	ASTM F1216-07a is not a suitable design method for pipe profile

Table 2. ASTEE 3R2014-v2, design method – specified materials – non-circular design

Liner Type	Design Method	Liner Finished Thickness	Comment
Non-VOC resin + felt tube, per specifications	2% deflection 1% deflection .016 % deflection	50 mm 60 mm 75 mm	All not constructible

Table 3.WRc SRM Type II method – specified materials – non-circular design

Liner Type	Design Method	Liner Finished Thickness	Comment
Non-VOC resin + felt tube, per specifications	3% deflection	42.5 mm	Not cost effective, significant risk

Table 4. ASTEE 3R2014-v2, design method – alternate materials – non-circular design

Liner Type	Design Method	Liner Finished Thickness	Comment
Standard styrene resin + glass-fiber reinforced felt hybrid tube	3% deflection Higher physical properties	33.2 mm	The ASTEE method results in a 5.4% decrease in thickness versus standard-design

CIPP DESIGNS AND REQUIRED LINER THICKNESSES

The first design was completed using ASTM12607a as specified in the contract. The design used a retention factor of 44% for the non-VOC resin. This design satisfied the owners' requirements for the use of a non-VOC resin and ASTM standard; however, based on the pipe profile, there was a need for a non-circular CIPP design. The required install thickness would be over 46 mm with a total resin volume of 60,000 lbs per section.

The second set of design used ASTEE, which incorporates values required for non-circular design and the use of non-VOC which has relatively low physical properties and low retention, results in liner thicknesses that are not ideal for construction. The ASTEE deign template allows for a maximum deflection of 2%, which still results in a finished liner thickness of 50 mm.

This WRc method results in a 21% increase in thickness versus ASTM design. The liner is extremely thick and at limit of constructability with a high risk level. It also includes a significant cost increase due to added material costs and installation cost. The option could be considered only if the non-VOC resin requirement can be changed. This is the only suitable solution for the non-VOC resin and felt liner.

The ASTEE method results in a 5.4% decrease in thickness versus standard design by removing the non-VOC resin requirement and selecting a reinforced hybrid tube. It results in a reasonable liner thickness well within constructability limits, with an average risk level. The sewer is 7 m deep in bedrock with no residential lateral connections, and risk of odours are extremely limited. The relative cost increase is low as the increased cost of the reinforced hybrid tube is partially offset by the drop in resin costs from a non-VOC resin to a standard resin. This design method and material selection is the preferred solution.

SUMMARY AND LESSONS LEARNED

The two sections of non-circular sewer were successfully lined utilizing a hybrid reinforced liner with neat polyester resin. The liner was designed as per ASTEE 3R2014 V2.0 Calculations for Non-Circular Pipe.

Despite the final agreed upon design and material selection, installation still had many challenges that had to be overcome. The middle maintenance hole had to be excavated down four feet in rock, to allow for a suitable opening for installation. The entire process from install, cure, cool down, and final CCTV

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Table 5. Summary of all designs

Parameters	ASTM 121607a Non-VOC/Felt	ASTEE Non-VOC/Felt	WRC Deigns with ASTM x1.3, x1.4 Check Non-VOC/Felt	ASTEE Styrene Resin & Reinforced Tube
Condition	FD	I, II, III (Soil)	N/A	I, II, III
Inside Diameter	1,200	Circ, H & W	H & W	Circ, H & W
Depth to Invert	7.88	7.88	7.88	Cover 6.63
Water table Below Surface	1.5	1.5	1.5	1.5
Ovality	3% & 4%	N/A	N/A	N/A
Soil Density	18.83 KN/m3	N/A	18.83 KN/m3	N/A
Soil Modulus	6.89 MPa	N/A	6.89 MPa	N/A
Live Load	HS-20	N/A	Hydrostatic Load Only	N/A
Flex Mod ST	1,724 MPa	2,100 MPa	2,100 MPa	4,800 MPa
Long-Term Retention	44%	44%	44%	60%
Flexural Strength ST	31 MPa	31MPa	31 MPa	65 MPa
Long-Term Retention	44%	44%	44%	60%
Enhancement Factor	7	N/A	N/A	N/A
Poisson's Ratio	0.3	0.3	N/A	.3
Safety Factor	2	Calculated	2	Calculated
Radius 1	N/A	Input	N/A	Input
Radius 2	N/A	Input	N/A	Input
Beam Length	N/A	Input	Calculated 3/2 Ratio	Input
Deflection of Beam	N/A	2% MAX, 1%, .016%	3% MAX	2% MAX
Design Thickness	35.1 / 37.6 mm	50/60/75 mm	42.5 mm	33.2 mm

inspection took 36 hours, and required application for public transit stop relocation and noise by-law permits. The by-pass system to handle 100 l/s was direct buried for over 70% of its length and the rest was overland. Several SFMP (Sewer Flow Management Plans) were submitted and revised before final acceptance was granted by the City. Each liner had approximately 245,000 US gallons of water that was required to be treated on site and discharged at a rate of 236 gpm. All the discharge requirements and testing is monitored and approved by the City of Ottawa Sewer Use Department. Each discharge is tested post-cure before discharge, mid discharge, and final discharge. Levels of styrene must be below .04 ppm, or discharge must stop.

Approval was also required to allow for the use of styrenated resin. The Keyworth area is an older part of the city and was assessed by the City pre-tender as an area that has significant risk for styrene odours. It was determined that the collector had no local services tying in, and the odour would be significantly lower than what was anticipated by the City.

The rehabilitation of these two sections was made possible by examining all possible solutions, from design, installation procedures and cure methods, and then eliminating one by one those that were not constructible. The process began by designing with the contract-specified products and design criteria, and then analyzing all the options before ultimately selecting the suitable rehabilitation method. The selection process not only involved the design and choice of suitable materials, but also had to consider styrene mitigation, water cure treatment, maintenance hole modification, duration of installation, and by-pass requirements. The owner was engaged through all the design scenarios and the selection process.

Not one CIPP system suits all scenarios. With the latest introduction and improvement of CIPP liners, resins, and cure methods, contractors and owners working together can develop a rehabilitation product to solve almost any deteriorated infrastructure sewer system. Having completed this project successfully, we have learned that with a thorough evaluation of all design methods and CIPP materials, complex projects that seem not constructable have the possibility to be rehabilitated within budget.

REFERENCES

ASTM International
www.astm.org/Standards/F1216.htm

The French association of professional water and waste
www.astee.org

Water Research Center Limited
www.wrcplc.co.uk

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