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Multi Trenchless Discipline Project for on Grade Sanitary Installation with Unique Design Challenges

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ABSTRACT: This paper describes challenges and triumphs of new on-grade sanitary sewer installations in a highly congested and wealthy major urban area. Highlights include parallel deployment of multiple methods of trenchless installation on a single project. Both Auger Boring and HDD works encountered interesting and challenging situations requiring the stakeholders to put aside traditional roles and work as a dynamic issue resolution team.

Earth Boring mobilized its 60/72-1MHD auger boring machine and its 220,000# HDD rig to approach a unique and challenging gravity sewer installation. The project located in the Bayview Nesbitt area referred to as Rosemount Heights, encountered extremely limited rights of way, dramatic soil condition changes, shaft design issues and traditional stakeholder role concepts requiring unique problem solving and issue management.

Over 265m of 1200mm on grade auger boring and 400m of 508mm on Grade HDD were installed on this project. Leveraging a 60,000# HDD rig the auger boring work was piloted using a 200mm pilot tube at grade from the sending shaft for the first section of 1200mm liner. This report details those challenges and the solutions applied relating to dramatic soils changes from expected.

The completion of 'upstream' sections of the sewer would impact the delivery of 'downstream' HDD work. The HDD works would occur in the Don Valley River right of way, skirting a closed landfill site (now a park) adjacent to the Don River. The tunnel liner installed from the upstream park, where the auger bore originated, would provide the conduit for the 508mm IPS DR 6.3 HDPE to be installed under Bayview Avenue. This was part of the original design submitted by Earth Boring as Bayview Avenue could not be blocked at anytime.

Challenging situations developed during the course of the work, requiring knowledge based solutions, delivered in a timely fashion.

1. INTRODUCTION

In the Fall of 2008, a pre-qualification process was held for the selection of qualified bidders for a combined storm/sanitary outfall for the City of Toronto. A project that had been in planning for over ten years was let for tender for a period of three weeks. As a contributor to the successful pre-qualification process, Earth Boring was challenged in receiving a set of bid documents and had to seek permission from the owner before a set at cost was provided. The bid document would prove critical in developing a successful sub-contract price to the winning bidder. The remainder of this discussion will focus on two sections of the pipe installation encompassing HDD, traditional auger bore methods and the use of HDD pilot auger boring.

2. GENERAL LAYOUT OF ROSEMOUNT HEIGHT COMBINED SANITARY PROJECT

For years, homes in the Rosemount Height area of Toronto, faced the looming threat of sewage backup due to inadequate infrastructure and the outfall siphon was leaking into the Don River. A project that had been in the design process for nearly a decade was brought to the forefront. Earth Boring was asked to consult on the design of the project, although much of the detail was either not available or not released for the design consultation. General, broad strokes of the job requirements were laid out to Earth Boring by the design engineer. Earth Boring was asked to comment on the information presented and those comments were to some extent considered by the designer in the overall tendered design.

The trenchless portions of the project are laid out in Table 1, with a visual representation in Figure 1.

Table 1. Details of the trenchless portions of Rosemount Heights Project

Section	Length / Grade	Method	Details
2A to 3A	217m / 3.6%	HDD	508mm IPS DR 6.3 HDPE
12 to 13A	175m / 6.2%	HDD	508mm IPS DR 6.3 HDPE
14A to 13A	111m / 0.7%	Auger Bore	1200mm Steel Liner with 400mm PVC DR 18
14A to 15A	69.5m / 0.7%	Auger Bore	1200mm Steel Liner with 400mm PVC DR 18
16A to 15A	54m / 0.7%	Auger Bore	1200mm Steel Liner with 400mm PVC DR 18

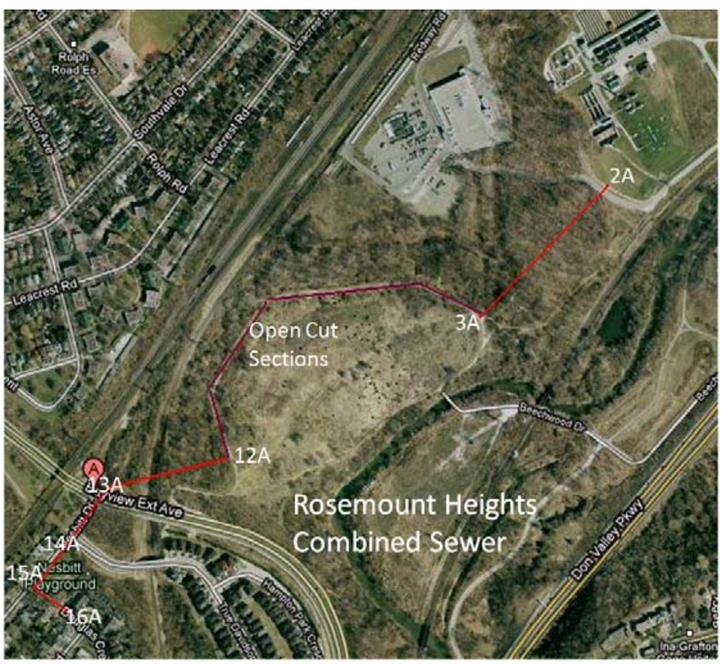

Figure 1. Graphic of overall project area – Rosemount Heights, Toronto, ON - source Google Maps

Section 2A to 3A installed 217m of HDPE within the expected parameters of the works. The HDD operation utilized a 220,000 pound Robbins TBM HDD rig, custom built under the direction of Earth Boring with Robbins TBM in Solon, Ohio. A Kemtron mud recycler was utilized on site to minimize mud expenditure. It operated per expectation and contributed to the overall success of this installation. Section 2A to 3A was a text book installation of HDPE by HDD means.

Sections 16A to 15A and 14A to 15A also were text book examples of liner installation by auger boring means. While 16A to 15A proved challenging in some respects, the overall solutions deployed were standard procedure and resulted in satisfactory and acceptable results.

The main challenges on this project were encountered in the installations of the 1200mm liner in sections 14A to 13A and 12A to 13A and are detailed further below.

3. ROSEMOUNT HEIGHT CHALLENGES

Limited right of way (ROW) has an impact on any construction operation. Working within the confines of pre-determined work areas limits the ability of a contractor to efficiently and economically stage the construction works. Understandably, it is socially responsible to limit construction sprawl. Economics and efficiency should be well thought out at design to ensure reasonable and adequate ROW for equipment, work zone and material.

For example, in an HDD operation utilizing HDPE pipe, it is ideal to have the entire length of installation pipe pre-fused. Consideration must be made as to lay down area for pullback. If one has 300m of pipe to install, 300m of space behind the termination point should be available. Good design will consider this need in order to mitigate risks associated with HDPE pullback. If the pullback operation must be halted for fusion of HDPE; risk increases that the pipe will seize in the ground. Unlike steel liner, which can be rapidly welded (diameter dependent) and pulled at weld completion, HDPE requires a specific heating period, fusion period and cooling period. If a project has an HDPE supplier willing to certify their product for HDPE installation, proper fusion and cooling times will factor greatly on that certification. Therefore, advance fusion of the complete HDPE pipe should be considered best practice and critical to risk mitigation.

One challenge on Rosemount for the HDD 12A to 13A portion was how to lay down pipe. Bayview Ave, a busy Toronto arterial road, could not be blocked and staging pipe ‘overhead’ of the intersection was not an approved option. Bending the pipe out of the shaft, and running parallel to the road was also not an approved solution. Solutions to this issue where ‘downloaded’ to the trenchless contractor.

Earth Boring suggested that order of construction would develop the best solution. In this method, the 1200mm liner for sections 14A to 15A and 14A to 13A would be installed first by the design method of auger bore. At the conclusion of this work, the HDPE pipe would be fused in the shaft at 14A. It would then be threaded to the East to shaft 13A and again West to shaft 15A. A single fuse would be required to complete the 174m length of HDPE pipe. This solution was indeed applied and was highly efficient and successful. See Figure2.

Figure 2. Fusion of HDPE pipe and threading through 1200mm liner

Addressing schedule would be another challenge on this project. Schedule was already behind before the first shovel appeared on site. Issues surrounding contracts and permitting between the General Contractor and the Owner were still unresolved into the expected start time for the trenchless works. A good rule of thumb is to front load trenchless elements of a large project, as unknown and unforeseen issues may arise. In a typical cut and cover project, most of the obstacles are known or at least seen. With trenchless works, problems are unseen even with the best soils reports. Unknown utilities are easier to deal with in a cut and cover job. Unknown utilities in a trenchless project can be extremely expensive to resolve. Earth Boring’s solution is covered in the following section.

14A to 13A – 111m of 1200mm steel liner – 0.7% grade

The pit installed at 14A was to be leveraged for installation of sections 14A to 13A and from 14A to 15A. The pit was oversized and constructed to account for the designed deflection in the combined sewer. The over-sizing was necessary as the auger bore machine would require the additional space to adequately address the azimuth angle of entry. At a final dimension of 6m width and 14m length, the depth to shaft floor was 7m. Even with over-sizing, the set-up of the auger bore machine was cramped, with the set-up in direct contact with the shaft wall in both directions.

Initial delays in the permitting and construction of the shaft led to early on schedule concerns. The owner and consultant looked to Earth Boring to expedite the installation of this section of pipe. It was explained that scheduled duration must consider several factors; ground conditions, diameter of pipe and of course line and grade management. In on grade auger bore installations, good practices dictate the need to frequently check line and grade by means of sewer grade laser systems. This requires the removal of the 1200mm augers within the liner. In short distance installations this is, as one would expect, a short duration operation. In just a few hours, 30m of augers can be removed, grade and line checked, augers 're-threaded' and the bore can continue. At greater distances, the required time is exponentially longer and ultimately variable. Contractually, tolerances for line and grade variance were very stringent on the Rosemount project.

Earth Boring proposed a solution that would leverage HDD to install a pilot tube to designed grade. The method of pilot tube auger boring is not new. A small diameter casing, the length of the entire drive, is installed to the designed line and grade. This casing or tube acts as a guide for the installation of larger pipe. Utilizing a horizontal directional drill (HDD), an initial pilot bore is completed to the designed line and grade. While it is ideal to design HDD installations at a minimum 1% grade, to account for limitations with commercially available locating technologies, it is possible to install at grades less than 1%. Quality locating electronics and more importantly, the experience of the HDD drilling crew, figure prominently in successful results. Upon completion of the HDD pilot, the HDD rig pulls back a small steel casing, the pilot tube. Subsequently, the auger bore operation commences; and using a modified bore head, 'follows' the pilot tube as the larger diameter casing is installed in the modified traditional manner of auger boring.

With the HDD pilot tube method, the number of line and grade checks can be reduced, thereby reducing working days. As the auger bore commences along the pilot tube path, the operator can be assured line and grade are being maintained. Where a bore of length 111m may require eight line and grade checks, frequency can be reduced to two to three depending on the in-field situational needs.

With great success, the HDD pilot tube was installed for 14A to 13A. A Robbins 4510 was lowered (Figure 3) into 14A and staged to the proper line and grade of the overall design.

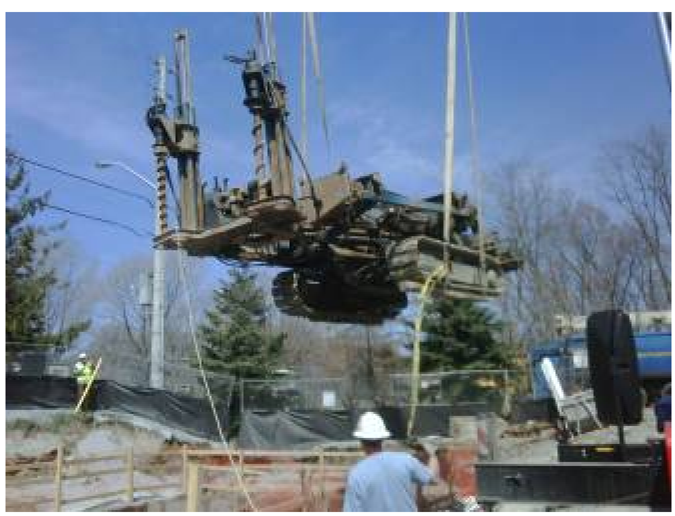

Figure 3. Lowering HDD rig into shaft 14A for pilot auger bore operation

The pilot bore was completed and a 150mm pilot tube was installed. The only concern noted during the operation was the loss of slurry flow in the middle section of the pilot bore. As no 'frac-outs' were discovered, the operation continued, and only a note of the incident remained. The slurry flows returned as the pilot and pull-back neared the start and termination point of the HDD works.

With the pilot tube installed the operation of auger boring commenced, but not without unexpected challenges. In the initial portion of installation, rocky debris was encountered, in a frequency and size greater than expected. The soils report indicated that the ground at the tunnel invert was clayey silt to silty clay with trace gravel and very stiff to hard. Significant pressures built, such that manual removal of the rocks and boulders was required. For several metres this effort was hard fought. The 1200mm casing had to be slightly retracted and the 150mm pilot tube carefully mined around and ultimately removed from the space of hand mining.

Once manual rock removal was completed, the jacking operation resumed and encountered extremely high jacking pressures. A second bore machine was brought in to 13A to provide pull assistance on the 150mm pilot tube. It was thought that in addition to the rock makeup, perhaps the pilot tube was generating some of the added frictional forces. This was an unsuccessful measure, and mechanical jacking and manual mining continued for several more meters. Eventually, the pressure eased and the pilot tube was removed from the bore path in shaft 13A. This was a disappointment as this would require augers to be pulled on a regular basis to verify line and grade. However, the auger operation was able to commence unimpeded and mechanically.

Progress changed dramatically at the 43.5m mark. While the casing advanced forward, no spoil appeared in the muck pile, and the jacking pressure dropped considerably. This continued for 3m and at the 46.5m mark, considerable fetid water appeared in the casing. The first inclination was that an unknown sewer had been breached. The city of Toronto does not provide locate services for its sanitary or storm sewer plant. Designers are left to identify manholes in the field and investigate to determine whether the line is sanitary or storm. Earth Boring was encouraged to proceed.

At 48.7m, the pressures returned and with that pressure, a very different soils matrix. What had been a grey clay, had become a reddish brown sloppy mess. As the bore progressed dry material of the same color was extracted (Figure 4 – left).

Investigation of the spoil pile concluded that indeed brick material had been encountered. Some fully intact bricks had been extracted including a stamped name of the manufacturer (Figure 4 – middle).

For the next 13m the spoil varied in composition. Pieces of cement, brick, foundation stone, wood debris and glass bottles were found in the spoil. As the bore progressed to the 61m mark, clay tile pipes, ceramic, railway spikes, and more concrete and wood debris were encountered. The most interesting piece of debris was the rim of a toilet (Figure 4 - right).

Figure 4. Debris spoil from tunnel installation - MH14A to MH13A – Vastly different from expectation

At this point it was imperative to halt the progress of the bore. With the drastically changed soils condition, Earth Boring and the General Contractor (GC) where ultimately concerned with the soil matrix ahead of the bore. Over 30m remained, including the crossing of Bayview Avenue, one of the City of Toronto's busiest thoroughfares.

As a matter of good practice, augers were pulled and the face of the bore bulk-headed. All information was presented to the consultant and the project owner. It was left to the General Contractor to determine the course of action. Ultimately, Earth Boring suggested that additional bore holes be installed to get a better picture of the soils matrix underneath Bayview. It should be noted that the initial bore holes were well done. The bore path from 14A to 13A was, initially, bookended with two boreholes. The results of the opposing end bore holes were identical. It has been this trenchless contractors experience, that only one bore hole appears in the general area of a trenchless crossing. That two were done relatively on line with the bore was excellent. However, as evidenced in this installation, fill zones in a city can pose serious challenges to success.

Seven additional bore holes were drilled along the bore path to further develop a 'picture' of the subsurface conditions. The encountered soils were confirmed to be fill material. In the interim, local residents had offered further information as to the soils makeup.

One local resident explained a long since abandoned brick manufacturer had operated in the area. Defective bricks were hauled by horse cart to the top of the hill and dumped into the valley. It became immediately clear what the trenchless crossing was up against. The entire area, and the Bayview Extension, had been built upon brick fill.

During this time, it was discovered that a sewer ran perpendicular to our proposed bore path. It had not been included in the design, and early field investigation by the consultant missed the underground plant. It was determined that this sewer ran in the middle of Bayview, so it had yet to be crossed by the bore path. Earth Boring offered its high frequency sondes to trace the path of the sewer as it was over 14m deep. The 1200mm horseshoe-shaped, brick-lined sewer was plotted and included in subsequent drawings provided by the soils engineer. Based on the in-field readings, the invert of the 1200mm combined sewer would cross less than 3m above this sewer.

Earth Boring pieced together the frictional problems that had been encountered early on during the HDD pilot auger bore. While the 150mm tube had been installed on line and on grade, it had traversed an extremely loose soils matrix. Bookended with dense clay formations the tube acted as a 'bow' when force was applied. This created the additional frictional resistance that was encountered after the initial rocks had been mined out. This also explained the loss of flow that was encountered during the pilot tube installation. The loose matrix did not provide sufficient annular space to allow the movement of the slurry to the sending and receiving pits as one would expect.

Five weeks passed while the consultant and owner considered the information put forth by Earth Boring on the suggested approach. The tunnel had progressed too far to abandon, and no additional right of way was available to try a secondary approach, therefore, the tunnel had to proceed with the auger bore approach. Additional line and grade checks would be required to complete the installation, more than on a conventional bore. Settlement monitoring was established to determine if the overhead road was at anytime in peril of sinking due to the agitation of the brick fill soils.

Rapidly, yet with caution, Earth Boring continued the proposed auger bore. The loose soils had allowed the bore path to shift to the North, requiring field forces to modify the lead casing to accommodate and correct the drift. The modification worked and the bore was completed 900mm to the north of the designed line, and on grade.

12A to 13A – 175m of 508mm IPS DR 6.3 HDPE 6.2% grade

With 14A to 13A of the installation complete, the next portion of work was the installation of HDPE line from 12A to 13A. This piece of work originated in the valley of an inactive city landfill. (Fortunately, lechate was not encountered in the installation.) The installation would cross beneath high voltage lines, a railway line and terminate in shaft 13A.

Early challenges involved addressing frequency issues with the locating electronics. Overhead interference with the hydro lines was expected. Earth Boring did detect some moderate interference in pre-installation walkthroughs. The locating device was brought to the site and the designed bore path was walked, receiver in hand to detect any 'spikes' in the display feedback. Interference from the overhead hydro wires was detected with the locating device.

To combat potential interference, a double sonde method was utilized. A walkover sonde was placed in the lead section of drill pipe, a secondary wire-line sonde was placed 6m behind this lead to provide additional and verification information. While makeup of the wire-line required additional time, the use of the system would mitigate the risk of costly trip outs should the walkover sonde fail. The offset balance of time favored the use of the wire-line system in series to the walkover sonde.

As the pilot bore progressed, interference from the overhead hydro affected the walkover readings. However, the wire-line sonde provided the required information that allowed the drill crew to effectively and accurately navigate through the area of interference. Once the interference section had been passed, the walkover system was primarily utilized.

This installation proceeded fairly well. Early field work prior to crew mobilization assisted in the smooth operation. These efforts included active and passive frequency interference detection, staging of equipment layout, survey line installation and area pre-cut. Area pre-cut is a beneficial method of reducing required set-back room for drilling. By cutting down the area where a drill is to be staged, the driller can then effectively attain key grade points in a shorter distance, depending on the expected profile of the bore. In this project the drill staging area was cut down 1.5m reducing the set back distance by over 15m. (Figure 5) This process is especially effective in areas where the ROW is very limited.

Figure 5 – MH12A to MH13A HDD rig set up – area cut down 1.5m

4. CONCLUSIONS

Several conclusions can be drawn from this project. Some of which have been previously concluded in earlier projects.

1. Pre-Qualification is ideal for complex projects and those projects in which the utilized technologies are less well known to the owner and consultant.

2. The soils report should be well founded, well documented and well understood by all stakeholders. Money spent on soils reports should be considered sound risk mitigation planning. The relational costs to money spent here versus money spent when different soils are discovered are inverse. This project had well developed bore hole locations, in fact it could be said ideal bore hole locations. The challenges illustrate the dynamic and changing nature of soils in short spans especially given non-native fill situations.

3. Large scale trenchless project owners and designers should seek to include participation from all stakeholders from conceptualization, to plan and design and in field resolution.
    a. Initial efforts for a collaborative approach fell short as key aspects of the design were not shared with the trenchless contractor.

b. Contractor needs to be advised of all related structures and appurtenances related to the general trenchless operation

4. Designers of trenchless intensive works must educate and immerse themselves in the planned technology, or contract a reputable firm to provide this function.

5. Design of HDD works should consider right of way and the space available to 'lay down' HDPE pipe.

Upon review of the details surrounding this project, it became clear that many of the conclusions drawn reflect those of previous efforts. While efforts to educate are continuous and on-going, they are only as effective as the audience is willing to listen. Several times throughout the course of this project, hard facts delivered to the owner were often lost in communication, leading to the early realization that the realities of the work were beyond what the owners representative was willing to understand and address.

Trenchless contractors must continue to be patient and diligent, working to educate the project stakeholders on the realities, challenges and expectations of underground work.

5. REFERENCES

Currey, J., Woodbridge, G., and Duyvestyn, G., On Grade Large Diameter Directional Drilling, (2009), Proceedings of No-Dig Show 2009, Toronto, Ontario March 29 – April 3, 2009