



FOUNDATION INVESTIGATION AND DESIGN REPORT

**Highway 127, Station 18+320, Township of Sabina
Culvert Replacement
Ministry of Transportation, Ontario
GWP 5151-13-00**

Submitted to:

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SP FOUN 0001	Concrete Working Slab
NSSP	Amendment to OPSS PROV 539 Temporary Protection System
NSSP	Pipe Installation by Trenchless Method, January 2019

PART A

FOUNDATION INVESTIGATION REPORT
HIGHWAY 127, STA 18+320, TOWNSHIP OF SABINA
CULVERT REPLACEMENT
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5151-13-00

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by D.M. Wills Associates Ltd. (Wills) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services related to the replacement of the culvert under Highway 127 at Station 18+320, approximately 600 m west of the Highway 127 intersection with MacKenzie North Road, in the Township of Sabina. The Key Plan of the general location of this section of Highway 127 and the location of the investigated area are shown on Drawing 1.

The purpose of this exploration is to establish the subsurface conditions at the culvert replacement site by borehole drilling, with laboratory testing carried out on selected soil samples.

The Terms of Reference (TOR) and the scope of services for the foundation investigation are outlined in MTO's Work Order # 7 of Agreement Number 5017-E-0022. The work has been carried out in accordance with Golder's Supplementary Specialty Plan for foundation engineering services for this project.

2.0 SITE DESCRIPTION

It should be noted that the orientation (i.e., north, south, east, west) stated in the text of the report is typically referenced to project north and therefore may differ from magnetic north shown on Drawing 1. For the purpose of this report, Highway 127 is oriented in a west-east direction with the culvert positioned north-south, perpendicular to the highway. At the culvert location the creek flows in a north-south direction.

The existing culvert consists of a 750 mm diameter, 32 m long Corrugated Steel Pipe (CSP). The culvert inlet (north end) and outlet (south end) inverts are approximately Elevations 427.9 m and 426.6 m, respectively. In general, the topography in the vicinity of the culvert consists of rolling terrain, with Highway 60, traversing through Algonquin Provincial Park, located about 12 km north of the site. At the culvert location, the highway grade is at approximately Elevation 433.0 m and the embankment is approximately 6 m high relative to the culvert invert. There are no indications of embankment or pavement distress in the immediate vicinity of the culvert other than minor surface cracking of the pavement. The conditions at the culvert ends and road surface in the area of the culvert are shown on Photographs 1 to 3.

3.0 INVESTIGATION PROCEDURES

Field work for this subsurface exploration was carried out between August 12 and 14, 2019 during which time three boreholes (Boreholes 19-1 to 19-3) were advanced at the locations shown on Drawing 1. One borehole was advanced through the roadway embankment using a track mounted Mobile B57 drilling rig supplied and operated by Landshark Drilling of Brantford, Ontario. Two boreholes were advanced near the toes of the highway embankment slopes adjacent to the culvert inlet/outlet using a portable tripod drilling rig supplied and operated by Ohlmann Geotechnical Services Inc. of Almonte Ontario. Traffic control was performed in accordance with MTO's Ontario Traffic Control Manual Book 7 – Temporary Conditions.

Borehole 19-1 and 19-2 were advanced with BW casing with wash boring techniques and Borehole 19-3 was advanced using 216 mm outside diameter hollow stem augers. Ohlmann Geotechnical Services supplied a water filled tote for use in the wash boring operations.

In Borehole 19-3, soil samples were obtained in the boreholes at 0.75 m and 1.5 m intervals of depth using 50 mm outer diameter split-spoon samplers driven by a full weight automatic hammer in accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586-18). In Boreholes 19-1 and 19-2, split spoon samples were taken continuously from ground surface using a full weight manual hammer. The groundwater level inside

the augers/casing was observed during the drilling operations. A standpipe piezometer, 19 mm in diameter, was installed in Borehole 19-1 to allow further groundwater level monitoring. A sand filter pack was placed to surround the screen in the piezometer. Above the screen/sand pack, the annulus surrounding the PVC pipe was backfilled to the ground surface with bentonite pellets. The remaining boreholes were backfilled to ground surface in accordance with Ontario Regulation 903. The roadway surface at the borehole drilled through Highway 127 was sealed using cement.

Field work was supervised on a full-time basis by a members of Golder's technical staff who: located the boreholes in the field; arranged for the clearance of underground services; supervised the drilling and sampling operations; logged the boreholes; and examined the soil samples. The soil samples were identified in the field, placed in labelled containers and transported to Golder's geotechnical laboratory in Whitby for further examination and laboratory testing. Index and classification testing consisting of water content determinations, grain size distributions and Atterberg limits was carried out on selected soil samples. The geotechnical laboratory testing was completed according to ASTM and MTO LS standards, as applicable.

The as-drilled borehole locations were surveyed by a member of Golder's technical staff using a Trimble GPS unit. The MTM NAD83-CSRS CBN v6-2010.0 (Zone 10) northing and easting coordinates, geographical coordinates, ground surface elevations referenced to Geodetic datum, and borehole depths at each borehole location are presented on the borehole records in Appendix A and summarized below.

Borehole Number	MTM NAD 83 Northing (m) (Latitude)	MTM NAD 83 Easting (m) (Longitude)	Ground Surface Elevation (m)	Borehole Depth (m)
19-1	5029829.2 (45.399981)	413429.5 (-78.112448)	426.4	4.3
19-2	5029862.0 (45.400272)	413449.3 (-78.112187)	428.4	4.3
19-3	5029848.0 (45.400147)	413444.2 (-78.112257)	432.9	11.3

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

According to published information, the site lies within the Algonquin Highlands physiographic region of southern Ontario (Map P.2715, Chapman and Putnam, 1984)¹. The site is located on an esker, which oriented in a north-south direction, with spills to the east and west. Drumlins are present towards the north and east of the site. Surficial geologic mapping in the vicinity of the site indicates glaciofluvial outwash deposits consisting of gravel and sand boarding on till deposits to the east. The glacial till, where encountered, is reportedly to be unsorted and un-stratified glacial sediment predominately consisting of silty sand with a mixture of any or all of clay, gravel, cobble and boulders. The soils encountered at the site were typical deposits generally encountered within the Algonquin Highlands.

¹ Chapman and Putnam, 1984. Physiography of Southern Ontario. Map P.2715

Based on geological mapping the site is underlain by biotite gneisses and migmatites (Map 2544, Ontario Ministry of Northern Development and Mines, Bedrock Geology of Ontario).²

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes, the standpipe piezometer installation details and the summary results of in situ and laboratory testing are given on the Record of Borehole sheets contained in Appendix A. The detailed results of geotechnical laboratory testing are contained in Appendix B. The results of the in-situ field tests (i.e., SPT “N”-values) as presented on the Record of Borehole sheets and discussed in Section 4.2 are uncorrected. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profile shown on Drawing 1 are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change.

The subsurface conditions will vary between and beyond the borehole locations, however, the factual data presented on the Record of Borehole Sheets governs any interpretation of the site conditions. A summary description of the soil deposits and groundwater conditions encountered in the boreholes is provided below. It should be noted that the interpreted stratigraphy shown on Drawing 1 is a simplification of the subsurface conditions.

4.2.1 Asphalt/ Road Structure

An approximately 75 mm thick layer of asphalt (pavement) was encountered at Borehole 19-3 at Elevation 432.9 m. Underlying the surface asphalt, the borehole penetrated a 265 mm thick layer of granular road base fill.

4.2.2 SILTY SAND (SM) to Sandy GRAVEL (GP) (FILL)

A 1.5 m to 5.3 m thick non-cohesive deposit of fill, generally comprised of silty sand to sandy gravel, trace to some fines, was encountered in all Boreholes at ground surface or beneath the road base fill between Elevations 432.6 m and 426.4 m. Organic inclusions and/or root fragments were observed in Boreholes 19-1 and 19-2 in and extend to depths of 1.5 m below ground surface (mbgs) and 1.2 mbgs, respectively. Cobbles and potentially boulders are inferred to be present within the fill based on rock fragments recovered in Boreholes 19-1 and 19-2 and auger grinding observed during drilling in Borehole 19-3.

The SPT “N”-values measured within the fill deposit generally range from 3 blows to 26 blows per 0.3 m of penetration, indicating a very loose to compact compactness condition. An SPT “N”-value of 52 blows per 0.3 m of penetration and 50 blows for 0.05 m of penetration was measured in Boreholes 19-3 and 19-1, respectively, indicating a very dense compactness condition, however these are not considered representative of the fill and are inferred to be the result of the SPT contacting cobbles and/or boulders within the fill.

Grain size distribution analysis was carried out on two samples of the silty sand fill and the results are presented on Figure B-1 in Appendix B. The in-situ moisture content measured on two samples of the fill deposit is 6 per cent and 25 per cent.

² Ontario Ministry of Northern Development and Mines. Bedrock Geology of Ontario, East-Central Sheet. Map 2544

4.2.3 SILTY SAND (SM)

A 0.6 m and 0.7 m thick deposit of non-cohesive silty sand, some gravel was encountered in Boreholes 19-2 and 19-3 beneath the fill at Elevations 426.6 m and 427.6 m, respectively.

Two SPT “N”-values measured with the silty sand are 28 and 42 blows per 0.3 m of penetration, indicating a compact to dense compactness condition.

A grain size distribution analysis was carried out on one sample of the silty sand deposit and the result is presented on Figure B-2 in Appendix B. The natural moisture content measured on two samples of the silty sand deposit are 11 per cent and 23 per cent.

4.2.4 SAND (SP)

A non-cohesive deposit of sand, trace to some gravel to gravelly sand, trace fines was encountered in all boreholes beneath the fill or silty sand deposit. The surface of the sand deposit was encountered between Elevations 426.9 m and 424.9 m. Cobbles and boulders are inferred to be present within the sand deposit based on rocks fragments recovered from the samples in Boreholes 19-1 and 19-2 and auger grinding observed during drilling in Borehole 19-3. The sand deposit was not fully penetrated in Boreholes 19-1 to 19-3 after exploring the deposit for depths between 1.9 m and 5.3 m.

The SPT “N”-values measured within the sand deposit range from 3 blows to 54 blows per 0.3 m of penetration, indicating a very loose to very dense compactness condition. SPT “N”-values of 83 blows for 0.23 m of penetration and 50 blows for 0.13 m of penetration were measured in Boreholes 19-2 and 19-3, respectively, however these are inferred to be the result of the SPT contacting cobbles and possibly boulders within the sand deposit.

Grain size distribution analysis was carried out on four samples of the sand to gravelly sand deposit and the results are presented on Figure B-4 in Appendix B. Atterberg limits tests was carried out on one sand sample of the deposit and returned a non-plastic result. The natural moisture content measured on six samples of the deposit range from 11 per cent to 30 per cent.

4.3 Groundwater Conditions

In general, the groundwater level observed in Boreholes 19-1 and 19-2 upon completion of drilling are not considered representative of the conditions observed on site due to the introduction of water during wash boring. The groundwater level in Borehole 19-3 upon completion of drilling was measured at 5.8 m below ground surface and Borehole 19-2 was dry. The groundwater level measured in the standpipe piezometer on August 24, 2019 is summarized below.

Borehole No.	Ground Surface Elevation (m)	Groundwater Level Below Ground Surface (m) in Piezometer	Groundwater Level Elevation (m)
19-1	426.4	1.7	424.7

4.4 Analytical Laboratory Testing Results

Analytical testing was carried out on a soil sample recovered at the bottom of the embankment fill in Borehole 19-3. The soil sample was submitted to AGAT Laboratories of Mississauga, Ontario for testing a suite of parameters

associated with potential corrosion to steel and deterioration of concrete. The analytical laboratory test results are summarized below, and the detailed analytical laboratory test report is included in Appendix B.

Borehole No.	Sample No.	Depth (m)	Parameters				
			Resistivity (ohm-cm)	Electrical Conductivity (mS/cm)	Soluble Sulphate (SO ₄) Content (µg/g)	Chloride (Cl) Content (µg/g)	pH
19-3	4	4.6-5.2	2,390	0.419	8	24	8.51

5.0 CLOSURE

The field drilling program was carried out under the supervision of Mr. Michael Bentley. This Foundation Investigation Report was prepared by Mr. Michael Bentley, and Ms. Sarah E. M. Poot, P.Eng. provided a technical review of the report. Mr. Jorge Costa, P.Eng., an MTO Foundations Designated Contact and Senior Consultant for Golder, conducted an independent quality control review of this report.

Signature Page

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PART B

FOUNDATION DESIGN REPORT
HIGHWAY 127, STA 18+320, TOWNSHIP OF SABINA
CULVERT REPLACEMENT
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5151-13-00

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation design recommendations for the replacement of the culvert crossing Highway 127 at Station 18+320, approximately 12 km south of the intersection with Highway 60, in the Township of Sabina, Ontario. These recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the current subsurface investigation. The discussion and recommendations presented are intended to provide the designer with sufficient information to assess feasible foundation alternatives and to design the proposed replacement culvert. The foundation investigation report, discussion and recommendations are intended for the use of the Ministry of Transportation, Ontario (MTO) and shall not be used or relied upon for any other purpose or by any other parties, including the construction or design-build contractor. The contractor must make their own interpretation based on the factual data in Part A (Foundation Investigation) of the report. Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project, and for which special provisions may be required in the Contract Documents. Those requiring information on the aspects of construction must make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

6.1 Proposed Culvert Alignment and Installation Options

The existing culvert consists of a 750 mm diameter, 32 m long Corrugated Steel Pipe (CSP). The existing culvert crosses Highway 127 embankment essentially perpendicular to the highway. It is understood that the culvert is in poor condition and requires replacement. We further understand that the proposed replacement culvert will be constructed across the highway on a new alignment near the existing culvert alignment and will be of similar circular size as the existing culvert. Based on drawings provided to us by Wills, the invert at the inlet (north end) and outlet (south end) of the existing culvert is about Elevations 427.9 m and 426.6 m, respectively, and the existing embankment is between about 5.1 m and 6.4 m high relative to the culvert invert at the inlet and outlet, respectively. We assume that a permanent grade raise or widening of the embankment in the culvert area is not required for culvert replacement. Based on the existing ground surface profile along the proposed culvert alignment, the existing soil cover over the top of the culvert ranges from 4.4 m to 5.7 m, and the ratio of cover- to- pipe diameter is greater than 5 (or about 5 if a 0.9 m diameter liner is used) which is considered suitable for a trenchless installation method.

As an alternative to trenchless construction of the new culvert, consideration may also be given to replacing the culvert using an open cut method.

A comparison between an open cut (cut-and-cover) method of culvert construction and the potential trenchless installation methods at this site (as discussed in Section 6.3.3) is presented in Table 1 following the text of this report.

6.2 Consequence and Site Understanding Classification

In accordance with Section 6.5 of the *Canadian Highway Bridge Design Code* (CHBDC, 2014) and its *Commentary*, the section of Highway 127 crossing over the proposed culvert and its foundation system is expected to carry medium traffic volumes and its performance will have potential impacts on other transportation corridors; hence, the structure is classified as having a “typical consequence level” associated with exceeding limits states design. In addition, given the typical project specific foundation investigation carried out at this site (as presented in Part A of the report), in comparison to the degree of site understanding in Section 6.5 of *CHBDC* (2014), the level of confidence for design is considered to be a “typical degree of site and prediction model understanding.” Accordingly, the appropriate corresponding Ultimate Limit State (ULS) and Serviceability Limit

State (SLS) consequence factor, Ψ , and geotechnical resistance factors, ϕ_{gu} and ϕ_{gs} , from Tables 6.1 and 6.2 of the CHBDC have been used for design.

6.3 Assessment of Trenchless Installation Methods

6.3.1 Subsurface Conditions and Tunnelman's Ground Classification

We understand that the preferred proposed method of culvert replacement at this site is by a trenchless method. The soil conditions encountered along the proposed culvert alignment are relatively consistent, and generally the soils encountered along the proposed tunnel horizon include very loose to compact silty sand embankment fill, dense silty sand and compact to very dense sand. Further, obstructions such as cobbles and potentially boulders or rock fragments were encountered in the boreholes within the fill and native materials as evidenced by split-spoons not achieving the full sample depth, no or poor recovery from split spoon samples, rock fragments in the split spoon samples, difficult augering, and grinding of the augers, could be encountered along the tunnel horizon. The groundwater level measured in the standpipe piezometer in Borehole 19-1 was at an Elevation of 424.7 m on August 24, 2019. Therefore, the groundwater level is expected to be below the proposed culvert invert.

Correlating the soil classification with the Tunnelman's Ground Classification System (Heuer, 1974), modified from Terzaghi, 1950), existing embankment fill along the tunnel horizon (silty sand) and the coarse, relatively uniform, native granular soils (silty sand to sand) can be considered "running" above the groundwater level and "flowing" below the groundwater level. It is expected that these soils, when exposed fully above groundwater or after dewatering, if required, may be able to stand unsupported for a limited length of time prior to "running" (in the order of a few minutes to hours). Below groundwater levels, the existing embankment fill and native soils will be unable to stand unsupported for any length of time and will exhibit "flowing" behaviour and destabilize any overlying materials.

6.3.2 General Description of Trenchless Technologies

The contractor should be responsible for choosing the method and equipment for the crossing installation, unless specific methods are otherwise prohibited. Ground behaviour will be, in part, dependent on the installation method adopted by the contractor, however this report provides guidance on the influence of ground behaviour on some possible pipe culvert/tunnel trenchless installation methods. It should not be construed that the contractor is restricted to the particular methods considered herein, and in the event of alternative methods, the contractor must make his own interpretation of the anticipated ground behaviour, based on the factual information from the investigation. Trenchless work should be carried out in accordance with MTO's Special Provision (SP) titled "*Pipe Installation by Trenchless Method*" presented in Appendix C for inclusion into the Contract Documents.

For the proposed culvert installation at this site, a number of trenchless construction methods were considered for completeness, though the practicality of some of these techniques for this project may be doubtful if not entirely unsuitable. The trenchless techniques considered from a general perspective include horizontal directional drilling (HDD), pipe jacking and horizontal auger boring, pipe ramming, micro-tunneling by MTBM, pilot tube micro-tunneling (PTMT), tunnel boring machine (TBM) and tunnel digging machine (TDM - i.e., open face shield tunnelling). In brief, these construction methods involve the following:

- **Horizontal Directional Drilling (HDD):** HDD involves the drilling of a pilot hole (in the order of 100 mm to 150 mm) using a steerable drill bit on a flexible string of drill rods while the bore is supported using a bentonite slurry. Once the pilot hole is complete, the bore would be reamed in one or more passes to a larger diameter, and then the pipe carrier would be pulled through the bore (using the drill rods to pull the pipe into place). HDD equipment is available for drilling in both bedrock and overburden but is very challenging in bouldery ground such as may be the case in the fill materials at this site. Deep entrance and

exit pits are generally not required, however, larger laydown areas are required to install the carrier pipe, and the crossing typically needs to be longer to accommodate the shallow entry and exit angles for the drilling equipment. Bores are typically limited to less than 1 m diameter. Control of line and grade to the degree needed for gravity flow for culvert slopes may be problematic.

- **Pipe Jacking and Horizontal Auger Boring (i.e. “Jack and Bore”):** A pipe jacking operation involves pushing an oversized steel liner pipe (casing) horizontally into the ground by jacking. The spoil is generally removed from within the casing using an auger boring machine. The cutting head is driven by, and is positioned at, the leading end of an auger string that is established within the casing pipe. The profile needs to be approximately horizontal. Jacking and receiving pits are required. There can be limited ability to steer the casing during jacking. This method is only applicable to construction in the overburden and may not be feasible in bouldery soils (e.g., glacial till or fill containing cobbles/boulders/rock fill). This method is also not feasible in “running” or “flowing” ground (dry or saturated silt, silt and sand, sand/silt).

Some trenchless contractors present the use of a “small boring unit (SBU)” as a “micro-tunnelling” system. In general, the SBUs often consist of a rotating cutter head system that is temporarily welded to the lead end of the steel casing. The ground is cut using a variety of face tools (similar to MTBMs and TBMs described below), but the spoil is transported to the surface using an auger system, much like a conventional jack and bore system. Face openings on the small boring unit are typically much smaller than the auger opening on conventional jack and bore system and the risk of uncontrolled ingress of ground into the lead end of the casing is lower for this system as compared to the jack and bore method. This system does not, however, provide consistent and positive support to the ground at all face openings with any slurry or cuttings, unlike the slurry-based TBM/MTBM machines. Therefore, while the small boring unit is more suitable and advantageous for cutting through stiff to hard cohesive glacial till, it should only be used with caution where non-cohesive soils are encountered along the alignment, such as is the case at this site.

- **Pipe Ramming:** Pipe ramming uses a pneumatic tool to hammer a steel pipe or casing into the ground. The pipe is almost always driven ‘open’ to thereby direct the soil into the pipe interior instead of compacting it outside the pipe. The leading edge of the pipe typically has a small overcut to reduce friction between the carrier pipe and soil and to improve the load conditions on the pipe. Soil/pipe friction reduction can also be achieved with lubrication, and different types of bentonite and/or polymers can be used for this purpose. Depending on the length of the installation, the soils inside the pipe can be removed either during or after the installation by augering, compressed air or water jetting. Pipe ramming methods are also better suited for penetrating through/displacing potential obstructions such as cobbles and boulders in comparison to the jack and bore installation method, though this method can still be obstructed by cobbles and boulders depending on their size and number. Pipe ramming has also been used to accomplish culvert replacement in which a larger diameter pipe is rammed through the ground immediately around an existing pipe and both the existing pipe and ground are removed from within the rammed pipe by manual methods. This technique is sometimes called “pipe eating” or “pipe swallowing”. Partial or full removal of materials from within the pipe, to facilitate driving, should not be carried out if the ground through which the pipe is being driven consists of saturated granular soils (silt, sand, gravel). As with traditional jack and bore methods, flowing ground conditions and/or operating the cleanout augers beyond, at or near the leading edge of the casing can result in significant ground losses, excessive surface settlement and, in some cases, sinkholes that propagate to the surface.
- **Micro-tunnelling Boring Machine (MTBM):** MTBM is a method of installing pipes in bores ranging from 0.6 m to 3 m diameter behind a steerable remote-controlled shield that is pressurized with a bentonitic slurry at

the cutting face to minimize ground losses. The process is essentially remote-controlled pipe jacking where all operations are controlled from the surface, cuttings are removed by the circulating slurry, and the necessity for personnel to enter the bore is eliminated. Micro-tunnelling equipment is generally more suited to tunnelling through overburden. Availability of this equipment in the project area may be limited. Non-slurry MTBM installation methods are not suitable for these cohesionless ground conditions at this site.

- **Pilot Tube Micro-tunnelling (PTMT):** PTMT employs augers for excavation and soil removal and a jacking system for advancing the drill pipes, casings and carrier pipes. The guidance system comprises a target with LEDs mounted in the steering head of the equipment that is monitored through a TV monitor. The PTMT operation includes pilot boring and reaming and, since this technique is used for smaller size pipes, the equipment and space required for this operation is smaller than what is normally required for pipe jacking or micro-tunnelling. PTMT can obtain an accuracy of 10 mm per 100 m of pipe length; however, the accuracy depends on the ground conditions, the accuracy of the guidance system and the operator's skill. The "pilot tube" is advanced in a similar fashion to horizontal directional drilling with a guidance system used to control alignment and grade.

In this method, a bore hole is drilled with a steering head connected to pilot tubes whose size is smaller than the required casing size. A steering head is used for pilot boring and adjustment of alignment and grade and the bore hole is subsequently enlarged by a reamer with an auger string inside the casing used to remove cuttings. Temporary casings, if applicable, or the final pipe follows the reamer into the ground.

- **Tunnel Boring Machine (TBM):** TBM tunnelling operations involve the advance of a steerable machine with a rotating cutter head that is jacked horizontally into the ground at the lead end of the pipe or temporary lining system. Successive sections of temporary liner pipe or the final product pipe advance behind the TBM by pipe jacking. Alternatively, steel liner plates, steel ribs and wood lagging or segmental precast concrete liner systems can be installed as the TBM advances. The spoil is removed from the tunnel as the TBM is advanced, using a combination of screw augers (in some instances), conveyor belts or mucking cars. The cutting head is driven and steered by an operator inside the TBM and the TBM head and face may be partially open or provided with doors to allow for access to the face. Jacking and receiving pits are required. Locally, this method is generally used for construction in overburden, and open-faced machines have been used in cohesive and bouldery soils that exhibit significant "stand up time" (e.g., glacial till). Excavations through sandy soils below groundwater level typically require dewatering to maintain face stability when using open faced machines. Specialized earth pressure balance or slurry shield TBMs, which pressurize the face of the excavation and improve face stability, or the use of micro-tunnelling.
- **Tunnel Digging Machine (TDM):** TDM tunnelling, also called open-face shield tunnelling, involves excavating the soils using a hydraulic excavator arm, working within a full-circumference tunnelling shield. Alternatively, hand mining (i.e., manual excavation) within the tunnelling shield could be carried out whereby the soil would be excavated using manual equipment with workers at the face. Typically, the temporary tunnel liner (i.e., steel casing, steel ribs and lagging, steel liner plates, etc.) will be constructed from within the machine or final pipe would be jacked in sections from the launching shaft. Unlike traditional "jack and bore" methods, this method allows personnel to enter the tunnel to allow more control over the operations, such as for removal of obstructions. Similar to jack and bore, however, groundwater lowering is necessary to control cohesionless soils below the groundwater level. Manual or machine-assisted excavation generally requires a tunnel diameter of about 1.8 m or more for a TBM and 1.2 m or more for a manual excavation.

6.3.3 Assessment for Feasible Trenchless Installation Methods

The ground conditions along the culvert alignment within the tunnel vertical limits are likely to generally consist of silty sand fill and native silty sand to sand above the groundwater level. Based on the ground conditions and the anticipated relatively short tunnel distance of about 32 m, HDD, jack and bore/SBU, TBM, TDM and PTMT methods are likely not suitable and are not cost-effective. MTBM would likely be effective in the anticipated ground conditions but is uneconomical over short distances but could be economical for multiple sites in the same area. Consideration should be given to modifying the SP for Pipe Installation by Trenchless Methods to restrict the contractor to only the feasible installation methods.

Considering the ground conditions, groundwater levels, tunnel distances and local capabilities, pipe ramming is likely to be the most feasible and suitable trenchless installation method for the culvert at this site. It should be noted that interventions to remove obstructions, if encountered, may still be necessary. The following geotechnical issues/risks associated with the trenchless construction including key issues and consequences, likelihood and mitigation measures are discussed in a Risk Register presented in Table 2 attached to this report. In summary, the key issues/risks that should be considered and evaluated at this site are:

- Ground or Road Heave – a culvert installed at shallow depth and with diameter that is relatively large as compared to the depth of burial is particularly susceptible to heaving the roadway if the pipe is rammed into place (i.e., having a cover to diameter ratio of less than about 2 which is not the case at this site given the anticipated about 1 m diameter liner/casing pipe to accommodate the 750 mm diameter culvert and 4 m to 5.5 m thickness of pipe cover over the liner).
- Obstructions – Cobbles and potentially boulders and rock fragments were encountered/inferred in all boreholes advanced at this site. It should be noted that cobbles, boulders, wood, etc. can obstruct or foul trenchless construction equipment if they are encountered while boring/ramming. As the culvert would be installed close to or within deposits containing these deleterious objects/materials there is a risk of encountering such objects. In some instances, low and wet areas near culvert ends have historically been filled with larger rock materials in attempts to stabilize the ground. Pipe ramming is the least susceptible to equipment fouling and damage if wood debris is encountered.
- Ground or Road Settlement – Given that the groundwater level at this site (as measured in the standpipe piezometer installed in Borehole 19-1) would likely be below the culvert invert at the time of construction, there is low potential for flow of saturated granular soils (silty sand and sand) and groundwater back through the spoils within the casing and towards the entrance pit. If groundwater or surface water is encountered within the tunnel horizon, such flow could cause significant loss of ground at and above the face of the excavation. These conditions are particularly problematic for traditional “jack and bore”, “small boring unit” and pilot tube micro-tunnelling systems that do not utilize pressurized viscous fluids to support the excavation face. Consideration should be given to specifically identifying the methods that are not suitable since they can commonly be less costly and can be attractive for achieving low bids except the risk of ground losses and roadway settlement would likely be unacceptable.

Given the very loose to compact sandy gravel to sand to silty sand embankment fill and compact native materials, as well as the presence of organics inclusions within the fill, the large vibrations caused by pipe ramming may densify the soils resulting in surface settlement.

As a general guideline, the depth of cover above the crown of the new pipe installation should be greater than or equal to the cut diameter of whatever trenchless system is used to excavate the ground or the largest pipe diameter that will be installed, whichever is greater. Similarly, the separation between newly installed pipes should

be at least one, and preferably two, tunnel diameters in both the vertical and horizontal directions. Oversize casings should be installed for subsequent installation of the culvert or to permit fine adjustments of the carrier pipe invert elevation for final flow control. Selection of casing size should consider the potential for misalignment over the tunnel length due to ground conditions (i.e., boulders), access to the tunnel face (if potentially necessary), proposed tunneling methodology and the length of the tunnel drive. From experience by the Northeastern Region we understand that a 2 pass-system of tunneling is not typical for centreline culverts in Northeast Region.

Settlement monitoring of the trenchless crossing should be carried out (refer to Section 6.6.7). Given the risk of potential settlement or heave for this project, contingency plans for traffic management and road repair should be in-place to rapidly mitigate or limit any distress to the overlying highway embankment, if needed.

6.4 Culvert Installation by Open Cut Excavation

6.4.1 Settlement and Stability

Provided the proposed reconstructed embankment is not widened or raised following culvert replacement, immediate or long-term settlement of the foundation soils beneath the replacement culvert is anticipated to be negligible. If a temporary or permanent grade raise or widening is ultimately required, then a settlement analysis should be carried out, although it is expected that settlement of the subgrade would be less than 25 mm and occur during construction given the presence of primarily non-cohesive native soils below ground surface.

The proposed reconstructed embankment (after culvert replacement) will be stable from a slope stability perspective if the embankment is reconstructed of granular material, such as Ontario Provincial Standard Specification (OPSS) PROV 1010 (*Aggregates*) Granular 'A' or Granular 'B' Type I or II, and with side slopes at an inclination of 2 horizontal to 1 vertical (2H:1V) or flatter.

6.4.2 Bedding and Cover

It is not necessary to found pipe culverts below the depth for frost penetration, as pipe culverts are tolerant of small magnitudes of movement related to freeze-thaw cycles. A circular concrete pipe culvert installed by open cut method should be completed in accordance with OPSD 802.031 (*Rigid Pipe Bedding, Cover and Backfill* for Type 3 Soil) and should be designed in accordance with the *MTO Gravity Pipe Design Guidelines* (2014). If the replacement culvert is to consist of a CSP or plastic pipe installed by open cut method, it should be constructed in accordance with OPSD 802.010 (*Flexible Pipe Embedment and Backfill*) for Type 3 soils. All unsuitable, deleterious and organic materials and fill materials are to be removed from the subgrade below the culvert footprint along the entire alignment. The bedding should be compatible with the class of pipe, surrounding subsoil, anticipated loading conditions and should consist of OPSS.PROV 1010 (*Aggregates*) Granular 'A' material. Depending on the success of the contractor's groundwater control methods, and the quality of the bearing stratum exposed at the base of the excavation, a thicker bedding layer may be required at some locations where wet and loosened soil conditions, unsuitable fill, or organic material are present at base of the excavation. Therefore, the Contract Documents should include a provision for additional thickness of compacted Granular 'A', if required.

From the top of the bedding to 300 mm above the obvert of the culvert, OPSS.PROV 1010 (*Aggregates*) Granular 'A' should be used to backfill around the culvert. All bedding and cover materials should be placed, and culvert construction carried out in accordance with OPSS.PROV 421 (*Pipe Culvert Installation in Open Cut*) and OPSS 401 (*Trenching, Backfilling and Compacting*), and the bedding/cover soil should be compacted in accordance with OPSS.PROV 501 (*Compacting*), as amended by SP 105S22, a copy of which is provided in Appendix C. If the bottom of the excavation is wet and dewatering is not satisfactorily maintaining the water level sufficiently below the base of the excavation to allow compaction, it is recommended that OPSS.PROV 1010

(*Aggregates*) Granular 'B' Type II material be used for bedding and as sub-excavation backfill below the bedding, as may be required.

6.4.3 Trench Backfill

The excavated materials from the culvert site will vary in quality and composition from fill to native sandy gravel to sand to silty sand containing cobbles and potentially boulders or other rock fragments. The existing embankment fill (granular materials) to be excavated to allow for culvert construction, where present above the water table, should be generally near their estimated optimum water contents for compaction provided they are protected from precipitation once they are exposed. Soils encountered below the water table would likely require significant drying in order to reach optimum water content for compaction. The excavated granular fill and native granular soils where encountered above the groundwater level and maintained at suitable water content, may be reused as trench backfill over the culvert cover material, provided these materials are free of organics, or other deleterious material, and are placed and compacted accordance with OPSS.PROV 501 (*Compacting*), as amended by SP 105S22.

Alternatively, granular material which meets the requirements of OPSS.PROV 1010 (*Aggregates*) Select Subgrade Material (SSM) or Granular 'B' Type I may be used as trench backfill. These materials should also be placed and compacted in accordance with OPSS.PROV 501 (*Compacting*), as amended by SP 105S22.

6.5 Analytical Testing for Construction Materials

The results of analytical tests on one sample of embankment fill recovered in Borehole 19-3, immediately above the native soils, is summarized in Section 4.4. The potential for sulphate attack and corrosion are discussed in the following paragraphs, however, it is ultimately up to the designer to determine the appropriate construction materials, including the exposure class, and ensuring that all aspects of CSA A23.1-14 (2014) Section 4.1.1 "Durability Requirements" are followed when designing concrete elements. The culvert should be designed with consideration given to Table 7.1 of the *MTO Gravity Pipe Design Guidelines* (2014).

6.5.1 Potential for Sulphate Attack

The analytical test results were compared to CSA A23.1-14 Table 3 (*Additional requirements for concrete subjected to sulphate attack*) for the potential for sulphate attack on concrete. The water soluble-sulphate concentration measured in the soil sample is much less than 0.10 per cent (i.e., 0.0008 per cent), which is below the exposure class of S-3 (Moderate), and is considered Negligible according to Table 7.2 in the *MTO Gravity Pipe Design Guidelines* (2014). Therefore, based on the test result for the sample of the embankment fill, when the designer is selecting the exposure class for the structure, the effects of sulphates from within the embankment fill may not need to be considered.

6.5.2 Potential for Corrosion

The soil has a pH of 8.5 and according to the *MTO Gravity Pipe Design Guidelines* (2014), the measured pH is not considered detrimental to culvert durability. The resistivity of the embankment fill is 2,390 ohm-cm, which indicates that the soil corrosiveness is Moderate ($2000 < R < 4,500$ ohm-cm), as per Table 3.2 of the *MTO Gravity Pipe Design Guidelines* (2014). As the culvert will also be located under the roadway shoulders and be exposed to de-icing salt, the concrete should be designed for a "C" type exposure class as defined by CSA A23.1-14 Table 1.

6.6 Construction Considerations

6.6.1 Open Cut Excavations for Entry/Receiving Pits or Culvert Construction

The proposed pits/shafts associated with the tunnelling or excavations for cut installation of the culvert, will generally advance through sandy gravel to silty sand fill and into the native silty sand to sand soil above the groundwater level. Where space permits, an open cut excavation into these materials should be carried out in accordance with the guidelines outlined in the *Occupation Health and Safety Act* (OHSA) for *Construction Activities*. Above the groundwater level, the existing fill materials and underlying native soils are classified as Type 3 soil (assuming that the native soils are dry or dewatered), according to OHSA and temporary excavations (i.e. those which are open for a relatively short time period) should be made with side slopes no steeper than 1H:1V. Below the groundwater level the existing fill materials and underlying native soils are classified as Type 4 soil, according to OHSA and temporary excavations (i.e. those which are open for a relatively short time period) into this soil type should be made with side slopes no steeper than 3H:1V. It should be noted that where the excavation exceeds 6 m in depth, the Act indicates that an engineered support system, designed by a professional engineer for the specific location and project, shall be used.

Depending upon the construction procedures adopted by the contractor, groundwater seepage conditions and weather conditions at the time of construction, some local flattening of the slopes of open cut excavations may be required, especially in looser/softer zones or where localized seepage is encountered. Further, layering of soils and the effectiveness of the contractor's dewatering systems could affect the OHSA classification and, therefore, the classification of soils for OHSA purposes must be made at the time the excavation is open and can be directly observed during construction.

6.6.2 Groundwater Control

The groundwater level is expected to be below the proposed culvert invert and therefore groundwater control is not anticipated to be required at this site. Should localized groundwater or surface water be encountered in the excavations, the water level should be lowered to at least 1 m below the base of excavation and can likely be accomplished using properly filtered sump pumps installed below the excavation base. Although not anticipated for the inverts proposed, should the base of the shafts (or open-cut excavations) be lower than these levels or the culvert lowered for any reason, a more proactive dewatering/depressurization system may be required to control groundwater installed and operated in advance of the excavation, or in combination with a sheet pile cut-off wall.

The contractor is responsible for the assessment of dewatering requirements, which depends on his chosen method of open cut excavation, final excavation depths, as well as constructions / operation / maintenance and decommissioning. The contractor is also responsible for confirming that the radius of the drawdown does not impact the existing embankment and any nearby utilities or infrastructure that may be present. Groundwater and/or surface water control may be required for excavation and construction of the culvert. Dewatering should be carried out in accordance with OPSS.PROV 517 (*Dewatering*) and in accordance with OPSS.PROV 421 (*Pipe Culvert Installation in Open Cut*), as applicable.

Surface water into excavations should be directed away from open excavation areas to prevent ponding of water that could result in disturbance and weakening of the subgrade.

6.6.3 Temporary Protection Systems

Temporary excavation protection and support systems shall be designed and constructed in accordance with OPSS.PROV 539 (*Temporary Protection Systems*), as amended by SP105S09. The lateral movement requirements of the protection systems shall meet Performance Level 2 as specified in OPSS.PROV 539 or as

determined by the contractor based on the magnitude of deformation that any utilities can tolerate., which ever is more stringent.

It is anticipated that a driven interlocking sheet pile system would be suitable at this site, however, the possibility of encountering obstructions should be taken into consideration. The contractor may elect to use a soldier pile and lagging system; however, the site would need to be adequately dewatered, if required depending on the depth of the excavation relative to the groundwater level, prior to installation of the lagging boards as the silty sand and sand deposits will not have adequate stand-up time to permit installation of the lagging boards, if below the groundwater level.

The sheet piles, or soldier piles, will need to extend to a sufficient depth to provide the necessary passive resistance for the retained soil height, plus any surcharge loads behind the protection system. Lateral support to the sheet pile wall or soldier pile wall could be provided in the form of rakers or temporary anchors, if and as required.

Vibratory equipment for the installation of temporary protection systems may be used at this site provided that it does not impact the embankment or nearby buried infrastructure. The installation of temporary protection systems by vibratory equipment should be monitored to ensure the vibration levels produced by such construction activity are within tolerable limits and in consultation with the infrastructure / utility and property owners within the zone of influence of the site.

While the selection and design of the temporary protection system will be the responsibility of the design build contractor, the following information is provided to aid in the assessment of the feasible alternatives and approximate construction costs during detail design:

Stratigraphic Unit	Bulk Unit Weight, γ (kN/m ³)	Internal Angle of Friction, ϕ (degrees)	Undrained Shear Strength, s_u (kPa)	Lateral Earth Pressure Coefficients ^{1/2}		
				Passive, K_p^3	Active, K_a	At-rest, K_o
Embankment Fill – Very loose to very dense silty sand	20	29	-	2.88	0.35	0.52
Fill – Loose sandy gravel	18	28	-	2.77	0.36	0.53
Fill – Loose to very dense sand	18	28	-	2.77	0.36	0.53
Compact to dense silty sand	21	31	-	3.12	0.32	0.48
Very loose to very dense sand	20	29		2.88	0.35	0.52

Notes:

1. The design groundwater level may be assumed to be Elevation 424.7 m, based on the water level measured in the piezometer in Borehole 19-1.
2. The lateral earth pressure coefficients presented above are based on a horizontal surface adjacent to the excavation. If sloped surfaces are expected, the coefficients should be corrected accordingly.
3. The total passive resistance below the base of the excavation (i.e., adjacent to the temporary protection system) may be calculated based on the values of K_o indicated above but reduced by an appropriate factor that considers the allowable wall movement in accordance with Figure C6.16 of the CHBDC (2014) to account for the fact that a large strain would be required for mobilization of the full passive resistance.

It is recommended that the ground surface extending back / upwards from the top of the protection system to the existing Highway 127 be graded to an inclination no steeper than 2H:1V. This should be shown on the Contract staging drawings.

The loading from construction equipment as well as any material stockpiles within a distance defined by a 1H:1V line drawn from the bottom of the excavation to the existing ground surface should be included as a surcharge in the design of the temporary protection system.

A shoring displacement monitoring program shall be implemented that is consistent with OPSS.PROV 539 (*Temporary Protection Systems*), as amended by SP105S09, at the entry and exit pits. A copy of SP105S09 is presented in Appendix C for inclusion into the Contract Documents.

Consideration could be given to either partial or full removal of the temporary protection system upon completion of construction or each stage of construction (as required). It is recommended that full removal of the protection system at this site be required to mitigate potential impediments to future rehabilitation/reconstruction work. If partial removal is ultimately required rather than full removal, the partial removal should be carried out as the referenced NSSP included in Appendix C which should be included in the Contract Documents. Vibration and noise controls during extraction of any temporary systems should meet the same tolerable limits used for installation.

6.6.4 Obstructions

Cobbles were encountered/inferred within the embankment fill and native silty sand and sand at the site during the drilling of all boreholes. Further, based on experience on similar projects, cobbles and boulders or rock fill/fragments can be present within highway embankment fill which could affect the installation of temporary protection systems or tunnelling operations. There is also the potential for the presence of organic material (as encountered in Boreholes 19-1 and 19-2) within the fill in the culvert inlet/outlet area. A Notice to Contractor to identify to the contractor the possible presence of cobbles, boulders and organic material within the fill soils, should be included in the Contract Documents, a copy of which is included in Appendix C.

6.6.5 Subgrade Protection

For the tunnelling shafts/pits and for open cut culvert installation and, the subgrade soils will be susceptible to disturbance from construction traffic and/or ponded water. To limit this degradation, it is recommended that the granular bedding layer be placed immediately after preparation and approval of the subgrade or a concrete working slab as per SP FOUN 0001, should be placed on the subgrade in the case of the entry/exit pits; a copy of which is included in Appendix C for inclusions into the Contract Documents.

6.6.6 Embankment Reconstruction/Erosion Protection/Topsoil-Seeding

Fill for reconstruction of the embankment after open cut culvert replacement should consist of OPSS.PROV 1010 (*Aggregates*) Granular 'A' or Granular 'B' Type I or Type II material. The embankment fill should be placed and compacted in accordance with OPSS.PROV 501 (*Compacting*), as amended by SP 105S22, and OPSS.PROV 206 (*Grading*). Embankment side slopes should be constructed no steeper than 2H:1V in granular fill.

Erosion protection at the culvert ends, such as concrete cut-off or a clay seal should be addressed by the designers if the potential for hydraulic scour is possible depending on the level of water flow.

To reduce surface water erosion on the granular embankment side slopes, topsoil and seeding as per OPSS 802 (*Topsoil*) and OPSS.PROV 804 (*Seed and Cover*) should be carried out as soon as possible after construction of the embankments. If this slope protection is not in place before winter, then alternate protection measures, such as covering the slope with straw, or gravel sheeting as per OPSS.PROV 1004 (*Aggregates – Miscellaneous*) and constructed by OPSS.PROV 511 (*Rip Rap, Rock Protection and Granular Sheeting*), will be required to reduce

the potential for erosion and to reduce the potential for the requirement of remedial works on the side slopes in the spring prior to topsoil dressing and seeding.

6.6.7 Instrumentation and Monitoring Program for Pipe Installation by Trenchless Methods

The maximum cover over the pipe is up to about 5.6 m at the highway grade and ranges from this thickness to minimal cover at the inlet and outlet ends. For the anticipated soil cover and pipe ramming method, it is anticipated that settlement of the ground surface and overlying highway will be less than 10 mm, provided that good tunneling procedures are followed. An instrumentation and monitoring program is recommended at the culvert location if a trenchless installation method is to be used for culvert construction to:

- Document the effects of the culvert installation on the overlying highway and adjacent underground utilities/services, if applicable.
- Potentially identify adverse ground movement trends that could occur due to the construction methods and equipment or unforeseen ground conditions.
- Evaluate the contractor's compliance with the settlement limits specified in the Contract Documents.
- Allow adjustments to be made to the culvert installation methods such that the settlement limits established are not exceeded.

The Special Provision for "*Pipe Installation by Trenchless Method*" (Appendix C) contains the details of the settlement monitoring program to be implemented to measure ground settlement at the existing roadway prior to, during and following the proposed installation. In general, monitoring points should be placed over the entire centreline length of the new culvert alignment at the edge of all pavements, in landscape areas leading to the pavement from the entry pit and at perpendicular off-sets of about 2 m from the centre line at all pavement shoulder edges for a distance equal to the depth from road surface to invert. If a trenchless installation method is adopted, a site-specific Supply/Installation of Instrumentation Plan and a Monitoring Plan for embankment construction/staging options and settlement monitoring should be prepared for the contractor and Contract Administrator assignment for inclusion in the Contract Documents/Provided to the CA.

It is also recommended that, to the extent practicable and possible, the weight or volume of ground removed from beneath the highway be measured and compared to the theoretical cut hole volume on a frequency of at least once per 3 m section of tunnel / pipe installed. On-site observations of construction operations and measurements of grout and/or lubricant volumes should assist in identifying atypical conditions that could be indicative of unacceptable ground losses.

Provision should be included in the Contract Documents for rehabilitation of the Highway 127 platform and embankment along the culvert alignment in the event of settlement during the installation process. It is understood from previous experiences on similar projects that driving restrictions typically govern timing of paving such that if settlement occurs, repairs would be performed during the Contract.

Further, the location (depth/alignment), type and tolerances to movement and vibrations of any existing buried utilities (functioning or decommissioned) would have to be clearly established prior to any trenchless installation operation, and the Review Level and Alert Level tolerances for settlement confirmed in the SP for "*Pipe Installation by Trenchless Method*", included in Appendix C.

The installation of the culvert using pipe ramming should be monitored to ensure the vibration levels produced by such construction activity are within tolerable limits and in consultation with the infrastructure / utility and property

owners within the zone of influence of the site. This is also required to monitor the potential impact on densification of the soils over the pipe potentially leading to ground settlement.

6.6.8 Grouting

Post installation grouting to fill the annular space between the carrier pipe (culvert) and the casing (if used on this site) may need to be carried out after the permanent culvert pipe is installed within the casing as noted in the SP for "*Pipe Installation by Trenchless Method*" included in Appendix C. For any installations at which the settlement monitoring or excavation volume monitoring indicates that pavement settlement or ground loss might have occurred, or where signs of ground loss have been noted, provision should also be made for a program of compensation grouting above the casing pipe and/or repair of the pavement.

6.6.9 Recommendations for Further Work During Design

The foundation investigation and design recommendation presented in this Foundation Investigation and Design Report addresses the MTO Terms of Reference in the Guideline for Foundation Engineering-Tunnelling Specialty. The subsurface conditions encountered at this site are considered suitable for the pipe ramming trenchless method of pipe installation, and may be considered suitable by the contractor for other methods of trenchless installation that they have at their disposal, given their understanding of the such installation methods, equipment and manpower capabilities, and their experience. The contractor should be alerted to the presence of cobbles and potentially boulders, within the embankment fill and the native silty sand and gravelly sand to sand deposits, as encountered in Boreholes 19-1 to 19-3.

As part of the design phase and selection of the trenchless installation method, the contractor should assess whether additional field investigation is required, based on the final configuration and location/depth of the culvert and the chosen installation method. The scope and results of the subsurface investigation presented herein should be reviewed by the contractor as part of the tendering to determine if they are sufficient for the final culvert type, invert level and trenchless installation method under consideration by the contractor. Additional subsurface investigation work, if deemed necessary, should be carried out by the contractor during their detailed design and selection of the trenchless installation method. If the final alignment and/or invert elevation are altered, then additional sampling within the tunnel horizon would be warranted along with confirming the soil behaviour in response to the tunnelling. If a grade raise or widening of the roadway is required, an assessment of the potential settlement of the pipe and embankment and analysis of the embankment would be required.

7.0 CLOSURE

This foundation design report was prepared by Mr. Michael Bentley a member of the geotechnical group with Golder, and the technical aspects were reviewed by Ms. Sarah E. M. Poot, P.Eng., a senior geotechnical engineer and Associate of Golder. Mr. Jorge Costa, P.Eng., an MTO Foundations Designated Contact and Senior Consultant with Golder conducted an independent and quality control review of the report.

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- Chapman and Putnam, 1984. Physiography of Southern Ontario. Map P.2715
- Ontario Ministry of Northern Development and Mines. Bedrock Geology of Ontario, East-Central Sheet. Map 2544
- Ontario Regulation 903 (Wells)
- Occupational Health and Safety Act and Regulation for Construction Projects (as amended).
- ASTM D1586-18 Standard Test Method for Standard Penetration Test and Split-Barrel Sampling of Soils

Ontario Provincial Standard Drawings (OPSD)

OPSD 802.010	Flexible Pipe Embedment in Embankment and Backfill: Earth or Excavation
OPSD 802.031	Rigid Pipe Bedding, Cover, And Backfill, Type 3 Soil - Earth Excavation

Ontario Provincial Standard Specifications (OPSS) – Provincial Oriented

OPSS.PROV 206	Construction Specification for Grading
OPSS.PROV 401	Construction Specification for Trenching, Backfilling and Compacting
OPSS PROV 421	Construction Specification for Pipe Culvert Installation in Open Cut
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 511	Construction Specification for Rip-Rap, Rock Protection, and Granular Sheetting
OPSS.PROV 517	Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 802	Construction Speciation for Topsoil
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS.PROV 1004	Material Specification for Aggregates - Miscellaneous
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material

TABLE 1 – Evaluation of Culvert Installation Methods
Highway 127, Station 18+320, Township of Sabina, G.W.P. 5151-13-00

Installation Method	Advantages	Disadvantages	Relative Costs	Risk / Consequences
Horizontal Directional Drilling	<ul style="list-style-type: none"> • Deep entry and exit pits are generally not required • Existing pipe diameter is within installation method's capabilities. 	<ul style="list-style-type: none"> • Drilling is challenging in boulder ground. • Large laydown area required for carrier pipe. 	<ul style="list-style-type: none"> • Similar cost to jack and bore. Less expensive than MTBM. 	<ul style="list-style-type: none"> • Less risk of ground loss when compared to jack and bore methods. • Obstructions can result in deflection of the casing/pipe resulting in misalignment of the sewer.
Traditional Jack and Bore	<ul style="list-style-type: none"> • Suitable for proposed installation length under existing embankment. • Tunnel is fully lined as excavation progresses (i.e., culvert/casing pipe is installed behind the boring head during forward advancement). • Existing culvert size of 0.75 m diameter is within the installation diameters by jack and bore. 	<ul style="list-style-type: none"> • Traditional jack and bore is not considered suitable for granular material below water levels or in granular soils above water levels if a plug of soil cannot be maintained in lead end of casing. • Dewatering might be required along tunnel alignment to be used successfully. • Difficult to control line and grade using jack and bore, potentially requiring installation of a larger culvert/casing pipe than that specified to accommodate variation during installation. 	<ul style="list-style-type: none"> • Similar cost as pipe ramming. Less expensive than MTBM. • Cost of dewatering for shafts as well as along the tunnel alignment. • Less costly than MTBM. 	<ul style="list-style-type: none"> • Significant potential for loss of ground into casing/pipe without dewatering of bore alignment, especially in wet/flowing conditions and even with plug of soil ahead of augers. • Obstructions can result in deflection of the casing/pipe resulting in misalignment of the sewer. Cutter head can be specified to have capability for cutting through boulders.

Installation Method	Advantages	Disadvantages	Relative Costs	Risk / Consequences
Pipe Ramming	<ul style="list-style-type: none"> • Less risk of subsidence above sewer alignment when compared to jack and bore installation methods. • Likely suitable for proposed installation length at this site when used beneath existing embankment and supplemented with bentonite lubrication and potential shortening of drive if headwalls excavated and supported in embankment. • Better suited for penetrating through potential obstructions such as cobbles and boulders when compared to jack and bore methods. • Better suited to site soils below the groundwater level when compared to jack and bore methods. • Potentially slightly smaller footprint for entry/exit shafts than that required for jack and bore and MTBM. • Existing culvert size of 0.75 m diameter is considered within the installation diameters by pipe ramming. 	<ul style="list-style-type: none"> • Proposed culvert size of 1.8 m diameter is considered at the upper limit for installation diameters by pipe ramming. • Difficult to control line and grade using pipe ramming. • Potential for heaving at ground surface (where cover is thin) as a long plug of soil is maintained inside pipe – may require periodic removal of soil plug which is not recommended in saturated ground. • Ramming vibration could affect adjacent service lines (if any). • Noise can be a public nuisance. 	<ul style="list-style-type: none"> • Similar cost to jack and bore. Less expensive than MTBM. 	<ul style="list-style-type: none"> • Less risk of ground loss during tunnelling when compared to jack and bore methods. • Obstructions can result in deflection of the casing/pipe resulting in misalignment of the sewer. • Vibration from pipe ramming may impact adjacent buried service lines. • No frac-out risk.









Installation Method	Advantages	Disadvantages	Relative Costs	Risk / Consequences
Microtunnelling with Slurry MTBM	<ul style="list-style-type: none"> • Slurry-type MTBM is able to counterbalance earth and groundwater pressures in a controlled manner, providing continuous face support and eliminating need for dewatering at the tunnel face along the alignment. • Can be steered continuously, providing good control over line and grade. • Tunnel is fully lined as excavation progresses (i.e., culvert/casing pipe is installed behind the MTBM during forward advancement). • No personnel entry required. • Potential effects on structures and underground utilities next to the tunnel alignment can be better controlled than most other methods. • Machines can include rock-cutting face tools and internal crushers. • Considered suitable for site subsurface conditions. 	<ul style="list-style-type: none"> • Susceptible to hydraulic fracture ("frac-out") especially in low cover conditions. • Slurry processing systems/separation plants required along with additional working area at shaft locations for some systems. • Relatively expensive for short installation length (approximately 32 m). • Existing pipe size or 0.75 m on lower limit of installation method capabilities. 	<ul style="list-style-type: none"> • Relatively expensive when compared to traditional tunneling methods 	<ul style="list-style-type: none"> • Relatively low risk of ground loss during tunnelling when a counterbalancing and appropriately viscous slurry and pressure is used. • Greater risk of fluid losses to the surface compared to other methods that do not utilize slurries, but the potential of fluid losses to the surface depends on slurry composition, viscosity, pressure and the existence of available pathways (old boreholes or wells, utility bedding, etc.). • Subsurface conditions at interface of fill and native ground may include risks of encountering wood debris or other materials that obstruct tunnelling.

Installation Method	Advantages	Disadvantages	Relative Costs	Risk / Consequences
Jack and Bore with Guided Boring Machine (Pilot Tube Boring)	<ul style="list-style-type: none"> • Suitable for proposed installation length under existing embankment (approximately 32 m). • Tunnel is fully lined as excavation progresses (i.e., sewer pipe is installed behind the boring head during forward advancement). • Pilot tube is steered, providing better line and grade control for final installation as compared to traditional jack and bore. • Existing culvert size of 0.75 m diameter is considered within the installation diameters of this method. 	<ul style="list-style-type: none"> • Jack and bore with guided boring machine (GBM) is no more suitable to penetrate through granular material above and below the water table when compared to traditional jack and bore. • Dewatering might be required along tunnel alignment to be used successfully. • Very stiff/hard or very dense subsurface material may limit penetration of the pilot tube, depending on equipment used for advancement of pilot tube. 	<ul style="list-style-type: none"> • Somewhat more expensive than jack and bore and pipe ramming but less expensive than MTBM. • Potential cost of dewatering for shafts as well as along the tunnel alignment. 	<ul style="list-style-type: none"> • Significant potential for loss of ground into casing/pipe without dewatering of bore alignment, especially in wet/flowing conditions and even with plug of soil ahead of auger. • Obstructions can result in deflection of the pilot tube resulting in misalignment of the sewer, although this can be better managed than for traditional jack and bore. • Unexpectedly hard/dense ground conditions can halt penetration of the pilot tube, depending on equipment details.

Installation Method	Advantages	Disadvantages	Relative Costs	Risk / Consequences
Tunnelling with EPB TBM	<ul style="list-style-type: none"> • EPB TBM is able to counterbalance earth and groundwater pressures in a controlled manner, providing continuous face support and eliminating need for dewatering at the tunnel face along the alignment. • Can be steered continuously, providing good control over line and grade. • Tunnel is fully lined as excavation progresses (i.e., culvert/casing pipe is installed behind the MTBM during forward advancement). • Potential effects on structures and underground utilities next to the tunnel alignment can be better controlled than most other methods. • Machines can include rock-cutting face tools and older systems that use load or pressure-controlled gates for spoil discharge from forward chamber can pass some larger potential obstructions depending on face opening and relieving gate sizes. • Considered suitable for site subsurface conditions. 	<ul style="list-style-type: none"> • Susceptible to ground losses depending on operator control of face pressures, relieving gate or screw conveyor operations • Addition of appropriate conditioning agents (e.g., bentonite) may be required to modify spoil for appropriate consistency and face pressure control • Relatively expensive for short installation length (approximately 32 m). • Existing pipe size or 0.75 m on lower limit of installation method capabilities. 	<ul style="list-style-type: none"> • Relatively expensive when compared to traditional tunneling methods. 	<ul style="list-style-type: none"> • Relatively low risk of ground loss during tunnelling when a counterbalancing face pressure is used and conditioning agents may be required.

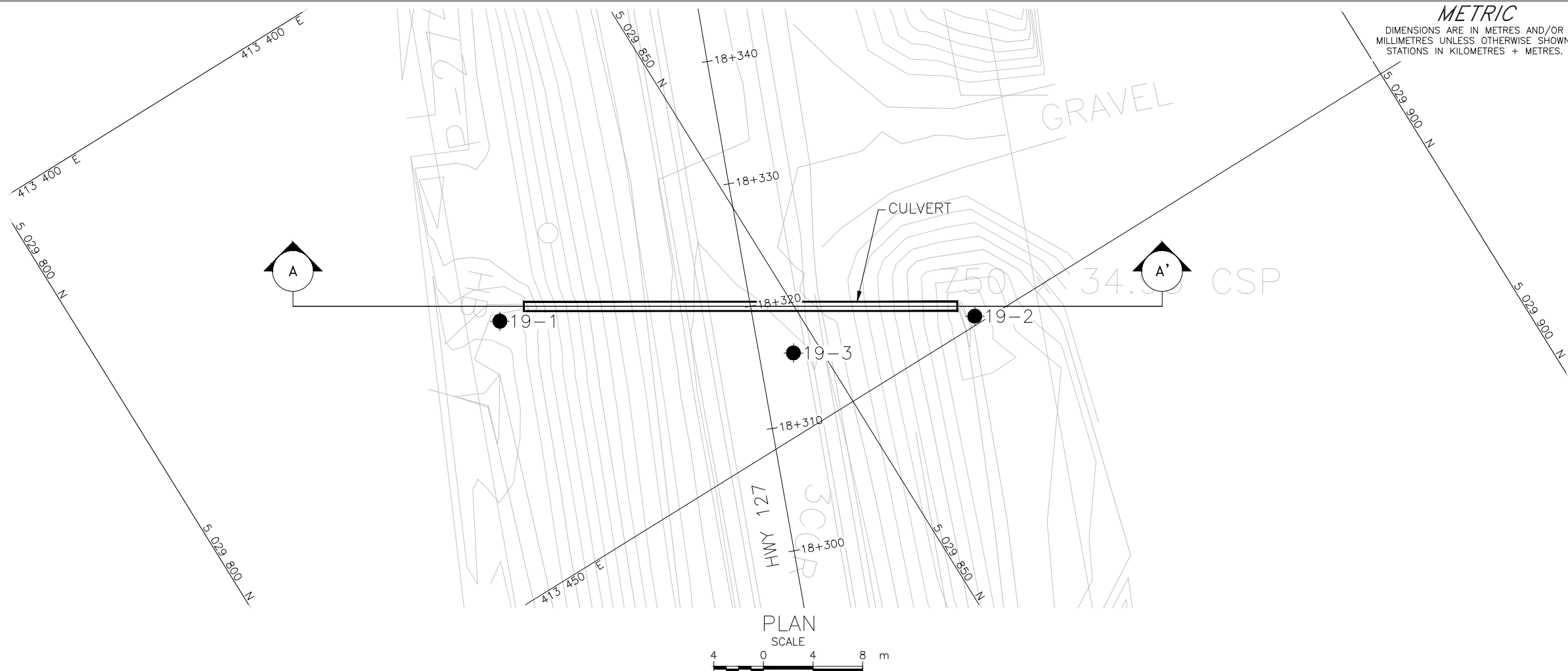
Installation Method	Advantages	Disadvantages	Relative Costs	Risk / Consequences
Mechanically Assisted and Hand Mining (Shield Tunnelling)	<ul style="list-style-type: none"> Proposed length is achievable under existing embankment Obstructions can be easily removed by personnel at the tunnel face. Range of pipe diameters within typical range of shield diameters. Backhoe-arm excavator possible in the larger diameters considered for this project. 	<ul style="list-style-type: none"> Typically, shield mining is not considered suitable for “flowing” conditions, such as saturated sand as encountered at this site, unless dewatering and special provisions are used to manage groundwater issues. Dewatering might be required along alignment to be used successfully. Line and grade control might require installation of a larger culvert/casing pipe than that specified to accommodate variation during installation. “Hooded” or angled-face shield required and poling plates or spiling needed to control ravelling of ground near crown and above spring-line of tunnel. 	<ul style="list-style-type: none"> More expensive than jack and bore and pipe ramming. Cost of potential dewatering near culvert invert. 	<ul style="list-style-type: none"> Potential for loss of ground into the tunnel.
Open Cut (Cut-and-Cover)	<ul style="list-style-type: none"> Risks of ground losses affecting traffic are better controlled than for trenchless methods. Depth of excavation is within typical limits for conventional excavation support, slopes and dewatering systems. With appropriate planning, excavation methods can be adapted to address boulders or other obstructions, and loose soils. 	<ul style="list-style-type: none"> Traffic disruption (staging of crossing construction). Roadway protection required for staged excavation. Proactive dewatering required (e.g., vacuum well points). 	<ul style="list-style-type: none"> Similar cost to jack and bore. Less expensive than MTBM. 	<ul style="list-style-type: none"> Difficulties may be experienced during installing temporary roadway protection if cobbles/boulders are present in embankment fill and native soils Traffic staging problems (e.g., temporary concrete barriers, seasonal construction). Dewatering planning as part of bid may not be adequate and result in real or strategic claims.

TABLE 2 - Risk Register for Culvert installation BY PIPE RAMMING
Highway 127, Station 18+320 Culvert REPLACEMENT, Township of Sabina, GWP 5151-13-00

Risk Item	Key Issues and Consequences	Mitigation	Likelihood	Impact	Mitigation Measures Recommended
Item 1: Settlement of road due to vibrations from pipe ramming. IMPACT: Liability for settlement damage to private property, utilities and/or roadways.	<ul style="list-style-type: none"> Vibrations from pipe ramming can lead to densification and settlement of very loose to compact sandy gravel/sand/silty sand fill surrounding pipe and result in settlement of roadway. High density of ground in some areas may encourage/require premature removal of soils from within the casing resulting in the potential for settlement. Travelling public may experience strong vibrations and surface depressions while driving through the area. 	Unmitigated			<ul style="list-style-type: none"> Project site isolated in relatively remote area with low traffic volume and no known utilities or private properties nearby. Obtaining pre-construction baseline settlement monitoring data over culvert alignment. Comprehensive settlement monitoring program to be implemented during pipe ramming operations, including stopping of operations if critical levels are exceeded. Provide contractual tools to require implementation of appropriate contingency measures to stop/slow/divert traffic and/or repair roadway surface if excessive settlement or sinkholes are measured/observed.
		Mitigated			
Item 2: Settlement of road due to groundwater infiltration greater than anticipated for tunnel drive and at shafts. IMPACT: Liability for settlement damage to private property, utilities and/or roadways.	<ul style="list-style-type: none"> Tunnel or shaft construction encounters local inflow. Mixed-face conditions and groundwater handling. Flowing ground into excavations or pipe resulting in settlement of roadway. Slower than anticipated advancement rates. More frequent intervention delays and/or delays completing work. Potential Differing Site Condition (DSC) Claims. Travelling public may experience surface depressions while driving through the area. 	Unmitigated			<ul style="list-style-type: none"> Comprehensive subsurface investigation program conducted to characterize risks, extents of issue and impacted areas, and effectiveness of proposed mitigation measures. Groundwater level measured in native silty sand to sand deposits at a depth greater than 1 m below the pipe invert. Perched water not identified in fill. Requirements for watertight shaft construction (TPS). Select tunnelling method (pipe ramming) to mitigate the potential for water inflow.
		Mitigated			

Risk Item	Key Issues and Consequences	Mitigation	Likelihood	Impact	Mitigation Measures Recommended
Item 3: Heave of road due to limited thickness of soil cover over tunnel. IMPACT: Liability for settlement damage to private property, utilities and/or roadways.	<ul style="list-style-type: none"> Heave of roadway due to localized compaction of soils at the leading edge of the pipe. Travelling public may experience surface bumps while driving through the area. 	Unmitigated	M	L	<ul style="list-style-type: none"> Project site is located in relatively remote area with low traffic volume and no known utilities or private properties nearby. Obtaining pre-construction baseline settlement monitoring data over culvert alignment. Comprehensive settlement monitoring program to be implemented during pipe ramming operations, including stopping of operations if critical levels are exceeded. Provide contractual tools to require implementation of appropriate contingency measures to stop/slow/divert traffic and/or repair roadway surface if excessive settlement or sinkholes are measured/observed.
		Mitigated	L	L	
Item 4: Obstructions impede advance of tunnel or shoring (TPS) installation. IMPACT: Boring operations suspended to address conditions with associated cost and schedule implications.	<ul style="list-style-type: none"> Obstructions such as cobbles, boulders or large rock fill fragments may impede advance of pipe depending on size and frequency. Other unknown obstructions associated with original construction of road or culvert may be present (such as wood along the fill – native soil interface). Work stoppage and/or delays. Obstructions may require shaft excavation from the surface. Removal of soils from within the casing may be required to remove obstructions and may result in an unstable face and the potential for settlement. Steering-alignment problems. Potential for DSC claims. 	Unmitigated	M	M	<ul style="list-style-type: none"> Comprehensive subsurface investigation program conducted to characterize risks, extents of issue and impacted areas, and effectiveness of proposed mitigation measures. Select tunnelling method (pipe ramming) that has least susceptibility to obstructions. Provide contractual tools to require implementation of appropriate contingency measures to remove obstructions while maintaining stable face conditions.
		Mitigated	L	L	

Risk Item	Key Issues and Consequences	Mitigation	Likelihood	Impact	Mitigation Measures Recommended
Item 5: Excessive noise from pipe ramming. IMPACT: Sensitivity of property owners.	<ul style="list-style-type: none"> Property owners may be impacted by excessive loud noise. 	Unmitigated	M	L	<ul style="list-style-type: none"> Project site is located in relatively remote area with low traffic volume and no private properties nearby. Restrict ramming operations to daytime hours. Conduct noise monitoring.
		Mitigated	L	L	
Item 6: Major equipment failure IMPACT: Boring operations suspended to address conditions with associated cost and schedule implications.	<ul style="list-style-type: none"> Work stoppage and/or delays. 	Unmitigated	M	L	<ul style="list-style-type: none"> Specifications on type and quality of equipment. Specified requirements for performance as well as maintenance frequency. Equipment monitoring and progress reporting.
		Mitigated	L	L	



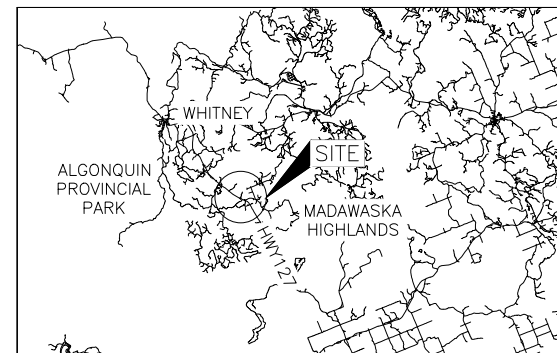
METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No. .
GWP No. 5151-13-00



HWY 127 STATION 18+320
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL
STRATA

SHEET



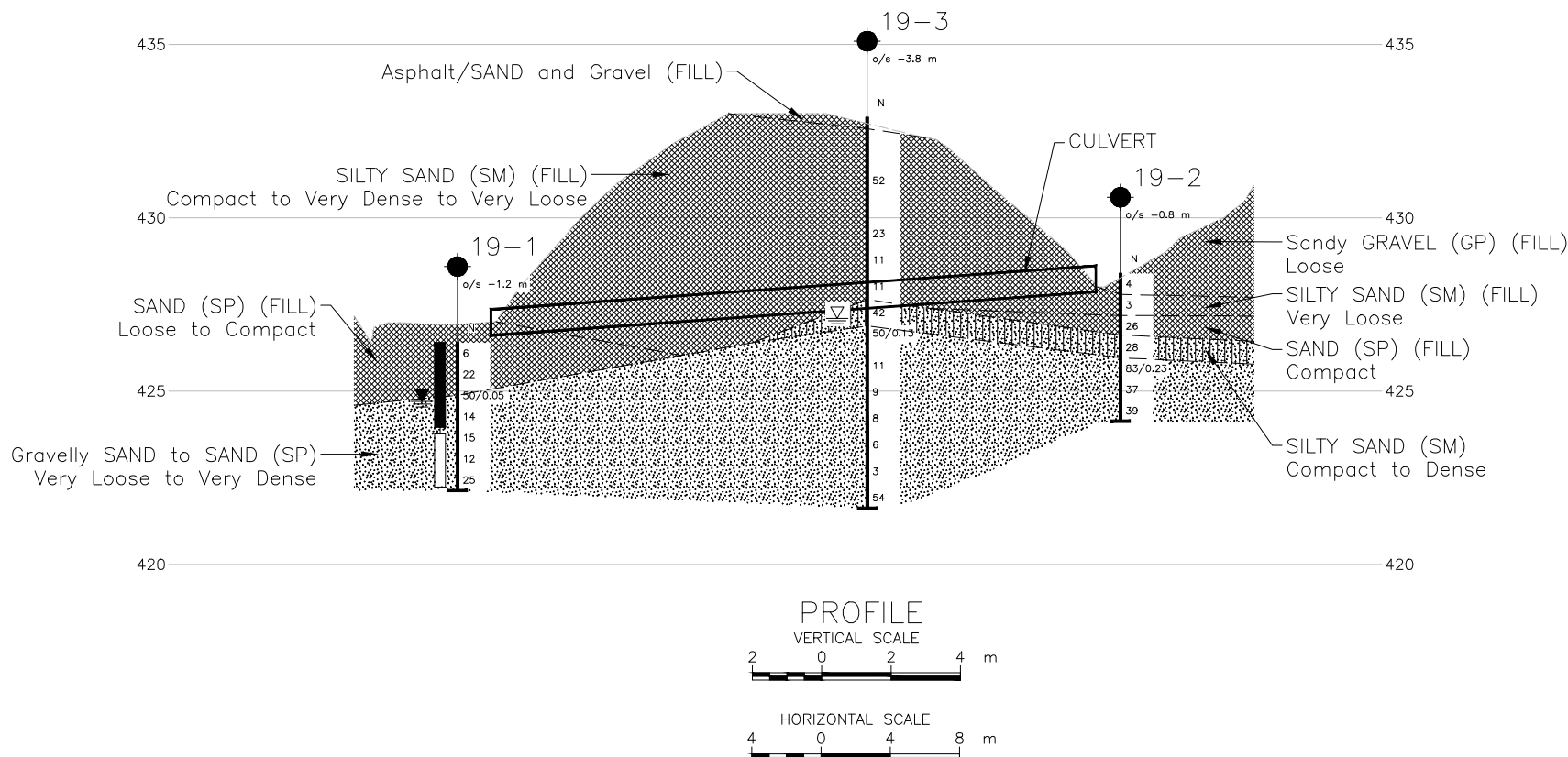
KEY PLAN
SCALE
10 0 10 20 km

LEGEND

- Borehole - Current Investigation
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated
(Std. Pen. Test, 475 j/blow)
- WL upon completion of drilling
- WL in Piezometer

BOREHOLE CO-ORDINATES (MTM NAD83 ZONE 10)

No.	ELEVATION	NORTHING	EASTING
19-1	426.4	5029829.2	413429.5
19-2	428.4	5029862.0	413449.3
19-3	432.9	5029848.0	413444.2



NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

REFERENCE

Base plans provided in digital format by D.M. Wills Associates Ltd., file no. wp52651301a.dwg, received September 18, 2019.



NO.	DATE	BY	REVISION
Geocres No. 31E-408			
HWY. 127	PROJECT NO. 18104224-7		DIST. .
SUBM'D. MJB	CHKD. MJB	DATE: 11/26/2019	SITE: .
DRAWN: DD	CHKD. SEMP	APPD. JMAC	DWG. 1



Photograph 1: Culvert Outlet, South End (August 2019)



Photograph 2: Culvert Inlet, North End (August 2019)



Photograph 3: Highway 127 Facing East Towards Culvert Area (August 2019)

APPENDIX A

Record of Boreholes and Drillholes

ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

MINISTRY OF TRANSPORTATION, ONTARIO

PARTICLE SIZES OF CONSTITUENTS

Soil Constituent	Particle Size Description	Millimetres	Inches (US Std. Sieve Size)
BOULDERS	Not Applicable	>300	>12
COBBLES	Not Applicable	75 to 300	3 to 12
GRAVEL	Coarse Fine	19 to 75 4.75 to 19	0.75 to 3 (4) to 0.75
SAND	Coarse Medium Fine	2.00 to 4.75 0.425 to 2.00 0.075 to 0.425	(10) to (4) (40) to (10) (200) to (40)
FINES	Classified by plasticity	<0.075	< (200)

MODIFIERS FOR SECONDARY COMPONENTS^{1,2}

Percentage by Mass	Modifier
> 35	Use 'and' to combine primary and secondary component (<i>i.e.</i> , SAND and gravel)
> 20 to 35	Primary soil name prefixed with "gravelly, sandy" as applicable
> 10 to 20	some (<i>i.e.</i> , some sand)
≤ 10	trace (<i>i.e.</i> , trace fines)

1. Only applicable to components not described by Primary Group Name.

2. Classification of Primary Group Name based on Unified Soil Classification System (ASTM D2487) for coarse-grained soils; fine-grained soils described per current MTO Soil Classification System.

PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) split-spoon sampler for a distance of 300 mm (12 in.). Values reported are as recorded in the field and are uncorrected.

Cone Penetration Test (CPT)

An electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (*q_t*), porewater pressure (*u*) and sleeve friction (*f_s*) are recorded electronically at 25 mm penetration intervals.

Dynamic Cone Penetration Resistance (DCPT); N_d:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

SAMPLES

AS	Auger sample
BS	Block sample
CS	Chunk sample
DD	Diamond Drilling
DO or DP	Seamless open ended, driven or pushed tube sampler – note size
DS	Denison type sample
GS	Grab Sample
MC	Modified California Samples
MS	Modified Shelby (for frozen soil)
RC / SC	Rock core / Soil core
SS	Split spoon sampler – note size
ST	Slotted tube
TO	Thin-walled, open – note size (Shelby tube)
TP	Thin-walled, piston – note size (Shelby tube)
WS	Wash sample
OD / ID	Outer Diameter / Inner Diameter
HSA / SSA	Hollow-Stem Augers / Solid-Stem Augers

SOIL TESTS

w	water content
PL, w _p	plastic limit
LL, w _L	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D _R	relative density (specific gravity, G _s)
DS	direct shear test
GS	specific gravity
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO ₄	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V (FV)	field vane (LV-laboratory vane test)
Y	unit weight

1. Tests anisotropically consolidated prior to shear are shown as CAD, CAU.

COARSE-GRAINED SOILS

Compactness¹

Term	SPT 'N' (blows/0.3m) ²
Very Loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	≥ 50

3. Definition of compactness terms are based on SPT 'N' ranges as provided in Terzaghi, Peck and Mesri (1996). Many factors affect the recorded SPT 'N' value, including hammer efficiency (which may be greater than 60% in automatic trip hammers), overburden pressure, groundwater conditions, and grain size. As such, the recorded SPT 'N' value(s) should be considered only an approximate guide to the soil compactness. These factors need to be considered when evaluating the results, and the stated compactness terms should not be relied upon for design or construction.

4. SPT 'N' in accordance with ASTM D1586, uncorrected for the effects of overburden pressure.

FINE-GRAINED SOILS

Consistency

Term	Undrained Shear Strength (kPa)	SPT 'N' ^{1,2} (blows/0.3m)
Very Soft	< 12	0 to 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	> 200	> 30

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.

2. SPT 'N' values should be considered ONLY an approximate guide to consistency; for sensitive clays (e.g., Champlain Sea clays), the N-value approximation for consistency terms does NOT apply. Rely on direct measurement of undrained shear strength or other manual observations.

Field Moisture Condition

Term	Description
Dry	Soil flows freely through fingers.
Moist	Soils are darker than in the dry condition and may feel cool.
Wet	As moist, but with free water forming on hands when handled.

LIST OF SYMBOLS

MINISTRY OF TRANSPORTATION, ONTARIO

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
$\ln x$	natural logarithm of x
\log_{10}	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
FoS	factor of safety

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)

σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
U	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
E	void ratio
N	porosity
S	degree of saturation

* Density symbol is ρ . Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index = $(w_l - w_p)$
NP	non-plastic
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_C	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_α	secondary compression index
m_v	coefficient of volume change
C_v	coefficient of consolidation (vertical direction)
C_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = $\tan \delta$
c'	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

Notes: 1
2

$\tau = c' + \sigma' \tan \phi'$
shear strength = (compressive strength)/2

PROJECT		18104224-7		RECORD OF BOREHOLE No 19-1		SHEET 1 OF 1		METRIC													
G.W.P.		5265-13-01		LOCATION		N 5029829.2; E 413429.5 MTM NAD 83 ZONE 10 (LAT. 45.399981; LONG. -78.112448)		ORIGINATED BY													
DIST		HWY 127		BOREHOLE TYPE		Portable Equipment, BW Casing with Wash Boring		COMPILED BY													
DATUM		Geodetic		DATE		August 12 and 13, 2019		CHECKED BY													
								SEMP													
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV	DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20	40	60	80	100	W _p	W	W _L	γ	GR	SA	SI	CL
426.4	0.0	GROUND SURFACE		1	SS	6		426													
		SAND (SP), some gravel, trace to some fines, rootlets, organic inclusions, some cobbles (FILL) Loose to compact Dark brown to brown Wet		2	SS	22															
424.9	1.5	- Rock fragments recovered from wash boring between depths of 1.2 m and 1.4 m - No recovery from Sample 3 Gravelly SAND (SP) to SAND (SP), some gravel, trace fines Compact Brown Wet - No recovery from Sample 5 - Possible cobble at 3.1 m depth		3	SS	50/0.05		425													
				4	SS	14		424													
				5	SS	15															
				6	SS	12		423													
				7	SS	25															
422.1	4.3	END OF BOREHOLE																			
NOTES: 1. Water measured at a depth of 0.3 m below ground surface (Elev. 426.1 m) upon completion of drilling (Elev. 424.7 m). 2. Water level measured in piezometer at a depth of 1.7 m below ground surface (Elev. 424.7 m), August 24, 2019. 3. NP-Non-plastic.																					

PROJECT		18104224-7		RECORD OF BOREHOLE No 19-2		SHEET 1 OF 1		METRIC					
G.W.P.		5265-13-01		LOCATION		N 5029862.0; E 413449.3 MTM NAD 83 ZONE 10 (LAT. 45.400272; LONG. -78.112187)		ORIGINATED BY					
DIST		HWY 127		BOREHOLE TYPE		Portable Equipment, BW Casing with Wash Boring		COMPILED BY					
DATUM		Geodetic		DATE		August 13 and 14, 2019		CHECKED BY					
								SEMP					
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	W _p W W _L	10 20 30		
428.4	GROUND SURFACE												
0.0	Sandy GRAVEL (GP), root fragments (FILL)		1	SS	4								
427.8	Loose Brown Wet		2	SS	3								
0.6	- Rock fragments recovered from wash boring between depths of 0.4 m and 1.5 m												
427.2	SILTY SAND (SM), trace gravel, organic inclusions (FILL)		3	SS	26								
1.2	Very loose Dark brown Wet		4	SS	28								
426.6	SAND (SP) and gravel, some fines, some cobbles (FILL)		5	SS	83/0.23								
1.8	Compact Brown												
426.0	SILTY SAND (SM)		6	SS	37								
2.4	Compact Brown Wet												
424.1	SAND (SP), some gravel, trace to some fines, some cobbles		7	SS	39								
4.3	Dense to very dense Brown Wet												
	- Rock fragments recovered from wash boring between depths of 3.0 m and 3.7 m												
	END OF BOREHOLE												
NOTES: 1. Borehole dry upon completion of drilling. 2. Borehole caved to a depth of 2.1 m below ground surface (Elev. 426.3 m) upon completion of drilling.													

GTA-MTO 001 S:\CLIENTS\MTOWHY_12702_DATA\GINT\HWY_127.GPJ GAL-GTA.GDT 11/28/19

PROJECT 18104224-7		RECORD OF BOREHOLE No 19-3				SHEET 1 OF 1		METRIC						
G.W.P. 5265-13-01		LOCATION N 5029848.0; E 413444.2 MTM NAD 83 ZONE 10 (LAT. 45.400147; LONG. -78.112257)				ORIGINATED BY MJB								
DIST _____ HWY 127		BOREHOLE TYPE 216 mm O.D. Hollow Stem Augers				COMPILED BY MJB								
DATUM Geodetic		DATE August 14, 2019				CHECKED BY SEMP								
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
432.9	GROUND SURFACE							20 40 60 80 100	20 40 60 80 100	10 20 30				
0.0	Asphalt (75 mm)													
0.3	SAND and gravel (SW) (FILL)													
	SILTY SAND (SM) and gravel (FILL)													
	Very dense to compact													
	Brown													
	Moist													
	- Auger grinding between depths of 0.3 m and 3.8 m		1	SS	52									41 42 15 2
	- Low recovery in Sample 2		2	SS	23									
			3	SS	11									
	- Auger grinding between depths of 4.6 m and 5.3 m		4	SS	11									
427.6														
5.3	SILTY SAND (SM), some gravel, oxidation staining		5	SS	42									20 60 18 2
	Dense													
	Brown													
	Moist													
426.9			6	SS	50/0.13									
6.0	SAND (SP), some to trace gravel, trace fines, oxidation staining													
	Loose to very dense													
	Brown													
	Moist to wet													
	- Auger grinding between depths of 7.6 m and 8.4 m		8	SS	9									16 77 6 1
			9	SS	8									
			10	SS	6									
			11	SS	3									3 92 5 0
			12	SS	54									
421.6														
11.3	END OF BOREHOLE													
	NOTES:													
	1. Water measured in open borehole at a depth of 5.8 m below ground surface (Elev. 427.1 m) upon completion of drilling.													
	2. Borehole caved to a depth of 6.0 m below ground surface upon completion of drilling.													

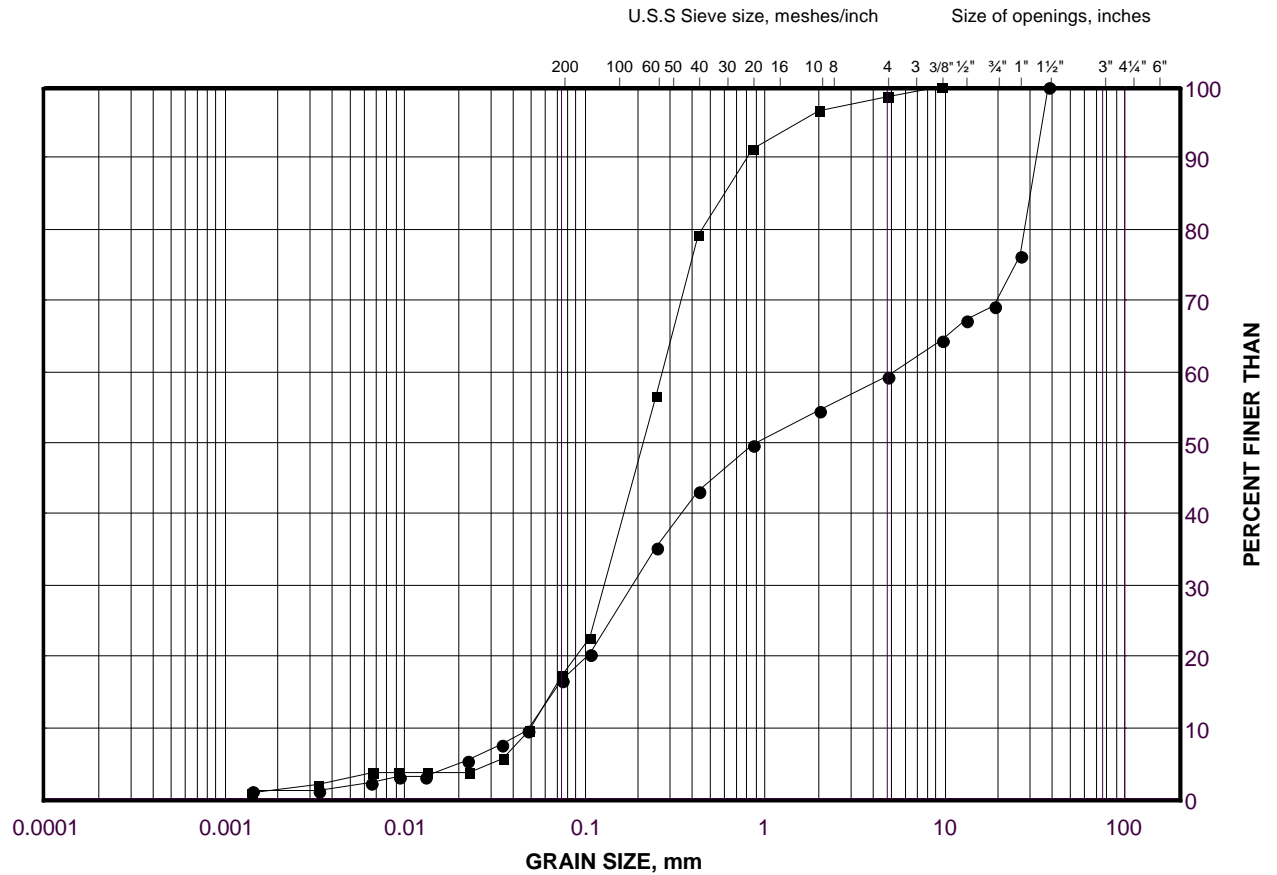
APPENDIX B

Laboratory Test Results

GRAIN SIZE DISTRIBUTION

SILTY SAND (SM) to Sandy GRAVEL (GP) (FILL)

FIGURE B-1



SILT AND CLAY SIZES			FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED			SAND SIZE			GRAVEL SIZE		SIZE

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	19-3	1	431.1
■	19-2	2	427.5

Project Number: 18104224

Checked By: MJB

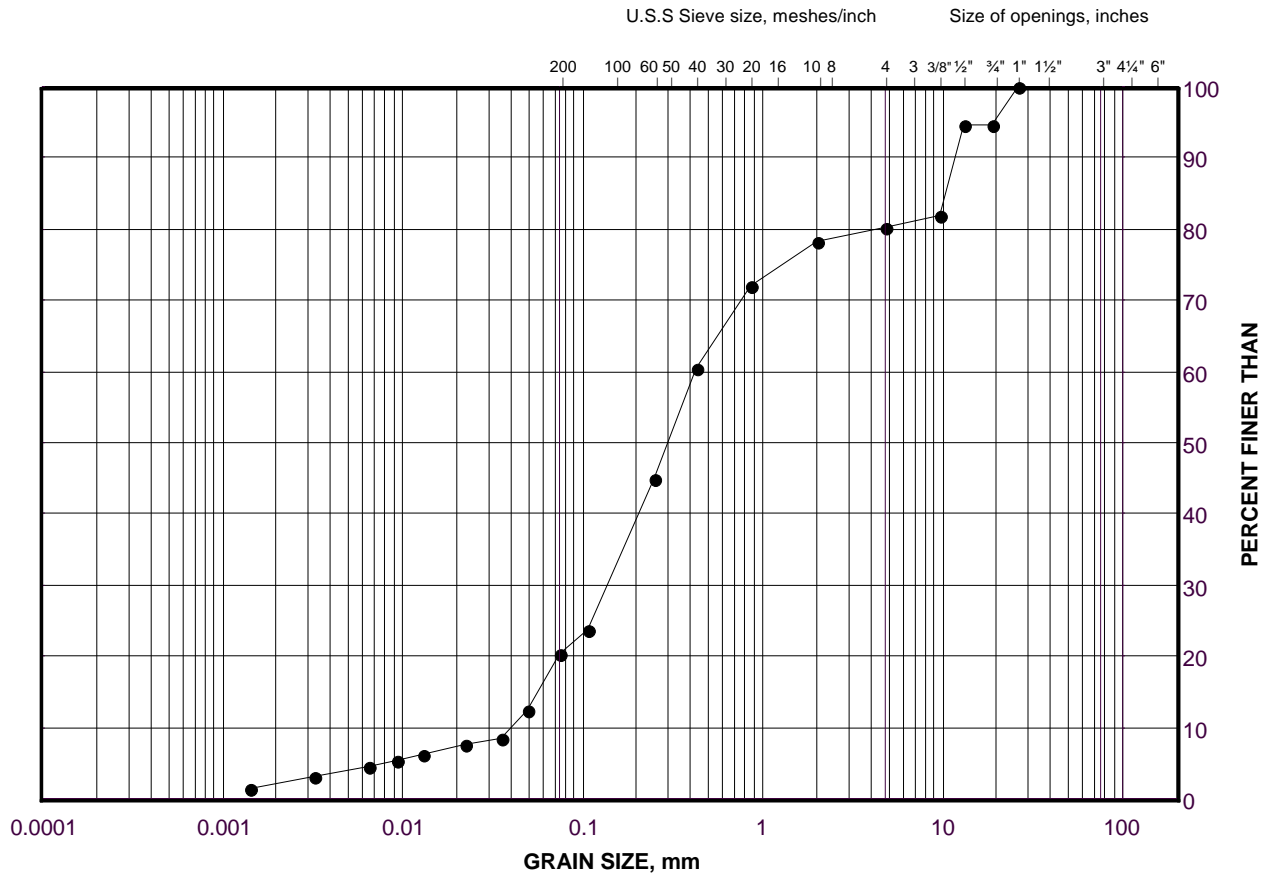
Golder Associates

Date: 08-Oct-19

GRAIN SIZE DISTRIBUTION

SILTY SAND (SM)

FIGURE B-2



SILT AND CLAY SIZES		FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED		SAND SIZE			GRAVEL SIZE		SIZE

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	19-3	5	427.3

Project Number: 18104224

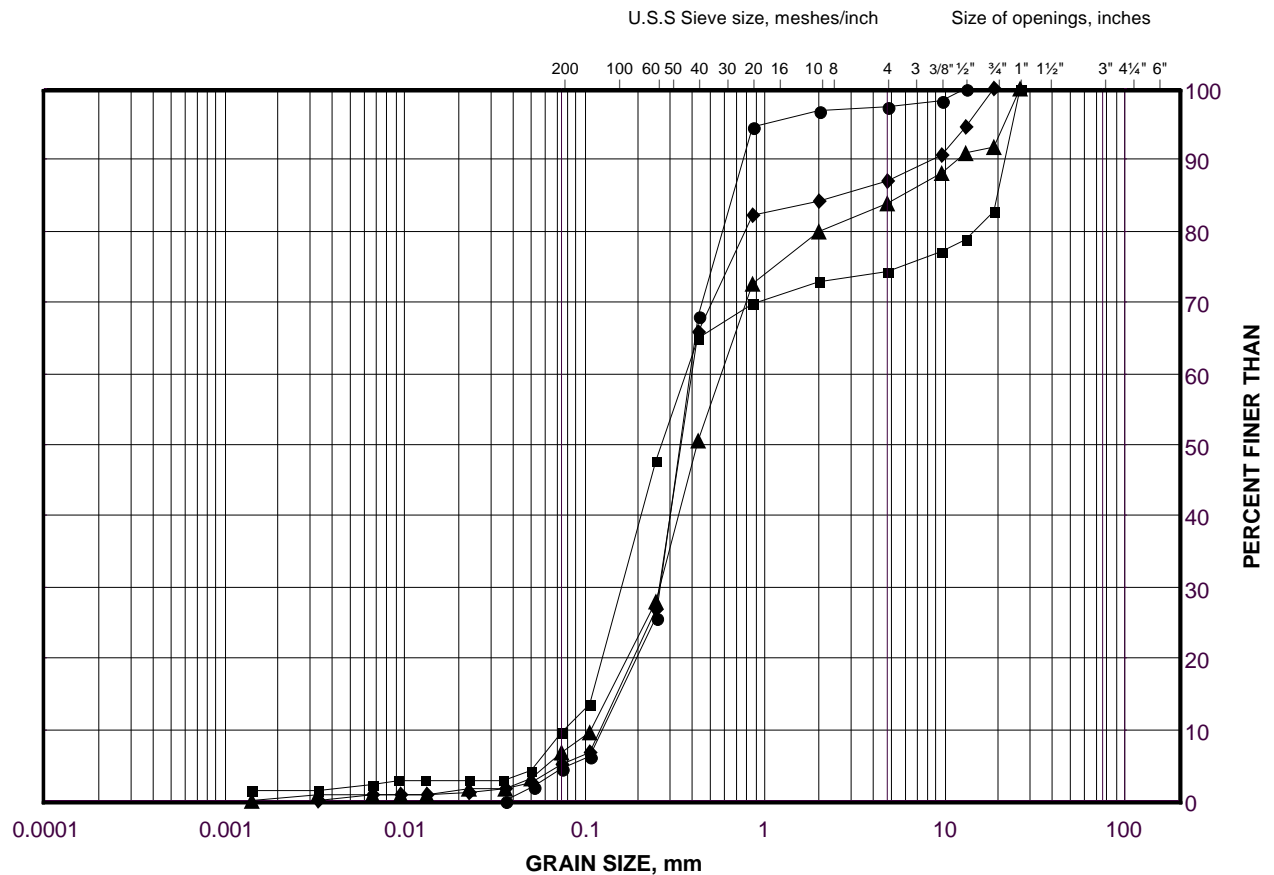
Checked By: MJB

Golder Associates

Date: 08-Oct-19

GRAIN SIZE DISTRIBUTION SAND (SP)

FIGURE B-3



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		SIZE

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	19-3	11	422.7
■	19-1	4	424.3
◆	19-1	6	423.0
▲	19-3	8	425.0

Project Number: 18104224

Checked By: MJB

Golder Associates

Date: 08-Oct-19

**CLIENT NAME: GOLDER ASSOCIATES LTD.
100 SCOTIA COURT
WHITBY, ON L1N8Y6
(905) 723-2727**

ATTENTION TO: Mike Cleverdon

PROJECT: 18104224

AGAT WORK ORDER: 19T509895

SOIL ANALYSIS REVIEWED BY: Nivine Basily, Inorganics Report Writer

DATE REPORTED: Sep 05, 2019

PAGES (INCLUDING COVER): 5

VERSION*: 1

Should you require any information regarding this analysis please contact your client services representative at (905) 712-5100

***NOTES**

All samples will be disposed of within 30 days following analysis. Please contact the lab if you require additional sample storage time.



AGAT Laboratories

Certificate of Analysis

AGAT WORK ORDER: 19T509895

PROJECT: 18104224

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
<http://www.agatlabs.com>

CLIENT NAME: GOLDER ASSOCIATES LTD.

SAMPLING SITE: Hwy 127

ATTENTION TO: Mike Cleverdon

SAMPLED BY: MJB

Corrosivity Package

DATE RECEIVED: 2019-08-26

DATE REPORTED: 2019-09-05

SAMPLE DESCRIPTION: 19-3 Sa4
SAMPLE TYPE: Soil
DATE SAMPLED: 2019-08-14
G / S RDL 472797

Parameter	Unit	G / S	RDL	472797
Chloride (2:1)	µg/g		2	24
Sulphate (2:1)	µg/g		2	8
pH (2:1)	pH Units		NA	8.51
Electrical Conductivity (2:1)	mS/cm		0.005	0.419
Resistivity (2:1) (Calculated)	ohm.cm		1	2390
Redox Potential 1	mV		NA	35.4
Redox Potential 2	mV		NA	44
Redox Potential 3	mV		NA	39.5

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard

472797 EC, pH, Chloride and Sulphate were determined on the extract obtained from the 2:1 leaching procedure (2 parts DI water: 1 part soil). Resistivity is a calculated parameter.

PI note: Redox Potential is not an accredited parameter.

Redox potential measured on as received sample. Due to the potential for rapid change in sample equilibrium chemistry with exposure to oxidative/reduction conditions laboratory results may differ from field measured results.

Analysis performed at AGAT Toronto (unless marked by *)

Certified By:

Divine Basily

Quality Assurance

CLIENT NAME: GOLDER ASSOCIATES LTD.

PROJECT: 18104224

SAMPLING SITE: Hwy 127

AGAT WORK ORDER: 19T509895

ATTENTION TO: Mike Cleverdon

SAMPLED BY: MJB

Soil Analysis

RPT Date: Sep 05, 2019			DUPLICATE			Method Blank	REFERENCE MATERIAL		METHOD BLANK SPIKE			MATRIX SPIKE			
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits		Recovery	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper		Lower	Upper

Corrosivity Package

Chloride (2:1)	472797	472797	24	24	0.0%	< 2	102%	80%	120%	106%	80%	120%	111%	70%	130%
Sulphate (2:1)	472797	472797	8	8	NA	< 2	97%	80%	120%	109%	80%	120%	114%	70%	130%
pH (2:1)	472797	472797	8.51	8.49	0.2%	NA	100%	90%	110%						
Electrical Conductivity (2:1)	472797	472797	0.419	0.410	2.2%	< 0.005	99%	90%	110%						
Redox Potential 1	1					NA	97%	90%	110%						

Comments: NA signifies Not Applicable.

Duplicate Qualifier: As the measured result approaches the RL, the uncertainty associated with the value increases dramatically, thus duplicate acceptance limits apply only where the average of the two duplicates is greater than five times the RL

pH duplicates QA acceptance criteria was met relative as stated in Table 5-15 of Analytical Protocol document.

Certified By:

AGAT QUALITY ASSURANCE REPORT (V1)

Page 3 of 5

AGAT Laboratories is accredited to ISO/IEC 17025 by the Canadian Association for Laboratory Accreditation Inc. (CALA) and/or Standards Council of Canada (SCC) for specific tests listed on the scope of accreditation. AGAT Laboratories (Mississauga) is also accredited by the Canadian Association for Laboratory Accreditation Inc. (CALA) for specific drinking water tests. Accreditations are location and parameter specific. A complete listing of parameters for each location is available from www.cala.ca and/or www.scc.ca. The tests in this report may not necessarily be included in the scope of accreditation. RPDs calculated using raw data. The RPD may not be reflective of duplicate values shown, due to rounding of final results.

Results relate only to the items tested. Results apply to samples as received.

Method Summary

CLIENT NAME: GOLDER ASSOCIATES LTD.

PROJECT: 18104224

SAMPLING SITE: Hwy 127

AGAT WORK ORDER: 19T509895

ATTENTION TO: Mike Cleverdon

SAMPLED BY: MJB

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Soil Analysis			
Chloride (2:1)	INOR-93-6004	McKeague 4.12 & SM 4110 B	ION CHROMATOGRAPH
Sulphate (2:1)	INOR-93-6004	McKeague 4.12 & SM 4110 B	ION CHROMATOGRAPH
pH (2:1)	INOR 93-6031	MSA part 3 & SM 4500-H+ B	PH METER
Electrical Conductivity (2:1)	INOR-93-6036	McKeague 4.12, SM 2510 B	EC METER
Resistivity (2:1) (Calculated)	INOR-93-6036	McKeague 4.12, SM 2510 B, SSA #5 Part 3	CALCULATION
Redox Potential 1	INOR-93-6066	G200-09, SM 2580 B	REDOX POTENTIAL ELECTRODE
Redox Potential 2	INOR-93-6066	G200-09, SM 2580 B	REDOX POTENTIAL ELECTRODE
Redox Potential 3	INOR-93-6066	G200-09, SM 2580 B	REDOX POTENTIAL ELECTRODE

APPENDIX C

**Non-Standard Special Provisions
and Notice to Contractor**

OBSTRUCTIONS – Item No.

Notice to Contractor

The contractor shall be alerted to the presence of cobbles and potentially boulders within the embankment fill and native silty sand and native sand deposits, as inferred present in Boreholes 19-1 to 19-3, and the presence of organic material within the sandy gravel fill, sand fill and silty sand fill as encountered in Boreholes 19-1 and 19-2 at the Highway 127, Station 18+320, Township of Sabina culvert site. Consideration of the presence of these obstructions must be made in the selection of appropriate equipment and procedures for open cut excavations, trenchless installation methods and installation of temporary protection systems.

AMENDMENT TO OPSS 539, NOVEMBER 2014

Special Provision No. 105S09

March 2018

539.03 DEFINITIONS

Section 539.03 of OPSS 539 is amended by the deletion of the definitions for **Certificate of Conformance** and **Quality Verification Engineer**.

539.04 DESIGN AND SUBMISSION REQUIREMENTS

539.04.02.05 Milestone Inspections

Clause 539.04.02.05 of OPSS 539 is deleted in its entirety.

539.07 CONSTRUCTION

539.07.03.03.02 Excavation Depths Less Than or Equal to Three Metres

Clause 539.07.03.03.02 of OPSS 539 is amended with the following:

The Contractor's Engineer shall inspect the following Work:

- a) Installation of the protection system, including excavation to dredge line.
- b) Removal of the protection system.

539.07.03.03.03 Excavation Depths Exceeding Three Metres

Clause 539.07.03.03.03 of OPSS 539 is amended with the following:

The Contractor's Engineer shall inspect the following Work:

- a) Layout and extent of protection system.
- b) Piling.
- c) Installation of protection system, including excavation to dredge line.
- d) Removal of protection system.

539.07.03.04 Inspection of Protection Systems

539.07.03.04.01 Excavation Depths Less Than or Equal to Three Metres

Clause 539.07.03.04.01 of OPSS 539 is deleted in its entirety and replaced with the following:

For protection systems to facilitate excavation depths less than or equal to 3 m and provided that surcharge loading due to vehicular traffic, construction equipment and materials, or other is beyond a horizontal distance defined by a 1H : 2V line projected from the dredge line at the face of the protection system to the roadway

surface, the Contractor's Engineer shall inspect and verify that the that the protection system was installed, monitored, and subsequently removed according to the Contract Documents.

A Certificate of Conformance shall be submitted to the Contractor Administrator upon completion of the installation of the protection system.

A Certificate of Conformance shall be submitted to the Contractor Administrator upon completion of the removal of the protection system.

Should the traffic be within a horizontal distance defined by a 1H: 2V line projected from the dredge line at the face of the protection system to the roadway surface, the Certificate of Conformance requirements as specified in the Excavation Depths Exceeding Three Metres clause shall apply.

539.07.03.04.02 Excavation Depths Exceeding Three Metres

Clause 539.07.03.04.02 of OPSS 539 is deleted in its entirety and replaced with the following:

For protection systems to facilitate excavation depths that exceed 3 m or should traffic, construction equipment and materials, or other be within a horizontal distance defined by a 1H:1V line projected from the dredge line at the face of the protection system to the roadway surface.

The Contractor's Engineer shall inspect and verify that the materials have been supplied and installed according to the Contract Documents. A Certificate of Conformance shall be submitted to the Contract Administrator upon completion of the installation of the materials.

The Contractor's Engineer shall inspect and verify and that the protection system was installed, monitored, and subsequently removed according to the Contract Documents. A Certificate of Conformance shall be submitted to the Contract Administrator upon completion of the removal of the protection system.

AMENDMENT TO OPSS 501, NOVEMBER 2014

Special Provision No. 105S22

June 2016

501.07 CONSTRUCTION

501.07.01 General

Subsection 501.07.01 of OPSS 501 is deleted in its entirety and replaced with the following:

The method of placing and lift thickness of earth or granular material shall be according to the specifications that govern the Work. When not specified, the lift thickness of earth shall not exceed 300 mm and the lift thickness for granular materials shall not exceed 150 mm.

When field testing indicate that the required degree of compaction cannot be obtained with the equipment in use or the procedure being followed, the operations shall be modified so that the equipment and procedures will produce the required results.

501.07.04 Quality Control

501.07.04.02 Compaction Requirements

501.07.04.02.04 Target Density

Clause 501.07.04.02.04 of OPSS 501 is deleted in its entirety and replaced with the following:

New target densities shall be established for each separate component of the Work (e.g., backfilling of a trench, construction of a granular base, or placement of cover) at the following times:

- a) For earth and granular materials:
 - i. At the time of initial use of each source.
 - ii. When there is a perceptible change in the appearance or gradation of the materials or both.
 - iii. At least once per calendar year on all carry-over Contracts.
- b) For earth being placed:
 - i. As backfill, after QC lots representing 2000 tonnes or 1000 m³ of material have been completed, whether accepted or rejected, on the basis of one set of target density values, or
 - ii. For all other purposes, after each 10 QC lots of material have been completed, whether accepted or rejected, on the basis of one set of target density values.
- c) For granular materials being placed:
 - i. As backfill, or at the discretion of the Contract Administrator, any other areas, after QC lots representing 5000 tonnes or 2500 m³ of material have been completed, whether accepted or rejected, on the basis of one set of target density values, or
 - ii. For all other purposes, after each 25 QC lots of material have been completed, whether accepted or rejected, on the basis of one set of target density values.

The new target density shall be established by the construction of a control strip according to the Control Strip clause, except the new target density shall be based on the maximum dry density (MDD) as determined by LS-706 not more than 14 Days prior to placing the material, when:

- a) Placing material in confined areas that do not allow equipment meeting the requirements specified in the Compaction clause to be used.
- b) With the consent of the Contract Administrator, a control strip cannot be reasonably constructed or is impractical.

The MDD used for the new target density shall be the average of the MDD calculated from a minimum of 3 independent samples selected from the materials to be used.

501.07.04.02.04.01 Control Strip

Prior to construction of a control strip:

- a) A minimum notice of 24 hours shall be given to the Contract Administrator, and
- b) The optimum moisture content (OMC) of the material shall be determined according to LS-706.

Each control strip shall consist of a single uniform lift not more than 0.30 m in depth and covering at least 400 m² in area. The surface of each control strip shall be graded flat.

Prior to compaction, the field moisture content of the control strip material shall be determined using a nuclear gauge at a minimum of 3 randomly selected locations. The average moisture content at those three locations shall be within the range of no less than 2.0% lower than and no more than 1.0% greater than the OMC of the control strip material. If the average moisture content is not within this range, the moisture content of the material shall be uniformly adjusted (e.g. by adding water and re-mixing or scarifying and drying). The material shall then be graded flat and re-tested using a nuclear gauge. This process shall be repeated until the average moisture content of the material, at a minimum of 3 randomly selected locations, is within the range of no less than 2.0% lower than and no more than 1.0% greater than the OMC of the control strip material.

When the OMC is within the acceptable range, the compaction equipment shall make 6 passes over the entire surface of the control strip. A pass shall be deemed to be compaction of the full width of the control strip in one direction only. The field wet density and field moisture content shall be determined at a minimum of 3 randomly selected locations. The dry density shall be calculated for each of these locations and the average dry density used as the initial value for the dry density.

All passes of the compaction equipment for the control strip shall be carried out in vibratory mode at a speed of no more than 5 km/hour.

The compaction equipment shall then make 2 additional passes over the entire surface of the control strip.

A minimum of 3 separate random field density and moisture content determinations shall then be made and a new average dry density shall be calculated.

If the new average dry density exceeds the previous value by more than 0.030 t/m³, then additional passes of the equipment shall be carried out as described above. If the new average dry density does not exceed the

previous value by more than 0.030 t/m³, then the compaction of the control strip shall be considered satisfactory and complete.

Upon satisfactory completion of the control strip, an additional 7 field wet density and moisture content tests shall be taken at random locations and the dry density values determined. The final dry density of the control strip, which shall be deemed to be the target density, shall be the average of the dry density values determined at these 7 additional random locations plus the 3 most recent values that were determined upon completion of the control strip.

WORKING SLAB - Item No.

Special Provision

1.0 SCOPE

This Special Provision covers the requirements for the supply and placement of a concrete working slab under structure foundations.

2.0 REFERENCES

This Special Provision refers to the following standards, specifications or publications:

Ontario Provincial Standard Specifications, Construction

OPSS 902 Excavating and Backfilling - Structures

3.0 DEFINITIONS - Not Used

4.0 DESIGN AND SUBMISSION REQUIREMENTS - Not Used

5.0 MATERIALS

Concrete for working slabs shall have a minimum 28 day strength of 20 MPa.

6.0 EQUIPMENT - Not Used

7.0 CONSTRUCTION

7.01 Excavation

Excavation for the working slab shall be according to OPSS 902.

7.02 Protection of Founding Soil

Following inspection and approval of the prepared subgrade, a working slab with a minimum thickness of 100 mm shall be placed on the foundation subgrade as specified in the Contract Documents.

7.03 Protection of Founding Bedrock

The surface of the footing founding rock shall be exposed, cleaned and any loose or fractured parts removed so that sound rock is exposed. The working slab shall be placed on the exposed cleaned sound founding rock surface as specified in the Contract Documents.

Thickness of the mass concrete pad shall depend on the slope and irregularities in the exposed founding rock surface. A nominal thickness and a footprint plan view area has been specified on the Contract Documents

7.04 Dewatering

Dewatering shall be carried out according to OPSS 902.

8.0 **QUALITY ASSURANCE - Not Used**

9.0 **MEASUREMENT FOR PAYMENT - Not Used**

10.0 **BASIS OF PAYMENT**

10.01 **Working Slab - Item**

Payment at the Contract price for the above tender item shall be full compensation for all labour, Equipment and Material to do the work.

TEMPORARY PROTECTION SYSTEM – Item No.

Non-Standard Special Provision

Amendment to OPSS 539, November 2014

593.07.02 Removal of Protection Systems

Subsection 539.07.02 of OPSS 539 is deleted in its entirety and replaced with the following:

Protection systems shall be removed from the right-of-way unless it is specified in the Contract Documents that the protection system may be left in place.

Where piles are left in place, the top shall be removed to at least 1.2 m below the finishing grade or ground surface.

The method and sequence of removal shall be such that there shall be no damage to the new work, existing work or facility being protected.

All disturbed areas shall be restored to an equivalent to better condition than existing prior to the commencement of construction.

PIPE INSTALLATION BY TRENCHLESS METHOD – Item No.

Special Provision

January 2019

CONSTRUCTION SPECIFICATION FOR THE INSTALLATION OF PIPES BY TRENCHLESS METHODS

TABLE OF CONTENTS

1.0	SCOPE
2.0	REFERENCES
3.0	DEFINITIONS
4.0	DESIGN AND SUBMISSION REQUIREMENTS
5.0	MATERIALS
6.0	EQUIPMENT
7.0	CONSTRUCTION
8.0	QUALITY ASSURANCE- Not Used
9.0	MEASUREMENT FOR PAYMENT
10.0	BASIS OF PAYMENT
1.0	SCOPE

This specification covers the requirements for the installation of pipe by a selected trenchless method.

2.0 REFERENCES

This specification refers to the following standards, specifications, or publications:

Ontario Provincial Standard Specifications, General

OPSS 180 Management of Disposal of Excess Material

Ontario Provincial Standard Specifications, Construction

OPSS 401	Trenching, Backfilling, and Compacting
OPSS 402	Excavating, Backfilling, and Compacting for Maintenance Holes, Catch Basins, Ditch Inlets and Valve Chambers
OPSS 403	Rock Excavation for Pipelines, Utilities, and Associated Structures in Open Cut
OPSS 404	Support Systems
OPSS 409	Closed-Circuit Television (CCTV) Inspection of Pipelines

OPSS 491	Preservation, Protection, and Reconstruction of Existing Facilities
OPSS 492	Site Restoration Following Installation of Pipelines, Utilities and Associated Structures
OPSS 517	Dewatering
OPSS 539	Temporary Protection Systems

Ontario Provincial Standard Specifications, Material

OPSS 1004	Aggregates - Miscellaneous
OPSS 1350	Concrete - Materials and Production
OPSS 1440	Steel Reinforcement for Concrete
OPSS 1802	Smooth Walled Steel Pipe
OPSS 1820	Circular and Elliptical Concrete Pipe
OPSS 1840	Non-Pressure Polyethylene (PE) Plastic Pipe Products

CSA Standards

B182.6	Profile polyethylene (PE) sewer pipe and fittings for leak-proof sewer applications
A3000	Cementitious Materials Compendium
W59	Welded Steel Construction (Metal Arc Welding)

American Society for Testing and Materials (ASTM) International Standards

A 252	Standard Specification for Welded and Seamless Steel Pipe Piles
D 2657	Standard Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings
D 3350	Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
D6910	Standard Specification for Marsh Funnel Viscosity of Clay Construction Slurries
F 894	Standard Specification for Polyethylene Large Diameter Profile Wall Sewer and Drain Pipe

International Organization for Standardization/International Electrotechnical Commission (ISO/IEC)

17025	General Requirements for the Competence of the Testing and Calibration Laboratories
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3.0 DEFINITIONS

For the purpose of this specification, the following definitions apply:

Auger Jack & Bore means a method of forming a horizontal bore in the subsurface by simultaneously or alternately jacking into the ground a casing pipe and rotating a cutter head at the lead end of an auger flight with removal of material from inside the casing by using continuous-flight augers.

Backreamer or Reamer means a cutting head suitably designed for the subsurface conditions that is attached to drilling equipment and used to enlarge the bore

Bore Path means a drilled path according to the grade and alignment tolerances specified in the Contract Documents.

Design Engineer means the Engineer retained by the Contractor who produces the design and working drawings and other engineering documents required of the Contractor. The Design Engineer shall be licensed to practice in the Province of Ontario.

Design Checking Engineer means the Engineer retained by the Contractor who checks the original design and working drawings. The design checking engineer shall be licensed to practice in the Province of Ontario, shall not be an employee of the Contractor and shall be independent from the Design Engineer.

Digger Shield/Hand Mining means a method of forming a horizontal bore in the subsurface by essentially simultaneously jacking a casing pipe, with or without a protective shield at the lead end, into the ground while tunnelling and removal of earth and rock is completed using manually-operated tools (e.g., pneumatic spades, rams, shovels, breaker bars, etc.) or a “digger” type shield with a hydraulic excavator arm or “road-header” rock cutting machine to remove materials from inside the shield and liner pipe.

Horizontal Directional Drilling (HDD) means horizontal directional boring or guided boring.

Drilling Fluids means a mixture of water and additives, such as bentonite, polymers, surfactants, and soda ash, designed to block the pore space on a bore wall, reduce friction in the bore, and to suspend and carry cuttings to the surface.

Drilling Fluid Hydraulic Fracture or “Frac Out” means a condition where the drilling fluid’s pressure in the bore is sufficient to fracture the soil and/or rock materials and allow the drilling fluids to migrate to the surface at an unplanned location.

Earth Pressure Balance (EPB) means a tunnelling system that provides support to the excavated face of the ground and resistance to groundwater inflow through the pressure of mixed earth, rock and any drilling fluids or additives (spoil) as maintained by and in a chamber behind the cutting face of a tunnel boring machine through which spoil can pass only by manner of controlled-load relieving gates or an internal screw-conveyor that is separate from subsequent spoil conveyance systems (e.g., flight augers, belt conveyor, spoil bucket rail cars, etc.). Trenchless systems that apply pressure to the excavated face of the ground only through mechanical and jacking forces on metal parts of the machinery (e.g., steel parts of cutting tools, adjustable gates or doors at cutting face, etc.) will not be considered equivalent to EPB systems.

Excavation means all materials encountered regardless of type and extent and shall include removal of natural soil, boulders, cobbles, wood and fill regardless of means necessary to break consolidated materials for removal.

Environmentally Sensitive Area (ESA) means areas specified in the Contract Documents that are prohibited from entry or use.

Fill means man-made mixture of previously placed or handled materials such as sand, clay, silt, gravel, broken rock, sometimes containing organic and/or deleterious materials, placed in an excavation or other area to raise the surface elevation.

Guidance System means an electronic system capable of indicating the position, depth and orientation of the drill head during the directional drilling process.

Hand Mining means a method of forming a horizontal bore in the subsurface by simultaneously jacking ahead while tunnelling advances using hand-mining (man-entry operation or “Jack and Mine”) or a “digger” type shield with a hydraulic excavator arm to remove materials from inside the liner pipe.

Inadvertent Returns means the unexpected flow of fluids, saturated materials (or flowing soil) towards the drilling rig that typically originated from an artesian aquifer encountered during the drilling process.

Loss of Circulation means the discontinuation of the flow of drilling fluid in the bore back to the entry or exit point or other planned recovery points.

Microtunnelling means an underground method of constructing a passage by using a microtunnel boring machine (MTBM) or hand mining using a shield to support the opening.

Pilot Bore means the initial bore to set directional controlled horizontal and vertical alignment between the connecting points.

Pipe Jacking means a method for installing steel casing, concrete pipe or other acceptable material in the subsurface utilizing hydraulically operated jacks of adequate number and capacity for the smooth and uniform advancement of the casing or pipe.

Pipe means pipe culverts, pipe storm and sanitary sewers, watermain pipe, conduits and ducts.

Pipe Ramming means a method for installing steel casings utilizing the energy from a percussion hammer to advance a steel casing with a cutting shoe attached at the front end of the casing.

Project Superintendent means an individual representing the Contractor that oversees the trenchless or tunnelling operation qualified to provide the services specified in the Contract Documents.

Pullback means that part of the HDD method in which the drilling equipment is pulled back through the bore path to the entry point.

Reaming means a process for enlarging the bore path

Rock means natural beds or massive fragments, or the hard, stable, cemented part of the earth's crust, igneous, metamorphic, or sedimentary in origin, which may or may not be weathered and includes boulders having a volume of 0.5 m³ or greater.

Shaft means an excavation used as entry and/or exit points, alternatively called entry/exit pits, from which the trenchless method is initiated for the installation of the pipe product.

Slurry Pressure Balance (SPB) means a tunnelling system that provides support to the excavated face of the ground and resistance to groundwater inflow through the pressure of slurry as maintained by and in a chamber behind the cutting face of a TBM or MTBM through which spoil can pass only by manner of controlled-pressure and controlled flow slurry pumping systems.

Strike Alert means a system that is intended to alert and protect the operator in the case of inadvertent drilling into an electrical utility cable. The strike alert system consists of a sensor and an alarm connected to the drill rig and a grounding stake. The alarm may be audio or visual or both.

Slurry means a mixture of soil and/or rock cuttings, and drilling fluid.

Soil means all soils except those defined as rock, and excludes stone masonry, concrete, and other manufactured materials.

Spoil means mix of earth cuttings, rock cuttings, water (groundwater or added water), bentonite, polymers and/or other additives that is discharged from the trenchless construction systems.

Trenchless Installation means an underground method of constructing a passage open at both ends that involves installing a pipe product by auger jack & boring, pipe ramming, horizontal directional drilling, or tunnelling.

Trenchless Contractor means the subcontractor retained by the Prime Contractor qualified to provide the services specified in the Contract Documents.

Tunnelling means an underground method of constructing a passage using a tunnel boring machine (TBM) operated by personnel within the tunnel, a microtunnel boring machine (MTBM) operated by personnel at a remote control station or excavation using a shield to support the opening and protect workers.

Zone of Influence means a zone defined by lines projected outward and upward at 45 degrees from horizontal to the ground surface from the vertical and horizontal alignment of the pipe constructed using trenchless/tunnel methods.

4.0 DESIGN AND SUBMISSION REQUIREMENTS

4.01 Design

4.01.01 General

The Contractor shall determine the most appropriate method of installation for each location within the terms of this specification.

The installation method selected for each pipe crossing shall be designed for the subsurface conditions as reported in the Contract Documents.

The detailed design of the installation method selected to carry out the work as specified in the Contract Documents shall be completed.

4.02 Submission Requirements

4.02.01 Qualifications

At least two weeks prior to construction, the names and the demonstrated project experience of the Project Superintendent, Trenchless contractor, Design Engineer, and Design Checking Engineer shall be submitted to the Contract Administrator.

4.02.01.01 Project Superintendent

The Project Superintendent shall have a minimum of five years' demonstrated experience on projects with similar scope and complexity.

During construction, the project superintendent shall not change without written permission from the Contract Administrator. A proposal for a change in the project superintendent shall be submitted at least one week prior to the actual change in project superintendent.

4.02.01.02 Trenchless Contractor

The Trenchless Contractor shall have a minimum of five years' demonstrated experience on projects with similar scope and complexity

4.02.01.03 Design Engineer

The Design Engineer shall have a minimum of five years' demonstrated experience on projects with similar scope and complexity

4.02.01.04 Design Checking Engineer

The Design Checking Engineer shall have a minimum of five years' demonstrated experience on projects with similar scope and complexity

4.02.02 Working Drawings

Three sets of Working Drawings for the trenchless installation method selected shall be submitted to the Contract Administrator (CA) for purposes of documentation and quality assurance at least two week prior to the commencement of the work. All Working Drawings shall bear the seal and signature of the Design Engineer and Design Checking Engineer.

The working drawings shall be submitted to the Contract Administrator under cover with a Request to Proceed.

The Contractor shall not proceed with the work until a Notice to Proceed has been received from the Contract Administrator

A copy of the Working Drawings shall be kept at the site during construction.

Information and details shown on the Working Drawings shall include, but not be limited to:

a) Plans and Details:

- i. Plans and profiles defining all horizontal and vertical alignment positions and positions of all utilities and other infrastructure within the zone of influence of the work;
- ii. A work plan outlining the materials, procedures, methods and schedule to be used to execute the work.
- iii. A list of personnel, including backup personnel, and their qualifications and experience.
- iv. A safety plan including the company safety manual and emergency procedures.
- v. The work area layout.
- vi. An erosion and sediment control plan that includes a contingency plan in the event the erosion and sediment control measures fail.
- vii. A contingency plan with specific details of the manner in which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the liner.
- viii. A drilling fluid management plan, if applicable, that addresses control of frac-out pressures, any potential environmental impacts and includes a contingency plan detailing emergency procedures in the event that the fluid management plan fails.
- ix. Lighting, ventilation and fire safety details as may be required by applicable occupational health and safety regulations.
- x. Excavated materials disposal plan.
- xi. Locations of protection systems.

b) Designs

- i. Primary liner design (e.g., steel liner plates, steel ribs and wood lagging, steel casing pipe, etc.),

- ii. Design assumption and material data when materials other than those specified are proposed for use.
- iii. Drill path design, details of alignment and alignment control, maximum curvature and reaming stages.

c) Materials:

- i. Certification from the manufacturer that the product furnished on the contract meets the specifications cited in the manufacturer's product specification and that the materials supplied are suitable for the application.
- ii. Manufacturer data sheets for all drilling fluids and additives for use in Earth Pressure Balance, Slurry Pressure Balance
- iii. Manufacturer data sheets for drilling systems.
- iv. Mix designs, target rheology criteria (e.g., viscosity, density, shear strength, gel time, pressure-filtration – fluid losses under pressure, etc.) and additive dosage rates for all slurries and EPB TBM and MTBM operations.
- v. The proposed grout mix design for grouts to be used for lubricating jacking pipe and for filling of voids and annular spaces.
- vi. Compressive strength of concrete pipe products.
- vii. Pipe class for all steel pipe products.
- viii. Steel for Permanent Casings
 - One copy of a mill test certificate certifying that the steel meets the requirements for the appropriate standards for permanent casings shall be submitted to the Contract Administrator at the time of delivery.
 - Where mill test certificates originate from a mill outside Canada or the United States of America, the information on the mill certificates shall be verified by testing by a Canadian laboratory. The laboratory shall be certified by an organization accredited by the Standards Council of Canada to comply with the requirements of ISO/IEC 17025 for the specific tests or type of tests required by the material standard specified on the mill test certificate.
 - The mill test certificates shall be stamped with the name of the Canadian testing laboratory and appropriate wording stating that the material conforms to the specified material requirements. The stamp shall include the appropriate material specification number, the date (i.e., yyyy-mm-dd), and the signature of an authorized officer of the Canadian testing laboratory
- ix. The Contractor shall submit the followings to the Contract Administrator two weeks prior to construction:
 - type, source, and physical and chemical properties of bentonite, polymer or other additives;
 - source of water;
 - method of mixing;
 - the water to solids ratio and the mass and volumes of the constituent parts, including any chemical admixtures or physical treatment employed to achieve required physical properties;
 - details of procedure to be used for monitoring physical properties of slurry, drilling fluids and tunnelling fluids or EPB spoil; and method of disposal of the slurry, drilling fluids and associated spoil

d) Upstream/Downstream Portal Installation Procedure:

- i. The access shaft or entry/exit pit details, as applicable.
- ii. Face support and other temporary support details, if applicable.

e) Primary Liner/Secondary Liner Installation and Grouting Procedure:

- i. Excavation and pipe installation procedures, including methods to handle obstructions and prevent soil cave-in.
- ii. Details of tunnelling equipment/methods to be used for the works.

f) Excavation and Dewatering:

- i. Equipment and methods for control, handling, treatment, and disposal of groundwater and water or fluids introduced by the Contractor;
- ii. Equipment and methods for maintaining control of ground inflow at the excavation face during excavation;
- iii. Equipment and methods for removal of cobbles and boulders;
- iv. Manufacturer data sheets for each TBM, shield, tunnelling system or drilling system noting all intermediate and final cut dimensions, and methods and equipment for controlling and measuring drilling fluid, SPB and EPB pressures;
- v. Methods for measuring excavated volumes or weights of earth and rock materials cut from ground on a per meter or per pipe basis up to a maximum of 3 m long intervals per measurement;
- vi. Target operating pressures (minimum and maximum) and range of expected pressure variation for slurry or EPB spoil at excavated face or drilling fluids at lead end of drilling equipment and in annular gap between maximum excavated dimensions and outside dimensions of tunnelling equipment, drilling equipment and primary liner systems;
- vii. Basis for setting target operating conditions (pressures, flow rates, advance rates) and the relationship of target operating conditions to ground conditions;
- viii. Basis for selection of excavation tools (e.g., bits, TBM face tools, MTBM face tools, excavator fittings, etc.) as related to expected ground conditions;
- ix. Jacking forces for installation of pipe, for driving of trenchless equipment forward and, in the case of Auger Jack & Bore, for advancing the lead end of the casing ahead of the lead end of the auger cutting tools.

g) Monitoring Method:

Methods, equipment, frequency and repeatability (accuracy and precision) of data collection to be employed for measuring and monitoring shall be submitted for:

- i. Maintaining the alignment of the installation;
- ii. EPB, SPB and drilling fluid pressures at the leading edge of excavation (face), flow rates and volume or weights of spoil;
- iii. Jacking forces on pipes, linings and cutting tools;
- iv. Torque, total revolutions and revolution rates on rotating equipment such as TBM or MTBM heads, auger flights, drill bits, etc.
- v. Grout injection pressures and volumes;
- vi. Longitudinal position of all casings and excavation cutting tools (auger flight heads, TBM face, drill bit position, etc.);
- vii. Ground displacements (heave and settlement); and noise and ground vibrations induced by trenchless construction

4.02.03 Quality Control Certificate

The Contractor shall submit a Quality Control Certificate to the Contract Administrator for documentation and quality assurance purposes, prepared and stamped by the Design and Design Checking Engineers, a minimum of two weeks prior to commencement of work under this item. The Certificate shall state that the construction procedures are in conformance with the requirements and specifications of the contract documents.

The Contractor shall submit to the Contract Administrator a Quality Control Certificate sealed and signed by the Design and Design Checking Engineer upon completion of each of the following operations and prior to commencement of each subsequent operation for each pipe installation:

- Site Surveying (as noted in Section 4.02)
- Excavation for pits including dewatering of excavations
- Jacking/Ramming/Directional Drilling of Casing/Liner
- Installation of the Product
- Grouting Operations

Each Quality Control Certificate shall state that the work has been carried out in general conformance with the contract documents, specifications and/or stamped working drawings.

The Contractor shall submit a Request to Proceed to the Contract Administrator upon completion of each of the milestones.

The Contractor shall not proceed to the subsequent operation until a Notice to Proceed has been received from the Contract Administrator

In addition, upon completion of the installation of the pipe at each location, the Contractor shall submit to the Contract Administrator a final Quality Control Certificate sealed and signed by the Design and Design Checking Engineer. The Certificate shall state that the pipe has been installed in general conformance with the Contractor's Submission and Design Requirements, stamped working drawings and contract documents.

5.0 MATERIALS

5.01 Pipe

5.01.01 General

The product shall be concrete pipe, steel pipe or high density polyethylene pipe as specified.

All joints shall be suitable for jacking operations as specified in the working drawings.

Fittings shall be suitable and compatible with the class and type of pipe with which they will be used.

All fittings shall be designed to be watertight.

5.01.02 Steel Pipe

Steel pipe shall be according to ASTM A252.

All steel casing pipe shall be square cut.

Steel casing pipe shall meet a straightness tolerance of 1.5 mm/m. When placed anywhere on the pipe parallel to the pipe axis, there shall not be a gap more than 1.5 mm between a 1 m long straightedge and the pipe.

5.01.03 HDPE Pipe

High density polyethylene (HDPE) pipe according to OPSS 1840 shall be used in accordance with ASTM D3350.

Fittings shall be according to CAN/CSA-B182.6 or ASTM F894 and suitable for the class and type of pipe with which they will be used.

Jointing of HDPE piping shall be completed according to the manufacturer's recommended procedures and ASTM D2657. Where conflicts exist between the manufacturer's instructions and ASTM D2657, the manufacturer's instructions are to be followed.

Jointing of HDPE piping to other piping materials or appurtenances shall be completed using flanged connections.

5.01.04 Concrete Pipe

Concrete pipe shall be according to OPSS 1820.

5.02 Concrete

Concrete shall be according to OPSS 1350. The concrete strength shall be as specified on the Working Drawings.

5.03 Steel Reinforcement

Steel reinforcement for concrete work shall be according to OPSS 1440.

5.04 Wood

Wood shall be according to OPSS 1601.

5.05 Drilling Fluids

Drilling fluid shall be mixed according to the working drawings.

Selection of drilling fluid type shall be based on the soils encountered in the subsurface investigation.

The drilling fluids shall be mixed according to the manufacturer's recommendations.

Slurry shall be mixed according to the submitted slurry design and be appropriate for the anticipated subsurface conditions. The viscosity of slurry used for SPB tunnelling shall be no less than 40 seconds Marsh Funnel viscosity, as defined by ASTM D6910, measured prior to introduction of groundwater and spoil and as required to ensure:

- ## 5.06 Grout

6.0 EQUIPMENT

6.03.01 General

The Horizontal Directional Drilling equipment shall consist of a directional drilling rig and a drilling fluid mixing and delivery system to successfully complete the product installation without exceeding the maximum tensile strength of the product being installed.

6.03.02 Drilling Rig

The horizontal directional drilling rig shall:

- a) Consist of a leak free hydraulically powered boring system to rotate, push, and pull hollow drill pipe into the ground at a variable angle while delivering a pressurized fluid mixture to a guidable drill head.
- b) Have drill rod that is suitable for both the drill and the product pipe installation.
- c) Contain a drill head that is steerable, equipped with the necessary cutting surfaces and fluid jets, and be suitable for the anticipated ground conditions.
- d) Have adequate reamers and down-bore tooling equipped with the necessary cutting surfaces and fluid jets to facilitate the product installation and be suitable for the anticipated ground conditions.
- e) Contain a guidance system to accurately guide boring operations.
- f) Be anchored to the ground to withstand the rotating, pushing, and pulling forces required to complete the product installation.
- g) Be grounded during all operations unless otherwise specified by the drilling rig manufacturer.

6.03.03 Drill Head

The drill head shall be steerable by changing its rotation, be equipped with the necessary cutting surfaces and drilling fluid jets, and be of the type for the anticipated subsurface conditions,

6.03.04 Guidance System

The guidance system shall be setup, installed, and operated by trained and experienced personnel. The operator shall be aware of any magnetic or electromagnetic anomalies and shall consider such influences in the operation of the guidance system when a magnetic or electromagnetic system is used.

6.03.05 Drilling Fluid Mixing System

The drilling fluid mixing system shall be of sufficient size to thoroughly and uniformly mix the required drilling fluid.

6.03.06 Drilling Fluid Delivery System

The delivery system shall have a means of measuring and controlling fluid pressures and be of sufficient flow capacity to ensure that all slurry volumes are adequate for the length and diameter of the final bore and the anticipated subsurface conditions. Connections between the delivery pump and drill pipe shall be leak-free.

6.04 Tunnelling

Tunnelling equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein. Specific details of tunnelling equipment included in the submission shall be provided for:

- a) rock or boulder breaking and removal;
- b) equipment used within shields for spilling, fore-poling, face drainage, breasting boards/plates and for otherwise maintaining support of the tunnel crown and face under all anticipated conditions;
- c) jacking systems;
- d) alignment control systems;

Use of rock fracturing chemicals shall only be considered subject to a field demonstration satisfactory to the Ministry prior to its use. Use of explosives is prohibited without specific application and acceptance by the Ministry prior to construction.

6.05 Microtunnelling Equipment

The Contractor shall be responsible for selecting microtunnelling equipment which, based on past experience, has proven to be satisfactory for excavation of the soils that will be encountered.

The Contractor shall employ microtunnelling equipment that will be capable of handling the various anticipated ground conditions.

The MTBM shall also be capable of controlling loss of soil ahead of and around the machine and shall provide continuous pressurized support of the excavated face.

- a) Remote Control System – The Contractor shall provide a MTBM that includes a remote control system with the following features:
 - i. Allows for operation of the system without the need for personnel to enter the microtunnel. Has a display available to the operator, at a remote operation console, showing the position of the shield in relation to a design reference together with other information such as face pressure, roll, pitch, steering attitude, valve positions, thrust force cutter head torque, rate of advance and installed length.
 - ii. Integrates the system of excavation and removal of spoil and its simultaneous replacement by Product Pipe. As each pipe section is jacked forward, the control system shall synchronize all of the operational functions of the system.
 - iii. The system shall be capable of adjusting the face pressure to maintain face stability for the particular soil condition encountered.
 - iv. The system shall monitor and continuously balance the soil and ground water pressure to prevent loss of soil or uncontrolled ground water inflow.
 - v. The pressure at the excavation face shall be managed by controlling the volume of spoil removal with respect to the advance rate.
 - vi. The system shall include a separation process designed to provide adequate separation of the spoil from the slurry so that slurry with a sediment content within the limits required for successful microtunnelling, can be returned to the cutting face for reuse. Appropriately contain spoil at the site prior to disposal.

- vii. The type of separation process shall be suited to the size of microtunnel being constructed, the soil type being excavated, and the work space available at each work area.
 - viii. The system shall allow the composition of the slurry to be monitored to maintain the slurry weight and viscosity limits required.
- b) Active Direction Control - Provide an MTBM that includes an active direction control system with the following features:
- i. Controls line and grade by a guidance system that relates the actual position of the MTBM to a design reference Provides active steering information that shall be monitored and transmitted to the operating console and recorded.
 - ii. Provides positioning and operation information to the operator on the control console.

6.05.01 Pipe Jacking Equipment

Provide a pipe jacking system with the following features:

- a) Has the main jacks mounted in a jacking frame located in the launch shaft.
- b) Has a jacking frame that successively pushes towards a receiving shaft, a string of Product Pipe that follows the microtunnelling excavation equipment.
- c) Has sufficient jacking capacity to push the microtunnelling excavation equipment and the string of pipe through the ground.
- d) The main jack station may be complemented with the use of intermediate jacking stations as required.
- e) Has a capacity at least 20 percent greater than the calculated maximum jacking load.
- f) Develops a uniform distribution of jacking forces on the end of the casing pipe.
- g) Provides and maintains a pipe lubrication system at all times to lower the friction developed on the surface of the pipe during jacking.
- h) Jack Thrust Blocking shall adequately support the jacking pressure developed by the main jacking system.
- i) Special care shall be taken when setting the pipe guide rails in the jacking shaft to ensure correctness of the alignment, grade, and stability.

6.05.02 Spoil Separation System

The Contractor shall determine the type of spoil separation equipment needed for each drive based on the geotechnical information available and other project constraints.

6.05.03 Electrical Equipment, Fixtures and Systems

Electrical equipment shall be suitably insulated for noise reduction. Noise produced by electrical equipment must comply with local municipal noise by-laws.

Electrical systems shall conform to requirements of the Canadian Electrical Code – CSA C22.1.

7.0 CONSTRUCTION

7.01 General

The Contractor shall notify the Contract Administrator at least 48 hours in advance of starting work. The proposed method of pipe installation to be used by the Contractor shall be subject to the limitations presented in the following subsections.

The Project Superintendent shall supervise the work at all times.

7.01.01 Layout, Alignment and Depth Control

The location of the installation shall be established from the lines, elevations and tolerances specified in the Contract Documents. The pipe installation shall be to the horizontal and vertical alignments specified in the Contract Drawings. Deviations from location, alignment, grades and/or invert levels shall be corrected by the Contractor at no cost to the Ministry.

All reference points necessary to construct the pipe installation and appurtenances shall be laid out.

The Contractor shall calibrate tracking and locating equipment at the beginning of each work day, and shall monitor and record the alignment and depth readings provided by the tracking system every 2 m.

The Contract Administrator shall be provided with the assistance and access necessary to check the layout of the pipe installation and associated appurtenances.

The Contractor shall submit records of the alignment and depth of the installation to the Contract Administrator at the completion of the installation.

7.01.02 Construction Shafts

Construction shafts shall be specified in the Contractor's submission. The boundaries and protection of these shall be as required to contain all disturbances to areas outside of the ESA limits.

Shafts shall be maintained in a drained condition.

A minimum 2.4 m high secure fence shall be installed around the perimeter of the construction shaft area with gates and truck entrances. The fence shall be removed on completion of the work.

7.01.03 Protection Systems

The construction of all protection systems shall be according to OPSS539. Where the stability, safety, or function of an existing roadway, watercourse, other works, proposed works or ESA's may be impaired due to the method of operation, protection shall be provided. Protection may include sheathing, shoring, and piles where necessary to prevent damage to such works or proposed works.

7.01.04 Settlement or Heave

Any disturbance to the ground surface (settlement or heave) as a result of the pipe installation shall be immediately corrected by the Contractor, at no additional cost to the Ministry.

7.01.05 Stability of Excavation

The construction methods, plant, procedures, and precautions employed shall ensure that excavations are stable, free from disturbance, and maintained in a drained condition.

The construction methods, plant, procedures, and materials employed shall prevent the migration of soil and/or rock material into the excavation from adjacent ground.

7.01.06 Preservation and Protection of Existing Facilities

Preservation and protection of existing facilities shall be according to OPSS 491.

Minimum horizontal and vertical clearances to existing facilities as specified in the Contract Documents shall be maintained. Clearances shall be measured from the nearest edge of the largest cut diameter required to the nearest edge of the facility being paralleled or crossed.

Existing underground facilities shall be exposed to verify its horizontal and vertical locations when the outlet pipe path comes within 1.0 m horizontally or vertically of the existing facility. Existing facilities shall be exposed by non-destructive methods. The number of exposures required to monitor work progress shall be as specified in the Contract Documents.

7.01.07 Transporting, Unloading, Storing and Handling Materials

Manufacturer's handling and storage recommendations shall be followed.

7.01.08 Trenching, Backfilling and Compacting

Trenching, backfilling, and compacting for entry and exit points or other locations along the pipe path shall be according to OPSS 401.

7.01.09 Support Systems

Support systems shall be according to OPSS 404.

If any open excavation will encroach into the highway embankment the protection system shall satisfy the requirements for Performance Level 2 as specified in OPSS 539.

7.01.10 Dewatering

The work of this Section includes control, handling, treatment, and disposal of groundwater. The Contractor shall review the foundation investigation report for reference to soil and groundwater conditions on the project site and plan a dewatering scheme accordingly.

The Contractor shall control groundwater inflows to excavations to maintain stability of surrounding ground, to prevent erosion of soil, to prevent softening of ground exposed in the excavation, and to avoid interfering with execution of the work.

The Contractor shall maintain excavations free of standing water at all times during excavation, including while concrete is curing.

Should water enter the excavation in amounts that could adversely affect the performance of the work or could cause loss of ground, the Contractor shall take immediate steps to control the inflow.

The Contractor is alerted that seepage zones of perched water within the fill materials should be expected, particularly where granular materials are excavated.

Dewatering shall be according to OPSS 517.

7.01.11 Removal of Cobbles and Boulders

The Contractor is alerted that cobbles and boulders are expected within the soil deposits at the site. Accordingly, the Contractor shall address the removal of cobbles and boulders in the proposed method of construction. Removal of cobbles shall be expected to be routine and will not be considered cause for delay or additional compensation and the Contractor's trenchless equipment shall be appropriately equipped and operated for these conditions. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered.

7.01.12 Removal of Obstructions

The Contractor is alerted that obstructions such as, but not limited to wood debris, roots, and stumps, and construction debris consisting of (broken asphalt, concrete etc.) are expected within the trenchless alignment as identified in the Contract Documents. Accordingly, the Contractor shall address methods for the removal of obstructions in the proposed method of construction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered and the Contractor's expected method of and schedule for removal.

7.01.13 Management of Excess Material

Management of excess material shall be according to OPSS 180. Satisfactory re-usable excavated material required for backfill shall be separated from unsuitable excavated material.

7.01.14 Site Restoration

Site restoration shall be according to OPSS 492.

7.02 Auger Jack & Bore Installation

7.02.01 Method of Installation Procedure

The installation procedure to be used shall be subject to the following limitations:

- a) Hydraulically operated jacks of adequate number and capacity shall be provided to ensure smooth and uniform advancement without over-stressing of the pipe.
- b) A suitably padded jacking head or collar shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.
- c) The jacking pipe shall be fully supported in the jacking pit at the specified line and grade.
- d) Selection of the excavation method and jacking equipment shall take into consideration the conditions at each pipe crossing.

7.02.02 Pipe Installation

Concrete pipe joints shall be water tight and according to OPSS 1820 and must withstand jacking forces, determined by the Contractor.

During the jacking of the liner the space between the liner and the wall of the excavated volume (e.g., maximum cut diameter) shall be kept filled with bentonite slurry. Upon completion of jacking, the space between the liner and the wall of the excavated volume shall be filled with grout or slurry with gel strength properties demonstrated to be sufficient to form a semi-solid or solid gap filling material, prevent ground convergence around the pipe and subsequent ground surface subsidence and prevent long-term water flow at the outside boundary of any pipe and ground.

The annular space between the liner and the product shall be fully grouted with a water tight, expandable and stable grout.

7.03 Pipe Ramming Installation

For pipe ramming installation the following requirements apply:

Only smooth walled steel pipe shall be used. Butt welding of pipe joints shall conform to CAS W59.

Ramming equipment of adequate capacity shall be provided to ensure smooth and uniform advancement between the shafts/pits without overstressing of the pipe. Delays shall be avoided between ramming operations.

A ramming head shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.

Two or more lubricated guide rails or sills shall be provided of sufficient length to fully support the pipe at the specified line and grade in the ramming pit. Pipe shall be installed to the line and grade specified.

Removal of materials from within the pipe shall not be undertaken until the lead end of the pipe has passed fully through and beyond the zone of influence of any overlying infrastructure.

Following installation of the liner pipe, all material shall be removed from the pipe to the satisfaction of the Contract Administrator. Any voids remaining between the pipe and the excavation wall shall be grouted as soon as the pipe is rammed. The annular space between the liner pipe and the product shall be fully grouted with a water tight, expandable and stable grout.

7.04 Horizontal Directional Drilling Installation

7.04.01 General

When strike alerts are provided on a drilling rig, they shall be activated during drilling and maintained at all times.

For horizontal directional drilling, the contractor shall ensure that during pilot hole drilling the maximum degree of deviation or “dog-leg” shall be 2.5 degrees per 9 m drill pipe length. Any deviation exceeding 2.5 degrees will necessitate a pull-back and straightening of the alignment at the Contractor’s sole expense. The pilot hole exit location shall be within 0.5m of the target location.

7.04.02 Site Preparation

The work site shall be graded or filled to provide a level working area for the drilling rig. No alterations beyond what is required for HDD operations are to be made. All activities shall be confined to designated work areas.

7.04.03 Pilot Bore

The pilot bore shall be drilled along the bore path in accordance with the grade, alignment, and tolerances as indicated on the Contractor’s submitted drilling plan to ensure that the product is installed to the line and grade shown on the Contract Drawings. The Contractor’s methods shall take into consideration the conditions at each

crossing within the pipe alignment and shall be suitable to advance through such obstructions such as cobbles and boulders and address the potential for deflection off these obstruction and/or soil conditions.

In the event the pilot bore deviates from the submitted path, the Contract Administrator shall be notified. The Contract Administrator may require the Contractor to pullback, fill and abandon the hole and re-drill from the location along the bore path before the deviation.

If a drill hole beneath highways, roads, watercourses or other infrastructure must be abandoned, the hole shall be backfilled with grout or bentonite to prevent future subsidence and subsurface water conveyance.

The Contractor shall maintain drilling fluid pressure and circulation throughout the HDD process, including during the initial pilot bore and during the reaming process.

The Contractor shall at all times and for the entire length of the installation alignment be able to demonstrate the horizontal and vertical position of the alignment, the fluid volume used, return rates and pressures.

7.04.04 Drilling Fluid Losses to Surface (“Frac-Out”)

To reduce the potential for hydraulic fracturing of the hole during horizontal directional drilling, a minimum depth of cover of 5 m shall be maintained between the top of pipe and the surface of any pavements or beds of water courses. Sections of the pipe close to the entry and exit pit with less than 5 m cover shall be cased. The Contractor shall ensure that drilling fluid pressures are properly set and controlled for the full length of the bore to prevent frac-out for the depth of cover available between the bottom of the pavement structure (bottom of the subbase material) and the top of the bore.

Once a fluid loss or frac-out event is detected, the Contractor shall halt operations immediately and conduct a detailed examination of the drill path and implement measures to collect all fluids discharged to surface, mitigate and prevent additional fluid loss.

7.04.05 Reaming

The bore shall be reamed using the appropriate tools to a diameter at least 50% greater than the outside diameter of the product.

7.04.06 Product Installation

7.04.06.0 General

The product shall be jointed according to manufacturer’s recommendations. The length of the product to be pulled shall be jointed as one length before commencement of the continuous pulling operation.

The product shall be protected from damage during the pullback operation.

The minimum allowable bending radius for the product shall not be contravened.

Product shall be allowed to recover to static conditions from thermal and installation stresses before connections to new or existing facility are made. Product recovery time shall be according to manufacturers recommendations.

7.04.06.02 Pullback and Grouting

After successfully reaming the bore to the required diameter, the product pipe shall be pulled through the bore path. Once the pullback operation has commenced, it shall continue without interruption until the product pipe is completely pulled into bore unless otherwise approved by the Contract Administrator.

A swivel shall be used between the reamer and the product being installed to prevent rotational forces from being transferred to the product. A weak link or breakaway connector shall be used to prevent excess pulling force from damaging the product.

The product pipe shall be inspected for damage where visible at excavation pits and where it exits the bore. Any damage noted shall be rectified to the satisfaction of the Contract Administrator.

The pull back and reaming operations shall not exceed the fluid circulation rate capabilities. Reaming and back pulling operations shall be planned to insure that, once started, all reaming and back pulling operations are completed without stopping and within the permitted work hours.

The space between the pipe and the walls of the excavated volume shall be filled with grout or slurry with gel strength properties demonstrated to be sufficient to form a semi-solid or solid gap filling material, prevent ground convergence around the pipe and subsequent ground surface subsidence and prevent long-term water flow at the outside boundary of any pipe and ground.

7.05 Tunnelling Installation

7.05.01 General

Excavation of native soil and fill shall be done in a manner to control groundwater inflow to the excavation and to prevent loss of ground into the excavation.

Methods of excavating the tunnel shall be capable of fully supporting the face and shall accommodate the removal of boulders and other oversize objects from the face. Continuous ground support shall be maintained during excavation.

As the excavation progresses, the Contractor shall continuously monitor (every 2 m) indications of support distress, such as cracking, deflection or failure of support system and subsidence of ground near the excavation.

The Contractor shall provide ventilation and lighting in accordance with OSHA requirements for the entire length of the tunnel installed as tunneling progresses.

The tunnel is to be kept sufficiently dry at all times to permit work to be performed in a safe and satisfactory manner.

The Contractor shall maintain clean working conditions at all times in tunnels.

If excavation threatens to endanger personnel, the Work, or adjacent property, the Contractor shall cease excavation and make the excavation face secure. The Contractor shall then evaluate methods of construction and revise as necessary to ensure the safe continuation of the work.

The Contractor shall maintain tunnel excavation line and grade to provide for construction of final lining within specified tolerances.

7.05.01 Tunnelling Method

The tunnelling method shall be suitable to provide face support in changing ground conditions that may be encountered during the progress of the work. The selection of the tunnelling method should consider the soil conditions at each pipe crossing and the presence of obstructions, such as cobbles and boulders, with respect to the tunnel alignment.

7.05.02 Primary Liner (Support System)

Primary support systems shall prevent deterioration, loosening, or unravelling of ground surfaces exposed by excavation.

The primary liner support system shall be designed and installed to achieve the intended performance requirements.

Primary liner support system shall maintain the safety of personnel, minimize ground movement into the excavation, ensure stability and maintain strength of ground surrounding the excavation.

The primary liner shall be designed to support all subsurface conditions and hydrostatic pressures and to withstand any additional loads caused by installation and grouting, and shall ensure that no ground loading or other loading will be placed on the new work until after design strength has been reached.

The primary liner shall be installed so that the exterior is as tight as possible to the excavated surface of the tunnel and allows the placement of the full design thickness of the secondary lining.

Primary support systems shall be compatible with the encountered ground conditions, with the method of excavation, with methods for control of water, and with placement of the permanent lining.

All voids between the primary lining and the wall of the excavated volume shall be filled with cement grout or slurry with gel strength properties demonstrated to be sufficient to form a semi-solid or solid gap filling material, prevent ground convergence around the pipe and subsequent ground surface subsidence and prevent long-term water flow at the outside boundary of any pipe and ground. If an unexpanded liner is used, the space outside the liner plates shall be filled at least daily.

7.05.03 Secondary Liner

7.05.03.01 Placing of Grout

The void outside the finished secondary liner shall be filled with cement grout according to the Contractor's submission.

Grout shall not be placed until the lining has achieved 85% of its specified strength or 30 MPa. Grouting shall be limited to such sequences and programs as are necessary to avoid damaging any part of the works or any other structure or property. Grout mix design shall be chemically and thermally compatible with all pipe systems.

7.06 Microtunnelling

7.06.01 General

Excavation of soil, rock and fill shall be done in a manner to control and prevent groundwater inflow to the tunnel.

The MTBM shall be capable of fully supporting the face and shall accommodate the removal of boulders and other obstructions from the face. Continuous ground support shall be maintained during excavation.

The tunnel is to be kept well drained at all times to permit work to be performed in a safe and satisfactory manner.

The Contractor shall maintain clean working conditions at all times.

In the event that excavation threatens to endanger personnel, the Work, adjacent property, roadways, railways, waterways, or the public in any way, the Contractor shall cease excavation. The Contractor shall then evaluate the methods of construction and revise as necessary to ensure the safe continuation of the Work.

The Contractor shall maintain the tunnel excavation line and grade to provide for construction of the product within the specified tolerances.

7.06.02 Method of Installation

The installation procedure to be used shall be subject to the following limitations:

- The jacking pipe shall be fully supported in the jacking pit at the specified line and grade.
- Selection of the excavation method and jacking equipment shall take into consideration the subsurface conditions within the tunnel alignment.
- Perform microtunnelling operations in a manner that will minimize the movement of the ground in front of and surrounding the tunnel in conformance with the limits listed in the Contract Documents.
- Prevent damage to structures and utilities above and in the vicinity of the microtunnelling operations.

- Excavated diameter should be the minimum size required to permit pipe installation by jacking.
- Whenever there is a condition encountered which could endanger the microtunnel excavation or adjacent structures if tunnelling operations cease, continue to operate without intermission including 24-hour working days, weekends and holidays, until the condition no longer exists.
- Maintain an envelope of lubricant around the exterior of the pipe during the jacking and excavation operation to reduce the exterior soil/pipe friction and possibility of the pipe seizing in place.
- In the event a section of pipe is damaged during the jacking operation or a joint failure occurs, as evidenced by inspection, visible ground water inflow or other observations, the Contractor shall submit for approval his methods for repair or replacement of the pipe.

7.06.03 Casing Installation

Casing must withstand the jacking forces determined by the Contractor.

The space between the Casing and the wall of the excavation shall be kept filled with lubricant during the pipe jacking operation. Upon completion of pipe jacking, the space between the Casing and the wall of the excavation shall be filled with grout that is compatible with the Casing.

The Casing shall act as a support system to maintain the safety of personnel, minimize ground movement into the excavation, ensure stability and maintain strength of ground surrounding the Casing.

The Casing shall be designed to support all subsurface conditions and hydrostatic pressures and to withstand any additional loads caused by installation and grouting.

7.07 Instrumentation and Monitoring

The work specified in this Section includes furnishing and installing instruments for monitoring of settlement (and heave) and ground stability.

7.07.01 Surface Monitoring Points

Surface settlement points for monitoring ground stability shall be installed at the pavement/ground surface level on the shoulder, side slope and pavement at intervals of 5 m or less along the tunnel alignment centreline and as arrays of three points in each shoulder of the highway crossing and centred on the tunnel alignment. The equipment and procedures used for settlement monitoring during construction must be capable of surveying the settlement point elevations to within a repeatability (combined accuracy and precision of equipment and methods) ± 2 mm of the actual elevation.

Surface settlement markers shall be hardened steel markers treated or coated to resist corrosion, with an exposed convex head having a minimum diameter of 12 mm and similar to surveyor's PK nails. Markers shall be rigidly affixed so as not to move relative to the surface to which it is attached. Traffic shall be managed by the contractor using short-term lane closures in accordance with the Ontario Traffic Manual (OTM). Surface markers shall be recessed or otherwise designed for safe passage of vehicles at highway speeds and protected from snow removal equipment in the event that work occurs during snow removal seasons.

7.07.02 In-Ground Monitoring Points

In-ground settlement monitoring points shall be 12-18 mm rebar encased in a 50-70 mm, SCH40 PVC pipe, set to a depth of 1.5 m below ground surface or below frost penetration depth whichever is greater. The assembly

shall be placed in a drill hole, backfilled with uniform sand and provided with protective covers suitable for high vehicular traffic areas.

7.07.03 Installation, Replacement and Abandonment

The Contractor shall install all settlement monitoring points a minimum of two weeks prior to the start of works to permit baseline surveying to be completed. The settlement monitoring points shall be clearly labelled for easy field identification. The Contractor shall submit to the Contract Administrator a site plan showing the locations of the monitoring points, a geodetic survey of the settlement monitoring points including station, offset and elevation. Instruments damaged by the Contractor's operations or other causes shall be replaced and surveyed at the time of installation within 24 hours at no additional cost. At the completion of the job, the Contractor shall abandon all instrumentations installed during the course of the Work and restore the surface at instrument locations.

7.07.03 Monitoring and Reporting Frequency

The Contractor shall survey and otherwise obtain elevations of all settlement monitoring points at the following time intervals:

- a) Three consecutive readings at least one week prior to commencement of the work (Baseline Reading);
- b) Once per shift or once daily during tunnelling operations period whichever results in the more frequent reading intervals; and
- c) Weekly after completion of the work for one month, or until such time at which all parties agree that further movement has stopped.

All readings shall be submitted to the Contract Administrator for information purposes on a weekly basis.

Each report shall include all survey data collected in tabular and graphical format as plots of time versus settlement in comparison to survey data collected prior to commencement of the work.

7.07.03 Benchmarks

Two independent benchmarks shall be used for all settlement monitoring surveying and shall be located sufficiently outside the zone of influence such that the benchmarks are not influenced by any trenchless or other construction activity or weather conditions (e.g., frost heave). All surveying shall be reported using the geodetic datum and coordinate system as defined in the Contract Documents.

7.08 Criteria for Assessment of Roadway Subsidence/Heave

Based on the monitoring of ground movement as specified in Subsections 4.02 and 7.07, the following represents trigger levels that define magnitude of movement and corresponding action:

- a) Review Level: If a maximum value of 10 mm relative to the baseline readings is reached, the Contractor shall review or modify the method, rate or sequence of construction or ground stabilization measures to mitigate further ground displacement. If this Review Level is exceeded, the Contractor shall immediately notify the CA and review and discuss response actions. The Contractor shall submit a plan of action to prevent Alert Levels from being reached. All construction work shall be continued such that the Alert Level is not reached.

- b) Alert Level: If a maximum value of 15 mm relative to the baseline readings is reached, the Contractor shall cease construction operations, inform the Contract Administrator and execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic. No construction shall take place until all of the following conditions are satisfied:

- i. The cause of the settlement has been identified.
- ii. The Contractor submits a corrective/preventive plan.
- iii. Any corrective and/or preventive measure deemed necessary by the Contractor is implemented.
- iv. The CA deems it is safe to proceed.

9. MEASUREMENT FOR PAYMENT

Measurement shall be by Plan Quantity Payment as may be revised by Adjusted Plan Quantity Payment in metres, following along the centre line of the pipes from centre to centre of maintenance holes or chambers (catch basins) or from/to the end of the pipe where no maintenance hole or chamber is installed, of the actual length of pipe installed by trenchless methods.

10. BASIS OF PAYMENT

Payment at the contract price shall be full compensation for all labour, equipment and materials required for excavation (regardless of material encountered), dewatering, sheathing and shoring, settlement instrumentation and monitoring, site restoration, and all other work necessary to complete the installation as specified.

Where a protection system is made necessary because of the Contractor's operations (e.g., choice of trenchless installation method), the cost shall be included in this item and shall be full compensation for all labour, equipment and materials required to carry out the work including subsequently removing the temporary protection system and performing any necessary restoration work.

Payment for connecting intercepted drains and service connections shall be made on the following basis:

- (a) Where such drains and service connections are shown on the contract drawings the cost of connections shall be included in the contract price for pipe installation.
- (b) Where such drains and service connections are not shown on the contract drawings, the cost of connections will be considered an allowable extra to the contract.



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