

REPORT

**Foundation Investigation and Design
Culvert Replacement
Highway 417 Eastbound Off-Ramp to Walkley Road
0.3 km North of Walkley Road, Ottawa, Ontario
*G.W.P. No. 4099-11-00***

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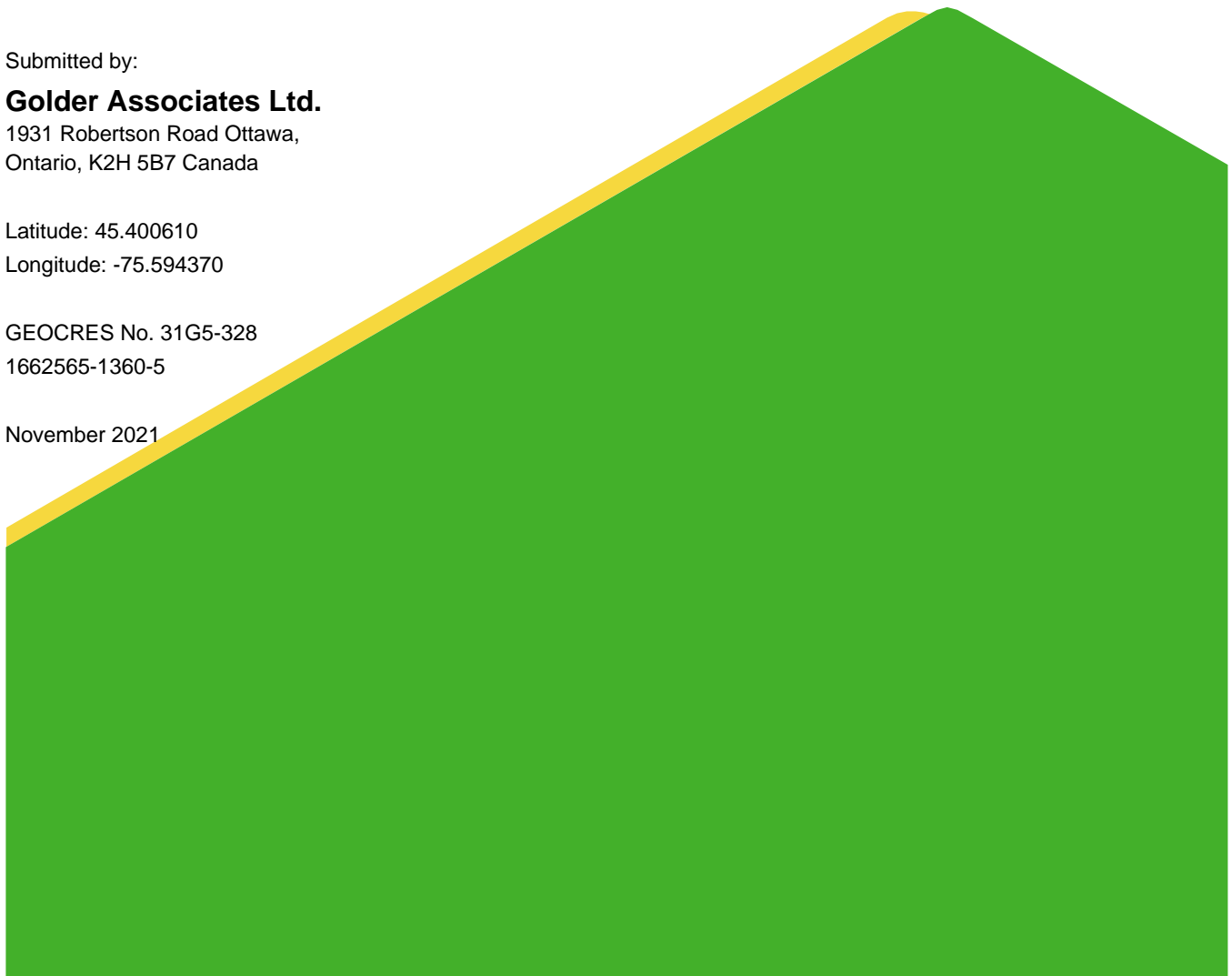
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PART A

Foundation Investigation
Culvert Replacement
Highway 417 Eastbound Off-Ramp to Walkley Road
0.3 km North of Walkley Road
Ottawa, Ontario

1.0 INTRODUCTION

Golder Associates Limited (Golder) has been retained by WSP Canada Group Limited (WSP) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out foundation investigations associated with nine culvert rehabilitations and/or replacements on Highway 417 between the Aviation Parkway and Ramsayville Road as well as the widening of Highway 417 from Ottawa Road 174 to Hunt Club Road in Ottawa, Ontario (Assignment number 4016-E-0008).

This report presents the results of the foundation investigation carried out to provide foundation design recommendations for the replacement of an existing culvert located on the Highway 417 Eastbound Off-Ramp to Walkley Road, about 300 m north of the Walkley Road, in Ottawa, Ontario (G.W.P. 4099-11-00).

The terms of reference and scope of work for the foundation investigation are outlined in the MTO's Request for Proposal (RFP), dated May 2016, and subsequent addenda. Golder's scope of work for foundation engineering services associated with this non-structural culvert crossing is contained in Table 17.8.3 of WSP's Technical Proposal for this assignment. The work has been carried out in accordance with Golder's Quality Control Plan for foundation engineering services for this project, dated March 13, 2017.

2.0 SITE DESCRIPTION AND GEOLOGY

2.1 General

At the proposed crossing location, Highway 417 is a divided highway with two travel lanes in each direction separated by a wide, vegetated median. The W-EW Highway 417 / Walkley Road off ramp consists of a single travel lane with fully paved shoulders. Cattails were noted in the ditchline in the area adjacent to the culvert.

The existing culvert is located at Station 26+865 under the offramp, approximately 0.3 km north of the Highway 417 Underpass at Walkley Road. Information provided by WSP for this assignment indicates that the existing corrugated steel pipe culvert is 38 m long and has an internal diameter of 1.05 m. There are no headwalls at this location and flow through the culvert is from east to west. The proposed replacement culvert is to be about 39 m long with an internal diameter of 1.05 m and invert elevations ranging from Elevation 61.3 m to 61.9 m. Currently the new culvert is to be installed about 15 m south of the existing culvert using trenchless methods and the new culvert will not have headwalls.

The location of the existing and proposed culverts is shown on the Key Plan on Drawing 1.

2.2 Regional Geology

As delineated in *The Physiography of Southern Ontario*¹, this section of Highway 417 lies within the minor physiographic region known as the Ottawa Valley Clay Plain, which lies within the major physiographic region of the Ottawa-St. Lawrence Lowland.

¹ Chapman, L. J. and Putnam, D. F., 1984. *The Physiography of Southern Ontario*, Ontario Geological Survey. Special Volume 2, Third Edition. Accompanied by Map P.2715, Scale 1:600,000. Ontario Ministry of Natural Resources.

The Ottawa Valley Clay Plain region is characterized by relatively thick deposits of sensitive marine clay, silt and silty clay that were deposited within the former Champlain Sea basin. These deposits, known as the Champlain clay or Leda clay, overlie relatively thin, commonly reworked glacial till and glaciofluvial deposits, that in turn overlie bedrock².

This region is underlain by a series of sedimentary rocks, consisting of sandstones, dolostones, limestones and shales that are, in turn, underlain at depth by igneous and metamorphic bedrock of the Precambrian Shield. The bedrock geology mapping³ indicates that the bedrock at study area is primarily Carlsbad Formation shale bedrock.

3.0 INVESTIGATION PROCEDURES

The subsurface investigation for this project was carried out in the fall of 2019 and early winter 2020 and included advancement of a total of three boreholes, numbered 19-3613 to 19-3615; with one located within the paved shoulder of the off ramp; and one each at the proposed culvert inlet and outlet.

An additional borehole 20-1936A was advanced at the site in January 2021 to assess the artesian groundwater conditions encountered during the original investigations.

The boreholes were advanced using a combination of truck mounted (shoulder Borehole 19-3614), and portable rotary drill drilling equipment (inlet/outlet Boreholes 19-3615, 19-3613 and 20-1936A). The truck mounted drilling equipment was supplied and operated by George Downing Estate Drilling Limited of Hawkesbury, Ontario. The portable drilling equipment was supplied and operated by CCC Geotechnical & Environmental Drilling Limited of Ottawa, Ontario.

Traffic control required to close the driving lanes and shoulders of the offramp while carrying out the field operations was provided by Beacon Lite Limited of Ottawa, Ontario.

Soil samples were obtained using a 50 mm outer diameter split-spoon sampler in general accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586). In Borehole 19-3614, soil samples were obtained at vertical sampling intervals of about 0.76 m. Soil samples from the inlet/outlet boreholes, advanced with portable drilling equipment, were obtained in continuous vertical increments of about 0.6 m using a full-weight hammer as per ASTM.

Bedrock core samples were obtained using NQ diamond drilling equipment in all boreholes with the exception Borehole 20-1936A.

A monitoring well was installed in 20-1936A to measure the stabilised groundwater level across the site and to monitor the artesian pressure noted during drilling of the other boreholes. The monitoring well consisted of 32 mm outside diameter PVC tubing with a 1.5 m long slotted tip. The groundwater level was measured in the well on February 8, 2021, and April 23, 2021. The well was subsequently decommissioned according to Ontario MOE Regulation 903 (O.Reg 903) by a licenced well technician.

² Belanger, J.R. "Urban Geology of Canada's National Capital Area", in *Urban Geology of Canadian Cities*, Geological Association of Canada Special Paper 42, Ed. P.F. Karrow and O.L. White, 1998.

³ Ontario Geological Survey 2011. 1:250 000 scale bedrock geology of Ontario; Ontario Geological Survey, Miscellaneous Release---Data 126-Revision 1.

The boreholes were backfilled with bentonite within the bedrock and bentonite mixed with soil cuttings within the overburden, in general accordance with the intent of O.Reg 903, as amended. The boreholes were then capped with either cold patch asphalt or granular material to match the surrounding surface cover. The site conditions were restored following completion of the fieldwork.

The fieldwork was supervised on a full-time basis by members of Golder's staff who located the boreholes in the field, directed the drilling, sampling, and in-situ testing operations, logged the boreholes and examined and cared for the samples. The soil and bedrock core samples were identified in the field, placed in labelled containers, and transported to Golder's laboratory in Ottawa for further examination and testing. Index and classification tests consisting of water content determinations and grain size distribution analyses were carried out on selected soil samples at Golder's Ottawa laboratory. Uniaxial Compressive Strength (UCS) testing was carried out on a single bedrock core sample at Geomechanica's Inc. laboratory in Toronto, Ontario. The laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate.

Two soil samples were submitted to Eurofins Environment Testing for chemical analysis related to potential corrosion of exposed buried steel and potential sulphate attack on buried concrete elements (corrosion and sulphate attack).

The borehole locations and elevations were surveyed by Golder using a Trimble R10 GPS unit referenced to the NAD83 CSRS CBNv6-2010.0 MTM Zone 9 geodetic datum. The borehole locations, including northing and easting coordinates, ground surface elevations, and drilled depths, are summarized in Table 1.

Table 1: Borehole Location Summary

Borehole	Borehole Location	NAD83 CSRS CBNv62010.0 MTM Zone 9		Ground Surface Elevation (m)	Drilled Length (m)
		Northing (m)	Easting (m)		
19-3613	Proposed Culvert Outlet	5029380.3	375686.8	61.8	9.1
20-1936A	Proposed Culvert Outlet	5029377.7	375688.1	61.9	5.8
19-3614	Highway 417 Offramp Shoulder Proposed Culvert Alignment	5029362.7	375699.7	64.7	13.3
19-3615	Proposed Culvert Inlet	5029346.0	375719.9	62.2	9.6

4.0 DESCRIPTION OF SUBSURFACE CONDITIONS

4.1 General

The subsurface soil, bedrock and groundwater conditions encountered in the boreholes and the results of in-situ testing from the investigations are given on the Record of Borehole, and Drillhole sheets presented in Appendix A. The results of the laboratory testing carried out during the investigation are presented on the Record of Borehole and Drillhole sheets as well as on Figures B1 to B6 in Appendix B. The borehole locations and the interpreted stratigraphic profiles projected along the proposed culvert alignment are provided on Drawing 1.

Photographs of the bedrock core recovered at the boreholes are shown on Figures A1 to A3 provided in Appendix A. The results of basic chemical analysis completed on select soil samples are provided in Appendix C.

The stratigraphic boundaries shown on the Record of Borehole and Drillhole sheets and on the interpreted stratigraphic section on Drawing 1 are inferred from observations of drilling progress and noncontinuous sampling and therefore represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

4.2 Site Stratigraphy Overview

At the boreholes, the subsurface conditions generally consist of embankment fill or asphaltic concrete at surface, overlying silty clay, overlying silt and sand overlying glacial till which is all underlain by Carlsbad Formation interbedded shale and limestone bedrock.

The groundwater level was measured at Borehole 20-1936A at 1.2 m in above the existing ground surface, corresponding to Elevation 63.1 m.

Detailed descriptions of the overburden deposits, bedrock geology and groundwater conditions encountered at the proposed crossing location during the field investigation are provided in the following sections.

4.3 Surface Cover / Surficial Materials

Borehole 19-3614 was advanced through the shoulder of the offramp. The road structure consists of 100 mm of asphaltic concrete overlying a 300 mm thick gravelly sand base layer.

A layer of topsoil with a thickness of 0.1 m was encountered at the ground surface at Borehole 20-1936A.

4.4 Fill

Fill consisting predominantly of sand and silt, with trace amounts of gravel, was encountered below the topsoil fill at Borehole 20-1936A and below the surficial clayey silt fill at Borehole 19-3615. The top of this layer was encountered at Elevations 61.6 and 61.8 and is about 0.5 m thick. SPT N values of 1 and 3 blows per 0.3 m of penetration were measured in this layer, indicating a very loose state of compactness. The results of a grain size analysis test carried out on a single sample of the sand and silt fill are provided on Figure B1 in Appendix B.

Fill consisting predominantly of clayey silt or silty clay, with varying amounts of sand and gravel, was encountered at the ground surface at Boreholes 19-3613, 19-3615 and below the sand and silt fill at Borehole 20-1936A. The top of this layer was encountered at elevations ranging from 61.3 to 62.2 m. The thickness of this layer ranges from about 0.6 to 1.2 m. The SPT N values ranged from Weight of Hammer (WH) to 3 blows per 0.3 m of penetration indicating a firm to stiff consistency. The results of a grain size analysis test carried out on a single sample of the clayey silt fill are provided on Figure B2 in Appendix B.

Silty sand and gravel fill was encountered beneath the road structure fill at Borehole 19-3614. The top of this layer was encountered at Elevation 64.3 m and the layer is about 2.3 m thick. SPT N values of 31 and 43 blows per 0.3 m of penetration indicates a dense state of compactness. The measured moisture contents of two samples tested was 3%.

4.5 Sand and Silt

Sand and silt, with some clay, was encountered underlying the embankment fill at Borehole 19-3614. The top of this layer was encountered at Elevation 62.0 m and the layer is about 1.1 m thick. An SPT N value of 3 blows per 0.3 m of penetration was recorded in this layer, indicating a very loose state of compactness. The measured moisture content of a single sample of this material was 34%. The results of a grain size analysis test carried out on a single sample of the sand and silt material are provided on Figure B3 in Appendix B.

4.6 Silty Clay to Clayey Silt

A deposit of silty clay to clayey silt was encountered underlying the fill at Boreholes 19-3613, 19-3615 and 20-1936A, and below the sand and silt layer at Borehole 19-3614. The top of clay layer was encountered at elevations ranging from 60.6 to 61.0 m. The thickness of this layer ranges from 1.8 to 2.3 m. The SPT N values ranged from 1 to 6 blows per 0.3 m of penetration. Two in-situ shear vane test results of 28 and 52 kPa indicate a firm to stiff consistency. Based on ratios of the measured in-situ natural shear strength to the remolded shear strength of 4 and 9, the clay is classified as sensitive to extra sensitive.

The results of grain size analysis testing conducted on two samples of this material are illustrated on Figure B4 in Appendix B. The results of Atterberg Limits testing completed on five samples of the clay indicate liquid limits ranging from 30 to 42, plastic limits ranging from 19 to 20 and plasticity indices ranging from 11 to 22. The Atterberg Limits analysis results are illustrated on Figure B5 in Appendix B and indicate a clay with low to intermediate plasticity (CL to CI). The moisture content of the samples tested ranged from 32 to 47% and were at or in excess of the liquid limit.

4.7 Glacial Till

A deposit of glacial till was encountered beneath the clay in all four boreholes at elevations ranging from 58.5 to 59.2 m. The glacial till generally consists of a heterogeneous mixture of sand and silt with varying amounts of gravel. Shale fragments, cobbles and boulders were also encountered in this layer in all boreholes. Coring techniques were required to penetrate the till layer in Borehole 19-3615. The thickness of the till layer at the borehole locations ranges from 2.9 to 3.4 m.

The SPT N values ranged from 4 to 55 blows per 0.3 m of penetration, but more typically 23 to 46, indicating a compact to dense state of compactness. The higher refusal blow counts (i.e., 50/0.10 and >50) noted on the Record of Boreholes for the till layer may have been influenced by the presence of cobbles or boulders within the till or the presence of bedrock, rather than the state of packing of the soil matrix.

The measured moisture content of the eight samples tested ranged from 6 to 74% but more typically 6 to 29%. The 74% measurement of the till in Borehole 19-3613 is not considered representative of the till layer. The results of grain size analysis testing carried out on five samples of the till are provided on Figure B6 in Appendix B.

4.8 Bedrock/Auger Refusal

Bedrock was encountered beneath the glacial till deposit at all boreholes except Boreholes 20-1936A.

Auger refusal was encountered at Borehole 20-1936A at Elevation 56.1 m, which could indicate the presence of bedrock surface or could reflect the presence of cobbles and boulders.

Bedrock was proven by coring using NQ sized equipment in Boreholes 19-3613 to 19-3615 for lengths between 3.1 and 4.3 m. Photographs of the bedrock core obtained at the boreholes are shown on Figures A1 to A3 provided in Appendix A.

Table 2 summarizes the depths and the elevations of the bedrock surface as encountered at the borehole locations.

Table 2: Summary of Bedrock and Refusal Depths and Elevations

Borehole	Borehole Location	Ground Surface Elevation (m)	Depth to Bedrock (m)	Bedrock Surface Elevation (m)
19-3613	Proposed Culvert Outlet	61.8	5.8	56.0
20-1936A	Proposed Culvert Outlet	61.9	5.8 ^R	56.1 ^R
19-3614	Highway 417 Offramp Shoulder Proposed Culvert Alignment	64.7	9.0	55.7
19-3615	Proposed Culvert Inlet	62.2	6.5	55.7

Note: ^R Denotes auger refusal; bedrock was not proven.

The bedrock consists of slightly weathered to fresh, thinly to medium bedded, black, fine grained shale of the Carlsbad formation.

The Rock Quality Designation (RQD) values measured on recovered bedrock core samples ranged from approximately 0 to 90%, but generally ranged between 24 to 90% indicating a poor to good quality rock.

The results UCS testing carried out on a single bedrock core specimen provided a UCS value of 105 MPa, indicating a very strong bedrock. It is noted that this result is likely indicative of the strength for the interbedded limestone bedrock.

4.9 Groundwater Conditions

A monitoring well was installed in Borehole 20-1936A to observe the stabilized groundwater level at the site.

Table 3 summarizes the depths and the elevations of the groundwater levels measured in the monitoring well installed at the site. The final groundwater levels were measured in the wells on the dates indicated in Table 3.

The groundwater level was measured at the ground surface in Boreholes 19-3613 and 19-3615 in the open boreholes prior to backfilling.

It is expected that the groundwater levels will be subject to fluctuations both seasonally and as a result of precipitation events.

Table 3: Summary of Groundwater Conditions

Borehole	Location	Screened Interval	Ground Surface Elevation (m)	Depth (m)	Elevation (m)	Date
20-1936A	Proposed Culvert Outlet	Glacial Till	61.9	1.2 [*]	63.1	February 8, 2021
				1.2 [*]	63.1	April 23, 2021

Note: ^{*} Denotes metres above existing ground surface.

4.10 Corrosion and Sulphate Attack Potential

Two soil samples were submitted to Eurofins Environment Testing for chemical analysis related to potential corrosion of exposed buried steel (corrosion and sulphate attack). The test results are provided in Appendix C and are summarized in Table 4.

Table 4: Results of Chemical Analysis

Borehole	Sample Depth (m)	Chloride Soil (%)	pH	Electrical Conductivity Soil (mS/cm)	Resistivity (ohm-cm)	Sulphate Soil (%)
19-3614	6.8 – 7.5	0.009	8.22	6.59	151	0.03
20-1936A	0.6 – 1.2	0.028	8.16	0.48	2,080	0.01

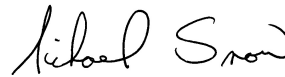
5.0 CLOSURE

This report was prepared by Mr. Kenton Power, P.Eng. It was reviewed by Michael Snow, P.Eng. a Senior Geotechnical Engineer with Golder. William Cavers, P.Eng. an Senior Geotechnical Engineer with Golder and the Designated MTO Foundations Contact for this project, carried out an independent quality control review of this report.

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KCP/MSS/WC/hwd

[https://golderassociates.sharepoint.com/sites/11263g/shared documents/01_foundations/6 - reports/1360 trenchless crossings/tc5 - eb off-ramp walkley/3-final tc5/1662565-1360-5-rev0 tc5 hwy 417 walkley offramp 2021-11-11.docx](https://golderassociates.sharepoint.com/sites/11263g/shared%20documents/01_foundations/6%20reports/1360%20trenchless%20crossings/tc5%20-%20eb%20off-ramp%20walkley/3-final%20tc5/1662565-1360-5-rev0%20tc5%20hwy%20417%20walkley%20offramp%202021-11-11.docx)

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PART B

Foundation Design
Culvert Replacement
Highway 417 Eastbound Off-Ramp to
Walkley Road
0.3 km North of Walkley Road
Ottawa, Ontario

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

This report presents the results of the foundation investigation carried out to provide foundation design recommendations for the replacement of an existing non-structural culvert located under the Highway 417 Eastbound Off-Ramp to Walkley Road, in Ottawa, Ontario (G.W.P. 4099-11-00). The input provided herein is based on interpretation of the factual data obtained from the boreholes advanced during the current investigations, and in accordance with the 2014 Canadian Highway Bridge Design Code CAN/CSA-S6-14 (CHBDC) and MTO's Pipe Installation by Trenchless Method Special Provision dated January 2019.

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 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. 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.

A description of the proposed culvert and general guidelines for design of the crossing are provided below.

6.2 Proposed Structure

The proposed works related to the installation of the replacement culvert is based on the information provided by WSP on April 7, 2020.

The proposed culvert is to be located at Station 26+880 under the Highway 417 eastbound offramp approximately 280 m north of Walkley Road. The proposed culvert is to be about 39 m long with an internal diameter of 1.05 m and invert elevations ranging from 61.3 m to 61.9 m.

It is understood that it is currently proposed to install this culvert employing trenchless techniques. However, from a foundation perspective it is considered feasible to construct this culvert using the conventional open cut method.

As such, recommendations for both trenchless (Section 6.0) and open cut installation methods (Section 7.0) have been provided in this report.

6.3 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 and this report provides guidance on the influence of ground behaviour on possible installation methods. It should not be construed that the Contractor is restricted to the particular methods considered herein, and in the event that alternative methods are considered, the Contractor must make their own interpretation of the anticipated ground behaviour, based on the factual information from the investigations undertaken at this site.

Common trenchless construction methods include horizontal directional drilling, pipe jacking and horizontal auger boring, pipe ramming, micro-tunneling, pilot tube micro-tunneling, tunnel boring machine and tunnel digging machine (i.e., open face shield tunnelling). A brief description of each method is included below.

Further requirements on the various trenchless methods are outlined in the MTO's Pipe Installation by Trenchless Method Special Provision provided in Appendix D.

The following is a general summary of the geotechnical considerations for the design and construction of the particular trenchless methodologies.

1) Pipe Jacking and Horizontal Auger Boring (also referred to as Auger Jack and Bore):

A pipe jacking operation involves pushing an oversized liner pipe (casing) horizontally into the ground by jacking through reaction against a thrust block (i.e., backstop) located within the jacking pit. 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 casing may be lubricated to reduce the frictional forces between casing and the surrounding soil. The profile needs to be approximately horizontal and there is limited ability to steer the casing during jacking.

The jack and bore method is generally suitable for penetrating cohesive soils (silt and clay) and wet but unsaturated cohesionless soils that are well-graded (i.e., broadly graded). This method is not feasible in flowing ground which can lead to excessive ground losses, settlement and development of sinkholes extending to the surface when passing through saturated (flowing) sand, silt and/or gravel.

This method is only applicable to installation in the overburden and may not be feasible in bouldery soils

(e.g., glacial till) as the presence of boulders and cobbles can obstruct augering operations, damage the equipment and require manual interventions that slow progress. The removal of obstructions may also result in loss of ground at the face and ground settlement at the ground surface, depending on the soil conditions.

However, this method can be adapted for use in mixed-face conditions and ground with boulders, with the addition of a Small Boring Unit (SBU) cutterhead. The SBU is equipped with mini disc cutters on the cutterhead and is welded to the lead casing to facilitate cutting through mixed ground, ground containing cobbles and boulders and/or bedrock. With the addition of the rotating cutterhead, the SBU also allows for some steering capability.

Jacking and receiving pits are required. The size of the jacking pit is controlled by the equipment size, operator access requirements and the length of the casing sections which are being installed. Typically, a work area of about 10 m long by about 3 m to 5 m wide is required to accommodate the jacking/drive pit for jack and bore operations. The receiving pit is typically about 3 m square. The excavation depth for the pits will depend on the final invert elevation of the crossing alignment.

2) Pipe Ramming:

Pipe ramming is a trenchless method that uses a pneumatic tool to hammer a steel pipe or casing with a cutting shoe attached into the ground. The pipe is almost always driven open-ended to thereby direct the soil into the pipe interior instead of compacting it outside the pipe, reducing the potential for ground loss into the casing during driving. As each casing length is installed, the hammer is removed, the next casing is welded in place and the hammer replaced and restarted. 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.

Entry and receiving pits are also required for pipe ramming but, as there is no need for a thrust block in the entry pit, a smaller pit size is required than in jack and bore installations (which is an advantage for congested urban highways). The excavation depth for the pits will depend on the final invert elevation of the crossing alignment.

Pipe ramming is best suited for overburden installations in soft to firm clays and very loose to compact sands above the water table. This method is not considered feasible in mixed face conditions. These methods are also better suited for penetrating through/displacing potential obstructions such as cobbles and boulders in comparison to jack and bore installation method, although this method can still be obstructed by cobbles and boulders depending on their size and number. Pipe ramming is not-steerable, so there is no control over the profile and alignment of the bore once the pipe ramming has started. Vibrations from the pipe ramming operations may result in settlement of loose materials in the immediate vicinity of the installation. Furthermore, a “plug” of soil may form at the head of the casing inducing surficial heave as the pipe is advanced.

Compared to the jack and bore method, the most important advantage of pipe ramming is that the soil is typically removed from the pipe only after the pipe has fully passed beneath overlying infrastructure. Depending on the length of the installation, the soils inside the pipe can be removed either during or after the installation by auguring, compressed air or water jetting.

3) Pilot Tube Micro-tunneling:

Pilot Tube Micro-Tunneling (PTMT), also known as guided auger boring, employs augers for excavation and soil removal and a jacking system for advancing the drill pipes, casings and product 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 slanted steering head is used for pilot boring and adjustment of alignment and grade and the bore hole is subsequently enlarged by a reamer with a casing following behind the reamer, with an auger string inside the casing used to remove cuttings. The product pipes follow the casing to be installed in the ground.

A typical PTMT construction sequence is as follows.

- Excavate and prepare the driving and receiving shafts.
- Lower the thrust frame into the driving shaft and set it up. Set up the guidance system including the steering head and target in the driving shaft.
- Install the pilot tube behind the steering head. The boring process proceeds with the rotation and thrust of the pilot tube. Deviations are continuously adjusted through video monitor surveillance of the illuminated target.
- When the steering head reaches the receiving shaft, the reamer and casing with auger inside are connected to the last segment of pilot tube. The reamer and auger enlarge the pilot bore hole by rotating and thrusting the reamer and casing. The steering head and the pilot tubes are then retrieved at the receiving shaft.

4) Micro-tunneling:

Micro-tunnelling is a method of installing pipes in bores ranging from 0.6 to greater than 3 metres in diameter behind a steerable remote-controlled shield that is pressurized with a bentonitic fluid 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. Availability of this equipment locally is limited.

Micro-tunnelling is a very precise method of tunnelling and there is relatively little settlement with this method, if the face pressure and cutting tools are appropriate for the ground and are maintained over the length of the drive.

This method can be applied to a wide range of ground conditions from saturated sands and gravels, through to soft or stiff, dry or saturated clays and mudstones, to solid rock. Specialist advice on machine selection should be sought and recommendations regarding the machine design for the given ground conditions should be supported by the manufacturer. Appropriate machine design refinements may be used to extend the application range of the machine to cover more adverse soil conditions, including mixed face conditions and handling of obstructions such as cobbles and boulders.

5) Horizontal Directional Drilling (HDD):

HDD involves the drilling of a pilot hole 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 would be pulled through the bore (using the drill rods to pull the pipe into place). HDD is typically used for smaller diameter crossings below embankments or rivers and is not suited to gravity pipes (such as sewers). HDD equipment is available for drilling in both bedrock and overburden but is very challenging in bouldery ground. Deep entrance and exit pits are generally not required, however, larger laydown areas are required to install the product 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 1.2 m in diameter. Sufficient cover is important to minimize the risk of hydraulic fracturing of the ground and loss of drilling fluid to the surface.

6) Tunnel Boring Machine (TBM):

TBM tunnelling operations involve the advance of a steerable machine with a rotating cutter head horizontally into the ground with successive sections of either an oversized liner pipe or the final product pipe advanced behind the TBM by pipe jacking. The spoil is removed from the tunnel as the TBM is advanced, using augers, conveyor belts or mucking carts. The cutting head is driven and steered by an operator inside the TBM and may be partially open to allow for access to the face. The tunnel profile needs to be approximately horizontal. Jacking and receiving pits are required. Locally, this method is generally used for construction in overburden, and open-faced machines have been used in bouldery soils (e.g., glacial till). Excavations through sandy soils below the water table 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.

7) 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 liner (i.e., steel casing) or final pipe would be jacked in sections from the launching shaft. Unlike jack and bore, 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 1.2 m or more.

6.4 Proposed Alignment and Profile Considerations

Based on the proposed invert elevations, the proposed culvert crossing will generally be advanced through variable granular fill. Within the length of the alignment between the borehole locations, the crossing may encounter the native sand and silt that overlies the native silty clay deposit.

The base plan mapping provided by WSP for this project and the ground surface elevations at the borehole locations surveyed during the field investigation indicate that the top of roadway elevation of the Highway 417 offramp lane in the vicinity of the proposed culvert ranges from 64.8 to 65.0 m. As outlined above, the proposed culvert is to have invert elevations ranging from 61.3 m to 61.9 m with a diameter of 1.05 m, corresponding to obvert Elevations of 62.3 m to 62.9 m. However, depending on tunnelling method, a casing liner with a diameter of about 1.2 to 1.5 m would be installed in conjunction with installation of the smaller 1.05 m diameter culvert pipe. Therefore, the minimum cover below the offramp surface would be estimated based on the larger liner pipe diameter, which would correspond to a maximum obvert elevations ranging from about 62.8 to 63.4 m. Therefore, the minimum cover below the highway surface range from 1.6 m, providing a cover-to-diameter ratio of at least 1.1 through the majority of the alignment. The minimum will be reduced at the entry/exit pit locations, depending on how close to the embankment the pits are located. As such, it is assumed the entry/exit pits will be constructed closer to the embankment to provide the minimum sufficient cover for trenchless installation.

For tunnels under 400-series highways, MTO generally requires that the minimum overburden cover shall not be less than one (and preferably two) tunnel diameters, at any point along the entire length of the tunnel crossing. Based on the profiles provided by WSP and the estimates given above, the offramp crossing has generally greater than one tunnel diameter (i.e., 1.8 m) of cover along the alignment length.

Typically, it is recommended that the tunnel invert or obvert be a minimum of 0.5 m above or below (respectively) the interface of the fill materials, native materials and/or bedrock so that the tunnel horizon is not through mixed face conditions. It should be noted that, based on the results of the borehole investigation, the proposed culvert could be through a mixed fill / native silt and sand interface.

6.5 Anticipated Ground Behaviour

At the crossing location, the subsurface conditions within the tunnel horizon will consist of clayey silt fill, gravel and sand embankment fill, overlying sand and silt overlying silty clay all underlain by shale bedrock of the Carlsbad formation.

Artesian groundwater conditions were encountered at the site within the glacial till underlying the clay soils. The groundwater level was measured at 1.2 m above the ground surface, corresponding to Elevation 63.1 m (approximately 0.8 m above the proposed culvert obvert). Although the groundwater will fluctuate seasonally, dewatering measures to lower the groundwater level is anticipated to be required to facilitate the excavation of the entry/exit pits.

Basal heave due to hydrostatic uplift can result when only a limited thickness of low-permeability soil (e.g., silty clay) beneath the base of the excavation is underlain by higher permeability soil (e.g., glacial till) under high groundwater pressures. This condition can result in a disturbed/destabilized subgrade and slope failures, which would not be suitable for support of structures, and the recompression of which, upon backfilling, would lead to unacceptable settlements. Basal heave can also cause construction issues (disturbed subgrades, poor trafficability, etc.) and in extreme cases, safety issues. The boreholes advanced on this site indicate a limited thickness of silty clay below the depth of excavation. At the location of the entry and exit pits, there are unacceptable factors of safety (i.e., less than 1) against basal heave for excavations that extend 1 m below the culvert inlet and outlet (i.e., about Elevation 60.0 m). A Non-Standard Special Provision (NSSP) should be added to the contract documents alerting the Contractor to the potential of basal heave during while carrying out excavation on site. Sample wording has been provided in Appendix D.

For the entry and exit pit excavations, it is therefore expected that depressurization of the underlying glacial till carried out in advance of the excavation will be required based on the groundwater elevations presented herein. Passive relief wells which discharge into the pit excavations could be considered as a means of depressurizing the underlying glacial till and preventing basal heave.

Based on the currently proposed culvert invert elevations (Elevation 61.3 m to 61.9 m) artesian groundwater pressures should not be an issue from a tunneling perspective, although some limited surface water and groundwater inflows during tunnelling should be expected.

It is recommended that the replacement be conducted during a drier season such as after the spring freshet or prior to the fall season.

The ground conditions along the majority of culvert alignment within the tunnel vertical limits (i.e., invert and obvert of the casing) are likely to consist of mixed face conditions of gravel and sand embankment fill with some silty clay embankment fill at the culvert ends and the top of the native sand and silt, thus mixed face conditions. Cobbles and boulders were also noted in the embankment fill at the borehole locations. Based on interpolation between boreholes, this should be expected to be the case for the majority of length of the proposed tunnel.

Based on the soil descriptions, the granular gravel and sand embankment fill, silty clay fill and native clayey silt and silty clay has been classified according to the Tunnelman's Ground Classification System by Terzaghi as reported in Heuer (1974). This system is commonly used to describe the expected behaviour of an unsupported tunnel face during excavation and uses qualitative "stand-up time" criteria to classify the ground at and above the tunnel face into the following principal categories: hard, firm, slow ravelling, fast ravelling, squeezing, swelling, cohesive-running, running, very soft squeezing, flowing, and bouldery.

Under the Tunnelman's Ground Classification System, the silty clay fill would be classified as firm to slow ravelling and the gravelly sand embankment fill and native silt and sand would be classified as cohesive-running material above the groundwater level (i.e., if unsaturated) and flowing below the groundwater level.

6.6 Feasibility of Tunneling Methods

Based on the available information for this project and the list of methods discussed above, the following methods are not considered suitable or necessary for this crossing and are therefore not considered further in this report.

- Pilot Tube Micro-tunneling – This method is not considered feasible in mixed face conditions.
- HDD – Method not suitable for gravity pipes (i.e., sewers) and/or confined sites.
- TBM – Method not suited for small diameter pipes and low cover.
- TDM – Method not suited for small diameter pipes and low cover.

Mixed face conditions are a potential issue wherever the soil-soil or soil-bedrock interface is within the elevation horizon of the proposed bore or where the face conditions are expected to change significantly along the length of the crossing. According to the anticipated subsurface conditions (see Drawing 1), a mixed-face condition consisting of a mixed interface of varying embankment fill and native sand and silt was encountered along the vertical limit of tunnel at this site. Based on interpolation between boreholes, this should be expected to be the case for the majority of length of the proposed tunnel. A mixed face condition is expected to materially affect the selection of trenchless methods.

Given the anticipated mixed face conditions along the bore alignment, groundwater elevation and relatively small culvert diameter, of the methods outlined in Section 6.3, auger boring with a SBU, pipe-ramming or micro-tunnelling are considered feasible installation options for this site. The feasibility of these methods to install the proposed culvert is summarized in Table 5 provided after the text of this report. A summary comparison of the advantages, disadvantages, relative costs, and risks associated with the installation methods is presented in Table 6 also provided after the text of this report.

6.6.1 Auger Boring with Small Boring Unit

To reduce the risk of project delays resulting from encountering significantly variable soil conditions in the embankment fill, completing the installation by auger boring with a SBU may be considered.

The use of an SBU would provide some additional steering capability of the bore to maintain the alignment, particularly if obstructions are encountered.

Since auger boring with an SBU creates a partially open face, dewatering and lowering of the groundwater table at the pits and beneath the offramp embankment along the bore alignment would be required for construction using this method. Further discussion on groundwater control is provided in Section 6.11.2.

6.6.2 Pipe Ramming

Pipe ramming is not steerable, so there is no control over the profile and alignment of the bore once the pipe ramming has started. Considering the interface conditions between the embankment fill and native silt and sand anticipated along the majority of the alignment (Borehole 19-3614) which are different in compactness and consistency (gravel and sand fill overlying silt and sand), issues with alignment and face stability are anticipated. However, 'pilot tube' pipe ramming methods can be used, which is a newer technology that uses a directional initial pilot hole to guide the casing, which can reduce the risks.

Vibrations from the pipe ramming operations also poses an increased risk of settlement of the upper fill.

With pipe ramming the soil is typically removed from the pipe following full or partial advancement of the pipe along the alignment. A “plug” of soil may form at the head of the casing inducing surficial heave as the pipe is advanced. Depending on the length of the installation, the soils inside the pipe can be removed either during or after the installation by auguring, compressed air or water jetting.

However, cleaning out the spoil from inside the casing (if required prior to completion of the drive) may result in the loss of ground at the face of the casing, particularly if the amount of cover above the casing is low. As noted in Section 6.4 the proposed alignment, considering a conservative assumption of the larger diameter crossing (1.5 m), has a minimum cover-to-diameter ratio of at least 1.1 through the majority of the alignment of the Highway 417 offramp surface, so the loss of ground at the face would pose a moderate risk of subsidence at the surface.

6.6.3 Micro-Tunneling

Although micro-tunneling is more expensive than auger boring with an SBU and pipe ramming, it offers several advantages to deal with mixed face and challenging groundwater conditions. The micro-tunnel boring machine (MTBM) has a rotating cutting head to excavate the ground encountered and can be equipped with a leading crushing cone to crush larger particles or obstructions into smaller sizes for transport back to the jacking shaft through the slurry lines. A pressurized slurry mixing chamber is present behind the cutter head to maintain face stability. As such, the MTBM is capable of independently counter-balancing earth and hydrostatic pressures as the bore advances. Groundwater pressure can be counterbalanced by using pressurized slurry.

Since this method of boring is essentially a steerable, remote-controlled pipe jacking operation controlled from the surface, the necessity for personnel to enter the bore is eliminated and full dewatering of the alignment is not required.

6.7 Tunneling Risk Assessment and Mitigation

As a general guideline, the required cover above the crown of the tunnel/bore should be at least one tunnel/bore diameter relative to the ground surface provided the methodology would not have an unsupported face, and ideally two to three diameters should be provided to reduce the risk of settlement. As the overburden cover decreases, the risk of concentrated subsidence or heave increases. Based on the proposed crossing obverts summarized in Section 6.4, the minimum cover below the roadway surface based on the larger diameter liner pipe size (approximately 1.5 m diameter) would be 1.6 m providing a cover-to-diameter ratio of at least 1.1 through the majority of the alignment.

The soil and bedrock conditions observed at the crossing location indicate the bore will have a relatively consistent mixed-face condition of varying embankment fill and native sand and silt. The installation method proposed by the Contractor will need to be able to advance through the gravel and sand fill, silty clay fill and through the native sand and silt. An NSSP should be included in the contract documents to address the mixed face conditions. A sample version of the NSSP is included in Appendix D.

It is suggested to start the tunneling operation at the downstream end (outlet) as there is more space for excavation of the entry pit which generally have a larger footprint than an exit pit.

Further discussion on the potential ground movements is provided in Section 6.9. A plan should be in-place to rapidly repair any distress to the pavement, if needed (and to re-direct traffic, if required).

There is a significant risk that removal of spoil or equipment that is supporting the bore face for dealing with obstructions, if required, will result in loss of ground, sinkholes and potentially an immediate hazard to traffic on the highway offramp. As such the Contractor must develop and submit a response plan to the Contract Administrator prior to initiating the bore that outlines emergency procedures to be undertaken in the event such events occur. MTO's Pipe Installation by Trenchless Method Special Provision outlines the required submissions including mitigation plans outlining the required dewatering, instrumentation, monitoring and traffic control, that may include closing the ramp during such operations.

6.8 Pipe Materials and Liner Design

Installation of the culvert by micro-tunneling or SBU methods will require that a steel casing be installed during boring. The steel casing could remain in place, with a smaller diameter culvert pipe installed within the casing. It is recommended that post installation grouting to fill the annular space between the culvert and the casing should be carried out.

The casing must be designed to accommodate hoop stress and sufficient nominal wall thickness must be provided to meet this design requirement. The casing should conform to OPSS 1802 (Smooth Walled Steel Pipe) and at least the nominal wall thickness provided in Table 1 of this specification will apply.

6.9 Ground Movements

To reduce the risk of ground settlement/subsidence, trenchless installations require a minimum depth of overburden cover over the tunnel crown. As the depth of overburden cover decreases, the risk of concentrated subsidence increases, as does the risk of extreme events such as sinkholes forming at the ground surface. In Ontario, the general practice is to maintain a depth of cover equivalent to 2 to 3 tunnel diameters, at least for open-faced tunnelling methods. Lesser cover can be feasible (i.e., as low as 1 diameter) for some methods including micro-tunnelling where pressurized shield at the front face of the tunnel is used.

Artesian groundwater conditions were encountered at the site within the glacial till underlying the clay soils. The groundwater level was measured at 1.2 m above the ground surface, corresponding to Elevation 63.1 m. The water level reading was up to about 1.8 m above the proposed invert elevations and 0.8 m above the proposed obvert elevations at this location. Local dewatering/and depressurization of the till layer at each of the entry and exit pits will be necessary, regardless of tunneling methodology. It should be noted that artesian groundwater pressure should not be an issue from a tunneling perspective and depressurization should not be required along the tunnel alignment. However, since an SBU auger bore proceeds with only a partially supported face, dewatering along the entire alignment would materially reduce the risk of loss of face support in the observed ground conditions. Full alignment dewatering will be needed to avoid potential impacts to the highway. However, it is considered that once the entry and exit pits are dewatered below the base of the casing invert, the water level across the entire alignment will also be lowered. As such, the risk is anticipated to be relatively low once dewatering is carried out.

Micro-tunneling would require local dewatering during construction of the entry and exit pits, but since the MTBM is controlled from the ground surface and can be advanced with a pressure-balanced face, dewatering of the full alignment would not be necessary.

The potential settlement also depends on the construction practices.

To avoid excessive settlements:

- The groundwater level must be lowered in advance of work for tunneling methods without face stabilisation (e.g., auger boring with SBU).
- Pauses/delays in the tunneling operation should be minimized.

There is a somewhat lower potential for significant settlement with micro-tunnelling versus other trenchless methods as this methodology does not create an unsupported working face, a corresponding reduction in stress in the ground above the tunnel, and the potential for movement of the ground towards the face (such as would often be the case for conventional tunnel construction). The settlements should therefore be more limited in magnitude, provided the gap around the casing created by the overcut is limited in size.

For the ground conditions encountered for the proposed trenchless crossings, there is a significant risk of there being at least some level of impact (i.e., heave or settlement) to the highway surface. It is expected that settlements or heave directly over the tunnel would likely not exceed about 25 mm, provided good construction procedures are followed and obstructions are not encountered which require removal. But the risk of larger settlements or heave magnitudes is significant and contingency measures should be in place as per section 6.10.

It is expected that the bore construction will not result in measurable ground surface settlements beyond a distance on either side of the bore alignment exceeding the bore depth.

Basal heave due to hydrostatic uplift can result when only a limited thickness of low-permeability soil (e.g., silty clay) beneath the base of the excavation is underlain by higher permeability soil (e.g., glacial till) under high groundwater pressures. This condition can result in a disturbed/destabilized subgrade and slope failures, which would not be suitable for support of structures, and the recompression of which, upon backfilling, would lead to unacceptable settlements. Basal heave can also cause construction issues (disturbed subgrades, poor trafficability, etc.) and in extreme cases, safety issues. The boreholes advanced on this site indicate a limited thickness of silty clay below the depth of excavation.

At the location of the entry and exit pits, there are unacceptable factors of safety (i.e., less than 1) against basal heave for excavations that extend 1 m below the culvert inlet and outlet (i.e., about Elevation 60.0 m). For the entry and exit pit excavations, it is therefore expected that depressurization of the underlying glacial till carried out in advance of the excavation will be required based on the groundwater elevations presented herein. Passive relief wells which discharge into the pit excavations could be considered as a means of depressurizing the underlying glacial till and preventing basal heave.

6.10 Settlement Monitoring

6.10.1 General

The settlement monitoring for this project shall be in accordance with MTO's 2019 Pipe Installation by Trenchless Method Special Provision; a copy of which is provided in Appendix D.

Settlement monitoring will serve to:

- Document the effects of the culvert installation on the overlying roadways, adjacent structures, or services lines/pipes.
- Obtain warning of ground movements that could occur due to the construction methods.

- Allow adjustments to be made to the trenchless construction method such that the settlement limits established are not exceeded, recognizing however that there is typically some delay between the trenchless construction and the full manifestation of the ground surface settlements.

6.10.2 Instruments

A specialist surveying firm should be retained to confirm the set-up and to carry out the settlement monitoring during construction. 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.

Monitoring of settlement instruments on this project is constrained by the continuous and high traffic volume and the limited periods during which access to the highway ramp can be obtained. By necessity, a non-intrusive system is recommended for ground surface (i.e., pavement) monitoring points, such as with reflectorless total station monitoring.

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.

In-ground settlement monitoring points shall be installed beyond the traffic lanes and shoulders to monitor settlement and stability of the ground surface between the surface settlement monitoring points and the entry and exit portals.

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.

6.10.3 Monitoring and Reporting Frequency

Baseline readings:

- Three consecutive readings at least one week prior to commencement of the work.

Construction readings:

- Once per shift or once daily during tunnelling operations period whichever results in the more frequent reading intervals.
- Two sets of readings per day or shift, if 'review' or 'alert' levels are reached (see below).

Post-construction readings:

- 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.

6.10.4 Criteria for Assessment of Roadway Subsidence/Heave

A protocol for assessing the seriousness of any indicated movement is necessary to ensure a timely and appropriate response by the personnel on site. Any significant measured movement could indicate that a response and corrective measure is needed.

The following protocol is therefore recommended.

1) 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.

2) 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.

6.11 Tunneling Construction Considerations

6.11.1 Open Cut Excavations

Shallow excavations up to about 4.0 m deep are anticipated for the entrance and exit pits made through the existing highway embankment fill and native silty sand and silty clay soils.

No unusual problems are anticipated with excavating the overburden soils using conventional excavating equipment.

Basal heave due to hydrostatic uplift can result when only a limited thickness of low-permeability soil (e.g., silty clay) beneath the base of the excavation is underlain by higher permeability soil (e.g., glacial till) under high groundwater pressures. This condition can result in a disturbed/destabilized subgrade and slope failures, which would not be suitable for support of structures, and the recompression of which, upon backfilling, would lead to unacceptable settlements. Basal heave can also cause construction issues (disturbed subgrades, poor trafficability, etc.) and in extreme cases, safety issues. The boreholes advanced on this site indicate a limited thickness of silty clay below the depth of excavation will remain after the excavations are completed prior to installation.

Excavations along the alignment will have unacceptable factors of safety (i.e., less than 1) against basal heave for excavations that extend 1.0 m below the invert (i.e., about Elevation 60.0 m). Therefore, it is expected that depressurization of the underlying glacial till carried out in advance of the excavation will be required based on the groundwater elevations. Passive relief wells which discharge into pit excavations could be considered as a means of depressurizing the underlying glacial till and preventing basal heave. Subexcavation of the silty clay to an undisturbed subgrade could also be considered, however this option may be cost prohibitive.

Excavation works must be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act and Regulations for Construction Projects (OHSA). The soils at this site would be generally classified as Type 3 soils (previously excavated soils above the groundwater) and Type 2 soils (very stiff soils) in accordance with the OHSA. Accordingly, unsupported side slopes in these materials may be sloped at no steeper than 1 horizontal to 1 vertical (1H:1V). For the generally short depths of excavation and variable ground conditions at the crossing an on-site assessment at the time of construction would be required to confirm the safe/stable geometry. Any fill or native silty sand which extends below the groundwater table would be classified as Type 4 soil based on OSHA, and excavations in these materials should be sloped no steeper than 3H:1V. If 3H:1V open cut excavation side slopes cannot be accommodated, then a temporary protection system (i.e., temporary excavation shoring) will be required or the overburden should first be dewatered.

Due to the proximity of the existing highway, particularly at the exit pit, the excavations would most likely be carried out within full or partially shored excavations for worker safety, see Section 6.11.5 for further details.

6.11.2 Groundwater and Surface Water Control

The Contractor must be prepared to control the groundwater and surface water flow at the site to permit the excavation of the existing embankment, the preparation of the entry/exit pits and the installation of the proposed culvert in dry and stable excavations.

It is recommended that the culvert construction be conducted during a drier season such as after the spring freshet or prior to the fall.

According to O.Reg 63/16 and O.Reg 387/04, if the volume of water to be pumped from excavations for the purpose of construction dewatering is greater than 50,000 L/day and less than 400,000 L/day, the water taking will need to be registered as a prescribed activity in the Environmental Activity and Sector Registry (EASR). Alternatively, a Permit to Take Water (PTTW) is required from the Ministry of the Environment, Conservation and Parks (MECP) if a volume of water greater than 400,000 L/day is to be pumped from the excavations.

The selection and design of temporary unwatering/dewatering system is the responsibility of the Contractor. The Contract Documents must alert the Contractor to this responsibility and to design the required systems in accordance with MTO SPFOUN0003 (Dewatering Structure Excavations) which amends OPSS 902 and OPSS.PROV 517 (Dewatering) with amendments as per SP 517F01 (Dewatering System).

Given the groundwater and soil conditions at this site, it is required that the design Engineer and design-checking Engineer of the dewatering system have a minimum of 5 years of experience in designing systems of similar nature and scope to the required work as per Table A of SP 517F01.

6.11.3 Erosion Protection

Since the casing will be driven directly into the embankment, there will be no new granular bedding or cover material which might be vulnerable to forming a preferential seepage conduit along/around the culvert. There is therefore no particular requirement to provide a cut-off (such as a clay seal) at the inlet.

The need for (and design of) erosion protection at the culvert inlet and outlet will depend on the anticipated hydrologic/hydraulic conditions. Typically, rip-rap protection should be provided over these areas. The rip-rap layer should cover all surfaces on the embankment slopes against which creek water is likely to be in contact. If needed, rip-rap treatment should be consistent with the Ontario Provincial Standard Drawing OPSS 810.010.

Site restoration shall be in accordance with OPSS.PROV 492. Excavated material or new imported material conforming to OPSS.PROV 1010, imported Granular B Type II material may be used as backfill material. Compaction of backfill materials should be carried out in accordance with OPSS.PROV 501.

6.11.4 Embankment Design and Reinstatement

The existing embankments have slopes that are at approximately 2H:1V. Embankment reinstatement, after culvert replacement, should be carried out in accordance with OPSS.PROV 206 (*Construction Specification for Grading*) and should match the adjacent slope geometry. The new embankment material should consist of imported Granular B Type II material. Excavated granular fill may also be reused as embankment fill provided there is no organic material in the excavated fill and there is sufficient space to stockpile on site and control the moisture content within acceptable limits for compaction. Excavated granular fill must not be used as culvert bedding, backfill or highway base or subbase materials.

Granular fill should be placed and compacted in accordance with OPSS.PROV 501 (*Construction Specification for Compacting*). Where new embankment fill is placed against existing embankment slopes the existing earth or fill slope must be benched in accordance with OPSS 208.010 (*Benching of Earth Slopes*).

Provided the subgrade is prepared as outlined and embankment fill is placed as recommended herein, an embankment slope inclined at 2H:1V or flatter, will remain stable.

6.11.5 Temporary Protection Systems

If the required safe side slopes for the entry and exit pits by open cut excavations cannot be accommodated, then temporary roadway protection (i.e., excavation shoring) will be required to facilitate excavation to the required depth.

The design of the shoring will be entirely the responsibility of the contractor. Where required, temporary protection systems should be designed and constructed in accordance with OPSS.PROV 539 (*Temporary Protection Systems*), and the lateral movement should meet Performance Level 2 provided that any existing adjacent utilities can tolerate this magnitude of deformation. Traffic loading should be included as a surcharge. Traffic loading does not account for construction equipment loadings which may be higher; the contractor's shoring designer should confirm those load requirements.

7.0 OPEN CUT CONSTRUCTION CONSIDERATIONS

7.1 Open Cut with a Full Road Closure

Installation of a new culvert using open cut techniques during a full ramp closure with a detour route is a feasible alternative from a foundation perspective. This option may allow for an expedient construction schedule and reduced costs. However, it is understood that a detailed review including the availability of detour routes has yet to be undertaken and this may not be feasible from a traffic operations perspective.

7.2 Concrete Pipe or Steel CSP

A pipe culvert installed with invert elevations ranging from 61.3 m to 61.9 m and a 300 mm bedding layer consisting of Granular A is considered feasible at this site. The base of excavation is expected to be at an approximate elevation between 61.0 m to 61.6 m. At this elevation, the anticipated founding material would be the sand and gravel embankment fill for the majority of the culvert alignment. A portion of the alignment may be within the native sand and silt.

Design and installation of a pipe culvert should be carried out in accordance with the height of fill tables in the OPSD 800 drawing series.

7.3 Sliding Resistance

Resistance to lateral forces through sliding resistance between Granular A bedding materials should be evaluated using an unfactored coefficient of friction 0.4 for a steel culvert and 0.5 for concrete culvert.

7.4 Site Preparation and Construction

7.4.1 General

Construction for the installation of new pipe culverts should be carried out in accordance with OPSS.PROV 421 (*Construction Specification for Pipe Culvert Installation in Open Cut*).

7.4.2 Subgrade Preparation and Backfilling

Subgrade preparations for the culvert should include excavation of the existing pavement structure and embankment fill and portions of the native sand and silt.

Excavation recommendations outlined in Section 6.11.1 would apply for open cut installations.

The recommendations with regards to groundwater control outlined in Section 6.11.2 would also apply for open cut installation.

Backfill for the culvert should consist of compacted free-draining granular material. It is recommended that the backfill detailing of OPSD 803.010 (*Backfill and Cover for Concrete Culverts with Spans Less Than or Equal to 3.0 m*) be utilized with a frost penetration line above the top of the culvert. The frost treatment depth, k , should be set at 1.8 m. The depth of roadbed granulars, d , should be set at a minimum of 0.6 m as indicated in OPSD 803.010.

7.4.3 Embankment Design and Reinstatement

The existing embankments have slopes that are at approximately 3H:1V. Embankment reinstatement, after culvert replacement, should be carried out in accordance with OPSS.PROV 206 (*Construction Specification for Grading*) and should match the adjacent slope geometry. The new embankment material should consist of imported Granular B Type II material. Excavated granular fill may also be reused as embankment fill provided there is no organic material in the excavated fill and there is sufficient space to stockpile on site and control the moisture content within acceptable limits for compaction. Excavated granular fill must not be used as culvert bedding, backfill or highway base or subbase materials.

Granular fill should be placed and compacted in accordance with OPSS.PROV 501 (*Construction Specification for Compacting*). Where new embankment fill is placed against existing embankment slopes the existing earth or fill slope must be benched in accordance with OPSD 208.010 (*Benching of Earth Slopes*).

Provided the subgrade is prepared as outlined and embankment fill is placed as recommended herein, an embankment slope inclined at 2H:1V or flatter, will remain stable.

With an open cut culvert installation, new granular bedding or cover material will be placed as part of constructing the culvert which might be vulnerable to forming a preferential seepage conduit along/around the culvert. Therefore, it is recommended that to provide a cut-off (such as a clay seal) at the inlet.

7.4.4 Temporary Protection Systems

If the ramp is fully closed the use of temporary protection systems will likely not be required, however, the following foundation recommendations have been provided should temporary protection be necessary for staging.

If the required safe side slopes for the open cut excavations cannot be accommodated, then temporary roadway protection (i.e., excavation shoring) will be required to facilitate excavation to the foundation level for the replacement of the culvert and removal of the existing culvert.

The design of the shoring will be entirely the responsibility of the contractor. Where required, temporary protection systems should be designed and constructed in accordance with OPSS.PROV 539 (*Temporary Protection Systems*), and the lateral movement should meet Performance Level 2 provided that any existing adjacent utilities can tolerate this magnitude of deformation. Traffic loading should be included as a surcharge. Traffic loading does not account for construction equipment loadings which may be higher; the contractor's shoring designer should confirm those load requirements.

Increased difficulty with the installation of temporary protection systems should be anticipated due to the presence of cobbles and boulders within the embankment fill. Suggested wording for an NSSP to notify the Contractor to the likelihood of encountering obstructions during the installation of temporary protection systems has been provided in Appendix D.

8.0 CORROSION AND CEMENT TYPE

Two soil samples were submitted to Eurofins Environment Testing for chemical analysis related to potential corrosion of exposed buried steel (corrosion and sulphate attack). The test results are provided in Appendix C and are summarized in Table 3 in Section 4.10.

The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with soil and groundwater at the site. The sulphate results were compared with Table 3 of Canadian Standards Association Standards A23.1-14 (CSA A23.1) and generally indicate a low degree of sulphate attack potential on concrete structures at this site. Accordingly, GU cement could be specified for concrete in below grade applications.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. Generally, the test results indicated an elevated potential for corrosion of exposed ferrous metal at the site which should be considered in the design.

9.0 CLOSURE

This report was prepared by Mr. Kenton Power, P.Eng. It was reviewed by Michael Snow, P.Eng. a Senior Geotechnical Engineer with Golder. William Cavers, P.Eng. an Senior Geotechnical Engineer with Golder and the Designated MTO Foundations Contact for this project, carried out an independent quality control review of this report.

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Designated MTO Foundations Contact



KCP/MSS/WC/hwd

[https://golderassociates.sharepoint.com/sites/11263g/shared documents/01_foundations/6 - reports/1360 trenchless crossings/tc5 - eb off-ramp walkley/3-final tc5/1662565-1360-5-rev0 tc5 hwy 417 walkley offramp 2021-11-11.docx](https://golderassociates.sharepoint.com/sites/11263g/shared%20documents/01_foundations/6-reports/1360%20trenchless%20crossings/tc5-eb%20off-ramp%20walkley/3-final%20tc5/1662565-1360-5-rev0%20tc5%20hwy%20417%20walkley%20offramp%202021-11-11.docx)

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Table 5: Feasibility of Installation Methods

Approximate Station	Relevant Boreholes ¹	Existing Ground Surface Elevation (m)	Proposed Invert Elevation (m)	Proposed Pipe Diameter (m)	Soil Conditions ² (below surface cover to invert)	Behaviour	Feasibility of Method		
							Auger Boring	Pipe Ramming	Micro-Tunneling
26+880	19-3613	61.8	61.3 to 61.9	1.05	■ Clayey Silt, some sand (FILL)	■ Firm to slow ravelling	Feasible with the addition of a Small Boring Unit cutterhead and dewatering along the alignment	Feasible with the addition of dewatering along the alignment	Feasible
	20-1936A	61.9			■ Sand and silt, trace gravel (FILL) ■ Silty clay (FILL)	■ Cohesive-running above water level – Flowing below water level ■ Firm to slow ravelling			
	19-3614	64.7			■ Sandy gravel / Gravelly Sand (FILL) ■ Very loose Silt and Sand	■ Cohesive-running above water level – Flowing below water level			
	19-3615	62.2			■ Clayey silt (FILL) ■ Silty sand (FILL)	■ Firm to slow ravelling ■ Cohesive-running above water level – Flowing below water level			

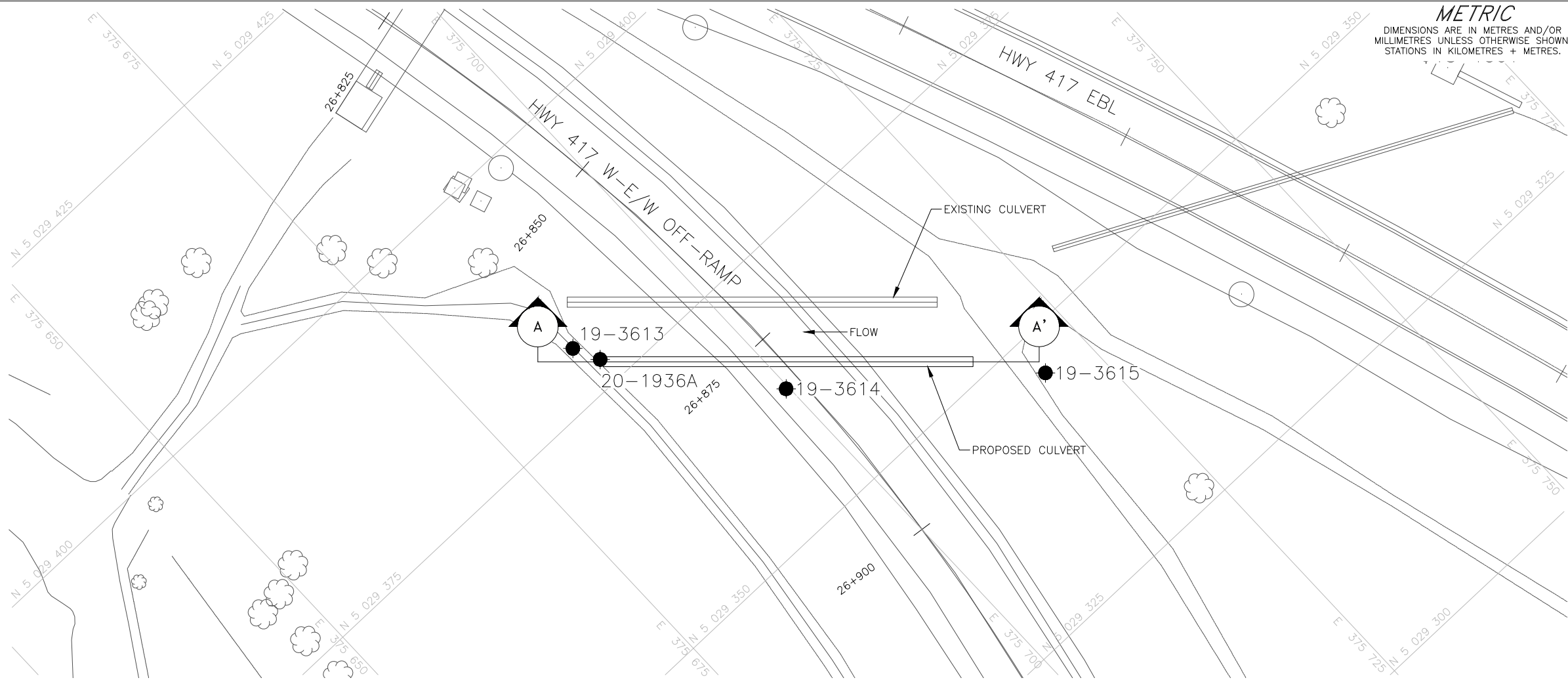
¹ Boreholes are listed from outlet to inlet of the pipe (up gradient)
² Soil conditions from ground surface to invert, where soils in bold indicate the anticipated conditions at the tunnel horizon

Table 6: Evaluation of Culvert Installation Methods

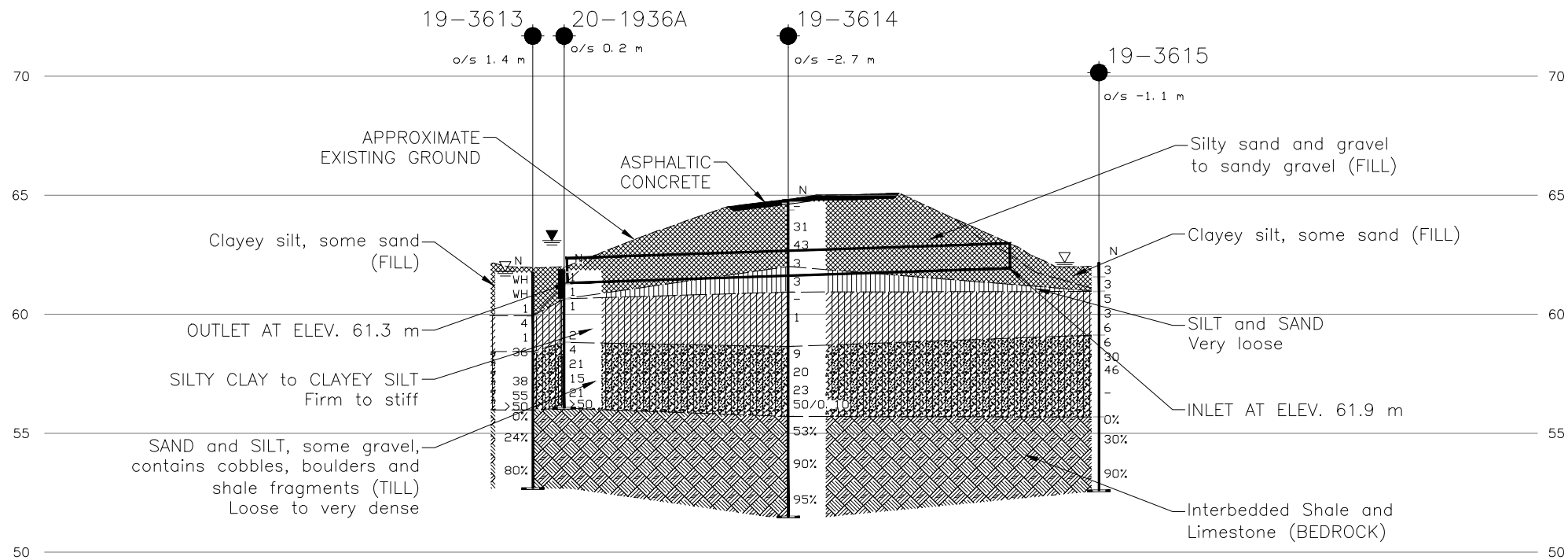
Method	Feasibility	Advantages	Disadvantages	Relative Cost	Risk/Consequences
Open Cut with ramp closure	<ul style="list-style-type: none">■ Feasible■ Preferred option from a foundation perspective	<ul style="list-style-type: none">■ Quicker installation than with trenchless methods■ Does not require traffic staging with ramp closure■ Better control over culvert grade and alignment■ Simple construction method.■ Equipment and skilled construction workforce available.	<ul style="list-style-type: none">■ Traffic impacts, ramp closure and detour routes would be required■ Groundwater lowering is required along the pipe alignment.	<ul style="list-style-type: none">■ Low	<ul style="list-style-type: none">■ Delays in construction could increase length of time highway ramp is closed.■ Detour maintenance could increase costs further
Auger Boring with SBU	<ul style="list-style-type: none">■ Feasible, with dewatering along alignment	<ul style="list-style-type: none">■ Simple construction method.■ Equipment and skilled construction workforce available.	<ul style="list-style-type: none">■ Significant backstop and jacking/receiving pits are required.■ Obstructions (e.g., cobbles and boulders) may deflect and/or halt bore. Higher risk of ground subsidence of highway, particularly if obstructions that slow installation procedures or if granular soils (particularly below the water table) encountered.■ Groundwater lowering is required at both the entry/exit pits and along the pipe alignment.■ Limited ability to steer to correct for line and grade during installation.	<ul style="list-style-type: none">■ Moderate	<ul style="list-style-type: none">■ Large cobbles and/or boulders can impede the auger boring operations where removal of obstructions is not possible.■ Obstructions can result in deflection of the casing resulting in misalignment of gravity culvert.■ Potential for loss of ground into casing, particularly if flowing conditions are encountered.■ Risk of ground surface subsidence increases with decreasing cover.
Pipe Ramming	<ul style="list-style-type: none">■ Feasible, with dewatering along alignment	<ul style="list-style-type: none">■ Simple construction method.■ Equipment and skilled construction workforce available.	<ul style="list-style-type: none">■ Ramming/receiving pits are required, likely smaller than auger boring however■ Obstructions (e.g., cobbles and boulders) may deflect and/or halt bore. Higher risk of ground subsidence of highway, particularly if obstructions that slow installation procedures or if granular soils (particularly below the water table) encountered.■ Groundwater lowering is required at both the entry/exit pits and along the pipe alignment.■ Limited ability to steer to correct for line and grade during installation.	<ul style="list-style-type: none">■ Moderate	<ul style="list-style-type: none">■ Large cobbles and/or boulders can impede the boring operations where removal of obstructions is not possible.■ Obstructions can result in deflection of the casing resulting in misalignment of gravity pipe.■ Potential for loss of ground into casing, particularly if flowing conditions are encountered.■ Risk of ground surface subsidence increases with decreasing cover.

Method	Feasibility	Advantages	Disadvantages	Relative Cost	Risk/Consequences
Micro-Tunneling	<div><div></div> Feasible</div>	<div><div></div> Unsupported face condition not created</div> <div><div></div> Ability to steer allowing greater certainty about final profile and alignment.</div> <div><div></div> Better suited for tunneling in mixed face conditions</div> <div><div></div> Better suited for penetrating through potential obstructions such as cobbles, boulders and bedrock than jack and bore methods.</div> <div><div></div> Does not require groundwater lowering along the pipe alignment.</div> <div><div></div> Relatively small working area required compared to other methods.</div>	<div><div></div> Limited availability of machines though availability has increased in recent years</div> <div><div></div> Relatively expensive compared to other methods.</div> <div><div></div> Requires skilled construction workforce</div>	<div><div></div> Higher than auger bore methods</div>	<div><div></div> Hydraulic fracture (frac-out) could occur at sites where relatively shallow overburden cover exists.</div> <div><div></div> Time delay in sourcing a machine.</div>
Horizontal Directional Drilling	<div><div></div> Not feasible</div>	<div><div></div> N/A</div>	<div><div></div> N/A</div>	<div><div></div> N/A</div>	<div><div></div> N/A</div>
Tunnel Boring Machine	<div><div></div> Not feasible</div>	<div><div></div> N/A</div>	<div><div></div> N/A</div>	<div><div></div> N/A</div>	<div><div></div> N/A</div>
Tunnel Digging Machine	<div><div></div> Not feasible</div>	<div><div></div> N/A</div>	<div><div></div> N/A</div>	<div><div></div> N/A</div>	<div><div></div> N/A</div>

 Limited availability of machines though availability has increased in recent years Relatively expensive compared to other methods. Requires skilled construction workforce Higher than auger bore methods



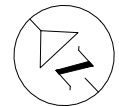
PLAN
SCALE
5 0 5 10 m



PROFILE A-A'
SCALE
5 0 5 10 m

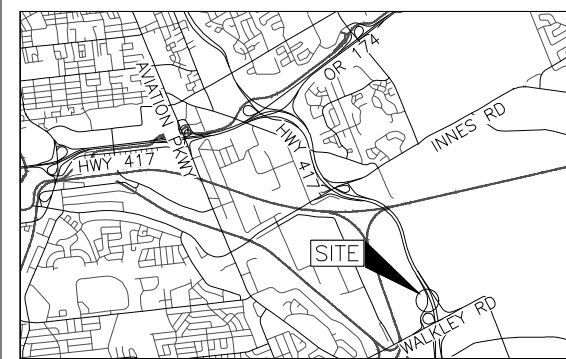
METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
GWP No. 4099-11-00



CULVERT REPLACEMENT HIGHWAY 417
EASTBOUND OFF-RAMP TO WALKLEY ROAD
BOREHOLE LOCATIONS AND SOIL STRATA
LAT. 45.400610, LONG. -75.594370

SHEET



KEY PLAN
SCALE
1 0 1 2 km

LEGEND

- Borehole - Current Investigation
- Borehole - Previous Investigation
- ⊥ Seal
- ⊥ Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% Rock Quality Designation (RQD)
- ≡ WL in piezometer, measured on April 28, 2021
- ≡ WL upon completion of drilling

BOREHOLE CO-ORDINATES NAD83 (CSRS) MTM ZONE 9			
No.	ELEVATION	NORTHING	EASTING
19-3613	61.8	5029380.3	375686.8
19-3614	64.7	5029362.7	375699.7
19-3615	62.2	5029346.0	375719.9
20-1936A	61.9	5029377.7	375688.1

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 plan provided in digital format by WSP, drawing file no. culvert borehole locations overall.dwg, received JULY 31, 2019.

NO.	DATE	BY	REVISION
Geocres No. 31G5-328			
HWY. 417		PROJECT NO. 1662565-1360	
SUBM'D. KM		DATE: 11/18/2021	
DRAWN: JM		SITE: -	
CHKD. KCP		APPD. WC	
CHKD. MMS		DWG. 1	

APPENDIX A

Borehole and Drillhole Records

Lists of Abbreviations and Symbols

Lithological and Geotechnical Rock Description Terminology

Records of Boreholes and Drillholes 19-3613 to 19-3615 and 20-1936A

Bedrock Core Photographs, Figures A1 to A3

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	>200	>8
COBBLES	Not Applicable	75 to 200	3 to 8
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.e., SAND and gravel)
> 20 to 35	Primary soil name prefixed with "gravelly, sandy" as applicable
> 10 to 20	some (i.e., some sand)
≤ 10	trace (i.e., 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 $= \sigma'_p / \sigma'_{vo}$

(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

$$\tau = c' + \sigma' \tan \phi'$$

$$\text{shear strength} = (\text{compressive strength})/2$$

LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

WEATHERING CLASSIFICATION

Fresh (W1): no visible sign of rock material weathering.

Slightly Weathered (W2): discoloration indicates weathering of rock mass material on discontinuity surfaces. **Less than 5%** of rock mass is altered or weathered.

Moderately Weathered (W3): less than 50% of the rock mass is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones.

Highly Weathered (W4): more than 50% of the rock mass is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones.

Completely Weathered (W5): 100% of the rock mass is decomposed and/or disintegrated to a soil. The original mass structure is still largely intact.

Residual Soil (W6): all rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported.

BEDDING THICKNESS

Description	Bedding Plane Spacing
Very thickly bedded	Greater than 2 m
Thickly bedded	0.6 m to 2 m
Medium bedded	0.2 m to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 mm to 60 mm
Laminated	6 mm to 20 mm
Thinly laminated	Less than 6 mm

JOINT OR FOLIATION SPACING

Description	Spacing
Very wide	Greater than 3 m
Wide	1 m to 3 m
Moderately close	0.3 m to 1 m
Close	50 mm to 300 mm
Very close	Less than 50 mm

GRAIN SIZE

Term	Size*
Very Coarse Grained	Greater than 60 mm
Coarse Grained	2 mm to 60 mm
Medium Grained	60 microns to 2 mm
Fine Grained	2 microns to 60 microns
Very Fine Grained	Less than 2 microns

Note: * Grains greater than 60 microns diameter are visible to the naked eye

CORE CONDITION

Total Core Recovery (TCR)

The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

Solid Core Recovery (SCR)

The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

Rock Quality Designation (RQD)

The percentage of solid drill core, greater than 100 mm length, recovered at full diameter, as measured along the centerline axis of the core, relative to the length of the total core run. RQD varies from 0% for completely broken core to 100% for core in solid segments.

DISCONTINUITY DATA

Fracture Index

A count of the number of discontinuities (physical separations) in the rock core, including both naturally occurring fractures and mechanically induced breaks caused by drilling.

Dip with Respect to Core Axis

The angle of the discontinuity relative to the axis (length) of the core. In a vertical borehole, a discontinuity with a 90° angle is horizontal.

Description and Notes

An abbreviation description of the discontinuities, whether naturally occurring separations such as fractures, bedding planes and foliation planes or mechanically induced features caused by drilling such as ground or shattered core and mechanically separated bedding or foliation surfaces. Additional information concerning the nature of fracture surfaces and infillings are also noted.

Abbreviations

AXJ Axial Joint	KV Karstic Void
BD Bedding	K Slickensided
BC Broken Core	LC Lost Core
CC Continuous Core	MB Mechanical Break
CL Closed	PL Planar
CO Contact	PO Polished
CU Curved	RO Rough
CT Coated	SA Slightly Altered
FLT Fault	SH Shear
FOL Foliation	SM Smooth
FR Fracture	SR Slightly Rough
GO Gouge	SY Stylolite
IN Infilled	UN Undulating
IR Irregular	VN Vein
JN Joint	VR Very Rough

ISRM Intact Rock Material Strength Classification

Grade	Description	Approx. Range of Uniaxial Compressive Strength (MPa)
R0	Extremely weak rock	0.25 – 1.0
R1	Very weak rock	1.0 – 5.0
R2	Weak rock	5.0 – 25
R3	Medium strong rock	25 – 50
R4	Strong rock	50 -100
R5	Very strong rock	100 -250
R6	Extremely strong rock	>250

ROCK WEATHERING CLASSIFICATION

Term	Symbol	Description	Discoloration Extent	Fracture Condition	Surface Characteristics
Residual soil	W6	All rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported.	Throughout	N/A	Resembles soil
Completely weathered	W5	100% of rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact.	Throughout	Filled with alteration minerals	Resembles soil
Highly weathered	W4	More than 50% of the rock material is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones.	Throughout	Filled with alteration minerals	Friable and possibly pitted
Moderately weathered	W3	Less than 50% of the rock material is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones. Visible texture of the host rock still preserved. Surface planes are weathered (oxidized or carbonate filling) even when breaking the "intact rock".	>20% of fracture spacing on both sides of fracture	Discoloured, may contain thick filling	Partial to complete discoloration, not friable except poorly cemented rocks
Slightly weathered	W2	Discoloration indicates weathering of rock material on discontinuity surfaces (usually oxidized). Less than 5% of rock mass altered.	<20% of fracture spacing on both sides of fracture	Discoloured, may contain thin filling	Partial discoloration
Fresh	W1	No visible sign of rock material weathering.	None	Closed or discoloured	Unchanged

Reference:

Brown, 1981. "Suggested Methods for Rock Characterization Testing and Monitoring", International Society for Rock Mechanics.

PROJECT 1662565-1360		RECORD OF BOREHOLE No 19-3613				SHEET 1 OF 2		METRIC									
G.W.P. 4099-11-00		LOCATION N 5029380.3; E 375686.8 MTM NAD 83 ZONE 9 (LAT. 45.400770; LONG. -75.594530)				ORIGINATED BY HRL											
DIST Eastern HWY 417		BOREHOLE TYPE Portable Drill, BW Casing Rotary Drill, NQ Core				COMPILED BY ZS											
DATUM Geodetic		DATE November 20, 2019				CHECKED BY KCP											
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									
61.8	GROUND SURFACE																
0.0	(CL) CLAYEY SILT, some sand (FILL) Firm Grey Moist		1	SS	WH												
60.6			2	SS	WH												
1.2	(CI/CL) SILTY CLAY to CLAYEY SILT Firm to stiff Grey Moist		3	SS	1												
			4	SS	4												
			5	SS	1												
58.5			6	SS	36												
3.3	(SM/ML) Gravelly SAND and SILT, contains cobbles, boulders and shale fragments (TILL) Very dense Grey Wet																
			7	SS	38												
			8	SS	55												
			9	SS	>50												
56.0																	
5.8	Shale (BEDROCK) Bedrock cored from depths 5.8 m to 9.1 m For bedrock coring details refer to Record of Drillhole 19-3613		1	RC	REC 92%												RQD = 0%
			2	RC	REC 85%												RQD = 24%
			3	RC	REC 97%												RQD = 80%
52.7																	
9.1	END OF BOREHOLE NOTES: 1. Water level in open borehole at ground surface (Elev. 61.8 m), measured during drilling																

PROJECT: 1662565-1360

RECORD OF DRILLHOLE: 19-3613

SHEET 2 OF 2

LOCATION: N 5029380.3 ;E 375686.8

DRILLING DATE: November 20, 2019

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: Portable Drill

DRILLING CONTRACTOR: CCC Drilling

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN	NOTE: For abbreviations, symbols and descriptions refer to LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY														FEATURES																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
							RECOVERY		R.Q.D. %	FRACT. INDEX PER	DIP w.r.t CORE AXIS °	DISCONTINUITY DATA		HYDRAULIC CONDUCTIVITY K, cm/sec	WEATH- ERING INDEX																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
							TOTAL CORE %	SOLID CORE %				TYPE AND SURFACE DESCRIPTION	Jr		Js	10 ⁻⁵ 10 ⁻⁴ 10 ⁻³ 10 ⁻²	W1 W2 W3 W4 W5 W6																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
6	Rotary Drill NQ Core	BEDROCK SURFACE Shale (BEDROCK) with limestone partings Slightly weathered to fresh Medium bedded Dark grey Fine grained Very poor to good quality Strong to very strong		55.98 5.79																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													

DEPTH SCALE

1 : 50




LOGGED: HRL

CHECKED: KCP

GTA-RCK 031 N:\ACTIVE\SPATIAL_IMMTO\HWY417\REHAB&WIDENING\02_DATA\GINT\1662565.GPJ GAL-MISS GDT 6/16/21 ZS

+³, ×³: Numbers refer to Sensitivity ○^{3%} STRAIN AT FAILURE

PROJECT 1662565-1360		RECORD OF BOREHOLE No 19-3614				SHEET 2 OF 3		METRIC										
G.W.P. 4099-11-00		LOCATION N 5029362.7; E 375699.7 MTM NAD 83 ZONE 9 (LAT. 45.400610; LONG. -75.594370)				ORIGINATED BY HRL												
DIST Eastern HWY 417		BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem)/Rotary Drill, NQ Core				COMPILED BY ZS												
DATUM Geodetic		DATE September 19, 2019				CHECKED BY KCP												
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										WATER CONTENT (%)
	--- CONTINUED FROM PREVIOUS PAGE ---							20	40	60	80	100						
	Shale (BEDROCK)		1	RC	REC 89%												RQD = 54%	
	Bedrock cored from depths 9.0 m to 13.3 m		2	RC	REC 95%													RQD = 78%
	For bedrock coring details refer to Record of Drillhole 19-3614		3	RC	REC 95%													RQD = 83%
51.4	END OF BOREHOLE																	
13.3																		

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PROJECT: 1662565-1360

RECORD OF DRILLHOLE: 19-3614

SHEET 3 OF 3

LOCATION: N 5029362.7 ;E 375699.7

DRILLING DATE: September 19, 2019

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 55

DRILLING CONTRACTOR: Downing Drilling

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN	NOTE: For abbreviations, symbols and descriptions refer to LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY														FEATURES																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
							RECOVERY		R.Q.D. %	FRACT. INDEX PER	DIP w.r.t CORE AXIS °	DISCONTINUITY DATA		HYDRAULIC CONDUCTIVITY K, cm/sec	WEATH- ERING INDEX																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
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UCS = 105 MPa

DEPTH SCALE

1 : 50



LOGGED: HRL

CHECKED: KCP

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PROJECT		1662565-1360		RECORD OF BOREHOLE No 19-3615		SHEET 1 OF 3		METRIC													
G.W.P.		4099-11-00		LOCATION		N 5029346.0; E 375719.9 MTM NAD 83 ZONE 9 (LAT. 45.400468; LONG. -75.594116)		ORIGINATED BY													
DIST		Eastern HWY 417		BOREHOLE TYPE		Portable Drill, BW Casing\Rotary Drill, NQ Core		COMPILED BY													
DATUM		Geodetic		DATE		January 21-23, 2020		CHECKED BY													
KCP																					
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
62.2	0.0	GROUND SURFACE																			
		(CL/ML) Clayey silt, some sand (FILL) Stiff Dark brown Moist		1	SS	3		62													
61.6	0.6	(SM) Silty sand, some clay (FILL) Very loose Dark brown Moist		2	SS	3		61													
61.0	1.2	(CL) CLAYEY SILT Very stiff Grey Wet		3	SS	5															
				4	SS	3		60													
				5	SS	6															
59.2	3.1	(SM/ML) SAND and SILT some gravel contains cobbles, boulders and shale fragments (TILL) Loose to very dense Brown Wet		6	SS	6		59													
				7	SS	30		58													
				8	SS	46															
		- Boulder cored from 4.8 m to 6.1 m																			
				9	WS	-		57													
								56													
55.7	6.5	Shale (BEDROCK)		1	RC	REC 100%		55													
		Bedrock cored from depths 6.5 m to 9.6 m																			
		For bedrock coring details refer to Record of Drillhole 19-3615		2	RC	REC 94%		54													
				3	RC	REC 100%		53													
		NOTES: 1. Water level in open borehole at ground surface (Elev. 62.2 m), measured during drilling																			
52.6	9.6	END OF BOREHOLE																			

GTA-MTO 001 N:\ACTIVE\SPATIAL_IMMITO\HWY417\REHAB&WIDENING\02_DATA\GINT\1662565.GPJ GAL-GTA.GDT 6/16/21 ZS

PROJECT: 1662565-1360

RECORD OF DRILLHOLE: 19-3615

SHEET 3 OF 3

LOCATION: N 5029346.0 ;E 375719.9

DRILLING DATE: January 21-23, 2020

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: Portable Drill

DRILLING CONTRACTOR: CCC Drilling

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	NOTE: For abbreviations, symbols and descriptions refer to LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY												FEATURES						
						RECOVERY		R.Q.D. %	FRACT. INDEX PER	DIP w.r.t CORE AXIS °	DISCONTINUITY DATA		HYDRAULIC CONDUCTIVITY K, cm/sec	WEATH- ERING INDEX										
						TOTAL CORE %	SOLID CORE %				TYPE AND SURFACE DESCRIPTION	Jr		Js	10 ⁻⁵	10 ⁻⁴	10 ⁻³		W1	W2	W3	W4	W5	W6
						88 8																		

DEPTH SCALE

1 : 50



LOGGED: HRL

CHECKED: KCP

GTA-RCK 031 N:\ACTIVE\SPATIAL_IMMTO\HWY417\REHAB&WIDENING\02_DATA\GINT\1662565.GPJ GAL-MISS.GDT 6/16/21 ZS

PROJECT		1662565-1360		RECORD OF BOREHOLE No 20-1936A				SHEET 1 OF 1		METRIC							
G.W.P.		4099-11-00		LOCATION		N 5029377.7; E 375688.1 MTM NAD 83 ZONE 9 (LAT. 45.400760; LONG. -75.594520)		ORIGINATED BY		KM							
DIST		Eastern HWY 417		BOREHOLE TYPE		Portable Drill, BW Casing		COMPILED BY		ZS							
DATUM		Geodetic		DATE		January 20, 2021		CHECKED BY		KCP							
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									
61.9	GROUND SURFACE																
0.0	(ML) Sandy silt, contains organic matter (TOPSOIL)		1	SS	1												5 53 (42)
0.1	Dark brown																
61.3	Sand and silt, trace gravel (FILL)		2	SS	1												0 1 39 60
0.6	Very loose Grey-brown Moist																
60.7	(CI) Silty clay (FILL)		3	SS	1												
1.2	Firm Grey Moist																
	(CL/CI) CLAYEY SILT to SILTY CLAY, with silt layers																
	Stiff Grey Wet																
58.9			4	SS	2												
3.1	(ML/SM) Sandy SILT to SILTY SAND, some gravel, contains shale fragments (TILL)		5	SS	4												
	Loose to compact Dark grey to grey moist to wet		6	SS	21												
			7	SS	15												
			8	SS	21												
			9	SS	>50												
56.1																	
5.8	END OF BOREHOLE																
	NOTE(S):																
	1. Artesian pressure observed in the TILL above bedrock.																
	2. Water level in open hole measured at 3.5 mbgs on Jan. 20, 2021 at 2:15pm																
	3. Water level in open hole measured at 1.1 mbgs on Jan. 20, 2021 at 2:35pm																
	4. Water level in open hole measured at 0.6 mbgs on Jan. 20, 2021 at 2:45pm																
	5. Water level in well screen at 1.2 m above the ground surface (Elev. 63.1 m), measured on Feb. 8, 2021																
	6. Water level in well screen at 1.2 m above the ground surface (Elev. 63.1 m), measured on April 23, 2021																

BH 19-3613 (Dry)
Cored From Elev. 55.98 to 52.68 m
Core Box 1 and 2 of 2

Top of Bedrock
Elevation 55.98 m



Elevation 52.68 m
End of Borehole



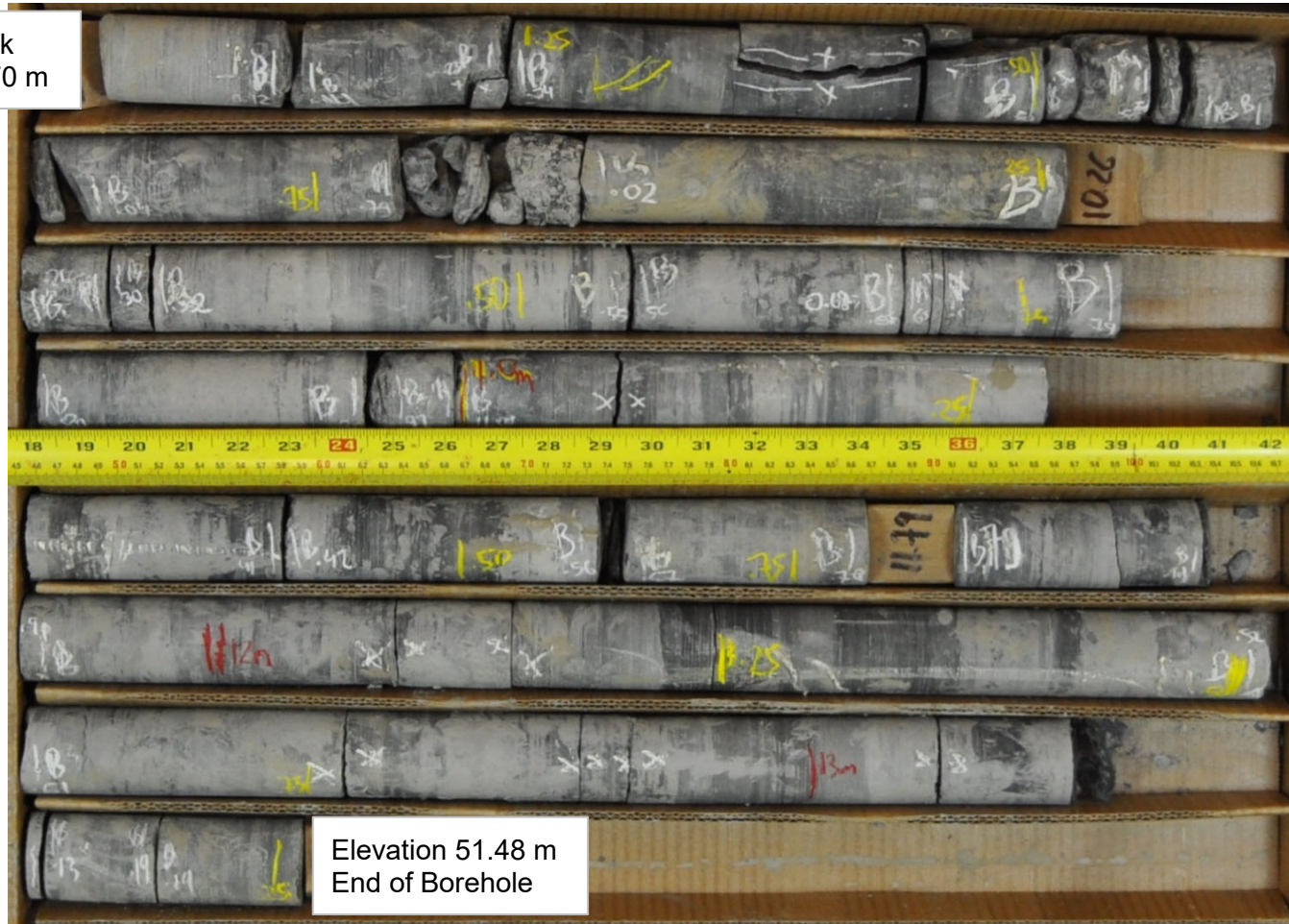
Foundation Investigation
Culvert Replacement
Highway 417 Eastbound Off-Ramp to Walkley Road
GWP: 4099-11-00
Ottawa, Ontario

Project No.	1662565 -1360
Drawn:	KM
Date:	2019-12-20
Checked:	KCP
Review:	MSS

Figure A1

BH 19-3614 (Dry)
Cored From Elev. 55.70 to 51.48 m
Core Box 1 and 2 of 2

Top of Bedrock
Elevation 55.70 m



Elevation 51.48 m
End of Borehole



Foundation Investigation
Culvert Replacement
Highway 417 Eastbound Off-Ramp to Walkley Road
GWP: 4099-11-00
Ottawa, Ontario

Project No.	1662565 -1360
Drawn:	KM
Date:	2019-12-20
Checked:	KCP
Review:	MSS

Figure A2

BH 19-3615 (Dry)
Cored From Elev. 55.68 to 52.58 m
Core Box 1 and 2 of 2



Foundation Investigation
Culvert Replacement
Highway 417 Eastbound Off-Ramp to Walkley Road
GWP: 4099-11-00
Ottawa, Ontario

Project No.	1662565 -1360
Drawn:	KM
Date:	2019-12-20
Checked:	KCP
Review:	MSS

Figure A3

APPENDIX B

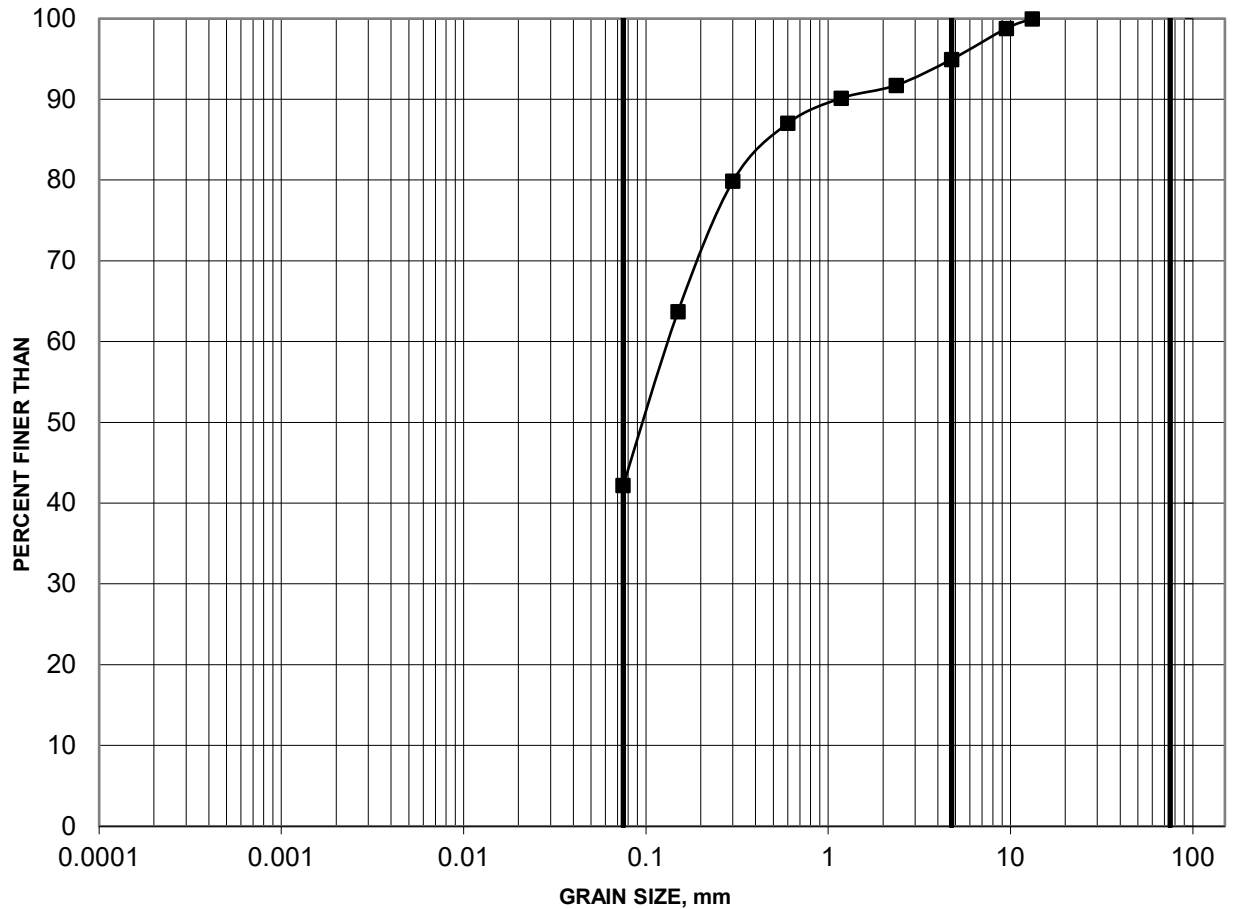
Laboratory Test Results

Figures B1 to B6

GRAIN SIZE DISTRIBUTION

FIGURE B1

SAND AND SILT (FILL)



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

	Borehole	Sample	Depth (m)
■	20-1936A	1	0.00-0.61

Project: 1662565 - 1360



Created by: KCP

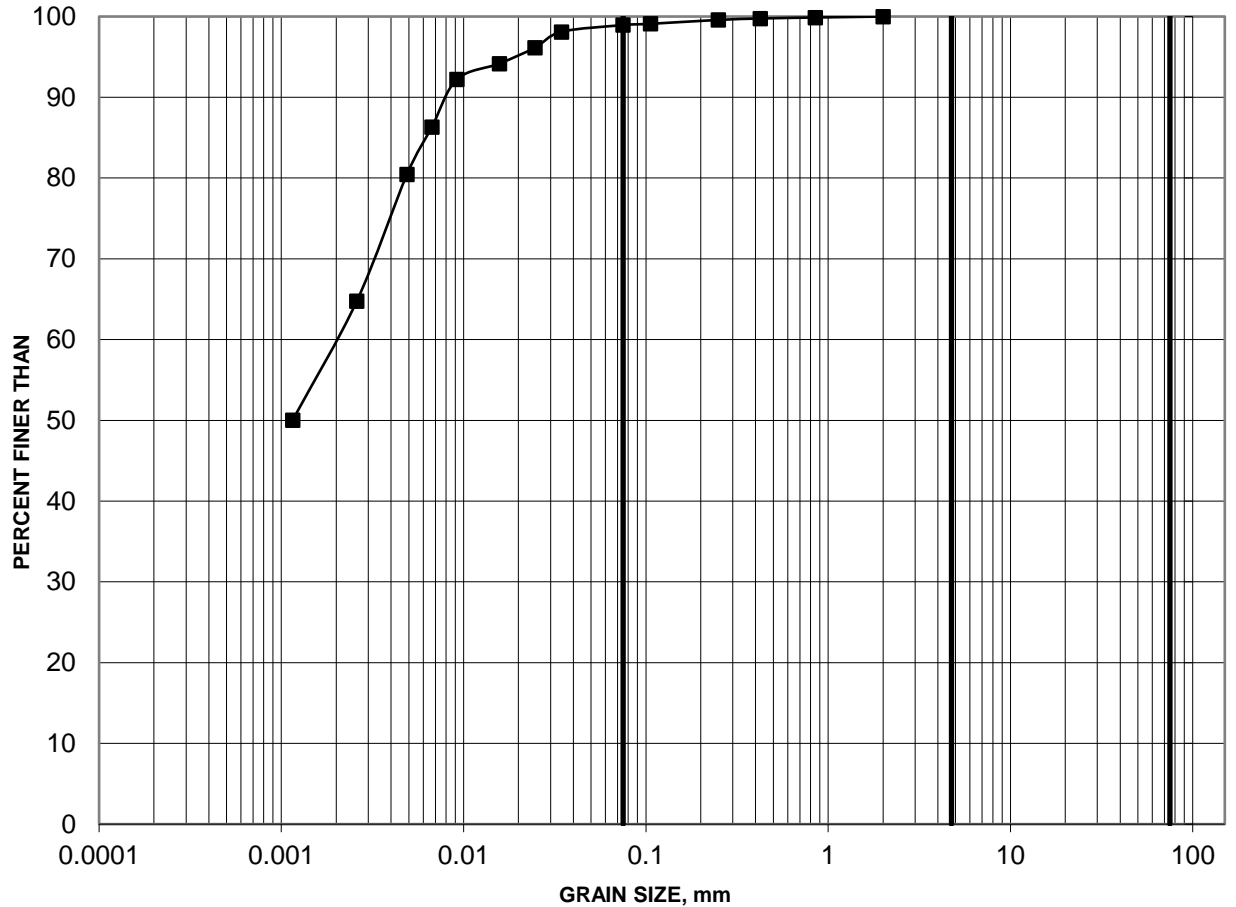
Checked by: MI

<https://golderassociates.sharepoint.com/sites/35409g/Shared Documents/Active/2016/1662565/Ph 1360/Figures/Figures for BH 3613, 3614, 3615, 1936A/>

GRAIN SIZE DISTRIBUTION

FIGURE B2

SILTY CLAY (FILL)



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

Borehole	Sample	Depth (m)
■ 20-1936A	2	0.61-1.22

Project: 1662565 - 1360



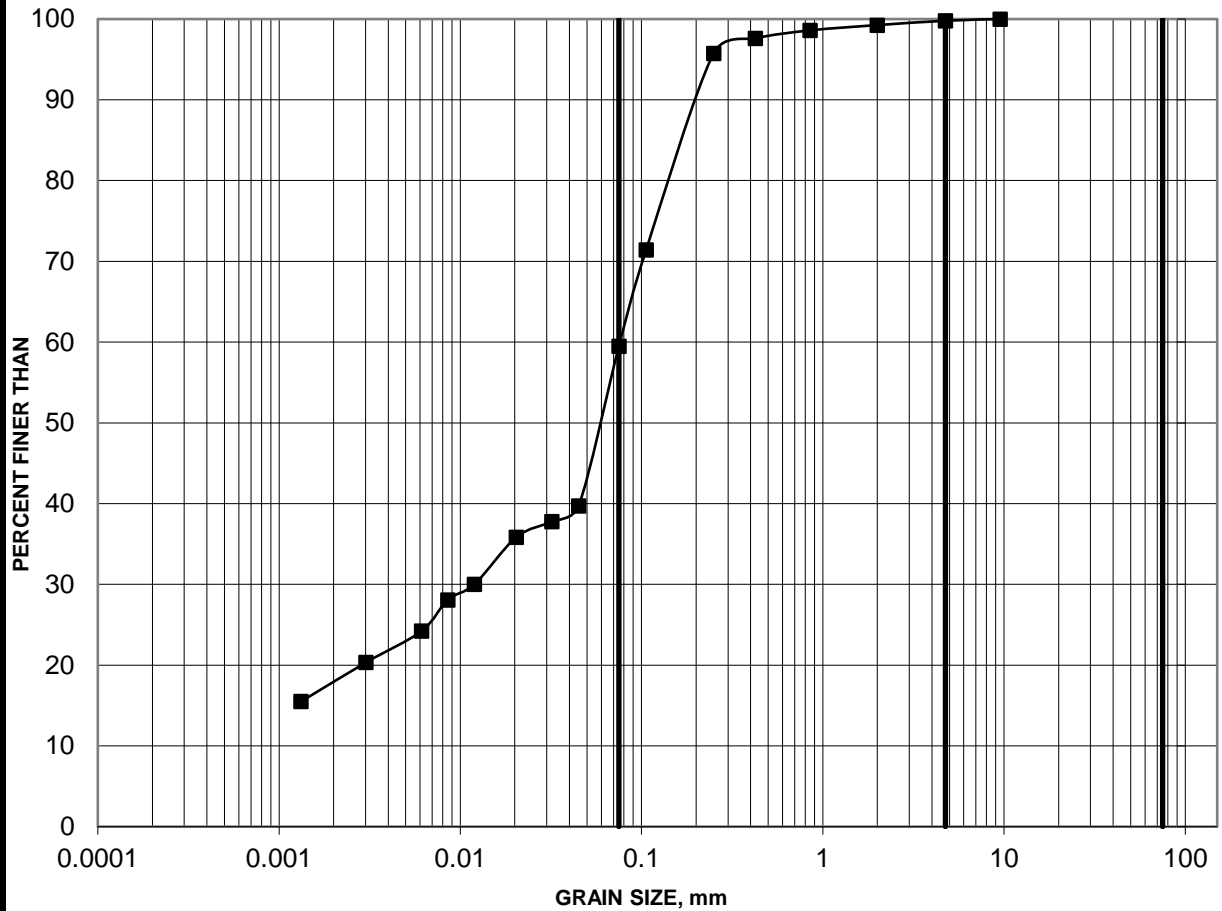
Created by: KCP
Checked by: MI

<https://golderassociates.sharepoint.com/sites/35409g/Shared Documents/Active/2016/1662565/Ph 1360/Figures/Figures for BH 3613, 3614, 3615, 1936A/>

GRAIN SIZE DISTRIBUTION

FIGURE B3

SAND AND SILT



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

Borehole	Sample	Depth (m)
19-3614	5	3.05-3.66

Project: 1662565/1360

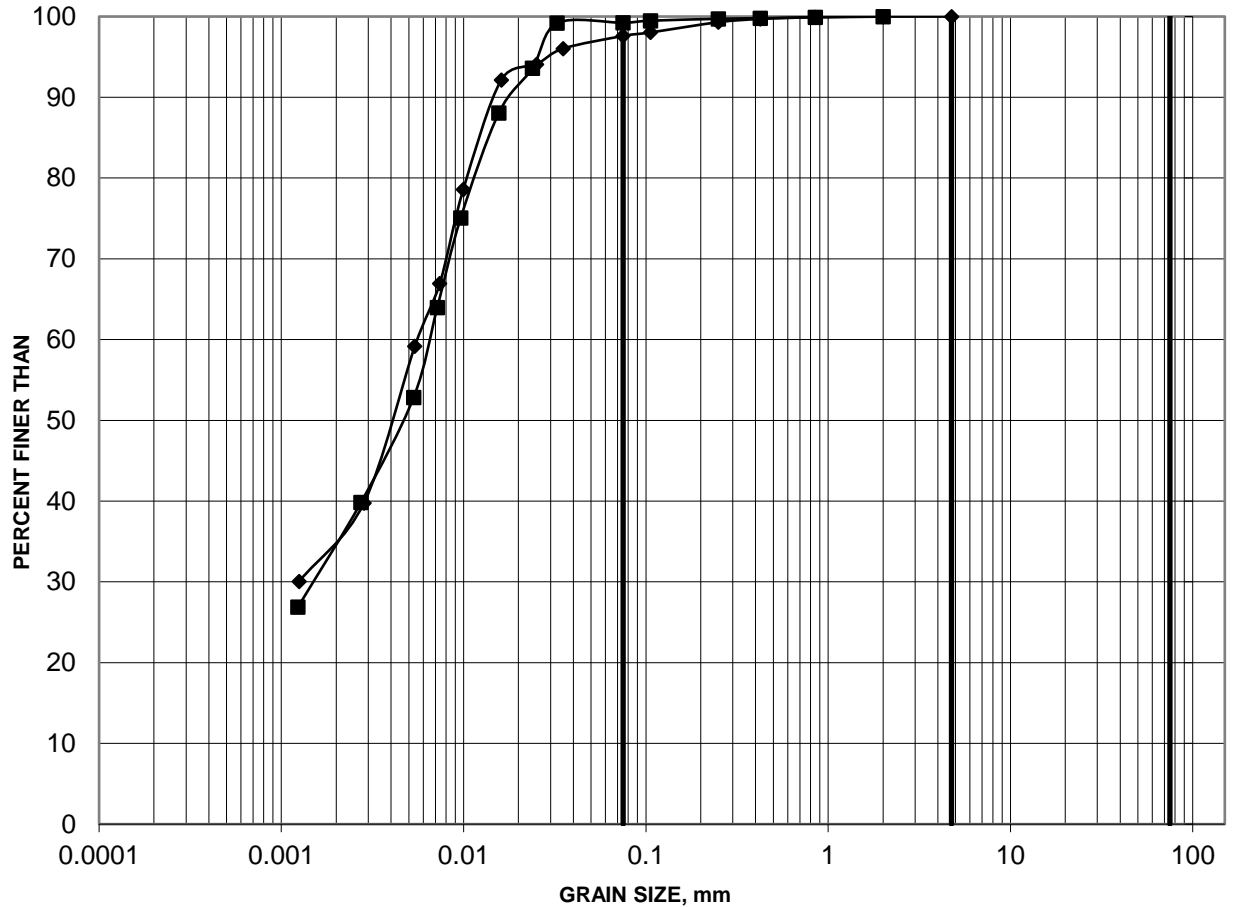


Created by: MI
Checked by: CW

GRAIN SIZE DISTRIBUTION

FIGURE B4

SILTY CLAY TO CLAYEY SILT



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

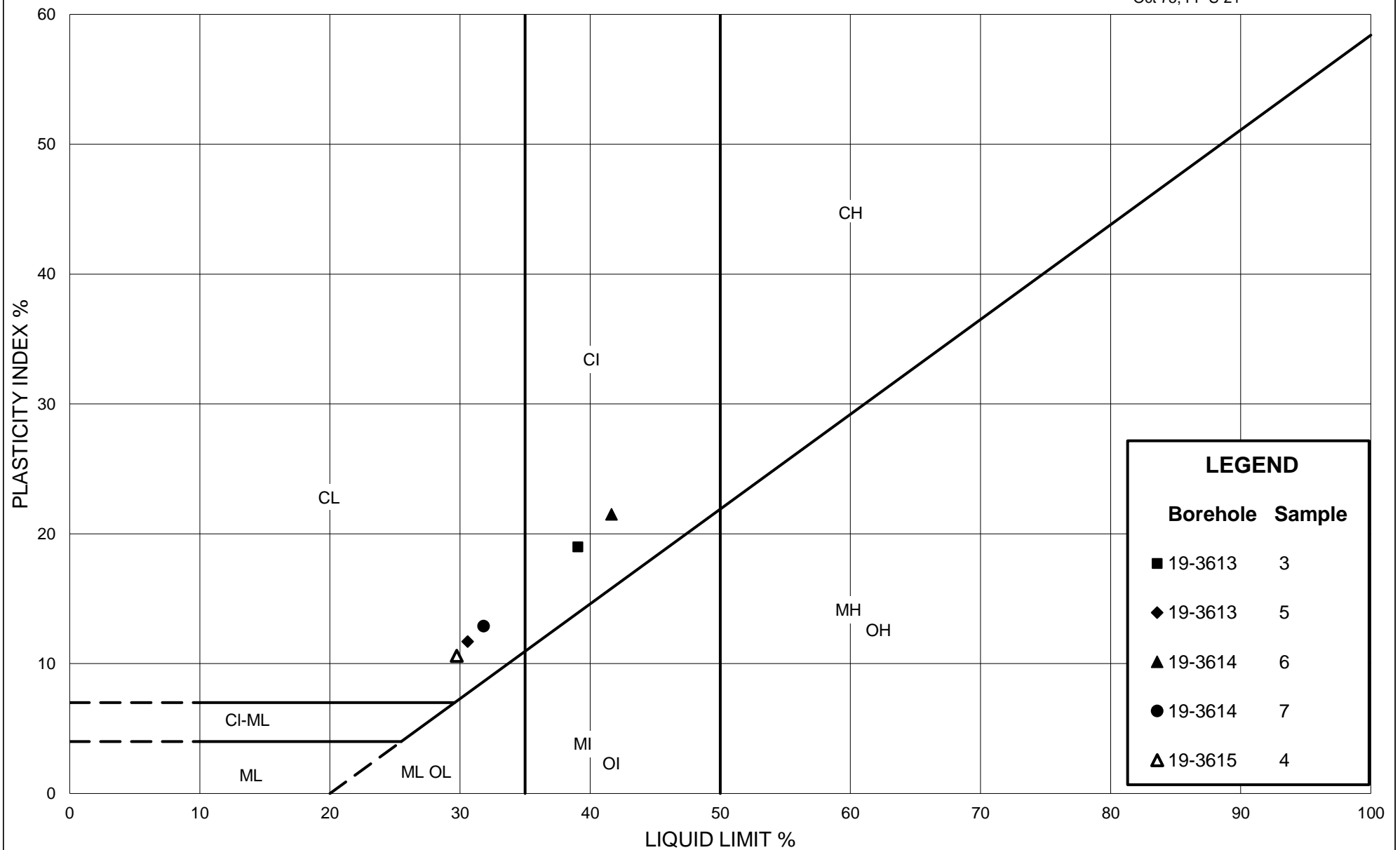
	Borehole	Sample	Depth (m)
■	19-3613	5	2.44-3.05
◆	19-3615	3	1.22-1.83

Project: 1662565/1360



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<https://golderassociates.sharepoint.com/sites/35409g/Shared Documents/Active/2016/1662565/Ph 1360/Figures/Figures for BH 3613, 3614, 3615, 1936A/>



Ministry of Transportation

PLASTICITY CHART

SILTY CLAY TO CLAYEY SILT

Figure: B5

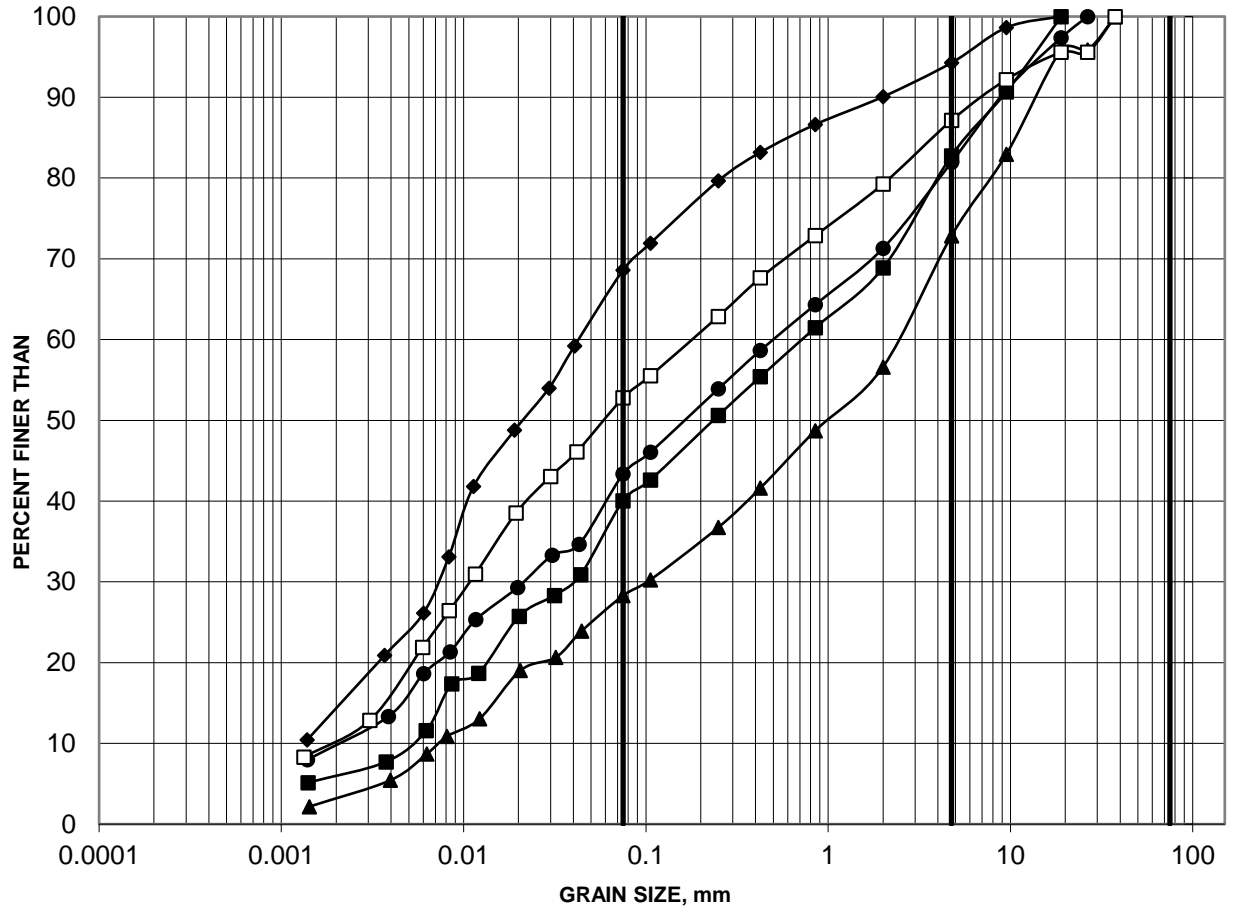
Project: 1662565/1360

Created By: MI Checked By: CW

GRAIN SIZE DISTRIBUTION

FIGURE B6

SILTY SAND TO SANDY SILT (TILL)



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

	Borehole	Sample	Depth (m)
■	19-3613	8	4.88-5.49
◆	19-3614	8B	6.33-6.71
▲	19-3614	10	7.62-8.23
●	19-3615	7	3.66-4.27
□	19-3615	8	4.27-4.75



Project: 1662565/1360

Created by: MI
Checked by: CW

<https://golderassociates.sharepoint.com/sites/35409g/Shared Documents/Active/2016/1662565/Ph 1360/Figures/Figures for BH 3613, 3614, 3615, 1936A/>

APPENDIX C

Basic Chemical Analysis

Eurofins Report Numbers 1924549 & 1946898



Environment Testing

Certificate of Analysis

Client: Golder Associates Ltd. (Ottawa)
1931 Robertson Road
Ottawa, ON
K2H 5B7
Attention: Ms. Kim MacDonald
PO#:
Invoice to: Golder Associates Ltd. (Ottawa)

Report Number: 1925987
Date Submitted: 2020-02-24
Date Reported: 2020-03-03
Project: 1662565 / 1360
COC #: 854649

					Lab I.D. Sample Matrix Sample Type Sampling Date Sample I.D.
Group	Analyte	MRL	Units	Guideline	
Anions	SO4	0.01	%		1481140 Soil
Cl in Concrete	Cl	0.002	%		2019-09-19 19-3614 sa9 / 22.5-24.5'
General Chemistry	Electrical Conductivity	0.05	mS/cm		
	pH	2.00			
	Resistivity	1	ohm-cm		

Guideline = * = **Guideline Exceedence**

Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

MRL = Method Reporting Limit, AO = Aesthetic Objective, OG = Operational Guideline, MAC = Maximum Acceptable Concentration, IMAC = Interim Maximum Acceptable Concentration, STD = Standard, PWQO = Provincial Water Quality Guideline, IPWQO = Interim Provincial Water Quality Objective, TDR = Typical Desired Range



Environment Testing

Certificate of Analysis

Client: Golder Associates Ltd (Ottawa)
1931 Robertson Road,
Ottawa, Ontario

Attention: Ms. Kimberley MacDonald

PO#:

Invoice to: Golder Associates Ltd

Report Number: 1946898
Date Submitted: 2021-01-26
Date Reported: 2021-02-01
Project: 1662565/1360
COC #: 869400

Lab I.D.
Sample Matrix
Sample Type
Sampling Date
Sample I.D.

1539732
Soil
2021-01-20
20-1936A sa2 / 2-4'

Group	Analyte	MRL	Units	Guideline	
Anions	Cl	0.002	%		0.028
	SO4	0.01	%		0.01
General Chemistry	Electrical Conductivity	0.05	mS/cm		0.48
	pH	2.00			8.16
	Resistivity	1	ohm-cm		2080

Guideline =

*** = Guideline Exceedence**

Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

MRL = Method Reporting Limit, AO = Aesthetic Objective, OG = Operational Guideline, MAC = Maximum Acceptable Concentration, IMAC = Interim Maximum Acceptable Concentration, STD = Standard, PWQO = Provincial Water Quality Guideline, IPWQO = Interim Provincial Water Quality Objective, TDR = Typical Desired Range

APPENDIX D

Non-Standard Special Provision

Obstructions / Mixed-Face Conditions

Basal Heave of Excavations

Pipe Installation by Trenchless Method, January 2019

NSSP OBSTRUCTIONS / MIXED-FACE CONDITIONS – Item No.

NON-STANDARD SPECIAL PROVISIONS

The soil and bedrock conditions observed at the crossing location indicate a mixed faced condition of embankment fill and cobbles and boulders and native sand and silt will be encountered during the boring or installation of temporary protection systems.

As such the installation method proposed by the Contractor will need to be able not only to operate in a mixed faced condition but must be able to tunnel through the cobbles and boulders to permit installation of the proposed culvert and any temporary protection systems.

Basis of Payment

Payment at the lump sum contract price for this tender item shall be full compensation for all labour, equipment and materials for completion of the work.

END OF SECTION

BASAL HEAVE OF EXCAVATIONS – Item No.

NON-STANDARD SPECIAL PROVISIONS

The excavations for the culvert replacement must consider the potential for basal heave of the excavation below the noted elevation in the geotechnical report. A basal heave failure could lead to disturbance of the excavation floor and/or unpredictable differential settlements of the excavation floor, and possible undermining and collapse of the shoring system. Mitigation measures to prevent basal heave, such as depressurization of the underlying glacial till, will need to be implemented for design and construction of the shoring system and excavation.

Basis of Payment

Payment at the contract price for the above tender item shall include full compensation for all labour and materials to complete the work.

END OF SECTION

NSSP – TEMPORARY PROTECTION SYSTEM – Item No

Temporary protection system will be installed in ground conditions that include cobbles, boulders and relatively shallow depth to bedrock. Such obstructions may lead to increased difficulty with the installation of temporary protection systems and may impede installation to the required designed depths. The Contractor's installation method and temporary protection system design shall take into account existing, soil and bedrock conditions and the Contractor shall be prepared to remove, drill through and/or penetrate these obstructions and extend the installations to the design depths.

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
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5.0	MATERIALS
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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:

- a) development of appropriate filter cake at excavation face to provide slurry support pressures exceeding ground and groundwater pressures at excavation face;
- b) lubricate installation of primary liners as required;
- c) transport spoil through pipe systems;

5.06 Grout

Purging grout shall conform to the requirements of OPSS 1004 wetted with only sufficient water to make the mixture plastic

6.0 EQUIPMENT

6.01 Auger Jack & Bore

Except in the case of dewatering to at least 1 m below the tunnel/bore invert for the full length of the pipe alignment, Auger Jack & Bore shall not be used and will not be permitted where subsurface conditions indicate that saturated gravel, sand and silt soils may be encountered at pipe level or within one pipe diameter above or below outside pipe dimensions.

Pipe auger jack & bore equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

Specific details of the equipment with 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 shall be submitted to the Contract Administrator for information purposes prior to proceeding with the works.

The lead end of the auger shall be maintained at least one pipe diameter inside the lead end of the casing. The auger cutting tools shall not extend to or beyond the lead end of the casing at any time unless specific exception is provided by the Ministry prior to construction. Submittals shall identify anticipated jacking forces for advancing casing ahead of leading edge of auger cutting tools in addition to friction forces that are to be overcome by jacking systems

6.02 Pipe Ramming

Pipe ramming equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

The pipe ramming hammer(s) shall be capable of driving the pipe casing from the entry pit to the exit pit through the existing subsurface conditions at the site without removal of soil from within the casing until the lead end of the pipe is outside the zone of influence for any overlying infrastructure.

Specific details of the equipment with which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the pipe shall be submitted to the Contract Administrator for information purposes prior to proceeding with the works.

6.03 Horizontal Directional Drilling

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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