



FINAL REPORT

**Foundation Investigation and Design
Borthwick Creek Culvert Rehabilitation
Site No. 3-730/C, Highway 417
Ottawa, Ontario**

G.W.P. No. 4099-11-00

W.P. 4326-13-01

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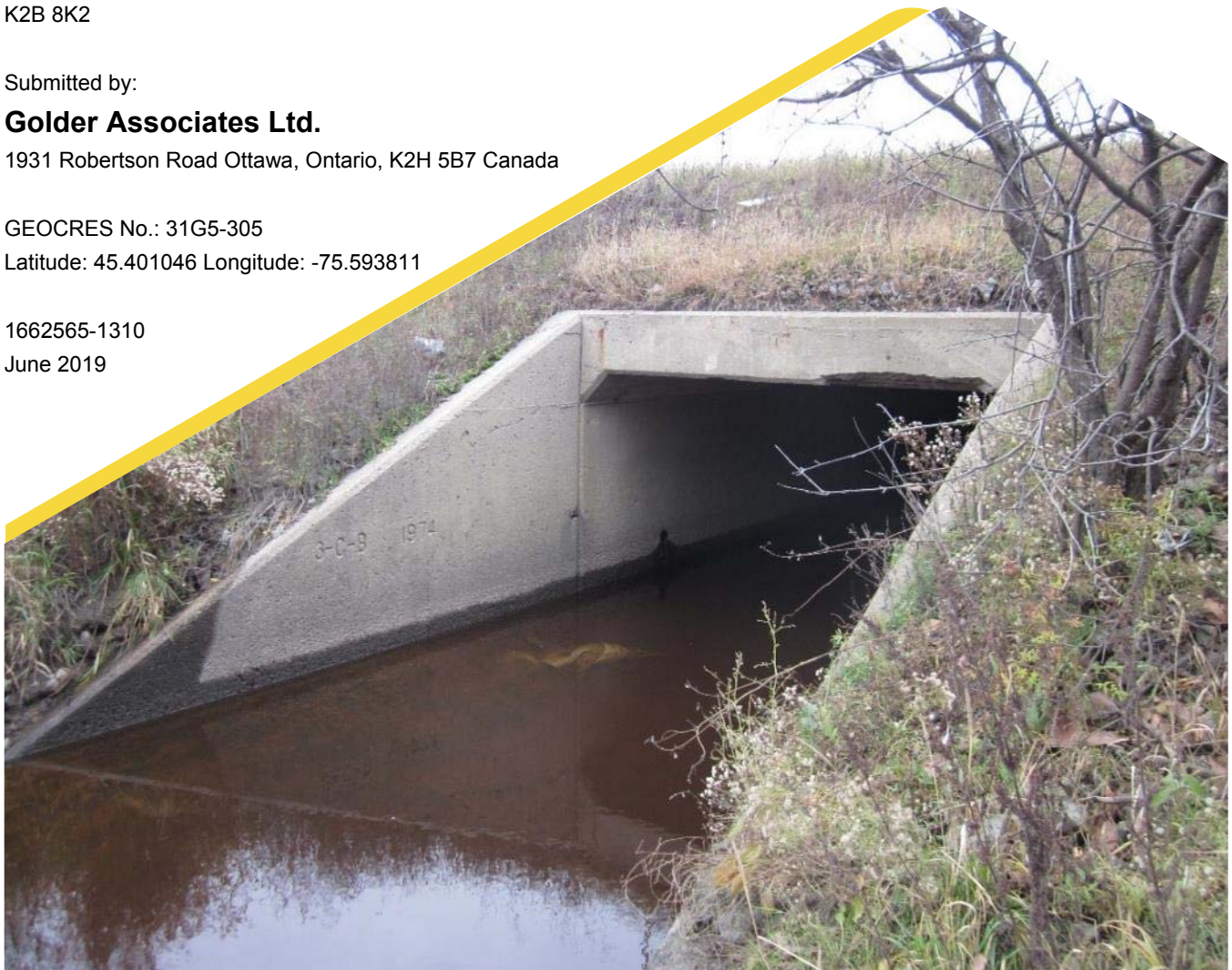
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PART A

Foundation Investigation
Borthwick Creek Culvert Rehabilitation
Site No. 3-730/C, Highway 417
Ottawa, Ontario
G.W.P. No. 4099-11-00
W.P. 4326-13-01

1.0 INTRODUCTION

Golder Associates Ltd. (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 numerous bridge and structural 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 Regional Road 174 (OR 174) to Hunt Club Road in Ottawa, Ontario (Assignment number 4016-E-0008).

This report presents the results of the foundation investigation carried out for the proposed rehabilitation and possible temporary water diversion systems associated with the Borthwick Creek culvert (Site No. 3-730/C) located beneath the eastbound and westbound lanes of Highway 417 in Ottawa, Ontario, (G.W.P. 4099-11-00 and W.P. 4326-13-01).

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 culvert site 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 May 13, 2017.

2.0 SITE DESCRIPTION AND GEOLOGY

2.1 General

Culvert 3-730/C is located at approximate Station 16+950 on Highway 417, approximately 350 m northwest of the Highway 417 / Walkley Road Interchange in Ottawa, Ontario. The location of the culvert is shown on the Key Plan on Drawing 1. Site photographs showing the general conditions at the site are present in Appendix E.

Highway 417 at this location has two through lanes in each direction consisting of a rural cross section with partially paved shoulders and ditches. The eastbound off-ramp and the westbound on-ramp for the Walkley Road Interchange also extend over the existing culvert. The travelled lanes including the on and off ramps are generally separated by vegetated median ditches.

Archival construction drawings indicate that the existing 116 m long, closed bottom, concrete culvert has an internal span of 3.0 m and height of 2.4 m. Based on the noted invert elevations of the culvert of between Elevations 60.5 and 60.7 m, the existing culvert is likely founded in the silty clay strata. The flow in the culvert is from east to west.

The existing pavement grade at the culvert location is at approximate Elevation 65.5 m in the eastbound and westbound lanes of Highway 417. Upwards of 2.0 m of fill has been placed over top of the existing culvert beneath the travel lanes of the highway; however only up to 1.0 m of fill was noted at the culvert inlet and outlet. Limited cover should also be anticipated within the median ditchlines. The existing embankment slopes at the culvert location are grass and brush covered and appear to be performing well with no signs of slope instability/distress observed during Golder's field investigation program.

2.2 Regional Geology

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

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 Champlain Sea basin. These deposits, known as the Champlain Sea 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. Regional bedrock mapping indicates that the bedrock at this site is primarily shale of the Carlsbad Formation.³ The shales were described as thinly bedded and fine grained.

The site falls within the Western Québec (WQ) seismic zone according to the Geological Survey of Canada. The WQ zone constitutes a large area which encompasses the urban areas of Montreal, Ottawa-Hull and Cornwall. Within the WQ zone recent seismic activity has been concentrated in two subzones; one along the Ottawa River and another more active subzone along the Montreal-Maniwaki axis. The two major earthquakes in the WQ zone includes the 1935 Témiscaming event which had a magnitude (i.e., a measure of the intensity of the earthquake) of 6.2, and the 1944 Cornwall-Massena event which had a magnitude of 5.6.

3.0 INVESTIGATION PROCEDURES

3.1 Current Investigation (2018)

The subsurface investigation for the culvert rehabilitation was carried out between August 9 and 20, 2018, and included advancing a total of five boreholes designated 18-3101 to 18-3105, inclusive. The NAD83 CSRS CBNv6-2010.0 MTM Zone 9 locations and ground surface elevations of the boreholes are shown on Drawing 1.

The embankment and median boreholes 18-3102 through 18-3104 were advanced using 108 mm inside diameter (200 mm outside diameter) continuous flight hollow stem augers on a track mounted drill rig, supplied and operated by George Downing Estate Drilling Ltd. These boreholes were drilled to depths ranging from about 11.3 to 12.4 m below the existing ground surface. The remaining inlet and outlet boreholes were advanced using a portable rotary drill equipment operated by Ohlmann Geotechnical Services Inc. and drilled to depths of 9.5 and 10.5 m below the existing ground surface.

Soil samples from the embankment and median boreholes were obtained at vertical intervals of about 0.76 m, using a 50 mm outside diameter split spoon samplers in general accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586). The inlet and outlet boreholes were sampled in continuous increments of about 0.6 m with a 50 mm outer diameter split-spoon sampler also in accordance with ASTM D1586. In-situ vane testing was carried out within the cohesive deposits, where possible, specifically in Boreholes 18-3102 and 18-3105.

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.

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 Williams, D.A. Rae, A.M., and Wolf, R.R. 1984: Paleozoic Geology of the Ottawa Area, Southern Ontario, Ontario Geological Survey, Map P.2716. Geological Series-Preliminary Map, scale 1:50,000. Geology 1982.

Upon reaching refusal to casing advancement, the boreholes were advanced into the bedrock surface to depths of 3.2 to 3.5 m using rotary diamond drilling techniques while retrieving NQ sized core. A water truck was on site to supply the drill rigs with water for advancing the casing in the overburden and for the coring the bedrock. Traffic control required to allow the water truck and support vehicles to park adjacent to the site was supplied by Beacon Lite Ltd. of Ottawa, Ontario.

A monitoring well was installed in Borehole 18-3103 to monitor the groundwater level at the site. The monitoring wells consisted of 30 mm inside diameter PVC tubing with a 1.5 m long screen. The final groundwater levels were measured in the well on October 12, 2018 and then the well was decommissioned in accordance with O.Reg 903.

The remainder of the boreholes were backfilled with bentonite mixed with soil cuttings. The site conditions were restored following completion of the field work.

The field work 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 soil samples. The soil samples were identified in the field, placed in appropriate containers, and transported to Golder's laboratory in Ottawa for further examination and testing. Index and classification tests consisting of water content determinations, Atterberg Limits testing, and grain size distribution analyses were carried out on selected soil samples. In addition, an unconfined compressive strength test was also carried out on a single bedrock core sample. The laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate.

One soil sample from Borehole 18-3102 was 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 R8 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 Summary 2018 Investigation

Borehole	Location	NAD83 CSRS CBNv6-2010.0 MTM Zone 9		Ground Surface Elevation (m)	Borehole Depth (m)
		Northing (m)	Easting (m)		
18-3101	East End of Culvert (inlet)	5029446.7	375790.2	64.1	10.5
18-3102	WBL Embankment	5029437.9	375759.6	65.6	12.3
18-3103	Highway Vegetated Median	5029433.7	375731.2	64.1	11.3
18-3104	EBL Embankment	5029426.8	375708.3	65.2	12.4
18-3105	West End of Culvert (outlet)	5029422.9	375681.0	63.1	9.5

3.2 Previous Investigation (1973)

A previous investigation was carried out in 1973 by the Ministry of Transportation and Communications, Ontario for the design of the existing culvert. The results of that investigation are contained in the report titled "Foundation Investigation Report for Proposed Culverts at the Crossing of the Borthwick Creek Diversion and the Walkley Rd. Extension Hwy. #417, District No. 9 (Ottawa), W.O. 71-11146 – W.P. 10-69-21/22" dated March 9, 1973 (GEOCREs No. 31G05-091).

As part of the current assignment, previously collected subsurface information pertinent to the site was reviewed and compiled.

A total of five boreholes were advanced at the site as part of the 1973 investigation, with three boreholes (Borehole 3 to 5) located along the then-proposed culvert alignment. The Record of Borehole sheets and laboratory testing results from the previous investigation are provided for reference in Appendix C.

The approximate borehole locations and ground surface elevations are included on the Record of Borehole and are also shown on Drawing 1. The locations and ground surface elevations of the previous test hole locations should be considered approximate since the locations were referenced to an imperial borehole location plan and elevation datum rather than metric MTM coordinates.

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 and laboratory testing from the current investigation are given on the Record of Borehole sheets presented in Appendix A. Photographs of the bedrock cored during the current investigation are provided in Figures A1 to A9 also provided in Appendix A. The results of geotechnical laboratory testing from the current investigation are presented on Figures B1 to B6 in Appendix B. The results of basic chemical analysis carried out on a single soil sample from Borehole 18-3102 are included in Appendix D. The borehole locations and the interpreted stratigraphic profile along the proposed alignment of the trenchless diversion pipe installation (north of the existing culvert) are shown on Drawing 1.

The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic section are inferred from non-continuous 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

In general, the subsurface conditions at the borehole locations consist of a thin layer of surficial topsoil materials (median, inlet/outlet boreholes) extending down to depths of 0.1 and 0.2 (Elevations 63.0 m to 64.0 m) or asphalt (roadway shoulder boreholes) extending down to a depth of 0.1 m (Elevations 65.0 m and 65.5 m). Below the surficial topsoil materials, the pavement structure and embankment fill materials, where encountered, extend down to depths of 1.4 to 2.4 m (Elevations 62.7 m to 64.0 m) overlying a clay / silty clay deposit extending down to depths of 4.4 to 6.7 m (Elevations 58.5 m to 59.5 m). The fill materials and clay / silty clay overlie a glacial till that extends down to depths of between 6.3 to 8.9 m (Elevations 56.0 to 56.8 m). The overburden materials are underlain by a shale bedrock. The depth to the bedrock surface was proved by coring in all boreholes at depths ranging between 6.3 and 8.9 m (Elevations 56.0 to 56.8 m). The boreholes from the current investigation were terminated in bedrock.

The groundwater level was measured at a depth of 1.3 m (Elevations 62.8 m) in Borehole 18-3103.

4.3 Surficial Materials

Boreholes 18-3102 and 18-31-04 were advanced through the Highway 417 pavement shoulder structure. The thickness of the asphalt at the borehole locations was 100 mm.

A layer of topsoil was encountered at the ground surface in Boreholes 18-3101, 18-3103 and 18-3105. The thickness of this layer ranged from 100 to 200 mm at the borehole locations.

4.4 Fill

Gravel and Sand

A fill layer consisting predominantly of gravel and sand with varying amounts of silt was encountered below the asphalt in the embankment boreholes 18-3102 and 18-3104. The top of this layer was encountered at Elevation 65.5 and 65.1 m. The thickness of the layer was 2.2 and 2.3 m. The SPT N values ranged from 3 to 31, indicating a very loose to dense condition, but typically compact. Cobbles were noted in this layer.

Silty Clay

A silty clay fill layer with varying amounts of sand and gravel was encountered beneath the topsoil layer in the median Borehole 18-3103. The top of this layer was encountered at Elevation 63.9 m. The thickness of the layer was 1.2 m. The SPT N values ranged from 7 to 15, indicating a stiff to very stiff consistency.

The moisture content for one soil sample was 23 percent.

4.5 Silty Clay

A grey-brown weathered clay crust deposit was encountered beneath the fill materials in the embankment boreholes and below the topsoil in Boreholes 18-3101, 18-1303 and 18-3105. The top of this layer ranges from Elevation 62.7 to 64.0 m. The thickness of this layer ranged from 1.7 to 2.0 m. The SPT N values ranged from 2 to 26, indicating a firm to very stiff consistency but typically very stiff.

The moisture content of the samples tested ranged from 29 to 51 percent. The results of grain size analysis testing conducted on samples of this material are illustrated on Figure B2 in Appendix B. The results of three Atterberg Limits tests completed on this material indicated liquid limits ranging from 56 to 57, plastic limits ranging from 19 to 21, and plasticity indices ranging from 34 to 37. Atterberg Limits analysis results are illustrated on Figure B1 in Appendix B and indicate a clay with high plasticity (CH).

A grey silty clay deposit was encountered beneath the clay crust in all boreholes. The top of this layer ranges from Elevation 60.8 to 62.0 m. The thickness of this layer ranged from 1.8 to 2.5 m. The SPT N values ranged from 1 to 13 for the silty clay. In-situ shear vane test results indicated undrained shear strengths of the silty clay ranges from 50 to 75 kPa, indicating a stiff consistency. Based on the ratio of the measured in-situ natural shear strength to the remolded shear strength ranging from 5.3 to 8.0 the silty clay is classified as sensitive.

The moisture content of the samples tested ranged from 28 to 44 percent. The results of six Atterberg Limits tests completed on this material indicated liquid limits ranging from 29 to 38, plastic limits ranging from 17 to 18, and plasticity indices ranging from 12 to 20. Atterberg Limits analysis results are illustrated on Figure B1 in Appendix B and indicate a silty clay with a low to intermediate plasticity to clayey silt (CL to CI).

4.6 Glacial Till

Silty Gravel and Sand

A non-cohesive glacial till deposit consisting of a heterogeneous mixture of sand, gravel and silt was encountered beneath the silty clay layer in Boreholes 18-3101, 18-3103 and 18-3104. The top of this layer ranges from Elevation 58.5 to 59.5 m. The thickness of this layer ranged from 1.8 to 2.8 m. The SPT N values ranged from 24 to greater than 100 indicating a compact to very dense condition, but typically dense. Cobbles and boulders were noted in this layer.

The moisture content of the samples tested ranged from 1 to 16 percent. The results of grain size analysis testing conducted on samples of this material are illustrated on Figure B3 in Appendix B.

Gravelly Silty Clay

A cohesive glacial till deposit consisting of a heterogeneous mixture of clay and silt with varying amounts of sand and gravel was encountered beneath the silty clay layer in Boreholes 18-3102 and 18-3105. The top of this layer ranges from Elevation 58.7 to 59.5 m. The thickness of this layer ranged from 1.9 to 2.8 m. The SPT N values ranged from 2 to 57, indicating firm to hard consistency, but typically stiff to very stiff. Cobbles and boulders were noted in this layer which may account for the higher SPT N values recorded.

The moisture content of the samples tested ranged from 8 to 12 percent. The results of grain size analysis testing conducted on samples of this material are illustrated on Figure B4 in Appendix B. The results of two Atterberg Limits tests completed on this material indicated liquid limits ranging from 18 to 20, plastic limits ranging from 12 to 15, and plasticity indices ranging from 5 to 6. Atterberg Limits analysis results are illustrated on Figure B5 in Appendix B and indicate a silty clay to clayey silt (CL-ML).

4.7 Bedrock

The overburden materials were underlain by a grey shale. Bedrock geology mapping indicates the shale bedrock is of the Carlsbad Formation. The boreholes were advanced into bedrock by coring with NQ-size coring equipment. Photographs of the bedrock core are provided in Appendix A.

Table 2 summarizes the depth to, and the elevation of the bedrock surface as encountered at the borehole locations from the current investigation.

Table 2: Summary of Bedrock Surface Depths and Elevation

Borehole Number	Existing Ground Surface Elevation (m)	Depth to Bedrock Surface (m)	Bedrock Surface Elevation (m)	Cored Length (m)
18-3101	64.1	7.3	56.8	3.2
18-3102	65.6	8.9	56.7	3.4
18-3103	64.1	8.1	56.0	3.2
18-3104	65.2	8.9	56.3	3.5
18-3105	63.1	6.3	56.8	3.2

The bedrock encountered in these boreholes consist of slightly weathered to fresh, thinly to thickly bedded, grey, fine grained, porous shale with limestone partings. The Rock Quality Designation (RQD) values measured on recovered bedrock core samples ranged from about 34 to 100 percent but was more typically from 70 to 100 percent indicating a fair to excellent quality.

Unconfined compressive strength testing was carried out on a single specimen of bedrock core; (see results on Figure B5 in Appendix B). Based on the measured compressive strength of 35 MPa, the shale bedrock is classified as medium strong.

4.8 Groundwater Conditions

A groundwater monitoring well was installed in Borehole 18-3103 to monitor the groundwater level at the site. Table 3 summarizes the depths and elevations of the groundwater level measured in the monitoring well on October 12, 2018, some two months after installation.

Table 3: Summary of Groundwater Conditions

Borehole	Ground Surface Elevation (m)	Screened Interval Material	Water Level	
			Depth (m)	Elevation (m)
18-3103	64.1	Bedrock	1.3	62.8

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

4.9 Steel Corrosion and Sulphate Attack, Chemical Analysis

One soil sample from Borehole 18-3102 was 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 test results are provided in Appendix D and are summarized in Table 4.

Table 4: Steel Corrosion and Sulphate Attack, Chemical Analysis

Borehole	Sample Depth (m)	Sample Type	Chloride (%)	pH	Electrical Conductivity (mS/cm)	Resistivity (ohm-cm)	Sulphate Soil (%)
18-3102	3.1 – 3.7	Clay	0.107	8.11	2.02	495	0.02


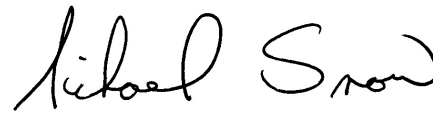
5.0 CLOSURE

This Foundation Investigation Report was prepared by Mr. Kenton Power, P.Eng. and was reviewed by Mr. Michael Snow, P.Eng., a Principal and senior geotechnical engineer with Golder. Mr. Fin Heffernan, P.Eng., Golder's Designated MTO Foundations Contact for this project, conducted an independent quality review of the report.


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[https://golderassociates.sharepoint.com/sites/11263g/shared documents/01_foundations/6 - reports/1310 borthwick/final/1662565-1310-r-rev0-borthwick creek culvert-06-2019_fid_r.docx](https://golderassociates.sharepoint.com/sites/11263g/shared%20documents/01_foundations/6%20-%20reports/1310_borthwick/final/1662565-1310-r-rev0-borthwick%20creek%20culvert-06-2019_fid_r.docx)

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PART B

Foundation Design
Borthwick Creek Culvert Rehabilitation
Site No. 3-730/C, Highway 417
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G.W.P. No. 4099-11-00
W.P. 4326-13-01

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

The following sections of the report provides foundation design recommendations for the rehabilitation and associated water diversion of the existing Borthwick Creek culvert (Site 3-370/C), located beneath the westbound and eastbound lanes including on/off ramps, of Highway 417 in Ottawa, Ontario. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the current subsurface investigation as well as the available GEOCRETS information for the site.

The foundation design 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.

6.2 Site and Project Overview

Archival construction drawings indicate that the existing 116 m long, closed bottom, concrete culvert has an internal span of 3.0 m and height of 2.4 m. Based on the noted invert elevations of the culvert from the General Layout Drawing (3-C-8-1) of between Elevations 60.5 and 60.7 m, the existing culvert is likely founded in the silty clay strata. The flow in the culvert is from east to west. Information provided in the RFP indicates that the culvert was constructed in 1974.

The existing pavement grade at the culvert location is at approximate Elevation 65.5 m at the eastbound and westbound lanes of Highway 417. Upwards of 2.0 m of fill has been placed over top of the existing culvert at these locations. Highway 417 at this location has two through lanes in each direction consisting of a rural cross section with partially paved shoulders and ditches. The Highway 417 eastbound, E-N/S off-ramp and the Walkley Road southbound S-W on-ramp westbound on-ramp for the Highway 417 / Walkley Road Interchange also extend over the existing culvert at this location. The approximate top of pavement elevation at the on/off ramps is Elevation 65.0 m. The existing embankment slopes at the culvert location are grass and brush covered and appear to be performing well with no signs of slope instability/distress observed during Golder's field investigation program.

6.3 Culvert Rehabilitation Options

It is understood that the rehabilitation of the Borthwick Creek culvert will include excavation and waterproofing / minor structural repairs of the existing culvert. The construction project may include the installation of a new diversion system along an alignment north and parallel to the existing culvert. Based on the information provided by WSP, it is understood that should it be required trenchless methods are the preferred methodology for the installation of the diversion pipe to reduce traffic disruption along Highway 417. However, open cut construction methods are also considered feasible at this site.

The new diversion pipe will provide temporary water diversion from the existing culvert during rehabilitation and also become a component of the final culvert design. It is understood that the proposed diversion pipe will be approximately 3.05 m in diameter and will be installed at a similar invert elevation as the existing culvert (i.e., Elevation 60.5 m). Section 6.4 below provides more information on the feasibility of trenchless technologies at this site.

6.3.1 Trenchless Technologies

The Contractor should be responsible for choosing the method and equipment for the crossing installations, 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 (TBM) and tunnel digging machine (TDM - 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 F.

A discussion on which method(s) are considered feasible for the proposed temporary diversion pipe installation is included in Section 6.4.

- **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 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 1200 millimetres in diameter.
- **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. The spoil is generally removed from within the casing using an auger boring machine. The cutting head is driven by, and is positioned at, the leading end of an auger string that is established within the casing pipe. The profile needs to be approximately horizontal. Jacking and receiving pits are required. There can be limited ability to steer the casing during jacking. This method is only applicable to construction in the overburden and may not be feasible in bouldery soils (e.g., glacial till). This method is also not feasible in flowing ground. If used in mixed face condition, this method can be adopted with a small boring unit (SBU) head which can advance through soil/bedrock mixed face condition and offers some steering ability.
- **Pipe Ramming:** Pipe ramming is a trenchless method that uses a pneumatic tool to hammer a steel pipe or casing into the ground. The pipe is almost always driven 'open' to thereby direct the soil into the pipe interior instead of compacting it outside the pipe. The leading edge of the pipe typically has a small overcut to reduce friction between the carrier pipe and soil and to improve the load conditions on the pipe. Soil/pipe friction reduction can also be achieved with lubrication, and different types of bentonite and/or polymers can be used for this purpose. Depending on the length of the installation, the soils inside the pipe can be removed either during or after the installation by augering, compressed air or water jetting. This method is not considered feasible in mixed face conditions including sound bedrock.

- **Micro-tunnelling:** 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. Micro-tunnelling equipment is generally more suited to drilling in overburden. Availability of this equipment locally is limited.
- **Pilot Tube Micro-tunneling (PTMT):** 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 microtunnelling. 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.
- **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.
- **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 Assessment of Feasible Installation Methods

The following presents the feasibility of using trenchless installation methods, advantages, disadvantages and geotechnical concerns.

6.4.1 Trenchless Technologies

The ground conditions along the diversion pipe within the tunnel vertical limits (i.e., invert and obvert of the pipe) are likely to consist of fill, consisting of sand and gravel, and silty clay. Depending on the final invert elevation of the pipe a silty sand to sandy silt glacial till could also form part of the tunnel face. The groundwater is anticipated to be above the invert of the pipe; however, groundwater levels may fluctuate both seasonally and with precipitation events and higher groundwater levels may be expected.

Based on the existing culvert invert of 60.5 m the available cover over the proposed 3.05 m diameter pipe is between 1 to 1.5 m or less than half the proposed culvert diameter (even less within the median ditchlines). As a general guideline, the required cover above the crown of the tunnel/bore for trenchless installation should be at least one tunnel/bore diameter (and preferably two diameters) relative to the ground surface. Lesser amounts of cover could jeopardize the stability of the working face (depending on the method) or lead to excessive ground movements both during and after installation.

It is understood that the proposed diversion pipe will be approximately 3.05 m. Based on this relatively large diameter, the limited amount of available cover over the pipe, and a major highway crossing over the existing culvert, a trenchless installation is considered high risk and is therefore not recommended for this project.

Due to the anticipated challenges and potential risks associated with the trenchless installation of a 3.05 m diameter pipe mentioned above, consideration may be given to following alternative installation methods.

- Option 1 is to lower the invert of the proposed 3.05 m diameter pipe by at least 2.0 m to increase the overall cover over the pipe however this is likely not hydraulically feasible.
- Option 2 is to install a series of pipes with diameters no greater than 1.5 m instead of a single 3.05 m diameter pipe. With smaller diameter pipes the proposed invert elevation could be maintained while increasing the available cover above the pipes reducing the risks associated with trenchless installation in limited cover conditions. For this option pipe jacking would be the preferred trenchless technology as noted in Section 6.5. If multiple pipes are installed, sufficient separation would need to be maintained between the pipes, generally a minimum of one to two bore diameters or minimum of 1.5 m of edge-to-edge separation between pipes would be required.
- Option 3 is to install the pipe(s) using convention open cut methods, although this will result in significant disturbance at the ground surface, would likely require the construction of median cross-overs and possibly closing of the on/off ramps during construction. Further details are provided in Section 6.4.2.

Table 5: Summary of Risk Register Associates with Trenchless Technologies

Risks	Trenchless Method	Risk (L/M/H)	Mitigation	Mitigated Risk (L/M/H)
Loss of alignment due to cobbles/boulders	1) Pipe Jacking	L to M	Limited	L to M
	2) Pipe Ramming	M to H	Limited	M to H
	3) HDD	H	Multiply Number of Reams	M
	4) TBM	L	N/A	L
	5) TDM	L	N/A	L
	6) PTMT	L	N/A	L

Risks	Trenchless Method	Risk (L/M/H)	Mitigation	Mitigated Risk (L/M/H)
Instability of working face, loss of crown cover, excessive ground movements	1) Pipe Jacking	H	Keep auger head back from face	L
	2) Pipe Ramming	L	N/A	N/A
	3) HDD	L	N/A	N/A
	4) TBM	M	Use head with reduced openings, monitor advances and soil volume removal	L
	5) TDM	H	Use partial face shield	M
	6) PTMT	H	Keep auger face back from face	M
Daylight into roadway, high fluid pressures (face-out)	1) Pipe Jacking	N/A	N/A	N/A
	2) Pipe Ramming	N/A	N/A	N/A
	3) HDD	H	Reduce fluid pressures	M
	4) TBM	L	N/A	L
	5) TDM	N/A	N/A	N/A
	6) PTMT	N/A	N/A	N/A

6.4.2 Open Cut Installation

Based on the existing ground conditions and proposed rehabilitation plan it is considered feasibility to install a diversion pipe using open cut excavation construction methods.

As the proposed invert elevation is above the bedrock surface and anticipated to be within the fill and silty clay overburden, as indicated by the borehole logs, there are no geotechnical concerns with using open cut excavation methods to install the diversion pipe, should it be required. Excavation work may encounter cobbles in the fill.

From a geotechnical standpoint, open-cut methods are the preferred method of installation of a 3.05 m diameter diversion pipe, over trenchless technologies given the limited amount of soil cover. However, open-cut methods would likely require the construction of median cross-overs and possibly closing of the on/off ramps during construction.

Frost tapers should conform to OPSD 205 and 803 series and are detailed in Section 6.6.1.

6.5 Recommendations and Considerations for Trenchless Replacement

Pipe installation by trenchless methods, if retained, should follow guidelines and specifications detailed in MTO's Special Provision – Pipe Installation by Trenchless Methods provided in Appendix F. As indicated above, pipe jacking is the preferred method with the auger placed at least 2 pipe diameters below the casing tip as outlined in Section 6.01 of the NSSP provided in Appendix F. A concrete pipe and steel outer casing are recommended from a geotechnical perspective. Pipe material section should be confirmed by the design engineer.

6.5.1 Ground Settlements

As mentioned above, the limited cover above the pipe could lead to excessive settlements at the road surface and as such a trenchless crossing to install a 3.05 m diameter pipe is not recommended.

If at least two pipe diameters of cover is provided for a steel casing of up to 1.5 m diameter, well executed work should result in negligible surface settlements.

Careful installation will be required. The magnitude of anticipated settlement will be dependent upon the final equipment selection (e.g. overcut resulting from the equipment size selection) and methodology. Should a trenchless installation be selected for the proposed diversion pipe installation, settlement estimates and settlement mitigation measures should be furthered evaluated when the equipment and methodology is selected.

In accordance with the NSSP provided in Appendix F a settlement monitoring program is outlined and will need to be implemented. That settlement monitoring will serve to:

- Document the effects of tunnelling;
- Obtain prior warning (i.e. alert levels) of ground movements that could occur due to the construction methods; and,
- 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.

6.5.2 Temporary Excavations, Shoring, and Groundwater Control

Excavations for the entry and exit pits/shafts would be made through the existing highway fill materials and into the silty clay and possibly the glacial till. It is anticipated that excavations of about 3 to 4 m below the road surface (i.e., depth of about 0.5 to 1 m below the invert of the diversion pipe) will be required depending rehabilitation works to be undertaken at this site.

It is anticipated that the entrance pit floor may be covered with a concrete mud slab to support the trenchless equipment and provide a trafficable excavation floor.

It is anticipated that the overburden soils can be excavated using conventional excavating equipment.

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 (compact to loose fill material above groundwater level and stiff to very stiff clay below the groundwater) in accordance with the OHSA. Accordingly, excavations should be made with side slopes no steeper than 1H:1V. Any fill which extends below the water table would be classified as Type 4 soil and excavations in these materials should be sloped no steeper than 3H:1V. As indicated in OHSA, if an excavation contains more than one type of soil, the soil type for the excavation shall be classified as the type with the highest number among the soil types present within the excavation.

However, due to the proximity of the existing highway, the excavations would most likely be carried out within supported (i.e. shored) excavations for worker safety and road embankment support. The excavation support may also need to be designed to act as a backstop for the jacking forces and boring operations. A conventional shoring system for these conditions could consist of soldier piling and lagging. This support system shall be designed and constructed by the contractor in accordance with the Ontario Provincial Standard Specification

(OPSS) OPSS.PROV 539. The lateral movement of the temporary shoring system shall meet Performance Level 2 as specified in OPSS.PROV 539. The recommended parameters for use in the design of the excavation support systems are provided in Table 7 in Section 6.9.

Bedrock is not anticipated within the depth of excavation along the culvert profile. The elevation of the bedrock surface encountered at the site is at about Elevation 56.0 and 56.8 m, which is at approximately 4.0 m below the proposed diversion pipe invert. If the invert elevation of the diversion pipe is lowered a further evaluation of the installation method with respect to the bedrock will be required.

Based on the measured groundwater levels, it is anticipated that the groundwater table may be encountered at or below the entry and exit pits/shafts. Therefore, groundwater inflow is expected to be minor, generally originating from the upper portion of the bedrock or glacial till. Groundwater control requirements will largely be dictated by the method of excavation support. If groundwater flow is encountered, pumping from sumps in the excavations would probably be adequate to handle the inflow to the pits/shafts. However, given that the pits/shaft will be adjacent to, and extend about 1 m below the creek, appropriate measures will need to be implemented to avoid inflow of creek water into the temporary excavations/shafts/pits. Further details on the recommendations for temporary water diversion systems are provided in Section 6.9.

A Permit-To-Take-Water (PTTW) is required from the Ministry of the Environment, Conservation and Parks (MECP) if a volume of water (groundwater water and surface water) greater than 400,000 litres per day is pumped from the excavations. If the volume of water to be pumped will be less than 400,000 litres per day, but more than 50,000 litres per day, the water taking will not require a PTTW, but will need to be registered in the Environmental Activity and Sector Registry (EASR) as a prescribed activity. Depending on the size of the excavations, the number of excavations that are open at one time, and the time of year that the excavating takes place, pumping of volumes greater than 50,000 litres per day (but less than 400,000 litres per day) may occur, and EASR registration may be required.

6.6 Recommendations and Considerations for Open-Cut Installation and Rehabilitation Works

6.6.1 Culvert Bedding, Backfill and Erosion Protection

Due to the limited soil cover present for a 3.05 m diameter pipe, open-cut replacement is the preferred installation method from a geotechnical perspective. It is expected that the cobbles within the embankment fill should not hinder the progression of the excavation. The pipe embedment material should consist of OPSS.PROV 1010 Granular A, fully encapsulated in non-woven geotextile. The granular material placed in the haunch area should be compacted to at least 95 percent of the material's Standard Proctor Maximum Dry Density (SPMDD) using suitable vibratory equipment prior to placing and compacting the remainder of the embedment material.

For a diversion pipe installation, the bedding levelling pad and backfill requirements should be in accordance with OPSS.PROV 421 (*Construction Specification for Pipe Culvert Installation in Open Cut*). The bedding and cover material should be placed in maximum 200 mm thick lifts and should be compacted to at least 95 percent of its SPMDD. The backfill should be placed in maximum 300 mm thick lifts and should be compacted to at least 95 percent the material's SPMDD. The backfill should extend vertically up to at least 1.5 m above the pipe to match existing grade. The fill depth during placement should be maintained equal on both sides of the diversion pipe and culvert, with one side not exceeding the other by more than 200 mm in height. To limit compaction induced stresses in the culvert, heavy equipment should not be allowed within 1 m of the diversion pipe / culvert during compaction of the backfill.

Based on the results of the investigations, the existing embankment fill consists of silty sand to sand mixed and silty clay. Gravel, and cobbles were encountered within the embankment fill, specifically in Boreholes 18-3102 and 18-3104. In accordance with the MTO Pavement Design Manual, the fill is classified to have a low to moderate susceptibility of frost heave and therefore frost tapers are considered necessary for the new diversion pipe and backfill for the existing culvert after rehabilitation works are completed.

As per Ontario Provincial Standard Drawing (OPSD) 3090.101 (Foundation Frost Penetration Depths for Southern Ontario), the frost penetration depth at the site is 1.8 m below the existing ground surface. This depth should be utilized when designing frost tapers in accordance with OPSD 205 and OPSD 803 series.

The diversion pipe installation should be designed for the full overburden pressure and live loads, assuming an embankment fill unit weight of 22 kN/m³ and silty clay unit weight of 17 kN/m³.

6.6.2 Excavations, Shoring and Temporary Roadway Protection

Temporary excavations for the installation of the diversion pipe and for rehabilitation works for the existing culvert will be made through the existing pavement structure and embankment fill and native silty clay. No unusual problems are anticipated with trenching in the overburden materials using conventional hydraulic excavating equipment, although cobble removal could be required within the embankment fill.

The soils at this site would be generally classified as Type 3 soils (compact to loose fill material above groundwater level and stiff to very stiff clay below the groundwater) in accordance with the OHSA. Accordingly, excavations should be made with side slopes no steeper than 1H:1V. Any fill which extends below the water table would be classified as Type 4 soil and excavations in these materials should be sloped no steeper than 3H:1V. As indicated in OHSA, if an excavation contains more than one type of soil, the soil type for the excavation shall be classified as the type with the highest number among the soil types present within the excavation.

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. The support system shall be designed and constructed by the Contractor in accordance with the OPSS.PROV 539. The lateral movement of the temporary shoring system shall meet Performance Level 2 as specified in OPSS.PROV 539. The recommended parameters for use in the design of the temporary excavation support systems are provided in Table 7 in Section 6.9.

6.7 Seismic Considerations

The site is located in an area where there exists a history of earthquake activity. A seismic Site Class needs to be assigned to this site, for use by the structural designer.

The CHBDC states that the seismic hazard values associated with the design earthquakes should be those established for the National Building Code of Canada (NBCC) by the Geological Survey of Canada (GSC). The current seismic hazard maps (referred to as the 5th generation seismic hazard maps) were developed by the GSC and were made available for public use in December 2015.

The seismic design provisions of the NBCC depend, in part, on the shear wave velocity of the upper 30 metres of soil and/or rock below the founding level. The NBCC permits the Site Class to be specified based solely on the stratigraphy and in-situ testing data (i.e., standard penetration test and in-situ shear strength test results), rather than from direct measurements of the shear wave velocity. Based on the anticipated foundation level within the silty clay and the relatively shallow depth to bedrock, the site may be classified as Site Class D in accordance with Table 4.1 of the CHBDC, in the absence of any geophysical testing. Geophysical measurement of the shear wave velocity profile for the upper 30 metres of soil and/or bedrock may be carried out subsequently to obtain a more accurate/favourable specification of the Seismic Site Classification.

6.8 Shallow Foundations

6.8.1 Bearing Resistance

For the design of the existing shallow foundations placed on the native clay soils may be assessed using the following factored geotechnical resistances:

- Ultimate Limit States (ULS) of 175 kPa; and,
- Serviceability Limit States (SLS) of 125 kPa.

Higher SLS capacities can be achieved if the shallow foundations are placed on the native glacial till. Shallow foundations placed on the native glacial may be assessed using the following factored geotechnical resistances:

- ULS of 300 kPa; and,
- SLS of 200 kPa.

The SLS resistance values provided above are based on a maximum of 25 mm of total settlement based on footings up to 2.5 m wide. For these shallow foundations, differential settlement magnitudes of less than 15 mm are expected, provided that proper subgrade preparation is carried out.

6.8.2 Sliding Resistance

The parameter values in Table 6 may be used to calculate the lateral resistance to sliding/shearing at the foundation-soil interface:

Table 6: Sliding Resistance Design Parameters

Interface Condition	Effective Friction Angle	Effective Cohesion (kPa)
Cast-in-Place Concrete – Native silty clay	–	50
Cast-in-Place Concrete – Native glacial till	35°	–

These values are unfactored; in accordance with the CHBDC, a factor of 0.8 is to be applied in calculating the horizontal resistance.

The above values assume that the subgrade materials are not be disturbed by construction activities or groundwater inflow.

6.9 Design and Construction Considerations

6.9.1 Temporary Water Diversion Systems

Control of the creek flow, surface water and groundwater will be necessary for the rehabilitation of the culvert, to allow construction to be carried out in dry conditions.

Depending on the creek flow, surface water flow conditions and the groundwater levels at the time of construction, water flow could be bypassed through either the existing culvert or through the newly installed diversion pipe(s) by diverting the flow toward or pumping from behind a temporary water diversion system. Temporary water diversion systems for these works could consist of either sand bags or glacial till / weather crust cofferdam advanced to an appropriate depth to control the surface water and groundwater inflow from the creek. Alternatively, an inflatable water diversion system could be used.

However, 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 system in accordance with Special Provision (SP) FOUN0003 (*Dewatering Structure Excavations*) which amends OPSS 902 (*Construction Specification for Excavating and Backfilling – Structures*).

In accordance with SP FOUN0003, the temporary dewatering system shall be designed and carried out in accordance with OPSS.PROV 517 (*Dewatering*) with amendments as per SP 517F01 (*Dewatering System*). Given the groundwater and soil conditions at this site, dewatering is expected to be of low complexity, and it is therefore not a requirement to carry out a preconstruction survey or to require a dewatering design engineer for the dewatering system as per Table A of SP 517F01.

As per Ontario Provincial Standard Drawing (OPSD) 3090.101 (*Foundation Frost Penetration Depths for Southern Ontario*), the frost penetration depth at the site is 1.8 m below the existing ground surface.

6.9.1.1 Sand Bags or Glacial Till / Weather Crust Cofferdam

The water diversion system could consist of a temporary sand bag or glacial till / weather crust embankment. The temporary embankment should have a thickness of 1 m and should extend from a depth of 1 m below the scour level to a minimum horizontal distance of 2 m on either side of the culvert inlet/outlet opening, and a minimum vertical height equivalent to the maximum 100-year water level including treatment of the adjacent side slopes. Alternatively, clay blankets may be constructed, extending upstream/downstream to a distance equal to three times the culvert height. Normally, a clay blanket would extend along the adjacent embankment side slopes to a height of two times the culvert height or the high-water level, whichever is higher; however, at this site where the cover over the culvert is relatively thin, it is recommended that a clay blanket, if adopted, extend to the top of the embankment side slope.

Where a clay blanket is used, the clay core should be covered with an approximately 1.0 m thick layer of OPSS.PROV 1010 (*Aggregates*) Granular B Type II to reduce the potential for erosion of the embankment side slopes.

6.9.1.2 Inflatable Water Diversion System

Consideration could also be given to the use of an inflatable water diversion system. These systems typically consist of vinyl coated polyester water-inflated bladders with internal baffle systems. Various barrier heights are available, with a standard maximum height of about 2.5 m. However, the height of barrier should typically maintain a minimum of at least 25 percent of freeboard above the static water level. Inflatable systems also rely on surface friction in order to stabilize when exposed to uneven water pressure. An anchoring system at the creek bank may also be required depending on the water flow in the creek at the time of construction. The design parameters provided in Table 7 can be used for the design of an inflatable water diversion system; however, it should be noted that these types of systems are proprietary to individual suppliers and may require additional investigation and/or input for design.

Table 7: Design Parameter – Inflatable Water Diversion System

Soil Type	Internal Angle of Friction (ϕ)	Unit Weight (γ , kN/m ³)	Coefficients of Earth Pressure		
			Active, Ka	At-Rest, Ko	Passive, Kp
Embankment Fill	30°	20	0.33	0.50	3.00
Silty Clay	28°	19	0.36	0.47	2.77
Till	35°	22	0.43	0.27	3.70

6.9.2 Cement Type and Steel Corrosion Potential

A single soil sample from Borehole 18-3102 was submitted for chemical analysis related to potential corrosion of exposed buried steel and potential sulphate attack on buried concrete elements (corrosion and sulphate attack).

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 in Table 4 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. The test results provided in Table 4 indicate a very high potential for corrosion of exposed ferrous metal at the site which should be considered in the design of below grade structures.


6.9.3 Erosion Protection

The need for (and design of) erosion protection at the culvert inlet and outlet (including the slopes and sides of the channel) 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 OPSD 810.010.

7.0 CLOSURE

This Foundation Design Report was prepared by Mr. Kenton Power, P.Eng. and was reviewed by Mr. Michael Snow, P.Eng., a Principal and senior geotechnical engineer with Golder. Mr. Fin Heffernan, P.Eng., Golder's Designated MTO Foundations Contact for this project, conducted an independent quality review of the report.

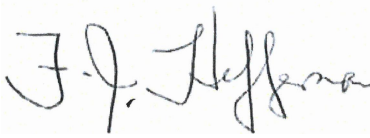
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Principal, Senior Geotechnical Engineer



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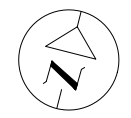
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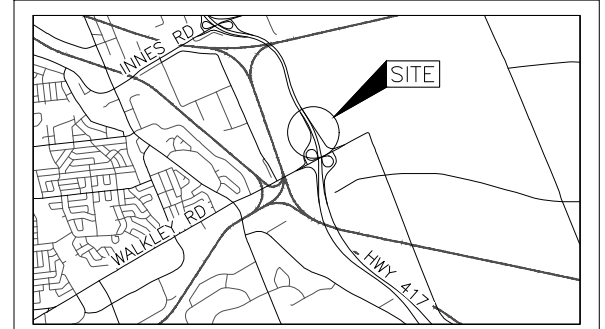
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METRIC
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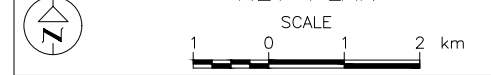
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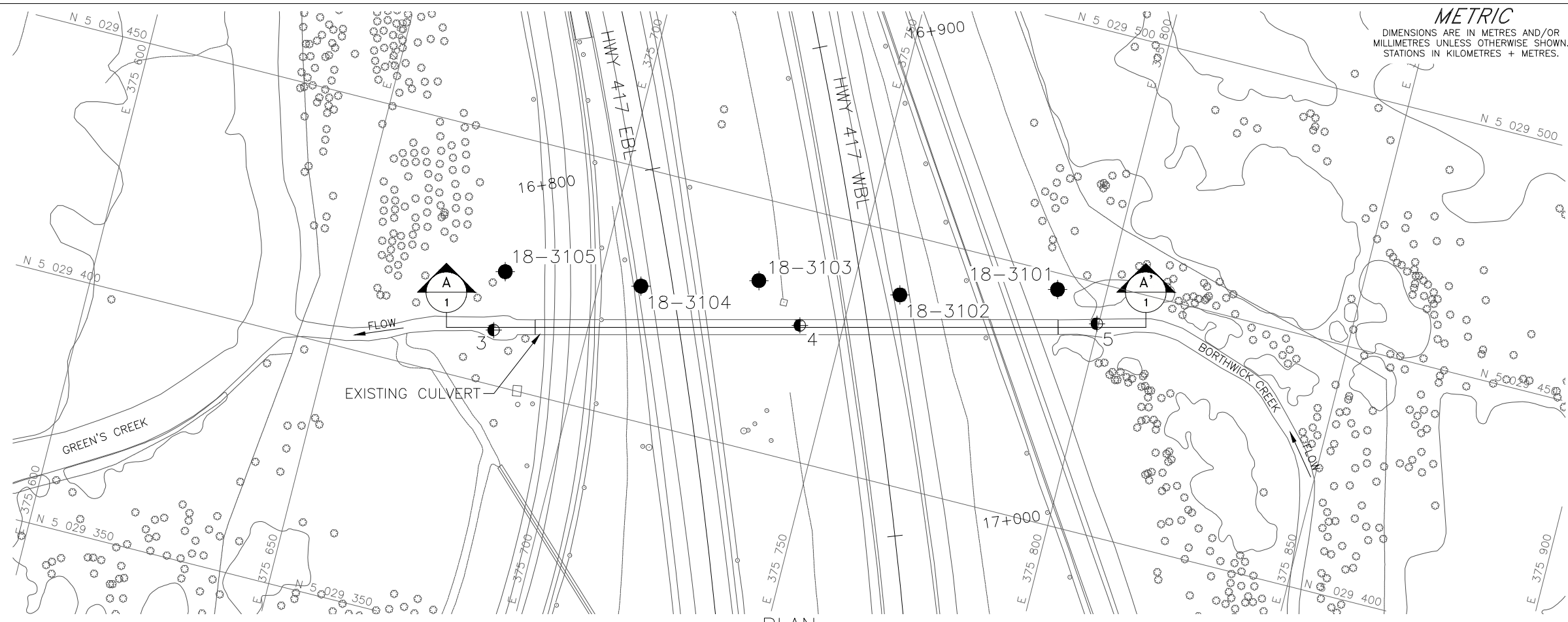


KEY PLAN

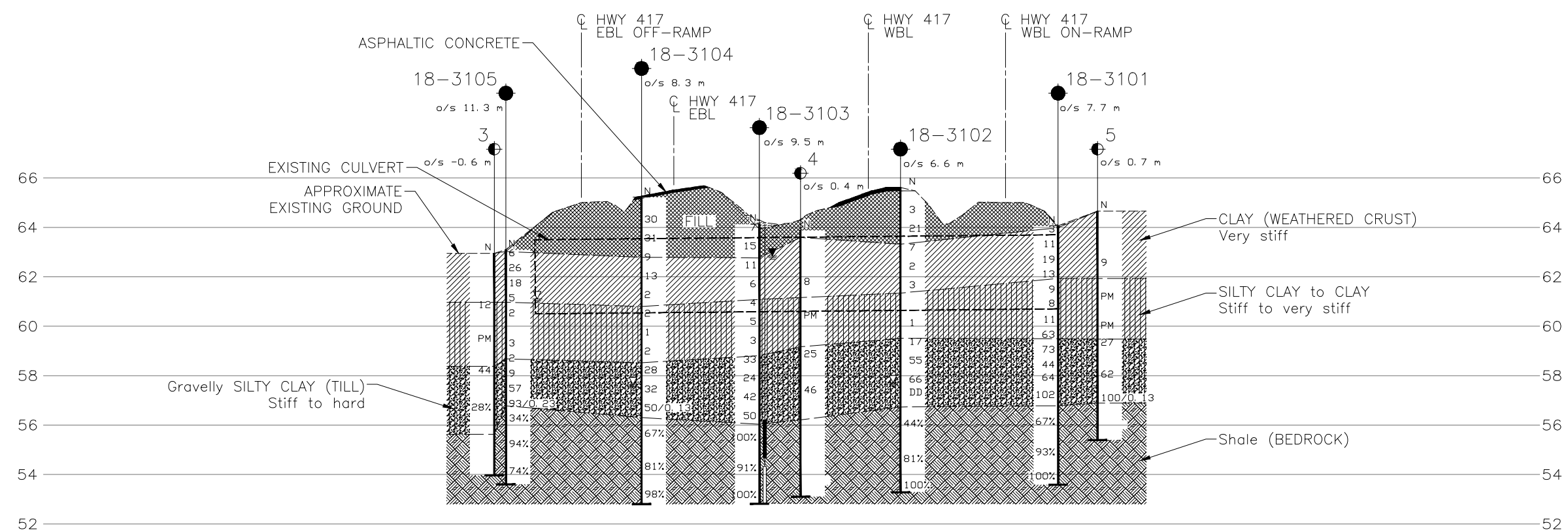


LEGEND

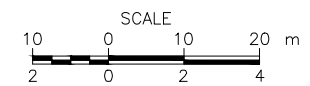
- Borehole - Current Investigation
- Borehole - Previous Investigation (Geocres No. 31605-091)
- ⊥ Seal
- ⊥ Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% Rock Quality Designation (RQD)
- ⊥ WL in piezometer, measured on Oct. 12, 2018
- ⊥ WL upon completion of drilling



PLAN



PROFILE A-A'



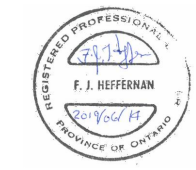
BOREHOLE CO-ORDINATES (MTM ZONE 9)			
No.	ELEVATION	NORTHING	EASTING
18-3101	64.1	5029446.7	375790.2
18-3102	65.6	5029437.9	375759.6
18-3103	64.1	5029433.7	375731.2
18-3104	65.2	5029426.8	375708.3
18-3105	63.1	5029422.9	375681.0
3	63.0	5029410.8	375681.6
4	63.9	5029426.9	375741.5
5	64.7	5029442.0	375799.7

NOTES
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

REFERENCE
Base plans provided in digital format by WSP, drawing file nos. XA1-NAD 83.dwg and XB1-NAD 83 (CSRS).dwg, received APR. 19, 2017.

NO.	DATE	BY	REVISION

Geocres No. 3165-305		PROJECT NO. 1662565-1310		DIST. EASTERN	
HWY. 417	CHKD. KP	DATE: 6/17/2019	SITE: 3-730/C		
SUBM'D. KP	CHKD. KP	APPD. FJH	DWG. 1		



PLOT DATE: 15-05-19
 FILENAME: N:\Active\Projects\1662565_1310\1662565_1310\1662565-1310-001.dwg

APPENDIX A

Record of Boreholes and Drillholes - Current Investigation

Lists of Abbreviations and Symbols

Lithological and Geotechnical Rock Description Terminology

Records of Boreholes 18-3101 to 18-3105

Bedrock Core Photographs, Figures A1 to A9

LIST OF SYMBOLS

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

I.	GENERAL	(a)	Index Properties (continued)
π	3.1416	w	water content
$\ln x$,	natural logarithm of x	w_l or LL	liquid limit
\log_{10}	x or log x, logarithm of x to base 10	w_p or PL	plastic limit
g	acceleration due to gravity	I_p or PI	plasticity index = $(w_l - w_p)$
t	time	w_s	shrinkage limit
FoS	factor of safety	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)
II.	STRESS AND STRAIN	(b)	Hydraulic Properties
γ	shear strain	h	hydraulic head or potential
Δ	change in, e.g. in stress: $\Delta \sigma$	q	rate of flow
ε	linear strain	v	velocity of flow
ε_v	volumetric strain	i	hydraulic gradient
η	coefficient of viscosity	k	hydraulic conductivity (coefficient of permeability)
ν	Poisson's ratio	j	seepage force per unit volume
	total stress	(c)	Consolidation (one-dimensional)
σ'	effective stress ($\sigma' = \sigma - u$)	C	compression index (normally consolidated range)
σ'_{vo}	initial effective overburden stress	C_r	recompression index (over-consolidated range)
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, minor)	C_s	swelling index
σ_{oct}	mean stress or octahedral stress = $(\sigma_1 + \sigma_2 + \sigma_3) / 3$	C_α	secondary compression index
τ	shear stress	m_v	coefficient of volume change
u	porewater pressure	c_v	coefficient of consolidation (vertical direction)
E	modulus of deformation	C_h	coefficient of consolidation (horizontal direction)
G	shear modulus of deformation	T_v	time factor (vertical direction)
K	bulk modulus of compressibility	U	degree of consolidation
III.	SOIL PROPERTIES	σ'_p	pre-consolidation stress
(a)	Index Properties	OCR	over-consolidation ratio = σ'_p / σ'_{vo}
$\rho(\gamma)$	bulk density (bulk unit weight)*	(d)	Shear Strength
$\rho_d(\gamma_d)$	dry density (dry unit weight)	τ_p, τ_r	peak and residual shear strength
$\rho_w(\gamma_w)$	density (unit weight) of water	ϕ'	effective angle of internal friction
$\rho_s(\gamma_s)$	density (unit weight) of solid particles	δ	angle of interface friction
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)	μ	coefficient of friction = $\tan \delta$
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)	c'	effective cohesion
e	void ratio	C_u, S_u	undrained shear strength ($\phi = 0$ analysis)
n	porosity	p	mean total stress $(\sigma_1 + \sigma_3) / 2$
S	degree of saturation	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
* Density symbol is ρ . Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)		Notes: 1	$\tau = c' + \sigma' \tan \phi'$
		2	shear strength = (compressive strength)/2

LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split-spoon
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

II. 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.) drive open sampler for a distance of 300 mm (12 in.)

Dynamic Cone Penetration Resistance; 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

Piezo-Cone Penetration Test (CPT)

A 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 (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

V. MINOR SOIL CONSTITUENTS

Per cent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (non-cohesive (cohesionless)) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

Compactness	N
Condition	Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils Consistency

	c_u, s_u	
	kPa	psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

IV. SOIL TESTS

w	water content
w _p	plastic limit
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
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	field vane (LV-laboratory vane test)
γ	unit weight

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

LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

WEATHERINGS STATE

Fresh: no visible sign of weathering

Faintly weathered: weathering limited to the surface of major discontinuities.

Slightly weathered: penetrative weathering developed on open discontinuity surfaces but only slight weathering of rock material.

Moderately weathered: weathering extends throughout the rock mass but the rock material is not friable.

Highly weathered: weathering extends throughout rock mass and the rock material is partly friable.

Completely weathered: rock is wholly decomposed and in a friable condition but the rock and structure are preserved.

BEDDING THICKNESS

<u>Description</u>	<u>Bedding Plane Spacing</u>
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

<u>Description</u>	<u>Spacing</u>
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

<u>Term</u>	<u>Size*</u>
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, measured relative to the length of the total core run. RQD varied from 0% for completely broken core to 100% for core in solid sticks.

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

JN Joint	PL Planar
FLT Fault	CU Curved
SH Shear	UN Undulating
VN Vein	IR Irregular
FR Fracture	K Slickensided
SY Stylolite	PO Polished
BD Bedding	SM Smooth
FO Foliation	SR Slightly Rough
CO Contact	RO Rough
AXJ Axial Joint	VR Very Rough
KV Karstic Void	
MB Mechanical Break	

PROJECT <u>1662565-1310</u>	RECORD OF BOREHOLE No 18-3101	SHEET 1 OF 3	METRIC
G.W.P. <u>4099-11-00</u>	LOCATION <u>N 5029446.7; E 375790.2 NAD 83 MTM ZONE 9 (LAT. 45.401368; LONG. -75.593202)</u>	ORIGINATED BY <u>DJG</u>	
DIST <u>Eastern</u> HWY <u>417</u>	BOREHOLE TYPE <u>Portable Drill, BW Casing/NQ3 Core</u>	COMPILED BY <u>ZS</u>	
DATUM <u>Geodetic</u>	DATE <u>August 9, 2018</u>	CHECKED BY <u>KP</u>	

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	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 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
			NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
							20	40	60	80	100						
64.1	GROUND SURFACE																
0.0	(ML) Clayey silt (TOPSOIL) Brown Moist		1	SS	3		64										
0.1	(CH) CLAY (WEATHERED CRUST) Firm to very stiff Grey-brown Moist		2	SS	11		63										
			3	SS	19												
62.0	(CI/CL) SILTY CLAY Very stiff Grey brown to grey Moist		4	SS	13		62										
2.1			5	SS	9		61										
			6	SS	8		60										
			7	SS	11												
59.5	(GM/SM) SILTY GRAVEL and SAND, contains clay/silt seams (TILL) Very dense Grey Wet		8	SS	63		59										
4.6			9	SS	73												
59.2	(SM) SILTY SAND, contains silt seams (TILL) Very dense Grey-brown Wet		10	SS	44		58										
4.9			11	SS	64											36 33 25 6	
58.6	(GM/SM) SILTY GRAVEL and SAND, contains cobbles and boulders (TILL) Dense to very dense Grey-brown Wet		12	SS	102		57										
5.5																	
56.8	Shale (BEDROCK) Bedrock cored from depths 7.3 m to 10.5 m For bedrock coring details refer to Record of Drillhole 18-3101		1	RC	REC 100%		56									RQD = 67%	
7.3			2	RC	REC 100%		55									RQD = 93%	
			3	RC	REC 100%											RQD = 100%	

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

PROJECT <u>1662565-1310</u>	RECORD OF BOREHOLE No 18-3101	SHEET 2 OF 3	METRIC
G.W.P. <u>4099-11-00</u>	LOCATION <u>N 5029446.7; E 375790.2 NAD 83 MTM ZONE 9 (LAT. 45.401368; LONG. -75.593202)</u>	ORIGINATED BY <u>DJG</u>	
DIST <u>Eastern</u> HWY <u>417</u>	BOREHOLE TYPE <u>Portable Drill, BW Casing/NQ3 Core</u>	COMPILED BY <u>ZS</u>	
DATUM <u>Geodetic</u>	DATE <u>August 9, 2018</u>	CHECKED BY <u>KP</u>	

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	20	40	60	80	100	W _p	W			W _L
53.6 10.5	END OF BOREHOLE		3	RC	REC 100%	54											

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+³, X³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

PROJECT <u>1662565-1310</u>	RECORD OF BOREHOLE No 18-3102	SHEET 1 OF 3	METRIC
G.W.P. <u>4099-11-00</u>	LOCATION <u>N 5029437.9; E 375759.6 NAD 83 MTM ZONE 9 (LAT. 45.401291; LONG. -75.593595)</u>	ORIGINATED BY <u>KM</u>	
DIST <u>Eastern</u> HWY <u>417</u>	BOREHOLE TYPE <u>Power Auger, 200 mm Diam. (Hollow Stem)/NW Casing/NQ3 Core</u>	COMPILED BY <u>ZS</u>	
DATUM <u>Geodetic</u>	DATE <u>August 15-16, 2018</u>	CHECKED BY <u>KP</u>	

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	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 (%)
			NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
65.6	GROUND SURFACE																
0.0	ASPHALTIC CONCRETE																
0.1	(SP/GP) Sand and gravel (FILL) Brown Moist																
65.1																	
0.5	(SP) Gravelly sand, contains cobbles (FILL) Brown Moist						65										
64.5			1	SS	3												
1.1	(SP) Sand, trace gravel (FILL) Compact Brown Moist						64										
63.3			2	SS	21												
2.3	(CH) CLAY (WEATHERED CRUST) Very stiff to stiff Grey-brown Moist						63										
61.3			3	SS	7												
4.3	(CH) CLAY (WEATHERED CRUST) Very stiff to stiff Grey-brown Moist						62										
61.3			4	SS	2												
4.3	(CL/CI) SILTY CLAY, contains silt seams/layers Stiff Grey Moist						61										
59.5			5	SS	3												
6.1	(CL-ML) Gravelly SILTY CLAY, some sand, contains cobbles and boulders (TILL) Very stiff to hard Grey Moist						60										
59.5			6	SS	1												
6.1			7	SS	17		59										19 18 52 11
56.7			8	SS	55		58										
8.9			9	SS	66		57										
8.9	Shale (BEDROCK)						56										
	Bedrock cored from depths 8.9 m to 12.3 m		1	RC	REC 92%												
	For bedrock coring details refer to Record of Drillhole 18-3102																

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

PROJECT <u>1662565-1310</u>	RECORD OF BOREHOLE No 18-3102	SHEET 2 OF 3	METRIC
G.W.P. <u>4099-11-00</u>	LOCATION <u>N 5029437.9; E 375759.6 NAD 83 MTM ZONE 9 (LAT. 45.401291; LONG. -75.593595)</u>	ORIGINATED BY <u>KM</u>	
DIST <u>Eastern</u> HWY <u>417</u>	BOREHOLE TYPE <u>Power Auger, 200 mm Diam. (Hollow Stem)/NW Casing/NQ3 Core</u>	COMPILED BY <u>ZS</u>	
DATUM <u>Geodetic</u>	DATE <u>August 15-16, 2018</u>	CHECKED BY <u>KP</u>	

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	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 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
			NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
	--- CONTINUED FROM PREVIOUS PAGE --- Shale (BEDROCK)		1	RC													RQD = 44%
			2	RC	REC 100%		55										RQD = 81%
			3	RC	REC 100%		54										RQD = 100%
53.3 12.3	END OF BOREHOLE NOTES: 1. Water level in open borehole at 7.9 m depth (Elev. 57.7 m), measured during drilling (before coring).																

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+³, X³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

PROJECT 1662565-1310 **RECORD OF BOREHOLE No 18-3103** **SHEET 1 OF 3** **METRIC**
G.W.P. 4099-11-00 **LOCATION** N 5029433.7; E 375731.2 NAD 83 MTM ZONE 9 (LAT. 45.401256; LONG. -75.593958) **ORIGINATED BY** KM
DIST Eastern **HWY** 417 **BOREHOLE TYPE** Power Auger, 200 mm Diam. (Hollow Stem)/NW Casing/NQ3 Core **COMPILED BY** ZS
DATUM Geodetic **DATE** August 19-20, 2018 **CHECKED BY** KP

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES			20	40	60	80	100			W _p	W	W _L	GR
64.1	GROUND SURFACE																
0.0	(ML) Sandy silt (TOPSOIL)																
63.9	Dark brown																
0.2	Moist	1	SS	7													
	(CI) Silty clay, some sand, trace gravel, contains sand seams (FILL)																
	Stiff to very stiff	2	SS	15													
	Brown																
	Moist																
62.7	(CH) CLAY (WEATHERED CRUST)																
1.4	Stiff to very stiff	3	SS	11													
	Grey-brown																
	Moist	4	SS	6													
61.0	(CL) SILTY CLAY, contains silt layers																
3.1	Stiff	5	SS	4													
	Grey																
	Moist	6	SS	5													
		7	SS	3													
58.8	(GM/SM) SILTY GRAVEL and SAND, trace clay, contains cobbles, boulders and shale fragments (TILL)																
5.3	Compact to very dense	8	SS	33													
	Grey																
	Wet	9	SS	24													
		10	SS	42													
		11	SS	50													
56.0	Shale (BEDROCK)																
8.1	Bedrock cored from depths 8.1 m to 11.3 m	1	RC	REC 100%													RQD = 100%
	For bedrock coring details refer to Record of Drillhole 18-3103	2	RC	REC 100%													RQD = 91%

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

PROJECT <u>1662565-1310</u>	RECORD OF BOREHOLE No 18-3103	SHEET 2 OF 3	METRIC
G.W.P. <u>4099-11-00</u>	LOCATION <u>N 5029433.7; E 375731.2 NAD 83 MTM ZONE 9 (LAT. 45.401256; LONG. -75.593958)</u>	ORIGINATED BY <u>KM</u>	
DIST <u>Eastern</u> HWY <u>417</u>	BOREHOLE TYPE <u>Power Auger, 200 mm Diam. (Hollow Stem)/NW Casing/NQ3 Core</u>	COMPILED BY <u>ZS</u>	
DATUM <u>Geodetic</u>	DATE <u>August 19-20, 2018</u>	CHECKED BY <u>KP</u>	

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	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 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
			NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
52.8	Shale (BEDROCK) --- CONTINUED FROM PREVIOUS PAGE ---		2	RC	REC 100%		54										RQD = 91%
53			3	RC	REC 100%		53										
11.3	END OF BOREHOLE NOTES: 1. Water level in well screen at a depth of 1.3 m below ground surface (Elev. 62.8 m), measured on October 12, 2018.																

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+³, X³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

PROJECT <u>1662565-1310</u>	RECORD OF BOREHOLE No 18-3104	SHEET 1 OF 3	METRIC
G.W.P. <u>4099-11-00</u>	LOCATION <u>N 5029426.8; E 375708.3 NAD 83 MTM ZONE 9 (LAT. 45.401196; LONG. -75.594251)</u>	ORIGINATED BY <u>KM</u>	
DIST <u>Eastern</u> HWY <u>417</u>	BOREHOLE TYPE <u>Power Auger, 200 mm Diam. (Hollow Stem)/NW Casing/NQ3 Core</u>	COMPILED BY <u>ZS</u>	
DATUM <u>Geodetic</u>	DATE <u>August 16-17, 2018</u>	CHECKED BY <u>KP</u>	

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	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 (%)	
			NUMBER	TYPE	"N" VALUES			20	40						60
65.2	GROUND SURFACE														
0.0	ASPHALTIC CONCRETE														
0.1	(SP/GP) SAND and GRAVEL (FILL)														
64.7	Brown Moist														
0.5	(SM/GM) Gravelly silty sand, contains cobbles (FILL)														
	Compact Brown Moist		1	SS	30										
63.5	(SP) Sand, trace gravel (FILL)														
1.7	Compact Brown Moist		2	SS	31										
62.8	(CH) CLAY (WEATHERED CRUST)														
2.4	Firm to very stiff Grey-brown Moist		3	SS	9										
			4	SS	13										
			5	SS	2										
60.8	(CI/CL) SILTY CLAY														
4.4	Stiff Grey Moist		6	SS	2										
			7	SS	1										
			8	SS	2										
58.5	(GM/SM) SILTY GRAVEL and SAND, contains cobbles and boulders (TILL)														
6.7	Compact to very dense Grey Moist to wet		9	SS	28										
			10	SS	32										
			11	SS	50/0.13										
56.3	- Contains cobbles and boulders from 8.8 m to 8.9 m depth.														
8.9	Shale (BEDROCK)														
	Bedrock cored from depths 8.9 m to 12.4 m		1	RC	REC 93%										
	For bedrock coring details refer to Record of Drillhole 18-3104													RQD = 67%	

GTA-MTO 001 N:\ACTIVE\SPATIAL_IMMTO\HWY417\REHAB&WIDENING\02_DATA\GINT\1662565.GPJ GAL-GTA.GDT 5/31/19 ZS

Continued Next Page

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

PROJECT <u>1662565-1310</u>	RECORD OF BOREHOLE No 18-3104	SHEET 2 OF 3	METRIC
G.W.P. <u>4099-11-00</u>	LOCATION <u>N 5029426.8; E 375708.3 NAD 83 MTM ZONE 9 (LAT. 45.401196; LONG. -75.594251)</u>	ORIGINATED BY <u>KM</u>	
DIST <u>Eastern</u> HWY <u>417</u>	BOREHOLE TYPE <u>Power Auger, 200 mm Diam. (Hollow Stem)/NW Casing/NQ3 Core</u>	COMPILED BY <u>ZS</u>	
DATUM <u>Geodetic</u>	DATE <u>August 16-17, 2018</u>	CHECKED BY <u>KP</u>	

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	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 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
			NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
	--- CONTINUED FROM PREVIOUS PAGE --- Shale (BEDROCK)		1	RC			55										RQD = 67%
			2	RC	REC 95%		54										RQD = 81%
			3	RC	REC 100%		53										RQD = 98%
52.8 12.4	END OF BOREHOLE NOTES: 1. Water level in open borehole at 7.6 m depth (Elev. 57.6 m), measured during drilling (before coring).																

GTA-MTO 001 N:\ACTIVE\SPATIAL_IMMTO\HWY417\REHAB&WIDENING\02_DATA\GINT\1662565.GPJ GAL-GTA.GDT 5/31/19 ZS

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

PROJECT <u>1662565-1310</u>	RECORD OF BOREHOLE No 18-3105	SHEET 1 OF 2	METRIC
G.W.P. <u>4099-11-00</u>	LOCATION <u>N 5029422.9; E 375681.0 NAD 83 MTM ZONE 9 (LAT. 45.401164; LONG. -75.594601)</u>	ORIGINATED BY <u>DJG</u>	
DIST <u>Eastern</u> HWY <u>417</u>	BOREHOLE TYPE <u>Portable Rotary Drill, BW Casing/NQ3 Core</u>	COMPILED BY <u>ZS</u>	
DATUM <u>Geodetic</u>	DATE <u>August 13, 2018</u>	CHECKED BY <u>KP</u>	

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	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 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
			NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
							20	40	60	80	100						
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					WATER CONTENT (%)					
							20	40	60	80	100	25	50	75			
63.1	GROUND SURFACE																
0.0	(ML) Clayey silt (TOPSOIL) Dark brown Moist		1	SS	6												
	(CH) CLAY, contains trace organic matter (rootlets) (WEATHERED CRUST) Very stiff Grey-brown Moist		2	SS	26												
			3	SS	18												
61.0			4	SS	5	▽											
2.1	(CL) SILTY CLAY, contains silt layers Stiff to firm Grey Moist to wet		5	SS	2												
			6	SS	3												
58.7			7	SS	2												
4.4	(CL-ML) Gravelly SILTY CLAY, some sand and clay, contains cobbles and boulders (TILL) Firm to hard Grey-brown Wet		8	SS	9											27 32 29 12	
			9	SS	57											24 23 42 11	
56.8			10	SS	93/0.23												
6.3	Shale (BEDROCK) Bedrock cored from depths 6.3 m to 9.5 m For bedrock coring details refer to Record of Drillhole 18-3105		1	RC	REC 100%											RQD = 34%	
			2	RC	REC 100%											RQD = 94%	
			3	RC	REC 82%											RQD = 74%	
53.6																	
9.5	END OF BOREHOLE																

GTA-MTO 001 N:\ACTIVE\SPATIAL_IMMTO\HWY417REHAB&WIDENING\02_DATA\GINT\1662565.GPJ GAL-GTA.GDT 5/31/19 ZS

Continued Next Page

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

PROJECT <u>1662565-1310</u>	RECORD OF BOREHOLE No 18-3105	SHEET 2 OF 2	METRIC
G.W.P. <u>4099-11-00</u>	LOCATION <u>N 5029422.9; E 375681.0 NAD 83 MTM ZONE 9 (LAT. 45.401164; LONG. -75.594601)</u>	ORIGINATED BY <u>DJG</u>	
DIST <u>Eastern</u> HWY <u>417</u>	BOREHOLE TYPE <u>Portable Rotary Drill, BW Casing/NQ3 Core</u>	COMPILED BY <u>ZS</u>	
DATUM <u>Geodetic</u>	DATE <u>August 13, 2018</u>	CHECKED BY <u>KP</u>	

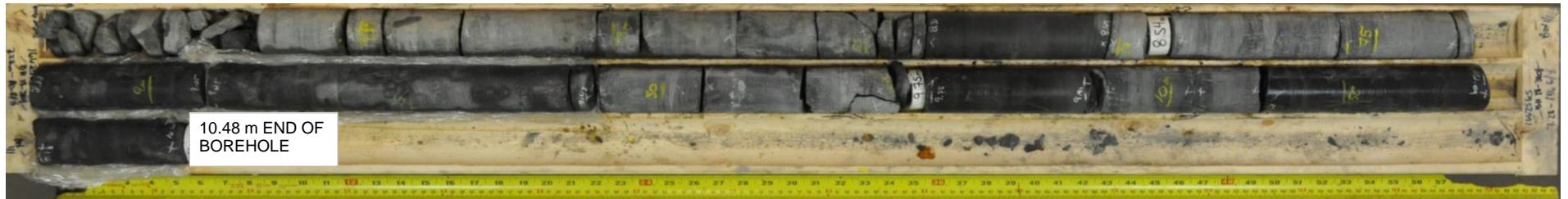
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
	--- CONTINUED FROM PREVIOUS PAGE ---															
	NOTES: 1. Water level in open borehole at 2.0 m depth (Elev. 61.1 m), measured during drilling.															

GTA-MTO 001 N:\ACTIVE\SPATIAL_IMMTO\HWY417REHAB&WIDENING\02_DATA\GINT\1662565.GPJ GAL-GTA.GDT 5/31/19 ZS

+³, X³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

BH 18-3101 DRY
7.28 m to 10.48 m

7.28 m
BEDROCK
SURFACE



10.48 m END OF
BOREHOLE



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Review:	

FIGURE A1

BH 18-3101 WET
7.28 m to 10.48 m

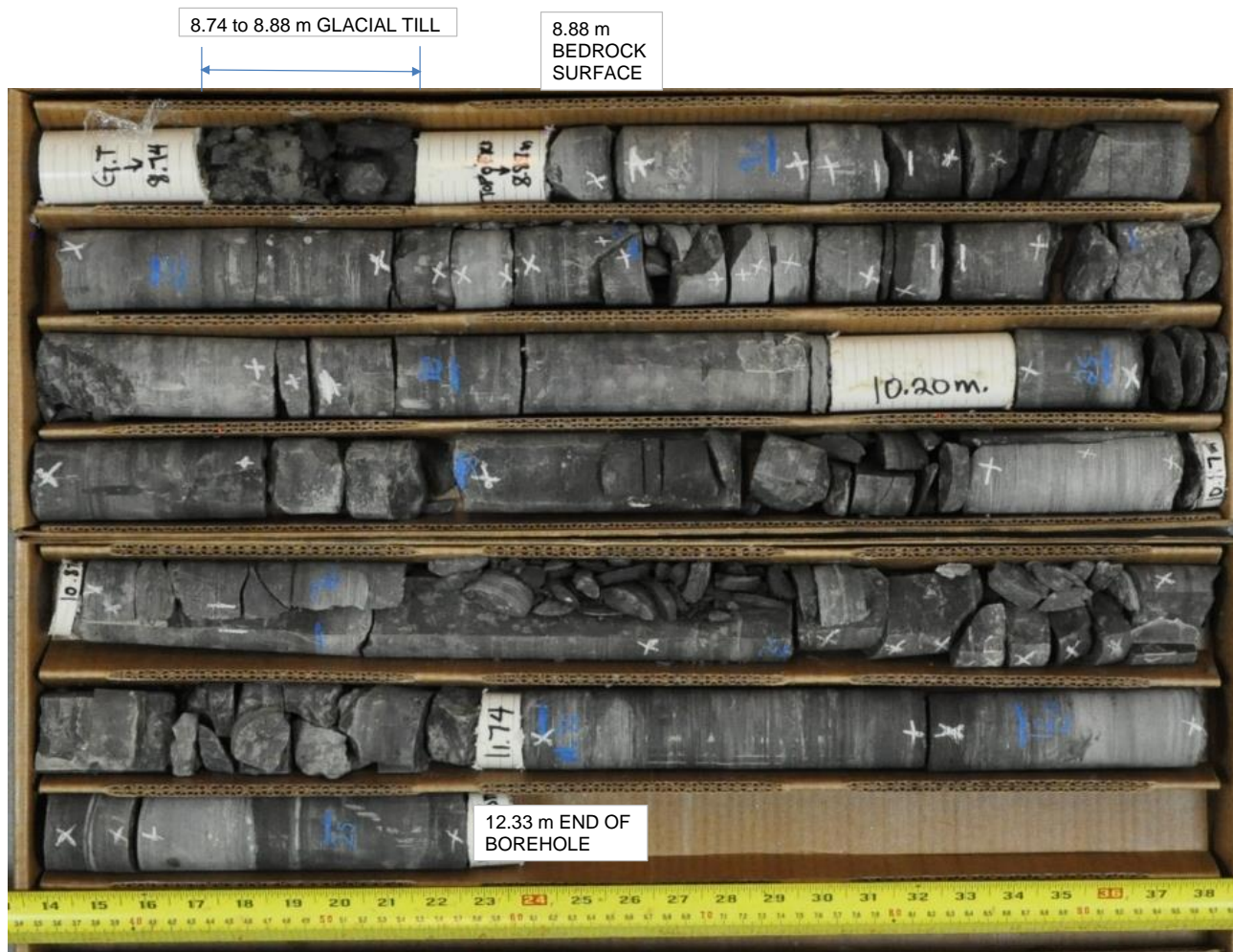


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FIGURE A2

BH 18-3102 DRY
8.74 m to 12.33 m



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FIGURE A3

BH 18-3103 DRY
8.10 m to 11.32 m

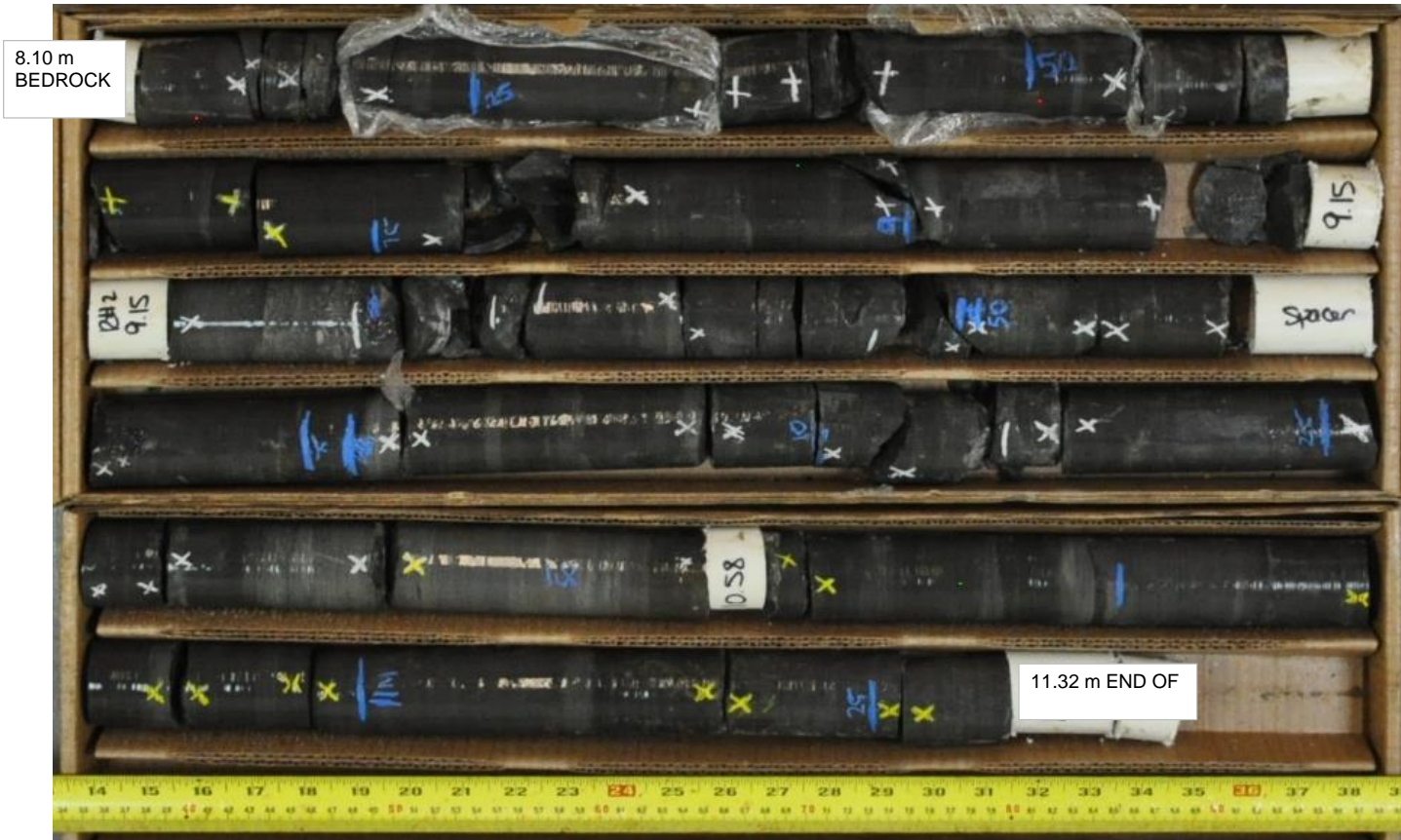


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FIGURE A4

BH 18-3103 WET
8.10 m to 11.32 m



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Ottawa, Ontario

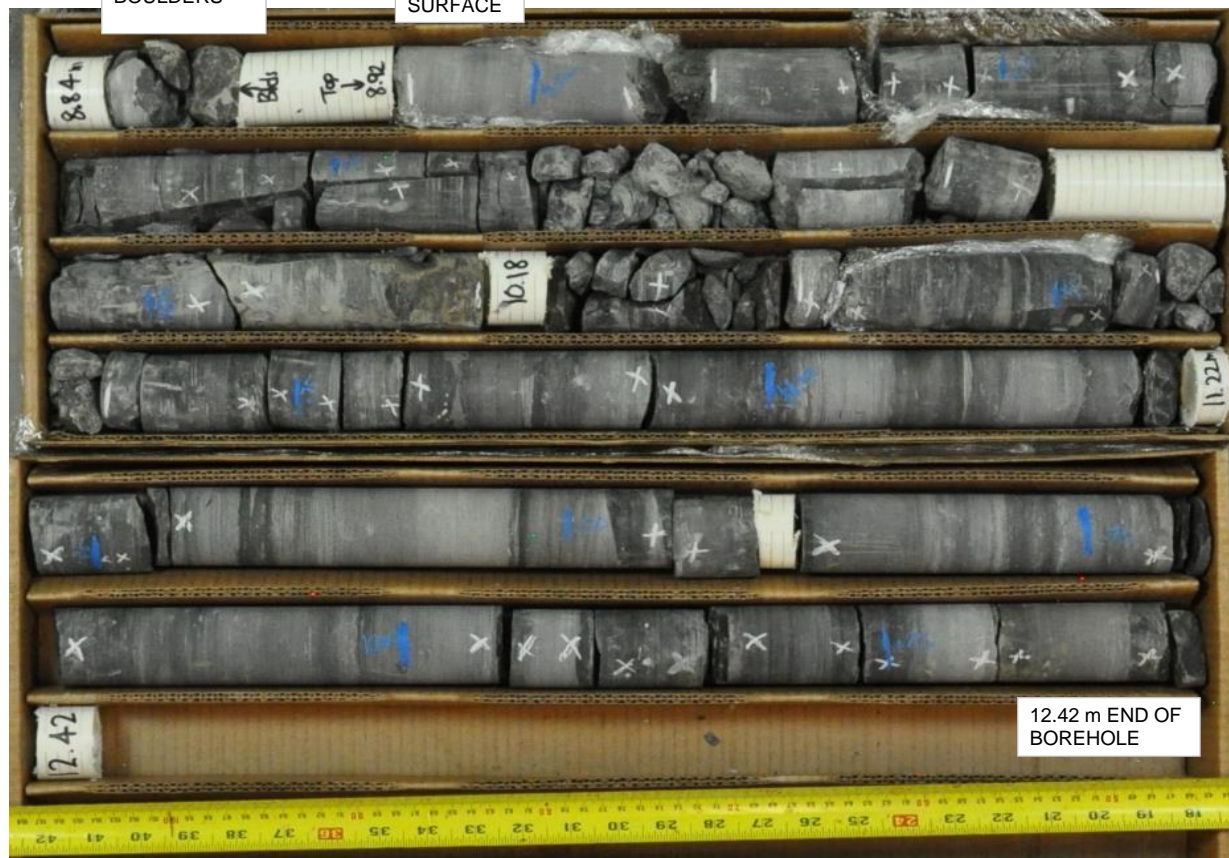
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Review:	

FIGURE A5

BH 18-3104 DRY
8.92 m to 12.42 m

8.84 to 8.92 m
BOULDERS

8.92 m
BEDROCK
SURFACE



12.42 m END OF
BOREHOLE



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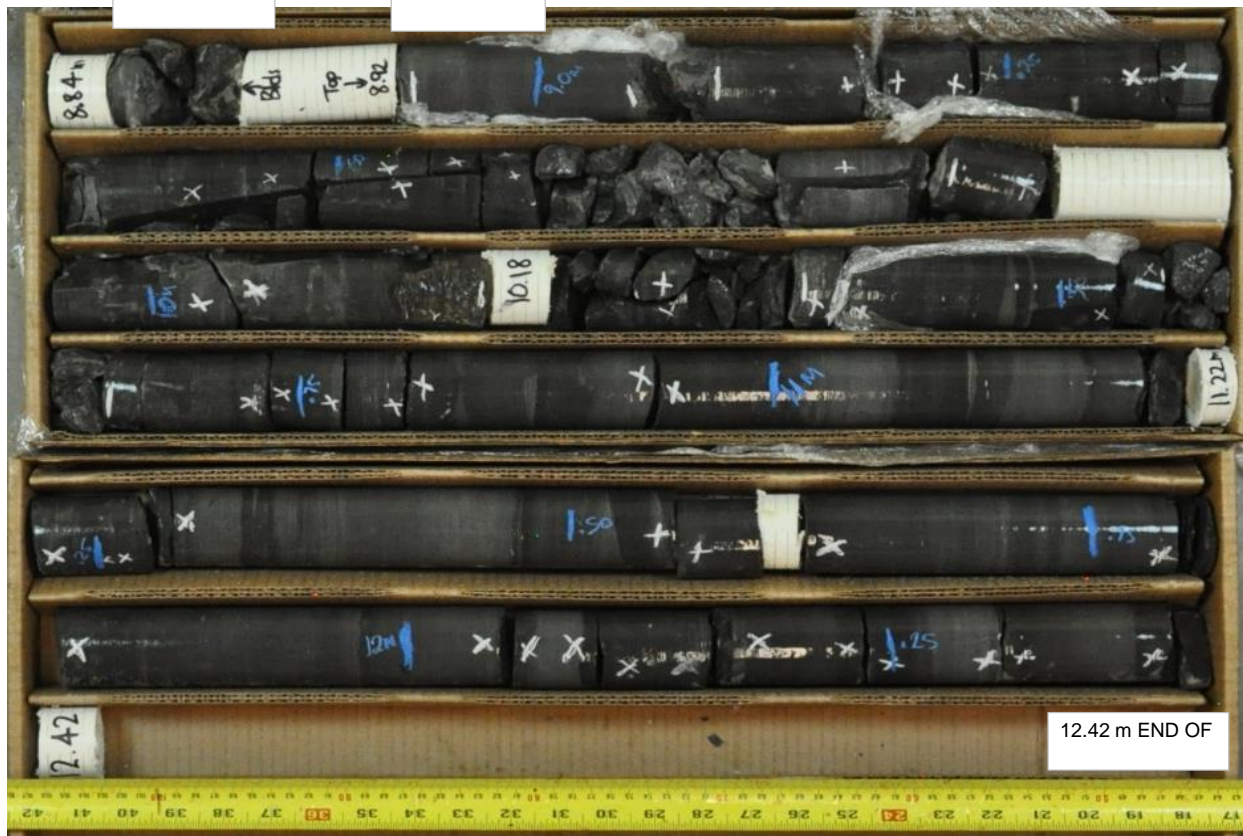
FIGURE A6

BH 18-3104 WET

8.92 m to 12.42 m

8.84 to 8.92 m
BOULDERS

8.92 m
BEDROCK



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FIGURE A7

BH 18-3105 DRY
6.32 m to 9.50 m

6.32 m
BEDROCK



9.50 m END
OF
BOREHOLE



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Date:	27/11/2018
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Review:	

FIGURE A8

BH 18-3105 WET
6.32 m to 9.50 m

6.32 m
BEDROCK



9.50 m END
OF
BOREHOLE



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Date:	27/11/2018
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FIGURE A9

APPENDIX B

Laboratory Test Results - Current Investigation

Figure B1 – Plasticity Chart – Clay

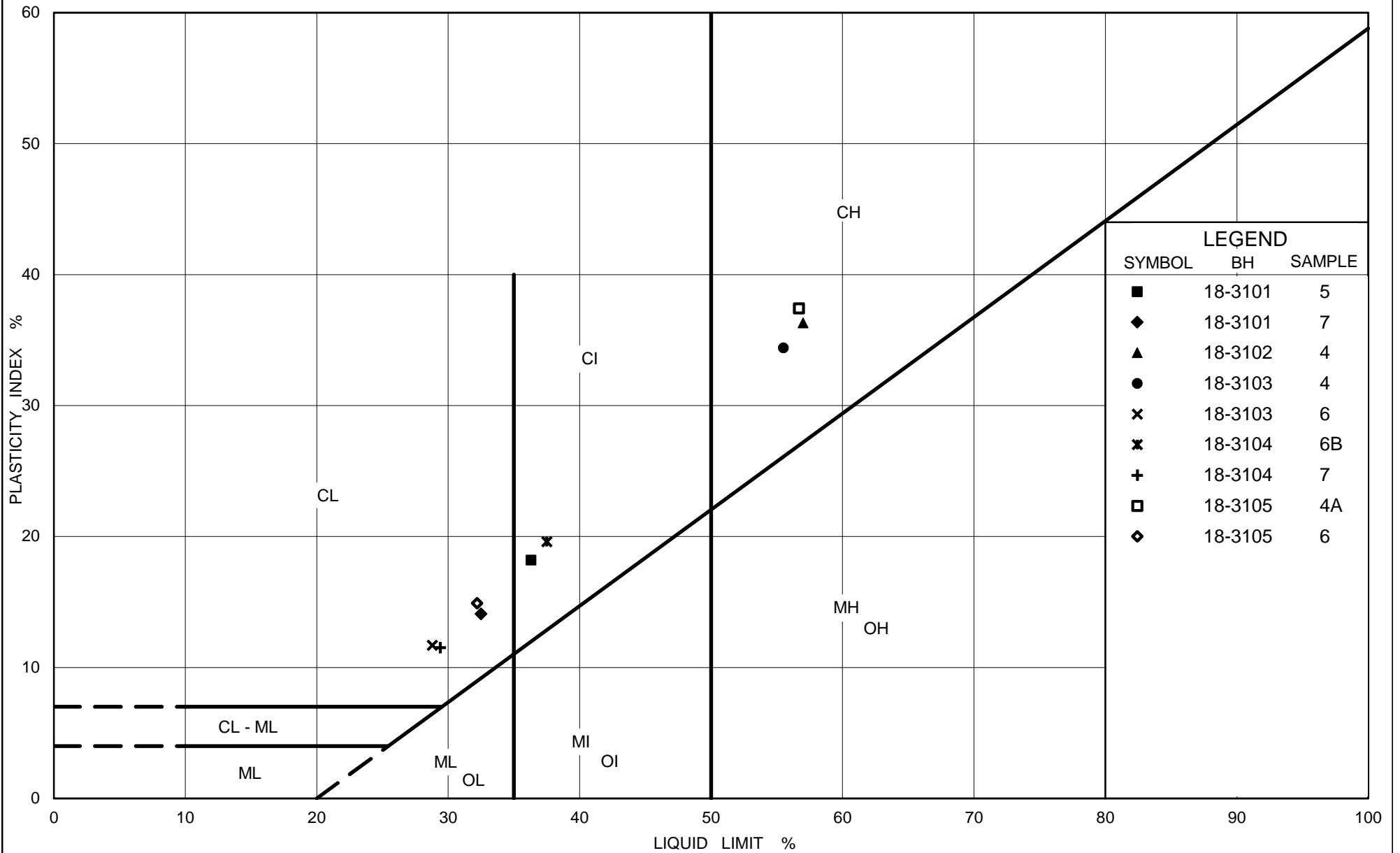
Figure B2 – Grain Size Distribution Test Results – Clay

Figure B3 – Grain Size Distribution Test Results – Silty Gravel and Sand (Till)

Figure B4 – Grain Size Distribution Test Results – Gravelly Silty Clay some Sand (Till)

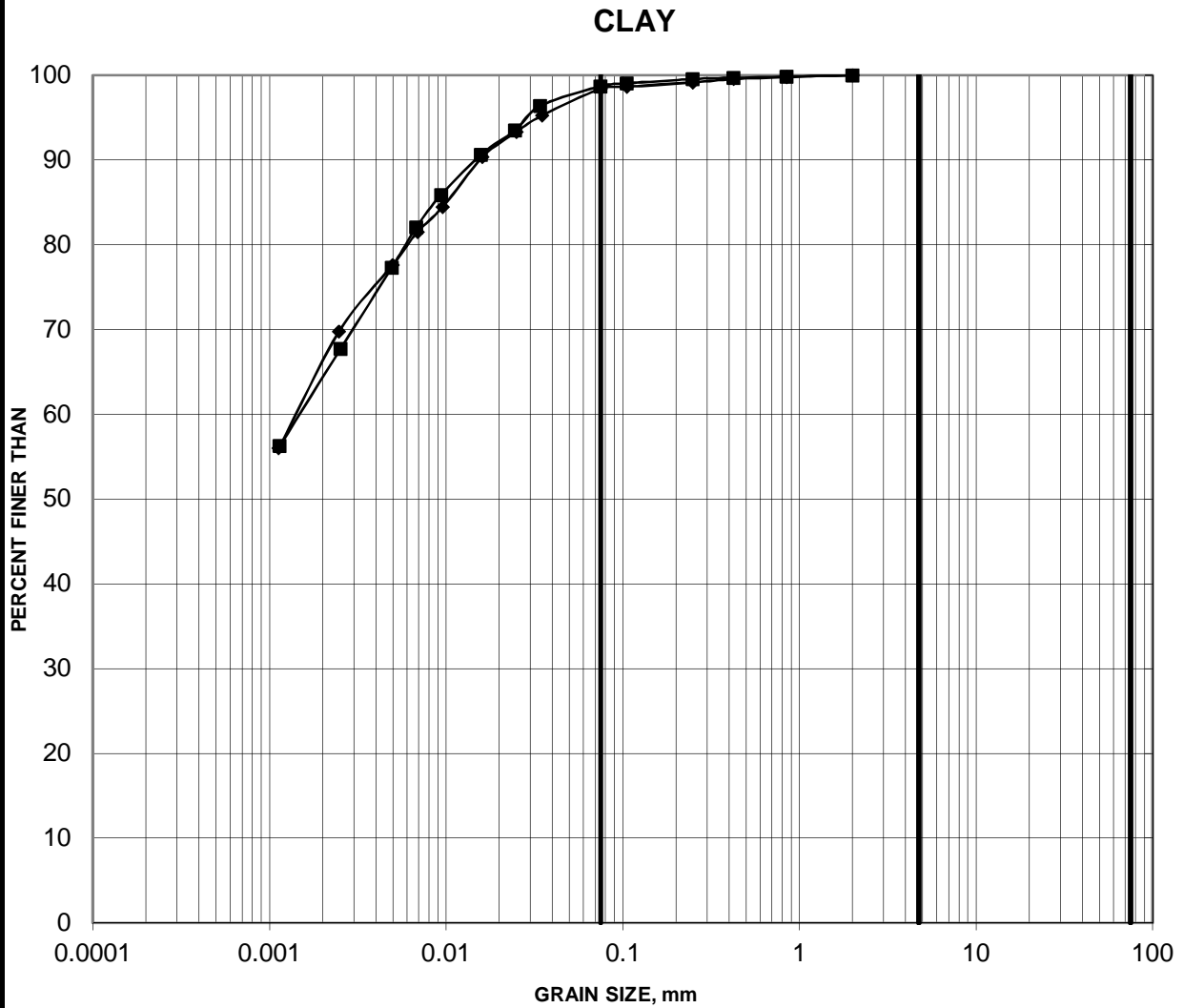
Figure B5 – Plasticity Chart – Glacial Till

Figure B6 – Summary of Laboratory Compressive Strength Unconfined Compression Tests



GRAIN SIZE DISTRIBUTION

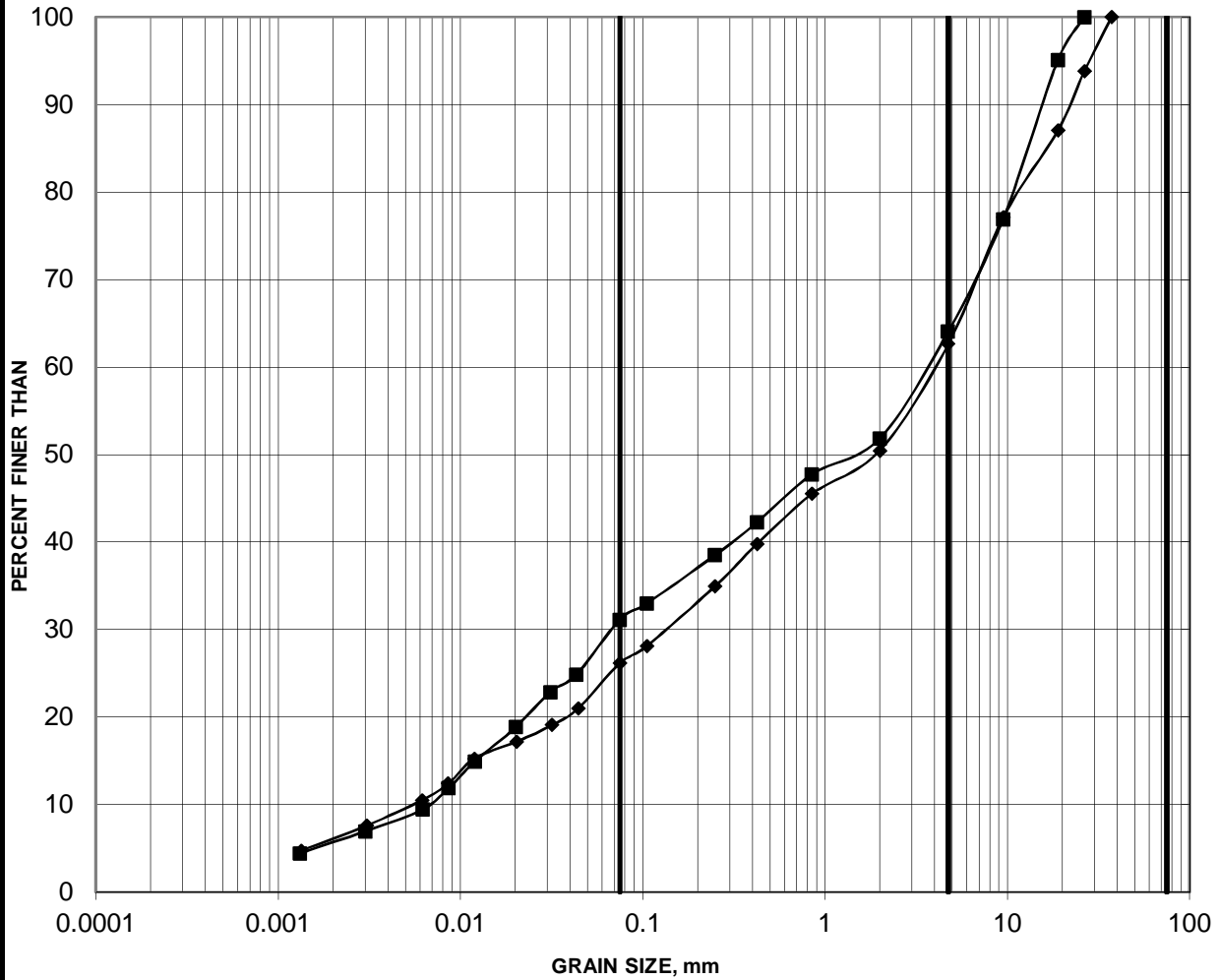
FIGURE B2



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

Borehole	Sample	Depth (m)
—■— 18-3103	4	2.29-2.90
—◆— 18-3104	5	3.81-4.42

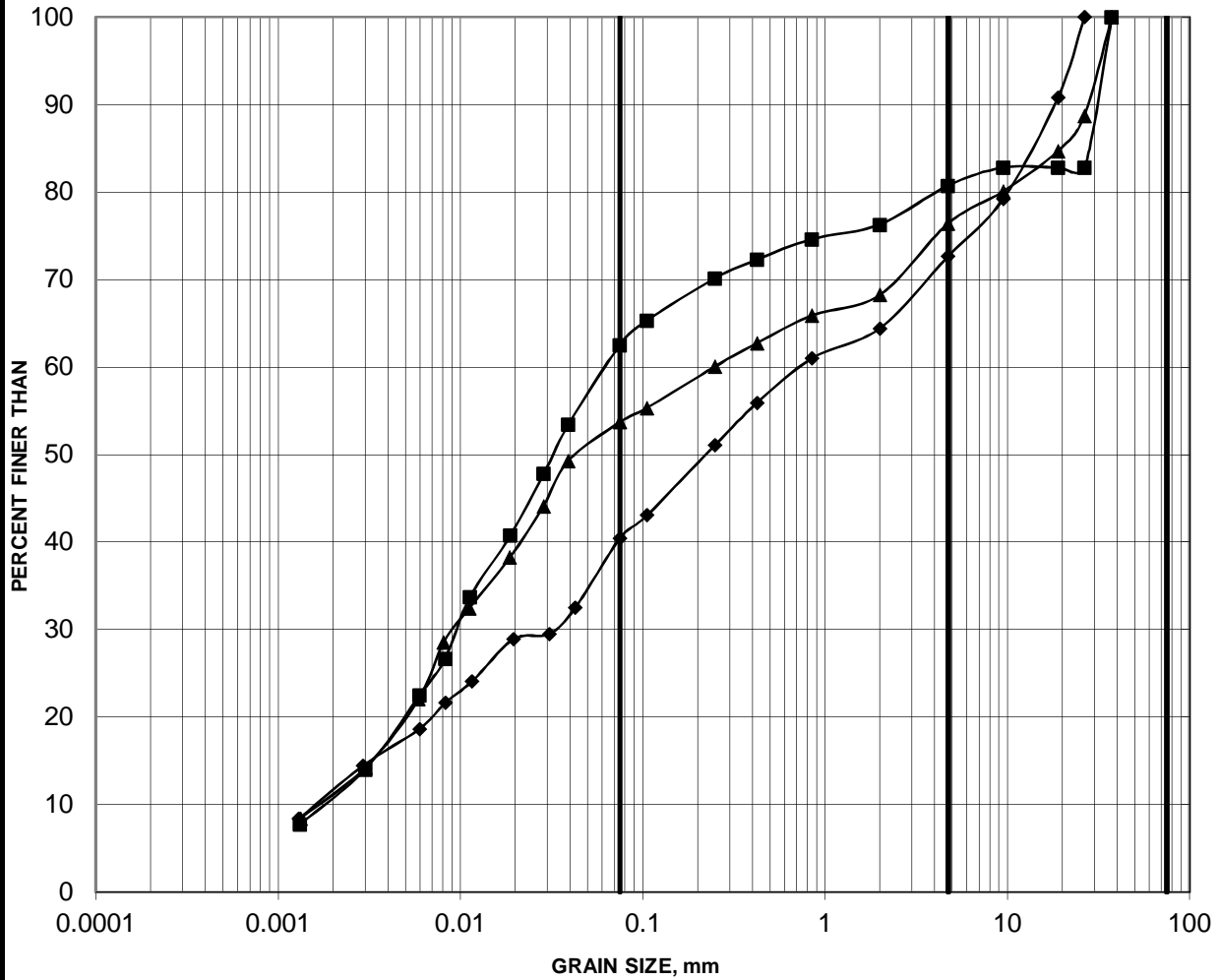
SILTY GRAVEL AND SAND (TILL)



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

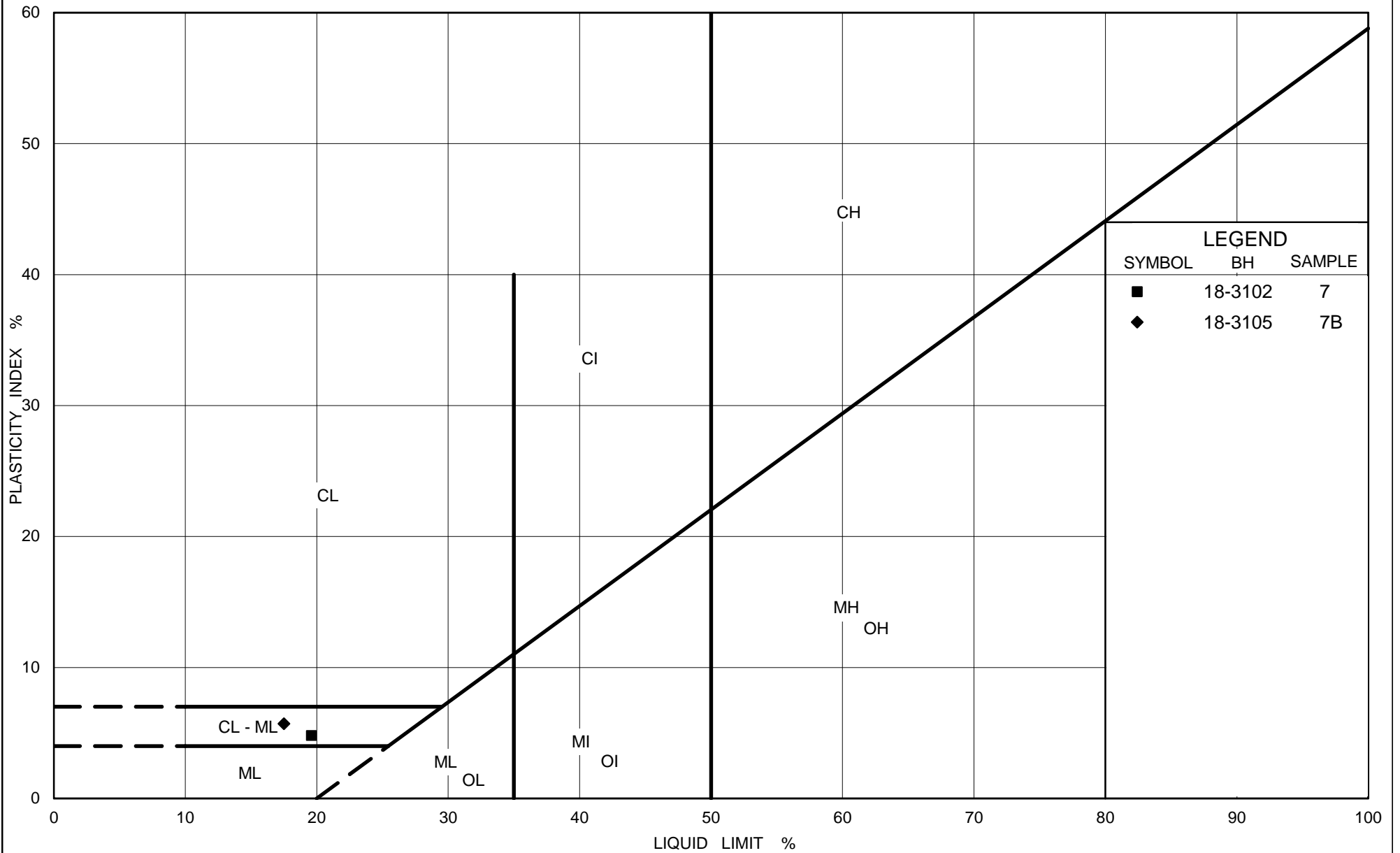
Borehole	Sample	Depth (m)
—■— 18-3101	11	6.10-6.71
—◆— 18-3103	8	5.33-5.94

GRAVELLY SILTY CLAY SOME SAND (TILL)



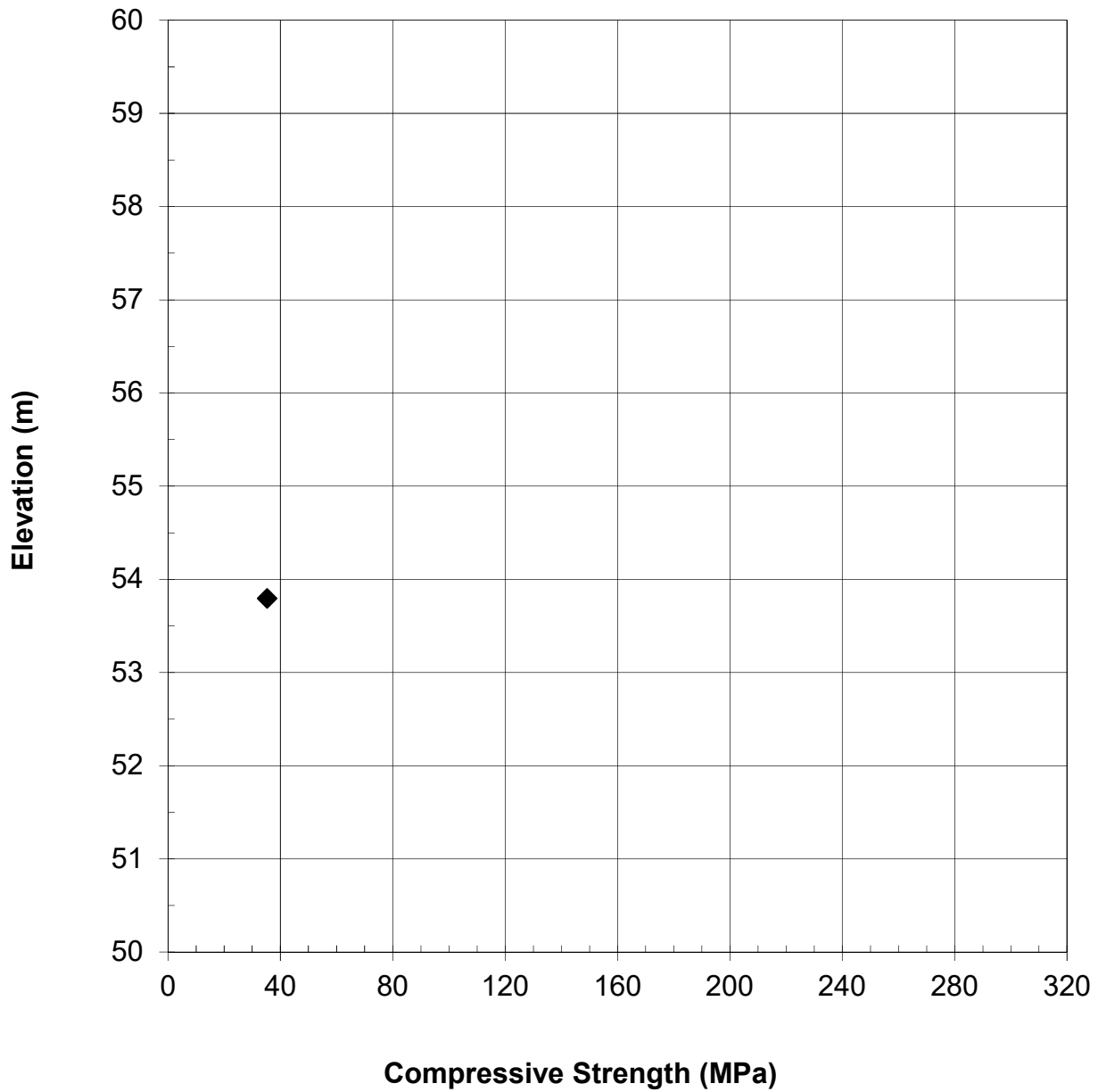
SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

Borehole	Sample	Depth (m)
18-3102	7	6.10-6.71
18-3105	7B	4.39-4.88
18-3105	9	5.49-6.10



**SUMMARY OF LABORATORY COMPRESSIVE STRENGTH
UNCONFINED COMPRESSION TESTS**

FIGURE B6



APPENDIX C

**Borehole Record and Laboratory Test Results
(Previous Investigation, GEOCREs No. 31G05-091)**

Records of Previous Boreholes BH 3 to BH 5

Laboratory Test Results

Bore Hole Location and Soil Strata Drawing

DESIGN SERVICES BRANCH

FOUNDATIONS OFFICE

RECORD OF BOREHOLE NO 1

JOB 72-11146

LOCATION Co-Ords. 499,529 N, 233,953 E.

ORIGINATED BY D.B.

W.P. 10-69

BORING DATE January 18, 19, 1973

COMPILED BY D.B.

DATUM Geodetic

BOREHOLE TYPE Washboring - NX BX Casing-BX Rock Core

CHECKED BY

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT			LIQUID LIMIT — W _L PLASTIC LIMIT — W _P WATER CONTENT — W			BULK DENSITY γ	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT		SHEAR STRENGTH P.S.F. ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE			W _P	W	W _L		
206.4	Ground Level													
205.4	Sandy Top Soil													EL. 207.4 ▽ Head
1.0	Sand, Trace to Some Gravel		1	CS	-	200								0 98 (2) In open BH Jan. 1973
	Grey to Brown		2	SS	5									
	Loose to Compact		3	SS	5									17 77 (6)
			4	SS	9									
189.8			5	SS	30	190								34 50 (16)
16.6	Het. Mixture of Silt, Sand & Gravel Trace of Clay, (Till) Dense													
	Bouldery Zone Boulders up to 5 inches in size		6	BX-Rec RC	31%									
182.2	Very Dense		7	BX-Rec RC	53%									Elev. 182.2
24.2	Bedrock Interbedded shale and shaley to silty limestone Grey Sound		8	BX-Rec RC	100%									Artesian Head Encountered Elev. 182.2
			9	BX-Rec RC	98%	180								
			10	BX-Rec RC	100%									
171.7														
34.7	End of Borehole					170								

OFFICE REPORT SOIL EXPLORATION

DESIGN SERVICES BRANCH

FOUNDATIONS OFFICE

RECORD OF BOREHOLE NO 2

JOB 72-11146

LOCATION Co-ords. 499,443 N., 234,049 E.

ORIGINATED BY D.B.

W.P. 10-69

BORING DATE January 23, 1973

COMPILED BY D.B.

DATUM Geodetic

BOREHOLE TYPE Washboring-NX BX Casing-BX Rock Core

CHECKED BY 10

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT				LIQUID LIMIT W_L PLASTIC LIMIT W_P WATER CONTENT W			BULK DENSITY γ	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT		SHEAR STRENGTH P.S.F.				WATER CONTENT %				
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE				15	30	45	P.C.F.	GR. SA. SI. CL.
206.9	Ground Level														
205.9	Clayey Topsoil														206.1
1.0	Sand Trace to some Gravel Grey to Brown		1	CS	-										In open B.H.
	Loose to Compact		2	SS	5	200									0 99 (1)
			3	SS	15										
			4	SS	27	190									9 87 (4)
187.9	Het. Mixture of Sand & Gravel, trace of silt & clay (Glacial Till)		5	SS	36										
19.0	Dense to V. Dense		6	RC	Rec										
182.9	Bouldery Zone														
24.0	Bedrock		7	RC	97% REC	180									
	Interbedded shale and shaley to silty limestone. Grey														
177.6	Sound														
29.3	End of Borehole					170									

OFFICE REPORT SOIL EXPLORATION

DESIGN SERVICES BRANCH

FOUNDATIONS OFFICE

RECORD OF BOREHOLE NO 3

JOB 72-11146 LOCATION Co-Ords. 499.960 N, 232.463 E. ORIGINATED BY D.B.
 W.P. 10-69 BORING DATE January 29, 30, 1973 COMPILED BY B.T.D.
 DATUM Geodetic BOREHOLE TYPE Washboring NX. BX Casing- BX Rock Core CHECKED BY LD

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT					LIQUID LIMIT W_L PLASTIC LIMIT W_P WATER CONTENT W			BULK DENSITY γ	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT		SHEAR STRENGTH P.S.F.					WATER CONTENT %				
						400	800	1200	1600	2000	15	30	45			
206.4	Ground Level															
0.0	Varved Material Dark Grey Varves Silty Clay Grey Varves Clayey Silt to Silt Individual Varves Range from 1/2" to 1" Very Stiff to Firm		1	SS	12	200									205.0	
			2	TW	PM		+8	+26								
							+12									
191.4																
15.0	Het. Mixture of Silt & Sand, Some Clay & Gravel Glacial Till Very Dense		3	SS	44	190									14 53 23	
	Bouldery Zone Boulders up to 5" in size		4	BX-RC	28% Rec.											
182.4																
24.0	Bedrock interbedded shale and shaley limestone Sound		5	BX-RC	97% Rec.	180										
176.9																
29.5	End of Borehole					170										

OFFICE REPORT SOIL EXPLORATION

DESIGN SERVICES BRANCH

FOUNDATIONS OFFICE

RECORD OF BOREHOLE NO 4

JOB 72-11146

LOCATION Co-ords. 500.012 N. 232.660 E.

ORIGINATED BY D.B.

W.P. 10-69

BORING DATE January 25, 26 1973

COMPILED BY D.B.

DATUM Geodetic

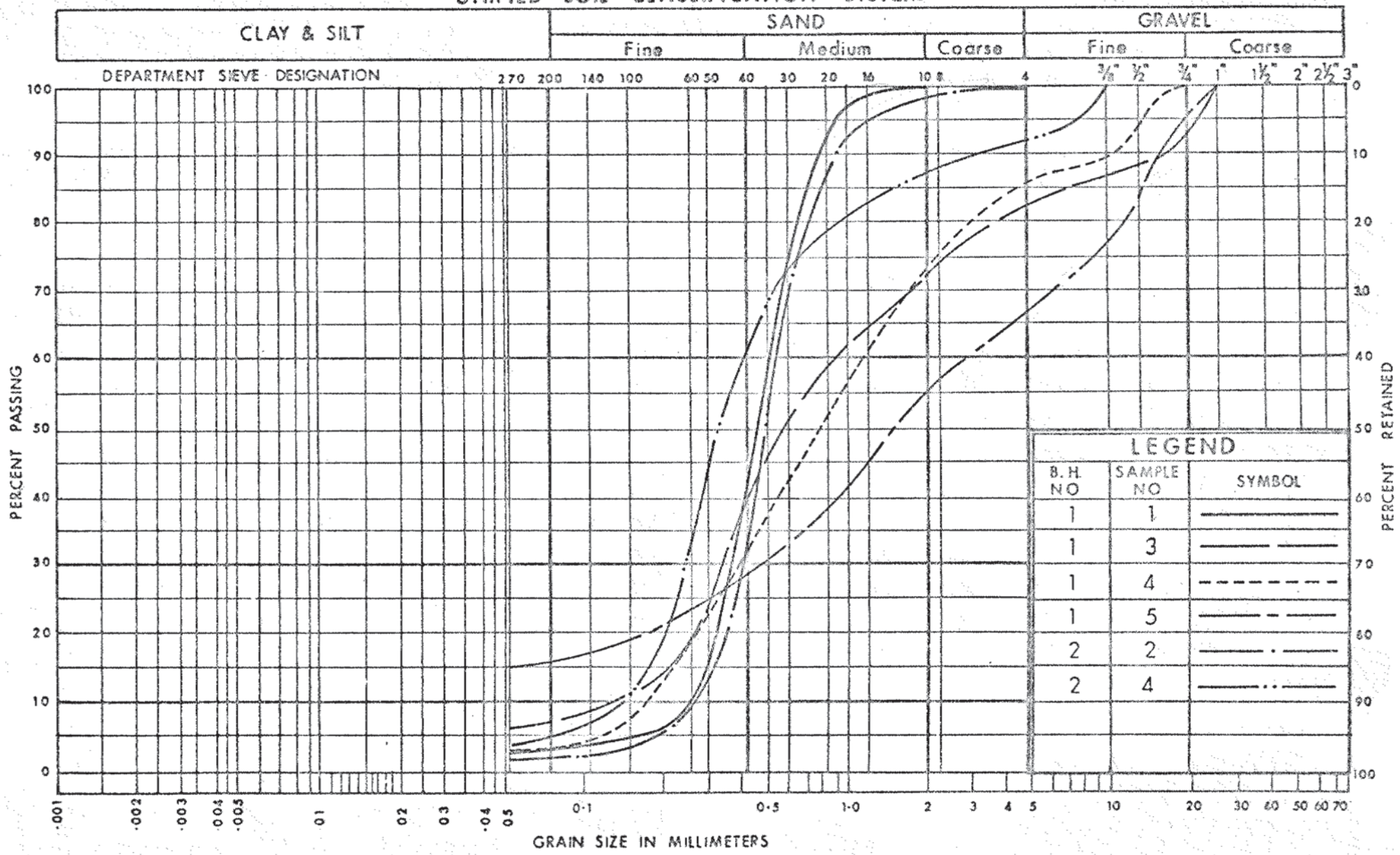
BOREHOLE TYPE Washboring - NX BX Casing - BX Rock Core

CHECKED BY

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT					LIQUID LIMIT — W _L PLASTIC LIMIT — W _P WATER CONTENT — W			BULK DENSITY γ	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT		SHEAR STRENGTH P.S.F.					WATER CONTENT %				
						400	800	1200	1600	2000	15	30	45	P.C.F.	GR.SA.SI.CL.	
209.5	Ground Level															
208.5	Clayey Topsoil														Elev. 208.8	
1.0	Varved Material		1	CS	-										In open BH Jan. 26 1973	
	Dark Grey Varves															
	Silty Clay		2	SS	8											
	Grey Varves															
	Clayey Silt to Silt															
	Individual varves range from 1/2" to 1"		3	TW	PM										clay	
	Very Stiff to Firm														clayey silty	
194.0	Silt with Gravel		4	SS	25										117.5 e _s =0.65 C _c =0.06	
15.5	Compact															
191.2	Het. Mixture of Silt & Sand with Some Clay and Gravel, Glacial Till.		5	SS	46										8 27 50 15	
18.3	Dense to V. Dense		6	BX RC	18% Rec.											
184.3	Bedrock		7	BX-RC	99% Rec.											
25.2	Interbedded shale and Shaley limestone															
	Sound		8	BX-RC	100% Rec.											
174.1																
35.4	End of Borehole															

OFFICE REPORT SOIL EXPLORATION

UNIFIED SOIL CLASSIFICATION SYSTEM

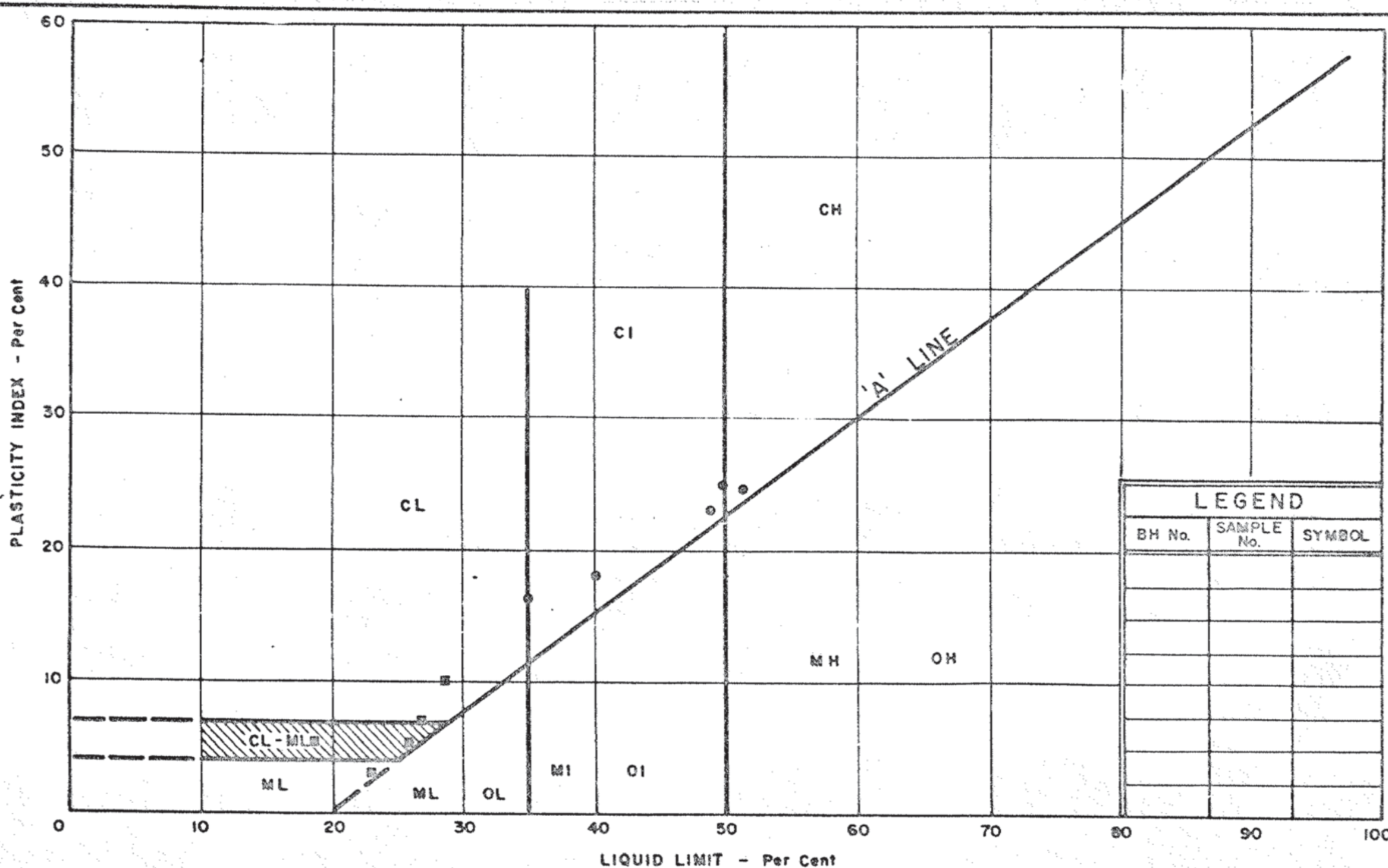


DEPARTMENT
OF
TRANSPORTATION AND COMMUNICATIONS

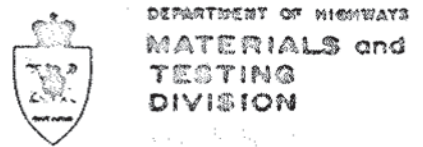
DESIGN SERVICES
BRANCH

GRAIN SIZE DISTRIBUTION
SAND
TRACE TO SOME GRAVEL

W.P. No. 10 - 69
JOB No. 72 - 11146
FIG. 1



LEGEND		
BH No.	SAMPLE No.	SYMBOL



DEPARTMENT OF HIGHWAYS
MATERIALS and TESTING DIVISION

PLASTICITY CHART

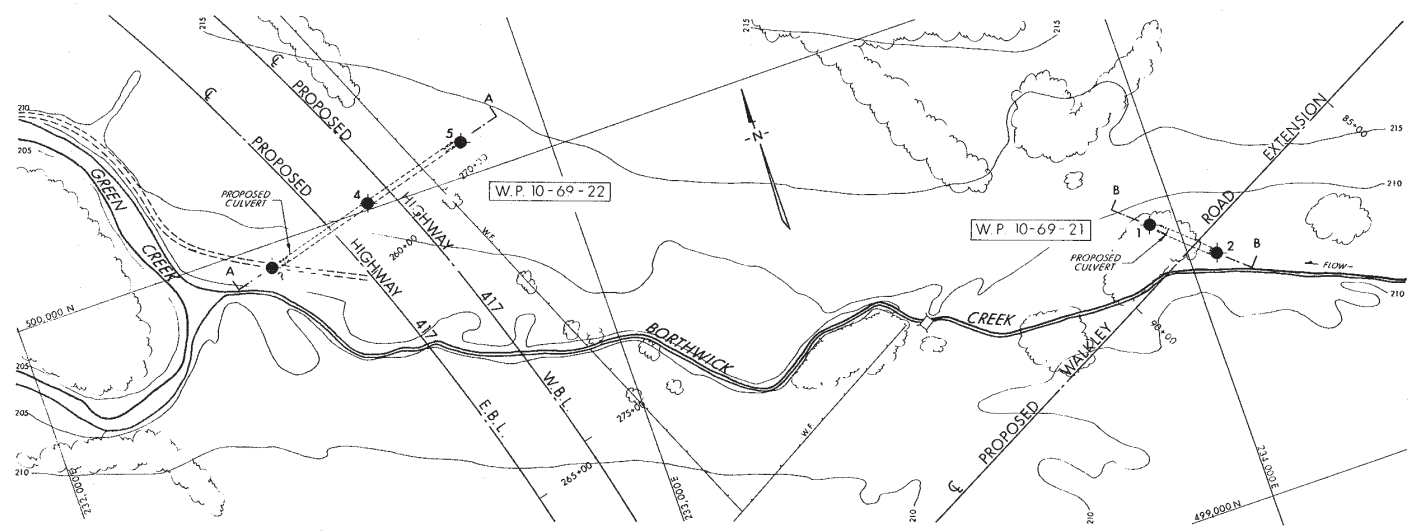
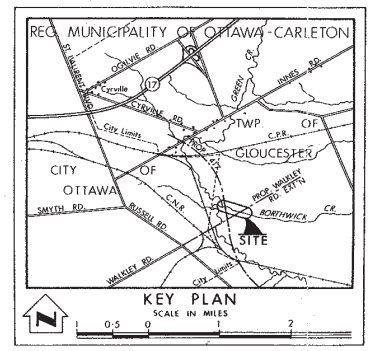
VARVED SILTY CLAY STRATUM

- SILTY CLAY VARVES
- CLAYEY SILT TO SILT VARVES

WP No. 10-69

JOB No. 72-11146

FIG. 2



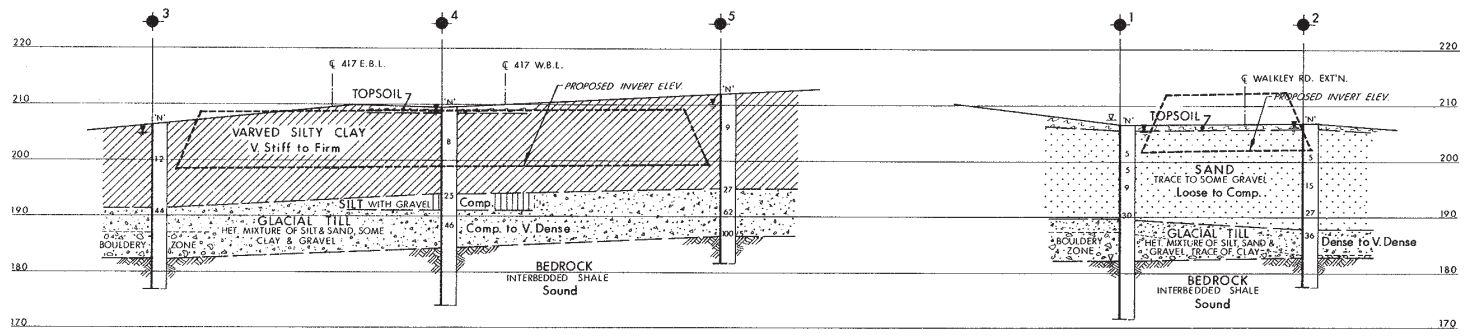
LEGEND

- Bore Hole
- ⊕ Cone Penetration Test
- ⊕ Bore Hole & Cone Test
- ⊕ Water Levels established at time of field investigation, JAN. 1973
- ⊕ Head
- ⊕ Encountered ARTESIAN WATER

NO.	ELEVATION	CO-ORDINATES	
		NORTH	EAST
1	206.4	499,529	233,953
2	206.9	499,443	234,049
3	206.4	499,960	232,463
4	209.5	500,012	232,660
5	212.0	500,060	232,852

NOTE
 The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.

REVISIONS	DATE	BY	DESCRIPTION



NOTE: The complete soil investigation report for this structure may be examined at the Bridge Office and Foundation Office, Downsview, and at the OTTAWA District Office.

MINISTRY OF TRANSPORTATION AND COMMUNICATIONS—ONTARIO
 DESIGN SERVICES BRANCH—FOUNDATIONS OFFICE

BORTHWICK CREEK CULVERTS

HIGHWAY NO. 417 & WALKLEY RD. EXT'N. DIST. NO. 9
 REG. MUNICIPALITY OF OTTAWA-CARLETON
 TWP. GLOUCESTER LOT CON.

BORE HOLE LOCATIONS & SOIL STRATA

SUBWD. D.B. CHECKED	W.P. NO. 10-69-21	DRAWING NO.
DATE 23 FEB. 1973	W.O. NO. 72-11146	72-11146A
APPROVED	SITE NO. 3-C-A	BRIDGE DRAWING NO.
	CONT. NO. 73-6D	3-C-A-2

APPENDIX D

Basic Chemical Analysis – Eurofins Report Number 1816326

Certificate of Analysis

Client: Golder Associates Ltd (Ottawa)
 1931 Robertson Road,
 Ottawa, Ontario
 K2E 7Y1
 Attention: Ms. Gabrielle Marcotte
 PO#:
 Invoice to: Golder Associates Ltd

Report Number: 1816326
 Date Submitted: 2018-09-10
 Date Reported: 2018-09-13
 Project: 1662565/1310
 COC #: 835566

Lab I.D. 1386358
 Sample Matrix Soil
 Sample Type
 Sampling Date 2018-08-15
 Sample I.D. 18-3102 SA4 /0-12

Group	Analyte	MRL	Units	Guideline	
Anions	Cl	0.002	%		0.107
	SO4	0.01	%		0.02
General Chemistry	Electrical Conductivity	0.05	mS/cm		2.02
	pH	2.00			8.11
	Resistivity	1	ohm-cm		495

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 E

Site Photographs



Photograph 1: Looking west towards culvert inlet



Photograph 2: Looking east towards culvert outlet



Photograph 3: Looking upstream from culvert inlet



Photograph 4: Looking downstream from culvert outlet

APPENDIX F

Special Provision – Pipe Installation by Trenchless Method

CONSTRUCTION SPECIFICATION FOR THE INSTALLATION OF PIPES BY TRENCHLESS METHODS

TABLE OF CONTENTS

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

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

2.0 REFERENCES

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

Ontario Provincial Standard Specifications, General

OPSS 180 Management of Disposal of Excess Material

Ontario Provincial Standard Specifications, Construction

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

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

Ontario Provincial Standard Specifications, Material

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

CSA Standards

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

American Society for Testing and Materials (ASTM) International Standards

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Reaming means a process for enlarging the bore path

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

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

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

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

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

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

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

Trenchless Installation means an underground method of constructing a passage open at both ends that

involves installing a pipe product by auger jack & boring, pipe ramming, horizontal directional drilling, or tunnelling.

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

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

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

4.0 DESIGN AND SUBMISSION REQUIREMENTS

4.01 Design

4.01.01 General

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

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

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

4.02 Submission Requirements

4.02.01 Qualifications

At least two weeks prior to construction, the names 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' 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' experience on projects with similar scope and complexity

4.02.01.03 Design Engineer

The Design Engineer shall have a minimum of five years' 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' 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 two pipe diameters 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. 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 should be anticipated in 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 obstruction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered.

7.01.14 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.

7.01.15 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 Instrumentation and Monitoring program shall be project specific.

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, supply and installation of pipe liners, settlement instrumentation and monitoring, site restoration, and all other work necessary to complete the installation as specified.

Payment for the pipe installed inside the pipe liner shall be paid separately under the appropriate tender items.

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.

Payment for removal of boulders exceeding Boulder Volume Ratios (BVR) and Boulder Number Ratio (BNR) shall be by Time and Material.

A Foundation Engineering Specialist shall be retained by the Contract Administrator to assist the CA in ensuring that the Design and Submission Requirements are met and to ensure quality management of the work. Terms of Reference for the Foundation Engineering Specialist shall be provided by the Foundations Office and finalized in collaboration with the Regional Operations.



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