REPORT

Foundation Investigation and Design

Proposed Culvert Replacement, Station 11+540, Highway 60
Sinclair Township, Ontario
G.W.P 5333-11-00, (DB-2017-5005)

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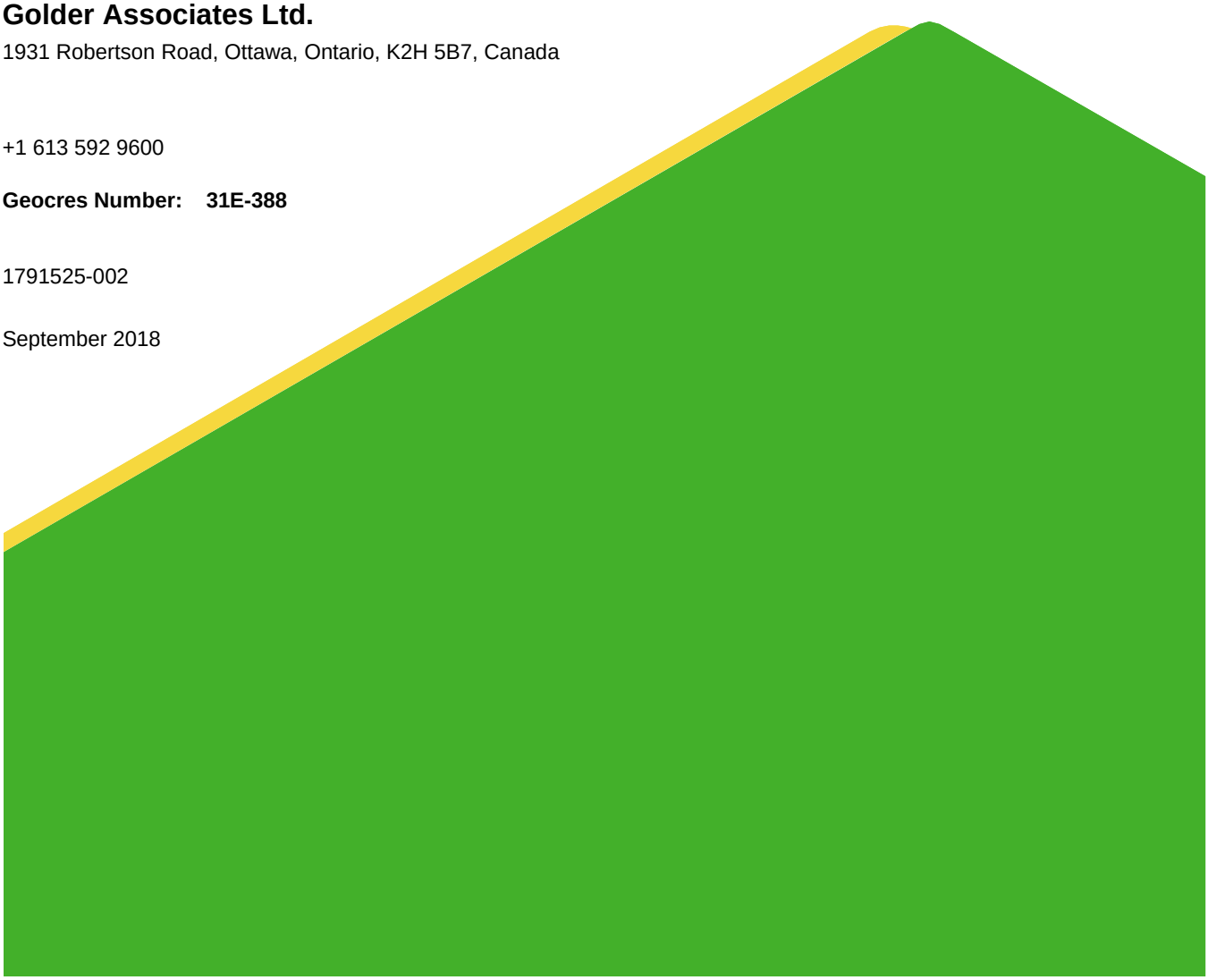

Distribution List

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PART A

Foundation Investigation Report
Proposed Culvert Replacement
Station 11+540, Highway 60
Sinclair Township, Ontario
DB-2017-5005

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by R.W. Tomlinson Limited (Tomlinson) to provide geotechnical investigation and engineering services to the design-build team, relating to the proposed replacement of an existing culvert, using trenchless methods in the Township of Sinclair, Ontario (DB-2017-5005).

The purpose of the investigation is to evaluate the subsurface soil and groundwater conditions along the proposed culvert alignment by means of advancing a limited number of test holes. Specifically, the geotechnical investigation consists of borings, test pit excavations, soil and rock sampling, borehole / test pit logging, and field and laboratory testing. Based on our interpretation of the findings of the investigation, this report provides an assessment of potential geotechnical issues and geotechnical engineering recommendations for the trenchless installation of the proposed culvert. It is noted that a Preliminary Foundation Investigation and Design Report was previously completed by others, as referenced in Section 3.1.

The terms of reference and scope of work for the geotechnical investigation are outlined in MTO's Request for Proposals (RFP) dated November 8, 2017. This report has been completed in general accordance with the RFP.

2.0 SITE DESCRIPTION

It is our understanding that an existing Corrugated Steel Pipe (CSP) culvert (Culvert No. 43) is to be replaced, as identified by the Ministry of Transportation, Ontario (MTO). MTO. The existing culvert is located perpendicular to Highway 60, about 1.3 km east of the intersection of Highway 60 and Harp Lake Road in the Township of Chaffey, Ontario. The center of the existing culvert is located at chainage 11+540 of the Highway 60 alignment as shown on Drawing 1.

The existing culvert is 1520 mm in diameter and is about 53 m in length and the existing inverts are at about Elevations 289.7 m and 288.4 m, at the inlet (east) and outlet (west) ends, respectively. The date of construction of the culvert is unknown. An unnamed creek flows through the existing culvert perpendicular to Highway 60 in an east to west orientation.

In the site area, Highway 60 is a 2 lane, undivided highway, running in a north-south direction. The maximum height of the existing embankment at the culvert location is about 10 m and the existing pavement grade of Highway 60 at the culvert location is at about Elevation 298.8 m. The existing embankment side slopes are formed at about 1.6 to 3.6 horizontal to 1 vertical (1.6 to 3.6H:1V).

The new culvert is proposed to be a concrete pipe having an inside diameter of approximately 1500 mm. We understand that the new culvert will be installed to the north of and parallel to the existing culvert, while maintaining the same inlet and outlet invert elevations as the existing culvert. Due to the significant depth of cover and the potential for substantial disruption to traffic, trenchless construction methods have been selected by the Contractor for the installation of the culvert.

3.0 INVESTIGATION PROCEDURE

3.1 Previous Investigation

A preliminary foundation investigation was previously carried out for this project by LVM-Merlex (now Englobe Corp.) on behalf of the MTO. The results of that investigation were provided in a report titled "*Final Preliminary Foundation Investigation and Design Report, Culvert Replacement, Highway 60, Station 11+540 - Township of Sinclair, GWP 5333-11-00, Ref. No. 14/07/14083-F4, Geocres No. 31E-350*," dated April 22, 2015.

Three boreholes were advanced by LVM-Merlex as part of the preliminary investigation at this site in 2014. The borehole locations including MTM NAD83 northing and easting coordinates and ground surface elevations referenced to Geodetic datum are summarized below.

Borehole Number	Borehole Location	Northing (m)	Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)	Piezometer/ Monitoring Well
BH 1	Inlet Side	5024782.9	335957.9	290.7	5.0	Yes
BH 2	Outlet Side	5024755.5	335911.0	289.1	5.5	None
BH 3	Midspan	5024767.4	335927.7	298.8	16.3	Yes

3.2 Current Investigation

A site specific geotechnical investigation for the proposed culvert was carried out by Golder between August 14 and 16, 2018. During this period, five boreholes (18-102, 18-103, 18-103A, 18-103B & 18-103C) and two test pits (18-108A & 18-108B) were advanced to depths ranging from 1.6 to 13.1 m below ground surface. The borehole and test pit locations are shown on Drawing 1. The Records of Borehole, Drillhole and Test Pit Sheets from the current investigation are provided in Appendix A. Lists of abbreviations and symbols as well as lithological and geotechnical rock description terminology are also provided in this Appendix to assist in the interpretation of the borehole records.

The boreholes were advanced using 210 mm outside diameter continuous-flight hollow-stem augering, casing and wash boring and rock coring using a truck-mounted drill rig (supplied and operated by Marathon Drilling Co. Ltd. of Ottawa, Ontario) fitted with capability for Standard Penetration Testing (SPT).

Continuous soil samples were obtained within the tunnel horizon, using a 50 mm outside and 35 mm inside diameter split spoon sampler. The sampler is driven by an automatic hammer, in accordance with the SPT procedures, as specified in ASTM D1586. Note that the split spoon samplers used in the investigation limit the maximum particle size that can be sampled and tested to about 40 mm. Therefore, particles or objects that may exist within the soils that are larger than this dimension would not be sampled or represented in the grain size distributions (i.e., coarse gravel, cobbles and boulders). The results of the in-situ field tests (i.e. SPT ‘N’ values) as presented on the Record of Borehole sheets and in Section 4.2 are uncorrected. Note that Boreholes 18-103A, 18-103B & 18-103C were advanced for the sole purpose of confirming the bedrock level at the site and thus, no soil sampling was performed in these boreholes.

Where practical refusal to augering was encountered due to the presence of possible bedrock, diamond core drilling with an ‘NQ’ size diamond bit was used to prove bedrock. The bedrock where encountered, was cored to depths ranging from 0.5 to 3.0 m below bedrock surface.

Test pits 18-108A and 18-108B were advanced within the proposed entry pit (outlet) area and at the toed of the existing embankment slope using a truck mounted hydraulic excavator supplied and operated by Tomlinson. The test pits were advanced to depths of about 1.6 m to 2.0 m below ground surface.

The fieldwork was supervised on a full-time basis by a member of Golder’s technical staff who located the boreholes and test pits in the field, directed the drilling, excavating and sampling operations, logged the boreholes and test pits, and took custody of the samples retrieved. The groundwater conditions and water levels in the open boreholes were observed during and immediately following drilling operations. The groundwater seepage conditions in the test pits were also observed during the short time they remained open.

The recovered soil samples were identified visually and select samples were subjected to a laboratory testing program consisting of natural moisture content testing and gradation analyses in accordance with MTO LS and/or ASTM Standards, as appropriate. The results of this testing program are shown on the Record of Borehole Sheets in Appendix A as well as graphically in Appendix B.

Upon completion of drilling, the boreholes were backfilled with a mixture of bentonite and auger cuttings in general accordance with the Ontario Regulation 903 (as amended). The test pits were backfilled and nominally compacted using excavator bucket upon completion of excavating and sampling. The site conditions were restored following completion of the fieldwork.

The ground surface elevations at the test hole locations were surveyed by McIntosh Perry Consulting Engineers Ltd. using a Trimble GPS unit. The borehole and test pit locations, including MTM NAD83 northing and easting coordinates and ground surface elevations referenced to Geodetic datum, are summarized in the following table and are shown on Drawing 1.

Test hole Number	Type	Test Hole Location	Northing (m)	Easting (m)	Ground Surface Elevation (m)	Test Hole Depth (m)	Piezometer/ Monitoring Well
18-102	Borehole	Inlet side	5024787.8	335936.4	296.3	10.8	None
18-103	Borehole	Mid span	5024793.4	335921.9	298.4	13.1	None
18-103A	Borehole	Mid span	5024783.4	335927.1	298.5	4.9	None
18-103B	Borehole	Mid span	5024782.3	335927.8	298.5	4.6	None
18-103C	Borehole	Mid span	5024779.4	335929.9	298.6	13.1	None
18-108A	Test Pit	Entry pit	5024757.7	335910.4	289.7	2.0	Not Applicable
18-108B	Test Pit	Entry pit	5024761.5	335911.8	290.9	1.6	Not Applicable

4.0 SITE GEOLOGY AND STRATIGRAPHY

4.1 Regional Geological Conditions

As delineated in *The Physiography of Southern Ontario*[1], the site lies within the physiographic region known as the Mount Elgin Ridges. Surficial geologic mapping in the vicinity of the site indicates silt and clay, with minor sand and gravel bordering on fine textured glaciolacustrine deposits[2]. Bedrock in this region consists of siliceous crystalline migmatitic rocks and gneisses.

4.2 Site Stratigraphy

Details of the subsurface soil and groundwater conditions encountered in the test holes advanced as part of the current investigation are shown on the Record of Borehole, Drillhole and Test Pit sheets contained in Appendix A. The results of the geotechnical laboratory testing carried out as part of the current investigation are included in Appendix B. The Record of Borehole sheets and lab testing results from the previous investigation are presented in Appendices C and D, respectively. Photographs of the test pits from the current investigation are provided in Appendix E.

[1] Chapman, L.J. and D.F. Putnam. *The Physiography of Southern Ontario*, Ontario Geological Survey Special Volume 2, Third Edition, 1984. Accompanied by Map P.2715, Scale 1:600,000.
[2] Surficial Geology of Southern Ontario, Ontario Geological Survey, 2003.

An interpreted soil stratigraphy section projected along the centreline of the existing trenchless alignment is shown on Drawing 1. Note that the stratigraphic boundaries shown on the Record of Borehole and Test Pit 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 and test pit locations.

The following is a summarized account of the subsurface conditions encountered in the test holes, followed by more detailed descriptions of the major soil strata and groundwater conditions in the following sub-sections.

In general, the subsurface conditions at the site consist of granular embankment fill, overlying non-cohesive deposits of sand to sand and gravel to sandy gravel. The fill and native deposits contain cobbles and boulders and/or rockfill. The overburden soils are underlain by gneiss bedrock. The groundwater level is approximately at the creek level.

4.2.1 Pavement Structure

The pavement structure of the highway, encountered at the ground surface at Elevation 298.8 m, was penetrated in Borehole 3 and consisted of approximately 40 mm of asphalt underlain by about 270 mm of crushed gravel. A separate 50 mm thick layer of asphalt was also encountered at a depth of 1.8 m below ground surface (Elevation 297.0 m) in this borehole.

4.2.2 Embankment Fill

Embankment fill was encountered in all boreholes and test pits except for Boreholes 1 and 2 and was fully penetrated to depths ranging from 6.1 to 10.2 m below ground surface. The base of the fill, where fully penetrated ranges from Elevation 288.6 m to 290.3 m and the thickness ranges from 6.1 m to 10.2 m.

The fill is variable in composition, consisting of non-cohesive silty sand, sand, gravelly sand, sand and gravel as well as cohesive clayey silt and clayey silt and sand, mixed with rock fill. A total of four boulders were encountered and cored within the fill in Boreholes 18-102 and 18-103C. Other instances of augers grinding or SPT sampler that did not penetrate the full sample length are also indicative of the presence of cobbles, boulders or rock fill. Boreholes 18-103A and 18-103B were terminated prematurely within the embankment fill due to auger refusal on inferred boulders. Cobbles and boulders ranging in size from 300 mm to 800 mm were encountered in Test Pits 18-108A and 18-108B.

The SPT ‘N’ values measured within the non-cohesive fill range from 5 to 66 blows per 0.3 m of penetration, indicating a loose to very dense compactness condition, but were generally compact to very dense. One SPT ‘N’ value of 6 blows per 0.3 m of penetration was obtained in the cohesive clayey silt fill, indicating a firm consistency.

The results of grain size distribution tests carried out by LVM-Merlex on four samples obtained from the embankment fill are provided on Figure L-1 in Appendix B. The measured water contents of samples from the fill ranged from about 3 to 20 percent.

4.2.3 Sand to Sand and Gravel

A deposit of sand to sand and gravel was encountered in all boreholes sampled, ranging in thickness from about 1.3 m to 4.1 m. The surface of this deposit was generally encountered below the embankment fill, between Elevation 288.6 m and 290.3 m. The deposit extends to depths ranging from 2.0 to 13.3 m below ground surface (Elevations 285.6 m to 288.7 m).

This deposit generally consists of sand, some gravel to gravelly, sandy gravel and sand and gravel and contained some silt to silty and trace to some clay in some samples. Three boulders were encountered and cored within this deposit in Borehole 18-102 ranging in size from 450 mm to 750 mm. Other instances of augers grinding or SPT

sampler that did not penetrate the full sample length are also indicative of the presence of cobbles and boulders, as noted in Boreholes 1 and 18-103. Cobble size rock pieces were also noted in Borehole 2.

The SPT 'N' values measured in the sand to sand and gravel deposit range from 3 blows to 72 blows per 0.3 m of penetration, indicating a very loose to very dense compactness condition, but generally dense to very dense.

The results of grain size distribution tests carried out by Golder on three samples obtained from the sand to sand and gravel deposit are provided on Figures B1 to B3 in Appendix B. Grain size distribution test results carried out by LVM-Merlex on four samples obtained from the deposit are provided on Figures L-2 and L-3 in Appendix D. The natural water content measured on samples of the sand to sand and gravel deposit range from about 7 to 32 percent.

4.2.4 Organic Silty Sand

A 0.7 m thick deposit of organic silty sand was encountered at ground surface in Borehole at Elevation 290.7 m.

One SPT 'N' value of 1 blow per 0.3 m of penetration was measured in this deposit, indicating a very loose compactness condition. The measured natural water content of a sample from this deposit is about 49 percent.

4.2.5 Bedrock

Bedrock was encountered beneath the sand to sand and gravel deposits in Boreholes 18-102, 18-103, 18-103C, 1, 2 and 3 and cored to depths ranging from 0.5 to 3.0 m below bedrock surface. The retrieved core is described as grey, coarse grained, slightly weathered to fresh, medium strong, gneiss bedrock, as presented on the borehole records.

The following table summarizes the bedrock surface depths, elevations and Rock Quality Designation (RQD) values for each borehole that encountered bedrock during both the current and previous investigations.

Borehole Number	Existing Ground Surface Elevation (m)	Depth to Bedrock (m)	Bedrock Surface Elevation (m)	Rock Quality Designation (RQD)
18-102	296.3	9.8	286.6	100%
18-103	298.4	10.0	288.4	61% - 75%
18-103C	298.6	12.6	285.5	96%
BH 1	290.7	2.0	288.7	53% - 73%
BH 2	289.1	2.2	286.9	75% - 82%
BH 3	298.8	13.3	285.6	95% - 96%

The RQD values measured on the recovered core samples range from about 53 to 100 percent, indicating fair to excellent quality rock. As evident in the table, varying bedrock depths should be expected across the site.

4.2.6 Groundwater Conditions

The groundwater conditions were observed in the open boreholes and test pits during and immediately following the drilling/excavating operations and are shown on the borehole and test pit records. Unstabilized water levels ranging from at ground surface to 9.1 m below ground surface (Elevations 289.3 m to 290.7 m) were measured in Boreholes 1, 18-102 and 18-103, although these levels may be influenced by addition of water for drilling/coring. No valid water level was obtained in Borehole 18-103C due to coring and Boreholes 18-103A and 18-103B were dry upon completion of drilling and did not penetrate through the fill.

The groundwater depths and elevations measured in the piezometers installed in Boreholes 1 and 3 during the previous investigation are summarized in the table below.

Borehole/ Well ID	Depth (m)	Elevation (m)	Date
BH 1	0.0	290.7	November 7, 2014
BH 3	8.6	290.2	August 26, 2014

At the time of the current investigation in August 2018, the water level in the creek was measured to be at approximately Elevations 290.8 m and 288.3 m, at the inlet (east) side and outlet (west) side of the culvert, respectively. Similar creek water levels (approximately Elevations 290 m and 288 m at the inlet and outlet sides, respectively) were measured by LVM-Merlex during the previous investigation in November 2014. It should be noted the unstabilized groundwater levels appear to generally coincide with the creek level.

It should be noted that groundwater levels are subject to seasonal fluctuations and precipitation events and are expected to be higher during wet seasons and sustained periods of precipitation.

5.0 CLOSURE

This Foundation Investigation Report was prepared by Ms. Mo'oud Nasr, P.Eng., and the technical aspects were reviewed by Ms. Sarah E. M. Poot, P.Eng., a senior geotechnical engineer and Associate of Golder. Mr. William (Bill) Cavers, P.Eng., Golder's MTO Designated Tunneling Contact for this project, conducted an independent quality control review and audit of the report.

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https://golderassociates.sharepoint.com/sites/21813g/deliverables/rpt-002 culvert 11+540/final/1791525-002-r-rev0-culvert 11+540-september2018.docx

PART B

Foundation Design Report
Proposed Culvert Replacement
Station 11+540, Highway 60
Sinclair Township, Ontario
DB-2017-5005

6.0 DISCUSSION

6.1 General

This section of the report provides engineering recommendations for the proposed trenchless installation of a new concrete pipe culvert undercrossing Highway 60, located at approximate Station 11+540, as part of the Design Build Contract DB-2017-5005. The following details summarize our current understanding of the proposed works:

- Trenchless construction methods will be used to install the new pipe along an alignment north of and parallel to the existing culvert. This method of installation will minimize traffic disruptions along Highway 60;
- The pipe to be installed is a Class 140-D reinforced concrete jacking pipe, having an inside diameter of approximately 1500 mm and length of 52.2 m; and,
- The invert levels (i.e. inside of the concrete pipe) of the new pipe will be at about Elevation 289.7 m and 288.4 m, at the inlet (east) and outlet (west) side, respectively.

This work is being carried out as part of a design-build assignment, with the team consisting of:

- R.W. Tomlinson Ltd. – General/Prime contractor
- McIntosh Perry Consulting Engineers – Designer
- Marathon Drilling Co. Ltd. – Trenchless contractor

We note that the discussion and recommendations presented in this report are based on our understanding of the project, consultations with the design-build team, and our interpretation of the factual data obtained from the current and previous subsurface investigations at the site.

6.2 Anticipated Ground Behaviour

The anticipated soil conditions within the proposed tunnel horizon consist of loose to dense sand to silty sand to sandy silt embankment fill, firm clayey silt to silt embankment fill, as well as native dense to very dense silty sand to silty sand and gravel. Cobbles and boulders were encountered within the fill and native soils.

It is expected that the groundwater level in the overburden deposits and embankment fill material will likely be coincident with the creek water levels. This conclusion appears consistent with the stabilized and unstabilized open borehole groundwater level observations made in the boreholes, at the time of the previous and current investigations.

The Terzaghi 'Tunnelman's Ground Classification System', as reported in Heuer (1974)[3], may be used to classify the anticipated strata that the tunnel would extend through. The System is commonly used in trenchless applications to describe the potential behaviour of an unsupported tunnel face during excavation by using qualitative stand-up time criteria. Stand-up time is defined as the time before the exposed soils will ravel, run or flow. Based on this system, the ground is classified into six principal categories: firm, slow raveling, fast raveling, squeezing, running, flowing and swelling. The ground behaviour above and below the groundwater table is also differentiated in this method.

[3] Heuer, R. 1974. *Important Ground Parameters in Soft Found Tunnelling.* Subsurface Exploration for Underground Excavation in Heavy Construction, New England College, Henniker, NH. New York, ASCE, pp.41-55

The Tunnelman's Ground Classification System has been adopted to provide an objective evaluation of the anticipated ground behaviour at the project site and is described below:

- **Cohesive embankment fill above the groundwater level**: The cohesive clayey silt to silt embankment fill may be classified as 'firm' ground above the water table.
- **Non-Cohesive embankment fill above the groundwater level**: These materials may exhibit some apparent cohesion due to the weak suction forces which can exist between the soil particles in a moist/unsaturated state (particularly for siltier zones with relatively high 'fines' content and for zones immediately above the groundwater level). The embankment fill would in this case have some limited stand-up time and may be classified as 'slow raveling'. Where more gravelly or sandy zones are encountered, the fill material would behave as 'running' ground.
- **Native sand to sand and gravel (silty) and non-cohesive embankment fill below the groundwater level**: When fully saturated, this material may be classified as 'flowing' ground, potentially having very little stand-up time. This would particularly be the case in areas where sandy/gravelly zones are encountered.

Based on the above assessment, tunneling through mixed-face conditions of firm, slow raveling and running/flowing ground should be expected, depending on the actual water table at the time of boring. It is likely that the groundwater level is coincident with the creek level, likely to be in the lower third of the tunnel horizon (higher at the inlet and closer to the invert at the outlet). The presence of obstructions (i.e., cobbles and boulders) should also be considered by the contractor, as discussed further in Section 6.11.

In addition, it should be recognized that within embankment fill materials, there can be considerable variation in the fines content, leading to significant variation in the anticipated 'stand-up' time. For this reason, it is considered appropriate to assume that all fill material below the groundwater level, may potentially behave as flowing ground.

6.3 Installation Method and Feasibility

It is understood that the design-build team's preferred method of culvert installation is pipe jacking, using a non-slurry Tunnel Boring Machine (TBM). Installation with this method involves excavating the soil using a rotating cutter head, working within a shield, with the tunnel muck conveyed to the launching pit using a system of auger, conveyor, or buggies.

As a general criterion for tunneling to be feasible, and to reduce the risk of subsidence or heave, tunneling installations require minimum levels of overburden cover. As the overburden cover decreases, the risk of concentrated subsidence or heave increases, as does the risk of extreme events such as sinkholes at the ground surface. In Ontario, the general practice is to maintain a depth of cover equivalent to 2 to 3 tunnel diameters. For this project, there is sufficient cover along the proposed culvert alignment for pipe jacking to be feasible from a geometric/cover perspective. An exception exists in the immediate area of the inlet and outlet; however, the cover becomes less critical at these locations. The contractor may need to place temporary additional material over the ditch areas nearest the entry/exit pits to temporarily provide additional cover.

An advantage of pipe jacking with a non-slurry TBM is that it provides for the installation of the rigid and impervious ground support immediately behind the tunneling shield. It also allows direct access to the ground being tunneled, allowing for inspection and manual removal of obstructions, if encountered. However, a particular drawback in tunneling with this method is the risk of flowing ground conditions occurring, if groundwater is present above the tunnel invert level, thereby creating an unsupported tunnel face. Therefore, maintaining face stability is key in controlling ground movements for this method.

Based on the existing cover and in view of the anticipated ground conditions at the site, it is considered that pipe jacking, using a non-slurry TBM is likely to be feasible for the proposed trenchless installation. This assumes that the face stability and tunnel support recommendations provided in this report (Sections 6.4 and 6.5) are fully implemented during the tunneling operations. The settlement instrumentation and monitoring program outlined in Section 6.8 must also be implemented, as per MTO requirements.

6.4 Face Stability

The cohesive embankment fill materials, if excavated during the tunneling operation are expected to behave as firm ground. However, the non-cohesive native deposits and embankment fill soils may behave as slow raveling/running ground (above the water table) or flowing ground (below the water table), if exposed. These non-cohesive soils are expected to be encountered across the full tunnel length under the highway.

To maintain face stability and minimize ground movements, the groundwater should be lowered to below the tunnel invert level along the full alignment so that the soils exposed on the working face will have a longer stand-up time. The suitable season for tunneling for this project is considered to be winter, when drier months and a lower groundwater table may be anticipated. Further, creek water should be diverted away from the proposed bore location.

It is also strongly recommended that boring operations continue non-stop once started (24 hours per day, 7 days per week). If it is necessary to stop tunneling operations for any reason, the face should be completely supported by a bulkhead which could consist of breasting boards. Such face support should be pre-cut and assembled prior to the start of tunneling so that it can be readily installed, if required. Further, filter fabric, straw and other packing materials should be available on site to contain any localized occurrences of flowing ground.

6.5 Tunnel Support

The proposed concrete pipe must be designed to accommodate the hoop stress from the weight of the overlying soils plus the jacking forces, which develop as a result of friction along the pipe. The following parameters may be used in assessing the hoop stresses acting upon the pipe:

Soil Type	Unit Weight (kN/m^3)	Drained Shear Strength Parameters	
		Effective Cohesion (kPa)	Effective Friction Angle (degrees)
Embankment Fill (generally non-cohesive)	21	0	32

Since the culvert pipe will be jacked directly into place, it is recommended that the stresses on the pipe, and the adequacy of the proposed pipe to support the vertical/hoop load, be evaluated using the methods described in the Ontario Concrete Pipe Association's 'Concrete Pipe Design Manual' (and the associated software), using a 'bedding factor' appropriate to jacked pipe (for a non-grouted condition).

The jacking forces required to advance the pipe are dependent upon a number of factors directly related to construction equipment and methodology. This includes the following:

- The size of the over-cut between the shield and pipe;
- The alignment maintained during jacking;

- The rate of boring achieved;
- The use of lubricants and the timing of lubricant injection; and,
- The frequency and duration of stoppages during tunneling.

For these reasons and considering the natural variability of the ground, it is not possible to predict actual jacking forces prior to construction. However, assuming that lubrication will be injected through the pipe throughout the jacking operation and that the boring will be carried out on a continuous basis, it is expected that the unit jacking resistance on the surface area of the pipe will be in the range of 5 kPa to 15 kPa. Resistance at the shield face is expected to be within the range of 500 kN to 1,500 kN, assuming that the shield steel is less than 25 mm thick. Higher shield face resistance will be met where boulders are encountered.

Given the uncertainties in predicting jacking forces and the limitations on jacking forces imposed by the pipe strength, the following general recommendations are made:

- The pipe supplier should confirm that the proposed jacking pipe will not be overstressed by the anticipated jacking forces;
- Lubrication should be provided by means of bentonite injection at the shield and along the pipe itself, to reduce the frictional forces to acceptable levels;
- If the jacking is stopped, the frictional resistance to advancement of the pipe could increase significantly. To prevent this, the tunneling and pipe jacking should be a continuous operation. The length of any required stoppages, such as for equipment maintenance and/or removal of obstructions, should be minimized;
- A provision should be made for the installation of intermediate jacking stations along the pipe length; and,
- Jacking forces should be monitored throughout the tunneling operation, in relation to the length of pipe driven. This is to ensure that allowable pipe stresses are not exceeded and to determine if jacking from the intermediate jacking stations is necessary. The operators should be provided with a chart/guideline of the corresponding anticipated jacking force for various lengths of jacked pipe.

6.6 Grouting

The need for grouting around the pipe should be evaluated once jacking is complete. The amount of spoil removed during tunneling should be monitored during jacking to determine whether there is over-excavation occurring. If there is suspicion that over-excavation has occurred, and/or if the settlement monitoring indicates that the ground has settled, then a plan should be in-place for investigating for the presence of gaps/voids around the pipe and for filling them with grout.

6.7 Ground Settlements

The effects of stress relief at the tunnel face and partial closure of the over-cut between shield and pipe may result in settlement of the ground and overlying highway. Given the amount of cover between the crown of the tunnel and the highway, it is anticipated that ground surface settlement can be maintained at 15 mm or less, provided good tunneling procedures are followed, as outlined below:

- The measures to control face stability as described in Section 6.4 are implemented;
- The over-cut between the tunneling shield and the pipe is 12.5 mm (i.e. ½ inch) or less;

- Suitable lubricant is applied directly behind the shield to minimize friction between the pipe and the ground; and,
- The gap created between the soil and the pipe is grouted with cement grout at the completion of jacking. To achieve appropriate grouting, it is recommended that the spacing between grout ports around the circumference of the pipe, be limited to 2 m.

As per the MTO's requirements of this project, it is essential that a settlement monitoring program as described below be implemented during tunneling.

6.8 Instrumentation and Monitoring

As required by Section 7.06 of the 'Pipe Installation by Trenchless Method' NSSP for this project, and in accordance with MTO's "*Guidelines for Foundation Engineering – Tunneling Specialty for Corridor Encroachment Permit Application*", a settlement monitoring program will need to be implemented. This settlement monitoring program will serve to:

- Document the effects of tunneling on the overlying highway;
- Obtain prior warning of ground movements that could occur due to the construction methods and equipment or unforeseen ground conditions;
- Verify the Contractors compliance with the settlement limits imposed in the Contract; and,
- Allow adjustments to be made to the tunneling 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.

In brief, the settlement monitoring plan is to include the installation of surface settlement points and in-ground monitoring points. The surface settlement points shall be installed at the pavement/ground surface along the full length of the tunnel alignment as well as shoulders and side slopes. The settlement points shall be installed directly above the centreline at a maximum spacing of 5 m.

The in-ground monitoring points should consist of three sets of sleeved iron bar, with three monitors in each set, encased in a 50-70 mm PVC pipe. The in-ground monitoring points should be set on the highway shoulders, perpendicular to the alignment at a depth of 2.1 m below ground surface. A stick-up casing should be used and adequately protected from traffic. A sufficiently high marker should be placed adjacent to the casing if the bore takes place during winter conditions.

Monitoring of settlement instruments on this project is constrained by the potentially high traffic volume and the potentially limited periods during which access to the highway can be obtained. Typically on 2-lane highways, flagging could be used to read the monitoring points with short one-lane closures for this purpose. However, if it is desired to minimize traffic disruptions completely, a non-intrusive system for the surface monitoring points could be considered, such as by the use of a reflectorless total station, however an elevated platform is required to "see" the points, which may be difficult at this high fill embankment location. In both cases, winter road conditions, if applicable, may impact the points themselves and every effort should be made to ensure the points are installed to avoid being damaged by snow clearing equipment and to be made "accessible" for surveying (i.e. clear of ice). The equipment and procedures used to carry out the settlement monitoring must be capable of surveying the settlement point elevations to within $\pm$ 1 mm of the actual elevation.

The survey frequency of the monitoring program is to be as follows:

- Baseline readings: Three consecutive readings at least one week prior to tunnel construction.

- Construction readings:
  - Three sets of readings per day, provided settlements are below 'review' level.
  - Double that frequency if 'review' or 'alert' levels are reached.
- Post-construction readings: Weekly for a period of one month.

Additional readings may be required if excessive settlements are measured.

6.9 Shaft Excavations

The shafts for the entry and exit pits will be constructed in the low-lying areas adjacent to the inlet and outlet of the new culvert alignment. The shaft excavation depths are anticipated to be shallow extending to approximately 0.5 m below the culvert invert depth. The founding soil at this depth will generally consist of compact to dense sand/sand and gravel, below the groundwater level.

A concrete mud slab (working slab) or granular bedding will be required at the base of the shaft excavations to maintain the integrity of the base during construction by providing a trafficable excavation floor. This is provided that adequate groundwater controls are applied, as discussed in Section 6.10.

Excavation works must be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act (OHSA) and Regulations for Construction Projects. According to OHSA, the soil classification and corresponding excavation side slopes for the soils to be removed are provided below. Care must also be taken during excavation to ensure that adequate support is provided for any existing structures, roadways and underground services located adjacent to the excavations.

Soil Description	Above/Below Groundwater	OHSA Soil Type	Maximum Shaft Excavation Side Slope
Loose to very dense/firm embankment fill	Above	Type 3	1 Horizontal :1 Vertical
	Below	Type 4	3 Horizontal :1 Vertical
Very loose silty sand/sand	Above	Type 3	1 Horizontal :1 Vertical
	Below	Type 4	3 Horizontal :1 Vertical
Compact to dense sand/sand and gravel	Above	Type 2	1 Horizontal :1 Vertical
	Below	Type 3	1 Horizontal :1 Vertical

To maintain temporary excavation stability, excavated materials should be placed away from the edge of the excavation a distance equal to the depth of the excavation or greater. In addition, stockpiling of the material should be prohibited adjacent to the excavation to minimize surcharge loading near the excavation crest. Where sufficient space is not available to stockpile the excavated material at the site, off-site disposal of the excavated material intended for reuse would need to be arranged

If the open cut excavation side slopes noted in the table above cannot be accommodated (due to the proximity of the embankment and active highway lanes), then a temporary protection system (i.e., temporary excavation shoring) will be required. The shoring system could consist of braced soldier pile and lagging, braced sheet piles or potentially a slide rail system, designed by a Professional Engineer and including an assessment of the potential for basal heave. If shoring is implemented at the site, the requirements of OPSS.PROV 539 should be followed.

It is noted that some difficulty may be expected in excavating the pits and/or installation the temporary shoring system due to the likely presence of cobbles and boulders in the site area.

6.10 Groundwater Control

Based on an assessment of the groundwater conditions encountered at the entry and exit pits, the groundwater is generally interpreted to be near the creek water level or essentially at the ground surface.

Based on a shaft excavation depth of approximately 0.5 m below the culvert invert depth, the excavations are anticipated to extend to 0.4 m and 1.6 m below the groundwater level at the entry and exit pit locations, respectively. As such, it is anticipated that control of seepage for the entry pit shaft construction can be achieved by conventional pumping from sumps in oversize excavations, if the excavation base is within 0.6 m of the prevailing groundwater level at the time of construction. This dewatering can be achieved by gravity drainage and pumping from strategically placed and properly filtered sumps with side ditches.

For the exit pit shaft, additional groundwater control efforts may be required since the exit pit may be about 1.6 m below the creek water level. The design of the dewatering system should consider the sandy, potentially permeable, materials below the groundwater level and additional measures, such as multiple sumps excavated and dewatered in advance of the excavation, may be required.

The selection of a suitable dewatering system should also take into account water levels and creek flow conditions at the time of construction, as dewatering requirements will be impacted by water levels in the creek. The creek water should be diverted away from the bore, presumably within the existing culvert. The method used should not undermine any existing road embankment or adjacent side slopes. The provision of toe protection at side slopes during drawdown may be required to minimize sloughing and undercutting during dewatering. All dewatering operations should be carried out in accordance to OPSS.PROV 517, OPSS 518 and the OSHA. Water should not be discharged within 30 m of surface water or watercourses. Care should be taken at all times to ensure trenching operations adhere to OHSA requirements.

The actual rate of groundwater inflow to the excavations will depend on many factors including the contractor's schedule and rate of excavation, the size of the excavation, and the time of year at which the excavation is made. Also, there may be instances where significant volumes of precipitation, surface runoff and/or groundwater may collect in an open excavation and must be pumped out. Surface water runoff should be directed away from open excavations.

The combined rate of pumping from the entry and exist pits may exceed 50,000 L (50 m^3) per day. An Environment Activity Section Registry (EASR) registration is required for dewatering between 50,000 L/day and 400,000 L/day, and a Permit-to-Take-Water (PTTW) is required for dewatering greater than 400,000 L/day from the Ministry of Environment. A registration or application should be made as soon as possible to avoid construction delays. The design of the dewatering system for the excavations is the responsibility of the Contractor who is expected to retain dewatering specialists for this task, including permit application and supporting documentation.

6.11 Obstructions

Obstructions (i.e. cobbles and boulders) were encountered within the tunnel horizon in both the previous and current boreholes / test pits as well as exposed on the embankment side slopes. Therefore, it is anticipated that obstructions will be encountered during construction works for the tunnel and entry/exit pits. These potential obstructions may impact tunneling operations resulting in significant difficulties in advancing the bore, as well as excavations, elements of temporary protection systems and/or dewatering systems. The contractor must be prepared with suitable equipment to remove/penetrate through any obstructions that may be encountered during construction.

6.12 Erosion Protection

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

The need for (and design of) erosion protection at the culvert inlet and outlet (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 Ontario Provincial Standard Drawing OPSD 810.010.

7.0 CLOSURE

This Foundation Investigation Report was prepared by Ms. Mo'oud Nasr, P.Eng., and the technical aspects were reviewed by Ms. Sarah E. M. Poot, P.Eng., a senior geotechnical engineer and Associate of Golder. Mr. William (Bill) Cavers, P.Eng., Golder's MTO Designated Tunneling Contact for this project, conducted an independent quality control review and audit of the report.

Golder Associates Ltd.

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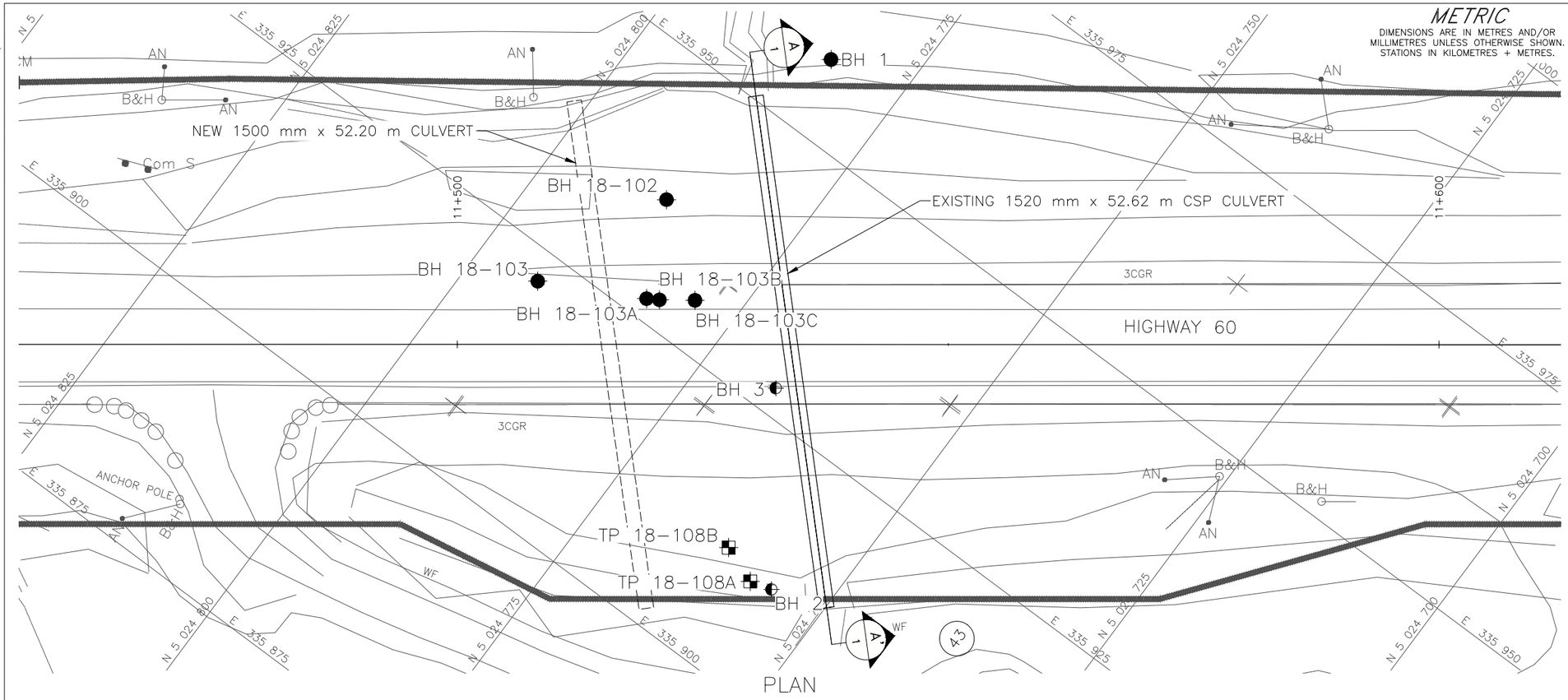
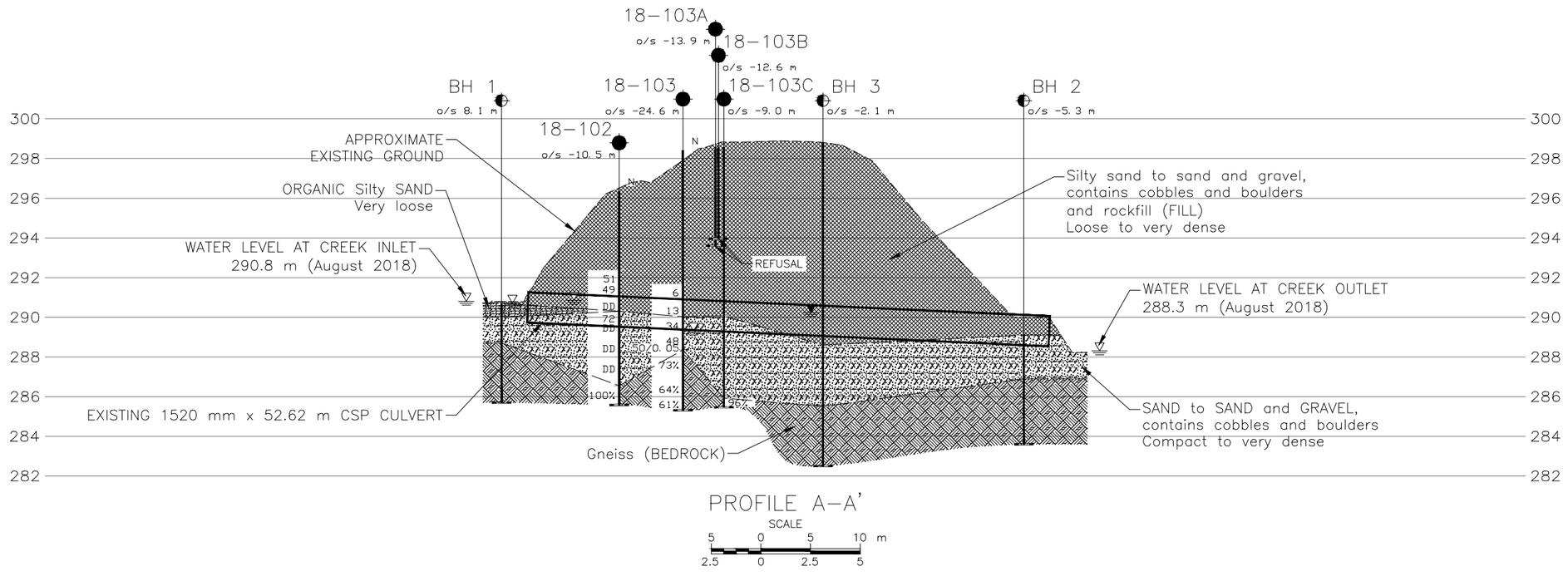
MN/SEMP/WC/mvrd
https://golderassociates.sharepoint.com/sites/21813g/deliverables/rpt-002 culvert 11+540/final/1791525-002-r-rev0-culvert 11+540-september2018.docx



PLAN

SCALE

5 0 5 10 m



PROFILE A–A'

SCALE

5 0 5 10 m

2.5 0 2.5 5

METRIC

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

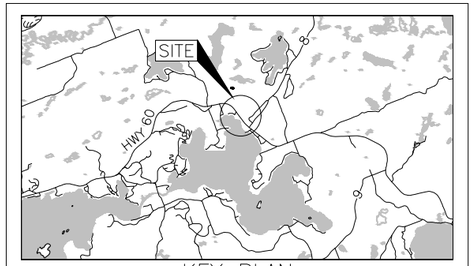
CONT No.

GWP No. 5333–11–00

HIGHWAY 60 CULVERT
AT STATION 11+540
LAT. 45.362181; LONG. –79.102609
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

GOLDER



KEY PLAN

SCALE

2 0 2 4 km

LEGEND

- Borehole – Current Investigation
- Test Pit – Current Investigation
- Borehole – Previous Investigation (Geocres No. 31E–350)
- N — Standard Penetration Test Value
- 16 — Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% — Rock Quality Designation (RQD)
- Stabilized WL in monitoring well
- WL upon completion of drilling

BOREHOLE/TEST PIT CO–ORDINATES (MTM ZONE 10)

No.	ELEVATION	NORTHING	EASTING
BH 18–102	296.3	5024787.8	335936.4
BH 18–103	298.4	5024793.4	335921.9
BH 18–103A	298.5	5024783.4	335927.1
BH 18–103B	298.5	5024782.3	335927.8
BH 18–103C	298.6	5024779.4	335929.9
TP 18–108A	289.7	5024757.7	335910.4
TP 18–108B	290.9	5024761.5	335911.8
BH 1	290.7	5024782.9	335957.9
BH 2	289.1	5024755.5	335911.0
BH 3	298.8	5024767.4	335927.7

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 McIntosh Perry, drawing file nos. PKP 17–7137–00A_020NEW.dwg and X–KP–17–7137 HWY 60_BASE.dwg, received JUL. 23, 2018.

NO.	DATE	BY	REVISION
.	.	.	.

Geocres No. 31E–388

HWY. 60	PROJECT NO. 1791525		DIST. NORTHEASTERN
SUBM'D. CK	CHKD. CK	DATE: 8/29/2018	SITE: .
DRAWN: JM	CHKD. FJH	APPD. FJH	DWG. 1

PLOT DATE: September 7, 2018
FILENAME: N:\Active\Spatial_MTO\Vway60\Vuntwine\99_PRO\1791525_Tomlinson_Foundations\40_PROD\0003_Foundations_Station 11+540\1791525-0003-BS-0001.dwg

APPENDIX A

List of Abbreviation and Symbols

Lithological and Geotechnical Rock Description Terminology

Record of Borehole and Drillhole Sheets - Current Investigation

LIST OF SYMBOLS

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

I. GENERAL

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

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

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

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

(a) Index Properties (continued)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

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

Notes: 1 $\tau = c' + \sigma' \tan \phi'$

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, 60º 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 cm^2 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.

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

Compactness Condition	N 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	c_u, s_u psf
Very soft	0 to 12	0 to 250
Firm Stiff	12 to 25	250 to 500
Very stiff	25 to 50	500 to 1,000
Hard	50 to 100	1,000 to 2,000
	100 to 200	2,000 to 4,000
	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.

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

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

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

JOINT OR FOLIATION SPACING

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

GRAIN SIZE

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

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

CORE CONDITION

Total Core Recovery (TCR)

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

Solid Core Recovery (SCR)

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

Rock Quality Designation (RQD)

The percentage of solid drill core, greater than 100 mm length, recovered at full diameter, 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^{o} 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
FLT Fault
SH Shear
VN Vein
FR Fracture
SY Stylolite
BD Bedding
FO Foliation
CO Contact
AXJ Axial Joint
KV Karstic Void
MB Mechanical Break

PL Planar
CU Curved
UN Undulating
IR Irregular
K Slickensided
PO Polished
SM Smooth
SR Slightly Rough
RO Rough
VR Very Rough

GOLDER

RECORD OF BOREHOLE No 18-102

SHEET 1 OF 3 **METRIC**

PROJECT 1791525

G.W.P. GWP 5333-11-00 LOCATION N 5024787.8; E 335936.4 MTM ZONE 10 (LAT. 45.362352; LONG. -79.102553) ORIGINATED BY CRG

DIST Northeastern HWY 60 BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem)/Wash Boring/Rotary Drill, HQ/NQ Core COMPILED BY JM

DATUM Geodetic DATE August 16, 2018 CHECKED BY CK

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
296.3	GROUND SURFACE										
0.0	(SM/SP) Silty sand to sand, some gravel to gravelly, contains cobbles and boulders (Fill) Light brown to dark brown Moist						296				
292.4							295				
4.0	(SP/SW) Sand, some gravel to gravelly, some silt, contains cobbles and boulders (FILL) Dense to very dense Brown Moist - Boulder encountered and cored between 5.1 and 6.1 m		1	SS	51		294				
			2	SS	49		293				
			2A	RC	DD	▽	292				
290.3							291				
6.1	(GW) Sandy GRAVEL, some silt, trace clay, contains cobbles and boulders Very dense Grey-brown Moist - Boulder encountered and cored between 6.6 and 7.0 m		3	SS	72		290		○		56 25 17 2
			4	RC	DD						
	- Boulder encountered and cored between 7.5 and 8.1 m		5	RC	DD		289				
	- Boulder encountered and cored between 8.4 and 9.1 m		6	RC	DD		288				
286.6							287				
9.8			1	RC	REC 100%						RQD = 100%

Continued Next Page

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

GOLDER

RECORD OF BOREHOLE No 18-102

SHEET 2 OF 3

METRIC

PROJECT 1791525

G.W.P. GWP 5333-11-00 LOCATION N 5024787.8; E 335936.4 MTM ZONE 10 (LAT. 45.362352; LONG. -79.102553) ORIGINATED BY CRG

DIST Northeastern HWY 60 BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem)/Wash Boring/Rotary Drill, HQ/NQ Core COMPILED BY JM

DATUM Geodetic DATE August 16, 2018 CHECKED BY CK

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (20 40 60 80 100): ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
	Gneiss (BEDROCK) Bedrock cored from depths 9.8 m to 10.8 m For bedrock coring details refer to Record of Drillhole 18-102		1	RC	REC 100%		286				RQD = 100%
285.6 10.8	END OF BOREHOLE										

NOTES:

1. Soil description above 4.0 m inferred from soil cuttings and resistance from casing advancement.

2. Water level in open borehole at a depth of 5.5 m below ground surface (Elev. 290.8 m). measured on August 16, 2018, but may be influenced by addition of water for drilling/coring.

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

GTA-MTO 001 N:\ACTIVE\SPATIAL_IMMTO\HWY60\HUNTSVILLE\02_DATA\GINT\1791525.GPJ GAL-GTA.GDT 9/6/18 JM

PROJECT: 1791525

RECORD OF DRILLHOLE: 18-102

SHEET 3 OF 3

LOCATION: N 5024787.8 ;E 335936.4

DRILLING DATE: August 16, 2018

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG:

DRILLING CONTRACTOR: Marathon Drilling

NOTE:
For abbreviations, symbols and descriptions refer to
LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. / DEPTH (m)	RUN No.	FLUSH RETURN	RECOVERY: TOTAL CORE % (80 60 40 20)	RECOVERY: SOLID CORE % (80 60 40 20)	R.Q.D. % (80 60 40 20)	FRACT. INDEX PER (5 10 15 20)	DISCONTINUITY DATA: DIP w.r.t. CORE AXIS (0 30 60 90)	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	Jr	Ja	HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-6} 10^{-5} 10^{-4} 10^{-3})	WEATHERING INDEX (W1 W2 W3 W4 W5 W6)	FEATURES
		BEDROCK SURFACE		286.55													
10	Rotary Drill / NQ Core	Gneiss (BEDROCK) Fresh Thinly to medium bedded Grey Fine grained Non-porous Medium strong		9.80	1	100											
				285.58													
		END OF DRILLHOLE		10.77													
11																	
12																	
13																	
14																	
15																	
16																	
17																	
18																	
19																	

DEPTH SCALE
1 : 50

GOLDER

LOGGED: CRG
CHECKED:

GOLDER

RECORD OF BOREHOLE No 18-103

SHEET 1 OF 3

METRIC

PROJECT 1791525

G.W.P. GWP 5333-11-00 LOCATION N 5024793.4; E 335921.9 MTM ZONE 10 (LAT. 45.362402; LONG. -79.102738) ORIGINATED BY CRG

DIST Northeastern HWY 60 BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem)/Rotary Drill, NQ Core COMPILED BY JM

DATUM Geodetic DATE August 15, 2018 CHECKED BY CK

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
298.4	GROUND SURFACE										
0.0	(SM/SP) Silty sand to sand, some gravel to gravelly, contains cobbles and boulders (Fill) Brown Moist						298				
							297				
							296				
							295				
							294				
							293				
291.7							292				
6.7	(ML) Clayey silt to silt (FILL) Firm Grey-brown Moist		1	SS	6						
290.9							291				
7.5	(SM/ML) Sandy silt to silty sand, contains sand seams (FILL) Compact Yellow to grey-brown Wet		2	SS	13						
290.0							290				
8.4	(SM/GM) Silty SAND and GRAVEL to Gravelly Silty SAND, contains cobbles and boulders Dense Grey-brown to brown Wet		3	SS	34	▽			○		32 44 21 3
			4	SS	48		289		○		21 51 24 4
			5	SS	50/0.05						

Continued Next Page

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

GOLDER

RECORD OF BOREHOLE No 18-103

SHEET 2 OF 3

METRIC

PROJECT 1791525

G.W.P. GWP 5333-11-00 LOCATION N 5024793.4; E 335921.9 MTM ZONE 10 (LAT. 45.362402; LONG. -79.102738) ORIGINATED BY CRG

DIST Northeastern HWY 60 BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem)/Rotary Drill, NQ Core COMPILED BY JM

DATUM Geodetic DATE August 15, 2018 CHECKED BY CK

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---							20 40 60 80 100	10 20 30		
288.4 10.1	Gneiss (BEDROCK) Bedrock cored from depths 10.1 m to 13.1 m For bedrock coring details refer to Record of Drillhole 18-103		1	RC	REC 87%		288				RQD = 75%
			2	RC	REC 89%		287				RQD = 64%
			3	RC	REC 91%		286				RQD = 61%
285.3 13.1	END OF BOREHOLE NOTES: 1. Soil description above 6.7 m inferred from auger cuttings and auger advancement. 2. Water level in open borehole at a depth of 9.1 m below ground surface (Elev. 289.3 m). measured on August 15, 2018, but may be influenced by addition of water for drilling/coring.										

$+^3, \times^3$: Numbers refer to Sensitivity $\circ^{3\%}$ STRAIN AT FAILURE

PROJECT: 1791525

RECORD OF DRILLHOLE: 18-103

SHEET 3 OF 3

LOCATION: N 5024793.4 ;E 335921.9

DRILLING DATE: August 15, 2018

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG:

DRILLING CONTRACTOR: Marathon Drilling

NOTE:
For abbreviations, symbols and descriptions refer to
LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. / DEPTH (m)	RUN No.	FLUSH RETURN	RECOVERY: TOTAL CORE %	RECOVERY: SOLID CORE %	R.Q.D. %	FRACT. INDEX PER	DISCONTINUITY DATA: DIP w.r.t. CORE AXIS	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	Jr	Ja	HYDRAULIC CONDUCTIVITY K, cm/sec	WEATH-ERING INDEX	FEATURES
		BEDROCK SURFACE		288.34													
11	Rotary Drill / NQ Core	Gneiss (BEDROCK) Slightly weathered to fresh Thinly to medium bedded Grey Fine grained Non-porous Strong		10.06	1	80-100											
12					2	0-100											
13				285.31	3	0											
		END OF DRILLHOLE		13.09													
14																	
15																	
16																	
17																	
18																	
19																	
20																	

DEPTH SCALE
1 : 50

GOLDER

LOGGED: CRG
CHECKED:

GOLDER

RECORD OF BOREHOLE No 18-103A

SHEET 1 OF 1

METRIC

PROJECT 1791525

G.W.P. GWP 5333-11-00 LOCATION N 5024783.4; E 335927.1 MTM ZONE 10 (LAT. 45.362313; LONG. -79.102672) ORIGINATED BY CRG

DIST Northeastern HWY 60 BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem) COMPILED BY JM

DATUM Geodetic DATE August 15, 2018 CHECKED BY CK

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
298.5	GROUND SURFACE										
0.0	(SM/SP) Silty sand to sand, some gravel, contains cobbles and boulders (Fill) Brown Moist						298				
							297				
							296				
							295				
							294				
293.6											
4.9	END OF BOREHOLE AUGER REFUSAL ON BOULDERS										

NOTES:

1. Borehole 18-103A was moved approximately 10 m from borehole 18-103.
2. Soil description inferred from soil cuttings and auger advancement.
3. Borehole dry on August 15, 2018.

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

GOLDER

RECORD OF BOREHOLE No 18-103B

SHEET 1 OF 1

METRIC

PROJECT 1791525

G.W.P. GWP 5333-11-00 LOCATION N 5024782.3; E 335927.8 MTM ZONE 10 (LAT. 45.362303; LONG. -79.102663) ORIGINATED BY CRG

DIST Northeastern HWY 60 BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem) COMPILED BY JM

DATUM Geodetic DATE August 15, 2018 CHECKED BY CK

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
298.5	GROUND SURFACE										
0.0	(SM/SP) Silty sand to sand, some gravel, contains cobbles and boulders (Fill) Brown Moist						298 297 296 295				
294.0							294				
4.6	END OF BOREHOLE AUGER REFUSAL ON BOULDERS NOTES: 1. Borehole 18-103B was moved approximately 1 m from borehole 18-103A. 2. Soil description inferred from soil cuttings and auger advancement. 3. Borehole dry on August 15, 2018.										

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

GOLDER

RECORD OF BOREHOLE No 18-103C

SHEET 1 OF 3

METRIC

PROJECT 1791525

G.W.P. GWP 5333-11-00 LOCATION N 5024779.4; E 335929.9 MTM ZONE 10 (LAT. 45.362276; LONG. -79.102637) ORIGINATED BY CRG

DIST Northeastern HWY 60 BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem)/Wash Boring/Rotary Drill, HQ/NQ Core COMPILED BY JM

DATUM Geodetic DATE August 16, 2018 CHECKED BY CK

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
298.6	GROUND SURFACE										
0.0	(SM/SP) Silty sand to sand, some gravel, contains cobbles and boulders (Fill) Brown Moist						298				
							297				
							296				
							295				
	- Boulder encountered and cored between 5.3 and 5.8 m						294				
							293				
	- Boulder encountered and cored between 6.7 and 7.2 m						292				
							291				
	- Boulder encountered and cored between 7.9 and 8.5 m										
290.1											
8.5	Probable Sand and Gravel						290				
							289				

Continued Next Page

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

GOLDER

RECORD OF BOREHOLE No 18-103C

SHEET 2 OF 3 **METRIC**

PROJECT 1791525

G.W.P. GWP 5333-11-00 LOCATION N 5024779.4; E 335929.9 MTM ZONE 10 (LAT. 45.362276; LONG. -79.102637) ORIGINATED BY CRG

DIST Northeastern HWY 60 BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem)/Wash Boring/Rotary Drill, HQ/NQ Core COMPILED BY JM

DATUM Geodetic DATE August 16, 2018 CHECKED BY CK

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---							20 40 60 80 100	10 20 30		
	Probable Sand and Gravel - Boulder encountered and cored between 10.7 and 11.0 m						288 287				
285.9 12.6	Gneiss (BEDROCK) Bedrock cored from depths 12.6 m to 13.1 m		1	RC	REC 98%		286				RQD = 96%
285.5 13.1	For bedrock coring details refer to Record of Drillhole 18-103C END OF BOREHOLE										

NOTES:

1. Borehole 18-103C was moved approximately 2 m from borehole 18-103B.

2. Soil description inferred from soil cuttings and auger advancement.

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

PROJECT: 1791525

RECORD OF DRILLHOLE: 18-103C

SHEET 3 OF 3

LOCATION: N 5024779.4 ;E 335929.9

DRILLING DATE: August 16, 2018

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG:

DRILLING CONTRACTOR: Marathon Drilling

NOTE:
For abbreviations, symbols and descriptions refer to
LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. / DEPTH (m)	RUN No.	FLUSH RETURN	RECOVERY: TOTAL CORE % (80 60 40 20)	RECOVERY: SOLID CORE % (80 60 40 20)	R.Q.D. % (80 60 40 20)	FRACT. INDEX PER (5 10 15 20)	DISCONTINUITY DATA: DIP w.r.t. CORE AXIS (0 30 60 90)	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	DISCONTINUITY DATA: Jr	DISCONTINUITY DATA: Ja	HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-6} 10^{-5} 10^{-4} 10^{-3})	WEATHERING INDEX (W1 W2 W3 W4 W5 W6)	FEATURES
		BEDROCK SURFACE		285.92													
13	Rotary Drill / NQ Core	Gneiss (BEDROCK) Fresh Thinly to medium bedded Grey Fine grained Non-porous Strong		12.64	1												
		END OF DRILLHOLE		285.46 13.10													
14																	
15																	
16																	
17																	
18																	
19																	
20																	
21																	
22																	

DEPTH SCALE
1 : 50

GOLDER

LOGGED: CRG
CHECKED:

GTA-RCK 031 N:\ACTIVE\SPATIAL_IMMTO\HWY60\HUNTSVILLE\02_DATA\GINT\1791525.GPJ GAL-MISS.GDT 9/6/18 JM

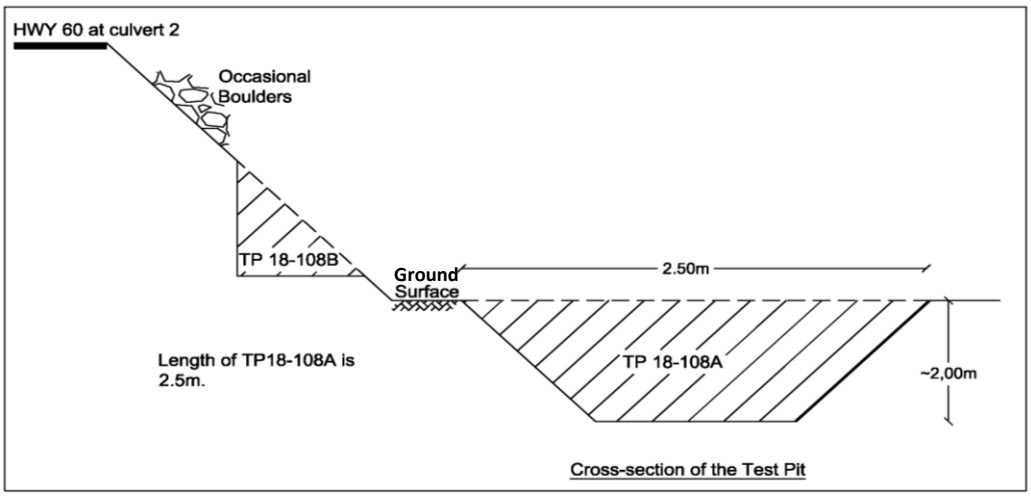
RECORD OF TEST PIT

GOLDER

1931 Robertson Rd,
Nepean, ON K2H 5B7
Téléphone: (613) 592-9600

Project No:	1791525	**Test Pit No:**	TP18-108A	
Project name:	MTO HWY 60 Design-Build	**Sub-contractor:**	R. W. Tomlinson Ltd.	
Northing/Easting:	5024757.7 / 335910.4 (MTM Zone 10)	**Equipment**	Kubota KX080 Excavator	
Latitude/Longitude:	45.3621, -79.1029	**Weather:** **Temperature:**	Sunny ~20°C	
Field Technicien/Engineer:	R.Goyal	**Reviewed by:**	F. Ghobrial	
Date:	14/08/2018	**Ground Surface Elevation:**	289.684	m (Geodetic)

Depth (metre)	Elevation (metre)	Visual Description (SYMBOL) GROUP NAME, description, other constituants, coulour, contamination, behaviour, moisture condition	Remarks
0.00	289.68	(SM/GM) Silty SAND and GRAVEL, contains cobbles, boulders and rootlets (FILL) Grey Wet	* Cobbles and boulders encountered throughout test pit. * Average size of boulders varies from about 30-80 cm. * Parts of the test pit were caving in. * ~5-10 cm of groundwater seeped in within 5 minutes of digging. * Seepage observed between depth of 1.5 - 2.0m
0.50	289.18		
1.00	288.68	*SAMPLE 1 from 1.0 m to 1.7 m*	
1.50	288.18		
2.00	287.68	End of Excavation	



Cross-section of the Test Pit

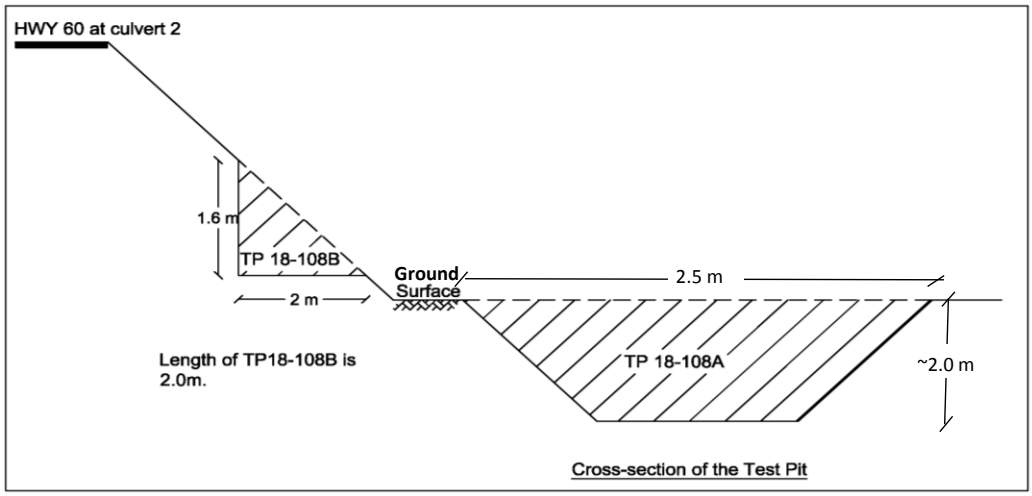
RECORD OF TEST PIT

GOLDER

1931 Robertson Rd,
Nepean, ON K2H 5B7
Téléphone: (613) 592-9600

Project No:	1791525	**Test Pit No:**	TP18-108B	
Project name:	MTO HWY 60 Design-Build	**Sub-contractor:**	R. W. Tomlinson Ltd.	
Northing/Easting:	5024761.5 / 335911.8 (MTM Zone 10)	**Equipment**	Kubota KX080 Excavator	
Latitude/Longitude:	45.3621, -79.1029	**Weather:** **Temperature:**	Sunny ~20°C	
Field Technicien/Engineer:	R. Goyal	**Reviewed by:**	F. Ghobrial	
Date:	14/08/2018	**Ground Surface Elevation:**	290.933	m (Geodetic)

Depth (metre)	Elevation (metre)	Visual Description (SYMBOL) GROUP NAME, description, other constituants, coulour, contamination, behaviour, moisture condition	Remarks
0.00	290.93	(ML) Clayey SILT with SAND, contains cobbles, boulders and rootlets (FILL) Grey-brown Wet	* Boulders less frequent than in TP18-108A * Average size of boulders varies from about 40-50 cm. * Parts of the test pit were caving in. * ~5 cm of groundwater seeped in within 5 minutes of digging.
0.50	290.43		
1.00	289.93	*SAMPLE 1 from 1.0 m to 1.6 m*	
1.50	289.43		
1.60	289.33	End of Excavation	
2.00	288.93		



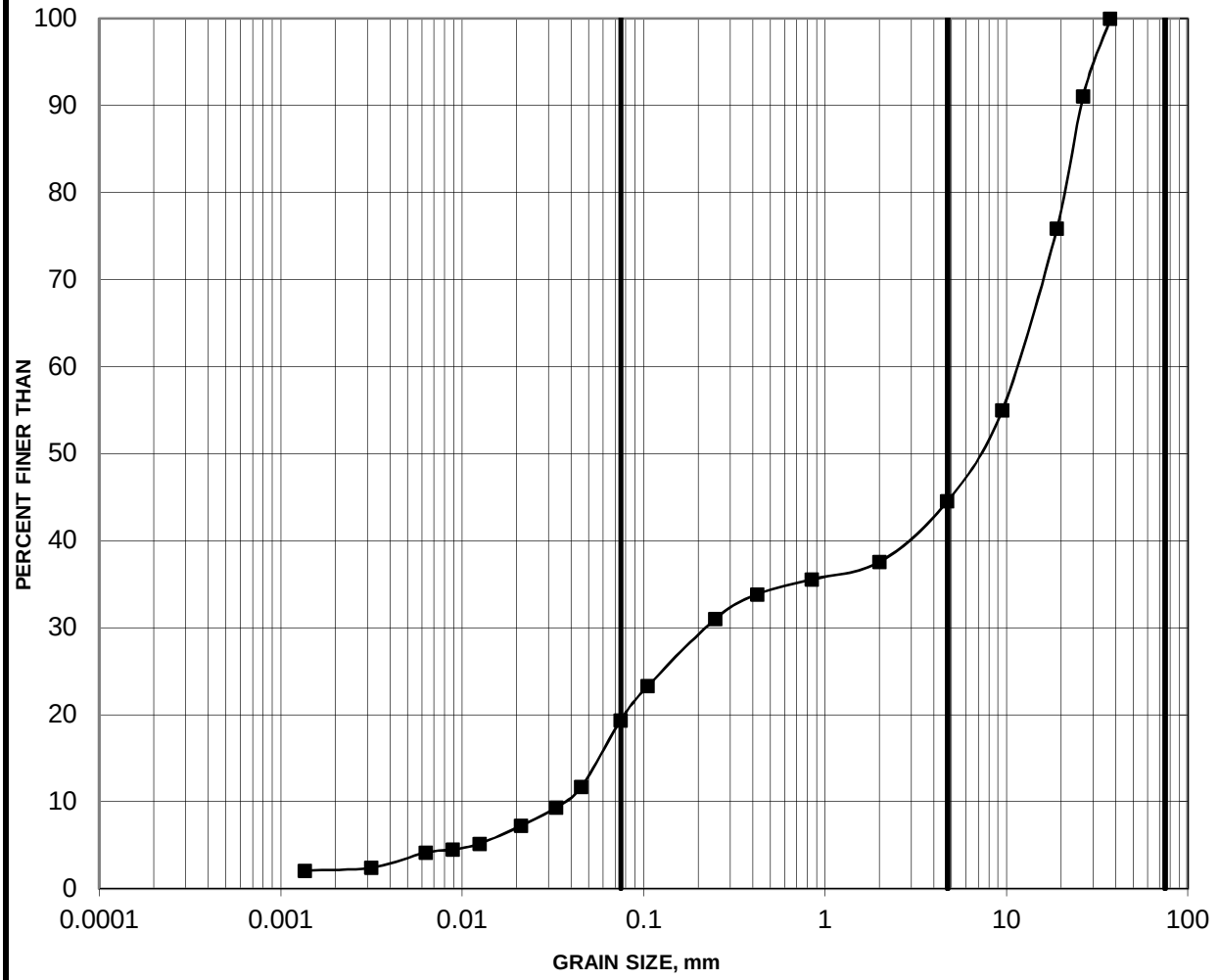
Cross-section of the Test Pit

APPENDIX B

Laboratory Test Results - Current Investigation

GRAIN SIZE DISTRIBUTION	FIGURE B1

SANDY GRAVEL



Borehole	Sample	Depth (m)
18-102	3	6.05-6.55

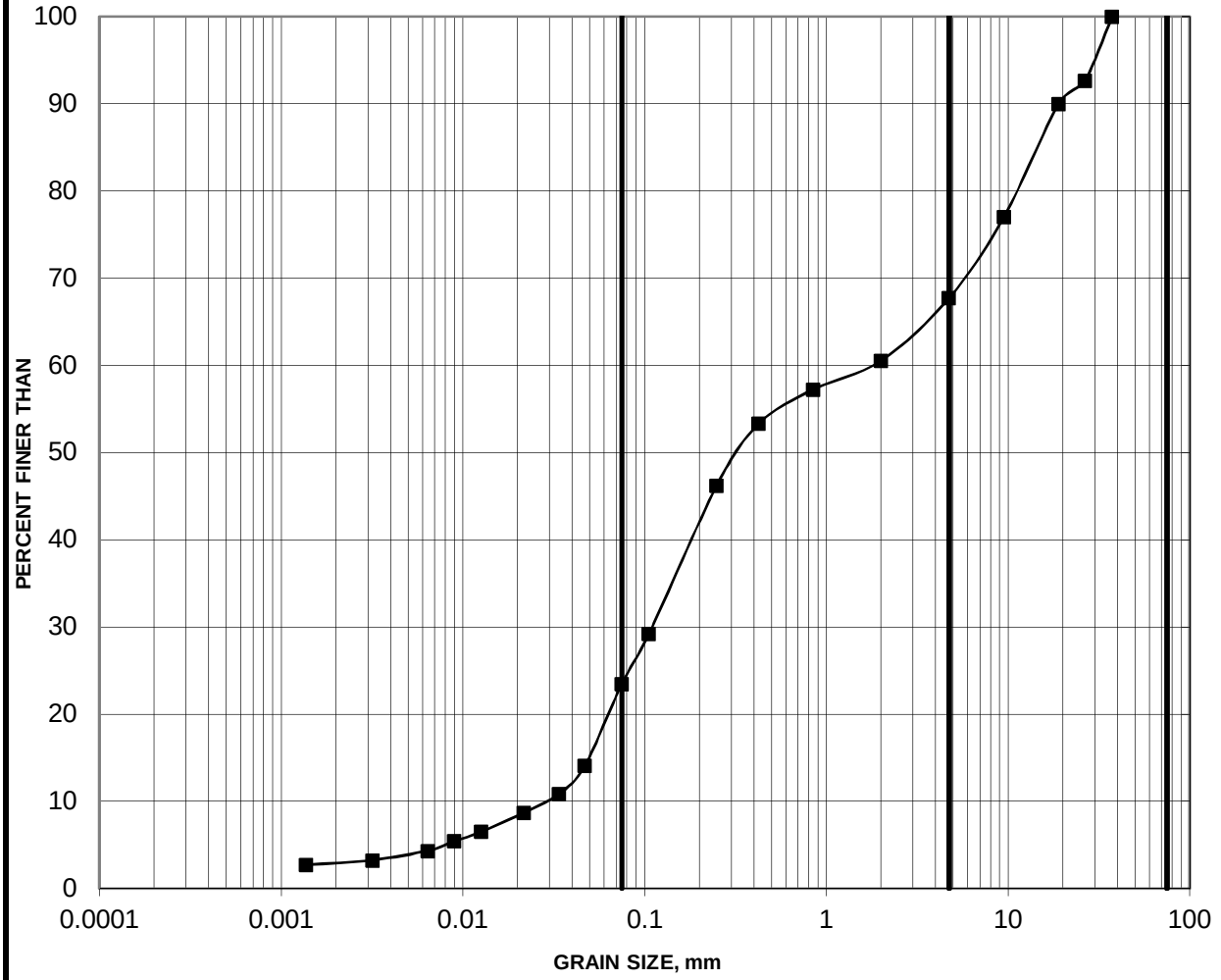
Project: 1791525

Golder Associates

Created by: CW
Checked by: MI

GRAIN SIZE DISTRIBUTION	FIGURE B2

SILTY SAND AND GRAVEL



Borehole	Sample	Depth (m)
18-103	3	8.38-8.99

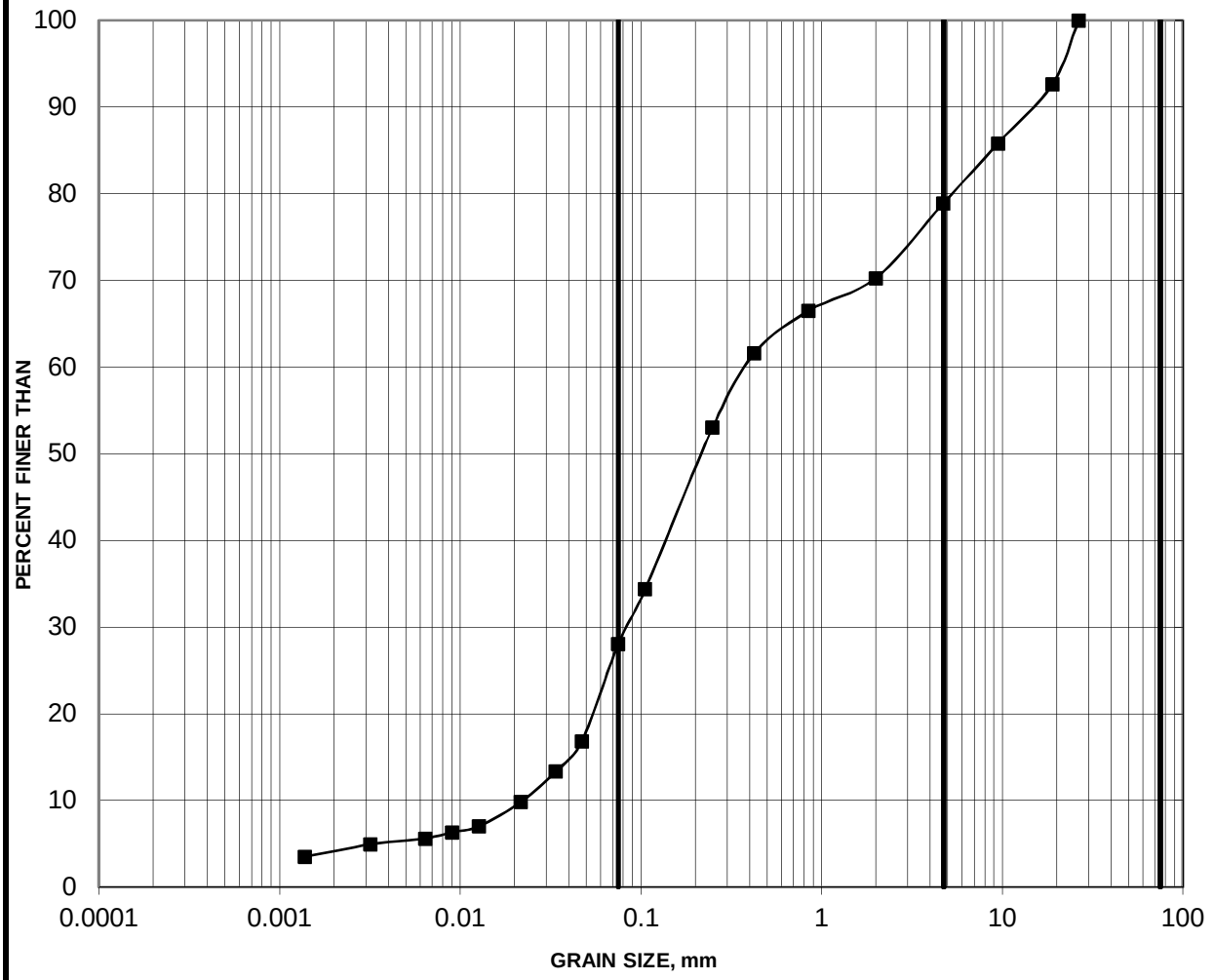
Project: 1791525

Golder Associates

Created by: CW
Checked by: MI

GRAIN SIZE DISTRIBUTION	FIGURE B3

GRAVELLY SILTY SAND



Borehole	Sample	Depth (m)
18-103	4	9.14-9.75

Project: 1791525

Golder Associates

Created by: CW
Checked by: MI

APPENDIX C

Record of Borehole and Drillhole Sheets

Previous Investigation by LVM (GEOCRES No. 31E-350)

ENCLOSURE NO.:2 (Pg. 1 of 1)

METRIC

RECORD OF BOREHOLE NO. 1

LVM Merlex

REFERENCE 14/07/14083 DATUM Geodetic LOCATION N 5024782.9 E 335957.9 - Sinclair Twp., Station 11+538 ORIGINATED BY JL

PROJECT GWP 5333-11-00, Highway 60 - F4 BOREHOLE TYPE Track Mounted CME 45 - Hollow Stem Augers COMPILED BY SH

CLIENT AECOM DATE (Started) 2014 November 07 TIME (Completed) 12:10:00 PM CHECKED BY MAM

DATE (Completed) 2014 November 07

ELEV / DEPTH	DESCRIPTION	STRATA PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
290.7	Ground Surface										
0.0	Organic silty sand trace gravel occasional grasslets dark brown (very loose)		1	SS	1						
290.0							290				
0.7	SAND some gravel some silt and clay occasional cobble (compact/dense) grey		2	SS	11						
			3	SS	38		289				17 68 (15)
288.7											
2.0	Auger Refual Start to rock coring BEDROCK - grey gneiss fair quality		4	RC	Rec= 100% RQD= 53%		288				
			5	RC	Rec= 100% RQD= 73%		287				
							286				
285.7											
5.0	End of Sampling End of Borehole										

COMMENTS

The stratification lines represent approximate boundaries. The transition may be gradual.

+ 3, × 3 : Numbers on right refer to Sensitivity
Numbers on left refer to values greater than 120 kPa

○ 3% STRAIN AT FAILURE

WATER LEVEL RECORDS

Date (yy/mm/dd)/Time	Water Depth (m)	Cave In (m)
1) 14/11/07 12:00:00 PM	0	3.35
2) 14/11/07 12:10:10 PM	0	-
3)	-	-

MEL-GEO 14083 - BOREHOL LOGS - F4.GPJ MEL-GEO.GDT 15/01/19

LVM-Merlex, a Division of EnGlobe Corp.
120 Progress Court, North Bay, On P1A 0C2 Phone: (705)476-2550 Fax: (705)476-8882 Email: northbay@lvm.ca

ENCLOSURE NO.: 3 (Pg. 1 of 1)

METRIC

RECORD OF BOREHOLE NO. 2

LVM Merlex

REFERENCE 14/07/14083 DATUM Geodetic LOCATION N 5024755.5 E 335911.0 - Sinclair Twp., Station 11+532 ORIGINATED BY JL

PROJECT GWP 5333-11-00, Highway 60 - F4 BOREHOLE TYPE Track Mounted CME 45 - Hollow Stem Augers COMPILED BY SH

CLIENT AECOM DATE (Started) November 6, 2014 TIME (Completed) 12:00:00 PM CHECKED BY MAM

DATE (Completed) November 6, 2014

ELEV / DEPTH	DESCRIPTION	STRATA PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
289.1	Ground Surface										
0.0	SAND with gravel some silt and clay occasional grass rootlets dark brown (very loose)		1	SS	3		289				30 46 (24)
288.4											
0.7	SAND and GRAVEL trace silt and clay rock fragments of cobble size encountered (dense) brown		2	SS	48		288				40 51 (9)
			3	SS	47						
286.9							287				
2.2	Auger Refual Start to rock coring BEDROCK - grey gneiss good quality		4	RC	Rec= 100% RQD= 82%		286				
			5	RC	Rec= 100% RQD= 78%		285				
			6	RC	Rec= 100% RQD= 75%		284				
283.6											
5.5	End of Sampling End of Borehole										

COMMENTS

The stratification lines represent approximate boundaries. The transition may be gradual.

+ 3, × 3 : Numbers on right refer to Sensitivity
Numbers on left refer to values greater than 120 kPa

○ 3% STRAIN AT FAILURE

WATER LEVEL RECORDS

	Date (dd/mm/yy)/Time	Water Depth (m)	Cave In (m)
1)		-	-
2)		-	-
3)		-	-

MEL-GEO 14083 - BOREHOL LOGS - F4.GPJ MEL-GEO.GDT 4/21/15

LVM-Merlex, a Division of EnGlobe Corp.
120 Progress Court, North Bay, On P1A 0C2 Phone: (705)476-2550 Fax: (705)476-8882 Email: northbay@lvm.ca

ENCLOSURE NO.:4 (Pg. 1 of 2)

METRIC

RECORD OF BOREHOLE NO. 3

LVM Merlex

REFERENCE 14/07/14083 DATUM Geodetic LOCATION N 5024767.4 E 335927.7 - Sinclair Twp., Station 11+532.4 ORIGINATED BY TB

PROJECT GWP 5333-11-00, Highway 60 - F4 BOREHOLE TYPE Truck Mounted CME 75 - Hollow Stem Augers COMPILED BY SH

CLIENT AECOM DATE (Started) 2014 August 18 TIME (Completed) 9:30:00 PM CHECKED BY MAM

DATE (Completed) 2014 August 18

ELEV / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
298.8	Ground Surface										
0.0	40 mm Asphalt 270 mm Crushed Gravel FILL - sand trace to with gravel trace to some silt trace clay		1	SS	20		298				
			2	SS	21						26 62 (12)
	50 mm Asphalt encountered at depth of 1.8 m dark greyish trace organic encountered at depth of 3 m		3	SS	24		297				
	brown to grey		4	SS	35		296				
			5A	SS	35						9 73 (17)
			5B	SS			295				
	cobble / rockfill encounted at depths from 4.6 m to 5.2 m		6	SS	20		294				
			7	SS	18						16 58 19 7
			8	SS	12		293				
			9	SS	11		292				
			10A	SS	16						
			10B	SS			291				1 77 (22)
	seam of silt encountered at depth of 9.1 m		11	SS	5	▽	290				
	gravel and sand encountered at depths from 9.9 m to 10.2 m (compact/very dense)		12	SS	5		289				
288.6			13A	SS	66						
10.2	SAND with gravel some silt and clay grey		13B	SS			288				
	(dense/very dense)		14	SS	31						25 50 (25)
			15	SS	61		287				
	Continued Next Page						286				

COMMENTS

The stratification lines represent approximate boundaries. The transition may be gradual.

+ 3, × 3 : Numbers on right refer to Sensitivity
Numbers on left refer to values greater than 120 kPa

○ 3% STRAIN AT FAILURE

WATER LEVEL RECORDS

Date (yy/mm/dd)/Time	Water Depth (m)	Cave In (m)
1) 14/08/26 10:30:00 AM	8.56 ▽	-
2)	- ▽	-
3)	- ▽	-

MEL-GEO 14083 - BOREHOL LOGS - F4.GPJ MEL-GEO.GDT 15/01/19

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METRIC

RECORD OF BOREHOLE NO. 3

REFERENCE 14/07/14083 DATUM Geodetic LOCATION N 5024767.4 E 335927.7 - Sinclair Twp., Station 11+532.4 ORIGINATED BY TB

PROJECT GWP 5333-11-00, Highway 60 - F4 BOREHOLE TYPE Truck Mounted CME 75 - Hollow Stem Augers COMPILED BY SH

CLIENT AECOM DATE (Started) 2014 August 18 TIME (Completed) 9:30:00 PM CHECKED BY MAM

DATE (Completed) 2014 August 18

ELEV / DEPTH	DESCRIPTION	STRATA PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE) 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA (SI CL)
285.6	Continued from Previous Page										
13.3	Auger Refual Start to rock coring										
	BEDROCK - grey gneiss excellent quality		16	RC	Rec= 100% RQD= 95%		285				
			17	RC	Rec= 96% RQD= 96%		284				
282.5							283				
16.3	End of Sampling End of Borehole										

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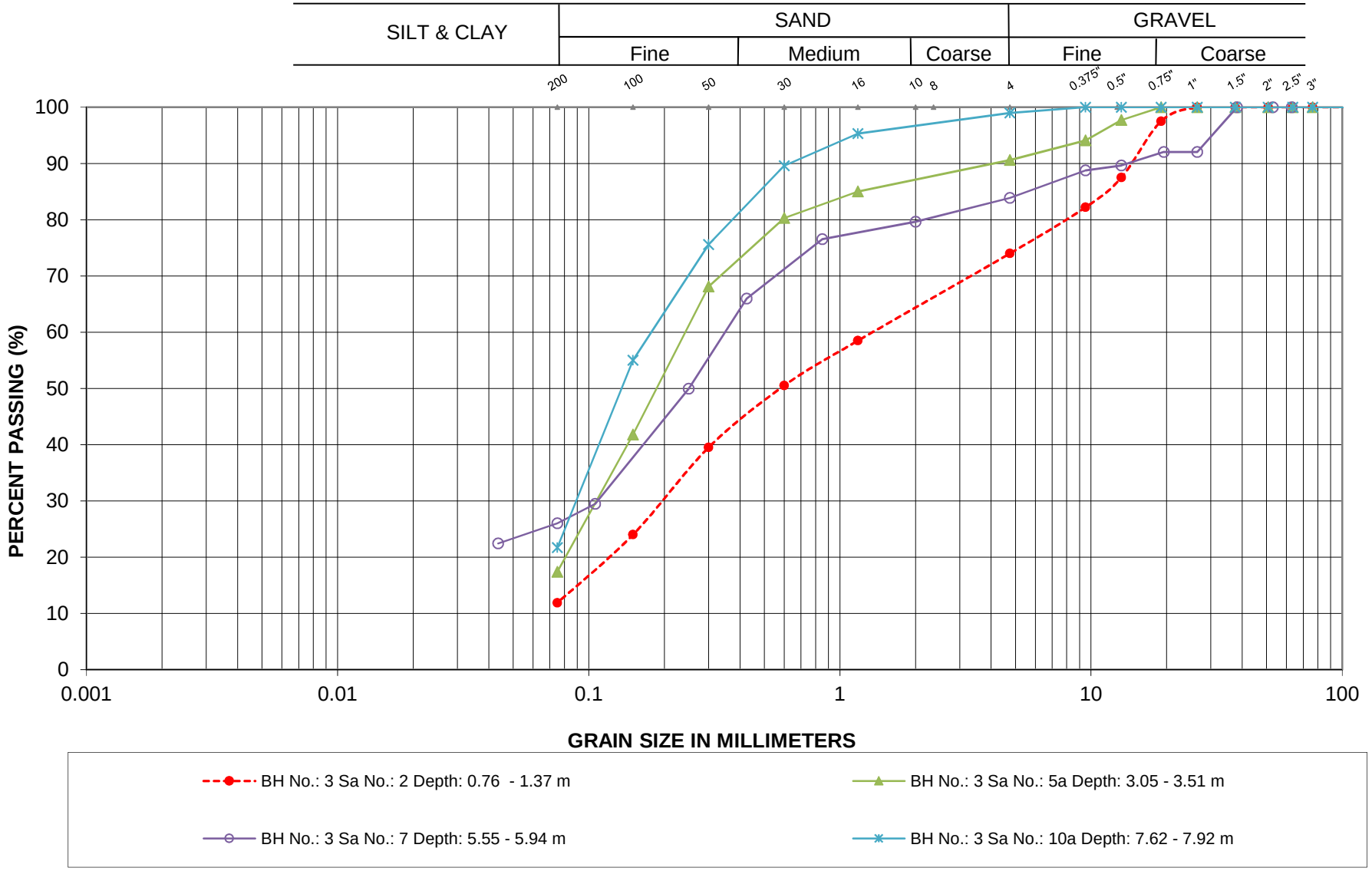
APPENDIX D

Laboratory Test Results

Previous Investigation by LVM (GEOCRES No. 31E-350)

Reference No.: 14/08/114083-F4
Date: April, 2015

GRAIN SIZE ANALYSIS



SAND FILL

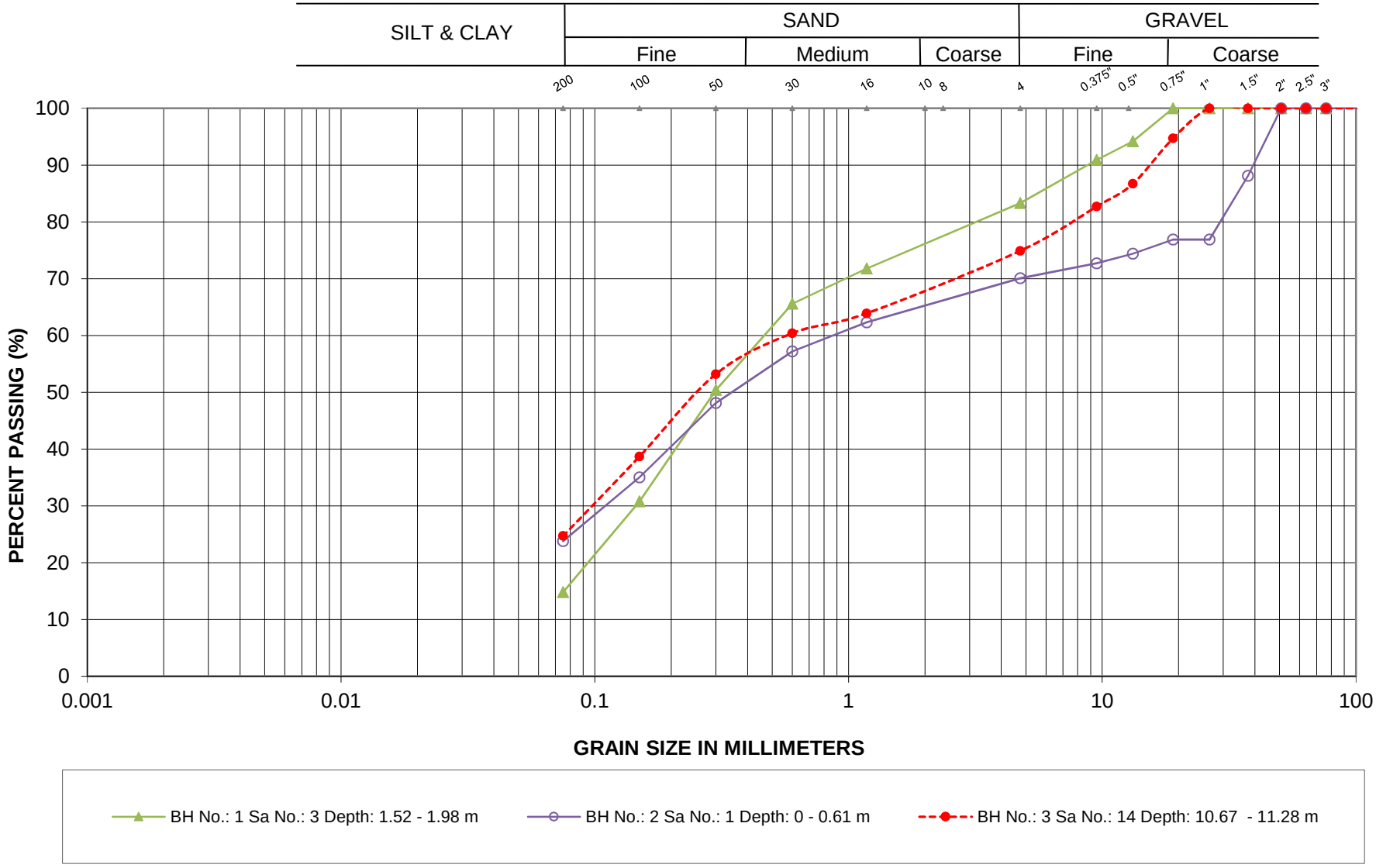
LOCATION: Hwy 60 Sta. 11+540 Culvert
TWP Sinclair, Ontario

LVM-Merlex, a Division EnGlobe Corp.

FIGURE L-1

Reference No.: 14/08/114083-F4
Date: April, 2015

GRAIN SIZE ANALYSIS



SAND

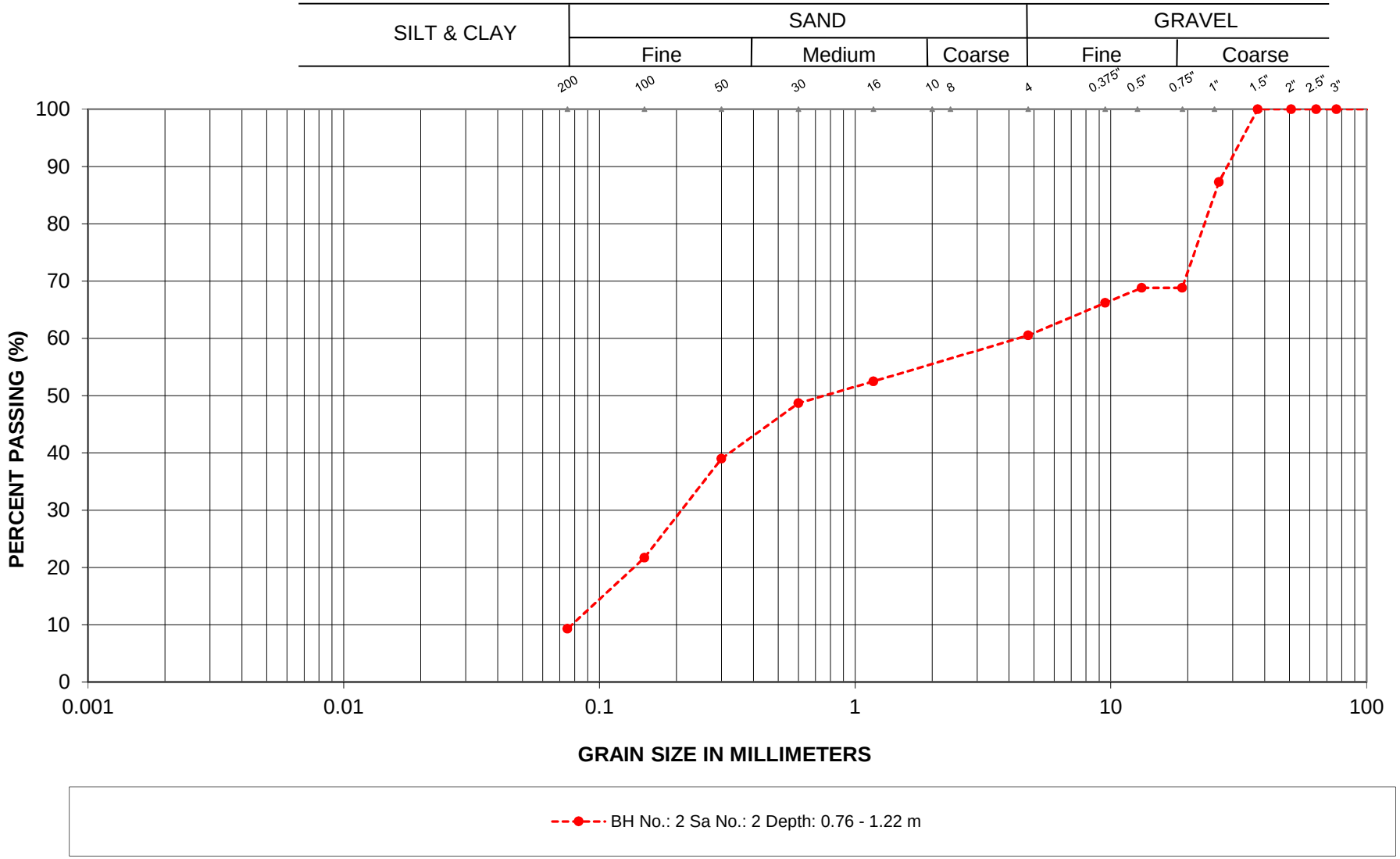
LOCATION: Hwy 60 Sta. 11+540 Culvert
TWP Sinclair, Ontario

LVM-Merlex, a Division EnGlobe Corp.

FIGURE L-2

Reference No.: 14/08/114083-F4
Date: April, 2015

GRAIN SIZE ANALYSIS



SAND and GRAVEL

LOCATION: Hwy 60 Sta. 11+540 Culvert
TWP Sinclair, Ontario

LVM-Merlex, a Division EnGlobe Corp.

FIGURE L-3

Reference No.: 14/07/14083-F4

Date: April, 2015

Laboratory Tests - Summary Sheet

Borehole No.	Sample No.	Depth	Grain Size Analysis				NMC	Atterberg Limits			SPT 'N'	USCS	Unit Weight (kN/m3)	Remarks
			Gravel Size (%)	Sand Size (%)	Silt Size (%)	Clay Size (%)		LL (%)	PL (%)	IP (%)				
1	1	0.3					48.5				1			
	2	1.0					32.2				11			
	3	1.8	17	68	15		14.4				38			
2	1	0.3	30	46	24		17.5				3			
	2	1.0	40	51	9		17.7				48			
	3	1.8					17.2				47			
3	1	0.3					5.1				20			
	2	1.1	26	62	12		9.0				21			
	3	1.8					7.6				24			
	4	2.6					11.0				35			
	5a	3.3	9	73	17		12.2				35			
	5b	3.6					3.4							
	6	4.9					13.7				20			
	7	5.6	16	58	19	7	11.4				18			
	8	6.4					11.5				12			
	9	7.2					12.7				11			
	10a	7.8	1	77	22		10.3				16			
	10b	8.0					16.7							
	11	8.7					14.1				5			
	12	9.5					20.0				5			
	13a	10.1					8.0				66			
	13b	10.4					8.7							
	14	10.98	25	50	25		9.22				31			
	15	12.5					16.42				61			

Project: Hwy 60, Culvert Sta. 11+540, Township of Sinclair

Table No. L-4

APPENDIX E

Test Pit Photographs

Photograph 1: Looking east (towards HWY 60 embankment) at TP 18-108A

Photograph 2: Boulder encountered in the excavated soil from TP 18-108A

Photograph 3: Quick water ingress at TP 18-108B (looking east towards HWY 60 embankment)

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