



FINAL REPORT

FOUNDATION INVESTIGATION AND DESIGN REPORT

Highway 11 Structural Culvert at Highway 117 Interchange (Site No. 42-194),

Bracebridge, Ontario

(Latitude 45.084724; Longitude -79.297552)

Agreement No. 9016-E-0009

Assignment No. 1

W.O. 2017-11021

MTO GEOCRES No. 31E-383

Prepared for:

Ontario Ministry of Transportation

Pavements and Foundations Section

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Ontario Ministry of Transportation

Pavement and Foundation Section

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1 FOUNDATION INVESTIGATION REPORT

1.1 Introduction

This foundation investigation report presents the results of a geotechnical investigation completed by **exp** Services Inc. (**exp**) for a new and existing culverts, as part of rehabilitation of Highway 11 Structural Culvert at Highway 117 Interchange, Site No. 42-194 (*Latitude 45.084724; Longitude -79.297552*), located in Bracebridge, Ontario. The work was undertaken under Agreement # 9016-E-0009, Assignment No. 1, GWP 5158-12-00. The terms of reference (TOR) were as presented in the MTO email dated July 7, 2017.

Based on email/ TOR, it is understood that the original scope of work included replacement of the existing Structural Culvert, with a new culvert, either on the existing alignment or new alignment by using trenchless methods. Since the concern was expressed that Highway 11 embankments consist of rockfill, the preliminary investigation was conducted at the current culvert alignment and at the initially propose new alignment (18 m north of the culvert) in the spring 2017 by Golder Associates (Golder). to identify if rockfill was present at the site. The results of that investigation were presented in the technical memorandum dated April 12, 2017. Later, the prime consultant, Morrison Hershfield (MH), together with the MTO design team has revised the scope of work suggesting the lining of the existing culvert. However, by lining the existing culvert, the channel size will be reduced, and the invert elevation will be at a higher elevation due to the liner. As a result, an additional culvert is proposed to accommodate for the flow and fisheries. It is also noted that some discontinuities were identified in the base slab of the existing culvert at the two locations (i.e. approximately 5 m east of the culvert outlet and approximately 44 m west of the culvert inlet).

It is understood that the new culvert with a 1.95 m diameter and approximate length of 76 m is proposed to be installed approximately 6.4 m south of the centreline of the existing culvert. It is further understood that the new culvert invert elevation will be at the same elevation or below the existing culvert invert elevations, at approximately Elev. 272.59 m at the inlet and Elev. 272.46 m at the outlet.

The purposes of the current investigation are: (i) to determine the subsurface conditions along the proposed alignment to permit detailed design for installation of an overflow culvert, and (ii) an assessment of subsurface conditions at two areas of suspected base failure at the existing culvert to provide detailed recommendations with clear alternatives to rectify problems. The site specific geotechnical investigation consisted of borings of vertical and horizontal boreholes, soil sampling, borehole logging, and field and laboratory testing.

The foundation investigation report has been prepared specifically and solely for the project described herein. It contains the factual results of the investigation and the laboratory testing completed for this project.

1.2 Site Description and Geological Setting

1.2.1 Site Description

The existing approximately 3 m wide cast-in place concrete box culvert is located on Highway 11 (STA. 16+312), approximately 200 m south of the Highway 117 overpass in Bracebridge. The culvert was originally constructed in the 1960s, but then extended in 1973 as part of the highway widening, resulting in a total length of approximately 76 m. Highway 11 at the site location is a four-lane divided highway with paved shoulders and a posted speed limit of 100 km/hr. The highway embankment above the creek bed is about 9.5 m high with side slopes of about 2.3H:1V to 2H:1V on east and west side, respectively. The site key plan is shown on Drawing 1 in Appendix B. Photographs of the site and existing culvert are presented in Appendix A.

During the site investigation, the general site conditions were assessed. At the site location, Highway 11 runs in a generally north-south direction and the creek flows from east to west direction crossing Highway 11 and Highway 11/117 IC (N-E/W and S-E/W) ramps. The creek crossing starts from east of Highway 11/117 IC and crosses Highway 11/117 IC N-E/W ramp via the SPCSP culvert discharging on the east side of Highway 11 at the inlet of structural box culvert, which further crosses Highway 11 and discharges west of Highway 11 (see Photo 10 in Appendix A). The creek further crosses Highway 11/117 IC S-E/W ramp via a twin concrete box culvert and ultimately it flows towards High Fall. The top of Highway 11 surface elevation at the existing culvert location is about 282 m. At the time of investigation, the water level at the inlet and outlet of the existing culvert was approximately at Elevations 272.7 m and 272.6 m, respectively.

The vicinity of inlet and outlet of the culvert is heavily vegetated with trees (Photos 5, 6 and 7 in Appendix A). Some fallen trees were observed on the outlet side (Photo 7 in Appendix A). The road surface of Highway 11 was generally in good shape with a few cracks along the existing culvert alignment (Photos 1 to 4 in Appendix A). The slopes of the embankment were covered with grass and trees (Photos 5 and 6 in Appendix A). Bedrock outcrops were observed in the vicinity of proposed site, adjacent to Highway 11/117 IC E/W-S ramp on west side of the culvert outlet. The immediate surrounding of proposed culvert site is cleared for utilities. Some street light poles were observed on shoulder of the Highway 11 at about 110 m south and north of the existing culvert location.

1.2.2 Geological Setting

In accordance with the Ministry of Northern Development and Mines Map 2556, Quaternary Geology of Ontario, Southern Sheet, the site is generally consisting of glaciofluvial outwash deposits of gravel and sand including proglacial river and deltaic deposits.

In accordance with the Ministry of Northern Development and Mines Map 2544, Bedrock Geology of Ontario, Southern Sheet, the bedrock at the site consists of migmatitic rocks and gneisses of undetermined

protolith: commonly layered biotite gneisses and migmatites; locally includes quartzofeldspathic gneisses, orthogneisses, paragneisses.

1.3 Investigation Procedures

1.3.1 Site Investigation and Field Testing

The field investigation was performed between August 29, 2017 and September 7, 2017. The field program consisted of drilling nine (9) vertical boreholes (BH-1 to BH-9) and one horizontal borehole (HP-1). Boreholes BH-1 to BH-8 were sampled using the Standard Penetration Test method (SPT), accordance with ASTM D1586. Vertical Borehole BH-9 and horizontal borehole HP-1 were non-sampled boreholes. The locations of these nine vertical boreholes and one horizontal borehole are shown on Drawing 1 in Appendix B.

Five (5) vertical boreholes (BH-1, BH-2, BH-3, BH-4 and BH-5) were strategically located along the proposed culvert alignment to provide subsurface information for the design of the proposed new culvert. Boreholes BH-5 and BH-4 were advanced at accessible locations near the inlet and outlet of the proposed culvert, respectively. BH-1 and BH-3 were advanced within the east side of NBL and west side of SBL, respectively, located about 2 m south of the proposed culvert centerline, while BH-2 was advanced approximately 2 m north of the proposed culvert centerline in the grass median. Two (2) vertical boreholes (BH-6 and BH-7) were advanced at the two areas of suspected base failure locations on centerline of the existing culvert alignment (i.e. approximately 44 m west of the inlet and 5 m east of outlet, respectively). Additional two (2) vertical boreholes (BH-8 and BH-9) were advanced from the top of Highway 11 at the locations of obstacles encountered during drilling of the horizontal borehole HP-1. Borehole BH-8 was advanced at about the middle of two SBLs and BH-9 was advanced within the east side shoulder of SBL, located about the centerline of proposed culvert alignment.

The vertical boreholes drilled from the road surface/ median ditch (BH-1, BH-2, BH-3, BH-6, BH-8 and BH-9) were advanced to depths ranging from 9.2 m to 19.8 m below the ground surface; while boreholes advanced at the inlet and outlet locations of proposed culvert (BH-4 and BH-5) were advanced to depths ranging from 11.6 m to 15.2 m below ground surface. Borehole BH-7 advanced at outlet of the existing culvert was advanced to depths about 11.6 m below ground surface.

The horizontal borehole HP-1 was advanced about 76.2 m in length from the inlet side along the centerline of the proposed culvert alignment (see Drawing 1 in Appendix B). The elevation of the entry point was approximately at 274.5 m, while the exit point of the drilling rod was measured approximately 2.6 m below the ground surface at approximate Elev. 272.5 m. The objective of this horizontal borehole drilling along the proposed culvert alignment was to investigate potential presence of some obstacles (i.e. boulders) at the trenchless installed pipe pathway. BH-8 and BH-9 were drilled at locations where possible obstacles were encountered based on the horizontal probe.

The preliminary investigation at the current culvert location and at the initially proposed new alignment (18 m north of the existing culvert) performed by Golder Associates in the spring 2017 included drilling of five (5) vertical boreholes numbered 17-1, 17-2, 17-2B, 17-3 and 17-4 to a maximum depth ranging from 8.2 to 24.4 m (Elev. 273.8 m to 257.7 m). The locations of boreholes 17-2 and 17-2B which were drilled at the location of current culvert are shown on Drawing 1 in Appendix B. The other boreholes were drilled north of the existing culvert along the initially proposed culvert alignment.

Boreholes drilled from the embankment crest/median ditch (BH-1, BH-2, BH-3, BH-6, BH-8 and BH-9) and the borehole drilled at the inlet location (BH-5) were advanced using a truck mounted CME-55 drill rig; while the boreholes drilled at the proposed outlet location (BH-4) and at the existing culvert outlet location (BH-7) were advanced using a portable drilling equipment Hilti DD 250. The drill rig and portable equipment equipped with a hollow stem auger and standard soil/rock sampling equipment were operated by a specialist drilling contractor Marathon Drilling Company Ltd (Marathon). A wash boring technique with casing was used to advance boreholes through the embankment. When cobbles and boulders were encountered, the core barrel was used to advance the borehole and obtain rock core samples. The horizontal borehole advanced through highway embankment was a pilot hole of a Horizontal Directional Drilling (HDD) equipment Ditch with 2720 drilling rig operated by Marathon as well. A platform was prepared at the inlet side to accommodate the HDD equipment as shown on photos in Appendix A.

Locations of boreholes (referenced to the MTM NAD83 coordinate system) and their ground surface elevations were temporary surveyed by **exp's** personnel using the Temporary Benchmark (TBM) set on BH 17-2 at Highway 11. The TBM elevation of 282.0 m was then obtained from provided information in the Golder's report. A summary of borehole locations (northing and easting given relative to NAD83 MTM Zone 10, as well as latitude and longitude), ground surface elevations and borehole depth are presented in the Record of Borehole sheets in Appendix C and summarized in Table 1.1 below.

Table 1.1. Summary of boreholes drilled

Borehole	MTM NAD 83 Coordinates Zone 10		Latitude and Longitude Coordinates		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing	Easting	Latitude	Longitude		
BH-1	4993880.6	320753.0	45.084721	-79.297362	282.2	19.7
BH-2	4993881.9	320737.2	45.084733	-79.297565	280.5	18.1
BH-3	4993873.9	320726.4	45.084663	-79.297694	281.6	19.8
BH-4	4993869.4	320709.2	45.084621	-79.297911	275.4	11.6
BH-5	4993888.7	320780.5	45.084797	-79.297004	275.1	15.2
BH-6	4993884.7	320733.9	45.084761	-79.297602	280.7	18.1
BH-7	4993877.4	320706.3	45.084694	-79.297947	275.4	11.6

Borehole	MTM NAD 83 Coordinates Zone 10		Latitude and Longitude Coordinates		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing	Easting	Latitude	Longitude		
BH-8	4993876.6	320727.1	45.084681	-79.297693	281.8	9.8
BH-9	4993877.5	320730.5	45.084689	-79.297642	282.0	9.2

During the drilling of vertical boreholes, soil samples were obtained using a 51 mm outside diameter (O.D.) split-spoon sampler in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586) at intervals ranging from 0.75 m to 1.5 m in depth when drilled with the drilling rig or 0.61 m to 1.22 m in depth with the portable equipment, as shown on the attached borehole logs (Appendix C). The original field (uncorrected) SPT "N" values were recorded on the borehole logs as recommended in the Canadian Foundation Engineering Manual (CFEM, pg. 40) and used to provide an assessment of in-situ consistency or relative density of non-cohesive soils. However, in the case of sampling done by the portable equipment with a manually lifting portable hammer (31.7 kg, half weight of conventional hammer weight) at BH-7, the corresponding blow counts were factored by 0.5. Since the sampling at BH-4 was performed, using a 51 mm outside diameter (O.D.) split-spoon sampler and 140 lbs (63.5 kg) hammer with portable tripod for lifting, the corresponding blow counts were not factored. When a hard stratum was reached (refusal of split spoon), sampling of hard material was performed by diamond core drilling using a 1.5 m long NQ double tube wireline core barrel during drilling with the drilling rig, while a 0.61 m BQ core barrel was used during drilling with the portable equipment. The horizontal borehole was drilled as a 2.5-inch pilot hole using a pilot steering drill bit, without any soil sampling.

Upon completion of the boreholes, ground water level measurements were carried out in the vertical boreholes in accordance with the MTO guidelines. However, vertical boreholes were advanced using a wash boring technique, so the stabilized ground water level could not be established by short term observations in boreholes. The drilled boreholes were decommissioned by bentonite/cement mixtures in accordance with the Ministry of the Environment Regulation 903, as amended by Regulation 128/03 (the well regulation under the Ontario Water Resources Act). The existing culvert cored were plugged and cemented with quick setting cement.

The fieldwork was supervised by members of **exp's** engineering who directed the drilling and sampling operations, logged borehole data in accordance with MTO and/or ASTM Standards for Soils Classification, and retrieved soil samples for subsequent laboratory testing and identification.

All the recovered soil samples placed in labelled moisture-proof bags were returned to **exp's** Brampton laboratory for additional visual, textual, olfactory examination and selective testing.

1.3.2 Previous Investigation

The following previous investigation report from the spring 2017 investigation was provided by MTO:

- Technical Memorandum- Assignment 5015-E-0045- Work Order 1; Culvert at Highway 11/ Highway 117 Interchange, Highway 11 STA 16+312, Site No. 42-194 Bracebridge, Ontario; April 12, 2017 by Golder Associates.

The borehole logs from the previous investigation report prepared by Golder Associates are attached in Appendix F of this report. The details of the borehole locations and elevations completed by Golder Associates are outlined in Table 1.2.

Table 1.2. Summary of boreholes completed by Golder

BH No.	Borehole Locations (Station and Offset from the Centreline)	Ground Elevation (m)	Borehole Depth (m)	Borehole Bottom Elevation (m)	Piezometer/ Monitoring Well
BH 17-1*	SBL, north side of existing culvert	280.9	21.6	259.3	None
BH 17-2	NBL, drilled at existing culvert	282	8.2	173.8	None
BH 17-2B	NBL, south side of existing culvert	282.1	24.4	257.7	None
BH 17-3*	SBL, north side of previously proposed culvert	280.7	21.3	259.4	None
BH 17-4*	NBL, south side of previously proposed culvert	281.6	10.3	271.3	None

Note: * - BH 17-1, BH 17-3 and BH17-4 were drilled for previously proposed culvert alignment located north of the existing culvert alignment. Therefore, these boreholes will not be discussed further for describing stratigraphic section at the existing culvert and the new proposed culvert locations.

1.3.3 Laboratory Testing

All samples returned to the laboratory were subjected to visual examination and classification. The laboratory testing program included the determination of natural moisture content on all samples and particle size distribution for approximately 25% of the collected soil samples. All the laboratory tests were carried out according to MTO and/or ASTM Standards as appropriate.

The laboratory test results are provided on the attached borehole log sheets in Appendix C. The results of the grain size analyses tests are presented graphically in Appendix D. The laboratory test results from Golder's investigation is provided on the attached borehole log sheets in Appendix F.

1.4 Subsurface Conditions

A borehole location plan and stratigraphic sections are provided in Appendix B. The locations of obstacles encountered during drilling of the horizontal borehole are also marked on those plan and sections. The detailed subsurface conditions encountered in the boreholes advanced during this investigation are presented on the borehole log sheets in Appendix C. Laboratory test results are provided in Appendix D. The “Explanation of Terms Used in Report” preceding the borehole logs in Appendix C forms an integral part of and should be read in conjunction with this report.

It should be noted that the stratigraphic boundaries indicated on the borehole logs and stratigraphic sections are inferred from semi-continuous sampling in vertical boreholes, observations of drilling progress and results of Standard Penetration Tests. These boundaries typically represent interpreted transitions from one soil type to another and should not be viewed as exact planes of geological change. Furthermore, subsurface conditions may vary between and beyond the borehole locations.

The general stratigraphy encountered within the investigated depths of previous and current investigations are inline. In general, the subsoil condition at the site consist of a layer of embankment fill (consisting of sand, rockfill, sand to gravelly sand and silty sand to sand and silt) followed by native deposit of sand and silt, sandy silt and silty sand to sand.

A detailed description of subsurface conditions encountered in drilled boreholes are discussed further in subsequent sections. It should be noted that the following sections are based on the geotechnical investigations conducted by **exp** and Golder.

1.4.1 Proposed New Culvert Location

1.4.1.1 Asphalt

An asphalt layer, approximately 0.11 m to 0.20 m thick, was encountered at the surface of boreholes advanced on the paved area, i.e. BH-1, BH-3, BH-8 and 17-2B .

1.4.1.2 Fill: Sand

A sand fill layer was encountered below the asphalt in boreholes BH-1, BH-3, BH-8 and 17-2B or at the surface of borehole BH-2. The sand fill extended to depth ranging between 3.1 m and 6.1 m below the ground surface with elevations ranging between 279.2 m and 274.4 m. The explored thickness of this layer was between 2.9 m and 6.1 m.

The composition of this fill layer was generally sand with trace to some silt, trace to some gravel and occasional cobbles and boulders. The material was brown to dark brown in color, and dry to moist. The SPT ‘N’ values within this layer ranged from 2 to 72 blows per 0.3 m penetration, suggesting very loose to very dense material, but generally compact in relative density.

Laboratory testing performed on selected samples consisted of moisture content and grain size distribution tests. The test results are as follows:

Moisture Content: (**exp** and Golder)

- 1.2% to 19.1%

Grain Size Distribution: (**exp** and Golder)

- 3% to 9 % gravel;
- 74% to 87% sand;
- 14% to 19% silt and clay; or
- 9% silt; and
- 1% clay.

The results of the moisture content and grain size distribution tests are provided on the record of borehole sheets in Appendix C. The results of the grain size distribution tests are also provided on Figure 1 in Appendix D. The results of tests performed by Golder are shown on the borehole logs attached in Appendix F.

1.4.1.3 Fill: Rockfill

A layer of rockfill was encountered below the sand fill in BH-1 and 17-2B, which extended to depth ranging between 3.8 m and 5.8 m below the ground surface with corresponding elevations ranging between 278.4 m and 276.3 m. The explored thickness of this layer was between 0.7 m and 2.3 m.

The composition of this layer was generally cobbles and boulders with some sand and some gravel. The SPT 'N' values within this layer were above 100 blows per 0.3 m penetration.

1.4.1.4 Fill: Sand to Gravelly Sand

A sand to gravelly sand fill layer was encountered below the rockfill layer in borehole BH-1, which extended to depth of 6.9 m below the ground surface with corresponding elevation of 275.3 m. The explored thickness of this layer was about 3.1 m.

The composition of this fill layer was generally sand with some gravel, trace to some silt and trace organics. The material was brown in color, and wet. The SPT 'N' values within this layer ranged from 4 to 59 blows per 0.3 m penetration, suggesting very loose to very dense in relative density.

Laboratory testing performed on selected samples consisted of moisture content tests and results are as follows:

Moisture Content: (exp)

- 1.3 to 6.2%

The results of moisture content tests are provided on the record of borehole sheets in Appendix C.

1.4.1.5 Fill: Silty Sand/ Sand and Silt

A silty sand/ sand and silt fill layer was encountered below the sand to gravelly sand layer in BH-1; below the sand fill layer in BH-2, BH-3 and BH-8; rockfill in borehole 17-2B; below topsoil in BH-4 or at the surface of BH-5. The silty sand/sand and silt fill extended to depth ranging between 1.5 m and 10.1 m below the ground surface with corresponding elevations ranging between 273.6 m and 272.0 m. The explored thickness of this layer was between 1.5 m and 4.3 m.

The composition of this fill layer was generally silt and sand with trace gravel, trace clay, occasional cobbles and boulders, trace to some organics and occasional wood log. The material was brown to greyish brown in color, and moist to wet. The SPT 'N' values within this layer ranged from 1 to 24 blows per 0.3 m penetration, suggesting very loose to compact in relative density. One SPT 'N' value of 50 blows per 0.05 m penetration was also obtained within this layer which could be influence of a wood log encountered.

Laboratory testing performed on selected samples consisted of moisture content tests and grain size distribution tests, and their results are as follows:

Moisture Content: (exp and Golder)

- 2.1% to 54.3%

Grain Size Distribution: (exp and Golder)

- 0% to 4 % gravel;
- 48% to 67% sand;
- 29% to 47% silt and clay; or
- 45% to 51% silt; and
- 1% to 4% clay.

The results of the moisture content and grain size distribution tests are provided on the record of borehole sheets in Appendix C. The results of the grain size distribution tests are also provided on Figure 2 in Appendix D. The results of tests performed by Golder are shown on the borehole logs attached in Appendix F.

During drilling of the horizontal borehole HP-1, obstacles were encountered in this layer about middle of two SBLs and within the east side shoulder of SBL. Borehole BH-8 and BH-9 were advanced at those two locations, and the findings suggest that those obstacles might be smaller boulders.

1.4.1.6 Sand and Silt

A native sand and silt layer was encountered below silty sand/sand and silt fill in boreholes BH-1, BH-3, BH-8 and 17-2B. The native sand and silt layer extended to depth ranging between 9.8 m and 14.7 m below the ground surface with corresponding elevations ranging between 272.0 m and 267.4 m. The explored thickness of this layer was between 0.6 m and 4.6 m. BH-8 was terminated within this layer.

The composition of this layer was generally silt and sand with trace clay, organics, and rootlets. The material was blackish brown to dark brown in color, and moist to wet. The SPT 'N' values within this layer ranged from 3 to 11 blows per 0.3 m penetration, suggesting very loose to compact in relative density.

Laboratory testing performed on selected samples consisted of moisture content tests, grain size distribution tests, organic content tests and Atterberg Limit tests. The test results are as follows:

Moisture Content: (**exp** and Golder)

- 23.6% to 43.9%

Grain Size Distribution: (**exp** and Golder)

- 0 % gravel;
- 39% to 60% sand;
- 39% to 58% silt; and
- 1% to 3% clay.

Organic Content: (exp and Golder)

- Organic content ranges from 3.3% to 4.8%

Two Atterberg Limits tests were conducted by Golder on selected samples of the silt and sand deposit and returned non-plastic results.

The result of moisture content, grain size distribution and organic content tests are provided on the record of borehole sheets in Appendix C. The results of the grain size distribution tests are also provided on Figure 3 in Appendix D. The results of tests performed by Golder are shown on the borehole logs attached in Appendix F.

1.4.1.7 Sandy Silt with Organics

A native sandy silt layer was encountered below silty sand/sand and silt fill in boreholes BH-4 and BH-5. The sandy silt layer extended to depth ranging between 3.7 m and 4.4 m below the ground surface with corresponding elevations ranging between 271.7 m and 270.7 m. The explored thickness of this layer was between 1.3 m and 2.9 m.

The composition of this layer was generally silt and sand with trace gravel trace to some clay, trace to some organics, trace roots and rootlets. The material was black to dark grey in color, and wet. The SPT 'N' values within this layer ranged from WH to 6 blows per 0.3 m penetration, suggesting very loose to loose in relative density.

Laboratory testing performed on selected samples consisted of moisture content tests, grain size distribution tests, organic content test and Atterberg Limit tests. The test results are as follows:

Moisture Content: **(exp)**

- 41.8% to 132.4%

Grain Size Distribution: **(exp)**

- 0 % gravel;
- 17% to 27% sand;
- 70% to 80% silt; and
- 3% to 4% clay.

Organic Content: **(exp)**

- Organic content about 7.3%

Two Atterberg Limits tests were conducted on selected samples of sandy silt deposit and returned non-plastic results.

The result of moisture content, grain size distribution and organic content tests are provided on the record of borehole sheets in Appendix C. The results of the grain size distribution tests are also provided on Figure 4 in Appendix D.

1.4.1.8 Silty Sand to Sand

A native silty sand to sand layer was encountered below sand and silt layer in boreholes BH-1, BH-3 and 17-2B; below silty sand fill in BH-2; and below sandy silt with organics in BH-4 and BH-5. The silty sand to sand layer extended to depths ranging between 9.8 m and 19.7 m below the ground surface with corresponding elevations ranging between 265.6 m and 261.4 m. The explored thickness of this layer was between 4.2 m and 9.7 m. BH- 1 and BH-2 were terminated within this layer.

The composition of this layer was generally sand some silt, trace gravel, trace clay and occasional cobbles. The material was brown to greyish brown in color, and wet. The SPT 'N' values within this layer ranged from 4 to 37 blows per 0.3 m penetration, suggesting very loose to dense, but generally compact in relative density. The dynamic cone penetration test (DCPT) was also performed below this layer in boreholes BH-3, BH-4, BH-5 and 17-2B, which extended to depths ranging between 11.6 m and 24.4 m with

corresponding elevations ranging between 263.8 m and 257.7 m. Boreholes BH-3, BH-4, BH-5 and 17-2B were terminated at the end of DCPT.

Laboratory testing performed on selected samples consisted of moisture content tests and grain size distribution tests, and the test results are as follows:

Moisture Content: (**exp**)

- 12.6% to 25.4%

Grain Size Distribution: (**exp** and Golder)

- 0% to 3% gravel;
- 72% to 95% sand;
- 5% to 28% silt and clay; or
- 11% to 14% silt; and
- 1% clay.

The results of the moisture content and grain size distribution tests are provided on the record of borehole sheets in Appendix C. The results of the grain size distribution tests are also provided on Figure 5 and Figure 6 in Appendix D. The results of tests performed by Golder are shown on the borehole logs attached in Appendix F.

1.4.2 Existing Culvert Location

1.4.2.1 Asphalt

An asphalt layer about 0.20 m thick, was encountered at the surface of borehole advanced on the paved area, i.e. 17-2.

1.4.2.2 Fill: Sand

A sand fill layer was encountered below the asphalt in boreholes 17-2 or at the surface of boreholes BH-6 and BH-7. The layer encountered was also interbedded with rockfill in the borehole 17-2. The upper sand fill extended to depth ranging between 1.2 m and 6.5 m below the ground surface with corresponding elevations ranging between 279.4 m to 274.2 m. The lower sand fill layer extended to depth of about 5.3 m with corresponding elevation of 276.7 m. The explored thickness of upper sand fill layer was between 1.2 m and 6.5 m and lower sand fill layer was 1.0 m.

The composition of this fill layer was generally sand with trace to some silt, trace to some gravel and occasional cobbles. The material was blackish brown to brown in color, and moist. The SPT 'N' values within this layer ranged from 1 to 44 blows per 0.3 m penetration, suggesting very loose to dense in relative

density. Some SPT 'N' values of above 50 blows per 0.025 m penetration was obtained within this layer which could be an influence of underlying boulder or concrete culvert.

Laboratory testing performed on selected samples consisted of moisture content tests and grain size distribution test, and the test results are as follows:

Moisture Content: (**exp** and Golder)

- 5.8% to 14.8%

Grain Size Distribution: (**exp**)

- 0% gravel;
- 89% sand; and
- 11% silt and clay.

The results of the moisture content and grain size distribution tests are provided on the record of borehole sheets in Appendix C. The results of the grain size distribution test are also provided on Figure 7 in Appendix D.

1.4.2.3 Fill: Rockfill

A layer of rockfill was encountered below sand fill in borehole 17-2. The upper rockfill layer extended to depth of about 4.3 m below the ground surface with elevation of 277.7 m and the lower rockfill layer extended to depth of about 6.9 m below ground surface with elevation of 275.1 m. The explored thickness of upper and lower rockfill layers were 1.7 m and 1.6 m, respectively.

The composition of this layer was generally cobbles and boulders with some sand and some gravel. One SPT 'N' value obtained within this layer was 44 blows per 0.3 m penetration suggesting dense relative density.

1.4.2.4 Fill: Silty Sand and Gravel

A silty sand and gravel fill layer was encountered below rockfill in borehole 17-2, which extended to depth about 8.2 m below the ground surface with elevation of 273.8 m. The explored thickness of this layer was 1.3 m. Borehole 17-2 was terminated below this layer at the existing culvert.

The composition of this fill layer was generally silt and sand with trace to some gravel. The material was brown in color, and moist. One SPT 'N' values within this layer obtained was 50 blows per 0.13 m penetration, suggesting very dense in relative density, which could be an influence of the underlying culvert.

Laboratory testing performed on selected samples consisted of moisture content test and grain size distribution test, and the test results are as follows:

Moisture Content: (Golder)

- 18%

Grain Size Distribution: (Golder)

- 36% gravel;
- 42% sand; and
- 22% silt and clay.

The results of tests performed by Golder are shown on the borehole logs attached in Appendix F.

1.4.2.5 Silt

A native silt layer was encountered below the existing culvert in BH-7. The silt layer extended to depth of about 5.5 m below the ground surface with elevation of 269.9 m. The explored thickness of this layer was 2.2 m.

The composition of this layer was generally silt and some fine sand trace gravel. The material was grey in color, and wet. The SPT 'N' values within this layer ranged from 3 to 8 blows per 0.3 m penetration, suggesting very loose to loose in relative density.

Laboratory testing performed on selected samples consisted of moisture content tests, and the test results are as follows:

Moisture Content: (exp)

- 17.4% to 18.3%

The results of the moisture content tests are provided on the record of borehole sheets in Appendix C.

1.4.2.6 Silty Sand to Sand

A native silty sand to sand layer was encountered below the silt layer in BH-7 and below the existing culvert in BH-6, which extended to depths ranging between 11.6 m and 18.1 m below the ground surface with corresponding elevations ranging between 263.8 m and 262.2 m. The explored thickness of this layer was between 6.1 m and 9.5 m. In BH-7, about 2.5 m thick layer of sandy silt was encountered between sand layer. The sandy silt layer was encountered at a depth of 7.3 m below the ground surface at elevation of 268.1 m. BH-6 and BH-7 were terminated within the silty sand to sand layer.

The composition of this layer was generally sand, some silt, trace to some gravel and trace clay. The material was brown to greyish brown in color, and wet. The SPT 'N' values within this layer ranged from 4 to 25 blows per 0.3 m penetration, suggesting very loose to compact in relative density.

Laboratory testing performed on selected samples consisted of moisture content tests and grain size distribution tests, and the test results are as follows:

Moisture Content: (exp)

- 16.8% to 25.4%

Grain Size Distribution: (exp)

- 0% to 12% gravel;
- 30% to 87% sand;
- 8% to 58% silt and clay; or
- 29% silt; and
- 1% clay.

The results of the moisture content and grain size distribution tests are provided on the record of borehole sheets in Appendix C. The results of the grain size distribution tests are also provided on Figure 8 in Appendix D.

1.5 Ground Water Conditions

Information regarding groundwater levels at the site was obtained by measuring water levels in open boreholes after completion of drilling. The groundwater levels measured in boreholes are shown on Table 1.2 and borehole logs. Water levels measured in open boreholes might not be stabilized due to a short-term observation, as well as due to using of a wash boring technique to advance the boreholes.

The groundwater levels measured in open boreholes upon completion of drilling were recorded at depths ranging between 1.83 m (BH-4) and 8.5 m (BH-8) below the ground surface with corresponding elevations ranging between 273.4 m and 274.5. At the time of investigation, the water level measured at the creek was approximately at elevation 272.7 m. Seasonal variations in the water table should be expected, with higher levels occurring during wetter periods of the year. Some mounding under the embankment should be expected.

Table 1.2 Groundwater levels recorded at the site

Borehole	Location relative to Hwy 11 CL	Date of Drilling	Groundwater level (Elevation, m)
BH-1	NBL (east)	08/29/2017	Dry (borehole caved at 279.15 m)
BH-2	Median ditch	08/30/2017	274.4
BH-3	SBL (west)	08/31/2017	273.4
BH-4	Toe (west)	09/7/2017	273.5
BH-5	Toe (East)	09/1/2017	273.0
BH-6	Median (Existing Culvert)	08/30/2017	Not Measured

Borehole	Location relative to Hwy 11 CL	Date of Drilling	Groundwater level (Elevation, m)
BH-7	Outlet (Existing Culvert)	09/6/2017	Not Measured
BH-8	SBL (west)	09/5/2017	273.3
BH-9	SBL (west)	09/5/2017	Not Measured
BH 17-2	NBL (east, existing culvert)	02/28/2017	Not Measured
BH 17-2B	NBL (east)	02/28/2017	274.5

1.6 Chemical Analyses

Two soil samples were selected for chemical analysis and were sent to Maxxam laboratories, a CALA-certified and accredited laboratory in Mississauga, Ontario. The analytical laboratory results are presented in Appendix E, and are summarized in Table 1.3.

Table 1.3. Corrosivity chemical analysis

Sample Identification	pH (unitless)	Soluble Chloride (ppm)	Soluble Sulphate (ppm)	Resistivity (ohm-cm)	Conductivity (umho/cm)	Redox Potential (mV)	Sulphide (ppm)
BH4-SS6	5.17	410	<20	1500	689	160	1.24
BH5-SS5	5.74	310	<20	1900	518	140	0.85

The chemical data indicates low resistivity and low pH (i.e. acidic environment) of the tested soil.

2 DISCUSSIONS AND ENGINEERING RECOMMENATIONS

2.1 General

This section of the report provides geotechnical design recommendations for the installation of proposed new Highway 11 culvert and rehabilitation of existing Highway 11 structural culvert at Highway 117 interchange (Site No. 42-194), in Bracebridge, Ontario. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the current investigation and previous investigation performed by Golder in the spring 2017 at the site, and presented in **Part I-Foundation Investigation Report**. The interpretation and recommendations provided are intended solely to permit designers to assess foundation alternatives, appropriate installation method of the new culvert and to adopt mitigation or stabilization method of existing culvert suspected base failure. Comments on construction are only provided to highlight issues that could affect the design. Contractors bidding on the works should make their own assessments of the factual data and how it might affect construction means and methods, scheduling and the like.

It is understood that the new culvert with a 1.95 m diameter is proposed to be installed approximately 6.4 m south of the centreline of the existing culvert. It is further understood that the new culvert invert elevation will be at the same elevation or below the existing culvert invert elevation at approximately 272.59 m at inlet and 272.46 m at the outlet. It is also understood that for the existing culvert is proposed to be lined. At the time of preparing this report, type of lining is not known.

This report addresses the geotechnical design of the foundation for the new culvert by providing geotechnical design parameters at the Ultimate Limit State (ULS) and Serviceability Limit States (SLS) as well as other geotechnical parameters that may be required in accordance with the latest edition of the *Canadian Highway Bridge Design Code (CHBDC)* (CAN/CSA-S6-14), the *Guideline for Professional Engineers Providing Geotechnical Engineering Service* (1992), the *Canadian Foundation Engineering Manual (CFEM)* (2006), MTO Gravity Pipe Design Guidelines (May 2007) and good practice. As requested in the TOR, this section also provides discussions on appropriate methods for culvert installation by trenchless method, including table with evaluated alternatives and cost estimates; ease of excavating of embankment, and any need for dewatering and roadway protection/shoring. Pertinent construction issues from a geotechnical standpoint are examined in general accordance with the TOR provided at July 7, 2017 together with the MTO request email.

2.2 Proposed New Culvert

2.2.1 Expected Ground Conditions

According to the results of current foundation investigation, the following ground conditions along the new culvert alignment are evident:

- a. The highway embankment consists of fill material composed of sand, rockfill, sand to gravelly sand and silty sand to sand and silt. The embankment fill is followed by native deposits of sand and silt, sandy silt and silty sand to sand.
- b. The total thickness of the embankment fill along the new culvert alignment ranged from 8.4 m to 10.1 m at the investigated locations (BH-1, BH-2, BH-3, BH-8 and BH 17-2B). Embankment fill is underlain by very loose to compact sand and silt (0.6 m to 4.6 m thick), followed by very loose to dense silty sand to sand (4.2 m to 9.7 m thick). DCPT advanced below silty sand to sand layer indicated that silty sand to sand layer is compact to very dense. The boreholes extended to depths ranging between 9.8 m and 24.4 m with elevations ranging between 272.0 m and 257.7 m.
- c. At the inlet side of the proposed culvert, a layer reworked silty sand fill (~1.5 m thick) is underlain by very loose to loose sandy silt with organics (2.9 m thick) followed by very loose to loose silty sand (4.0 m thick) and loose to compact sand (5.3 m thick). At the outlet side of the proposed culvert a layer of topsoil (~0.1 m thick) is underlain by very loose to loose sand to silt fill (~2.3 m thick) followed by very loose sandy silt (1.3 m thick) and loose to compact sand (~6.1 m thick).
- d. The proposed culvert inverts are assumed approximately at Elev. 272.59 m at the inlet and Elev. 272.46 m at the outlet. The possible excavation level will be through native very loose to loose sandy silt to loose to compact sand and silt.
- e. The groundwater levels measured in open boreholes upon completion of drilling were recorded at elevations ranging between 273.4 m and 274.5. At the time of investigation, the water level measured at the creek was approximately at elevation 272.7 m. Seasonal variations in the water table should be expected, with higher levels occurring during wetter periods of the year. Some mounding under the embankment should be expected.
- f. Based on the measured elevation of the stream flowing through the existing culvert and the water level measured in open hole, the inferred groundwater level within the embankment was estimated to be at approximate elevation of 274.5 m. Seasonal variations in the water table should be expected.
- g. The slopes of the embankment at inlet and outlet sides are covered grass and some trees. No slope instability on either embankment slopes was observed.

2.2.2 New Culvert Installation Options

In general, two alternatives can be considered for the installation of the proposed new culvert:

1. Traditional cut and cover methods; and/or
2. Trenchless (tunneling) methods (i.e. jack and auger bore; micro-tunneling; pipe ramming; horizontal directional drilling (HDD) and TBM tunneling)

The selection of appropriate construction methods for this culvert considered whether disruption of the traffic is acceptable or not, soil conditions at zone of culvert installation, and diameter and length of the culvert. However, since the proposed new culvert location site is at the proximity of Highway 11/117 interchange, the open cut method might not be a viable alternative. Therefore, the open cut method of culvert installation is not discussed further. Only trenchless methods (i.e. jack and auger bore; micro-

tunneling; pipe ramming; HDD and TBM tunneling) are discussed in this report. Table 2.1 below summarizes the advantages, disadvantages and respective estimated cost of possible methods.

Table 2.1 Installation methods for culvert replacement along the proposed new culvert alignment

Installation Method	Advantages	Disadvantages	Relative Cost	Ranking
<i>Jack and Auger Bore</i> (Non-entry Method)	<ul style="list-style-type: none"> • No traffic interruption and requirement for detour route • Commonly used in Ontario • Relatively simple operation • Short mobilization time • Auger can be manually removed to permit cleaning of obstructions such as cobbles and boulders • The existing culvert can be used to maintain the surface water flow during the construction • Less expensive than other trenchless methods 	<ul style="list-style-type: none"> • Groundwater control will be required since the GWL is above the invert level • Pipe can be difficult to steer/direct • Settlement of existing embankment due to loss of ground during jack and bore operations. Short and long-term settlement • Excavation and shoring required to achieve starting grade, as well as to minimize possible impact on the global stability of the embankment • Large entry pit size 	In general, less expensive than other trenchless methods, but extensive dewatering could be very expensive	2
<i>Micro-tunneling</i> (Non-entry Method)	<ul style="list-style-type: none"> • No traffic interruption and requirement for detour route • Handles wide variety of ground conditions • Ability to control excavation face stability • No dewatering required • Minimum surface disruption • Very accurate • The existing culvert can be used to maintain the surface water flow during the construction 	<ul style="list-style-type: none"> • High construction cost • Not suitable for short drive • Excavation and shoring require to achieve starting grade, as well as to minimize possible impact on the global stability of the embankment • Dewatering possibly required at launching and receiving pits 	Significantly more expensive than jack and bore method, but dewatering is not required	1

Installation Method	Advantages	Disadvantages	Relative Cost	Ranking
<i>Horizontal Directional Drilling (HDD)</i> (Non-entry Method)	<ul style="list-style-type: none"> • No traffic interruption and requirement for detour route • Handles wide variety of ground conditions • Steerable both horizontally and vertically to maintain and adjust alignment • Suitable for tunneling under groundwater table • Local contractors available • Short mobilization time • Rapid drilling • Only minor settlement if drilling fluid well controlled • Suitable for installation of pipes up to 1.2 m in diameter and longer lengths 	<ul style="list-style-type: none"> • Potential for inadvertent drilling fluid returns • Requires drilling fluid to maintain the bore which could allow subsidence • Space limited • Obstructions problematic, but alignment can be adjusted to avoid obstructions • Annular space filling (i.e. fluid or grouting) • Generally, not suitable for installation of pipes greater than 1.2 m in diameter, which is the case in this project 	Slightly more expensive than jack and bore method, but less expensive than micro-tunneling, but size of installed pipe is limited	4
<i>Pipe Ramming</i> (Non-entry Method)	<ul style="list-style-type: none"> • No traffic interruption and requirement for detour route • Not very sensitive to ground condition • Accommodates obstructions well • Little surface settlement • Soil removed after pipe in place • The existing culvert can be used to maintain the surface water flow during the construction 	<ul style="list-style-type: none"> • Pipe can be difficult to steer/direct • Excavation and possible shoring required to achieve starting grade • Proposed length and diameter is above typical limit of 1.8 m dia. and 50 m length • Large entry pit size • Possibility of ground heave, if obstruction encountered • Vibrations could potentially impact the stability of the existing slope • Slower than other trenchless methods • Dewatering possibly required at launching and receiving pits 	Slightly more expensive than jack and bore method, but less expensive than micro-tunneling	3

Installation Method	Advantages	Disadvantages	Relative Cost	Ranking
<i>TBM Tunneling</i> (Man-entry Method)	<ul style="list-style-type: none"> • No traffic interruption and requirement for detour route • Good control of settlement • Safe to use in mixed ground condition • Ability to access obstructions during tunneling • Cost may be reduced if and where existing contractor's suitable TBM is available • The existing culvert can be used to maintain the surface water flow during the construction 	<ul style="list-style-type: none"> • High capital investment • Not practical for small diameter pipe (min. 1.8 m diameter) • Dewatering possibly required at launching and receiving pits • Excavation and shoring require to achieve starting grade, as well as to minimize possible impact on the global stability of the embankment 	More expensive than non-entry methods	5

Based on the existing ground conditions and the list of advantages and disadvantages of all tunneling methods considered for this project, micro-tunneling is considered as a most feasible option for this culvert crossing. It might be more expensive than the jack and bore method, but it will provide more certainty to cost and schedule and will maintain the face of the tunnel in stable condition always with a minimum ground subsidence. Equipment for installation of the pipe culvert using micro-tunneling is now locally available and there are several good contractors available in the Province. The system gives a top-class product and can be guided very accurately through all ground conditions (less than 50 mm accuracy vertical & horizontal). It should be also noted that larger starting shaft is required at a launching shaft (about 6 m length if for example using Herrenknecht AVN1200 series TBM with mixed head).

The jack and bore technique is considered as a less feasible for excavation and installation of the culvert in loose to compact sandy soils with the groundwater level above the invert. Significant groundwater inflow into the tunnel could be anticipated, leading to instability of the soil face. Therefore, dewatering or grouting would be required.

The Horizontal Directional Drilling (HDD) method like micro-tunneling is insensitive for tunneling under the groundwater level. However, considering the size of the proposed pipe it is assessed that HDD method is not feasible for this project. The pipe ramming approach is also assessed as a less feasible trenchless installation method since the steering of this long culvert could be difficult, as well as, its vibration could destabilize the embankment slope. TBM tunneling is assessed as the most expensive trenchless installation method.

The launching and receiving pits for the tunneling equipment are expected to be located at the outlet and inlet of the proposed culvert. Access to launching and receiving pits could be difficult due to the high fill embankment. It should be noted that, at the proposed culvert location, construction of the launching or receiving pit at the inlet side would be very difficult due limited space between Highway 11 embankment and existing N-E/W ramp to Highway 117. It may require partial excavation of the existing embankments slope to create space for the launching or receiving pit at inlet side.

2.2.3 Comments on Trenchless (Tunneling) Installation Methods

Tunneling will be a viable installation method for culvert installation along the new culvert alignment if interruption of traffic on Hwy 11 and Hwy 117 interchange is not acceptable. Based on soil and groundwater conditions at the site and the dimensions of the new culvert, some tunneling methods are considered in Table 2.1 and discussed in the sections below. The analysis indicates that microtunnelling is the most suitable approach for the prevailing conditions. For all trenchless installation methods, the procedures should conform to all relevant Ontario Provincial Standard Specifications (OPSS), Non-Standard Special Provisions (NSSP) such as "Pipe Installation by Trenchless Methods" and industrial standards. It should be noted that the new culvert is proposed to be installed beside the existing box culvert. According to OPSS 421, the minimum spacing allowed between a new culvert and existing culvert is a 0.5 times of pipe diameter for the diameter between 1200 mm and 2400 mm and 1200 mm for the diameter greater than 2400 mm. The proposed spacing

between the existing box culvert and new culvert for this project (i.e. 1950 mm diameter) is approximately 4000 mm which meets the suggested criteria. For culvert installation by a trenchless method it should be noted that the stability of face must be maintained always. It is also recommended to be used shoring systems for excavation of entry and exit pits.

It is projected that the culvert trenchless (tunneling) excavation will be carried out generally through silty sand/ sand and silt fill to native sand and silt, assuming that the approximate elevation of the new culvert invert is between Elevation 272.59 m at the inlet and 272.46 m at the outlet. Based on the measurements during this investigation, the inferred ground water level within the embankment was estimated to be at approximate Elevation of 274.5 m or slightly above, which appears to be above the tunnel invert. However, seasonal variations in the groundwater table should be expected.

The Tunnelman's Ground Classification System (Terzaghi, 1950) is commonly used to describe the potential behavior of and unsupported tunnel face during excavation. This system uses qualitative "stand up time" criteria to classify the ground into six principal categories. Based on this system, for an exposed tunnel face, it is anticipated that the sandy soils within the tunnel horizon would generally behave as "flowing" ground. Therefore, tunneling methodologies that involve an unsupported tunnel face may not be feasible for this project, unless the groundwater level is lowered in advance of tunneling.

OBSTRUCTIONS

Some cobbles and boulders were also encountered in the zone of tunneling during drilling of the horizontal borehole as well as during vertical borehole investigations. In addition, some organics and wood fibers were encountered at the zone of tunneling. The horizontal drilling confirmed that there is no rockfill at the level of the proposed culvert, but cobbles and boulders should be expected to be present along the alignment. The NSSP for these obstructions in the fill and tunneling zone is included in Appendix I.

2.2.3.1 Pipe Jack and Auger Bore

Pipe jack and auger bore method involves jacking a pipe through the soil with a hydraulic ram and removal of soil with an auger. A cutting head is fixed to the leading edge of the pipe. The auger transports spoils from the cutting head back to the bore pit. The direction of the auger head can only be controlled using a rudimentary steering system where minor adjustments can be made. The procedures should conform to all relevant OPPS (i.e. OPSS 416) and industrial standards. One of the advantages of using the jack and bore method for the pipe installation is that the auger can be manually removed to permit cleaning of obstructions such as cobbles and boulders. Further, the auger can be adopted to use rock-cutting teeth, if necessary. However, the elevation and gradient of the pipe must be closely controlled during the jack and bore. To reduce (but not eliminate) loss of ground and associated disturbance, consideration may be given to jacking the pipe across the alignment as far as practical, prior auguring. It is recommended that auger would always be maintained at least 1 m behind the cutter edge. The jacking and boring operations should be continued without stoppage until completion. However, obstacles encountered in the embankment fill, could make this difficult or impractical. Lubrication may be provided to reduce the friction between

the pipe and the borehole walls. The characteristics of the surrounding soil should be considered in selecting the appropriate lubricant.

Based on the current investigation data and assumed invert levels, it appears that the pipe jacking and boring will be performed through very loose to compact silty sand/ sand and silt fill to native very loose to compact sand and silt, and the groundwater level will be above the invert of the pipe. Considering these soil and groundwater conditions, there are several items that must be addressed when considering the pipe jack and auger bore method for installation of the new culvert. First, due to presence of groundwater above the tunnel invert and presence of cohesionless soils around tunneling zone, control of the face of excavation will be difficult. Groundwater infiltration from the inlet through fill is expected. Using of pumps of sufficient capacity from jacking pit and design of suitable dewatering along the culvert alignment could require preventing groundwater infiltration into the tunnel. Conversely, grouting will be required during jacking and boring. Design of the suitable dewatering is the responsibility of the Contactor. Second, the problem associated with this method is deviation from the alignment, if not executed properly. The installation of the proposed culvert must not interfere with the existing culvert and/or utilities, if any. Therefore, driving of the pipes must be very accurate. Furthermore, any significant voids between the casing and the surrounding soil should be filled with pressurized cementitious grout to prevent / minimize ground loss. It is expected that the existing culvert will be utilized to convey the creek flow during construction.

To minimize possible negative impact on the stability of the existing embankment slope due to excavations required for the bore/jacking pits and installation of the pipe using the pipe jack and auger bore method, a protection system might be required for the existing roadway.

2.2.3.2 Micro-tunneling

Micro-tunneling method is a non-entry, remotely controlled, guided 2-stage process, which provides continuous support to the excavation face. In this method, a Micro Tunneling Boring Machine (MTBM) is used for soil cutting, while a pipe is jacked into place behind the cutting head with hydraulics. The MTBM is equipped with a slurry spoil removal system to control the groundwater inflow and counterbalance the earth and hydrostatic pressure while tunneling through the mixed face conditions. The cutting tool and the drilling fluid must be able to handle the different materials and the “mixed face” condition such as presence of cobbles and boulders. To minimize the resistance along the pipe exterior, a bentonite grout lubricant can be injected behind the cutting face. Steel, concrete or fiberglass pipes can be installed with this method.

Considering the soil and groundwater conditions at the site, the major advantage of micro-tunneling method for this project is that its performance is not affected by high groundwater levels, so the dewatering is not required. Major disadvantages of micro-tunneling for this project are the relatively high cost of mobilization and not viable for relatively short length. This option will be less expensive if potential bidders have available equipment in house.

For excavation of the launching pit, a protection system might be required to minimize possible negative impact on the stability of the existing embankment slope.

2.2.3.3 Horizontal Directional Drilling (HDD)

Horizontal directional drilling (HDD) may be used to install some pipes, provided the drill hole is always supported with a properly designed drilling fluid. The drilling fluid should be designed by a specialist contractor, based on factors such as the soil type, diameter and depth of the opening, rate of drilling etc., and may have to be adjusted as construction proceeds. The fluid pressure should not exceed the in-situ overburden pressure. In general, higher pressure could cause fracturing of the ground and loss of the drilling fluid, which in turn could cause instability and even collapse of the drill hole. The cutting tool and the drilling fluid must be able to handle different materials including cobbles and boulders. This method is suitable for installation of pipes up to 1.2 m in diameter under the groundwater table. However, the size of the proposed culvert for this project is greater than 1.2 m.

2.2.3.4 Pipe Ramming

Pipe ramming is a trenchless method for installation of steel pipes over distances typically up to 50 m long and up to 1.8 m in diameter. The method uses pneumatic percussive blows to drive the pipe into ground. Spoil removal from the pipe can be done by an auger. It typically requires excavation of two pits, but the ramming can be launched without an insertion pit if the ram is designed to start at the side of a slope.

Though, the length of the proposed culvert above the typical range for the pipe ramming, it may consider as suitable option for installation. However, installation is very noisy and difficult to steer, and its vibration could destabilize the embankment slope.

2.2.3.5 TBM Tunneling

TBM tunneling is a man-entry tunneling method and encompasses the use of a tunnel boring machine (TBM). This method utilizes laser-guided targeting that achieves a very accurate line and grade to the pipe being installed. To control ground movement behind the TBM a primary liner must be installed. TBM can employ single pass or two passes systems. In the two-pass system, the temporary liner can be ribs and lagging with the permanent liner cast-in-place afterwards. The primary liner can be provided by steel, cast iron or precast concrete liner plates. The space on the outside of the liner plates should be grouted as soon as possible, to reduce ground loss and ground settlement. Primary support can be also provided by jacking a pipe from a jacking station behind the boring machine. Pipes may be made of various materials (concrete, steel, fiberglass, etc.).

TBM tunneling is assessed as the most expensive trenchless installation method for the proposed culvert considering the short length of the tunnel. Cost might be reduced if, and where, existing Contractor's suitable TBM is available.

2.2.4 Considerations for Tunneling

2.2.4.1 Groundwater and Surface Water Control

As mentioned before, groundwater seepage into the tunnel should be expected in the zone of tunneling. However, dewatering might be required in the launching pit prior to advancing the pipe to ensure dry working conditions and stabilize the excavation in that zone. The dewatering would need to be carried out to temporarily lower the groundwater level to at least 1 m below the base of the excavation. Dewatering shall be carried out in accordance with OPSS.PROV 517. It is responsibility of the Contractor to propose a suitable dewatering system based on the time of construction, water levels and flow conditions for prior approval of the MTO. The method used should not undermine the existing road embankment or adjacent side slopes. In this connection, the provision of toe protection at side slopes during drawdown may be required to minimize sloughing and undercutting during dewatering. Alternatively, and in accordance with SP 517F01, the dewatering systems may be completed by a design Engineer and design-checking Engineer with a minimum of 5-year experience. For this application, this is considered a suitable approach but the owner should make final decision. Based on the estimated permeability of sand and silt ($k \sim 5 \times 10^{-5}$ m/s), the preconstruction survey distance should be approximately 100 m (a recommended value for Table A in SP 517F01).

The existing culvert could be used to convey the surface water flow towards the outlet. The Contractor has to propose a suitable surface water collection system to allow safe and dry installation of the new culvert.

As indicated above, if jack and bore technique is considered for installation of culvert, suitable dewatering systems along the culvert alignment should be designed to prevent groundwater infiltration into the tunnel. Conversely, grouting will be required prior jacking and boring. The ingress of groundwater and surface water into the jacking pit should be controllable to handle by using pumps of sufficient capacity.

2.2.4.2 Ground Grouting

Post tunneling grouting would also require as generally, there is a risk of over-excavation and the formation of voids around the liner pipe in any tunneling operation. To minimize ground surface settlement and to avoid unbalanced loads on the liner, grouting around the liner is generally recommended. The need for grouting around the liner pipe should be evaluated once tunneling is complete.

The amount of spoil removed during tunneling should be monitored to determine whether over-excavation is occurring. If there is suspicion that over-excavation has occurred, and/or if the settlement monitoring indicated that the ground surface has settled, then a plan should be in place for investigating of presence of gaps/voids in the soil above the pipe and for remediation measures such as filling the gaps/voids with grout. The contractor should develop a contingency plan incorporating appropriate soil volume monitoring to address loss of material from outside the pipe during the tunneling operation, as discussed in Section 2.2.4.6.

2.2.4.3 Ground Settlement

Settlement around the culvert is a result of ground loss or “immediate” settlement caused by tunneling. Presence of the organics within sand and silt or sandy silt layer may also aggravate the settlement during tunneling. The immediate settlement is a direct result of the overcut and movement of ground at the heading during tunneling. The factors that influence the immediate settlement include the soil strength, the method of tunneling, the tunnel size and depth, the form of primary support, the grouting procedure used to fill voids outside of the primary liner, the timing of the grouting and the contractor’s workmanship. Based on soil characteristics of the site, an experienced Contractor should be able to keep the settlement under the MTO’s required limit of 10 mm. Technical specifications should ensure that:

- The use of over-cutters (excavating to a diameter greater than the pipe diameter) is kept under 10 mm;
- The overcut area is grouted in a timely manner (if a man-entry tunnel is constructed grout should be injected immediately after support is installed); and
- The program of instrumentation is carried out as per MTO guidelines (see Section 2.2.4.6).

If the settlement is greater than the allowable 10 mm, some soil stabilization measures such as grouting or ground freezing might be applied to arrest or reduce settlement.

Generally, there is a risk of over-excavation and the formation of voids around the liner pipe in any tunneling operation. To minimize ground surface settlement and to avoid unbalanced loads on the liner, grouting around the liner is generally recommended.

The amount of spoil removed during tunneling should be monitored to determine whether over-excavation is occurring. If there is suspicion that over-excavation has occurred, and/or if the settlement monitoring indicated that the ground surface has settled, then a plan should be in place for investigating of presence of gaps/voids in the soil above the pipe and for remediation measures such as filling the gaps/voids with grout. The contractor should develop a contingency plan incorporating appropriate soil volume monitoring to address loss of material from outside the pipe during the tunneling operation, as discussed in Section 2.2.4.6.

2.2.4.4 Excavations

The launching and receiving pits for the tunneling equipment are expected to be located at the inlet and outlet of the proposed culvert location, respectively. The bases of the pits are expected to be set at about 0.5 to 1 m below the invert of the proposed culvert. Excavations for launching and receiving pits will be conducted through very loose to compact silty sand/ sand and silt fill to native very loose to compact sand and silt. To provide the required excavation geometry for the drilling (e.g. vertical front face for tunnel entry and a vertical rear face with a ballast system to act as a reaction force), the sides of the excavation must be shored. Recommendations for shoring are addressed in Section 2.2.4.7 below. Ingress of groundwater and surface water must be controlled as explained in

Section 2.2.4.1 above. Technical specifications must ensure that the Contractor submits a groundwater and surface water control plan describing the proposed method for control.

In general, all open cut excavations at this site must be conducted in accordance with the Occupational Health and Safety Act (OHSA) and Regulations for Construction (O. Reg. 213/91). All fills (i.e. sand fill to silty sand fill) may be classified as a Type 3 soil above the groundwater table in conformance with the OHSA. The native soils below the groundwater table may be classified as a Type 4 soil. To avoid disturbance of the founding subgrade and to allow placement of backfill in dry conditions, groundwater must be controlled to below the proposed invert excavation levels prior to digging to final levels. The ingress of surface water must be controlled using a suitable system as well.

Temporary excavation side slopes for Type 3 soil should not exceed 1H:1V in accordance with OHSA, and 2H:1V is recommended for global stability of deeper cuts (i.e. to maintain a global factor of safety greater than 1.3) where excavation will be left open for some time. Temporary excavation side slopes for Type 4 soils should not exceed 3H:1V where applicable.

2.2.4.5 Backfilling in Pits

It is anticipated that backfilling work will be required at the launching and receiving pits to return site condition to pre-construction grades. The following comments and recommendations are provided for backfilling such excavations:

All excavations should be backfilled with inorganic on-site soils placed in maximum 200 mm thick lifts and compacted to at least 98% of the Standard Proctor Maximum Dry Density (SPMDD). Any organic, excessively wet, compressible or otherwise deleterious materials should not be used for backfilling purposes. Any shortfall of suitable on-site excavated materials can be made up with imported and approved materials such as Granular B (OPSS 1010 and OPSS 402).

All backfill and compaction operations should be monitored by a qualified geotechnical personnel to approve materials, to evaluate placement operations, and to verify that the specified degree of compaction is being achieved throughout the fill.

2.2.4.6 Monitoring and Contingency Plan

It is emphasized that the resulting performance of the installed culvert will largely be dependent upon construction procedures and techniques. However, regardless of the method of tunneling selected for this project, it is recommended that the contractor develop a contingency plan incorporating appropriate soil volume monitoring to address loss of material from outside the pipe during the tunneling operation. This plan should include at a minimum the following items:

- a) an "Alert" level(s) at which the plan would be implemented;
- b) a means to close the tunnel, and preferably to pressurize the pipe; and
- c) an emergency personnel/agency contact list.

Settlements should be monitored during construction to ensure compliance with MTO guidelines and

the contract requirements. The instrumentation program should adequately verify effects of tunneling on the overlying highway and obtain warning of ground movements. The scope and layout of settlement instruments should be in general accordance with the MTO guidelines presented in Appendix: Settlement Monitoring Guideline – Tunneling. This should include a series of surface monitoring points placed at a maximum spacing of 5 m along the entire length of the proposed culvert. All monitoring points located in the unpaved portion of the right-of-way are to be founded below the frost penetration depth, which is typically 1.7 m in this area.

A reading schedule should be as follows:

- A minimum one set of readings prior to construction.
- A minimum three sets of readings during construction provided the movements are within the anticipated limits. Otherwise, the reading frequency may have to be increased.
- A minimum of two sets of readings on a weekly basis after completion of the work.

Instrumentation plans should be finalized once the Contractor is selected and when his construction methods are known.

As mentioned, control of ground settlement on this project depends on the behavior of soil at the tunnel face and on the tunneling methodology employed by the Contractor. Therefore, it is recommended that a geotechnical engineer be present during active excavation to verify that the ground conditions are consistent with those encountered in the investigation boreholes. Furthermore, it is recommended that the volume of the material removed from the tunnel be monitored and continuously compared to the rate of tunnel advance. This will provide an indication if any over-excavation is taking place.

The criteria for evaluation of settlement should be based on the following action levels:

1. *Review Level:* If a maximum value of 10 mm relative to the baseline readings is reached, the method, rate or sequence of construction, or ground stabilization measures shall be reviewed or modified to mitigate further ground displacements.
2. *Alert Level:* If a maximum of 15 mm relative to the baseline readings is reached, the Contractor shall be required to cease construction operation or to execute pre-planned measures to secure the site to mitigate further unacceptable settlement and to assure safety of public.

2.2.4.7 Protection Systems

Depending on the tunneling method chosen for this project and the excavations that will be required to implement them, protection system(s) may be required for the existing roadway. The need for these systems will depend on the proposed geometry of the required excavations and their proximity to the existing highway structure. If required, protection systems (design, materials, construction, maintenance, monitoring and removal) will be required to meet the specifications set out in OPSS PROV.539. The lateral movement of the temporary shoring system should meet Performance Level

2 as specified in OPSS.PROV 539. The complete design, construction, monitoring and removal of the installed protection system should be a responsibility of the contractor. Due to nature of this application it is expected that much of temporary shoring will be decommissioned in place noting the high cost for removal. Decommissioning must be consistent with good practice to avoid interference with highway systems and utilities, if any. The protection system should be designed to provide protection for excavations as required by the OHSA, at locations specified in the contract, and at any locations where the stability, safety or function of an existing structure and/or utility may be impaired by the construction work.

At this site a shoring system, such as soldier piles and timber lagging may be considered for design. It should be designed based on the earth pressures coefficients and soil parameters provided in Section 2.6.7.1 below. The actual depth of embedment should be determined by balancing moments about the pile tip. For design of the timber lagging, earth pressures can be reduced by 25 percent to account for soil arching effects. This is provided that the center-to-center spacing of the soldier piles does not exceed 2.5 m. Excavation can proceed following installation of the soldier piles. The unshored height of the excavation should not exceed 1.2 m at any given time. No excavation height should remain unshored for more than 24 hours.

As mentioned above, the protection system should be designed for the Performance Level 2 (for small, less important sections). The minimum requirements for monitoring should include the survey measurements of 6 m apart scaled targets attached to the shoring wall at the elevations specified. If movement approaches the allowable limit of 25 mm (Performance level 2), suitable measures should be taken to ensure stability of the protection system and to ensure that the movement does not exceed the performance level specified.

2.2.4.8 Lateral Earth Pressure

Culvert walls and a temporary shoring system that may be required for excavation should be designed to resist lateral earth pressure.

The expression for calculating lateral earth pressure is given by:

$$P = K(\gamma h + q) \text{ for non-braced cut, or } K(0.65\gamma H + q) \text{ for braced support}$$

where P = earth pressure intensity at depth h , kPa

K = earth pressure coefficient

γ = unit weight of retained soil, kN/m³

q = surcharge near wall, kPa

h = depth to point of interest, m

H = depth of excavation (m)

The above expression does not take into account hydrostatic pressure, which must be included for the groundwater levels measured on the site. Table 2.2 below lists earth pressure parameters for given materials. These recommendations assume level backfill and ground surface behind the walls.

Table 2.2. Material types and unfactored earth pressure properties under static conditions

Material	Unfactored Friction Angle ϕ (°)	Coefficient of Active Earth Pressure (K_a)	Coefficient of Passive Earth Pressure (K_p)	Coefficient of Earth Pressure at Rest (K_o)	Unit Weight γ (kN/m ³)
Compacted Granular A	35	0.27	3.69	0.43	22
Compacted Granular B, Type II	35	0.27	3.69	0.43	22
Compact to dense Sand Fill	32	0.31	3.25	0.47	20
Rockfill	36	0.26	3.87	0.41	20
Very loose to very dense Sand to Gravelly Sand	32	0.31	3.25	0.47	21
V. loose to compact Silty Sand/Sand and Silt Fill	30	0.33	3.0	0.5	19
Native loose to compact Sand and Silt	28	0.36	2.77	0.53	19
Native compact to dense Sand	32	0.31	3.25	0.47	21

The mobilization of full active or passive resistance requires a measurable and perhaps significant wall movement or rotation. Therefore, unless the structural element can tolerate these deflections, the at-rest earth pressure should be used in design.

The effect of compaction surcharge should be considered in the calculations of active and at-rest earth pressures. The lateral pressure due to compaction should be taken as at least 12 kPa at the surface, and its magnitude should be assumed to diminish linearly with depth to zero at the depth where the active (or at rest) pressure is equal to 12 kPa. This pressure distribution should be added

to the calculated active (or at rest) pressure. Notwithstanding, lighter compaction equipment and smaller lifts should be used adjacent to walls to prevent overstraining.

2.2.5 Slope Stability and Settlement Analyses

2.2.5.1 Stability

A preliminary slope stability analysis was performed to assess the global stability of the existing embankment and to check that a minimum Factor of Safety of 1.3 will be achieved for the embankment at the location of the proposed culvert. The static slope stability analyses were performed using the Morgenstern-Price method developed based on limit equilibrium. The SLOPE/W computer program developed by GeoSlope International was employed for computation.

Stability assessments of existing slopes under static conditions were performed on the cross-section perpendicular to the roadway at the proposed culvert location. The cross-section of the existing embankment with the approximate slopes of 2.3H:1V and 2H:1V on east and west side slopes were developed based on the drawings provided by MTO. The stratigraphy and groundwater condition at the site were developed based on the results of the geotechnical investigation presented in Part I - Foundation Investigation Report.

Based on the borehole information, the subsoils encountered at the work area consist of embankment fill, underlain by sandy silt to sand and silt and followed by sand deposits. Therefore, an effective stress analysis for a long-term assessment of the embankment slope was performed taking into consideration the subsoil conditions encountered beneath the existing embankment.

The SLOPE/W graphical printout, for analysis performed is included in Appendix G. Since the geometry and soil stratigraphy at the west side slope are more critical than that at the east side slope, the result of the slope analysis performed for the west side slope, is only presented.

Tabulated below in Table 2.3 are the soil parameters used for the slope stability analysis. The soil parameters were generally estimated based on the results of field and laboratory investigation.

Table 2.3 Soil properties used in slope stability analysis

Soil Type	Effective Stress Parameters		
	ϕ' (degrees)	c' (kPa)	γ' (kN/m ³)
Sand Fill	32	0	21
Sand and Silt Fill	30	0	19
Sandy Silt to Sand and Silt	28	0	19
Sand	32	0	21

The results of slope stability analyses for the ~2H:1V west side slope of the existing embankment (at the proposed culvert alignment) using drained (long term stability) soil parameters are presented graphically in Figure 1 attached in Appendix G. A minimum Factor of Safety is more than 1.3, indicating that the existing embankment is stable. If embankment slopes have to be reconstructed at the location of the proposed culvert they should not be steeper than those of the existing.

2.2.5.2 Settlement

The existing embankment grade is not going to be changed significantly at the culvert location. Therefore, there should be negligible additional settlements under the existing embankment.

2.2.6 Inlet and Outlet

2.2.6.1 Erosion Protection at Inlet and Outlet

Erosion/scour protection should be provided at the culvert inlet and outlet (including the side slopes). The erosion/scour protection should be designed by a specialist River Engineer/Scientist (as erosion and scour largely depend on the velocity of water in the watercourse and its regime), who is familiar with the findings of this report. The following are some general suggestions for preliminary guidance considering native material anticipated. In general, rip-rap protection should be provided where the culvert discharges into the open creek. The rip-rap should extend approximately 5 m beyond the ends of the culvert and line the embankment slope to the spring line of the culvert. The size of the rip-rap is a function of the creek's hydrology. As a rule of thumb, the thickness of the rip-rap should be a minimum of twice the median particle size, and 300 mm thick as a minimum. The rip-rap configuration at the creek bed should generally follow the OPSD 810.010, which is included in Appendix H of this report. If geotextile is used it should be nonwoven, Class II according to OPSS 1860, with an FOS of 75-150 mm. The erosion protection should consider the possible installation of seepage protection measures at both upstream and downstream ends.

Where the embankment side slopes have been scarred and/or excavated (beyond rip-rap limit) to facilitate the existing culvert replacement, the scarred and/or reinstated embankment side slopes are to be vegetated with sodding, seeding or planting as necessary depending on the flow rate and volume. Should seeding be utilized, a 100 mm thick layer of topsoil should be placed along with a degradable erosion blanket to help minimize erosion until the vegetation begins to grow.

2.2.6.2 Stream Bed Rip-Rap

The stream bed rip-rap thickness is to be at least twice the median particle size, and/or 300 mm thick as a minimum as outlined by OPSD 810.010 included in Appendix H of this report.

2.2.6.3 Seepage Cut-off Requirements

The seepage cut-off requirements should be reviewed in the following context. The native silty soils at the inlet, outlet side has a high potential for migration with high seepage gradients. For the new culvert installation, methods to avoid piping/undermining/scouring of material resulting from seepage

along the culvert must be considered and implemented. To prevent surface water from flowing beneath the culvert (potentially causing undermining/scouring) or around the culvert (seeping through embankment fill) these flows should be restricted. For culverts the following are typical methods: (i) clay seal, (ii) steel or wooden sheet pile cutoff at the upstream end of culvert, (iii) cut-off wall incorporated in the apron slab (if one is used) of the culvert, (iv) cut-off trench constructed with geotextile, and (v) rockfill at the upstream end of the culvert barrel to terminate below the granular bedding of the culvert. Only the clay seal and cut-off trench will be addressed since the sheet pile cut-off will require the understanding of the hydraulics of the stream.

2.2.6.4 Clay Seal

Where readily available a clay seal should be placed at the inlet of the proposed culvert, to prevent the migration of material along the face of the culvert, the formation of flow paths, and any potential internal erosion within the highway embankment (OPSD 802.095, Appendix H). OPSS. PROV 1205 specifies that material used for clay seals shall be natural clay, clay mixture (1-part Bentonite powder and 3.5 parts Granular "A") or a geosynthetic clay liner (GCL). The coefficient of permeability shall not exceed 1×10^{-6} cm/s.

The following outlines the installation procedures and minimum material requirement of the clay seal:

- The clay seal should be placed along the sides and top of the culvert a minimum of 1.0 m along the side of the culvert and extending out laterally 1.0 m from the culvert.
- The clay seal should be placed from the top of the culvert footings and extend along the side and the top of the culvert. The clay must not be placed below the culvert.
- The clay should have a Liquid Limit greater than 40% and a Plasticity Index greater than $0.73 \times (\text{Liquid Limit} - 20\%)$.
- The clay seal is to be placed in maximum 150 mm thick lifts and compacted to 95% SPMDD within 2% of the optimum moisture content.

If the GCL is used as a clay seal its material specifications containing the physical, mechanical and hydraulic properties shall be obtained from the manufacture. It is estimated that an approximately 12 mm thick GCL should be installed a minimum 1.0 m along the side of the culvert.

2.2.6.5 Cut-Off Trench

A cut-off trench can be used at both the upstream and downstream ends of the culvert and can be incorporated when the rip-rap apron at both ends of the culvert are being installed. In general, a trench is dug across the stream alignment to well beyond the walls of the culvert and a geomembrane liner is laid on the side of the trench keyed into the culvert at the top and on the base of the trench. The trench is then backfilled with graded rip-rap.

2.2.7 Corrosion Protection

The chemical data from two soil samples indicates low resistivity of the tested soil (1500 to 1900 ohm-cm), which suggests a severe potential for corrosion of buried metallic elements, particularly

pipes and appurtenances (MTO Gravity Pipe Design Guidelines, Page 25). Therefore, some level of pipe protection requires, depending upon the pipe material type. The pH level presented in Table 1.3, is less than 5.5 and indicates high potential for corrosion. Accordingly, buried metallic pipes and appurtenances would be susceptible to corrosion, unless they are protected.

The maximum water soluble sulphate content of the soils tested is < 20 ppm ($\mu\text{g/g}$), i.e. <0.002% and being less than 0.10%, does not indicate the potential to corrode normal Portland cement concrete.

2.3 Existing Culvert

2.3.1 Assessment of Existing Culvert Distress Area

Based on the TOR, from the visual assessment of the existing culvert, two distressed areas of the culvert were identified and base instabilities were suspected. Based on field observations, presence of very loose silt to fine silty sand or washout of the fines due to piping around the existing culvert could be the reason for causes of distress. However, during the site investigation within these distress areas (advancing boreholes BH-6 and BH-7) no voids or cavity were found and no signs of water flow under the culvert were observed.

2.3.2 Possible Remedial Measures

As indicated above, lining of existing culvert is considered to rehabilitate the existing culvert. At the time of writing this report, type of lining is not known. To fix the suspected base instability at existing distress location, it is recommended to use of chemical grouting to stabilize the base before lining of the existing culvert. Depending on type of lining chosen, it is also recommended to grout the gap between existing culvert and lining to avoid any leakage through lining.

October 18, 2018

3 CLOSURE

The comments given in this report are intended only for the guidance of design engineers. The number of boreholes required to determine the localized underground conditions between boreholes affecting construction costs, techniques, sequencing, equipment, scheduling, etc. could be greater than has been carried out for design purposes. Contractors bidding on or undertaking the works should, in this light, decide on their own investigations, as well as their own interpretations of the factual borehole results, so that they may draw their own conclusions as to how the subsurface conditions may affect them.

This Foundation Investigation and Design Report has been prepared by Mr. Nimesh Tamrakar, M.Eng, EIT. and Dr. S. Micic, Ph.D., P. Eng. and reviewed by Mr. T.C. Kim, M.E.Sc., P.Eng. and Mr. S.E. Gonsalves, M.Eng., P.Eng. designated MTO foundation contact. The field investigation was conducted by Mr. Nimesh Tamrakar, M.Eng, EIT.

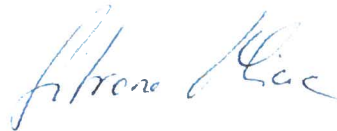
We trust that these comments provide you with sufficient information to for your present requirements. Should you have any questions, please do not hesitate to contact this office

Yours truly,

exp Services Inc.



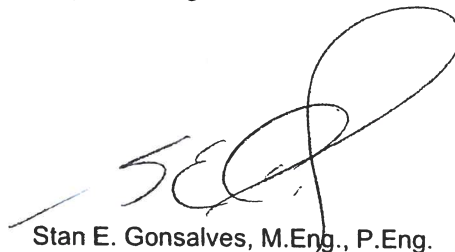
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4 LIMITATIONS AND USE OF REPORT

BASIS OF REPORT

This report ("Report") is based on site conditions known or inferred by the geotechnical investigation undertaken as of the date of the Report. Should changes occur which potentially impact the geotechnical condition of the site, or if construction is implemented more than one year following the date of the Report, the recommendations of exp may require re-evaluation.

The Report is provided solely for the guidance of design engineers and on the assumption that the design will be in accordance with applicable codes and standards. Any changes in the design features which potentially impact the geotechnical analyses or issues concerning the geotechnical aspects of applicable codes and standards will necessitate a review of the design by exp. Additional field work and reporting may also be required.

Where applicable, recommended field services are the minimum necessary to ascertain that construction is being carried out in general conformity with building code guidelines, generally accepted practices and exp's recommendations. Any reduction in the level of services recommended will result in exp providing qualified opinions regarding the adequacy of the work. exp can assist design professionals or contractors retained by the Client to review applicable plans, drawings, and specifications as they relate to the Report or to conduct field reviews during construction.

Contractors contemplating work on the site are responsible for conducting an independent investigation and interpretation of the borehole results contained in the Report. The number of boreholes necessary to determine the localized underground conditions as they impact construction costs, techniques, sequencing, equipment and scheduling may be greater than those carried out for the purpose of the Report.

Classification and identification of soils, rocks, geological units, contaminant materials, building envelopment assessments, and engineering estimates are based on investigations performed in accordance with the standard of care set out below and require the exercise of judgment. As a result, even comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations or building envelope descriptions involve an inherent risk that some conditions will not be detected. All documents or records summarizing investigations are based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated. Some conditions are subject to change over time. The Report presents the conditions at the sampled points at the time of sampling. Where special concerns exist, or the Client has special considerations or requirements, these should be disclosed to exp to allow for additional or special investigations to be undertaken not otherwise within the scope of investigation conducted for the purpose of the Report.

RELIANCE ON INFORMATION PROVIDED

The evaluation and conclusions contained in the Report are based on conditions in evidence at the time of site inspections and information provided to exp by the Client and others. The Report has been prepared for the specific site, development, building, design or building assessment objectives and purpose as communicated by the Client. exp has relied in good faith upon such representations,

information and instructions and accepts no responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of any misstatements, omissions, misrepresentation or fraudulent acts of persons providing information. Unless specifically stated otherwise, the applicability and reliability of the findings, recommendations, suggestions or opinions expressed in the Report are only valid to the extent that there has been no material alteration to or variation from any of the information provided to exp.

STANDARD OF CARE

The Report has been prepared in a manner consistent with the degree of care and skill exercised by engineering consultants currently practicing under similar circumstances and locale. No other warranty, expressed or implied, is made. Unless specifically stated otherwise, the Report does not contain environmental consulting advice.

COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment form part of the Report. This material includes, but is not limited to, the terms of reference given to exp by its client ("Client"), communications between exp and the Client, other reports, proposals or documents prepared by exp for the Client in connection with the site described in the Report. In order to properly understand the suggestions, recommendations and opinions expressed in the Report, reference must be made to the Report in its entirety. exp is not responsible for use by any party of portions of the Report.

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REPORT FORMAT

Where exp has submitted both electronic file and a hard copy of the Report, or any document forming part of the Report, only the signed and sealed hard copy shall be the original documents for record and working purposes. In the event of a dispute or discrepancy, the hard copy shall govern. Electronic files transmitted by exp have utilize specific software and hardware systems. exp makes no representation about the compatibility of these files with the Client's current or future software and hardware systems. Regardless of format, the documents described herein are exp's instruments of professional service and shall not be altered without the written consent of exp.

Appendix A – Photographs



Photo 1: Hwy 11 NBL looking north from proposed culvert location

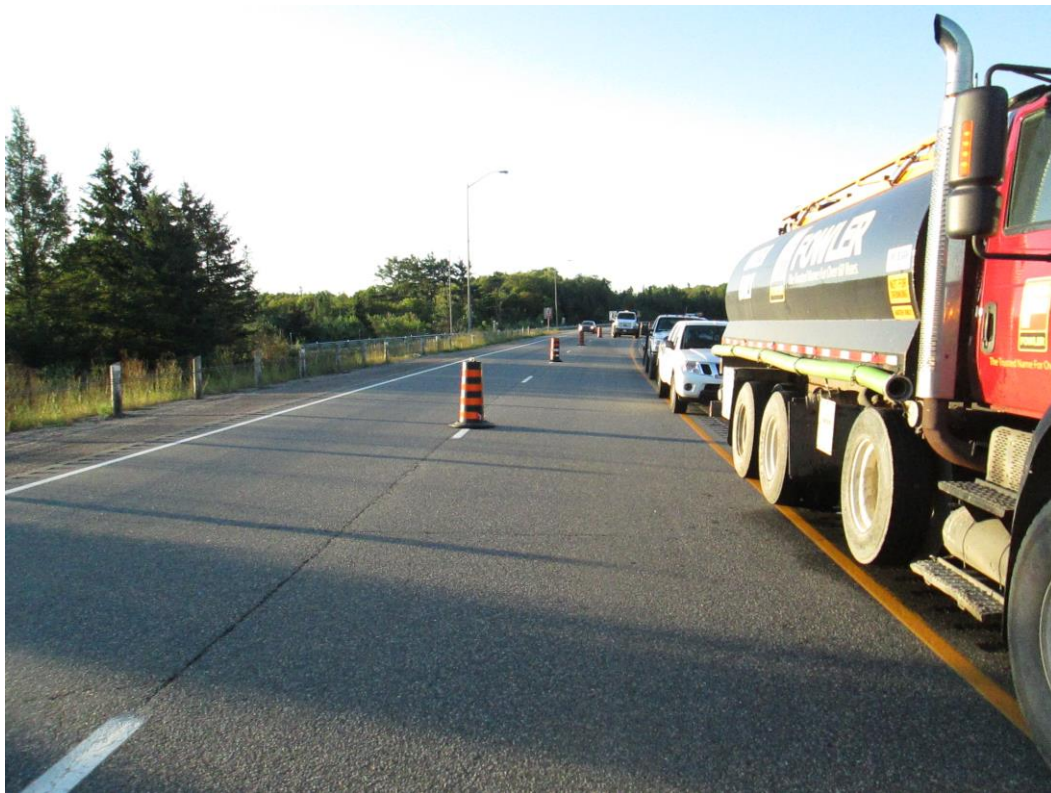


Photo 2: Hwy 11 NBL looking south from proposed culvert location



Photo 3: Hwy 11 SBL looking south from north of proposed culvert location



Photo 4: Hwy 11 SBL looking north from north of proposed culvert location



Photo 5: West embankment slope looking south from north of the existing culvert



Photo 6: West embankment slope looking north from north of the existing culvert



Photo 7: Looking west from outlet side of the existing culvert



Photo 8: Building platform for HDD and access for drill rig for BH-5



Photo 9: Reinstatement of slope to original condition



Photo 10: Existing Box Culvert inlet and outlet of CSP culvert



Photo 11: Existing Box Culvert outlet



Photo 12: Looking Internal view of existing Box Culvert from inlet side



Photo 13: Starting point of horizontal probe hole at inlet side



Photo 14: Location of BH-5 at proposed culvert inlet location



Photo 15: Portable drill at BH-7 location looking east from existing culvert outlet



Photo 16: Existing culvert at inlet and silt fence looking north from BH-5 location

Appendix B – Drawings

Appendix C – Boreholes Logs

Brampton, Ontario

RECORD OF BOREHOLE No BH-1

1 OF 2

METRIC

W.P. W.O. 2017-11021 LOCATION Hwy 11, Bracebridge, MTM ON10 N4993657.27, 320738.7 ORIGINATED BY NT
 DIST Muskoka HWY 11 BOREHOLE TYPE CME-55/HSA/NW Casing COMPILED BY NT
 DATUM TBM set on BH 17-2 (Elev. 282.0 m) DATE 2017.08.29 - 2017.08.29 LATITUDE 45.084721 LONGITUDE -79.297362 CHECKED BY SM

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 (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X P. PENETROMETER										
282.2	Road Surface						20	40	60	80	100	20	40	60	GR	SA	SI	CL
282.0	ASPHALT - about 175 mm																	
0.2	FILL: SAND -trace to some gravel, trace to some silt, occassional cobbles and boulder, brown, dry to moist, dense to very dense		1	AS		282						○			8	74	(18)	
			2	SS	72	281						○						
			3	SS	46	280						○						
	-becoming sand with cobbles @ 2.3 m		4	SS	67	279						○						
279.2	-Switch to wash boring below 3.05 m		5	SS		278						○						
3.1	ROCK FILL Spoon bouncing on boulder @ 3.05 m					277												
278.4	FILL: SAND TO GRAVELLY SAND -trace to some silt, trace organic spot, brown, wet, very loose to very dense		6	SS	4	276						○						
3.8			7	SS	59	275						○						
	- becoming gravelly sand @ 5.3 m					274												
275.3	FILL: SILTY SAND -trace gravel, trace clay, greyish brown, wet, very loose to compact		8	SS	23	273						○			3	58	(39)	
6.9			9	SS	1	272						○						
272.3	SAND AND SILT -trace clay, trace organics, trace rootlets, greyish brown to brown/black, wet, loose to compact		10	SS	5	271						○			0	39	58, 3	
9.9			11	SS	11							○			Organic Content = 4.8%			
			12	SS	10							○						

Continued Next Page

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

ONTARIO MTO ASSIGNMENT#1, MERO, GPJ, ONTARIO MTO, GDT, 10/18/18

Brampton, Ontario

RECORD OF BOREHOLE No BH-1

2 OF 2

METRIC

W.P. W.O. 2017-11021 LOCATION Hwy 11, Bracebridge, MTM ON10 N4993657.27, 320738.7 ORIGINATED BY NT
 DIST Muskoka HWY 11 BOREHOLE TYPE CME-55/HSA/NW Casing COMPILED BY NT
 DATUM TBM set on BH 17-2 (Elev. 282.0 m) DATE 2017.08.29 - 2017.08.29 LATITUDE 45.084721 LONGITUDE -79.297362 CHECKED BY SM

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 (%)			
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE										
								● QUICK TRIAXIAL X P. PENETROMETER										
								20	40	60	80	100						

ONTARIO MTO ASSIGNMENT#1, MERO_GPJ_ONTARIO MTO.GDT 10/18/18

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




Brampton, Ontario

RECORD OF BOREHOLE No BH-2

1 OF 2

METRIC

W.P. W.O. 2017-11021 LOCATION Hwy 11, Bracebridge, MTM ON10 N4993658.5, E320722.9 ORIGINATED BY NT
 DIST Muskoka HWY 11 BOREHOLE TYPE CME-55/HSA/NW Casing COMPILED BY NT
 DATUM TBM set on BH 17-2 (Elev. 282.0 m) DATE 2017.08.30 - 2017.08.30 LATITUDE 45.084733 LONGITUDE -79.297565 CHECKED BY SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X P. PENETROMETER										
280.5	Ground Surface						20	40	60	80	100						GR SA SI CL	
0.0	FILL: SAND -trace to some gravel, trace to some silt, trace clay, occassional cobbles, trace rootlets, blackish-brown to brown, moist, very loose to loose		1	AS		▽								○			6 75 (19)	
																○		
																○		
					2		SS	8										
					3		SS	5										
					4		SS	4								○		
			5	SS	2									○				
			6	SS	4									○				
274.4	FILL: SILTY SAND -trace gravel, brown, wet, loose to compact -switch to wash boring below 6.7 m		7	SS	5									○			4 67 (29)	
6.1																		
					8	SS	24											
272.1	SAND -fine sand, some silt, trace clay, brown to greyish brown, wet, loose to dense		9	SS	4									○				
8.4																		
					10	SS	15								○			
			11	SS	12									○				

Continued Next Page

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

ONTARIO MTO ASSIGNMENT#1, MERO GPJ ONTARIO MTO GDT 10/18/18


Brampton, Ontario

RECORD OF BOREHOLE No BH-2

2 OF 2

METRIC

W.P. W.O. 2017-11021 LOCATION Hwy 11, Bracebridge, MTM ON10 N4993658.5, E320722.9 ORIGINATED BY NT
 DIST Muskoka HWY 11 BOREHOLE TYPE CME-55/HSA/NW Casing COMPILED BY NT
 DATUM TBM set on BH 17-2 (Elev. 282.0 m) DATE 2017.08.30 - 2017.08.30 LATITUDE 45.084733 LONGITUDE -79.297565 CHECKED BY SM

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			SHEAR STRENGTH kPa								WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X P. PENETROMETER										
								20 40 60 80 100				20 40 60						
262.4 18.1	SAND -fine sand, some silt, trace clay, brown to greyish brown, wet, loose to dense (<i>continued</i>)						268								0 88 11 1			
			12	SS	15		267											
							266											
			13	SS	23		265											
							264											
			14	SS	25		263											
			15	SS	37													0 92 (8)
	END OF BOREHOLE AT 18.14 m DEPTH Notes: 1. This drawing is to be read with the subject report and project numbers as presented above. 2. Groundwater level was measured in open hole after completion of drilling. Since wash boring method was used to advanced boreholes, water levels measured in open boreholes might not be stabilized.																	

Brampton, Ontario

RECORD OF BOREHOLE No BH-3

1 OF 2

METRIC

W.P. W.O. 2017-11021 LOCATION Hwy 11, Bracebridge, MTM ON10 N4993650.5, E320712.1 ORIGINATED BY NT
 DIST Muskoka HWY 11 BOREHOLE TYPE CME-55/HSA/NW Casing COMPILED BY NT
 DATUM TBM set on BH 17-2 (Elev. 282.0 m) DATE 2017.08.31 - 2017.08.31 LATITUDE 45.084663 LONGITUDE -79.297694 CHECKED BY SM

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 (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X P. PENETROMETER									
281.6	Road Surface						20	40	60	80	100						GR SA SI CL
281.0	ASPHALT - about 200 mm																
0.2	FILL: SAND -trace to some gravel, trace to some silt, blackish brown to brown, moist to wet, compact to dense		1	AS													
			2	SS	39												
			3	SS	25												
			4	SS	23												
			5	SS	22												
			6	SS	29												
276.3	FILL: SAND AND SILT- trace clay, occasional boulder, brown, wet, compact to very loose		7	SS	12												
5.3																	
			8	SS	4												
	- boulder encountered @ 7.85 m depth																
273.2	SAND AND SILT -trace clay, trace rootlets, trace organic, blackish-brown to dark brown, wet, loose		9	SS	6												
8.4																	
			10	SS	6												
270.2	SAND -fine sand, some silt, occasional cobbles, brown to greyish brown, wet, loose to compact		11	SS	14												
11.4																	

Continued Next Page

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

ONTARIO MTO ASSIGNMENT#1, MERO_GPJ ONTARIO MTO GDT 10/18/18

2 OF 2

METRIC

DATUM TBM set on BH 17-2 (Elev. 282.0 m) DATE 2017.08.31 - 2017.08.31 LATITUDE 45.084663 LONGITUDE -79.297694 CHECKED BY SM

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

Brampton, Ontario

RECORD OF BOREHOLE No BH-4

1 OF 2

METRIC

W.P. W.O. 2017-11021 LOCATION Hwy 11, Bracebridge, MTM ON10 N4993646, E320694.9 ORIGINATED BY NT
 DIST Muskoka HWY 11 BOREHOLE TYPE Portable Hilty DD-250 /tripod/BW COMPILED BY NT
 DATUM TBM set on BH 17-2 (Elev. 282.0 m) DATE 2017.09.07 - 2017.09.07 LATITUDE 45.084621 LONGITUDE -79.297911 CHECKED BY SM

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 (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL						
275.4	Ground Surface															
275.0	TOPSOIL - topsoil-rootmat about 100 mm		1	SS	3	▽										
0.1	FILL: SAND AND SILT -trace gravel, trace to some clay, trace organics, trace rootlets and occasional wood log, brown, moist to wet, very loose to loose		2	SS	5											
	-spoon bounce on wood log @ 1.52, cored wood log from 1.52 m to 1.68 m		3	SS	50/50mm											
			4	SS	1											
273.0	SANDY SILT WITH ORGANICS - trace to some clay, trace to some organics, trace to some rootlets, blackish-brown, wet, very loose		5	SS	3											
2.4			6	SS	1											
271.7	SAND -fine sand, some silt, brown to greyish brown, wet, loose to compact		7	SS	12											
3.7			8	SS	8											
			9	SS	5											
			10	SS	8											
			11	SS	12											
			12	SS	20											
265.6	- Sand blow up @ 9.75 m, split spoon and casing jammed, switch to DCPT															
9.8	END OF BOREHOLE START OF DCPT															
263.8	DCPT bounce on possible boulder @ 11.63 m															
11.6	END OF BOREHOLE AND DCPT															

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

ONTARIO MTO ASSIGNMENT#1, MERO GPJ ONTARIO MTO GDT 10/18/18

2 OF 2

METRIC

W.P.	W.O. 2017-11021	LOCATION	Hwy 11, Bracebridge, MTM ON10 N4993646, E320694.9			ORIGINATED BY	NT			
DIST	Muskoka	HWY	11	BOREHOLE TYPE	Portable Hilty DD-250 /tripod/BW			COMPILED BY	NT	
DATUM	TBM set on BH 17-2 (Elev. 282.0 m)		DATE	2017.09.07 - 2017.09.07	LATITUDE	45.084621	LONGITUDE	-79.297911	CHECKED BY	SM

[illegible]

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

ONTARIO MTO ASSIGNMENT#1, MERO.GPJ ONTARIO MTO.GDT 10/18/18



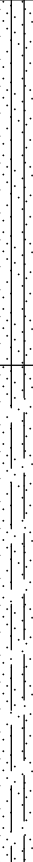

Brampton, Ontario

RECORD OF BOREHOLE No BH-5

1 OF 2

METRIC

W.P. W.O. 2017-11021 LOCATION Hwy 11, Bracebridge, MTM ON10 N4993665.3, E320766.1 ORIGINATED BY NT
 DIST Muskoka HWY 11 BOREHOLE TYPE CME-55/HSA/NW Casing COMPILED BY NT
 DATUM TBM set on BH 17-2 (Elev. 282.0 m) DATE 2017.09.01 - 2017.09.05 LATITUDE 45.084797 LONGITUDE -79.297004 CHECKED BY SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x P. PENETROMETER		W _P	W			W _L	WATER CONTENT (%)
275.1 0.0	Ground Surface		1	SS	8		275							0 27 70 3 non plastic	
	FILL: SILTY SAND (Reworked) - trace to some gravel, trace clay, trace woods, occasional cobbles and boulders, moist, loose to compact -boulder from 0.61 m to 0.91 m		2	NQ	REC 58%		274								
	-cobbles on tip of spoon		3	SS	12										
273.6 1.5	SANDY SILT WITH ORGANICS -trace gravel, trace to some clay, trace organics, trace roots and rootlets, black to dark grey, wet, very loose to loose		4	SS	WH		273								
			5	SS	WH		272								
			6	SS	1		271								
			7	SS	6		270								
270.7 4.4	SILTY SAND - trace gravel, trace clay, brown, wet, very loose to loose		8	SS	8		269								
		9	SS	4	268										
					267										
266.7 8.4	SAND -fine sand, trace to some silt, brown, wet, loose to compact		10	SS	21		266								
			11	SS	16		265								
			12	SS	17	264									

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

ONTARIO MTO ASSIGNMENT#1, MERO_GPJ ONTARIO MTO GDT 10/18/18

Brampton, Ontario

RECORD OF BOREHOLE No BH-5

2 OF 2

METRIC

W.P. W.O. 2017-11021 LOCATION Hwy 11, Bracebridge, MTM ON10 N4993665.3, E320766.1 ORIGINATED BY NT
 DIST Muskoka HWY 11 BOREHOLE TYPE CME-55/HSA/NW Casing COMPILED BY NT
 DATUM TBM set on BH 17-2 (Elev. 282.0 m) DATE 2017.09.01 - 2017.09.05 LATITUDE 45.084797 LONGITUDE -79.297004 CHECKED BY SM

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			SHEAR STRENGTH kPa								WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X P. PENETROMETER										
								20 40 60 80 100										
261.4	SAND -fine sand, trace to some silt, brown, wet, loose to compact (continued)						263											
			13	SS	8		262											
13.7	END OF BOREHOLE START OF DCPT						261											
259.9							260											
15.2	END OF BOREHOLE AND DCPT																	
<div>Notes: 1. This drawing is to be read with the subject report and project numbers as presented above. 2. Groundwater level was measured in open hole after completion of drilling. Since wash boring method was used to advance boreholes, water levels measured in open boreholes might not be stabilized.</div>																		

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

Brampton, Ontario

1 OF 2

METRIC

W.P.	W.O. 2017-11021	LOCATION	Hwy 11, Bracebridge, MTM ON10 N4993661.3, E320719.5			ORIGINATED BY	NT			
DIST	Muskoka	HWY	11	BOREHOLE TYPE	CME-55/HSA/NW Casing			COMPILED BY	NT	
DATUM	TBM set on BH 17-2 (Elev. 282.0 m)		DATE	2017.08.30 - 2017.08.30	LATITUDE	45.084761	LONGITUDE	-79.297602	CHECKED BY	SM

[illegible]

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

ONTARIO MTO ASSIGNMENT#1, MERO.GPJ ONTARIO MTO.GDT 10/18/18

Brampton, Ontario

RECORD OF BOREHOLE No BH-6

2 OF 2

METRIC

W.P. W.O. 2017-11021 LOCATION Hwy 11, Bracebridge, MTM ON10 N4993661.3, E320719.5 ORIGINATED BY NT
 DIST Muskoka HWY 11 BOREHOLE TYPE CME-55/HSA/NW Casing COMPILED BY NT
 DATUM TBM set on BH 17-2 (Elev. 282.0 m) DATE 2017.08.30 - 2017.08.30 LATITUDE 45.084761 LONGITUDE -79.297602 CHECKED BY SM

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			SHEAR STRENGTH kPa									
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL P. PENETROMETER									
								20 40 60 80 100	20 40 60								
	SILTY SAND - trace clay, trace gravel, brown, wet, very loose to loose <i>(continued)</i>						268										
267.7																	
13.0	SAND -fine sand, trace to some silt, trace clay, trace gravel, brown to greyish brown, wet, compact		10	SS	19		267										
			11	SS	12		266										
							265										
			12	SS	19												
							264										
262.6			13	SS	16		263										
18.1	END OF BOREHOLE AT 18.14 m DEPTH Notes: 1. This drawing is to be read with the subject report and project numbers as presented above. 2. Groundwater level was not measured as creek water level is the water level in borehole.																

ONTARIO MTO ASSIGNMENT#1, MERO_GPJ ONTARIO MTO.GDT 10/18/18

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


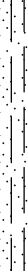

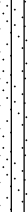

Brampton, Ontario

RECORD OF BOREHOLE No BH-7

1 OF 2

METRIC

W.P. W.O. 2017-11021 LOCATION Hwy 11, Bracebridge, MTM ON10 N4993654, E320692 ORIGINATED BY NT
 DIST Muskoka HWY 11 BOREHOLE TYPE Portable Hilti DD-250 /Manual Hammer/BW COMPILED BY NT
 DATUM TBM set on BH 17-2 (Elev. 282.0 m) DATE 2017.09.06 - 2017.09.06 LATITUDE 45.084694 LONGITUDE -79.297947 CHECKED BY SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE										
								● QUICK TRIAXIAL X P. PENETROMETER										
275.4	Ground Surface					20	40	60	80	100	20	40	60	GR	SA	SI	CL	
0.0	FILL: SAND some gravel, trace silt, trace rootlets, brown, wet, very loose		1	SS	1							○						
			2	SS	2								○					
274.2	EXISTING BOX CULVERT -from 1.22 m to 3.3 m		3	SS	50/ 0.025 m													
1.2																		
272.1																		
3.3	SILT -some sand, trace gravel, grey, wet, very loose to loose		4	SS	3													no recovery
	-becoming some sand, trace gravel		5	SS	8								○					
			6	SS	5								○					
269.9																		
5.5	SAND -fine sand, some silt, trace clay, brown to greyish brown, wet, compact		7	SS	10								○					0 77 (23)
			8	SS	15									○				
268.1																		
7.3	SANDY SILT -fine sand, trace clay, trace to some gravel, brown , wet, compact		9	SS	12								○					
			10	SS	16									○				12 30 (58)
265.6																		
9.8	SAND -fine sand, some silt, brown to greyish brown, wet, loose to compact		11	SS	7													no recovery
			12	SS	25									○				
263.8																		
11.6	- Sand blow up @ 11.58 m, split spoon and casing jammed END OF BOREHOLE AT 11.58 m DEPTH																	

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

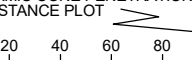
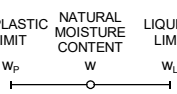
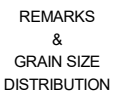
ONTARIO MTO ASSIGNMENT#1, MERO, GPJ, ONTARIO MTO, GDT, 10/18/18

Brampton, Ontario

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METRIC

W.P.	W.O. 2017-11021	LOCATION	Hwy 11, Bracebridge, MTM ON10 N4993654, E320692	ORIGINATED BY	NT
DIST	Muskoka	HWY	11	BOREHOLE TYPE	Portable Hilti DD-250 /Manual Hammer/BW
DATUM	TBM set on BH 17-2 (Elev. 282.0 m)	DATE	2017.09.06 - 2017.09.06	LATITUDE	45.084694
				LONGITUDE	-79.297947
				CHECKED BY	SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT <div></div>	PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT <div></div>	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) <div></div>
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	<div>Notes: 1. This drawing is to be read with the subject report and project numbers as presented above. 2. Groundwater level was not measured as creek water level is the water level in borehole.</div>										

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

ONTARIO MTO ASSIGNMENT#1, MERO.GPJ ONTARIO MTO.GDT 10/18/18

Brampton, Ontario

RECORD OF BOREHOLE No BH-8

1 OF 1

METRIC

W.P. W.O. 2017-11021 LOCATION Hwy 11, Bracebridge, MTM ON10 N4993653.2, E320712.8 ORIGINATED BY NT
 DIST Muskoka HWY 11 BOREHOLE TYPE CME-55/Continuous flight HSA COMPILED BY NT
 DATUM TBM set on BH 17-2 (Elev. 282.0 m) DATE 2017.09.05 - 2017.09.05 LATITUDE 45.084681 LONGITUDE -79.297693 CHECKED BY SM

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		20	40	60	80	100	W _p	W	W _L		
281.8	Road Surface															
281.8	ASPHALT - about 200 mm															
0.2	FILL: SAND -trace to some gravel, trace to some silt, trace asphalt, blackish brown to brown, dry to moist, compact to dense		1	AS												
						281										
			2	SS	31											
						280										
						279										
			3	SS	27											
						278										
						277										
			4	SS	24											
						276										
275.7	FILL: SAND AND SILT- trace clay, occasional cobbles and boulder, brown, moist to wet, compact to very loose		5	SS	13											
6.1						275										
						274										
			6	SS	4											
						273										
	- Auger grinding @8.53 m depth; becoming very loose															
272.7	SAND AND SILT -trace clay, trace rootlets, trace organic, blackish-brown to dark brown, wet, very loose		7	SS	3											
9.2																
272.0	END OF BOREHOLE AT 9.76 m DEPTH															
9.8	Notes: 1. This drawing is to be read with the subject report and project numbers as presented above. 2. Groundwater level was measured in open hole after completion of drilling. Since wash boring method was used to advance boreholes, water levels measured in open boreholes might not be stabilized.															

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

ONTARIO MTO ASSIGNMENT#1, MERO GPJ ONTARIO MTO.GDT 10/18/18

Brampton, Ontario

1 OF 1

METRIC

W.P.	W.O. 2017-11021	LOCATION	Hwy 11, Bracebridge, MTM ON10 N4993654.1, E320716.1			ORIGINATED BY	NT
DIST	Muskoka	HWY	11	BOREHOLE TYPE	CME-55/HSA	COMPILED BY	NT
DATUM	TBM set on BH 17-2 (Elev. 282.0 m)	DATE	2017.09.05 - 2017.09.05	LATITUDE	45.084689	LONGITUDE	-79.297642
						CHECKED BY	SM

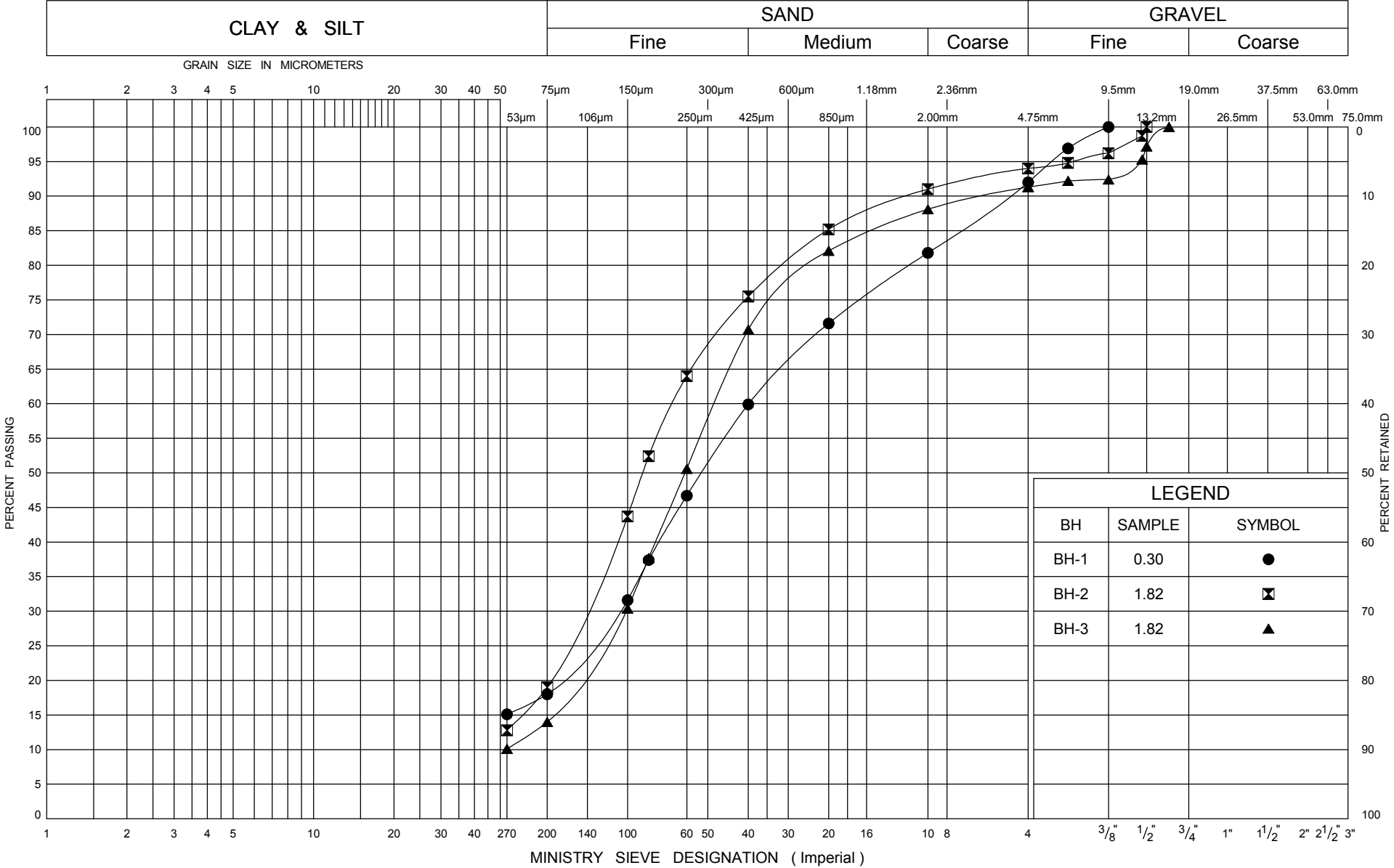
[illegible]

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

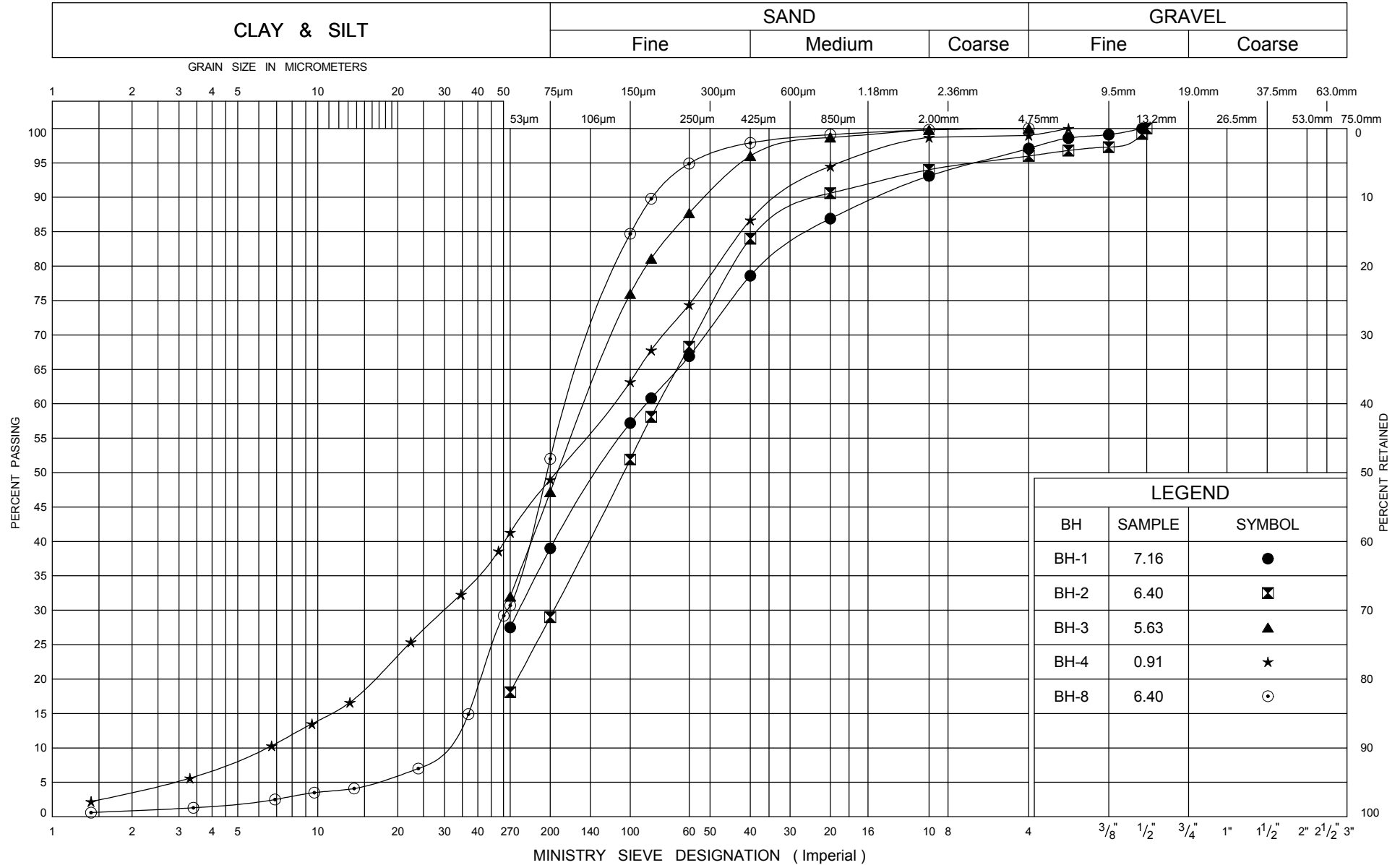
ONTARIO MTO ASSIGNMENT#1, MERO.GPJ ONTARIO MTO.GDT 10/18/18

Appendix D – Laboratory Test Results

UNIFIED SOIL CLASSIFICATION SYSTEM



UNIFIED SOIL CLASSIFICATION SYSTEM



GRAIN SIZE DISTRIBUTION
FILL: SILTY SAND/ SAND AND SILT

FIG No 2

W P.W.O. 2017-11021

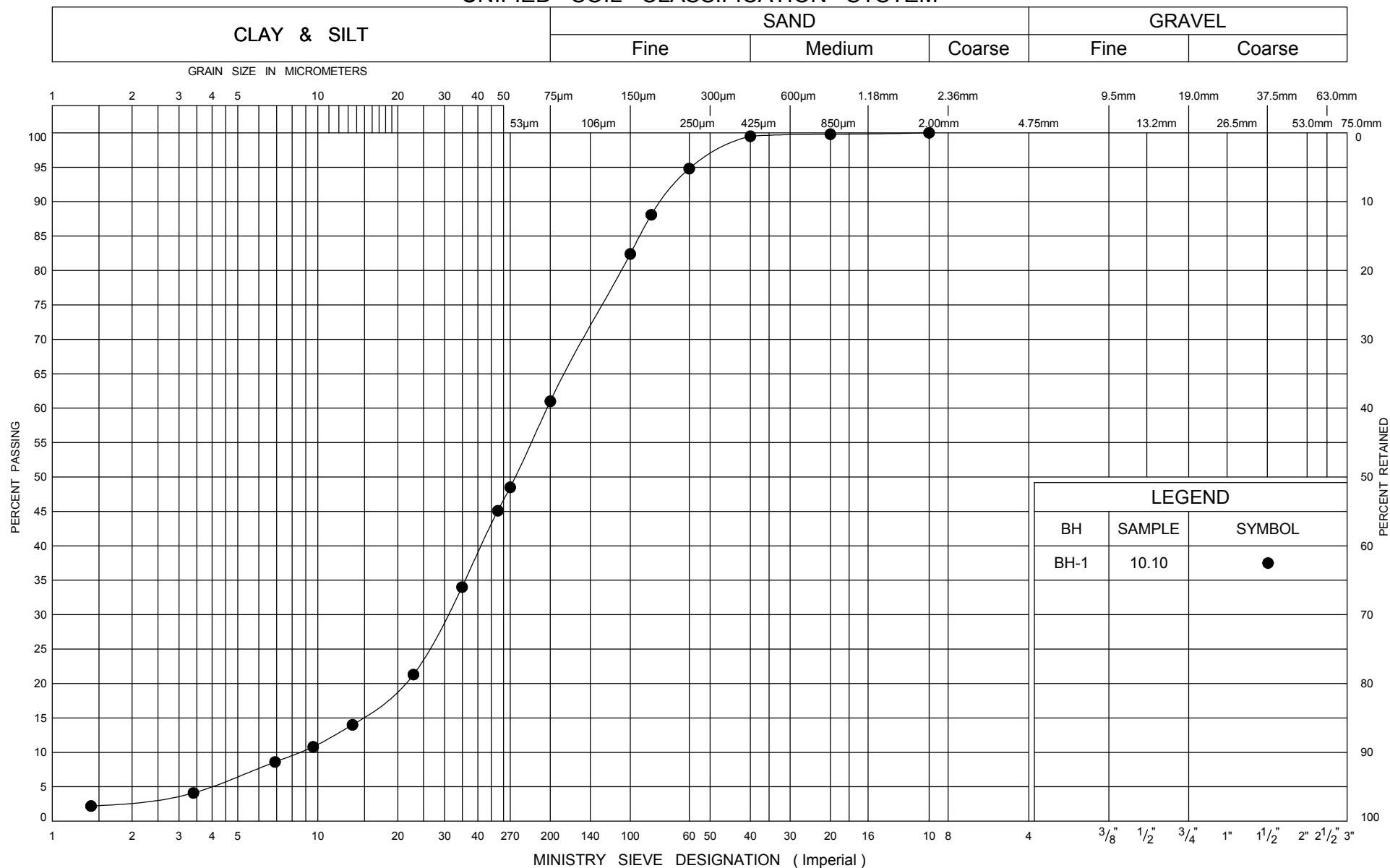
9016--E-0009, Assignment 1



Ministry of
Transportation

Ontario

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of
Transportation

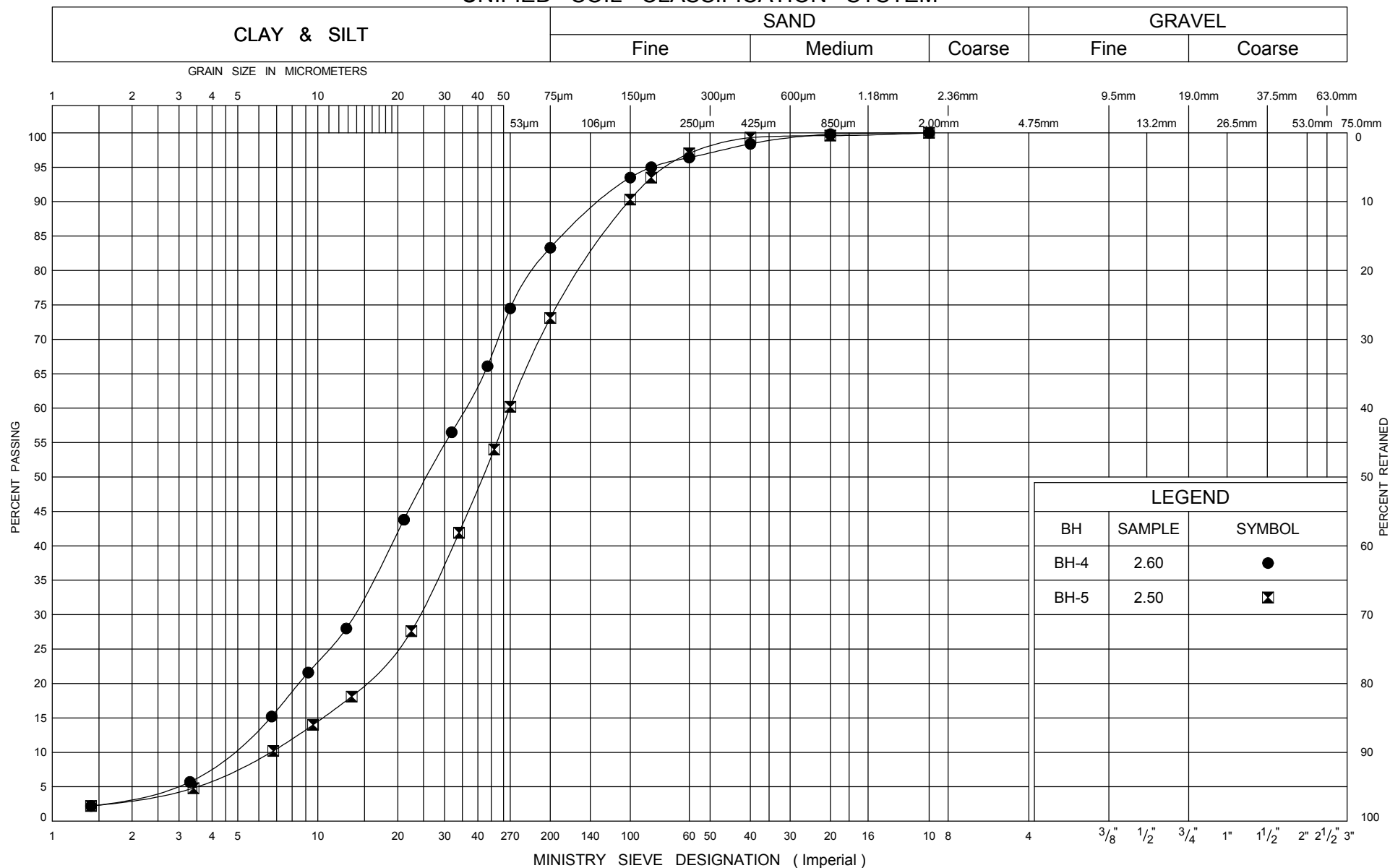
GRAIN SIZE DISTRIBUTION SAND AND SILT

FIG No 3

W P.W.O. 2017-11021

9016--E-0009, Assignment 1

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of
Transportation

GRAIN SIZE DISTRIBUTION
SANDY SILT WITH ORGANICS

FIG No 4

W P.W.O. 2017-11021

9016--E-0009, Assignment 1

UNIFIED SOIL CLASSIFICATION SYSTEM

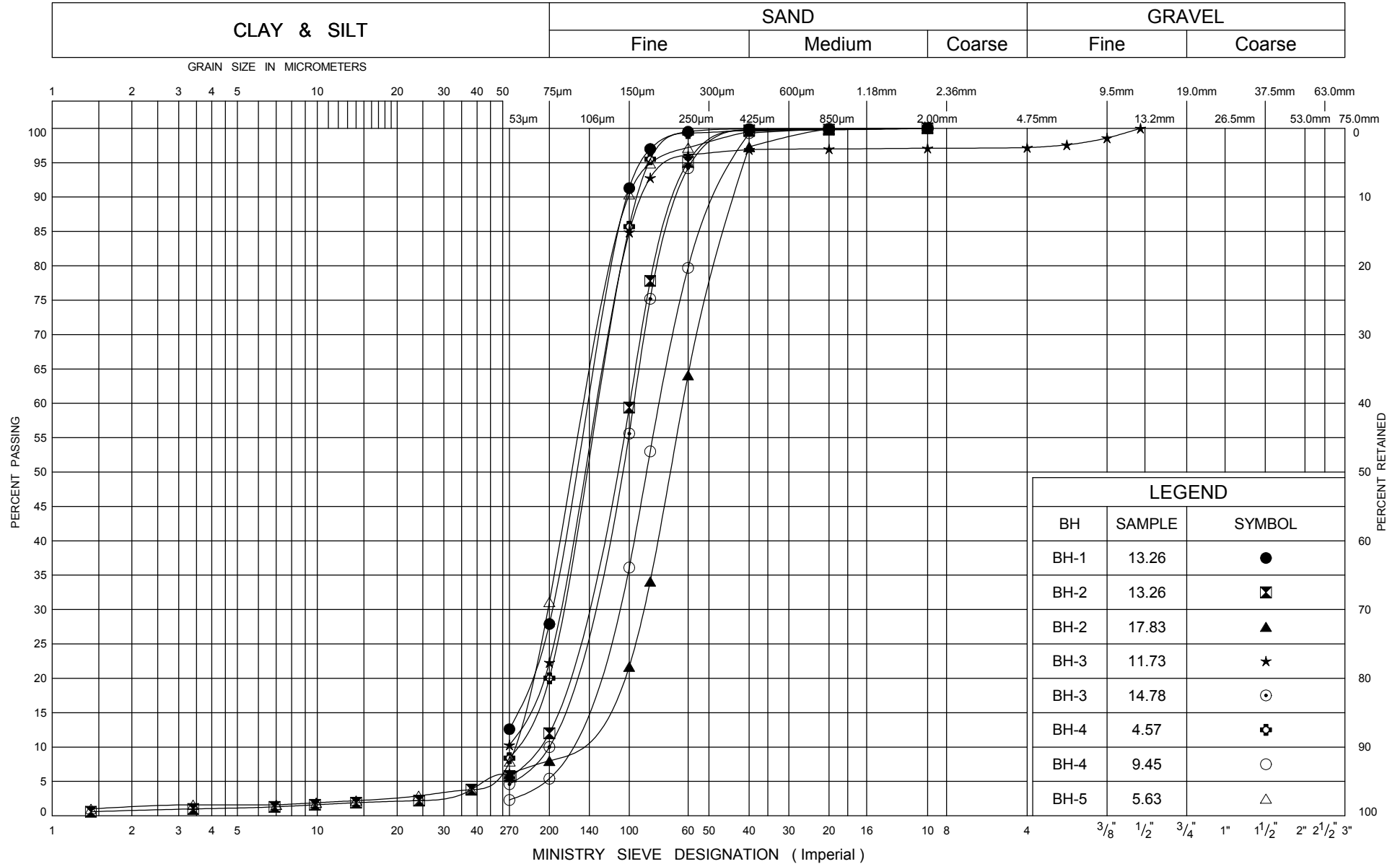
GRAIN SIZE DISTRIBUTION
SILTY SAND TO SAND

FIG No 5

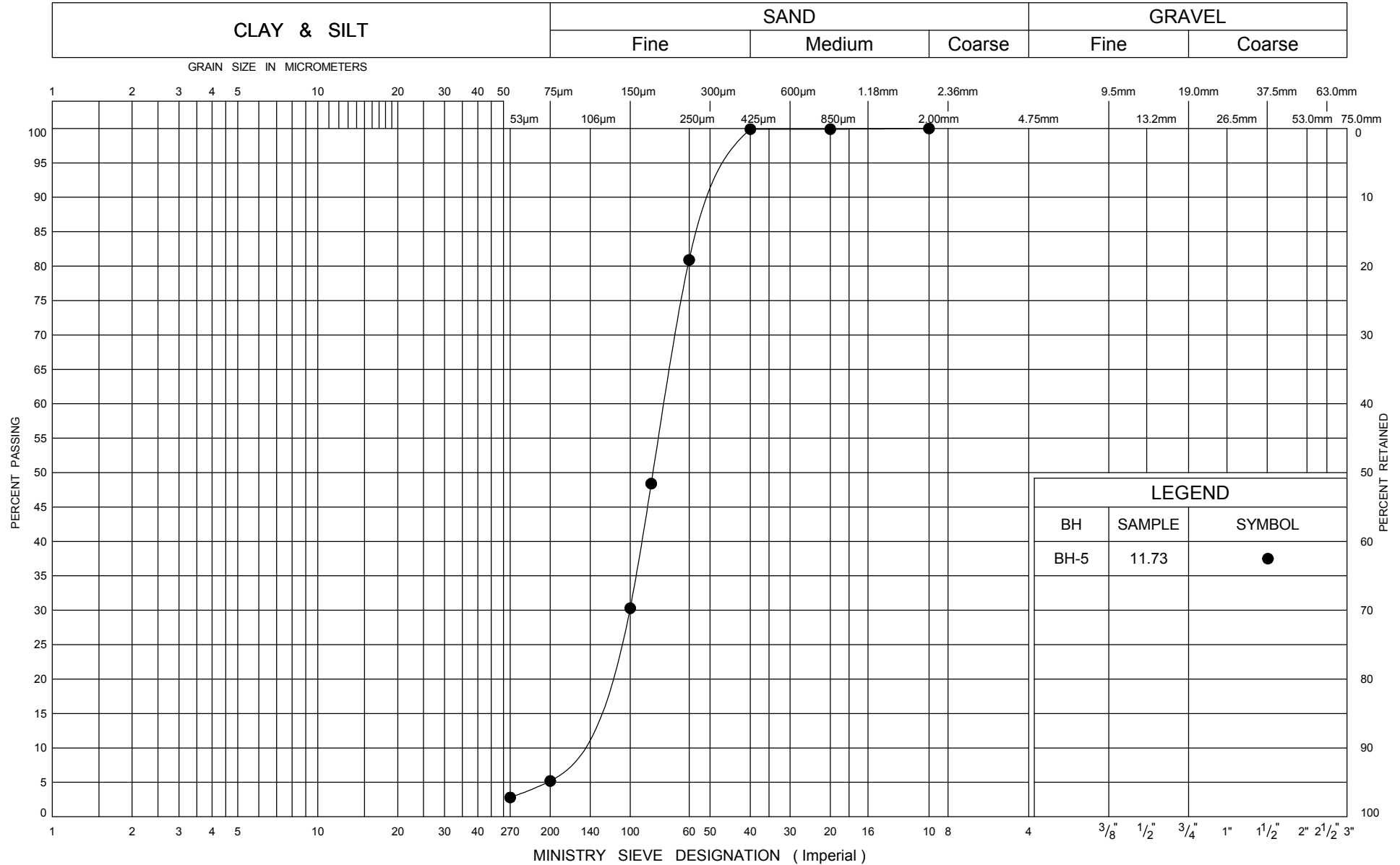
W P.W.O. 2017-11021

9016--E-0009, Assignment 1

Ministry of
Transportation

Ontario

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of
Transportation

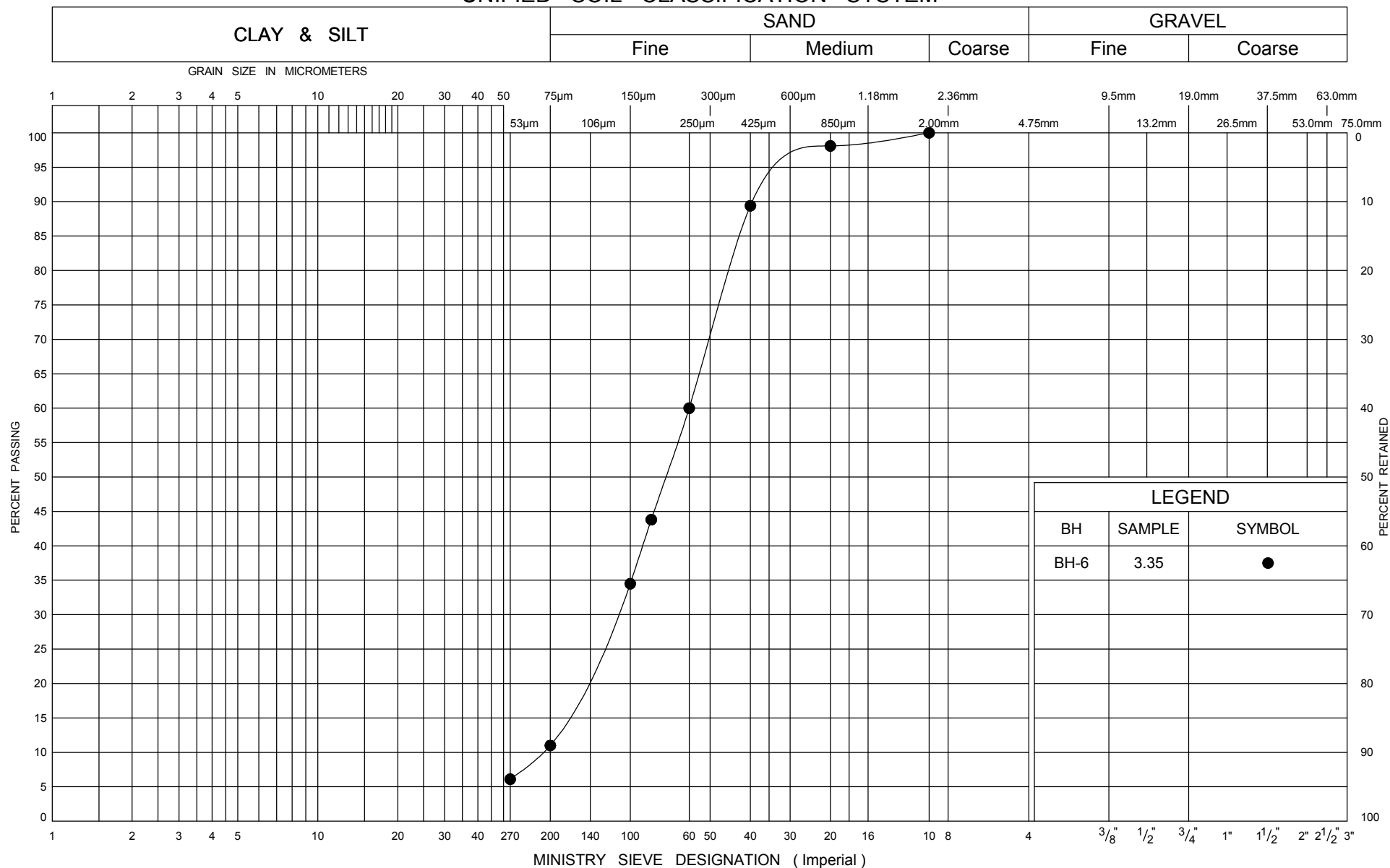
GRAIN SIZE DISTRIBUTION SILTY SAND TO SAND

FIG No 6

W P.W.O. 2017-11021

9016--E-0009, Assignment 1

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of
Transportation

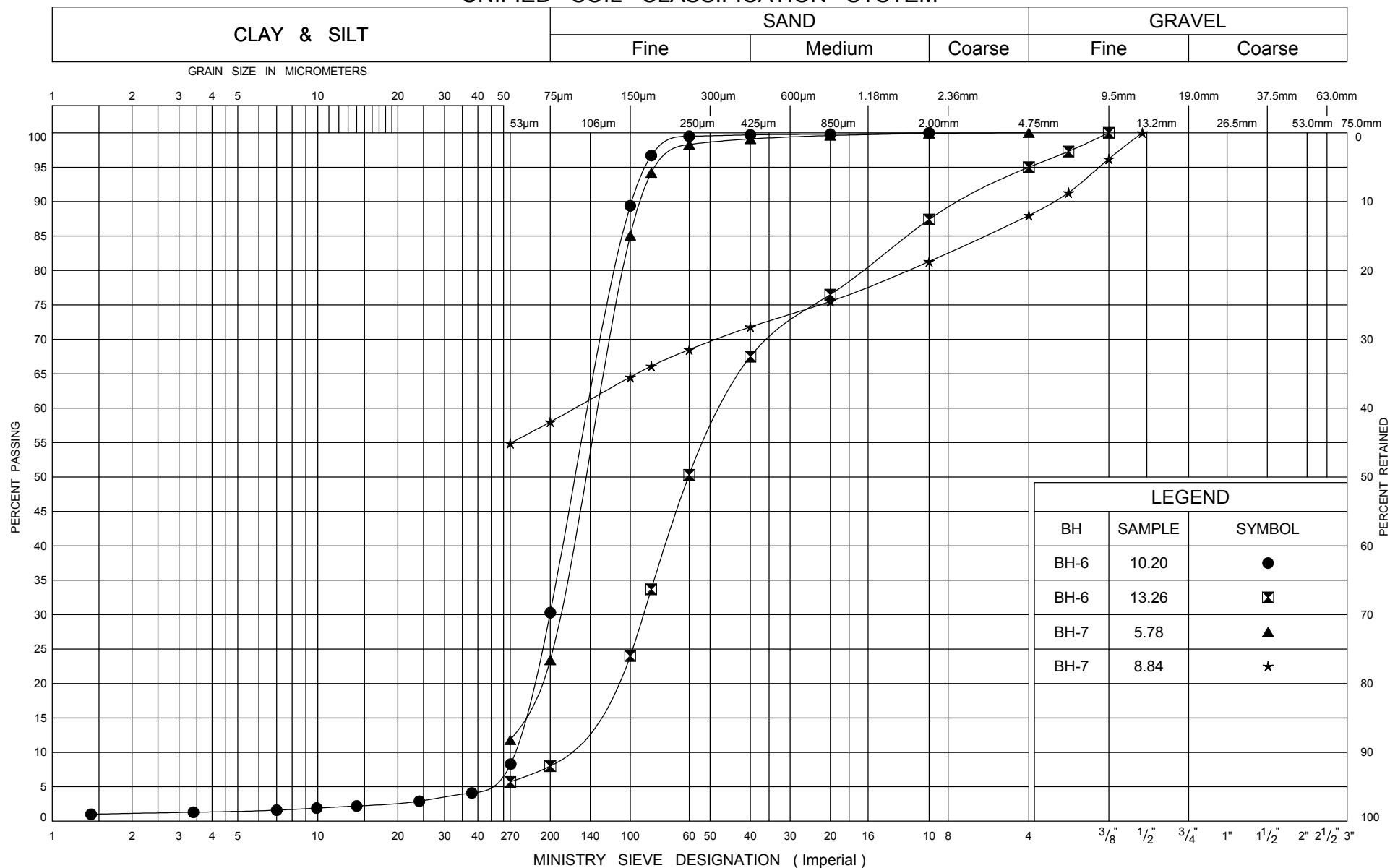
GRAIN SIZE DISTRIBUTION
FILL: SAND
(Existing Culvert Location)

FIG No 7

W P.W.O. 2017-11021

9016--E-0009, Assignment 1

UNIFIED SOIL CLASSIFICATION SYSTEM



GRAIN SIZE DISTRIBUTION
SILTY SAND TO SAND
(Existing Culvert Location)

FIG No 8

W P.W.O. 2017-11021

9016--E-0009, Assignment 1



Ministry of
Transportation

Ontario

Appendix E – Chemical Analyses

Your P.O. #: GEO
Your Project #: ADM-00241921-AO
Site Location: BRACEBRIDGE, HWY11
Your C.O.C. #: 68647

Attention: Nimesh Tamrakar

exp Services Inc
1595 Clark Blvd
Brampton, ON
L6T 4V1

Report Date: 2017/09/19

Report #: R4720236

Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B7J6282

Received: 2017/09/08, 18:06

Sample Matrix: Soil
Samples Received: 2

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Reference
Chloride (20:1 extract)	2	N/A	2017/09/13	CAM SOP-00463	EPA 325.2 m
Conductivity	2	N/A	2017/09/13	CAM SOP-00414	OMOE E3530 v1 m
pH CaCl ₂ EXTRACT	2	2017/09/13	2017/09/13	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	2	2017/09/09	2017/09/14	CAM SOP-00414	SM 22 2510 m
Sulphate (20:1 Extract)	2	N/A	2017/09/13	CAM SOP-00464	EPA 375.4 m

Remarks:

Maxxam Analytics' laboratories are accredited to ISO/IEC 17025:2005 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Maxxam are based upon recognized Provincial, Federal or US method compendia such as CCME, MDDELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Maxxam's profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Maxxam in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported: unless indicated otherwise, associated sample data are not blank corrected.

Maxxam Analytics' liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Maxxam has been retained to provide analysis of samples provided by the Client using the testing methodology referenced in this report. Interpretation and use of test results are the sole responsibility of the Client and are not within the scope of services provided by Maxxam, unless otherwise agreed in writing.

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods.

Results relate to samples tested.

This Certificate shall not be reproduced except in full, without the written approval of the laboratory.

Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

Attention:Nimesh Tamrakar

exp Services Inc
1595 Clark Blvd
Brampton, ON
L6T 4V1

Your P.O. #: GEO
Your Project #: ADM-00241921-AO
Site Location: BRACEBRIDGE, HWY11
Your C.O.C. #: 68647

Report Date: 2017/09/19
Report #: R4720236
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B7J6282

Received: 2017/09/08, 18:06

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Deepthi Shaji, Project Manager
Email: dshaji@maxxam.ca
Phone# (905)817-5700 Ext:5807

=====

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Maxxam Job #: B7J6282
Report Date: 2017/09/19

exp Services Inc
Client Project #: ADM-00241921-AO
Site Location: BRACEBRIDGE, HWY11
Your P.O. #: GEO
Sampler Initials: NI

SOIL CORROSIVITY PACKAGE (SOIL)

Maxxam ID		FCB639	FCB640		
Sampling Date		2017/09/05 11:00	2017/09/07 03:00		
COC Number		68647	68647		
	UNITS	BH5 SS5	BH4 SS6	RDL	QC Batch

Calculated Parameters					
Resistivity	ohm-cm	1900	1500		5157113
Inorganics					
Soluble (20:1) Chloride (Cl)	ug/g	310	410	20	5161620
Conductivity	umho/cm	518	689	2	5161515
Available (CaCl2) pH	pH	5.74	5.17		5159921
Soluble (20:1) Sulphate (SO4)	ug/g	<20	<20	20	5161621
RDL = Reportable Detection Limit					
QC Batch = Quality Control Batch					

Maxxam Job #: B7J6282
Report Date: 2017/09/19

exp Services Inc
Client Project #: ADM-00241921-AO
Site Location: BRACEBRIDGE, HWY11
Your P.O. #: GEO
Sampler Initials: NI

TEST SUMMARY

Maxxam ID: FCB639
Sample ID: BH5 SS5
Matrix: Soil

Collected: 2017/09/05
Shipped:
Received: 2017/09/08

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5161620	N/A	2017/09/13	Alina Dobreanu
Conductivity	AT	5161515	N/A	2017/09/13	Neil Dassanayake
pH CaCl2 EXTRACT	AT	5159921	2017/09/13	2017/09/13	Tahir Anwar
Resistivity of Soil		5157113	2017/09/14	2017/09/14	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5161621	N/A	2017/09/13	Alina Dobreanu

Maxxam ID: FCB640
Sample ID: BH4 SS6
Matrix: Soil

Collected: 2017/09/07
Shipped:
Received: 2017/09/08

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5161620	N/A	2017/09/13	Alina Dobreanu
Conductivity	AT	5161515	N/A	2017/09/13	Neil Dassanayake
pH CaCl2 EXTRACT	AT	5159921	2017/09/13	2017/09/13	Tahir Anwar
Resistivity of Soil		5157113	2017/09/14	2017/09/14	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5161621	N/A	2017/09/13	Alina Dobreanu

Maxxam Job #: B7J6282
Report Date: 2017/09/19

exp Services Inc
Client Project #: ADM-00241921-AO
Site Location: BRACEBRIDGE, HWY11
Your P.O. #: GEO
Sampler Initials: NI

GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	7.7°C
-----------	-------

Results relate only to the items tested.

QUALITY ASSURANCE REPORT

exp Services Inc
Client Project #: ADM-00241921-AO
Site Location: BRACEBRIDGE, HWY11
Your P.O. #: GEO
Sampler Initials: NI

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
5159921	Available (CaCl ₂) pH	2017/09/13			99	97 - 103			0.34	N/A
5161515	Conductivity	2017/09/13			99	90 - 110	<2	umho/cm	0.90	10
5161620	Soluble (20:1) Chloride (Cl)	2017/09/13	NC	70 - 130	107	70 - 130	<20	ug/g	6.6	35
5161621	Soluble (20:1) Sulphate (SO ₄)	2017/09/13	NC	70 - 130	105	70 - 130	<20	ug/g	2.5	35

N/A = Not Applicable

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spike amount was too small to permit a reliable recovery calculation (matrix spike concentration was less than the native sample concentration)

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

Cristina Carriere

Cristina Carriere, Scientific Service Specialist

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Your P.O. #: GEO
Your Project #: B7J6282/ADM-00241921-AO
Site Location: BRACEBRIDGE, HWY11
Your C.O.C. #: B7J6282-MFOY-01-01

Attention: SUBCONTRACTOR

MAXXAM ANALYTICS INC.
MISSISSAUGA CAMPO
6740 Campobello Rd
MISSISSAUGA, ON
Canada L5N 2L8

Report Date: 2017/09/14
Report #: R2318848
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B755670

Received: 2017/09/12, 10:30

Sample Matrix: SOIL
Samples Received: 2

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Primary Reference
Redox Potential***	2	2017/09/13	2017/09/13	QUE SOP-00151	SM 2580 B

Remarks:

Maxxam Analytics' laboratories are accredited to ISO/IEC 17025:2005 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Maxxam are based upon recognized Provincial, Federal or US method compendia such as CCME, MDDELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Maxxam's profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Maxxam in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported: unless indicated otherwise, associated sample data are not blank corrected.

Maxxam Analytics' liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Maxxam has been retained to provide analysis of samples provided by the Client using the testing methodology referenced in this report. Interpretation and use of test results are the sole responsibility of the Client and are not within the scope of services provided by Maxxam, unless otherwise agreed in writing.

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods.

Results relate to samples tested.

This Certificate shall not be reproduced except in full, without the written approval of the laboratory.

Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.

Note: RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

*** This analysis is not subject to MDDELCC accreditation.

Attention: SUBCONTRACTOR

MAXXAM ANALYTICS INC.
MISSISSAUGA CAMPO
6740 Campobello Rd
MISSISSAUGA, ON
Canada L5N 2L8

Your P.O. #: GEO
Your Project #: B7J6282/ADM-00241921-AO
Site Location: BRACEBRIDGE, HWY11
Your C.O.C. #: B7J6282-MFOY-01-01

Report Date: 2017/09/14
Report #: R2318848
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B755670
Received: 2017/09/12, 10:30

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Diane Goulet, Project Manager Assistant

Email: DGoulet@maxxam.ca

Phone# (418)658-5784 Ext:6442

=====

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Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Maxxam Job #: B755670
Report Date: 2017/09/14

MAXXAM ANALYTICS INC.
Client Project #: B7J6282/ADM-00241921-AO
Site Location: BRACEBRIDGE, HWY11
Your P.O. #: GEO

CONVENTIONAL PARAMETERS (SOIL)

Maxxam ID		EO1774	EO1775	
Sampling Date		2017/09/05 11:00	2017/09/05 15:00	
COC Number		B7J6282-MFOY-01-01	B7J6282-MFOY-01-01	
	Units	FCB639-BH5 SS5	FCB640-BH4 SS6	QC Batch
CONVENTIONALS				
Redox Potential	mV	140	160	1836707
QC Batch = Quality Control Batch				

Maxxam Job #: B755670
Report Date: 2017/09/14

MAXXAM ANALYTICS INC.
Client Project #: B7J6282/ADM-00241921-AO
Site Location: BRACEBRIDGE, HWY11
Your P.O. #: GEO

GENERAL COMMENTS

All results are calculated on a dry weight basis except where not applicable.

CONVENTIONAL PARAMETERS (SOIL)

Please note that the results have not been corrected for QC recoveries nor for the method blank results.

Results relate only to the items tested.

Maxxam Job #: B755670
Report Date: 2017/09/14

MAXXAM ANALYTICS INC.
Client Project #: B7J6282/ADM-00241921-AO
Site Location: BRACEBRIDGE, HWY11
Your P.O. #: GEO

QUALITY ASSURANCE REPORT

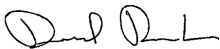

QA/QC									
Batch	Init	QC Type	Parameter	Date Analyzed	Value	Recovery	Units	QC Limits	
1836707	CB8	Spiked Blank	Redox Potential	2017/09/13		99	%	80 - 120	
Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.									

Maxxam Job #: B755670
Report Date: 2017/09/14

MAXXAM ANALYTICS INC.
Client Project #: B7J6282/ADM-00241921-AO
Site Location: BRACEBRIDGE, HWY11
Your P.O. #: GEO

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

David Provencher, B.Sc., Chemist, Senior Analyst

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Invoice Information		Report Information (if differs from invoice)		Project Information (where applicable)		Turnaround Time (TAT) Required	
Company Name: <u>EXP SERVICES INC</u>		Company Name: <u>EXP SERVICES INC</u>		Quotation #: _____		<input type="checkbox"/> Regular TAT (5-7 days) Most analyses PLEASE PROVIDE ADVANCE NOTICE FOR RUSH PROJECTS	
Contact Name: <u>Nimesh Tamrakar</u>		Contact Name: <u>NIMESH TAMRAKAR</u>		P.O. #/ AFE#: <u>GEO</u>		<input checked="" type="checkbox"/> Rush TAT (Surcharges will be applied) <input type="checkbox"/> 1 Day <input type="checkbox"/> 2 Days <input type="checkbox"/> 3-4 Days	
Address: <u>56 Queen St E, Suite 301</u> <u>Brampton</u>		Address: _____		Project #: <u>ADM-0024921-AD</u>			
Phone: <u>905-746-3200</u> Fax: _____		Phone: _____ Fax: _____		Site Location: <u>Bracebridge, Hwy 11</u>			
Email: <u>NIMESH.TAMRAKAR@EXP.COM</u>		Email: _____		Site #: _____			
				Sampled By: <u>Nimesh</u>		Date Required: _____	
MOE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE MAXXAM DRINKING WATER CHAIN OF CUSTODY							
Regulation 153		Other Regulations		Analysis Requested		LABORATORY USE ONLY	
<input checked="" type="checkbox"/> Table 1 <input type="checkbox"/> Res/Park <input type="checkbox"/> Med/ Fine <input type="checkbox"/> Table 2 <input type="checkbox"/> Ind/Comm <input type="checkbox"/> Coarse <input type="checkbox"/> Table 3 <input type="checkbox"/> Agri/ Other <input type="checkbox"/> Table _____ FOR RSC (PLEASE CIRCLE) Y / N		<input type="checkbox"/> CCME <input type="checkbox"/> Sanitary Sewer Bylaw <input type="checkbox"/> MISA <input type="checkbox"/> Storm Sewer Bylaw <input type="checkbox"/> PWQO <input type="checkbox"/> Region <input type="checkbox"/> Other (Specify) _____ <input type="checkbox"/> REG 558 (MIN. 3 DAY TAT REQUIRED)		REFER TO BACK OF COC REG 153 METALS & INORGANICS REG 153 ICPMS METALS REG 153 METALS (Hg, Cr VI, ICPMS Metals, HWS - B) <u>Continuity Package</u>		CUSTODY SEAL Y / N Present Intact <u>11/11</u> <u>61819</u> COOLING MEDIA PRESENT: <input checked="" type="checkbox"/> Y <input type="checkbox"/> N COMMENTS	
Include Criteria on Certificate of Analysis: Y / N							
SAMPLES MUST BE KEPT COOL (< 10°C) FROM TIME OF SAMPLING UNTIL DELIVERY TO MAXXAM							
SAMPLE IDENTIFICATION		DATE SAMPLED (YYYY/MM/DD)	TIME SAMPLED (HH:MM)	MATRIX	# OF CONTAINERS SUBMITTED	FIELD FILTERED (CIRCLE) Metals / Hg / CrVI	HOLD - DO NOT ANALYZE
1 <u>BH5 SS5</u>		<u>2017/09/05</u>	<u>11:00</u>	<u>Soil</u>	<u>2</u>		
2 <u>BH6 SS6</u>		<u>2017/09/07</u>	<u>3:00</u>	<u>Soil</u>	<u>2</u>		
3							
4							
5							
6							
7							
8							
9							
10							
RELINQUISHED BY: (Signature/Print)		DATE: (YYYY/MM/DD)	TIME: (HH:MM)	RECEIVED BY: (Signature/Print)		DATE: (YYYY/MM/DD)	TIME: (HH:MM)
<u>Nimesh Tamrakar</u>		<u>2017/09/08</u>	<u>15:00</u>	<u>[Signature]</u>		<u>2017/09/08</u>	<u>18:06</u>

08-Sep-17 18:06
Deepthi Shaji
B7J6282
GK1 ENV-592

Attention: Deepthi Shaji

MAXXAM ANALYTICS
CAMPOBELLO
6740 CAMPOBELLO ROAD
MISSISSAUGA, ON
CANADA L5N 2L8

Your P.O. #: GEO
Your Project #: MB7J6282
Site Location: ADM-00241921-AO
Your C.O.C. #: B7J6282-M058-01-01

Report Date: 2017/09/15
Report #: R2444926
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B778284

Received: 2017/09/12, 13:20

Sample Matrix: Soil
Samples Received: 2

Analyses	Date		Date Analyzed	Laboratory Method	Analytical Method
	Quantity	Extracted			
Moisture	2	2017/09/13	2017/09/14	BBY8SOP-00017	BCM0E BCLM Dec2000 m
Sulphide in Soil	2	2017/09/12	2017/09/14	BBY6SOP-00006	SM 22 4500 S2- D m

Remarks:

Maxxam Analytics' laboratories are accredited to ISO/IEC 17025:2005 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Maxxam are based upon recognized Provincial, Federal or US method compendia such as CCME, MDDELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Maxxam's profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Maxxam in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported: unless indicated otherwise, associated sample data are not blank corrected.

Maxxam Analytics' liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Maxxam has been retained to provide analysis of samples provided by the Client using the testing methodology referenced in this report. Interpretation and use of test results are the sole responsibility of the Client and are not within the scope of services provided by Maxxam, unless otherwise agreed in writing.

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods.

Results relate to samples tested.

This Certificate shall not be reproduced except in full, without the written approval of the laboratory.

Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

Attention:Deepthi Shaji

MAXXAM ANALYTICS
CAMPOBELLO
6740 CAMPOBELLO ROAD
MISSISSAUGA, ON
CANADA L5N 2L8

Your P.O. #: GEO
Your Project #: MB7J6282
Site Location: ADM-00241921-AO
Your C.O.C. #: B7J6282-M058-01-01

Report Date: 2017/09/15
Report #: R2444926
Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B778284
Received: 2017/09/12, 13:20

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Amandeep Nagra, Account Specialist

Email: ANagra@maxxam.ca

Phone# (604)639-2602

=====

This report has been generated and distributed using a secure automated process.

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Maxxam Job #: B778284
Report Date: 2017/09/15

MAXXAM ANALYTICS
Client Project #: MB7J6282
Site Location: ADM-00241921-AO
Your P.O. #: GEO
Sampler Initials: NI

RESULTS OF CHEMICAL ANALYSES OF SOIL

Maxxam ID		RY3020		RY3021		RY3021		
Sampling Date		2017/09/05		2017/09/07		2017/09/07		
COC Number		B7J6282-M058-01-01		B7J6282-M058-01-01		B7J6282-M058-01-01		
	UNITS	BH5 SS5 (FCB639)	RDL	BH4 SS6 (FCB640)	RDL	BH4 SS6 (FCB640) Lab-Dup	RDL	QC Batch
MISCELLANEOUS								
Sulphide	ug/g	0.85 (1)	0.60	1.24 (1)	0.50	0.71	0.55	8755809
RDL = Reportable Detection Limit								
Lab-Dup = Laboratory Initiated Duplicate								
(1) Headspace in sample jar was noted at the time of extraction. RDL raised due to high sample moisture content.								

Maxxam Job #: B778284
Report Date: 2017/09/15

MAXXAM ANALYTICS
Client Project #: MB7J6282
Site Location: ADM-00241921-AO
Your P.O. #: GEO
Sampler Initials: NI

PHYSICAL TESTING (SOIL)

Maxxam ID		RY3020	RY3021		
Sampling Date		2017/09/05	2017/09/07		
COC Number		B7J6282-M058-01-01	B7J6282-M058-01-01		
	UNITS	BH5 SS5 (FCB639)	BH4 SS6 (FCB640)	RDL	QC Batch
Physical Properties					
Moisture	%	39	33	0.30	8756467
RDL = Reportable Detection Limit					

Maxxam Job #: B778284
Report Date: 2017/09/15

MAXXAM ANALYTICS
Client Project #: MB7J6282
Site Location: ADM-00241921-AO
Your P.O. #: GEO
Sampler Initials: NI

TEST SUMMARY

Maxxam ID: RY3020
Sample ID: BH5 SS5 (FCB639)
Matrix: Soil

Collected: 2017/09/05
Shipped:
Received: 2017/09/12

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Moisture	BAL/BAL	8756467	2017/09/13	2017/09/14	Lolita Obusan
Sulphide in Soil	SPEC/COL	8755809	2017/09/12	2017/09/14	Karen Brunn

Maxxam ID: RY3021
Sample ID: BH4 SS6 (FCB640)
Matrix: Soil

Collected: 2017/09/07
Shipped:
Received: 2017/09/12

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Moisture	BAL/BAL	8756467	2017/09/13	2017/09/14	Lolita Obusan
Sulphide in Soil	SPEC/COL	8755809	2017/09/12	2017/09/14	Karen Brunn

Maxxam ID: RY3021 Dup
Sample ID: BH4 SS6 (FCB640)
Matrix: Soil

Collected: 2017/09/07
Shipped:
Received: 2017/09/12

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Sulphide in Soil	SPEC/COL	8755809	2017/09/12	2017/09/14	Karen Brunn

Maxxam Job #: B778284
Report Date: 2017/09/15

MAXXAM ANALYTICS
Client Project #: MB7J6282
Site Location: ADM-00241921-AO
Your P.O. #: GEO
Sampler Initials: NI

GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	3.7°C
-----------	-------

Results relate only to the items tested.

Maxxam Job #: B778284
Report Date: 2017/09/15

QUALITY ASSURANCE REPORT

MAXXAM ANALYTICS
Client Project #: MB7J6282
Site Location: ADM-00241921-AO
Your P.O. #: GEO
Sampler Initials: NI

QC Batch	Parameter	Date	Matrix Spike		Spiked Blank		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
8755809	Sulphide	2017/09/14	112 (1)	75 - 125	82	75 - 125	<0.50	ug/g	NC (2)	30
8756467	Moisture	2017/09/14					<0.30	%	5.9 (3)	20

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

NC (Duplicate RPD): The duplicate RPD was not calculated. The concentration in the sample and/or duplicate was too low to permit a reliable RPD calculation (absolute difference $\leq 2 \times \text{RDL}$).

(1) Matrix Spike Parent ID [RY3021-01]

(2) Duplicate Parent ID [RY3021-01]

(3) Duplicate Parent ID

Maxxam Job #: B778284
Report Date: 2017/09/15

MAXXAM ANALYTICS
Client Project #: MB7J6282
Site Location: ADM-00241921-AO
Your P.O. #: GEO
Sampler Initials: NI

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).



Rob Reinert, B.Sc., Scientific Spécialist

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Appendix F – Record of boreholes and laboratory data (Golder Associates)

PROJECT

1651997

W.P.

DIST

DATUM

GEODETIC

LOCATION

N 4993667.2; E 320702.6 (LAT. 45.084815; LONG. -79.297809)

BOREHOLE TYPE

108 mm I.D. Hollow Stem Augers

DATE

February 27, 2017

1 OF 2

METRIC

ORIGINATED BY

IK

COMPILED BY

TB

CHECKED BY

SEMP

[illegible]

Continued Next Page

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

PROJECT <u>1651997</u>				RECORD OF BOREHOLE No 17-1				2 OF 2 METRIC						
W.P. _____				LOCATION <u>N 4993667.2; E 320702.6 (LAT. 45.084815; LONG. -79.297809)</u>				ORIGINATED BY <u>IK</u>						
DIST _____ HWY <u>11 (SBL)</u>				BOREHOLE TYPE <u>108 mm I.D. Hollow Stem Augers</u>				COMPILED BY <u>TB</u>						
DATUM <u>GEODETIC</u>				DATE <u>February 27, 2017</u>				CHECKED BY <u>SEMP</u>						
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT W _p W 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			SHEAR STRENGTH kPa		WATER CONTENT (%)				
	--- CONTINUED FROM PREVIOUS PAGE ---							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED						
	SAND, trace to some gravel, trace to some silt Loose to compact Brown Wet		12	SS	9		268						19 75 (6)	
							267							
			13	SS	7		266							
							265							
			14	SS	13		264							
							263							
			15	SS	12		262							
							261							
			16	SS	9		260							
262.2 18.7	END OF BOREHOLE START OF DCPT													
259.3 21.6	END OF DCPT													
	Note: 1. Groundwater level not recorded due to water introduced during drilling to mitigate heaving sand.													

SUD-MTO 001 LATILONG 1651997.GPJ GAL-MISS.GDT 07/04/17 DATA INPUT:

PROJECT		1651997				RECORD OF BOREHOLE No 17-2				1 OF 1 METRIC						
W.P.						LOCATION				N 4993666.5; E 320736.3 (LAT. 45.084808; LONG. -79.297382)						
DIST		HWY 11 (NBL)				BOREHOLE TYPE				108 mm I.D. Hollow Stem Augers and HQ Casing/Coring						
DATUM		GEODETIC				DATE				February 28, 2017						
						ORIGINATED BY				IK						
						COMPILED BY				TB						
						CHECKED BY				SEMP						
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					WATER CONTENT (%)			
282.0	GROUND SURFACE						20	40	60	80	100	20	40	60		
0.0	ASPHALT (200 mm)															
0.2	Sand, some gravel, trace silt (FILL) Compact to very dense Brown Moist		1	AS	-											
			2	SS	44											
			3	SS	24											
			4	SS	50/0.05											
279.4	Auger grinding from 2.5 m to 2.6 m depth.															
2.6	ROCK FILL															
			R1	RC	REC 58%											
277.7																
4.3	Sand, some silt, some gravel (FILL) Compact Brown Moist		5A	SS	29											
276.7																
5.3	ROCK FILL															
			R2	RC	REC 7%											
			5B	SS	44											
			R3	RC	REC 0%											
275.1	No recovery in Sample 5B.															
6.9	Silty sand and gravel (FILL) Very dense Brown Moist															
			6	SS	50/0.13											
273.8																
8.2	END OF BOREHOLE															
	Note: 1. Cored through existing culvert at 8.2 m depth. Culvert obvert plugged and borehole backfilled.															

SUD-MTO 001 LAT/LONG 1651997.GPJ GAL-MISS.GDT 07/04/17 DATA INPUT:

RECORD OF BOREHOLE No 17-2B

1 OF 3 **METRIC**

PROJECT 1651997
W.P. LOCATION N 4993660.2; E 320739.0 (LAT. 45.084752; LONG. -79.297347) ORIGINATED BY IK
DIST HWY 11 (NBL) BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers and HQ Casing/Coring COMPILED BY TB
DATUM GEODETIC DATE February 28 and March 8, 2017 CHECKED BY SEMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)			
								20	40	60							80	100	
								○ UNCONFINED	+	FIELD VANE							×	REMOULDED	
282.1	GROUND SURFACE						20	40	60	80	100	20	40	60	GR	SA	SI	CL	
0.0	ASPHALT (110 mm)		1	AS	-		282												
0.1	Sand, trace to some silt, trace gravel (FILL) Compact to dense Brown to dark brown Moist		2	SS	32		281								3	87	9	1	
			3	SS	24		280												
	Split-spoon sampler bouncing on inferred cobble at 2.3 m depth.		4	SS	50/0.02		279												
	Auger grinding from 3.0 to 3.5 m depth.		5	SS	14		278												
278.6	ROCK FILL		R1	RC	REC 93%		277												
3.5			R2	RC	REC 10%		276												
276.3	Silty sand, trace gravel (FILL) Very loose to dense Brown to dark brown Moist to wet		6	SS	36		275												
5.8			7	SS	5		274												
			8	SS	10		273												
			9	SS	2		272												
272.0	SILT and SAND, trace clay, trace organics, trace rootlets Loose Black Moist		10A 10B	SS	6		271								OC = 3.3%	0	45	52	3
10.1															NP	0	48	52	0

Continued Next Page

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

SUD-MTO 001 LATILONG 1651997.GPJ GAL-MISS.GDT 07/04/17 DATA INPUT:

PROJECT <u>1651997</u>				RECORD OF BOREHOLE No 17-2B				2 OF 3 METRIC						
W.P. _____				LOCATION <u>N 4993660.2; E 320739.0 (LAT. 45.084752; LONG. -79.297347)</u>				ORIGINATED BY <u>IK</u>						
DIST _____ HWY <u>11 (NBL)</u>				BOREHOLE TYPE <u>108 mm I.D. Hollow Stem Augers and HQ Casing/Coring</u>				COMPILED BY <u>TB</u>						
DATUM <u>GEODETIC</u>				DATE <u>February 28 and March 8, 2017</u>				CHECKED BY <u>SEMP</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			SHEAR STRENGTH kPa		WATER CONTENT (%)				
	--- CONTINUED FROM PREVIOUS PAGE ---							20 40 60 80 100		20 40 60				
267.4	SILT and SAND, trace clay, trace organics, trace rootlets Loose Black Moist		11	SS	9		270							
							269							
			12	SS	6		268							0 60 39 1
14.7	SAND, some silt Compact to dense Brown Wet						267							
			13	SS	36		266							
							265							
			14	SS	33		264							
			15	SS	21		263							
			16	SS	33		262							
263.2	END OF BOREHOLE START OF DCPT						261							0 85 14 1
18.9							260							
							259							

Continued Next Page

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

SUD-MTO 001 LATILONG 1651997.GPJ GAL-MISS.GDT 07/04/17 DATA INPUT:

PROJECT <u>1651997</u>		RECORD OF BOREHOLE No 17-2B		3 OF 3 METRIC	
W.P. _____		LOCATION <u>N 4993660.2; E 320739.0 (LAT. 45.084752; LONG. -79.297347)</u>		ORIGINATED BY <u>IK</u>	
DIST _____ HWY <u>11 (NBL)</u>		BOREHOLE TYPE <u>108 mm I.D. Hollow Stem Augers and HQ Casing/Coring</u>		COMPILED BY <u>TB</u>	
DATUM <u>GEODETIC</u>		DATE <u>February 28 and March 8, 2017</u>		CHECKED BY <u>SEMP</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)		
								20 40 60 80 100	○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED							w _p w w _L		
257.7							258											
24.4	END OF DCPT Note: 1. Water level at a depth of 7.6 m below ground surface (Elev. 274.5) upon completion of drilling.																	

SUD-MTO 001 LATILONG 1651997.GPJ GAL-MISS.GDT 07/04/17 DATA INPUT:

SUD-MTO 001 LAT/LONG 1651997.GPJ GAL-MISS.GDT 07/04/17 DATA INPUT:

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

PROJECT 1651997				RECORD OF BOREHOLE No 17-3				2 OF 2 METRIC						
W.P. _____				LOCATION N 4993676.9; E 320698.4 (LAT. 45.084903; LONG. -79.297863)				ORIGINATED BY IK						
DIST _____ HWY 11 (SBL)				BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers and NQ Casing/Coring				COMPILED BY TB						
DATUM GEODETIC				DATE March 8, 2017				CHECKED BY SEMP						
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W _p	W	W _L		
	--- CONTINUED FROM PREVIOUS PAGE ---							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED	WATER CONTENT (%)					
266.0	SILT and SAND, trace clay, trace gravel Loose to compact Grey to brown Moist to wet Seam of coarse sand encountered in Sample 12. 0.3 m of sand heaving in augers at 12.2 m depth.		12	SS	8		268							
							267							
14.7	SAND, trace silt Compact Grey to brown Moist to wet		13	SS	8		266							
265.0			14	SS	17		265							0 98 (2)
15.7	END OF BOREHOLE START OF DCPT						264							
							263							
							262							
							261							
							260							
259.4	END OF DCPT													
21.3														

SUD-MTO 001 LATILONG 1651997.GPJ GAL-MISS.GDT 07/04/17 DATA INPUT:

PROJECT 1651997				RECORD OF BOREHOLE No 17-4				1 OF 2 METRIC						
W.P. _____				LOCATION N 4993677.7; E 320731.4 (LAT. 45.084909; LONG. -79.297443)				ORIGINATED BY IK						
DIST _____ HWY 11 (NBL)				BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers				COMPILED BY TB						
DATUM GEODETIC				DATE March 8, 2017				CHECKED BY SEMP						
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
281.6	GROUND SURFACE													
0.0	ASPHALT (120 mm)													
0.1	Sand, trace to some silt, trace gravel (FILL) Dense Brown Moist		1	AS	-									
			2	SS	37									
			3	SS	30									
279.5	Sand and gravel, trace to some silt, containing cobbles (FILL) Dense to very dense Grey Moist		4	SS	50/0.08									2 92 (6)
2.1			5	SS	30									
277.9	Sand, trace to some silt, trace to some gravel (FILL) Compact to dense Brown Moist		6	SS	15									54 36 (10)
3.7	Auger grinding from 2.3 m to 5.3 m depth.		7	SS	46									7 86 (7)
			8	SS	26									
274.3	GRANITE (BEDROCK) Bedrock cored from 7.3 m to 10.3 m depth. For coring details see Record of Drillhole 17-4.		1	RC	REC 95%									RQD = 86%
7.3			2	RC	REC 100%									RQD = 100%
271.3	END OF BOREHOLE													
10.3	Note: 1. Water level at a depth of 7.3 m below ground surface (Elev. 274.3) upon completion of drilling.													

SUD-MTO 001 LAT/LONG 1651997.GPJ GAL-MISS.GDT 07/04/17 DATA INPUT:

PROJECT: 1651997

RECORD OF DRILLHOLE: 17-4

SHEET 2 OF 2

LOCATION: N 4993677.7; E 320731.4 (LAT. 45.084909; LONG. -79.297443)

DRILLING DATE: March 8, 2017

DATUM: GEODETIC

INCLINATION: -90° AZIMUTH: —

DRILL RIG: CME 75

DRILLING CONTRACTOR: Downing Drilling

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	JN - Joint FLT - Fault SHR - Shear VN - Vein CJ - Conjugate BD - Bedding FO - Foliation CO - Contact OR - Orthogonal CL - Cleavage PL - Planar CU - Curved UN - Undulating ST - Stepped IR - Irregular PO - Polished K - Slickensided SM - Smooth Ro - Rough MB - Mechanical Break BR - Broken Rock NOTE: For additional abbreviations refer to list of abbreviations & symbols.										Q AVG.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
							FLUSH	RECOVERY		R.Q.D. %	FRACT. INDEX METRES	DISCONTINUITY DATA						ROCK STRENGTH INDEX		WEATH- ERING INDEX																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
								TOTAL CORE %	SOLID CORE %			B Angle	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja		Jn	R2	R3	R1	W1	W2	W3	W4																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
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DEPTH SCALE

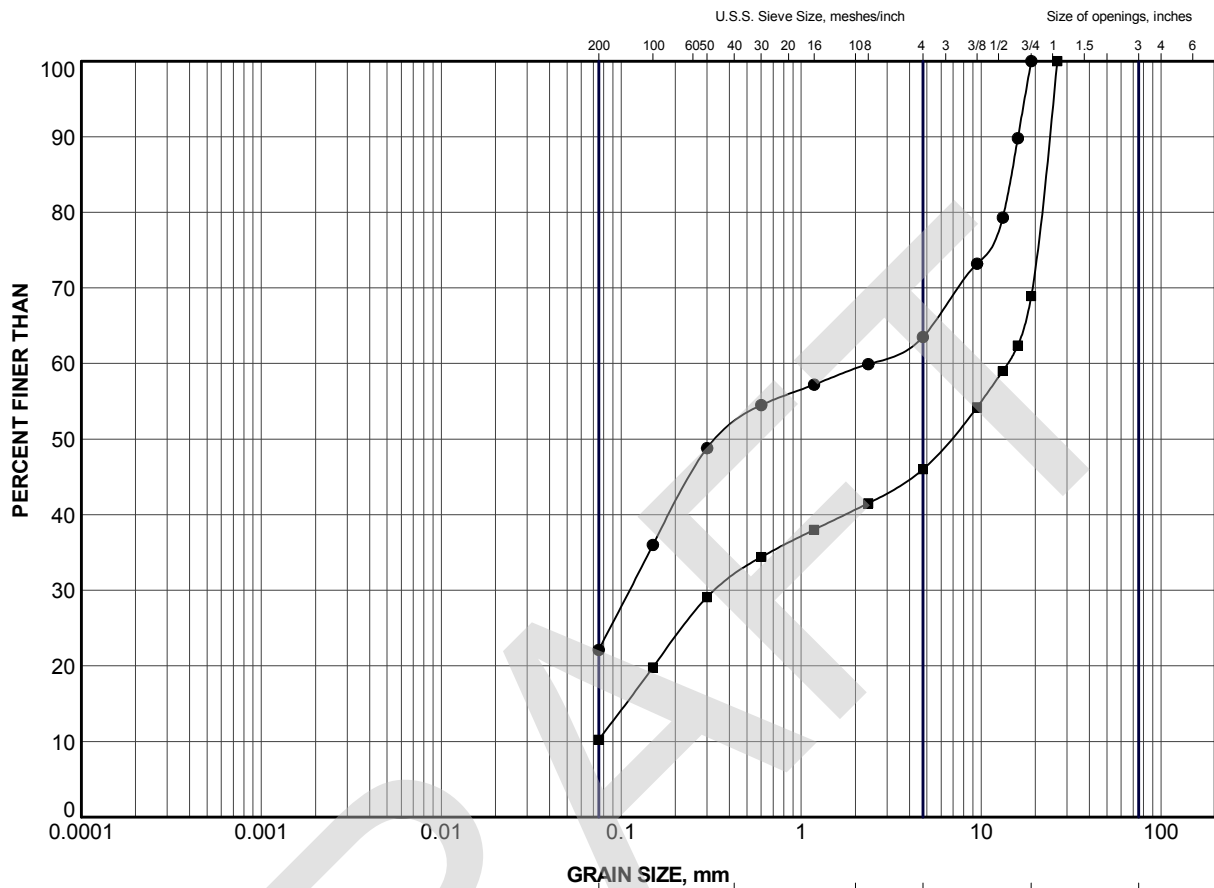
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LOGGED: IK

CHECKED: SEMP

SUD-RCK (LAT/LONG) 1651997 GRJ GAL-MISS GDT 31/03/17 DATA INPUT:



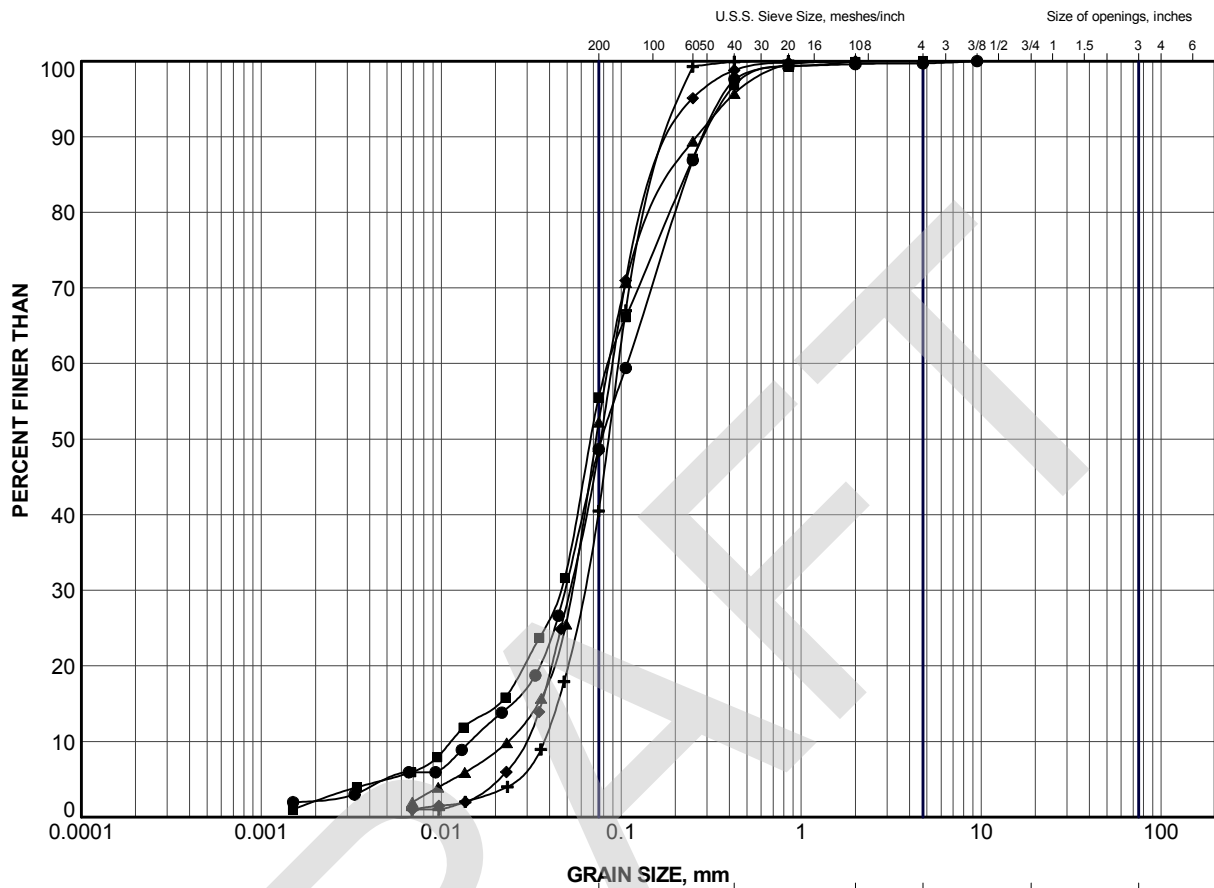
GRAVEL SIZE, mm							Cobble Size
CLAY AND SILT	fine	medium	coarse	fine	coarse		
	SAND SIZE			GRAVEL SIZE			

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	17-2	6	274.3
■	17-4	5	278.4

PROJECT						HIGHWAY 11 BRACEBRIDGE CULVERT STA 16+312					
TITLE						GRAIN SIZE DISTRIBUTION SAND and GRAVEL (FILL)					
PROJECT No.			1651997			FILE No.			1651997.GPJ		
DRAWN	TB	Mar 2017	SCALE	N/A	REV.						
CHECK	SEMP	Mar 2017									
APPR	LCC	Mar 2017									
						FIGURE 2					





LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	17-1	10	271.5
■	17-2B	10A	271.3
▲	17-2B	10B	271.1
+	17-2B	12	268.2
◆	17-3	10	271.3

PROJECT

HIGHWAY 11
BRACEBRIDGE CULVERT STA 16+312

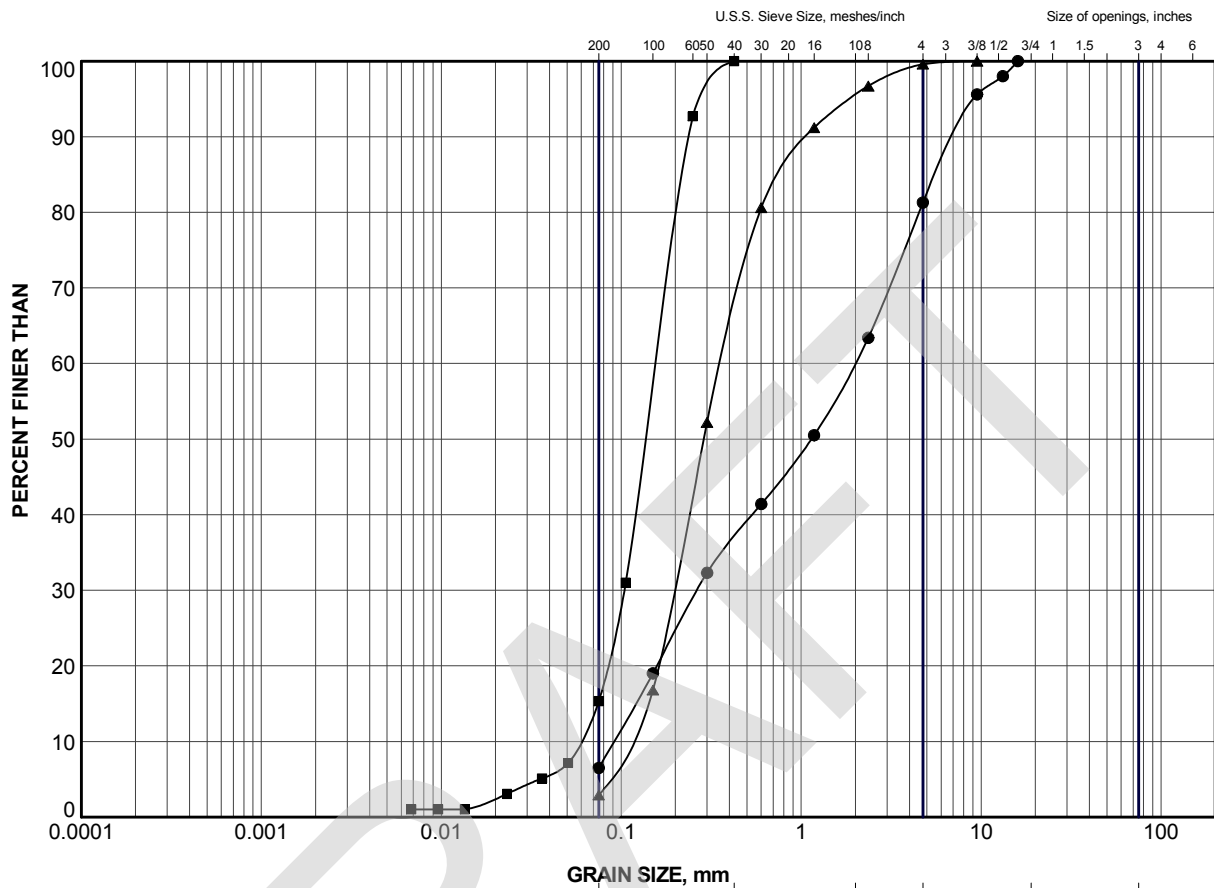
TITLE

GRAIN SIZE DISTRIBUTION
SILT and SAND



Golder Associates
SUDBURY, ONTARIO

PROJECT No. 1651997			FILE No. 1651997.GPJ		
DRAWN	TB	Mar 2017	SCALE	N/A	REV.
CHECK	SEMP	Mar 2017	FIGURE 3		
APPR	LCC	Mar 2017			



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	17-1	12	268.5
■	17-2B	16	263.5
▲	17-3	14	265.2

PROJECT					
HIGHWAY 11 BRACEBRIDGE CULVERT STA 16+312					
TITLE					
GRAIN SIZE DISTRIBUTION SAND					
PROJECT No.		1651997		FILE No. 1651997.GPJ	
DRAWN	TB	Mar 2017	SCALE	N/A	REV.
CHECK	SEMP	Mar 2017	FIGURE 4		
APPR	LCC	Mar 2017			



Appendix G – Results of Stability Analysis

New Overflow Culvert at Hwy 11/117 Interchange
 Bracebridge
 West Side Slope
 Drained Static condition

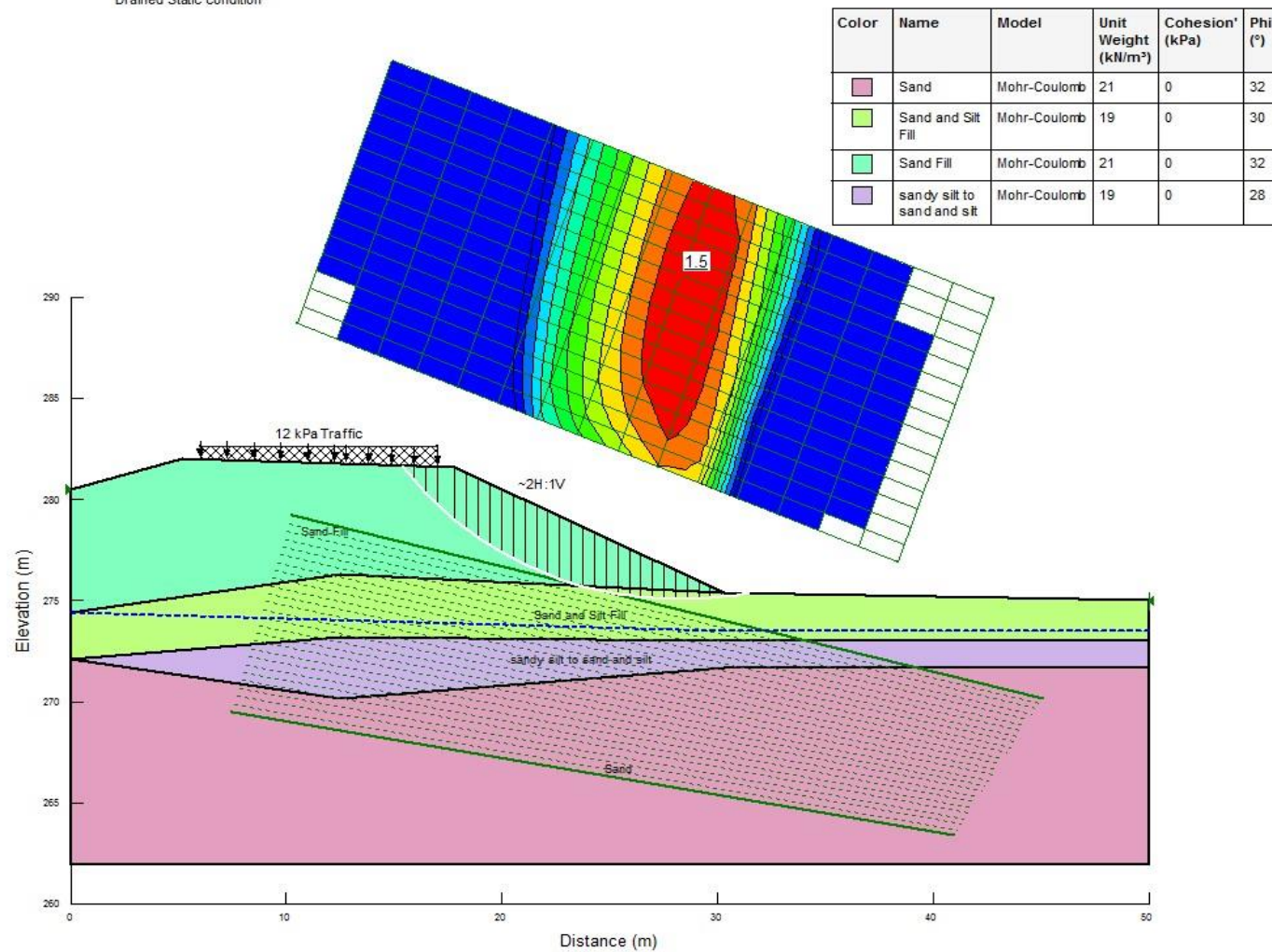
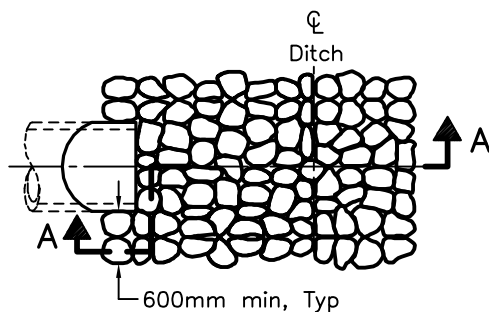
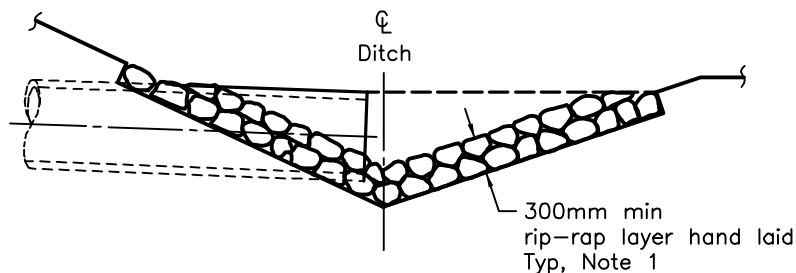


Figure 1: Slope stability analysis for west side slope

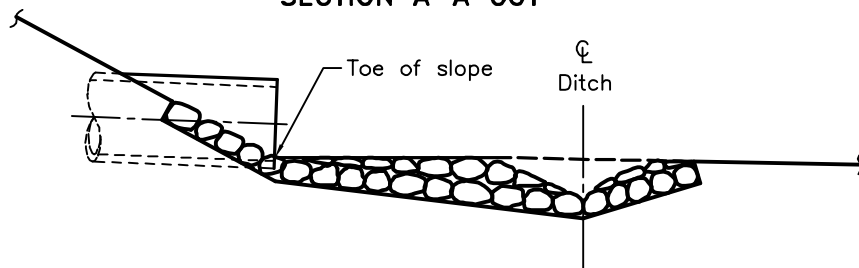
Appendix H– OPSDs



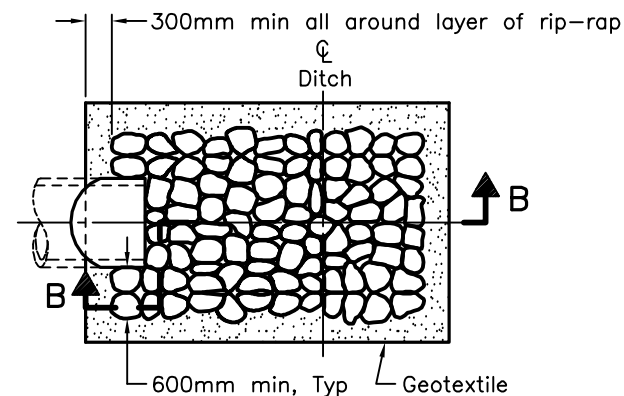
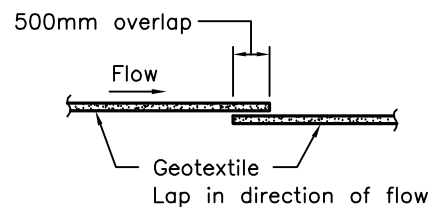
PLAN
CUT OR FILL



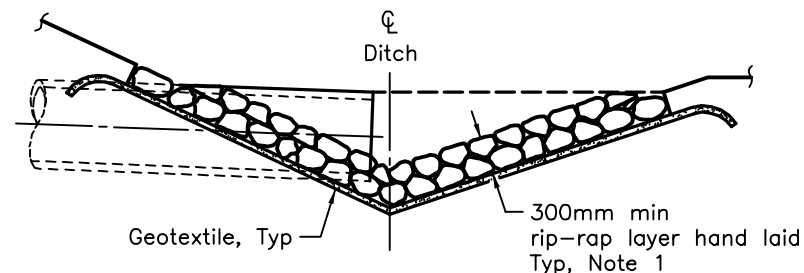
SECTION A-A CUT



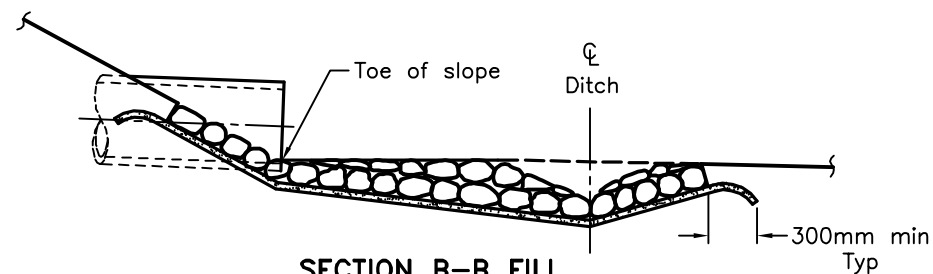
SECTION A-A FILL
TYPE A – WITHOUT GEOTEXTILE



PLAN
CUT OR FILL



SECTION B-B CUT



SECTION B-B FILL
TYPE B – WITH GEOTEXTILE

NOTES:

1 The thickness of the rip-rap layer shall be at least 1.5 times the rip-rap mean diameter.

A All dimensions are in millimetres unless otherwise shown.

ONTARIO PROVINCIAL STANDARD DRAWING

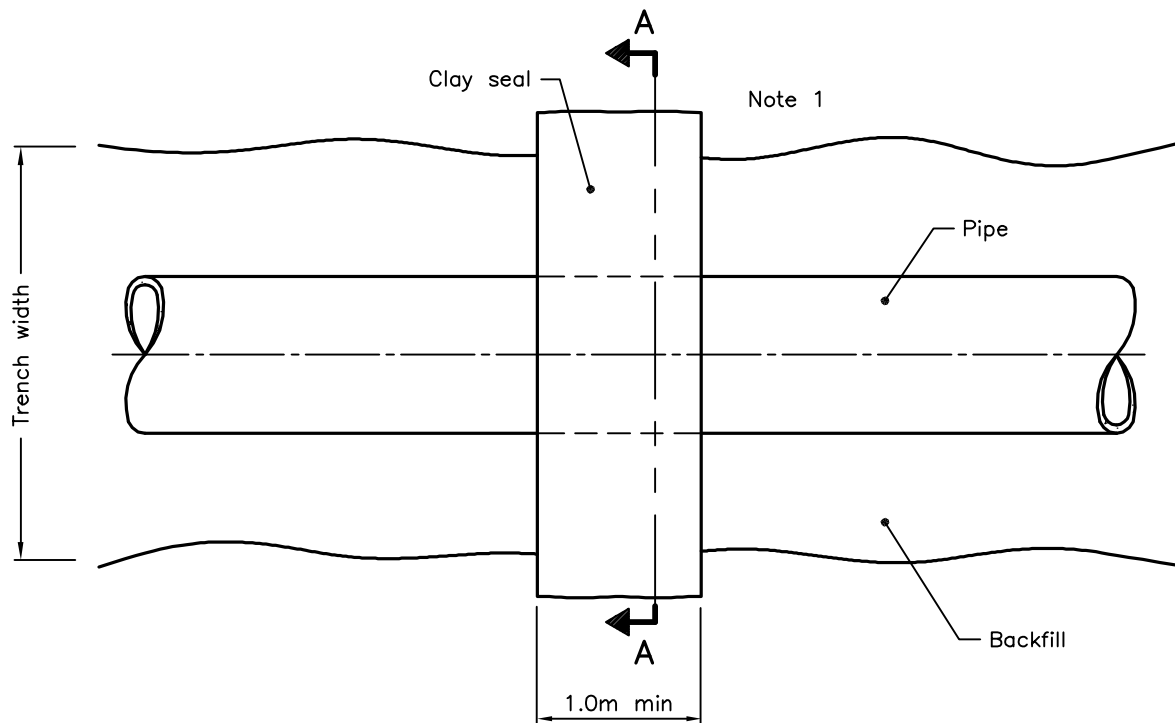
Nov 2013

Rev 2

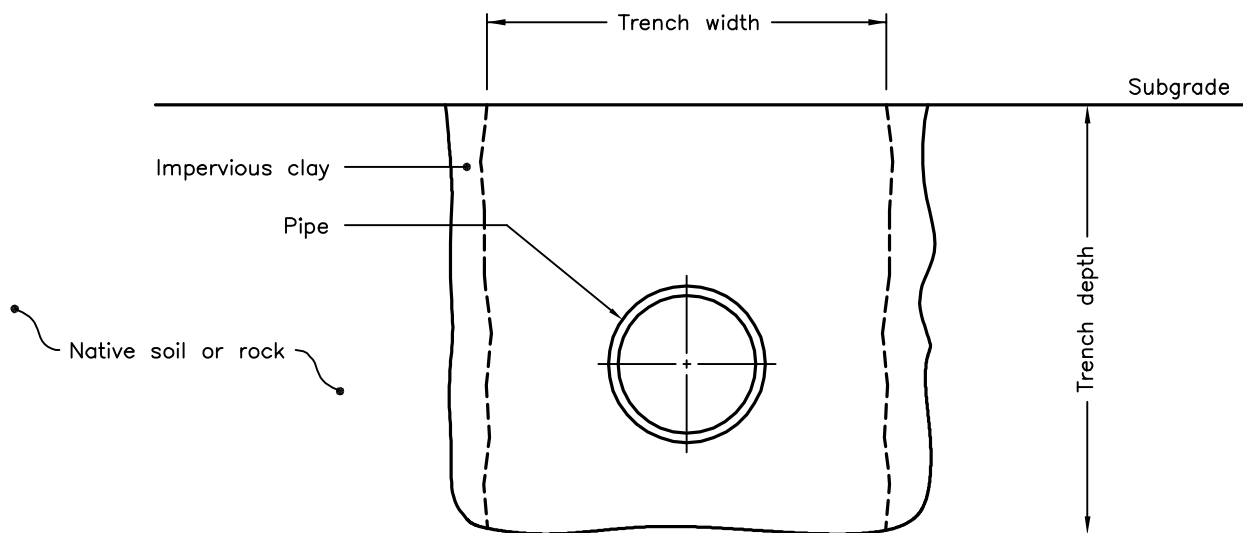
GENERAL RIP-RAP LAYOUT
FOR SEWER AND CULVERT OUTLETS

OPSD 810.010





PLAN



SECTION A-A

NOTES:

1. Key into undisturbed trench soil.

A Clay seal shall extend from bottom of trench excavation to the subgrade.

B Clay seal shall be located so that no pipe joints are within the clay seal material.

C All dimensions are in metres unless otherwise shown.

ONTARIO PROVINCIAL STANDARD DRAWING

Nov 2016

Rev 2

CLAY SEAL FOR PIPE TRENCHES

OPSD 802.095



Appendix I– NSSPs

NSSP FOR COBBLES AND/OR BOULDERs OBSTRUCTIONS

Scope of Work

The Contractor should be aware that the embankment fill at the site encountered some cobbles and boulders in the zone of tunneling during horizontal directional drilling and vertical borehole investigations and some organics and wood fibers were also encountered at the zone of tunneling. The horizontal drilling confirmed that there is no rockfill at the level of the proposed culvert, but cobbles and boulders should be expected to be present along the alignment, which may impact excavations, tunnelling and/or elements of temporary protection systems. Appropriate equipment and procedures will be required to penetrate/remove cobbles and/or boulders that are encountered during excavation, tunnelling or advancing elements of the temporary protection systems.

Basis of Payment

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