



August 15, 2018

FOUNDATION INVESTIGATION AND DESIGN REPORT

**CULVERT EXTENSIONS (STRUCTURE SITE NOS. 30-399/C AND 30-568/C), RECONSTRUCTION OF
HIGHWAY 400/89 INTERCHANGE
TOWN OF INNISFIL, SIMCOE COUNTY
MINISTRY OF TRANSPORTATION, ONTARIO
G.W.P. 2438-13-00**

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REPORT





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PART A

**FOUNDATION INVESTIGATION REPORT
CULVERT EXTENSIONS (STRUCTURE SITE Nos. 30-399/C AND 30-568/C)
FOR RECONSTRUCTION OF HIGHWAY 400/89 INTERCHANGE
TOWN OF INNISFIL, SIMCOE COUNTY
MINISTRY OF TRANSPORTATION, ONTARIO
G.W.P. 2438-13-00**



1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Morrison Hershfield Limited (MH) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the following culvert locations associated with the Highway 400/89 interchange, in the Town of Innisfil, Simcoe County, Ontario:

- Extension of Culvert C-14 located at approximately Station 10+280 relative to the Highway 400 mainline, and Station 10+280 on the Highway 400 / 89 N-E/W Ramp (MTO Structure Site No. 30-568/C);
- New headwall and wingwalls at Culvert C-43 located at approximately Station 10+280 on the east side of Highway 400 northbound lanes; and
- Extension of twin Culverts C-44A and C-44B (MTO Structure Site No. 30-399/C), located at approximately Station 10+760 on the west side of the Highway 400 southbound lanes.

The purpose of this investigation is to establish the subsurface soil and groundwater conditions at the proposed extensions of culverts or headwall/wingwall locations, by borehole drilling and geotechnical/analytical laboratory testing on selected soil samples.

The Terms of Reference (TOR) and the scope of work for the foundation investigation are outlined in MTO's Request for Proposal dated November 2, 2016, and Golder's letter dated January 8, 2018, which form part of the Consultant's Assignment (Agreement No. 2015-E-0038) for this project. The work has been carried out with Golder's Supplementary Specialty Plan for foundation engineering services for this project, dated April 25, 2017.

2.0 SITE DESCRIPTION

The Highway 400/89 interchange is located about 20 km south of the City of Barrie in the Town of Innisfil, Ontario, as shown on the Key Plan on Drawing 1. Highway 400 consists of three lanes of traffic in each of the northbound and southbound directions. Highway 89 is oriented east-west and consists of one lane of traffic in each direction, with speed changes lanes associated with the Highway 400 on-ramps. The culverts are located as follows:

- Culverts C-14 and C-43 are located at approximately Station 10+280, about 280 m north of Highway 89. Culvert C-43 extends under the Highway 400 mainline at this location, Culvert C-14 is located in line with Culvert C-43 near the north end of the N-E/W Ramp.
- Culverts C-44A and C-44B are located under the Highway 400 mainline at approximately Station 10+760, about 760 m north of Highway 89. These twin culverts convey Innisfil Creek, which flows in a westerly direction.

The northwest quadrant of the Highway 400/89 interchange is occupied by agricultural lands, and a decommissioned highway service centre. All infrastructure, excluding lamp standards, has been removed from the footprint of this closed service centre. A small pond and wetland area are present on the west side of the highway in this quadrant, at the outlet of the twin culverts C-44A and C-44B. The northeast quadrant of the interchange consists of an open field containing a small area vegetated with trees, and an industrial facility and yard.



The existing natural ground surface in the vicinity of Culverts C-14 and C-43 is at about Elevation 226 m; the existing N-E/W Ramp is about 2 m to 3 m above the surrounding grade, and the Highway 400 grade is about 4 m above the surrounding natural ground surface. The invert of Culverts C-44A and C-44B is at about Elevation 224.3 m and the grade of the Highway southbound lanes is at about Elevation 228.7 m.

3.0 INVESTIGATION PROCEDURES

3.1 2000 Investigation

A preliminary foundation investigation for the Highway 400/89 culverts was carried out by Golder in 2000. Two of the boreholes advanced for that project, designated as Boreholes C-1 and C-2, were advanced on the west and east sides of the Highway 400 lanes diagonally across the twin culverts near approximately Station 10+760. The boreholes were advanced to depths of 9.6 m and 9.8 m, respectively, below ground surface and geotechnical laboratory testing was carried out on selected soil samples. The results of this investigation are contained in a report titled "Preliminary Foundation Investigation and Design Report, Culverts, Structure Sites 30-399, 571, 572, 573 & 415, Highway 400 Widening from 1 Km South of Highway 89 to Highway 11, G.W.P. 30-95-00, Agreement No. 3005-A-000074", dated December 2001 (GEOCREs No. 31D00-482).

The locations of the boreholes advanced during the 2000 investigation are shown on Drawing 2, and the borehole records, including a summary of the laboratory testing results from this investigation, are presented in Appendix A. The northing and easting coordinates relative to the MTM NAD 83 (Zone 10) coordinate system and geographic coordinates, the ground surface elevations referenced to Geodetic datum, and the drilled depths are summarized below.

Borehole No.	Location (MTM NAD 83 Zone 10)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing (m) (Latitude, °)	Easting (m) (Longitude, °)		
C-1	4,896,326.9 (44.206842)	292,177.2 (-79.657948)	226.5	9.6
C-2	4,896,322.8 (44.206804)	292,130.0 (-79.658539)	227.2	9.8

3.2 2017/2018 Investigation

Field work for the current investigation was carried out on July 26 and August 10, 2017 and between February 13 and 28, 2018, during which time a total of eight boreholes, designated as Boreholes CE-01 to CE-08, were advanced near the proposed culvert extensions and headwall/wingwall locations, as follows and as shown on Drawings 1 and 2:

- Boreholes CE-01 and CE-02 were advanced near the footprint of the Culvert C-14 extension and through the existing N-E/W Ramp, respectively.
- Boreholes CE-03 and CE-04 were advanced near the footprint of the proposed Culvert C-43 headwall/wingwalls through the existing Highway 400 northbound shoulder and toe of the road embankment slope, respectively.



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- Boreholes CE-05 and CE-06 were advanced north and south of the proposed Culvert C-43A and C-43B extensions near the west toe of the Highway 400 southbound lanes embankment slope.
- Boreholes CE-07 and CE-08 were advanced through the shoulder of Highway 400 SBL, north and south of the proposed Culvert C-44A and C-44B extensions.

The field work was completed using a D-90 truck-mounted drill rig, as well as D-25 and D-50 track-mounted drill rigs supplied and operated by Walker Drilling Ltd. of Utopia, Ontario. The boreholes were drilled using 127 mm, 153 mm, and 203 mm outside diameter hollow stem augers. Soil samples were obtained at 0.75 m and 1.5 m intervals of depth, using 50 mm outside diameter split-spoon samplers driven by an automatic hammer, in accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586-08a). Boreholes CE-01 to CE-08 were advanced to depths ranging between 8.2 m and 17.4 m below the existing ground surface.

Groundwater conditions and water levels in the open boreholes were observed during and immediately following the drilling operations. A standpipe piezometer was installed in each of Boreholes CE-02 and CE-05 to permit monitoring of the groundwater level at these borehole locations. The standpipe piezometers consist of a 50 mm diameter PVC pipe, with a 3 m long slotted screen sealed at a depth within the borehole. The borehole annulus surrounding the piezometer screen was backfilled with sand and the remainder of the borehole was then backfilled with bentonite to near the ground surface. In Borehole CE-02, the upper 0.2 m length of the borehole was backfilled with concrete as it was advanced through the existing ramp. All other boreholes were backfilled with bentonite upon completion in accordance with Ontario Regulation 903 (as amended by Ontario Regulation 372).

The field work was observed by a member of Golder's engineering and technical staff, who located the boreholes, arranged for the clearance of underground services, observed the drilling, sampling and in situ testing operations, logged the boreholes, and examined the soil samples. The samples were identified in the field, placed in appropriate containers, labelled and transported to Golder's Mississauga geotechnical laboratory where the samples underwent further visual examination. Classification testing (water content, Atterberg limits, and grain size distribution) was carried out on selected soil samples, in accordance with MTO and/or ASTM Standards, as applicable.

Four selected soil samples were submitted, under chain-of-custody procedures, to Maxxam of Mississauga, Ontario (a Standards Council of Canada (SCC) accredited laboratory) for corrosivity testing. The soil samples were analyzed for a suite of parameters, including conductivity, resistivity, soluble chloride concentration, soluble sulphate concentration and pH.

The borehole locations and ground surface elevations were obtained using a GPS (Trimble XH 3.5G), having an accuracy of 0.1 m in the vertical and horizontal directions. The locations given on the borehole records and shown on Drawings 1 and 2 are positioned relative to MTM NAD 83 (Zone 10) coordinate system and the ground surface elevations are referenced to Geodetic datum. The borehole locations in MTM and geographic coordinates, ground surface elevations and drilled depths are summarized below.



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Borehole No.	Location (MTM NAD 83)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing (m) (Latitude, °)	Easting (m) (Longitude, °)		
CE-01	4,895,833.4 (44.202403)	292,221.1 (-79.657385)	227.0	11.3
CE-02	4,895,835.0 (44.202407)	292,256.3 (-79.656943)	228.5	15.9
CE-03	4,895,866.6 (44.202700)	292,347.4 (-79.655800)	229.3	15.9
CE-04	4,895,873.3 (44.202762)	292,362.1 (-79.655624)	226.0	12.8
CE-05	4,896,321.5 (44.206792)	292,123.5 (-79.658620)	227.2	15.9
CE-06	4,896,292.8 (44.206534)	292,139.6 (-79.658418)	226.9	15.9
CE-07	4,896,325.8 (44.206820)	292,137.7 (-79.658400)	228.8	8.2
CE-08	4,896,299.6 (44.206600)	292,146.4 (-79.658300)	228.7	17.4

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

The project area of the culvert sites is located within the Peterborough Drumlin Field physiographic region, as delineated in *The Physiography of Southern Ontario* (Chapman and Putman, 1894)¹. The surficial soils in the Peterborough Drumlin Field consist primarily of gravelly sand till or sand and gravel deposits. Drumlins (glacially-shaped hills) are more frequent in the southern portion of the section of the Peterborough Drumlin Field traversed by Highway 400. Deposits of silt, clay or peat may be found in the low-lying areas between drumlins. The Lindsay and Verulam Formations which underlies the Peterborough Drumlin Field consists mainly of fossiliferous limestone.

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions as encountered in the boreholes advanced during the current investigation are presented on the borehole records provided in Appendix B. The borehole records also present details of the standpipe piezometer installations and water level readings, and the results of geotechnical laboratory testing. Lists of abbreviations and symbols are provided in Appendix B to assist in the interpretation of the borehole records. The results of the in situ field tests (i.e. SPT "N"-values) as presented on the borehole records and in the sub-sections of Section 4.2 are uncorrected. The geotechnical laboratory testing plots are

¹ Chapman, L.J. and Putman, D.F., 1894, *The Physiography of Southern Ontario*, Ontario Geological Society, Special Volume 2, Third Edition. Accompanied by Map p. 2715, Scale 1:600,000.)



contained in Appendix C. The results of the analytical testing of soil samples by Maxxam are presented in Appendix D and summarized in Section 4.3.

The stratigraphic boundaries shown on the borehole records and on the stratigraphic profiles on Drawings 1 and 2 are inferred from non-continuous sampling, observations of drilling progress and the results of Standard Penetration Tests. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Furthermore, subsurface conditions will vary between and beyond the borehole locations; however, the factual data presented in the borehole records governs any interpretation of the site conditions. It should be noted that the interpreted stratigraphy shown on Drawings 1 and 2 is a simplification of the subsurface conditions.

In general, subsurface conditions near the west end of Culvert C-14 and near the wingwall/headwalls of Culvert C-43 consist of a layer of topsoil or asphalt pavement underlain by granular fill. The fill is underlain by an upper layered granular deposit comprised of silt, sandy silt, silt and sand and sand.

Near Culverts C-44A and C-44B, extensions the general subsurface conditions consist of a layer of topsoil or asphalt pavement underlain by fill consisting of silt to silt and sand to sand to sand and gravel, and clayey silt. The fill is underlain by a deposit of clayey silt, in places interlayered with silt, silt and sand, silty sand and sand. A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Culvert C-14 and Culvert C-43 Headwall/Wingwalls, Station 10+280

4.2.1.1 Topsoil

An approximately 180 mm and 700 mm thick layer of topsoil was encountered immediately below the ground surface in Boreholes CE-04 and CE-01, respectively. An SPT "N"-value of 3 blows per 0.3 m of penetration was measured in this layer in Borehole CE-01, indicating a very loose compactness condition.

4.2.1.2 Pavement Structure

Boreholes CE-02 and CE-03 advanced in the shoulders of the existing N-E/W Ramp and the shoulder of the Highway 400 SBL penetrated the pavement structure which is comprised of asphalt 100 mm and 220 mm thick, respectively. The asphalt is underlain by a layer of granular road base material consisting of gravelly sand to sand, approximately 600 mm and 500 mm thick in the respective boreholes.

An SPT "N"-value measured within the granular road base layer of 40 blows per 0.3 m of penetration, indicating a dense compactness condition.

The result of a grain size distribution test completed on one sample of the sand fill is shown on Figure C-1 in Appendix C. The water content measured on one sample of the granular road base sand fill is about 8 per cent.

4.2.1.3 Fill

Underlying the topsoil in Boreholes CE-01 and CE-04, and the underlying granular road base in Boreholes CE-02 and CE-03, fill consisting of silt, silt and sand, and silty sand was encountered. The surface of the fill deposit was encountered between Elevations 228.6 m and 225.8 m and the thickness of the fill layer ranges from about 0.5 m to 3.0 m; and the fill extends to depths of between 0.7 m and 3.7 m (between Elevation 2225.6 m to 225.2 m) below ground surface.



The SPT “N”-values measured within the granular fill range from 3 blows to 20 blows per 0.3 m of penetration, indicating the fill has a very loose to compact compactness condition.

The results of grain size distribution tests completed on three samples of the silt and sand fill are shown on Figure C-2 in Appendix C. An Atterberg limits test on a sample of the silt and sand fill indicates that the fill material is non-plastic. The water content measured on six samples of the silt and sand fill ranges from 11 per cent to 24 per cent.

4.2.1.4 *Silt to Sand*

The fill in Boreholes CE-01, CE-02, CE-03, and CE-04 is underlain by a granular deposit that is comprised of various layers ranging in composition from silt to sandy silt to silt and sand to sand. The surface of the granular deposit was encountered at depths between 0.7 m and 3.7 m (Elevation 225.6 m and 225.2 m) below ground surface and the thickness of the deposit ranges from 9.5 m to 13.0 m. Boreholes CE-01 to CE-04 were terminated in the granular deposit at depths between 11.3 m (Elevation 215.7 m) and 15.9 m (Elevation 212.7 m) below ground surface.

The SPT “N”-values measured within the granular deposit range from 4 blows to 46 blows per 0.3 m of penetration, indicating that the granular deposit has a loose to dense compactness condition.

The results of grain size distribution tests completed on ten samples of the granular deposit from Boreholes CE-01 to CE-04 are shown on Figures C-3, C-4 and C-5 in Appendix C. Atterberg limits tests were carried out on five samples of the silt, sandy silt and silt and sand layers of the deposit and indicate that the materials are non-plastic. The natural water content measured on twenty-two samples of the non-cohesive deposit ranges from 6 per cent to 25 per cent.

4.2.2 *Culverts C-44A and C-44B, Station 10+760*

4.2.2.1 *Topsoil*

An approximately 0.7 m thick layer of topsoil was encountered from ground surface at Elevations 227.6 m and 226.9 m in Boreholes CE-05 and CE-06, respectively.

The SPT “N”-values measured within the topsoil layer are 12 blows and 18 blows per 0.3 m of penetration, indicating a compact condition.

4.2.2.2 *Pavement Structure*

Boreholes CE-07 and CE-08 penetrated a 223 mm and 216 mm thick layer of asphaltic concrete and a 1.3 m thick layer of granular road base material comprised of sand and sand and gravel, in the respective boreholes.

The SPT “N”-values measured within the granular road base layer range from 22 blows to 35 blows per 0.3 m of penetration, indicating a compact condition.

The results of grain size distribution tests on two samples of the granular road base layer (sand and sand and gravel) are shown on Figure C-6 in Appendix C. The water content measured on three samples of the granular road base materials ranges from about 3 per cent to 11 per cent.



4.2.2.3 *Fill*

Underlying the topsoil in Boreholes CE-05 and CE-06 and underlying the granular road base material in Boreholes CE-07 and CE-08, the boreholes penetrated at 0.7 m to 1.5 m thick layer of silt to silt and sand fill or a 1.5 m thick layer of clayey silt fill (in Borehole CE-06 only), between about Elevations 227.4 m and 226.2 m; and the fill layer extends to depths of between 2.2 m and 3.0 m (Elevations 226.5 and 224.7 m) below ground surface.

The SPT “N”- values measured within the granular fill range from 13 blows to 20 blows per 0.3 m of penetration, indicating a compact condition. The SPT “N”-values measured within the clayey silt fill are 9 blows and 18 blows per 0.3 m of penetration, suggesting a stiff to very stiff consistency.

The results of grain size distribution tests completed on three samples of the silt to silt and sand fill are shown on Figure C-7 in Appendix C. Atterberg limits tests were carried out on two samples of the silt and sand fill and measured liquid limits of 14 per cent, plastic limits of 11 per cent and 12 per cent, and plasticity indices of 2 per cent and 3 per cent, indicating that the silt and sand fill has slight plasticity as presented on the plasticity chart on Figure C-8 in Appendix C; one Atterberg limits test on a sample of the silt fill indicates that the material is non-plastic. The water content measured on four samples of the silt to silt and sand fill ranges from about 9 per cent to 14 per cent.

4.2.2.4 *Clayey Silt*

The fill in Boreholes CE-05 to CE-08 is underlain by a cohesive deposit of clayey silt. In Boreholes CE-06, CE-07 and CE-08, granular interlayers that vary in composition from silt to silt and sand to sand and having a thickness between 0.6 m and 4.6 m, were encountered within the clayey silt deposit. The surface of the clayey silt deposit was encountered at depths between 2.2 m and 3.0 m (Elevations between 226.5 m and 224.7 m) below ground surface. Boreholes CE-05, CE-06, and CE-08 terminated in the clayey silt deposit at depths between 15.9 m and 17.4 m (between Elevations 211.4 m and 211.1 m); and Borehole CE-07 was terminated in a sand interlayer at a depth of 8.2 m (Elevation 220.6 m) below ground surface, having penetrated it for about 1 m.

The SPT “N”-values measured within the clayey silt deposit ranges from 4 blows to 83 blows per 0.3 m of penetration, suggesting that the clayey silt deposit has a firm to hard consistency. The SPT “N”-values measured within silt to silt and sand to sand interlayers range from 4 blows to 33 blows per 0.3 m of penetration, indicating a loose to dense compactness condition.

The results of grain size distribution tests completed on six samples of the clayey silt deposit are shown on Figure C-9 in Appendix C. The results of grain size distribution tests carried out on two samples of the silt and of the silt and sand interlayers are shown on Figure C-10 in Appendix C. Atterberg limits tests were carried out on six samples of the clayey silt and measured liquid limits between 23 per cent and 32 per cent, plastic limits between 14 per cent and 17 per cent, and plasticity indices between 7 per cent and 15 per cent, indicating that the clayey silt has low plasticity as presented on the plasticity chart on Figure C-11 in Appendix C. An Atterberg limits test carried out on a sample of the silt interlayers measure a liquid limit of about 18 per cent, a plastic limit of about 14 per cent and a plasticity index of about 4 per cent, as shown on the plasticity chart on Figure C-12 in Appendix C, indicating that the sample is silt of slight plasticity; and one test indicates that the silt and sand interlayers is non-plastic.



The natural water content measured on fourteen samples of the clayey silt deposit ranges from 12 per cent to 23 per cent. The water content measured on five samples of the silt to silt and sand to sand interlayers ranges from 18 per cent to 22 per cent.

4.2.3 Groundwater Conditions

The groundwater levels in the open boreholes were monitored during and upon completion of drilling operations. Standpipe piezometers were installed in Boreholes CE-02 and CE-05 to permit monitoring of the groundwater level at the sites. Details of the piezometer installation and measured groundwater levels are shown on the borehole records in Appendix B. The groundwater levels recorded in the open boreholes and the standpipe piezometer are summarized below:

Borehole No.	Depth to Water Level (m)	Groundwater Elevation (m)	Date	Comments
CE-01	2.0	225.0	August 10, 2017	Open borehole
CE-02	2.9	225.6	July 26, 2017	Open borehole
	2.7	225.8	August 15, 2017	Standpipe piezometer
	3.0	225.5	September 19, 2017	
	2.3	226.2	March 5, 2018	
CE-03	4.0	225.3	February 14, 2018	Open borehole
CE-04	0.2	225.8	February 28, 2018	Drilling mud used; water level not representative
CE-05	1.4	225.8	February 27, 2018	Open borehole
	2.5	224.7	March 5, 2018	Standpipe piezometer
CE-06	4.6	222.3	February 26, 2018	Open borehole
CE-07	5.0	223.8	February 13, 2018	Open borehole
CE-08	4.8	223.9	February 13, 2018	Open borehole

It should be noted that the groundwater level in the area is subject to seasonal fluctuations and precipitation events, and should be expected to be higher during wet periods of the year.

4.3 Analytical Testing of Soil Samples

Analytical testing was carried out on a composite soil sample from Borehole CE-02, and individual samples from Boreholes CE-04, CE-5, and CE-06 to assess the potential corrosivity of the site soils to steel and concrete. Detailed analytical test results are included in Appendix D and the results of the testing are summarized below.



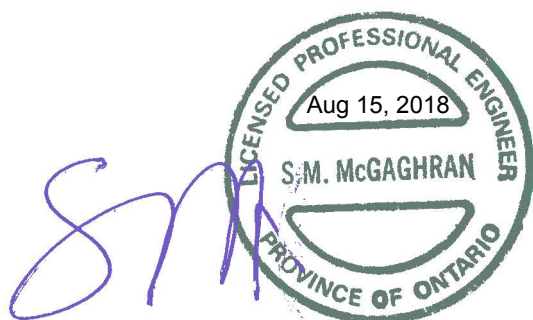
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Borehole No. / Sample ID	Depth (m)	Parameter				
		Resistivity (ohm-cm)	Electrical Conductivity (µmho-cm)	Soluble Sulphate (µg-g)	Chlorides (µg-g)	pH (pH)
CE-02/SS2, SS3 and SS4 Composite	0.7 to 2.9	330	3,010	<20	1,600	8.01
CE-05/SS6	3.8 to 4.4	2300	428	<20	200	7.87
CE-06/SS9	7.6 to 8.2	3700	271	86	<20	7.76
CE-04/SS5	3.0 to 3.7	2000	501	<20	220	7.82

5.0 CLOSURE

This Foundation Investigation Report was prepared by Ms. Sandra McGaghran, M.Eng., P.Eng., a geotechnical engineer and Associate with Golder. Mr. Jorge Costa, P.Eng, an MTO Designated Foundations Contact and Senior Consultant with Golder conducted a technical review of this report, and Ms. Lisa Coyne, P.Eng., a Principal and MTO Designated Foundations Contact for Golder, conducted an independent quality control review of the report.

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PART B

**FOUNDATION DESIGN REPORT
CULVERT EXTENSIONS (STRUCTURE SITE No. 30-399/C AND 30-568/C)
FOR RECONSTRUCTION OF HIGHWAY 400/89 INTERCHANGE
TOWN OF INNISFIL, SIMCOE COUNTY
MINISTRY OF TRANSPORTATION, ONTARIO
G.W.P. 2438-13-00**



6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides detailed foundation design recommendations for the following proposed culvert works:

- Extension of Culvert C-14 located at approximately Station 10+280 relative to the Highway 400 mainline, and Station 10+280 on the Highway 400 / 89 N –E/W Ramp (MTO Structure Site No. 30-568/C);
- New headwall and wingwalls at Culvert C-43 located at approximately Station 10+280 on the east side of the Highway 400 northbound lanes; and
- Extension of twin Culverts C-44A and C-44B (MTO Structure Site No. 30-399/C), located at approximately Station 10+760 on the west side of the Highway 400 southbound lanes.

The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the previous and current field investigations. The discussion and recommendations presented are intended to provide the designers with sufficient information to assess the feasible culvert foundation alternatives and carry out the design of the foundations aspects for the culvert extensions.

The discussion and recommendations in this Foundation Design Report are intended for the use of the MTO and their designers for G.W.P 2438-13-00, and shall not be used or relied upon for any other purpose or by any other parties, including the construction contractor. The contractor must make their own interpretation based on the factual data in Part A (Foundation Investigation) of the report. Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project and for which special provisions may be required in the Contract Documents. Those requiring information on the aspects of construction must make their own interpretation of the factual information provided, as such interpretation may affect equipment selection, proposed construction methods, scheduling, and the like.

6.1 General

Invert elevations for the existing culverts and their proposed extensions were provided by MH on May 9, 2018, and subsequently confirmed on June 15 and July 4, 2018; the following summarizes the details regarding the structural culverts.

Culvert Location	Interior Structure Dimensions (m)	Approx. Maximum Embankment Height (m) ¹	Channel Invert Elevation (m) (Culvert Base Elevation (m))	
			U/S	D/S
Culvert C-14 Extension Station 10+280 N-E/W Ramp	Existing: 4.3 x 1.3 Proposed: 5.0 x 3.2	3.5	225.6	225.5
Culvert C-43 Station 10+280 East side of Highway 400 NBL	U/S 4.6 X 2.7 m D/S 4.3 X 1.2 m	3.5	226.1	225.8
Culvert C-44A/B Extension Station 10+760 West side of Highway 400 SBL	4.9 x 2.7 m (52 and 53 m)	2 m (twin culverts) to 4.2 m (C-44C to north)	224.5	224.3

NOTES:

1. Maximum embankment height above top of culvert and average surrounding natural ground surface.



It is understood that the culvert at Station 10+380 on the N-E/W ramp will either be extended or replaced, and the culvert at Station 10+280 will require a headwall and wingwall east of the Highway 400 northbound lanes. The twin corrugated steel pipe arch (CSPA) culverts at Station 10+760 will be extended on the west side of the Highway 400 southbound lanes, with addition of a headwall/retaining wall at the new culvert outlet. In addition, temporary protection systems will be required at Station 10+760 to maintain traffic on the Highway 400 southbound lanes.

6.2 Consequence and Site Understanding Classification

In accordance with Section 6.5 of the 2014 *Canadian Highway Bridge Design Code* (CHBDC, 2014) and its *Commentary*, the culverts/walls and their foundation systems are expected to carry medium to high traffic volumes, and their performance will have potential impacts on other transportation corridors; hence, the structures are classified as having a “typical consequence level” associated with exceeding limits states design. Given the project-specific foundation investigation carried out at this site (as presented in Part A of the report) in comparison to the degree of site understanding in Section 6.5 of *CHBDC* (2014), the level of confidence for design is considered to be a “typical degree of site and prediction model understanding.” Accordingly, the appropriate corresponding ultimate limit state (ULS) and serviceability limit state (SLS) consequence factor, Ψ , and geotechnical resistance factors, ϕ_{gu} and ϕ_{gs} , from Tables 6.1 and 6.2 of the *CHBDC* have been used for design.

6.3 Foundations Options for New Culverts and Culvert Extensions

Box culverts, “open footing” (shallow foundation) concrete culverts and corrugated steel pipe arch (CSPA) culverts are feasible for replacement (if and where required) or extension of the existing culverts, from a geotechnical/foundations perspective. Associated retaining walls, if required, should be supported on shallow foundations. Deep foundations are not required as shallow foundations will provide sufficient bearing resistance and acceptable settlement performance. Both pre-cast (box culvert segments or footing elements) and cast-in-place (CIP) concrete elements are also feasible from a foundations perspective.

The advantages and disadvantages associated with various extension options are summarized in Table 1 following the text of this report. From a foundations perspective, a pre-cast box culvert extension is preferred over a cast-in-place open footing culvert extension for the following reasons:

- Pre-cast box culvert extensions minimize the depth of excavation and groundwater control requirements as compared with open footings;
- Pre-cast box culvert segments can usually be installed more expeditiously than cast-in-place open footing culverts, resulting in shorter durations for dewatering and surface water pumping; and
- Pre-cast box culvert segments are more tolerant of total and differential settlement, although this is not a significant concern based on the subsurface conditions at these culvert sites.

It is noted that where new or extended box culverts may not satisfy fisheries requirements related to channel substrate, open footing culverts are geotechnically feasible.

6.3.1 Founding Elevations and Sub-excavation Requirements

6.3.1.1 Box Culvert – Replacements or Extensions

It is not necessary to found box culvert replacements and extensions at the standard depth for frost protection purposes, as the box structures are tolerant of small magnitudes of movement related to freeze-thaw cycles,



should these occur. Box culverts should, however, be founded below any existing fill and surficial organic materials. Table 2, following the text of the report, provides recommended founding elevations and sub-excavation requirements for replacement box culverts or extensions, based on an assumed base slab thickness of 250 mm. In addition, it is recommended that the box culvert segments be placed on a minimum thickness of 150 mm (or more depending on the requirements for excavation backfill and bedding as noted in Table 2) of granular bedding material meeting Ontario Provincial Standard Specification (OPSS.PROV) 1010 (*Aggregates*) Granular A.

Where sub-excavation is recommended below replacement or extension box culverts (as per Table 2), the width of the required sub-excavation area should be defined by lines extending from 0.3 m beyond the outside edges of the proposed culvert base slab, outward and downward at 1H:1V. Depending on the depth of sub-excavation required relative to the existing culvert base or footings, temporary excavation support may be required to prevent loss of bedding material and/or native soils from below the existing culvert during sub-excavation. In wet conditions, the excavation backfill/bedding should be comprised of OPSS.PROV 1010 Granular B Type II material.

The box culvert subgrade should be inspected by a Foundation Engineer following sub-excavation to ensure that all existing fill, peat and surficial organic soils or other unsuitable material have been removed in accordance with OPSS 422 (*Box Culverts and Box Sewers in Open Cut*) and OPSS 902 (*Excavating and Backfilling Structures*). Following inspection, the sub-excavated area should be backfilled with granular material meeting OPSS.PROV 1010 Granular A or Granular B Type II as noted above that is placed and compacted in accordance with OPSS 501 (*Compacting*).

Groundwater and/or surface water control will be required for excavation and construction of box culverts at the culvert sites. Dewatering should be carried out in accordance with OPSS.PROV 517 (*Dewatering*) and SP517F01 (*Dewatering System*); it is recommended that the requirement for a dewatering design engineer be specified and that an inspection radius of 50 m be used in Table A contained in SP517F01. The SP517F01 is provided in Appendix E.

The subgrade for the box culvert replacements and extensions will be susceptible to loosening/softening and degradation on exposure to water and construction traffic. As discussed further in Section 6.3.5, as an alternative to the placement of granular bedding material on the native soil below the base slab, a 100 mm thick, 20 MPa concrete working slab could be placed on the subgrade to protect it from degradation followed by the required backfill bedding to the underside of the levelling course. In any case, a 75 mm thick layer of uncompacted OPSS.PROV 1010 (*Aggregates*) Granular A or concrete fine aggregate meeting the gradation requirements set out in OPSS.PROV 1002 (*Aggregates - Concrete*) should be placed on top of the bedding/backfill or concrete working slab, as applicable, to provide a "levelling pad" for the box culvert replacement or extension. An NSSP for the concrete working slab is included in Appendix E.

6.3.1.2 Open Footing Culvert Replacements and Extensions

Strip footings for open footing culvert replacements and extensions, and for any associated concrete wingwalls/retaining walls, should be founded at a minimum depth of 1.6 m below the lowest surrounding grade to provide adequate protection against frost penetration, as per Ontario Provincial Standard Drawing (OPSD) 3090.101 (Foundation, Frost Penetration Depths for Southern Ontario). In addition, the footings should extend below any existing fill and surficial organic materials, where present. Table 3, following the text of the report, provides recommended founding elevations and sub-excavation requirements for strip footings for the proposed culvert replacements/extensions and wingwalls.



For sites where open footing culverts are to be constructed on granular backfill, rather than on the native subgrade at greater depth in subexcavation areas, the width of the sub-excavation should be defined by lines extending from 0.3 m beyond the outside edges of the proposed culvert footing, outward and downward at 1H:1V. Depending on the depth of sub-excavation required relative to the existing culvert base or footings, temporary excavation support may be required to prevent loss of bedding material and/or native soils from below the existing culverts during sub-excavation.

The footing subgrade should be inspected following excavation, in accordance with OPSS 902 (*Excavating and Backfilling Structures*), to check that all existing fill and surficial organic soils or other unsuitable material have been removed. Where sub-excavation is required to remove unsuitable materials, the sub-excavated area should be backfilled with granular material meeting OPSS.PROV 1010 (*Aggregates*) Granular A or Granular B Type II that is placed and compacted in accordance with OPSS.PROV 501 (*Compacting*).

Groundwater and/or surface water control will be required for excavation and construction of open footing culverts for the majority of the culvert sites. As discussed further in Section 6.7, it is recommended that an NSSP be included in the Contract Documents to address groundwater control requirements for the culvert sites.

The footing subgrade will be susceptible to loosening and degradation on exposure to water and construction traffic. As discussed further in Section 6.7.6, it is recommended that a 100 mm thick, 20 MPa concrete working slab be placed on the inspected and approved footing subgrade, to protect the subgrade from degradation and to form a working surface for construction of the culverts. An example NSSP for the working slab is included in Appendix E.

6.3.2 Geotechnical Resistance

Tables 2 and 3, following the text of this report, provide factored ultimate and serviceability geotechnical resistance values for the box culvert option and open footing option at each culvert site, respectively.

6.3.2.1 Box Culverts – Replacements or Extensions

Replacement box culverts or extensions placed on the properly prepared subgrade, at or below the founding elevations recommended in Table 2, should be designed based on the recommended factored ultimate geotechnical resistances and the factored serviceability geotechnical resistances (for 20 mm of settlement) as given in Table 2. These recommendations are based on the box culvert span as given in Table 2.

The ultimate geotechnical resistances and settlement are dependent on the footing size, configuration and applied loads; the geotechnical resistances should, therefore, be reviewed if the culvert span or founding elevation differs significantly from that given in Table 2.

The geotechnical resistances provided in Table 2 are based on loading applied perpendicular to the surface of the footings or culvert base slab. Where the load is not applied perpendicular to the surface of the footing/base slab, inclination of the load should be taken into account in accordance with Section 6.10.2 of the CHBDC (2014).



6.3.2.2 Open Footing Culvert Replacements or Extensions and Associated Wingwalls and Retaining Walls

Strip footings placed on the properly prepared subgrade, at or below the founding elevations recommended in Table 3, should be designed based on the factored ultimate geotechnical resistance values and the factored serviceability geotechnical resistance values (for 20 mm of settlement) as given in Table 3. These recommendations are based on an assumed footing width of 0.6 m.

The geotechnical resistances and settlement are dependent on the footing size, configuration and applied loads; the geotechnical resistances should, therefore, be reviewed if the selected footing width or founding elevation differs from those given in Table 3.

The geotechnical resistances provided in Table 3 are given under the assumption that the loads will be applied perpendicular to the surface of the footings. Where the load is not applied perpendicular to the surface of the footing, inclination of the load should be taken into account in accordance with Section 6.10.2 of the CHBDC (2014).

6.3.3 Resistance to Lateral Loads / Sliding Resistance

Resistance to lateral forces/sliding resistance between the base slab or concrete footings for the culvert replacements or extensions and the subgrade should be calculated in accordance with Section 6.10.5 of the CHBDC. Table 4, following the text of this report, provides recommended coefficients of friction for pre-cast concrete box culvert sections or pre-cast footing elements and cast-in-place concrete footings relative to granular bedding, concrete working slabs and/or native subgrade soils.

6.3.4 Settlement

The existing Highway 400 and ramp embankments will be widened by up to 15 m at the culvert locations, which would require placement of a vertical thickness of between about 2.5 m up and 4.2 m of additional fill atop the existing embankment side slopes. This embankment widening will induce some settlement in the foundation soils beneath the culverts in the widening areas.

The settlement analyses for culvert sites were carried out using the commercially-available program Settle-3D from Rocscience, using estimated elastic deformation moduli as given below, based on correlations with the SPT 'N'-values, published literature (Bowles, 1982) and engineering judgement from experience with similar soils in this region of Ontario.

Soil Deposit	Bulk Unit Weight	Elastic Modulus
Embankment fill (existing and new)	21 kN/m ³	N/A
Loose to compact silt to sand	19 kN/m ³	20 MPa
Compact to dense silt to sand	20 kN/m ³	35 MPa
Stiff to hard clayey silt	20 kN/m ³	50 to 75 MPa

At Culvert C-14 where the height of fill placement will be the highest, the settlement of the foundation soils under the additional fill that is expected to be placed on the embankment side slope to facilitate construction staging is estimated to be up to approximately 40 mm under the actual widening area. At Culvert C-43, the estimated



settlement is estimated to be less than 15 mm under the actual widening area, considering a height of fill placement of up to 2.5 m at this location. The majority of the settlement at Culverts C-14 and C-43 is expected to occur during or shortly after construction in response to filling, based on the non-cohesive nature of the silt to sand soils at these culvert sites. Although post-construction settlement should be minimal for these culverts, where a total settlement of slightly more than 25 mm is estimated at Culvert C-14, it is recommended that the culvert design incorporate an appropriate camber to accommodate the estimated total and differential settlement. A camber would only be applicable to pre-cast concrete box culverts; cast-in-place open footing culverts would have to be structurally designed to accommodate or tolerate this settlement.

At Culverts C-44A and C-44B, the placement of a wedge of fill with a maximum thickness of about 2 m to 4 m over the westward extensions is expected to result in approximately 20 mm of settlement at the new west end of the culverts in the footprint of the retaining wall, tapering to less than 5 mm of settlement at the existing culvert ends. Although the soils underlying this culvert site are predominantly cohesive, they are also generally stiff to hard, and the majority of settlement at this site is also expected to occur during and relatively quickly following completion of construction. Based on the estimated settlement magnitude, no settlement mitigation measures are required for the culvert extension and retaining wall construction at the Culvert C-44A and C-44B site.

6.3.5 Culvert Bedding, Backfill and Erosion Protection

For the replacement culverts or extensions, the levelling pad, bedding and backfill requirements should be in accordance with OPSS 422 (*Box Culverts and Box Sewers in Open Cut*) for concrete box culverts, and OPSS 421 (*Pipe Culvert Installation in Open Cut*). Box or pipe culvert replacements and extensions should be provided with at least 150 mm of OPSS 1010 Granular A material for bedding purposes, or alternatively a 100 mm thick concrete working slab, and 75 mm thick levelling course. The distance between CSPA culverts (C-44A/C-44B – Structure Site No. 399/C) and the adjacent CSP culvert (C-44C) is about 1 m to 2 m, and consideration can also be given to the placement of unshrinkable fill for backfilling between and beneath the CSPA culverts, as well as to the north adjacent to CSP culvert C-44C. The unshrinkable fill should meet the material requirements of OPSS 1359 (*Unshrinkable Fill*), and its placement should be in accordance with OPSS.PROV 578 (*Placement of Unshrinkable Fill*).

Backfill and cover for the culverts should be completed in accordance with OPSD 803.010 (*Backfill and Cover for Concrete Culverts*) or OPSD 802.020 (*Flexible Pipe Arch Embedment and Backfill – Earth Excavation*). Backfill to culvert walls should consist of granular fill meeting the requirements of OPSS.PROV 1010 Granular A or Granular B Type II. The backfill and bedding should be placed and compacted in accordance with OPSS 501 (*Compacting*). The fill depth during placement should be maintained equal on both sides of the culvert walls, with one side not exceeding the other by more than 400 mm. The culvert replacements or extensions should be designed for the full overburden and hydrostatic pressures, and live load, assuming that the embankment fill has a unit weight of 22 kN/m³ for Granular A, and 21 kN/m³ for Granular B Type II or select earth fill above and/or surrounding the culvert.

Backfill placement for reconstruction or widening of the embankments over and along the culverts should be carried out as per OPSD 208.010 (*Benching of Earth Slopes*) to integrate the new fill into the existing embankment fill.

To prevent surface water from flowing either beneath the culvert (potentially causing undermining and scouring) or around the culvert (creating seepage through the embankment fill, and potentially causing erosion and loss of



fine soil particles), a concrete or clay cut-off wall should be provided at the upstream end of box culverts, while a clay seal should be provided at the upstream end of open footing culverts. Clay seals should also be placed adjacent to the culvert inlet opening for both box culvert and open footing structure types. The clay material should meet the requirements of OPSS 1205 (*Clay Seal*). The clay seal should have a thickness of 1 m, and the seal should extend from a depth of 1 m below the scour level to a minimum horizontal distance of 2 m on either side of the culvert inlet opening, and a minimum vertical height equivalent to the high water level including treatment of the adjacent side slopes. Alternatively, a clay blanket may be constructed, extending upstream to a distance equal to three times the culvert height, and extending along the adjacent side slopes to a height of two times the culvert height or the high water level, whichever is higher.

If the creek/ditch flow velocities are sufficiently high, provision should be made for scour and erosion protection (suitable non-woven geotextiles and/or rip-rap) at the culvert inlet and outlet, including in front of any wingwalls/retaining walls adjacent to the creek channel. The requirements for and design of erosion protection measures for the culvert inlet should be assessed by the hydraulic design engineer. As a minimum, rip-rap treatment for the culvert outlet should be consistent with the standard Treatment Type A presented in OPSD 810.010 (*Rip-Rap Layout for Sewer and Culvert Outlets*), with the rip-rap placed up to the toe of slope level, in combination with the cut-off measures noted above. Similarly, rip-rap should be provided over the full extent of the clay blanket if adopted, including the creek side slopes and embankment fill slope adjacent to the culverts.

6.4 Seismic Design

6.4.1 Seismic Site Classification

Subsurface ground conditions for seismic site characterization were established based on the results of the field investigation and laboratory testing. The SPT “N”-values measured in the soil layers and the interpreted shear wave velocity of soils up to 30 m below founding level were used to define the seismic site classification in accordance with Table 4.1 of the *CHBDC* (2014). Based on this methodology, it is considered that a Site Class of D would be applicable for the design of the structures.

6.4.2 Spectral Response Values and Seismic Performance Category

The *CHBDC* (2014) states that the seismic hazard values associated with the design earthquakes should be those established for the National Building Code of Canada (NBCC) by the Geological Survey of Canada (GSC). The GSC has developed a new set of seismic hazard maps (referred to as the 5th generation seismic hazard maps) that were made available for public use in December 2015.

In accordance with Section 7.5.5.2 of the *CHBDC* (2014), buried structures should be designed to resist inertial forces associated with a seismic event having a 2% exceedance in 50 years (i.e., a 2,475-year return period), where the horizontal ground acceleration ratio A_H is equal to the peak ground acceleration, PGA, as specified in Section 4.4.3 of *CHBDC*. Therefore, based on Section 4.4.3 and the location of the culverts (Latitude 44.2024 degrees, and Longitude -79.6573 degrees), the reference Site Class C PGA value based on the 5th generation seismic hazard maps published by the GSC is as follows.



Seismic Hazard Value for Reference Ground Condition Site Class C

Seismic Hazard Values	2% Exceedance in 50 years (2,475-year return period)
PGA (g)	0.069

The PGA value given above is for the reference ground condition Site Class C and must be modified to the site-specific seismic site classification given in Section 6.2.1 (i.e., Site Class D) in accordance with Section 4.4.3.3 of the *CHBDC*. As indicated in Section 4.4.3.3 of the *CHBDC*, the value of PGA_{ref} for use with Tables 4.2 to 4.9 shall be taken as 80 per cent of the PGA for Site Class C where $S_a(0.2)/PGA$ is less than 2.0. Based on this requirement a PGA_{ref} value of 0.055 for the 2,475-year return was used. The corresponding site-specific PGA value given in the table below can therefore be used for design of the culvert in accordance with Section 7.5.5.1 of the *CHBDC*.

Seismic Hazard Value for Site-Specific Conditions for Seismic Site Class D

Seismic Hazard Values	2% Exceedance in 50 years (2,475-year return period)
PGA (g)	0.071

6.5 Lateral Earth Pressures for Design of Culvert Walls, Wingwalls and Retaining Walls

The lateral earth pressures acting on the culvert walls, wingwalls and retaining walls will depend on the type and method of placement of the backfill materials, the nature of the soils behind the backfill, the magnitude of surcharge including construction loadings, the freedom of lateral movement of the structure, and the drainage conditions behind the walls. Seismic (earthquake) loading must also be taken into account in the design.

The following recommendations are made concerning the design of the walls.

- Free-draining granular fill meeting the specifications of OPSS.PROV 1010 (*Aggregates*) Granular 'A' or Granular B Type II should be used as backfill behind the walls. Longitudinal drains or weep holes should be installed to provide positive drainage of the granular backfill. Compaction (including type of equipment, target densities, etc.) should be carried out in accordance with OPSS.PROV 501 (*Compacting*). Other aspects of the granular backfill requirements with respect to subdrains and frost taper should be in accordance with OPSD 3101.150 (Walls, Abutment, Backfill, Minimum Granular Requirement), OPSD 3121.150 (Walls, Retaining, Backfill, Minimum Granular Requirement), and 3190.100 (Walls, Retaining and Abutment, Wall Drain).
- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the walls, in accordance with *CHBDC* (2014) Section 6.12.3 and Figure 6.6. Care must be taken during the compaction operation not to overstress the wall, with limitations on heavy construction equipment and requirements for the use of hand-operated compaction equipment per OPSS.PROV 501 (*Compacting*). Other surcharge loadings should be accounted for in the design, as required.
- For restrained walls, granular fill should be placed in a zone with the width equal to at least 1.5 m behind the back of the wall in accordance with Figure C6.20(a) of the *Commentary to the CHBDC* (2014). For



unrestrained walls, fill should be placed within the wedge-shaped zone defined by a line drawn at 1.5 horizontal to 1 vertical (1.5H:1V) extending up and back from the rear face of the footing or pile cap in accordance with Figure C6.20(b) of the *Commentary to the CHBDC* (2014).

6.5.1 Static Lateral Earth Pressures for Design

The following guidelines and recommendations are provided regarding the lateral earth pressures for static (i.e., not earthquake) loading conditions. These design recommendations and parameters assume level backfill and ground surface behind the walls. Where there is sloping ground behind the walls, the coefficient of lateral earth pressure must be adjusted to account for the slope.

- For a restrained wall, the pressures are based on the existing or proposed new embankment fill behind the granular backfill zone, and the following parameters (unfactored) may be used assuming the use of earth fill or Select Subgrade Material for the general embankment fill:

Fill Type	Unit Weight of Material	Coefficients of Static Lateral Earth Pressure	
		At-Rest, K_o	Active, K_a
Select Subgrade Material	20 kN/m ³	0.47	0.31

- For an unrestrained wall, the pressures are based on the granular fill in the backfill zone, and the following parameters (unfactored) may be used:

Fill Type	Unit Weight of Material	Coefficients of Static Lateral Earth Pressure	
		At-Rest, K_o	Active, K_a
Granular 'A'	22 kN/m ³	0.43	0.27
Granular 'B' Type II	21 kN/m ³	0.43	0.27

- If the wall support and superstructure allow lateral yielding, active earth pressures may be used in the geotechnical design of the structure. The movement required to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure for design, should be calculated in accordance with Section C6.12.1 and Table C6.6 of the *Commentary to the CHBDC*, 2014.
- If the wall does not allow lateral yielding (i.e., restrained structure where the rotational or horizontal movement is not sufficient to mobilize an active earth pressure condition), at-rest earth pressures (plus any compaction surcharge) should be assumed for geotechnical design.

6.5.2 Seismic Lateral Earth Pressures for Design

Seismic (earthquake) loading must also be taken into account in the design of culvert and wingwalls in accordance with Section 4.6.5 of the *CHBDC* (2014). In this regard, the following should be included in the assessment of lateral earth pressures:

- Seismic loading will result in increased lateral earth pressures acting on the headwall and wingwalls. The walls should be designed to withstand the combined lateral loading for the appropriate static pressure conditions given above, plus the earthquake induced dynamic earth pressure.
- In accordance with Sections 4.6.5 and C.4.6.5 of the *CHBDC* (2014) and its *Commentary*, for structures that allow lateral yielding, the horizontal seismic coefficient, k_h , used in the calculation of the seismic active pressure coefficient, is taken as 0.5 times the site-specific PGA. For structures that do not allow lateral



yielding, k_h is taken as equal to the site-specific PGA. For both cases the value of the vertical seismic coefficient k_v is taken as zero.

- The following seismic active pressure coefficients (K_{AE}) may be used in design; these coefficients reflect the maximum K_{AE} obtained for each of the earthquake design periods and backfill conditions. It should be noted that these seismic earth pressure coefficients assume that the back of the wall is vertical and the ground surface behind the wall is level. Where sloping backfill is present above the top of the wall, the lateral earth pressures under seismic loading conditions should be calculated by treating the weight of the backfill located above the top of the wall as a surcharge.

Wall Type	Design Earthquake	Site PGA	Seismic Active Pressure Coefficients, K_{AE}		
			Granular 'A'	Granular 'B' Type II	SSM
Yielding Wall	475-Year	0.036g	0.26	0.26	0.29
	975-Year	0.055g	0.26	0.26	0.29
	2,475 Year	0.089g	0.27	0.27	0.30
Non-Yielding Wall	475-Year	0.036g	0.27	0.27	0.30
	975-Year	0.055g	0.28	0.28	0.31
	2,475-Year	0.089g	0.30	0.30	0.33

- The K_{AE} value for a yielding wall is applicable provided that the wall can move up to $250 \cdot k_h$ (measured in mm), where k_h is the site specific PGA as given in the table above. This corresponds to displacements of 9 mm, 14 mm, and 22 mm for the 475-year, 975-year, and 2,475-year design earthquakes at this site.
- The earthquake-induced dynamic pressure distribution, which is to be added to the static earth pressure distribution, is a linear distribution with maximum pressure at the top of the wall and minimum pressure at its toe (i.e. an inverted triangular pressure distribution). The total pressure distribution (static plus seismic) may be determined per Section C4.6.5 of the *Commentary to CHBDC* (2014).

6.6 Analytical Testing for Construction Materials

The results of analytical testing on four samples obtained from the silt and sand fill, silt, silt and sand, and clayey silt deposits from the culvert locations are presented in Section 4.3 and in Appendix D. The analytical test results were compared to CSA A23.1 Table 3 ("*Additional requirements for concrete subjected to sulphate attack*") for potential sulphate attack on concrete. The sulphate concentrations measured in the tested samples are below the exposure class of S-3 (Moderate). Therefore, when the designer is selecting the exposure class for the structure, the effects of sulphates may not need to be considered.

The analytical test results of the soil sample were also compared to Table 2 of the U.S. Criteria for Assessing Ground Corrosion Potential (as derived from Federal Highways Administration (FHWA) 2003) for the potential for attack on buried steel. The resistivity and chloride concentrations measured in the soil samples obtained from the Culvert C-14 at Station 10+380 on the N-E/W Ramp and Culvert C-43 at Station 10+280 indicate "strong corrosion potential". The resistivity and chloride concentrations measured in the soil samples obtained from Culverts C-44A and C-44B at Station 10+760 indicated a "mild to strong corrosion potential". From the results of the analytical testing and given that the structure will be exposed to de-icing salt, consideration should be given by the designer to designing for a "C" type exposure class as defined by CSA A23.1 Table 1.

It is ultimately up to the structural designer to determine the appropriate exposure class and to ensure that all aspects of CSA A23.1 Section 4.1.1 "Durability Requirements" are followed.



6.7 Construction Considerations

6.7.1 Open Cut Excavation

The foundation excavations for construction of strip footings or box culverts will extend through existing fill and topsoil and into the underlying silt and sand deposit at Culverts C-14 and C-43, and into the underlying clayey silt deposit at Culverts C-44A and C-44B. Where space permits, open-cut excavations into these materials should be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act (OHSA) for Construction Activities. The existing fill materials, underlying silt to sand and clayey silt deposits are classified as Type 3 soil (assuming the non-cohesive soils are dewatered), according to the OHSA. Temporary excavations (i.e. those which are open for a relatively short time period) should be made with side slopes no steeper than 1 horizontal to 1 vertical (1H:1V).

6.7.2 Temporary Protection Systems

The temporary excavation support systems should be designed and constructed in accordance with OPSS.PROV 539 (*Temporary Protection Systems*). The lateral movement of the protection systems should meet Performance Level 2 as specified in OPSS.PROV 539, provided that any utilities, if present, can tolerate this magnitude of deformation.

It is anticipated that a driven interlocking sheet pile system would be suitable and constructable for the culvert sites, as the Standard Penetration Test (SPT) "N" values are generally less than about 30 blows per 0.3 m of penetration. Occasional SPT "N" values of approximately 35 to 45 blows per 0.3 m of penetration were encountered, but these generally represent a single sample within the generally compact or very stiff zones of soil. SPT "N" values greater than about 50 blows per 0.3 m of penetration were measured within the clayey silt deposit at the site of Culverts C-44A and C-44B below a depth of 12 m, and installation of driven sheet piles below this depth at this location is expected to be more challenging and potentially unfeasible. For this area, and potentially for all protection system sites where working around existing culvert structures, the contractor may elect to use a soldier pile and lagging system. In addition, it is understood that there may be a buried concrete thrust block associated with the existing CSP Culvert C-44C, located immediately to the north of the twin CSPA Culverts C-44A and C-44B. The contractor should be alerted to this on the Contract Drawings as they may need to make adjustments in the field for the installation of the temporary protection system.

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

While the selection and design of the temporary protection system will be the responsibility of the Contractor, the following information is provided to MTO and its designers to aid in assessment of the approximate construction costs during detail design.



FOUNDATION REPORT - CULVERT EXTENSIONS FOR HIGHWAY 400/89 INTERCHANGE, G.W.P. 2438-13-00

Soil Type	Unit Weight	Internal Angle of Friction	Undrained Shear Strength	Coefficient of Lateral Earth Pressure ¹		
	(γ , kN/m ³)	(ϕ , degrees)	(S_u , kPa)	Active K_a	At Rest K_o	Passive K_p ²
Existing Non-Cohesive Fill (Very Loose to Dense)	20	28	-	0.36	0.53	2.8
Silt, Sand, Silty Sand to Silt and Sand (Loose to Dense)	18	28	-	0.36	0.53	2.8
Clayey Silt (Stiff to Hard)	20	32	100	0.31	0.47	3.3

Notes:

1. The earth pressure coefficients noted above are based on a horizontal surface adjacent to the excavation. If sloped surfaces are present, the coefficient of earth pressure should be adjusted accordingly.
2. The total passive resistance below the base of the excavation (i.e. adjacent to the temporary protection system) may be calculated based on the values of K_p indicated above but reduced by an appropriate factor that considers the allowable wall movement in accordance with Figure C6.16 of the CHBDC (2014) to account for the fact that a large strain would be required for mobilization of the full passive resistance.

It should be noted that the pressure distributions given above are the minimum for the ultimate stress condition; a stiffer design than predicted by these distributions may be required to maintain displacements within an acceptable range to satisfy Performance Level 2 per OPSS.PROV 539. In addition, the earth pressure coefficients provided above are based on a horizontal surface adjacent to the top of the excavation; if sloped surfaces are present, the coefficient of earth pressure should be adjusted accordingly.

For the temporary protection system at Culverts C-14 and C-43, a design groundwater level of Elevation 226.2 m should be assumed. For culverts CE-44A and CE-44B, a design ground water level of Elevation 224.7 m should be assumed. If a soldier pile and lagging system is adopted, it would be necessary to control seepage or include measures to mitigate loss of soil particles through lagging boards.

Consideration should be given to either partial or full removal of the protection system upon completion of construction. Where possible, full removal of the protection system should be considered to mitigate potential impediments to future rehabilitation/reconstruction work.

6.7.3 Groundwater Control

The groundwater level measured in the standpipe piezometer installed in the sandy silt to silt and sand deposit in Borehole CE-02 is about 2.3 m below the ground surface, corresponding to about Elevation 226.2 m, which is up to about 1 m above the subgrade level for a box culvert, and about 1.7 m to 2.3 m above the recommended founding level for strip footings or wall foundations for Culvert C-14 and C-43 at Station 10+280. At the Culvert C-44A and C-44B locations at Stations 10+760, the excavations will extend about 3 to 4 m below the existing road surface into the cohesive clayey silt material. The groundwater level measured in the standpipe piezometer installed in the clayey silt deposit in Borehole CE-05 is about 2.5 m below ground surface, corresponding to about Elevation 224.7 m, which is about 0.6 m above the recommended founding level for strip footings for the culvert at Station 10+760.

The excavations for both culverts will extend through topsoil, silt and sand to sand and gravel fill, silt and sand (native), as well as clayey silt at the Culvert C-44A and C-44B site. Considering the relatively low permeability of



the clayey silt soils at the Culvert C-44A and C-44B site, it is anticipated that water inflow from these layers can be handled by pumping from filtered sump pumps placed at the base of the excavation. Where silt to silty sand soils are present at the subgrade level, as anticipated at Culverts C-14 and C-43, more active dewatering will be required to maintain a dry and stable subgrade. Surface water seepage into the excavations should be expected and will be heavier during periods of sustained precipitation and all surface water should be directed away from the excavations. It is recommended that SP 517F01 (Amendment to OPSS 517 – Dewatering System, Temporary Flow Passage System) be included in the Contract Documents to address dewatering for the culvert sites; the SP, including fill-ins, is included in Appendix E.

6.7.4 Obstructions During Installation of Temporary Protection Systems

It is anticipated that cobbles and/or boulders may be encountered within the sand, silt, and clayey silt deposits, which may affect the installation of protection system elements. It is recommended that an NSSP be included in the Contract Documents to warn the Contractor of the possible presence of cobbles and/or boulders within the overburden soils; an NSSP is provided in Appendix E.

6.7.5 Vibration Monitoring During Temporary Protection System Installation

If the temporary protection systems are installed using vibratory methods, significant vibrations are not anticipated, given the generally stiff to hard / compact nature of the native soil deposits. A maximum peak particle velocity (PPV) of 100 mm/s is generally considered applicable for bridge structures in good condition. Based on vibration monitoring experience, it is considered unlikely that vibrations will reach this threshold level; therefore, vibration monitoring on the existing culvert structures is not expected to be required during construction at this site.

No residential/commercial buildings are present in the vicinity of the Culverts C-44A, C-44B, and C-14. A commercial building is located approximately 50 m east of the proposed Culvert C-43 headwall location at Station 10+280. A lower PPV threshold of 50 mm/s is generally considered applicable for commercial buildings. While it is expected that vibration levels will not reach these thresholds at this structure, pre- and post-construction condition surveys and vibration monitoring at or near the building should be considered to defend against potential damage claims associated with vibration-inducing activities at these sites. A sample NSSP has been provided in Appendix E, and this NSSP will be modified as required to address condition surveys and/or vibration monitoring at this structure if elected for this contract.

6.7.6 Subgrade Protection

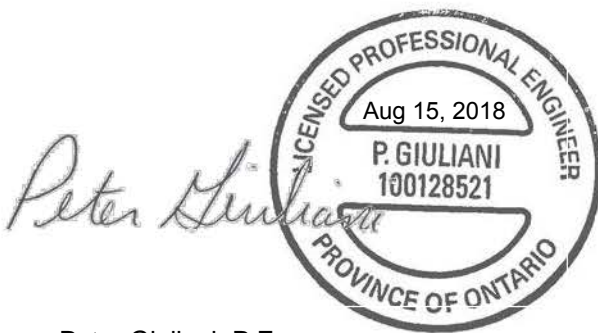
The subgrade soils will be susceptible to disturbance from construction traffic and/or ponded water. To limit this degradation, it is recommended that a concrete working slab be placed on the subgrade within four hours after preparation, inspection and approval of the footing subgrade for the box culverts. Alternatively, as discussed in Section 6.3.5, subgrade protection for box culverts could be provided by 150 mm of granular bedding or a working slab with 75 mm of granular bedding over the slab. This requirement can be addressed with a note on the General Arrangement drawing and/or with an NSSP. A sample NSSP for the working slab is included in Appendix E.



7.0 CLOSURE

This report was prepared by Mr. Peter Giuliani, P.Eng., a geotechnical engineer with Golder. Ms. Lisa Coyne, P.Eng., Principal and MTO Designated Foundations Contact, conducted an independent technical and quality control review of the report.

GOLDER ASSOCIATES LTD.



Peter Giuliani, P.Eng.
Geotechnical Engineer



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PG/SMM/JMAC/LCC/rb

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<https://golderassociates.sharepoint.com/sites/12201g/6-deliverables/fnds/reports/culverts/final/1668512fidr40089culvert2018aug15.docx>



REFERENCES

- Chapman, L.J., and Putnam, D.F., 1984. The Physiography of Southern Ontario, 3rd Edition. Ontario Geological Survey, Special Volume 2. Ontario Ministry of Natural Resources.
- Bowles, J.E. 1984. Physical and Geotechnical Properties of Soils, Second Edition. McGraw Hill Book Company, New York.
- Canadian Geotechnical Society. 1992. Canadian Foundation Engineering Manual (CFEM), 3rd Edition. The Canadian Geotechnical Society, BiTech Published Ltd., British Columbia.
- Canadian Geotechnical Society. 2006. Canadian Foundation Engineering Manual (CFEM), 4th Edition. The Canadian Geotechnical Society, BiTech Publisher Ltd., British Columbia.
- Canadian Highway Bridge Design Code (CHBDC (2014)) and Commentary on CAN/CSA-S6-14. Canadian Standard Association. (CSA) Group.
- Canadian Standards Association (CSA). 2006. Canadian Highway Bridge Design Code and Commentary on CAN/CSA-S6-06. CSA Special Publication, S6.1 06.
- Chapman, L.J. and Putnam, D.F. 1984. The Physiography of Southern Ontario, Ontario Geological Survey, Special Volume 2, Third Edition. Accompanied by Map P.2715, Scale 1:600,000.
- Kulhawy, F.H. and Mayne, P.W. 1990. Manual on Estimating Soil Properties for Foundation Design. EL6800, Research Project 14936. Prepared for Electric Power Research Institute, Palo Alto, California, U.S.
- Terzaghi, K., 1955. Evaluation of Coefficients of Subgrade Reaction/ Geotechnique, Vol. 5, No. 4, pp. 297-326. Discussion in Vol. 6, No. 2, pp. 94-98.
- Terzaghi, K. and Peck, R.B., 1967. Soil Mechanics in Engineering Practice, 2nd Edition, John Wiley and Sons, New York.
- Unified Facilities Criteria, U.S. Navy. 1986. NAVFAC Design Manual 7.02. Soil Mechanics, Foundation and Earth Structures. Alexandria, Virginia.
- U.S. Criteria for Assessing Ground Corrosion Potential (as derived from Federal Highways Administration (FHWA) 2003)

ASTM International:

ASTM D1586 Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils

Commercial Software:

Slide (Version 6) by Rocscience Inc.

Ontario Provisional Standard Drawings:

OPSD 208.010	Benching of Earth Slopes
OPSD 802.020	Flexible Pipe Arch Embedment and Backfill – Earth Excavation
OPSD 803.010	Backfill and Cover for Concrete Culverts
OPSD 3090.101	Foundation Frost Penetration Depths for Southern Ontario



FOUNDATION REPORT - CULVERT EXTENSIONS FOR HIGHWAY 400/89 INTERCHANGE, G.W.P. 2438-13-00

OPSD 3101.150	Walls, Abutments, Backfill, Minimum Granular Requirements
OPSD 3121.150	Walls, Retaining, Backfill, Minimum Granular Requirements
OPSD 3190.100	Walls, Retaining and Abutment, Wall Drain

Ontario Provincial Standard Specifications:

OPSS.PROV 206	Construction Specification for Grading
OPSS 421	Construction Specification for Pipe Culvert in Open Cut
OPSS.PROV 501	Construction Specifications for Compacting
OPSS.PROV 517	Construction Specification for Dewatering
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS 802	Construction Specification for Topsoil
OPSS 803	Construction Specification for Sodding
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS 902	Construction Specification for Excavating and Backfilling Structures
OPSS.PROV 1004	Material Specification for Aggregates – Miscellaneous
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material

Ontario Water Resources Act:

Ontario Regulation 903 Wells (as amended)

Ontario Occupational Health and Safety Act:

Ontario Regulation 213/91 Construction Projects (as amended)

Ministry of Transportation, Ontario

Structural Manual, Provincial Highways Management Division, Highway Standards Branch, Bridge Office, August 2014.

MTO Foundations Guideline, Embankment Settlement Criteria for Design, July 2010.



FOUNDATION REPORT - CULVERT EXTENSIONS FOR HIGHWAY 400/89 INTERCHANGE, G.W.P. 2438-13-00

Table 1: Comparison of Foundation Alternatives for Culvert Extensions

Option	Advantages	Disadvantages	Risks/Consequences
Box culvert extension or replacement	<ul style="list-style-type: none">■ Minimizes depth of excavation, excavation support and dewatering requirements compared to open footing option.■ Depending on the groundwater level, this option may avoid the need for a Permit to Take Water associated with construction dewatering when compared with an open footing culvert replacement option.■ Pre-cast box sections expected to allow faster construction than cast-in-place open footings, with shorter duration for dewatering and surface water pumping.	<ul style="list-style-type: none">■ It is likely that excavation will extend below the groundwater level and dewatering would still be required.	<ul style="list-style-type: none">■ Some risk of disturbance of the sensitive silt and clayey silt subgrade silt materials during construction.
Open footing culvert extension or replacement	<ul style="list-style-type: none">■ Would satisfy fisheries requirements related to natural channel substrate, if applicable■ May be feasible to build culvert extensions on pre-cast footing sections, to accelerate construction schedule and reduce time for dewatering and surface water pumping	<ul style="list-style-type: none">■ Excavation depths are greater than for box culvert option to found footings at/below depth of frost penetration, resulting in increased excavation support and dewatering requirements, including need for Permit to Take Water■ Cast-in-place footings may require a longer duration for construction, including dewatering and surface water pumping, as compared with pre-cast culvert segments or footing elements	<ul style="list-style-type: none">■ Some risk of disturbance of the sensitive silty subgrade and loose granular materials during construction



FOUNDATION REPORT - CULVERT EXTENSIONS FOR HIGHWAY 400/89 INTERCHANGE, G.W.P. 2438-13-00

Table 2: Box Culverts – Founding Elevations, Sub-Excavation Requirements and Geotechnical Resistances

Culvert Location	Culvert Station	Reference Boreholes	Proposed Culvert Invert Elevation ¹ Upstream / Downstream	Sub-excavation Required?	Culvert Span ²	Highest Base Slab Founding Elevation ³ Upstream /Downstream	Founding Material	Factored Ultimate Geotechnical Resistance ⁴	Geotechnical Serviceability Reaction (for 25 mm of settlement) ^{4,5}
C-14	Culvert C-14 Extension-Station 10+280 N-E/W Ramp	CE-01 and CE-02	225.6/225.5	Yes – approx.. 0.2 m at d/s	4.8 m	225.3 m / 225.2 m	Silt, sandy silt to silt and sand, loose to compact	425 kPa	150 kPa
C-43	Culvert C-43 – Headwall and Wingwall Station 10+280 East side of Hwy 400 NBL	CE-03 and CE-04	226.1/225.8	Yes – approx. 0.6 m at u/s end	5.1 m	225.8 m / 225.6 m	Silt and sand, compact to dense	325 kPa	200 kPa
C-44A/C-44B	Culvert C-44A and C-44B Extension and Retaining Wall Station 10+760 West side of Hwy 400 SBL	CE-05, CE-06, CE-07 and CE-08	224.5/224.3	Yes – approx. 0.6 m at u/s end at BH CE-08 location	5.4 m	224.2 m / 224.0 m	Stiff to hard clayey silt	300 kPa	150 kPa

NOTES:

Prepared by: PG Reviewed by: LCC

1.

Proposed culvert invert elevations provided by Morrison Hershfield Limited.
2.

Culvert span is based on 250 mm wide walls.
3.

Highest founding elevation based on invert elevations provided by MH, with an assumed base slab thickness of 250 mm. Per Section 6.4, it is recommended that the base slab be founded on either a 150 mm thick layer of compacted OPSS.PROV 1010 Granular A, or a 100 mm thick concrete working slab overlain by 75 mm of OPSS.PROV 1010 Granular A or OPSS.PROV 1002 concrete fine aggregate.
4.

The geotechnical resistances given in the above table are based on the culvert span (width) as listed above for each culvert. The recommended geotechnical resistances should be reviewed if the footing founding elevation and/or culvert span (width) differ significantly from those given above.
5.

The factored serviceability geotechnical resistances are given for settlements on the order of 15 to 20 mm.



FOUNDATION REPORT - CULVERT EXTENSIONS FOR HIGHWAY 400/89 INTERCHANGE, G.W.P. 2438-13-00

Table 3: Open Footing Culverts – Founding Elevations, Sub-Excavation Requirements and Geotechnical Resistances

Culvert Location	Culvert Station	Reference Boreholes	Proposed Culvert Invert Elevation ¹ Upstream/Downstream	Sub-excavation Required?	Highest Founding Elevation ² Upstream/Downstream	Founding Material	Factored Geotechnical Resistance at ULS ³	Geotechnical Reaction at SLS ^{3,4}
C-14	Culvert C-14 Extension- Station 10+280 N-E/W Ramp	CE-01 and CE-02	225.6/225.5	No	224.0/223.9	Silt, sandy silt to silt and sand, loose to compact	425 kPa	325 kPa
C-43	Culvert C-43 - Station 10+280 Headwall and Wingwall East side of Hwy 400 NBL	CE-03 and CE-04	226.1/225.8	No	224.5/224.2	Silt and sand, compact to dense	375 kPa	325 kPa
C-44A/ C-44B	Culvert C-44A and C-44B Extension and Retaining Wall Station 10+760 West side of Hwy 400 SBL	CE-05, CE-06, CE-07 and CE-08	224.5/224.3	No	222.9/222.7	Stiff to hard clayey silt	500 kPa	300 kPa

Prepared by: PG Reviewed by: LCC

NOTES:

1. Proposed culvert invert elevations provided by Morrison Hershfield Limited.
2. Highest founding elevation based on minimum footing depth of 1.6 m below lowest surrounding grade, for frost protection purposes.
3. The geotechnical resistances given in the above table are based on an assumed footing width of 0.6 m. The recommended geotechnical resistances should be reviewed if the footing founding elevation and/or footing width differ significantly from those given above.
4. The factored serviceability geotechnical resistances are given for settlements on the order of 15 to 20 mm.



FOUNDATION REPORT - CULVERT EXTENSIONS FOR HIGHWAY 400/89 INTERCHANGE, G.W.P. 2438-13-00

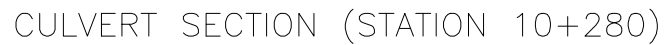
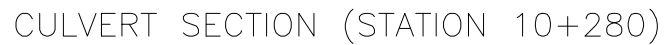
Table 4: Open Footing And Box Culverts – Resistance To Lateral Loads/Sliding Resistance

Culvert Location	Culvert Station	Reference Boreholes	Proposed Culvert Invert Elevation Upstream/Downstream	Pre-Cast Concrete Box Culverts		Cast-in-Place Concrete Footings	
				Coefficient of Friction, $\tan \delta$	Base Slab Founding Material	Coefficient of Friction, $\tan \phi'$	Footing Founding Material
C-14	Culvert C-14 Extension Station 10+280 N-E/W Ramp	CE-01 and CE-02	225.6/225.5	0.45	Compacted granular fill (bedding)	0.35	Silt, sandy silt to silt and sand, loose to compact
C-43	Culvert C-43 Headwall and Wingwall Station 10+280 East side of Hwy 400 NBL	CE-03 and CE-04	226.1/225.8	0.45	Compacted granular fill (bedding)	0.35	Silt and sand, compact to dense
C-44A/ C-44B	Culvert C-44A and C-44B Extension and Retaining Wall Station 10+760 West side of Hwy 400 SBL	CE-05, CE-06, CE-07 and CE-08	224.5/224.3	0.45	Compacted granular fill (bedding)	0.45	Stiff to hard clayey silt

Prepared by: PG Reviewed by: LCC

NOTES:

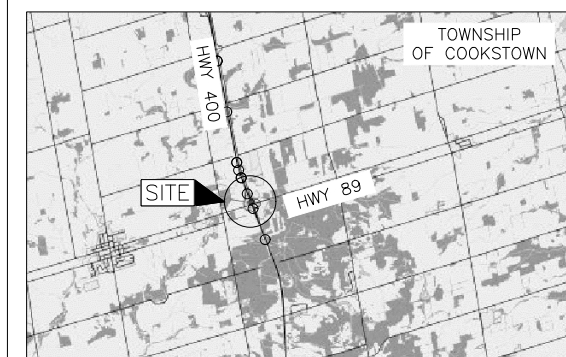
1. The coefficients of friction given in the table above are unfactored.




CONT No.
GWP No. 2438-13-00



CULVERT EXTENSION / REPLACEMENT,
STATION 10+280
(N-EW RAMP AND HIGHWAY 400 NBL)
BOREHOLE LOCATION AND SOIL STRATA








KEY PLAN
SCALE



2 0 2 4 km

LEGEND

- | | |
|---|--|
|  | Borehole – Current Investigation |
|  | Seal |
|  | Piezometer |
| N | Standard Penetration Test Value |
| 16 | Blows/0.3m unless otherwise stated
(Std. Pen. Test, 475 j/blow) |
|  | WL in piezometer, measured on March 5, 2018 |
|  | WL upon completion of drilling |

BOREHOLE CO-ORDINATES (MTM NAD 83 ZONE10)			
No.	ELEVATION	NORTHING	EASTING
CE-01	226.9	4895834.7	292221.0
CE-02	228.5	4895835.0	292256.3
CE-03	229.3	4895866.6	292347.4
CE-04	226.0	4895873.3	292362.1

NOTES

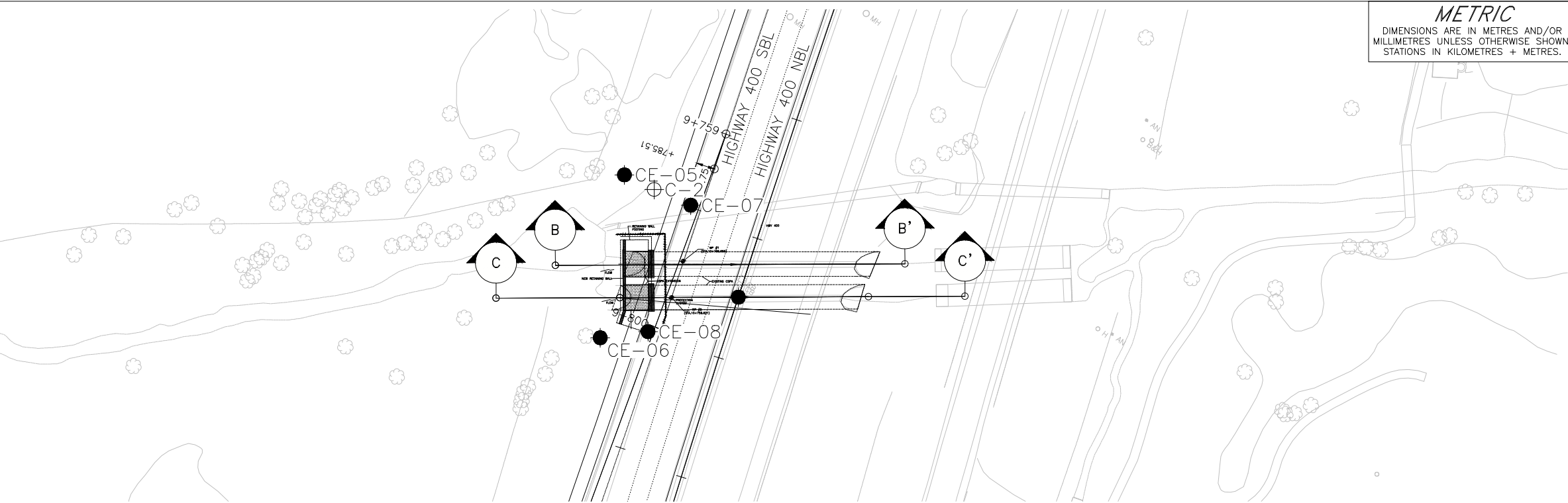
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

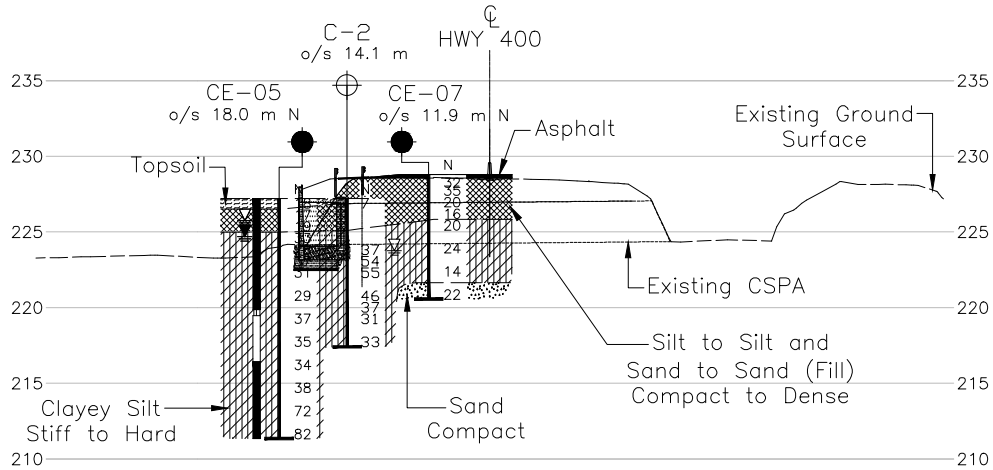
REFERENCE

Base plans provided in digital format by client, drawing file "X1170121Design_Interim.dwg" and "X1170121Base.dwg", received December 6, 2017 and 1170121-30-568C-CUL-01 - Copy.dwg, received July 5, 2018.

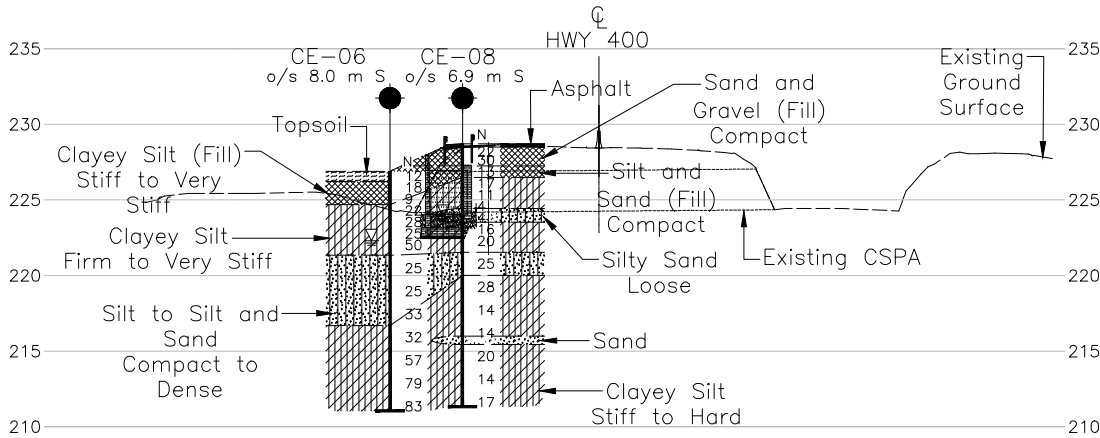
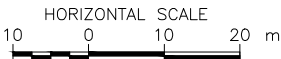
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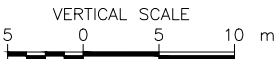
HIGHWAY 400 - PLAN



HORIZ. SCALE 1:500 m
VERT. SCALE 1:250 m
CULVERT SECTION B-B'



HORIZ. SCALE 1:500 m
VERT. SCALE 1:250 m
CULVERT SECTION C-C'



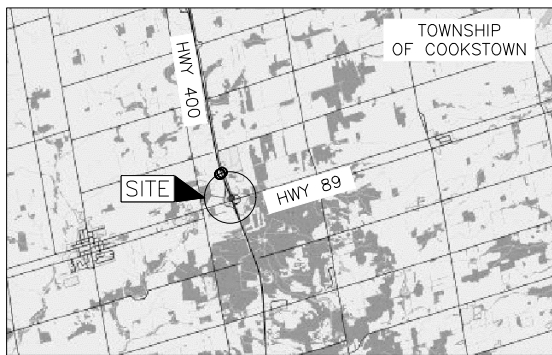
METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No. 1
GWP No. 2438-13-00



CULVERTS EXTENSION AT STATION
10+760
(HIGHWAY 400 SBL)
BOREHOLE LOCATION AND SOIL STRATA

SHEET



KEY PLAN
SCALE
2 0 2 4 km

LEGEND

- Borehole - Current Investigation
- ⊕ Borehole - GEOCRES No. 31D00-482
- ⊥ Seal
- ⊥ Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated
(Std. Pen. Test, 475 j/blow)
- ≡ WL in piezometer, measured on March 5, 2018
- ≡ WL upon completion of drilling

BOREHOLE CO-ORDINATES (MTM NAD 83 ZONE10)

No.	ELEVATION	NORTHING	EASTING
C-2	227.2	4896322.8	292130.0
CE-05	227.2	4896321.5	292123.5
CE-06	226.9	4896292.8	292139.6
CE-07	228.8	4896324.8	292137.7
CE-08	228.7	4896299.6	292146.4

NOTES

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

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

REFERENCE

Base plans provided in digital format by client, drawing file "X1170121Design_Interim.dwg" and "X1170121Base.dwg", received December 6, 2017.

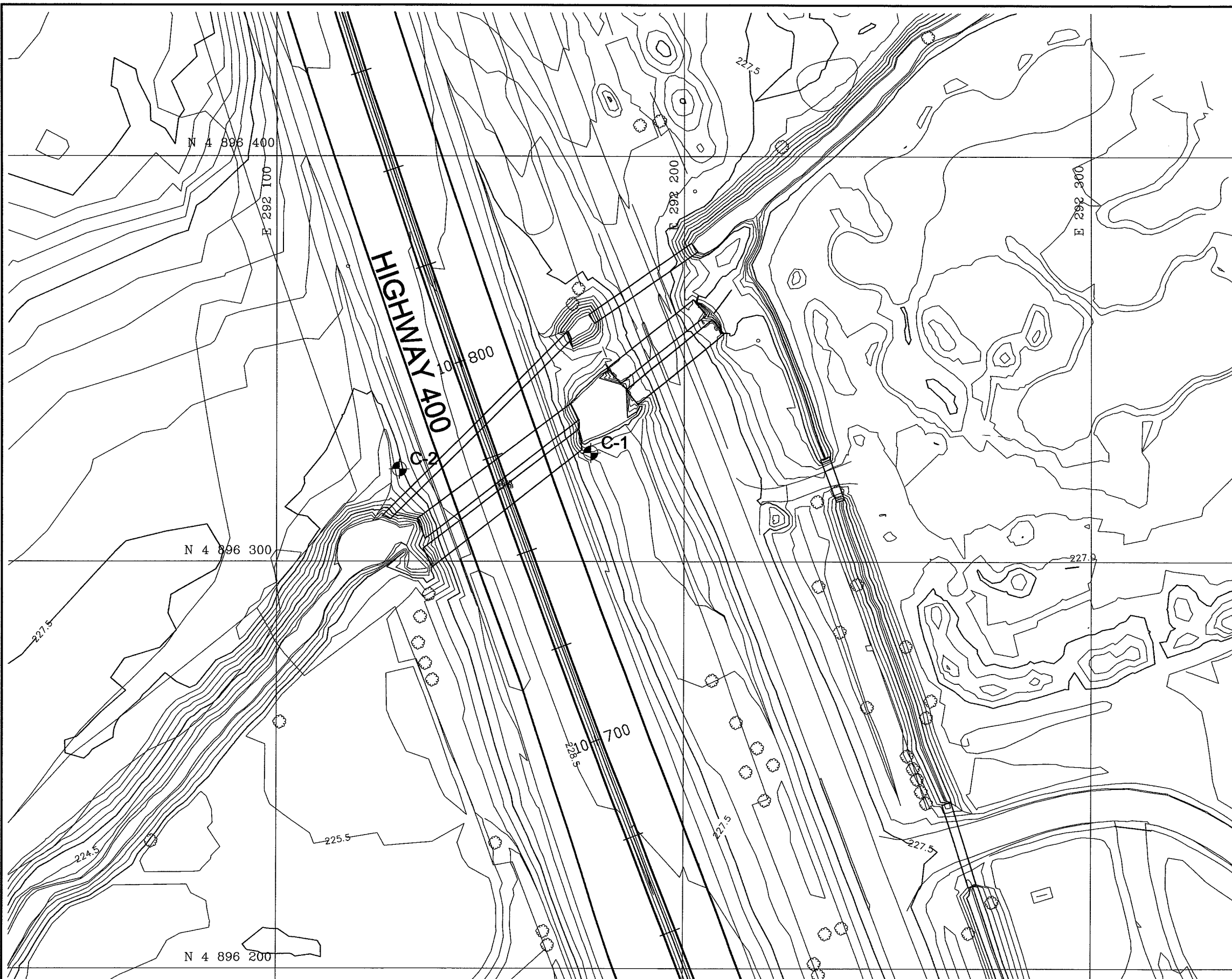


NO.	DATE	BY	REVISION
Geocres No. 31D-708			
HWY. 400		PROJECT NO. 1668512	DIST. CENTRAL
SUBM'D. DF	CHKD. DM	DATE: 8/16/2018	SITE: 30-399/C
DRAWN: SMD	CHKD. PG	APPD. LCC	DWG. 2



APPENDIX A

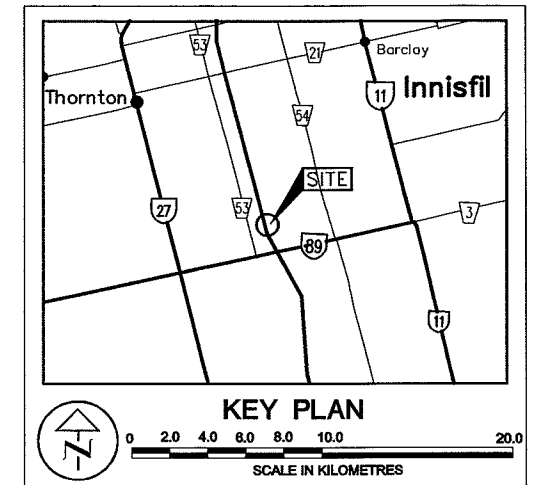
2000 Investigation - MTO GEOCRES No. 31D00-482





DIST	HWY	400
CONT. No.		
GWP No.	30-95-00	
CULVERT AT STATION 10+780		
HWY 400		
BOREHOLE LOCATION PLAN		



Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



LEGEND			
	Borehole, previous investigation		
	Borehole, present investigation		

No.	ELEVATION	LOCATION	
		NORTHING	EASTING
C-1	226.5	4,896,326.9	292,177.2
C-2	227.2	4,896,322.8	292,130.0

REFERENCE

This drawing was created from digital file "33811.dwg"
provided by URS Cole Sherman

NO.	DATE	BY	REVISION		
Geocres No.					
HWY. No. 400			PROJECT NO.: 001-1143F		
SUBM'D.	LCC	CHKD.	ASP	DATE: JANUARY 2001	SITE 30-399
DRAWN:	MHW	CHKD.	LCC	APPD. ASP	DWG. 1

LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

III. SOIL DESCRIPTION

(a) Cohesionless Soils

Density Index (Relative Density)	N Blows/300 mm or Blows/ft.
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

(b) Cohesive Soils

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

Dynamic Cone Penetration Resistance; N_d :

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

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

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

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

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

LIST OF SYMBOLS

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

I GENERAL

π	= 3.1416
$\ln x$,	natural logarithm of x
$\log_{10} x$ or $\log x$,	logarithm of x to base 10
g	acceleration due to gravity
t	time
F	factor of safety
V	volume
W	weight

II STRESS AND STRAIN

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

III SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight*)
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation
*	Density symbol is ρ . Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density x acceleration due to gravity)

(a) Index Properties (con't.)

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

(c) Hydraulic Properties

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

(d) Consolidation (one-dimensional)

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

(e) Shear Strength

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

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

2. Shear strength = (Compressive strength)/2

PROJECT 001-1143F				RECORD OF BOREHOLE No C-1				1 OF 1		METRIC							
W.P. 30-95-00				LOCATION N 4896326.9; E 292177.2				ORIGINATED BY PKS									
DIST Central HWY 400				BOREHOLE TYPE 108mm ID SOLID STEM AUGERS AND CASING				COMPILED BY LCC									
DATUM Geodetic				DATE Oct.26/2000				CHECKED BY ASP									
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS		ELEVATION SCALE		DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT		REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES					SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X REMOULDED		WATER CONTENT (%) Wp — W — WL		γ	GR SA SI CL		
226.5	GROUND SURFACE																
0.0	Topsoil		1	AS													
225.9																	
0.6	Clayey Silt, trace to some sand, trace gravel, trace to some organics (Fill) Stiff Brown Moist		2	SS	11												
			3	SS	8												
224.2																	
2.3	Fibrous Peat Firm Black Moist		4	SS	4												
			5	SS	66												
223.1																	
3.4	Sand, some silt, trace gravel Dense to very dense Grey Wet		6	SS	80												
			7	SS	65												
			8	SS	44												
219.2																	
7.3	Clayey Silt, trace sand and gravel, occasional sand seams/partings (Till) Hard Grey Moist		9	SS	57												
216.9			10	SS	111												
9.6	END OF BOREHOLE																
	Notes: 1. Water level in open borehole at 4.6m depth (Elev.221.9m) upon completion of drilling. 2. Water level in piezometer at 1.6m depth (Elev.224.9m) on March 19, 2001.																

ON_MOT 0011143F.GPJ ON_MOT.GDT 25/9/01

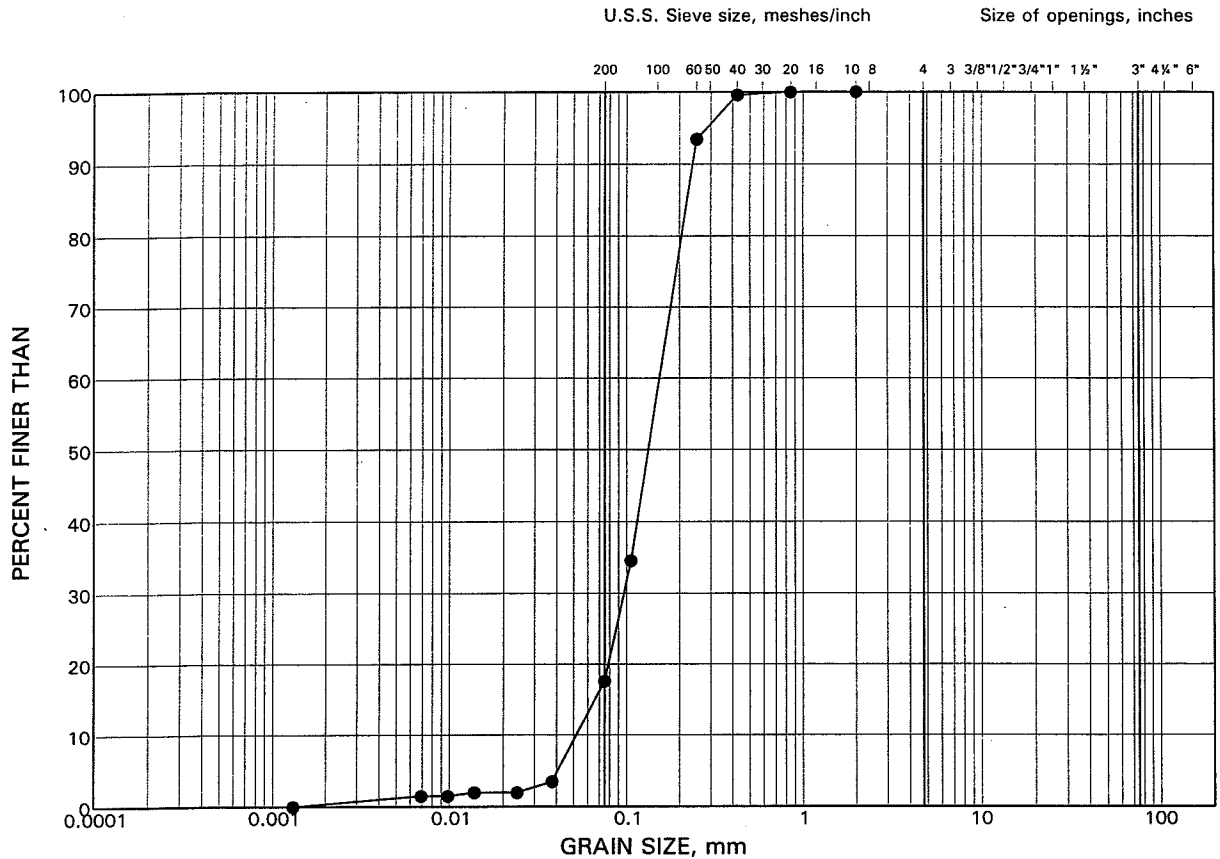
PROJECT 001-1143F				RECORD OF BOREHOLE No C-2				1 OF 1		METRIC				
W.P. 30-95-00				LOCATION N 4896322.8; E 292130.0				ORIGINATED BY AZ						
DIST Central HWY 400				BOREHOLE TYPE 108mm ID SOLID STEM AUGERS AND CASING				COMPILED BY LCC						
DATUM Geodetic				DATE Nov. 1/2000				CHECKED BY ASP						
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 X REMOULDED						
227.2	GROUND SURFACE													
0.0	Topsoil		1	SS	7		227							
0.3	Clayey Silt, some sand (Fill)						226							
225.1							225							
2.1	Clayey Silt, some sand, trace gravel (Till) Hard Grey Moist		2	SS	37		224							
			3	SS	54		223							2 11 55 32
			4	SS	55		222							
			5	SS	46		221							
			6	SS	37		220							
			7	SS	31		219							
			8	SS	33		218							
217.4	END OF BOREHOLE													
9.8	Note: 1. Open borehole dry upon completion of drilling.													

ON_MOT_0011143F.GPJ ON_MOT_GDI 25/9/01

GRAIN SIZE DISTRIBUTION

Sand

FIGURE 1



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

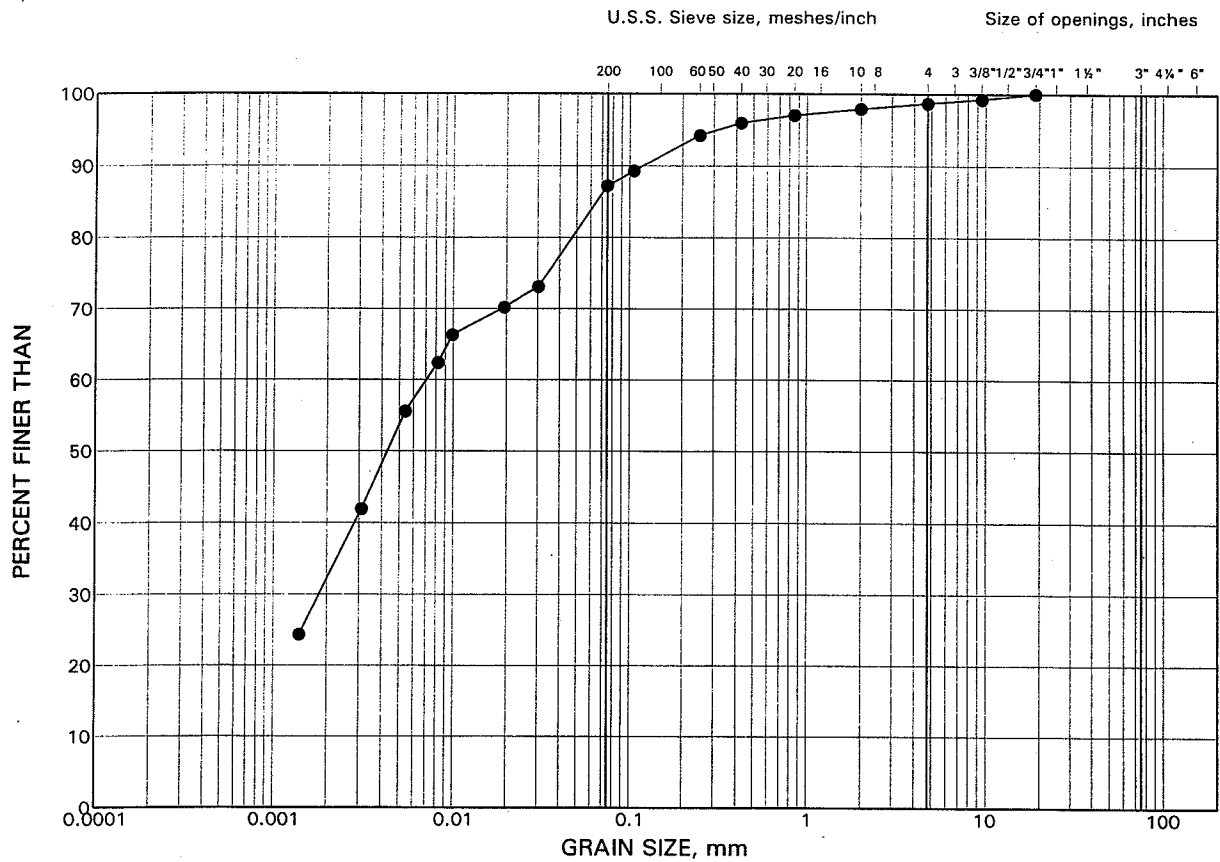
LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
•	C-1	6	222.2

GRAIN SIZE DISTRIBUTION

Clayey Silt (Till)

FIGURE 2



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
•	C-2	3	222.8



APPENDIX B

2017/2018 Investigation - Borehole Records



LIST OF SYMBOLS

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

I. GENERAL

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

II. STRESS AND STRAIN

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

III. SOIL PROPERTIES

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

(a) Index Properties (continued)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

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

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

Notes: 1
2

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

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



LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

Dynamic Cone Penetration Resistance; N_d :

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

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

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

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

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

(b) Cohesive Soils Consistency

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

IV. SOIL TESTS




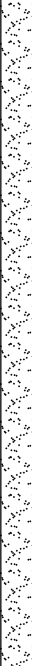
w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D_R	relative density (specific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

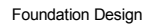
Note: 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

V. MINOR SOIL CONSTITUENTS

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

PROJECT <u>1668512</u>		RECORD OF BOREHOLE No CE-01		SHEET 1 OF 1		METRIC	
G.W.P. <u>2438-13-00</u>		LOCATION <u>N 4895833.4; E 292221.1 MTM NAD 83 ZONE 10 (LAT. 44.202403; LONG. -79.657385)</u>		ORIGINATED BY <u>DF</u>			
DIST <u>Central</u> HWY <u>400</u>		BOREHOLE TYPE <u>D50 Track Mount, 203mm O.D. Hollow Stem Augers</u>		COMPILED BY <u>DH</u>			
DATUM <u>Geodetic</u>		DATE <u>August 10, 2017</u>		CHECKED BY <u>SMM</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/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL	
								20	40	60	80	100	w _p	w	w _L						
227.0	GROUND SURFACE																				
0.0	TOPSOIL (686 mm)		1	AS	-	▽	226											0 46 40 14			
226.3																					
0.7	Silt and sand, some clay (FILL) Loose Brown Moist		2	SS	5																
225.2			3A	SS	10																
1.8	SILT, some sand, trace to some clay Loose to compact Grey Wet		3B					225													
			4	SS	8																0 13 76 11
			5	SS	12																
	6	SS	14																		
222.5						223															
4.5	SAND, some silt, trace clay Loose to compact Grey Wet		7	SS	15		222														
			8	SS	16			221													
			9	SS	15	220															
			10	SS	8	219															
			11	SS	16	218															
																		</			



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

PROJECT		RECORD OF BOREHOLE No CE-02				SHEET 2 OF 2		METRIC																					
G.W.P. 1668512		LOCATION N 4895835.0; E 292256.3 MTM NAD 83 ZONE 10 (LAT. 44.202407; LONG. -79.656943)				ORIGINATED BY DF																							
DIST Central HWY 400		BOREHOLE TYPE Power Auger (108mm Hollow Stem)				COMPILED BY DH																							
DATUM Geodetic		DATE July 26, 2017				CHECKED BY SMM																							
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)													
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa									WATER CONTENT (%)												
	--- CONTINUED FROM PREVIOUS PAGE ---						20	40	60	80	100																		
212.7	SILT, some sand, some clay Loose to compact Grey Wet		14	SS	19	213																							
15.9	END OF BOREHOLE																												
	NOTES: 1. Water level measured at a depth of about 2.9 m (Elev. 225.6 m) below ground surface upon completion of drilling. 2. Groundwater level measurements in piezometer: <table border="1" style="margin-left: 20px;"> <thead> <tr> <th>Date</th> <th>Depth(m)</th> <th>Elev(m)</th> </tr> </thead> <tbody> <tr> <td>15/08/17</td> <td>2.7</td> <td>225.8</td> </tr> <tr> <td>19/09/17</td> <td>3.0</td> <td>225.5</td> </tr> <tr> <td>05/03/18</td> <td>2.3</td> <td>226.2</td> </tr> </tbody> </table>	Date	Depth(m)	Elev(m)	15/08/17	2.7	225.8	19/09/17	3.0	225.5	05/03/18	2.3	226.2																
Date	Depth(m)	Elev(m)																											
15/08/17	2.7	225.8																											
19/09/17	3.0	225.5																											
05/03/18	2.3	226.2																											

GTA-MTO 001 S:\CLIENTS\MTOWHY_400_AND_HWY_89_INTERCHANGE02_DATA\GINT\HWY_400_AND_HWY_89_INTERCHANGE.GPJ GAL-GTA.GDT 08/16/18



GTA-MTO 001	S:CLIENTS	MTO	001	AND	HWY 89	INTERCHANGE	02	DATA\GINT	HWY 400	AND	HWY 89	INTERCHANGE	GRJ	GAL-GTA.GDT	08/16/18
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Continued Next Page

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

PROJECT		1668512		RECORD OF BOREHOLE No CE-03				SHEET 2 OF 2		METRIC							
G.W.P.		2438-13-00		LOCATION		N 4895866.6; E 292347.4 MTM NAD 83 ZONE 10 (LAT. 44.202700; LONG. -79.655800)				ORIGINATED BY		DF					
DIST		Central HWY 400		BOREHOLE TYPE		D50 Track-Mounted, 203mm O.D. Hollow Stem Augers				COMPILED BY		JIL					
DATUM		Geodetic		DATE		February 14, 2018				CHECKED BY		SMM					
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									
	--- CONTINUED FROM PREVIOUS PAGE ---							20	40	60	80	100					
213.5	SILT, some sand, trace to some clay Compact Grey Wet		14	SS	23		214										0 14 78 8
15.9	END OF BOREHOLE																
	NOTES: 1. Water level measured in open borehole at a depth of about 4.0 m (Elev. 225.3 m) below ground surface upon completion of drilling.																

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PROJECT		1668512		RECORD OF BOREHOLE No CE-04		SHEET 1 OF 2		METRIC								
G.W.P.		2438-13-00		LOCATION		N 4895873.3; E 292362.1 MTM NAD 83 ZONE 10 (LAT. 44.202762; LONG. -79.655624)		ORIGINATED BY								
DIST		Central HWY 400		BOREHOLE TYPE		D25 Track-Mounted, 152 mm O.D. Hollow Stem Augers with drilling mud		COMPILED BY								
DATUM		Geodetic		DATE		February 28, 2018		CHECKED BY								
								SMM								
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								
226.0	GROUND SURFACE															
0.0	TOPSOIL (178 mm)															
0.2	Silty sand, trace clay, trace gravel (FILL)		1	SS	12											
225.3	Compact Mottled brown and grey Wet		2	SS	22											
0.7	SILT and SAND, trace clay Compact to dense Grey Wet		3	SS	19											
			4	SS	34											
			5	SS	23											
			6	SS	24											
			7	SS	26											
			8	SS	25											
			9	SS	46											
217.3	Sandy SILT, trace to some clay Compact Grey Wet		10	SS	28											
215.8	SILT and SAND, trace to some clay Compact Grey Wet		11	SS	26											
214.3	Sandy SILT, trace to some clay Compact Grey Wet		12	SS	27											
213.2																
12.8																

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

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

PROJECT 1668512		RECORD OF BOREHOLE No CE-05		SHEET 1 OF 2		METRIC	
G.W.P. 2438-13-00		LOCATION N 4896321.5; E 292123.5 MTM NAD 83 ZONE 10 (LAT. 44.206792; LONG. -79.658620)		ORIGINATED BY DF			
DIST Central HWY 400		BOREHOLE TYPE D25 Track-Mounted, 127 mm O.D. Solid Stem Augers		COMPILED BY JIL			
DATUM Geodetic		DATE February 22 and 27, 2018		CHECKED BY SMM			

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	W _p	W	W _L		
227.2 0.0	GROUND SURFACE TOPSOIL (686 mm)		1	SS	18												
226.5 0.7	Silt, some sand, trace clay (FILL) Compact Mottled brown grey with oxidation stains Moist		2	SS	17											NP	0 16 78 6
			3	SS	19												
225.0 2.2	CLAYEY SILT, some sand, trace gravel Very stiff to hard Brown becoming grey below 3.1 m Wet		4	SS	33												
			5	SS	28												
			6	SS	37												
			7	SS	31												
			8	SS	29												
			9	SS	37												
			10	SS	35												
			11	SS	34												
			12	SS	38												
			13	SS	72												

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

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PROJECT <u>1668512</u>		RECORD OF BOREHOLE No CE-05		SHEET 2 OF 2		METRIC	
G.W.P. <u>2438-13-00</u>		LOCATION <u>N 4896321.5; E 292123.5 MTM NAD 83 ZONE 10 (LAT. 44.206792; LONG. -79.658620)</u>		ORIGINATED BY <u>DF</u>			
DIST <u>Central</u> HWY <u>400</u>		BOREHOLE TYPE <u>D25 Track-Mounted, 127 mm O.D. Solid Stem Augers</u>		COMPILED BY <u>JIL</u>			
DATUM <u>Geodetic</u>		DATE <u>February 22 and 27, 2018</u>		CHECKED BY <u>SMM</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/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL
								20	40	60	80	100	W _p	W	W _L					
	--- CONTINUED FROM PREVIOUS PAGE ---																			
211.4	CLAYEY SILT, some sand, trace gravel Very stiff to hard Brown becoming grey below 3.1 m Wet		14	SS	82								o							
15.9	END OF BOREHOLE																			
	NOTES: 1. Water level measured in open borehole at a depth of about 1.4 m (Elev. 225.8 m) below ground surface upon completion of drilling. 2. Groundwater level measurements in piezometer: Date Depth (m) Elev. (m) 05/03/18 2.5 224.7																			


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PROJECT 1668512		RECORD OF BOREHOLE No CE-06		SHEET 1 OF 2		METRIC							
G.W.P. 2438-13-00		LOCATION N 4896292.8; E 292139.6 MTM NAD 83 ZONE 10 (LAT. 44.206534; LONG. -79.658418)		ORIGINATED BY DF									
DIST Central HWY 400		BOREHOLE TYPE D25 Track-Mounted, 127 mm O.D. Solid Stem Augers		COMPILED BY JIL									
DATUM Geodetic		DATE February 26, 2018		CHECKED BY SMM									
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT		REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	W _p W W _L	WATER CONTENT (%)	γ	GR SA SI CL	
226.9 0.0	GROUND SURFACE TOPSOIL (686 mm)		1	SS	12								
226.2 0.7	Clayey silt, some sand, trace gravel (FILL) Stiff to very stiff Brown to black Moist		2	SS	18		226						
			3	SS	9		225						
224.7 2.2	CLAYEY SILT, some sand, trace gravel Very stiff to hard Grey Wet		4	SS	22		224					3 13 47 37	
			5	SS	28		223						
			6	SS	25		222						
			7	SS	50		221						
221.3 5.6	SILT, some clay, trace gravel, trace sand Very stiff to hard Grey Wet		8	SS	25		220					1 2 83 14	
			9	SS	25		219						
			10	SS	33		218						
216.7 10.2	CLAYEY SILT Hard Grey Moist to wet		11	SS	32		217					0 0 77 23	
			12	SS	57		216						
			13	SS	79		215						
							214						
							213						
							212						

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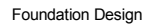
+³, ×³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

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PROJECT		1668512		RECORD OF BOREHOLE No CE-06				SHEET 2 OF 2		METRIC							
G.W.P.		2438-13-00		LOCATION		N 4896292.8; E 292139.6 MTM NAD 83 ZONE 10 (LAT. 44.206534; LONG. -79.658418)				ORIGINATED BY		DF					
DIST		Central HWY 400		BOREHOLE TYPE		D25 Track-Mounted, 127 mm O.D. Solid Stem Augers				COMPILED BY		JIL					
DATUM		Geodetic		DATE		February 26, 2018				CHECKED BY		SMM					
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									
	--- CONTINUED FROM PREVIOUS PAGE ---																
211.1	CLAYEY SILT Hard Grey Moist to wet		14	SS	83												
15.9	END OF BOREHOLE																
	NOTES: 1. Water level measured in open borehole at a depth of about 4.6 m (Elev. 222.3) below ground surface upon completion of drilling.																

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PROJECT 1668512		RECORD OF BOREHOLE No CE-07				SHEET 1 OF 1		METRIC									
G.W.P. 2438-13-00		LOCATION N 4896324.8; E 292137.7 MTM NAD 83 ZONE 10 (LAT. 44.206820; LONG. -79.658400)				ORIGINATED BY DF											
DIST Central HWY 400		BOREHOLE TYPE D50 Track-Mounted, 203mm O.D. Hollow Stem Augers				COMPILED BY JIL											
DATUM Geodetic		DATE February 13, 2018				CHECKED BY SMM											
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									
228.8	GROUND SURFACE																
0.0	ASPHALT (223 mm)																
0.2	Sand, some gravel, some silt, trace clay (FILL) Dense Brown Moist		1	SS	32												18 67 12 3
			2	SS	35												
227.4																	
1.5	Silt and sand, trace gravel, trace to some clay (FILL) Compact Mottled brown and grey Moist		3	SS	20												4 42 43 11
			4	SS	16												
225.8																	
3.0	CLAYEY SILT, some sand, trace gravel Very stiff to stiff Brown/grey to grey Moist		5	SS	20												
			6A	SS	24												
			6B														
			7	SS	14												
221.6																	
7.2	SAND, trace to some silt Compact Grey Wet		8	SS	22												
220.6																	
8.2	END OF BOREHOLE																
NOTES:																	
1. Water level measured in open borehole at a depth of about 5.0 m (Elev. 223.8) below ground surface upon completion of drilling.																	

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

PROJECT <u>1668512</u>		RECORD OF BOREHOLE No CE-08		SHEET 2 OF 2		METRIC	
G.W.P. <u>2438-13-00</u>		LOCATION <u>N 4896299.6; E 292146.4 MTM NAD 83 ZONE 10 (LAT. 44.206600; LONG. -79.658300)</u>		ORIGINATED BY <u>DF</u>			
DIST <u>Central</u> HWY <u>400</u>		BOREHOLE TYPE <u>D50 Track-Mounted, 203mm O.D. Continuous Flight Hollow Stem Augers</u>		COMPILED BY <u>JIL</u>			
DATUM <u>Geodetic</u>		DATE <u>February 13, 2018</u>		CHECKED BY <u>SMM</u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT						PLASTIC LIMIT NATURAL LIMIT MOISTURE LIQUID CONTENT LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						WATER CONTENT (%)				GR	SA	SI	CL
								○ UNCONFINED + FIELD VANE	● QUICK TRIAXIAL × REMOULDED												
	--- CONTINUED FROM PREVIOUS PAGE ---							20	40	60	80	100									
	CLAYEY SILT, trace sand Stiff to very stiff Grey Wet		15	SS	14																
211.3			16	SS	17																
17.4	END OF BOREHOLE																				
	NOTES: 1. Water level measured in open borehole at a depth of about 4.8 m (Elev. 223.9 m) below ground surface upon completion of drilling.																				

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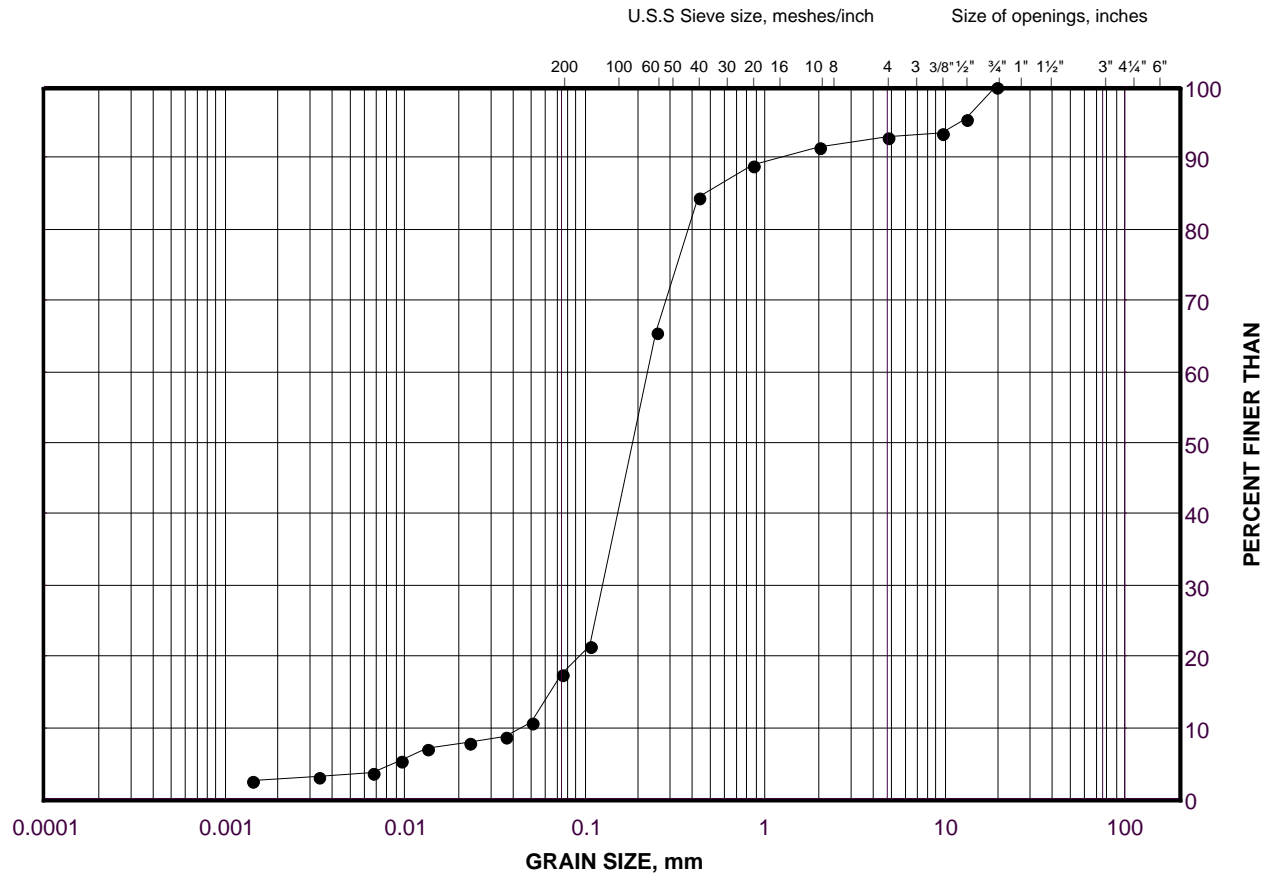
APPENDIX C

Geotechnical Laboratory Testing

GRAIN SIZE DISTRIBUTION

Sand (Fill)

FIGURE C-1



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

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
•	CE-03	1	228.9

Project Number: 1668512

Checked By: SMM

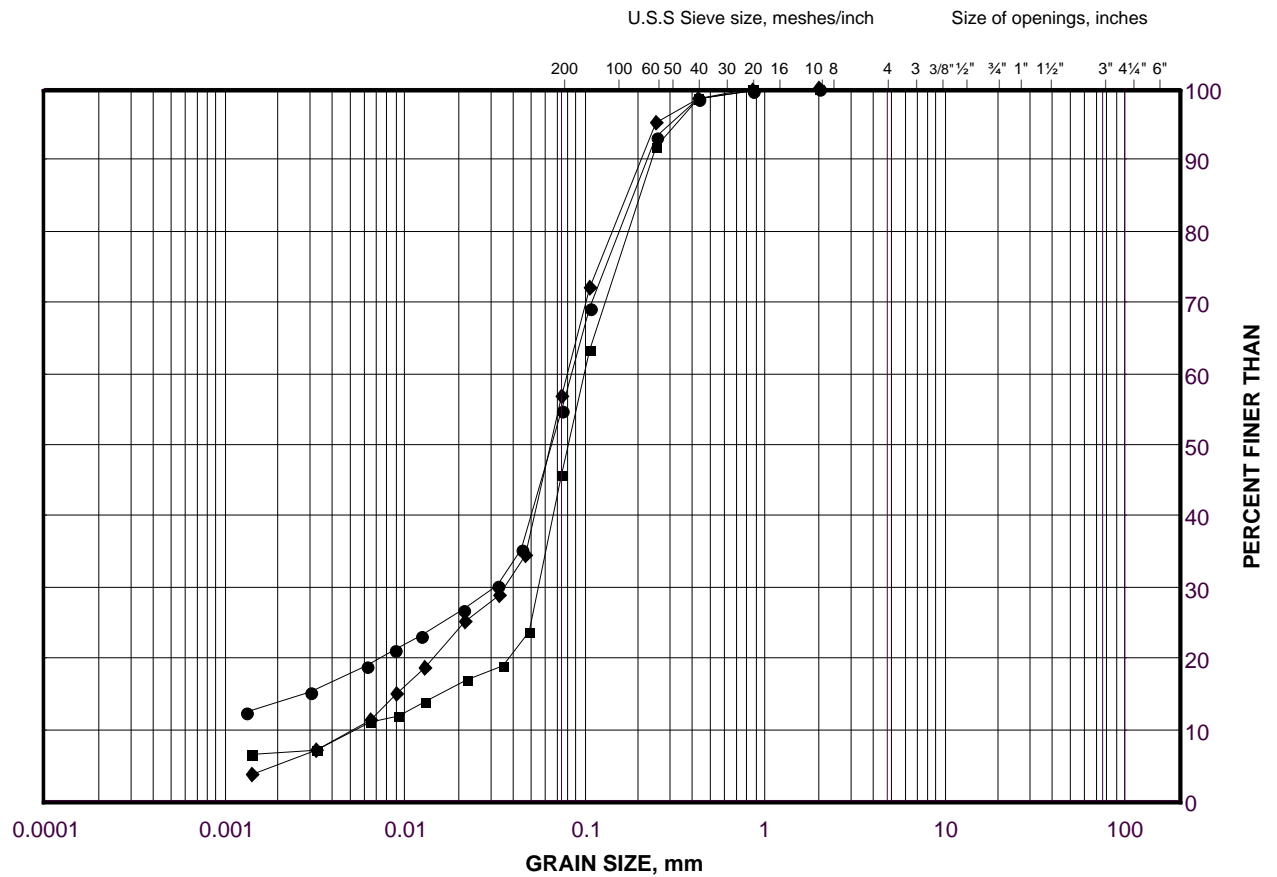
Golder Associates

Date: 09-May-18

GRAIN SIZE DISTRIBUTION

Silt and Sand (Fill)

FIGURE C-2



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

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	CE-01	2	225.9
■	CE-03	3	227.5
◆	CE-02	3	226.7

Project Number: 1668512

Checked By: SMM

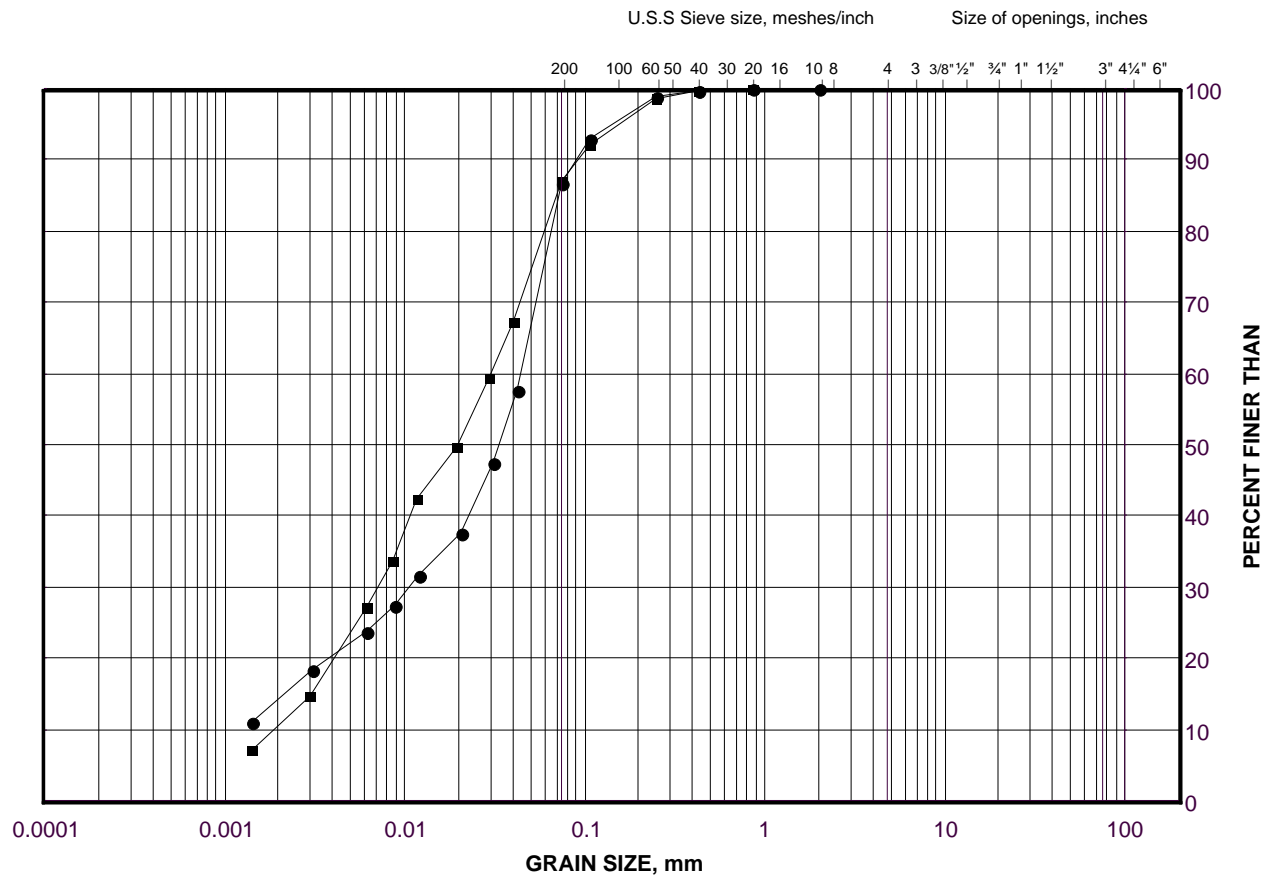
Golder Associates

Date: 09-May-18

GRAIN SIZE DISTRIBUTION

Silt

FIGURE C-3



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

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	CE-02	12	216.0
■	CE-01	4	224.4

Project Number: 1668512

Checked By: SMM

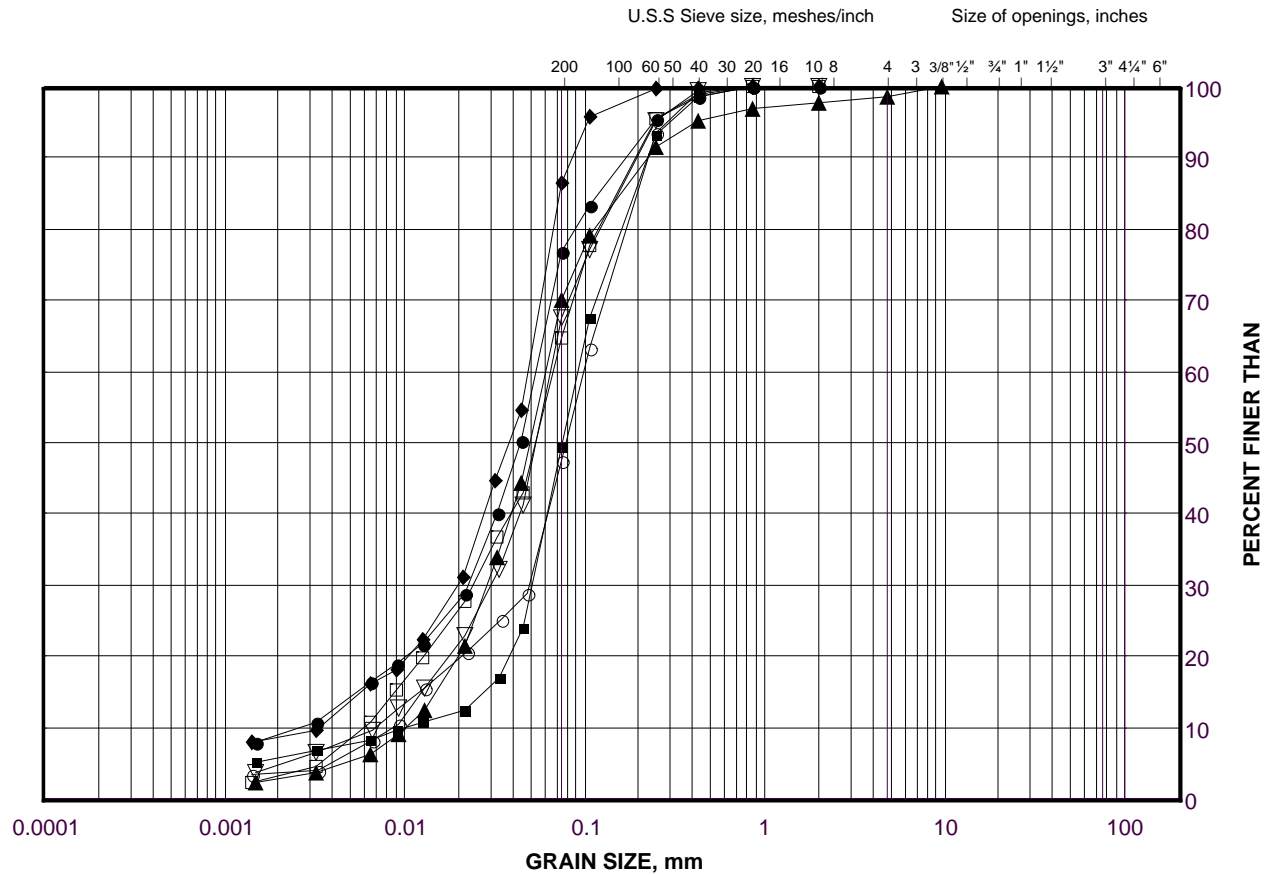
Golder Associates

Date: 09-May-18

GRAIN SIZE DISTRIBUTION

Silt to Sandy Silt to Silt and Sand

FIGURE C-4



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

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	CE-04	10	216.6
■	CE-04	11	215.0
◆	CE-03	14	213.8
▲	CE-02	5	225.1
▽	CE-04	6	221.9
○	CE-03	7	224.4
□	CE-02	8	222.1

Project Number: 1668512

Checked By: SMM

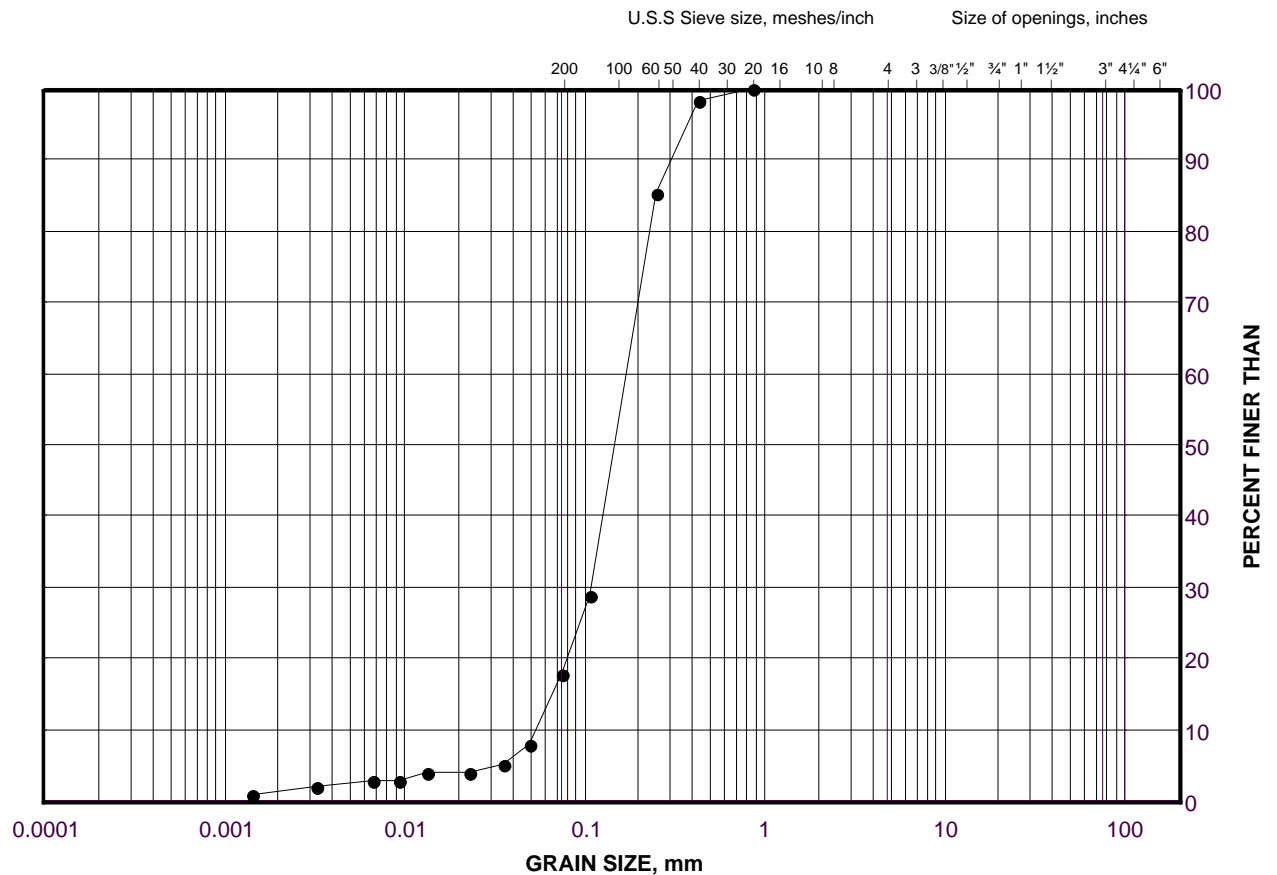
Golder Associates

Date: 30-Apr-18

GRAIN SIZE DISTRIBUTION

Sand

FIGURE C-5



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

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
•	CE-01	9	219.1

Project Number: 1668512

Checked By: SMM

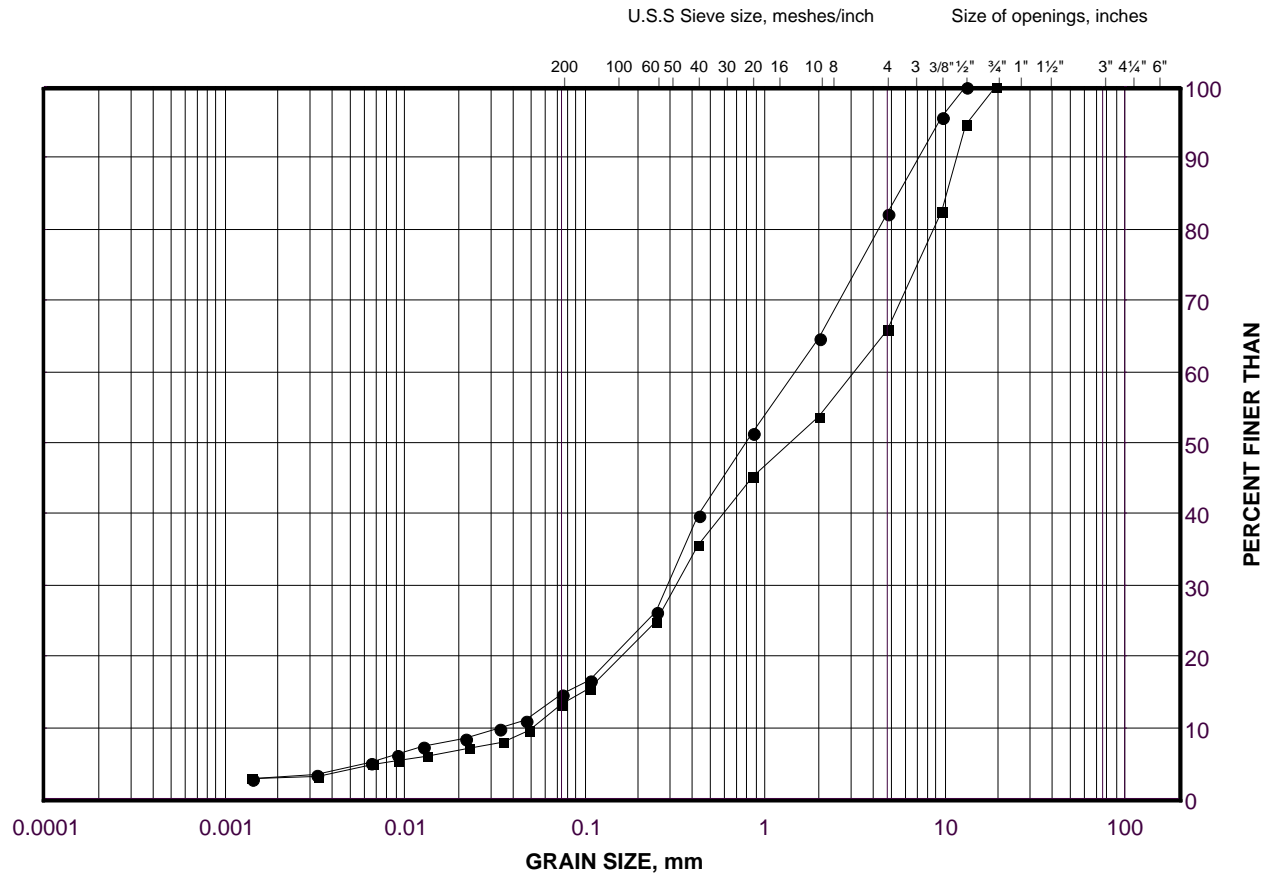
Golder Associates

Date: 26-Apr-18

GRAIN SIZE DISTRIBUTION

Sand and Gravel (Fill)

FIGURE C-6



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

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	CE-07	1	228.4
■	CE-08	1	228.4

Project Number: 1668512

Checked By: SMM

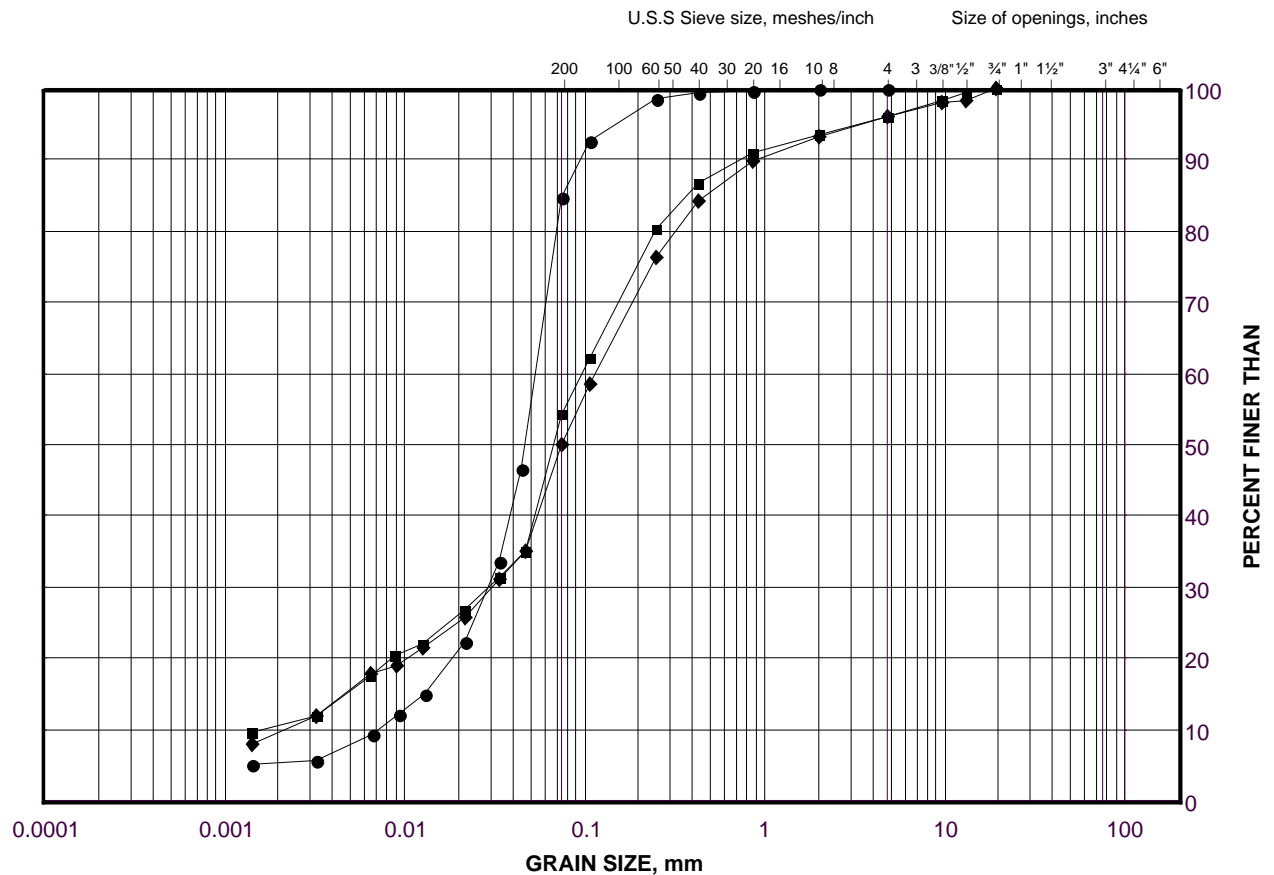
Golder Associates

Date: 09-May-18

GRAIN SIZE DISTRIBUTION

Silt to Silt and Sand (Fill)

FIGURE C-7



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

LEGEND

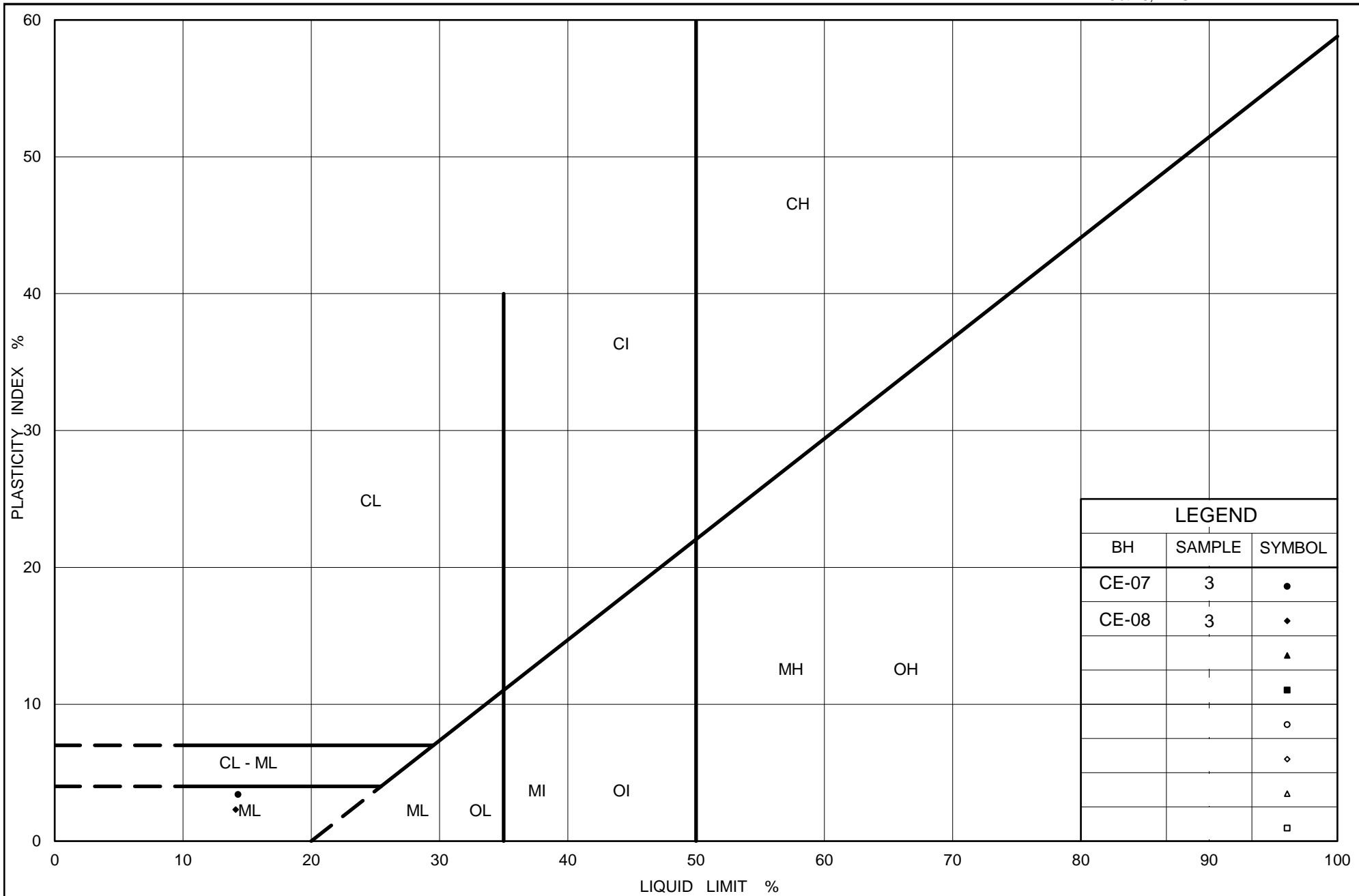
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	CE-05	2	226.1
■	CE-07	3	227.0
◆	CE-08	3	226.9

Project Number: 1668512

Checked By: SMM

Golder Associates

Date: 09-May-18



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Ontario

PLASTICITY CHART Silt and Sand (Fill)

Figure No. C-8

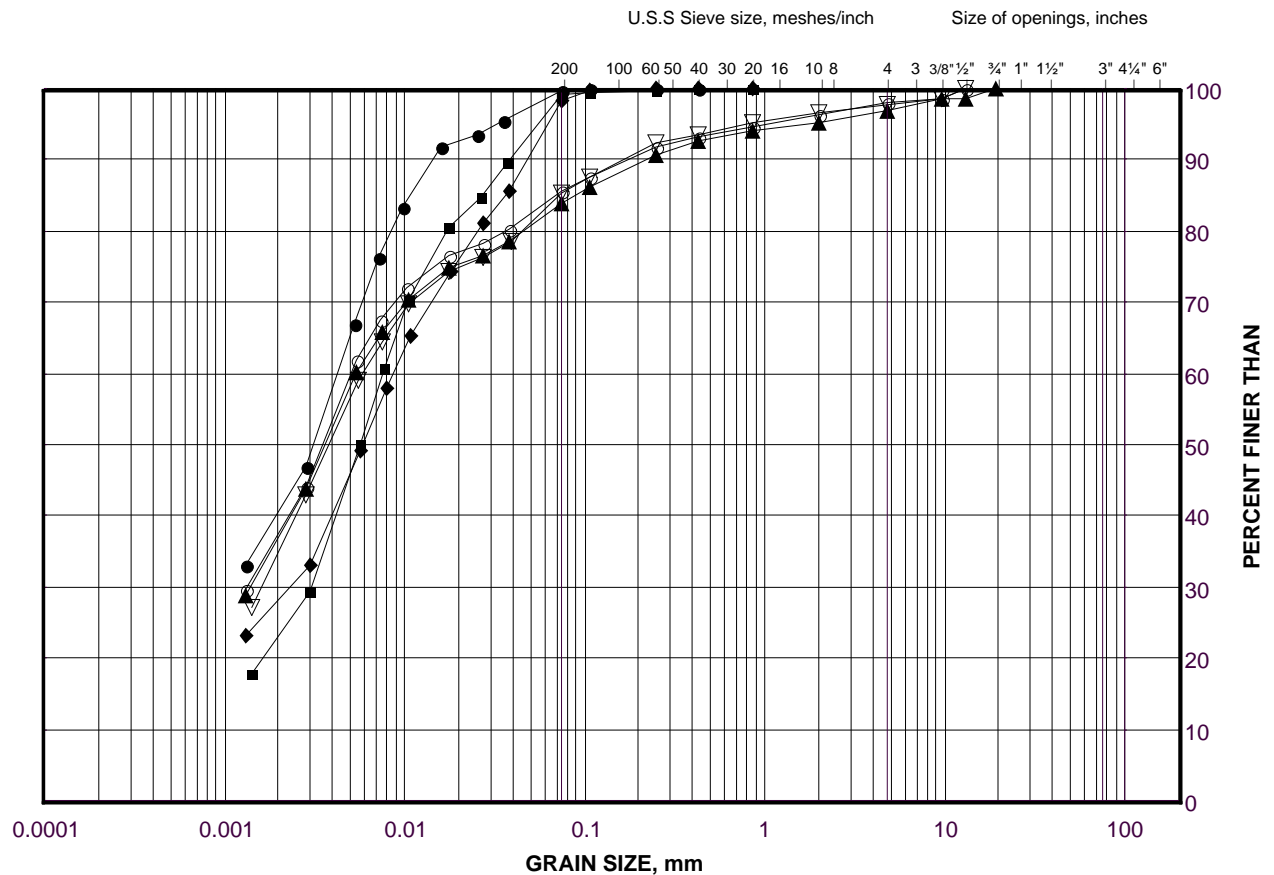
Project No. 1668512

Checked By: SMM

GRAIN SIZE DISTRIBUTION

Clayey Silt

FIGURE C-9



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

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	CE-05	10	217.8
■	CE-06	11	215.9
◆	CE-08	14	214.7
▲	CE-06	4	224.3
▽	CE-05	5	223.8
○	CE-07	6	223.9

Project Number: 1668512

Checked By: SMM

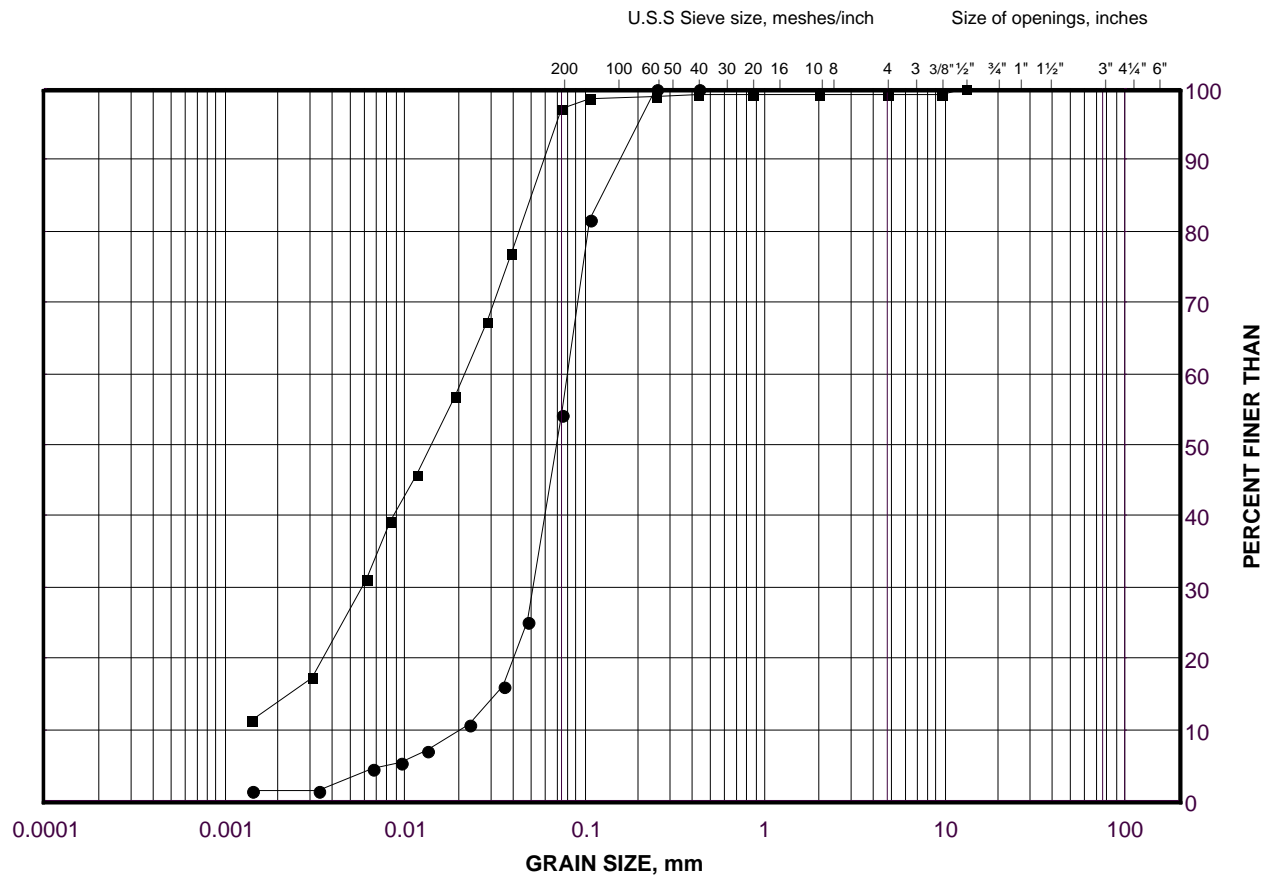
Golder Associates

Date: 26-Apr-18

GRAIN SIZE DISTRIBUTION

Silt to Silt and Sand (Interlayers)

FIGURE C-10



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

LEGEND

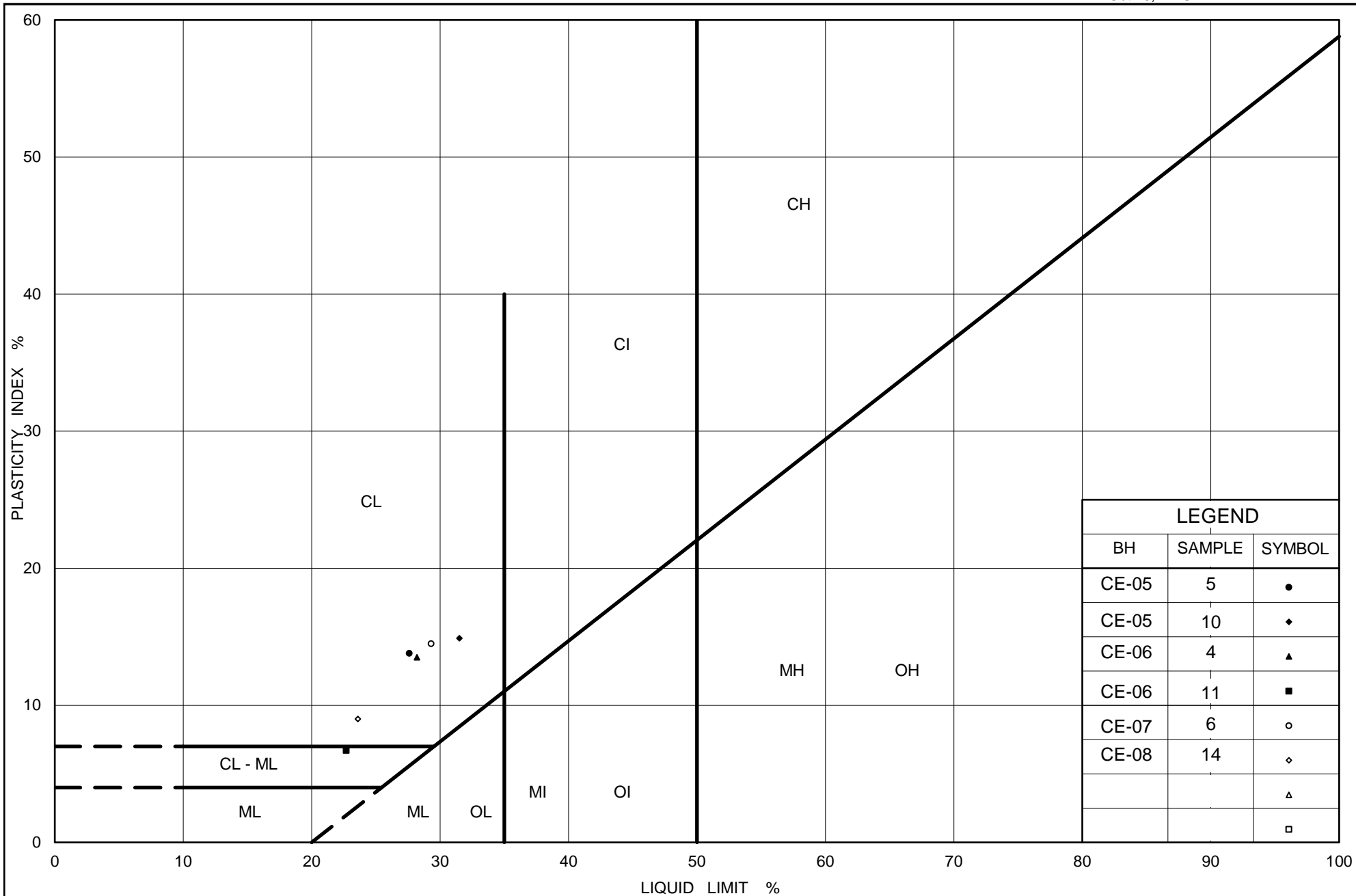
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	CE-08	10	220.8
■	CE-06	8	220.5

Project Number: 1668512

Checked By: SMM

Golder Associates

Date: 09-May-18



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Ontario

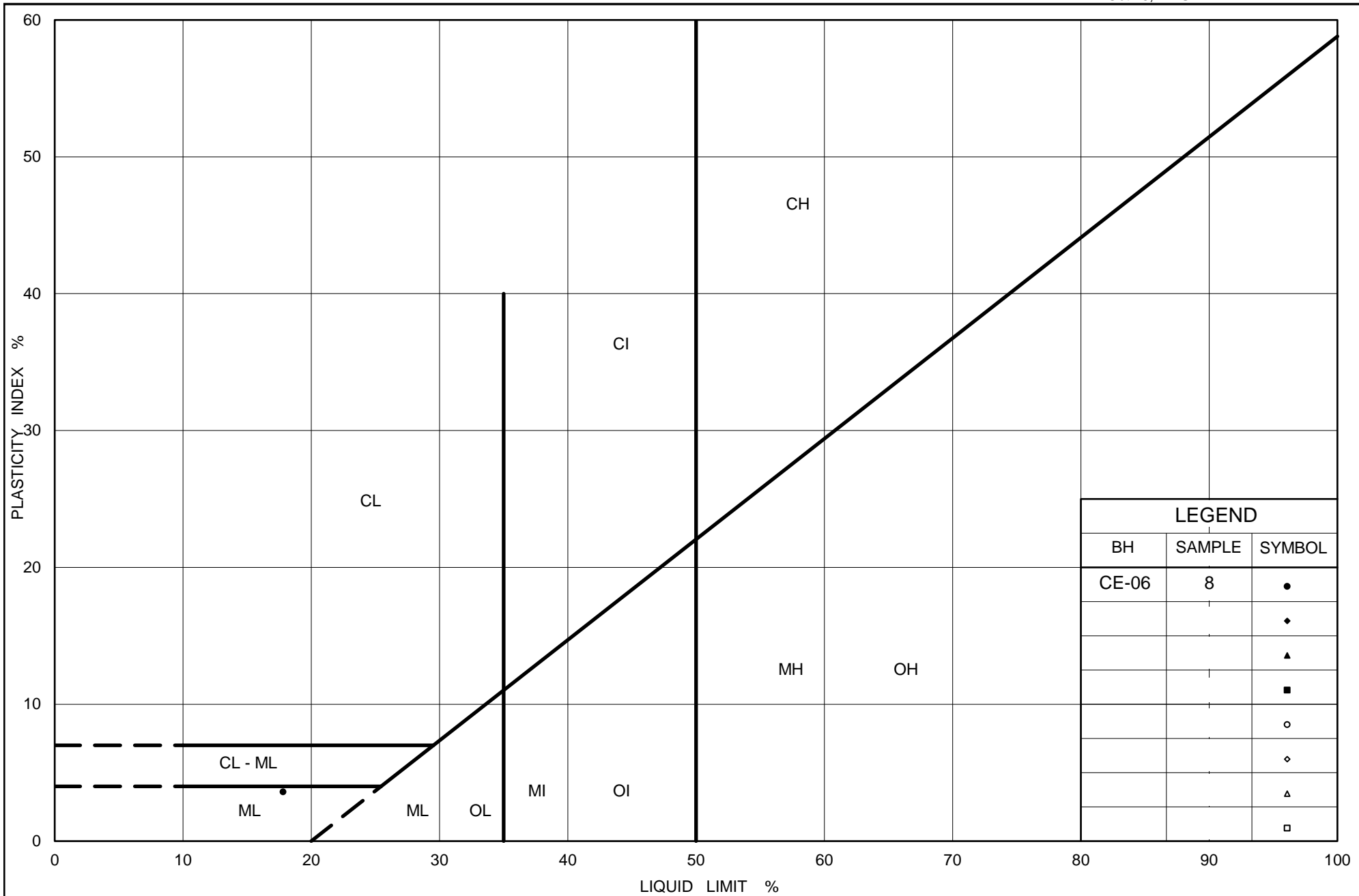
PLASTICITY CHART

Clayey Silt

Figure No. C-11

Project No. 1668512

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Ontario

PLASTICITY CHART Silt

Figure No. C-12

Project No. 1668512

Checked By: SMM



APPENDIX D

Analytical Testing

Your P.O. #: 1668512-1000
Your Project #: 1668512
Site Location: HWY 400/89
Your C.O.C. #: 81813

Attention: David Marmor

Golder Associates Ltd
Mississauga - Standing Offer
6925 Century Ave
Suite 100
Mississauga, ON
CANADA L5N 7K2

Report Date: 2017/11/17
Report #: R4862054
Version: 2 - Revision

CERTIFICATE OF ANALYSIS – REVISED REPORT

MAXXAM JOB #: B7K6177

Received: 2017/09/20, 17:04

Sample Matrix: Soil
Samples Received: 1

Analyses	Date		Date Analyzed	Laboratory Method	Reference
	Quantity	Extracted			
Chloride (20:1 extract)	1	N/A	2017/09/27	CAM SOP-00463	EPA 325.2 m
Conductivity	1	N/A	2017/09/27	CAM SOP-00414	OMOE E3530 v1 m
pH CaCl2 EXTRACT	1	2017/09/27	2017/09/27	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	1	2017/09/21	2017/09/27	CAM SOP-00414	SM 22 2510 m
Sulphate (20:1 Extract)	1	N/A	2017/09/27	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:David Marmor

Golder Associates Ltd
Mississauga - Standing Offer
6925 Century Ave
Suite 100
Mississauga, ON
CANADA L5N 7K2

Your P.O. #: 1668512-1000
Your Project #: 1668512
Site Location: HWY 400/89
Your C.O.C. #: 81813

Report Date: 2017/11/17
Report #: R4862054
Version: 2 - Revision

CERTIFICATE OF ANALYSIS – REVISED REPORT

MAXXAM JOB #: B7K6177

Received: 2017/09/20, 17:04

Encryption Key

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

Ema Gitej, Senior Project Manager

Email: EGitej@maxxam.ca

Phone# (905)817-5829

=====

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 #: B7K6177
Report Date: 2017/11/17

Golder Associates Ltd
Client Project #: 1668512
Site Location: HWY 400/89
Your P.O. #: 1668512-1000
Sampler Initials: DF

RESULTS OF ANALYSES OF SOIL

Maxxam ID		FDY880	FDY880		
Sampling Date		2017/07/26	2017/07/26		
COC Number		81813	81813		
	UNITS	CE-02-SS2-SS3-SS4	CE-02-SS2-SS3-SS4 Lab-Dup	RDL	QC Batch
Calculated Parameters					
Resistivity	ohm-cm	330			5175545
Inorganics					
Soluble (20:1) Chloride (Cl)	ug/g	1600		80	5182876
Conductivity	umho/cm	3010	3010	2	5184524
Available (CaCl2) pH	pH	8.01			5184263
Soluble (20:1) Sulphate (SO4)	ug/g	<20	<20	20	5182878
RDL = Reportable Detection Limit					
QC Batch = Quality Control Batch					
Lab-Dup = Laboratory Initiated Duplicate					

Maxxam Job #: B7K6177
Report Date: 2017/11/17

Golder Associates Ltd
Client Project #: 1668512
Site Location: HWY 400/89
Your P.O. #: 1668512-1000
Sampler Initials: DF

TEST SUMMARY

Maxxam ID: FDY880
Sample ID: CE-02-SS2-SS3-SS4
Matrix: Soil

Collected: 2017/07/26
Shipped:
Received: 2017/09/20

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5182876	N/A	2017/09/27	Alina Dobreanu
Conductivity	AT	5184524	N/A	2017/09/27	Neil Dassanayake
pH CaCl2 EXTRACT	AT	5184263	2017/09/27	2017/09/27	Tahir Anwar
Resistivity of Soil		5175545	2017/09/27	2017/09/27	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5182878	N/A	2017/09/27	Alina Dobreanu

Maxxam ID: FDY880 Dup
Sample ID: CE-02-SS2-SS3-SS4
Matrix: Soil

Collected: 2017/07/26
Shipped:
Received: 2017/09/20

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Conductivity	AT	5184524	N/A	2017/09/27	Neil Dassanayake
Sulphate (20:1 Extract)	KONE/EC	5182878	N/A	2017/09/27	Alina Dobreanu

Maxxam Job #: B7K6177
Report Date: 2017/11/17

Golder Associates Ltd
Client Project #: 1668512
Site Location: HWY 400/89
Your P.O. #: 1668512-1000
Sampler Initials: DF

GENERAL COMMENTS

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

Package 1	6.0°C
-----------	-------

Revised report (2017/11/17): Sample ID has been amended.

Results relate only to the items tested.

Maxxam Job #: B7K6177
Report Date: 2017/11/17

QUALITY ASSURANCE REPORT

Golder Associates Ltd
Client Project #: 1668512
Site Location: HWY 400/89
Your P.O. #: 1668512-1000
Sampler Initials: DF

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
5182876	Soluble (20:1) Chloride (Cl)	2017/09/27	107	70 - 130	104	70 - 130	<20	ug/g	NC	35
5182878	Soluble (20:1) Sulphate (SO ₄)	2017/09/27	115	70 - 130	105	70 - 130	<20	ug/g	NC	35
5184263	Available (CaCl ₂) pH	2017/09/27			100	97 - 103			0.42	N/A
5184524	Conductivity	2017/09/27			99	90 - 110	<2	umho/cm	0	10

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 (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 $\leq 2 \times \text{RDL}$).

Maxxam Job #: B7K6177
Report Date: 2017/11/17

Golder Associates Ltd
Client Project #: 1668512
Site Location: HWY 400/89
Your P.O. #: 1668512-1000
Sampler Initials: DF

VALIDATION SIGNATURE PAGE

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



Ewa Pranjić, M.Sc., C.Chem, Scientific Specialist

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.

6740 Campobello Road, Mississauga, Ontario L5N 2L8
Phone: 905-817-5700 Fax: 905-817-5779 Toll Free: 800-563-6266
CAM FCD-01191/2

CHAIN OF CUSTODY RECORD 81813 Page 1 of 1

Invoice Information		Report Information (if differs from invoice)		Project Information (where applicable)		Turnaround Time (TAT) Required	
Company Name: Golder Associates		Company Name:		Quotation #:		<input type="checkbox"/> Regular TAT (5-7 days) Most analyses <input checked="" type="checkbox"/> PLEASE PROVIDE ADVANCE NOTICE FOR RUSH PROJECTS	
Contact Name: David Marmor		Contact Name:		P.O. # / A/E #: 1668512-1000		Rush TAT (Surcharges will be applied) <input type="checkbox"/> 1 Day <input type="checkbox"/> 2 Days <input type="checkbox"/> 3-4 Days	
Address: 6925 Century Ave. Suite #100 Mississauga ON		Address:		Project #: 1668512			
Phone: 905-567-4444 Fax: 905-567-6561		Phone: Fax:		Site Location: HWY 400/89			
Email: david-marmor@golder.com		Email:		Site #:		Date Required:	
				Sampled By: D.F.			
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			
<input type="checkbox"/> Table 1	<input type="checkbox"/> Res/Park <input type="checkbox"/> Med/ Fine	<input type="checkbox"/> CCME <input type="checkbox"/> Sanitary Sewer Bylaw	# OF CONTAINERS SUBMITTED	FIELD FILTERED (CIRCLE) Metals /Hg/Cr/Vl	BTEX/PHC E1	PHCS F2 - F4	VOCs
<input type="checkbox"/> Table 2	<input type="checkbox"/> Ind/Comm <input type="checkbox"/> Coarse	<input type="checkbox"/> MISA <input type="checkbox"/> Storm Sewer Bylaw					
<input type="checkbox"/> Table 3	<input type="checkbox"/> Agri/ Other	<input type="checkbox"/> PWQO Region					
<input type="checkbox"/> Table		<input type="checkbox"/> Other (Specify)					
FOR RSC (PLEASE CIRCLE) Y / N		<input type="checkbox"/> REG 558 (MIN. 3 DAY TAT REQUIRED)					
Include Criteria on Certificate of Analysis: Y / N				HOLD- DO NOT ANALYZE			
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	REFER TO BACK OF COC REG 153 ICPMS METALS REG 153 METALS (Pb, Cr VI, ICPMS Metals, HWS - B) G/OSIIVITY Package (PH, Sulphate, chloride, conductivity) HOLD- DO NOT ANALYZE		
1	LE-02-SS2-SS3-SS4	2017/07/26	AM	Soil			
2							
3							
4							
5							
6							
7							
8							
9							
10							
REINQUISHED BY: (Signature/Print)		DATE: (YYYY/MM/DD)	TIME: (HH:MM)	RECEIVED BY: (Signature/Print)	DATE: (YYYY/MM/DD)	TIME: (HH:MM)	MAXXAM JOB #
Katie Allen - Katie Nero		2017/09/20	5:03 PM	[Signature]	2017/09/20	12:04	

Your Project #: 1668512
Site Location: HWY 400/89
Your C.O.C. #: 60260

Attention: David Marmor

Golder Associates Ltd
6925 Century Ave
Suite 100
Mississauga, ON
CANADA L5N 7K2

Report Date: 2018/04/24
Report #: R5089952
Version: 2 - Revision

CERTIFICATE OF ANALYSIS – REVISED REPORT

MAXXAM JOB #: B867737

Received: 2018/03/27, 10:34

Sample Matrix: Soil
Samples Received: 3

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Reference
Chloride (20:1 extract)	3	N/A	2018/04/03	CAM SOP-00463	EPA 325.2 m
Conductivity	3	N/A	2018/03/29	CAM SOP-00414	OMOE E3530 v1 m
pH CaCl2 EXTRACT	3	2018/04/02	2018/04/02	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	3	2018/03/27	2018/03/29	CAM SOP-00414	SM 23 2510 m
Sulphate (20:1 Extract)	3	N/A	2018/04/03	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.

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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.

Your Project #: 1668512
Site Location: HWY 400/89
Your C.O.C. #: 60260

Attention: David Marmor

Golder Associates Ltd
6925 Century Ave
Suite 100
Mississauga, ON
CANADA L5N 7K2

Report Date: 2018/04/24
Report #: R5089952
Version: 2 - Revision

CERTIFICATE OF ANALYSIS – REVISED REPORT

MAXXAM JOB #: B867737

Received: 2018/03/27, 10:34

Encryption Key

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

Ema Gitej, Senior Project Manager

Email: EGitej@maxxam.ca

Phone# (905)817-5829

=====

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 #: B867737
Report Date: 2018/04/24

Golder Associates Ltd
Client Project #: 1668512
Site Location: HWY 400/89
Sampler Initials: DMF

SOIL CORROSIVITY PACKAGE (SOIL)

Maxxam ID		GIJ130	GIJ131	GIJ132			GIJ132		
Sampling Date		2018/02/22	2018/02/26	2018/02/28			2018/02/28		
COC Number		60260	60260	60260			60260		
	UNITS	CE-05 SA6	CE-06 SA9	CE-04 SA5	RDL	QC Batch	CE-04 SA5 Lab-Dup	RDL	QC Batch
Calculated Parameters									
Resistivity	ohm-cm	2300	3700	2000		5458500			
Inorganics									
Soluble (20:1) Chloride (Cl)	ug/g	200	<20	220	20	5465322	220	20	5465322
Conductivity	umho/cm	428	271	501	2	5462448			
Available (CaCl2) pH	pH	7.87	7.76	7.82		5462934			
Soluble (20:1) Sulphate (SO4)	ug/g	<20	86	<20	20	5465323	<20	20	5465323
RDL = Reportable Detection Limit									
QC Batch = Quality Control Batch									
Lab-Dup = Laboratory Initiated Duplicate									

Maxxam Job #: B867737
Report Date: 2018/04/24

Golder Associates Ltd
Client Project #: 1668512
Site Location: HWY 400/89
Sampler Initials: DMF

TEST SUMMARY

Maxxam ID: GIJ130
Sample ID: CE-05 SA6
Matrix: Soil

Collected: 2018/02/22
Shipped:
Received: 2018/03/27

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5465322	N/A	2018/04/03	Deonarine Ramnarine
Conductivity	AT	5462448	N/A	2018/03/29	Tahir Anwar
pH CaCl2 EXTRACT	AT	5462934	2018/04/02	2018/04/02	Surinder Rai
Resistivity of Soil		5458500	2018/03/29	2018/03/29	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5465323	N/A	2018/04/03	Alina Dobreanu

Maxxam ID: GIJ131
Sample ID: CE-06 SA9
Matrix: Soil

Collected: 2018/02/26
Shipped:
Received: 2018/03/27

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5465322	N/A	2018/04/03	Deonarine Ramnarine
Conductivity	AT	5462448	N/A	2018/03/29	Tahir Anwar
pH CaCl2 EXTRACT	AT	5462934	2018/04/02	2018/04/02	Surinder Rai
Resistivity of Soil		5458500	2018/03/29	2018/03/29	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5465323	N/A	2018/04/03	Alina Dobreanu

Maxxam ID: GIJ132
Sample ID: CE-04 SA5
Matrix: Soil

Collected: 2018/02/28
Shipped:
Received: 2018/03/27

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5465322	N/A	2018/04/03	Deonarine Ramnarine
Conductivity	AT	5462448	N/A	2018/03/29	Tahir Anwar
pH CaCl2 EXTRACT	AT	5462934	2018/04/02	2018/04/02	Surinder Rai
Resistivity of Soil		5458500	2018/03/29	2018/03/29	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5465323	N/A	2018/04/03	Alina Dobreanu

Maxxam ID: GIJ132 Dup
Sample ID: CE-04 SA5
Matrix: Soil

Collected: 2018/02/28
Shipped:
Received: 2018/03/27

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5465322	N/A	2018/04/03	Deonarine Ramnarine
Sulphate (20:1 Extract)	KONE/EC	5465323	N/A	2018/04/03	Alina Dobreanu

GENERAL COMMENTS

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

Package 1	1.0°C
-----------	-------

Revised report (2018/04/24): Sample IDs have been updated as requested.

Sample GIJ130 [CE-05 SA6] : pH, Chloride, Sulphate, Conductivity/Resistivity: Sample submitted and analyzed past the recommended sample hold time. This may increase the variability associated with these results.

Sample GIJ131 [CE-06 SA9] : pH, Chloride, Sulphate, Conductivity/Resistivity: Sample submitted and analyzed past the recommended sample hold time. This may increase the variability associated with these results.

Sample GIJ132 [CE-04 SA5] : pH, Chloride, Sulphate, Conductivity/Resistivity: Sample submitted and analyzed past the recommended sample hold time. This may increase the variability associated with these results.

Results relate only to the items tested.

QUALITY ASSURANCE REPORT

Golder Associates Ltd
Client Project #: 1668512
Site Location: HWY 400/89
Sampler Initials: DMF

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
5462448	Conductivity	2018/03/29			99	90 - 110	<2	umho/cm	0.93	10
5462934	Available (CaCl ₂) pH	2018/04/02			100	97 - 103			1.4	N/A
5465322	Soluble (20:1) Chloride (Cl)	2018/04/03	NC	70 - 130	105	70 - 130	<20	ug/g	0.79	35
5465323	Soluble (20:1) Sulphate (SO ₄)	2018/04/03	101	70 - 130	98	70 - 130	<20	ug/g	NC	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)

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 <= 2x RDL).

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

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.

CHAIN OF CUSTODY RECORD 60260 Page 1 of 1

Invoice Information		Report Information (if differs from invoice)		Project Information (where applicable)		Turnaround Time (TAT) Required	
Company Name: <u>Golder Associates Ltd.</u>		Company Name:		Quotation #:		<input checked="" type="checkbox"/> Regular TAT (5-7 days) Most analyses	
Contact Name: <u>David Marmor</u>		Contact Name:		P.O. #/ AFEB:		PLEASE PROVIDE ADVANCE NOTICE FOR RUSH PROJECTS	
Address: <u>100-6925 Century Ave</u>		Address:		Project #: <u>1668512</u>		Rush TAT (Surcharges will be applied)	
<u>Mississauga, ON, L5N 7K2</u>				Site Location: <u>Hwy 400/89</u>		<input type="checkbox"/> 1 Day <input type="checkbox"/> 2 Days <input type="checkbox"/> 3-4 Days	
Phone: <u>905-567-4444</u> Fax: <u>905-567-6561</u>		Phone:		Site #:		Date Required:	
Email: <u>David.Marmor@golder.com</u>		Email:		Sampled By: <u>DMF</u>		Rush Confirmation #:	
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 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 <input checked="" type="checkbox"/> 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 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 (Hb, Cr, V, ICPMS Metals, HWS - B) Corrosivity Package		CUSTODY SEAL <input checked="" type="checkbox"/> Present <input type="checkbox"/> Intact COOLER TEMPERATURES 0/1/2 COOLING MEDIA PRESENT: <input type="checkbox"/> Y <input checked="" type="checkbox"/> N COMMENTS	
Include Criteria on Certificate of Analysis: <input checked="" type="checkbox"/> Y <input type="checkbox"/> 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 / GVI	HOLD - DO NOT ANALYZE
1 4005BLCE-01 SA6		2018/02/22	am	Soil	1	N	X
2 4005BLCE-03 SA9		2018/02/26	am	Soil	1	N	X
3 4005BLCE-02 SA5		2018/02/28	am	Soil	1	N	X
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>Jeremy Libow</u>		2018/03/27	10:30	<u>[Signature]</u>		2018/03/27	10:34

27-Mar-18 10:34

Ema Gitej
B867737

GID ENV-995



APPENDIX E

Non-Standard Special Provisions and Notice to Contractor

DEWATERING SYSTEM - Item No.
TEMPORARY FLOW PASSAGE SYSTEM - Item No.

Special Provision No. 517F01

July 2017

Amendment to OPSS 517, November 2016

Design Storm Return Period and Preconstruction Survey Distance

517.01 SCOPE

Section 517.01 of OPSS 517 is deleted in its entirety and replaced with the following:

This specification covers the requirements for the design, operation, and removal of a dewatering or temporary flow passage system or both to control water during construction for the culverts for Highway 400/89 and the control of the water prior to discharge to the natural environment and sewer systems.

517.04 SUBMISSION AND DESIGN REQUIREMENTS

517.04.01 Design Requirements

Subsection 517.04.01 of OPSS 517 is amended by deleting the first paragraph in its entirety and replacing it with the following:

A dewatering or temporary flow passage system or both shall be designed to control water at the locations specified in the Contract Documents and at any other location where a system is necessary to complete the work. The design of the system shall be sufficient to permit the work at each location to be carried out as specified in the Contract Documents.

Subsection 517.04.01 of OPSS 517 is further amended by deleting the second last paragraph in its entirety and replacing it with the following:

Temporary flow passage systems shall be designed, as a minimum, for a 2 year design storm return period and groundwater discharge, except for the work specified in Table A. For the work specified in Table A, the temporary flow passage system shall be designed, as a minimum, for the design storm return period specified in Table A and groundwater discharge. A longer return period shall be used when determined appropriate for the work.

Intensity-Duration Factor (IDF) curve location, site specific minimum return period, return period flow estimates, and other information is provided in Table A. The IDF information can be accessed through the MTO IDF Curve Look up Tool on the Drainage and Hydrology page of MTO's website. The return period flow estimates do not include flow volumes from groundwater discharge. The Owner specifically excludes these flow estimates from the warranty in the Reliance on Contract Documents subsection of OPSS 100, MTO General Conditions of Contract.

Table A

IDF Curve Location	Latitude: *			Longitude: *		
Temporary Flow Passage Systems						
Site Name / Station Reference	Minimum Return Period (Years)	Return Period Flow Estimates (m³/s)				Design Engineer Requirements (Note 1)
		2 Year	5 Year	10 Year	25 Year	
Culvert Structure No. 30-568/C Highway 400/89 N-E/W Ramp	2					Yes
Culvert Structure No. 30-399/C Highway 400/89 SBL Station 10+760	2					Yes
Dewatering Systems						
Site Name / Station Reference	Preconstruction Survey Distance (Note 2) (m)					Design Engineer Requirements (Note 1)
Culvert Structure No. 30-568/C Highway 400/89 N-E/W Ramp	50					Yes
Culvert Structure No. 30-399/C Highway 400/89 SBL Station	50					Yes
Note:						
1. “Yes” means the design Engineer and design-checking Engineer shall have a minimum of 5 years of experience in designing systems of similar nature and scope to the required work. “No” means a minimum experience level is not required for the design Engineer and design-checking Engineer.						
2. “N/A” indicates a preconstruction survey is not required.						

OBSTRUCTIONS – Item No.

Notice to Contractor

The Contactor shall be alerted to the potential presence of cobbles and boulders within the fill and the native deposits. The Contractor shall also be alerted to the presence of a thrust block adjacent to Culverts C-44A and C-44B, as indicated on the Contract Drawings. Consideration of the presence of these obstructions must be made in the selection of appropriate equipment and procedures for excavations and installation of temporary protection systems.

PROTECTION SYSTEM – Item No.

Special Provision

Amendment to OPSS 539, November 2014

593.07.02 Removal of Protection Systems

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

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

Where piles are left in place, the top shall be removed to at least 1.5 m below the finished grade or ground level.

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

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

VIBRATION MONITORING – Item No.

Special Provision

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- 10.0 BASIS OF PAYMENT**

1.0 SCOPE

This special provision describes requirements for vibration monitoring during the installation of deep foundations associated with the Highway 400/89 underpass, and installation of temporary protection systems at Culvert Structure Nos. 30-399/C and 30-568/C .

2.0 REFERENCES

The subsurface conditions at the site are described in the following Foundation Investigation Reports:

Culvert Extensions (Structure Site Nos. 30-568/C and 30-399/C) for Reconstruction of Highway 400/89 Interchange
Town Of Innisfil, Simcoe County
Ministry Of Transportation, Ontario
G.W.P. 2438-13-00

Highway 400/89 Underpass Replacement Structure Site No. 30-256, Reconstruction of Highway 400/89 Interchange
Town Of Innisfil, Simcoe County
Ministry Of Transportation, Ontario
G.W.P. 2438-13-00

3.0 DEFINITIONS

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

Contractor's Engineer means an Engineer with a minimum of five (5) years' experience in the field of installation of piling and vibration monitoring or, alternatively, with expertise demonstrated by providing satisfactory quality verification services for a minimum of two (2) projects of similar scope to the Contract. The Contractor's Engineer shall be retained by the Contractor to ensure general conformance with the Contract Documents and issue certificates of conformance.

Peak Particle Velocity (PPV) means the maximum component velocity in millimetres per second that ground particles move as a result of energy released from vibratory construction operations.

Pre-Construction Condition Survey means a detailed record, accompanied by film or video, as necessary, of the condition of private or public property, prior to the commencement of vibratory construction operations.

Post-Construction Condition Survey means a detailed record, accompanied by film or video, as necessary, of the condition of private or public property, after completion of vibratory construction operations.

4.0 DESIGN AND SUBMISSION REQUIREMENTS

4.1 Submission Requirements

The Contractor/Contractor's Engineer shall submit details of the vibration monitoring plan to the Contract Administrator for information purposes. The submittals shall satisfy the specifications and at a minimum contain the following specific information:

- a) Equipment and methods used by the Contractor to perform the work that may cause undue vibration.
- b) Qualifications of vibration monitoring specialist.
- c) Details regarding proposed instrumentation.
- d) Proposed location of instruments adjacent to the on the residences, utilities, wells, or other potentially vibration-sensitive structures within a 250 m radius from the protection system(s), as applicable.
- e) Action plan to be taken to adjust protection system installation methods if readings show vibrations exceeding tolerable levels.

6.0 EQUIPMENT

6.1 Vibration Monitoring Equipment

All vibration monitoring equipment shall be capable of measuring and recording ground vibration PPV up to 200 mm/s in the vertical, transverse, and radial directions. The equipment shall have been calibrated within the last 12 months either by the manufacturer or other qualified agent. Proof of calibration shall be submitted to the Contract Administrator prior to commencement of any monitoring operations.

7.0 CONSTRUCTION

7.1 Pre- and Post-Construction Condition Surveys

A Pre-Construction Condition Survey and Post-Construction Condition Survey shall be prepared for all buildings, utilities, structures, water wells, and facilities within 250 m of the Highway 400/89 underpass, and for each protection system location.

7.1.1 Pre-Construction Condition Surveys

The standard inspection procedure shall include the provision of an explanatory letter to the owner or occupant and owner with a formal request for permission to carry out an inspection.

The Pre-Construction Condition Survey, at each structure/well within a 250 m radius of the Highway 400/89 underpass and each protection system on the project, shall be completed a minimum of two (2) weeks prior to commencement of installation of the protection system(s). Only one Pre-Construction Condition Survey per structure or facility is required to be carried out in advance of temporary protection system installation, unless more than six (6) months will elapse between these operations, in which case an interim inspection will be required.

The Pre-Construction Condition Survey shall include, as a minimum, the following information:

- a) Type of structure, including type of construction and if possible, the date when built.
- b) Identification and description of existing differential settlements, including visible cracks in walls, floors, and ceilings, including a diagram, if applicable, room-by-room. All other apparent structural and cosmetic damage or defects shall also be noted. Defects shall be described, including dimensions, wherever possible.
- c) Digital photographs or digital video or both, as necessary, to record areas of significant concern.

Photographs and videos shall be clear and shall accurately represent the condition of the property. Each photograph or video shall be clearly labelled with the location and date taken.

A copy of the Pre-Construction Construction Survey limited to a single residence or property, including copies of any photographs or videos that may form part of the report, shall be provided to the owner of that residence or property, upon request.

7.1.2 Post-Construction Condition Surveys

The standard inspection procedure shall include the provision of an explanatory letter to the owner or occupant and owner with a formal request for permission to carry out an inspection.

A Post-Construction Condition Survey at each structure within a 250 m radius of the bridge or protection system(s), is required within two (2) months of completion of the installation of deep foundations for the Highway 400/89 underpass, and protection systems on this contract.

The Post-Construction Condition Survey shall include, as a minimum, the following information:

- a) Identification and description of existing differential settlements, including visible cracks in walls, floors, and ceilings, including a diagram, if applicable, room-by-room. All other apparent structural

and cosmetic damage or defects shall also be noted. Defects shall be described, including dimensions, wherever possible.

- b) Digital photographs or digital video or both, as necessary, to record areas of significant concern.
- c) Comparison between pre-condition survey documented concerns and post-condition concerns.

Photographs and videos shall be clear and shall accurately represent the condition of the property. Each photograph or video shall be clearly labelled with the location and date taken.

A copy of the Post-Construction Condition Survey limited to a single residence or property, including copies of any photographs or videos that may form part of the report, shall be provided to the owner of that residence or property, upon request. The report shall confirm that there have been no changes to the property between the Pre-Construction Condition Survey and the Post-Construction Condition Survey as a result of the installation of deep foundations and protection systems.

7.2 Monitoring

The vibration monitoring equipment shall be placed on the ground surface in the vicinity of each foundation element or protection system, and on the ground surface at radial distances of 25 m, 50 m, and 100 m from the foundation element or protection system locations at the bridge site(s) or culvert site(s). The Contractor shall take readings continuously during deep foundation installation and during installation of temporary protection systems, and shall immediately notify the Contract Administrator if the vibrations exceed the limits specified herein.

The vibrations measured on private structures, wells, etc. shall not exceed 25 mm/s. Those measured on utilities, if applicable, shall not exceed 10 mm/s.

If the readings are not within the limits stated above, the Contractor must alter the installation procedures until the vibrations at the various locations are within acceptable levels.

7.3 Records

The Contractor/Contractor's Engineer shall submit details of the vibration monitoring to the Contract Administrator as follows:

- a) The time/duration of each reading.
- b) Construction operations (i.e. installation of sheet piling) and timing of such relative to the readings.
- c) Details of exceedances and modifications to operations.
- d) Final report containing all relevant data including vibration monitoring and Pre- and Post-Construction Condition Surveys.

10.0 BASIS OF PAYMENT

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

WORKING SLAB - Item No.

Non-Standard Special Provision

1.0 Scope

This Special Provision covers the requirements for the supply and placement of a concrete working slab under the culverts and retaining wall for the Highway 400 and 89 site.

2.0 References

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

Ontario Provincial Standard Specifications, Construction
OPSS 902 Excavating and Backfilling - Structures

3.0 Definitions - Not Used

4.0 Design and Submission Requirements - Not Used

5.0 Materials

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

6.0 EQUIPMENT - Not Used

7.0 CONSTRUCTION

7.01 Excavation

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

7.02 Protection of Founding Soil

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

7.04 Dewatering

Dewatering shall be carried out according to OPSS 902.

8.0 Quality Assurance - Not Used

9.0 Measurement for Payment - Not Used

10.0 Basis of Payment

10.01 Working Slab - Item

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

END OF SECTION

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

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