Foundation Investigation Report

Hwy 401 / Sixteen Mile Creek Culvert Replacement, Site No. 10-592/C (Latitude: 43.50832; Longitude: -79.95266); Detail Design for Structural Culvert Rehabilitation/Replacement; Ministry of Transportation, Ontario; G.W.P. 2219-14-00

Submitted to:

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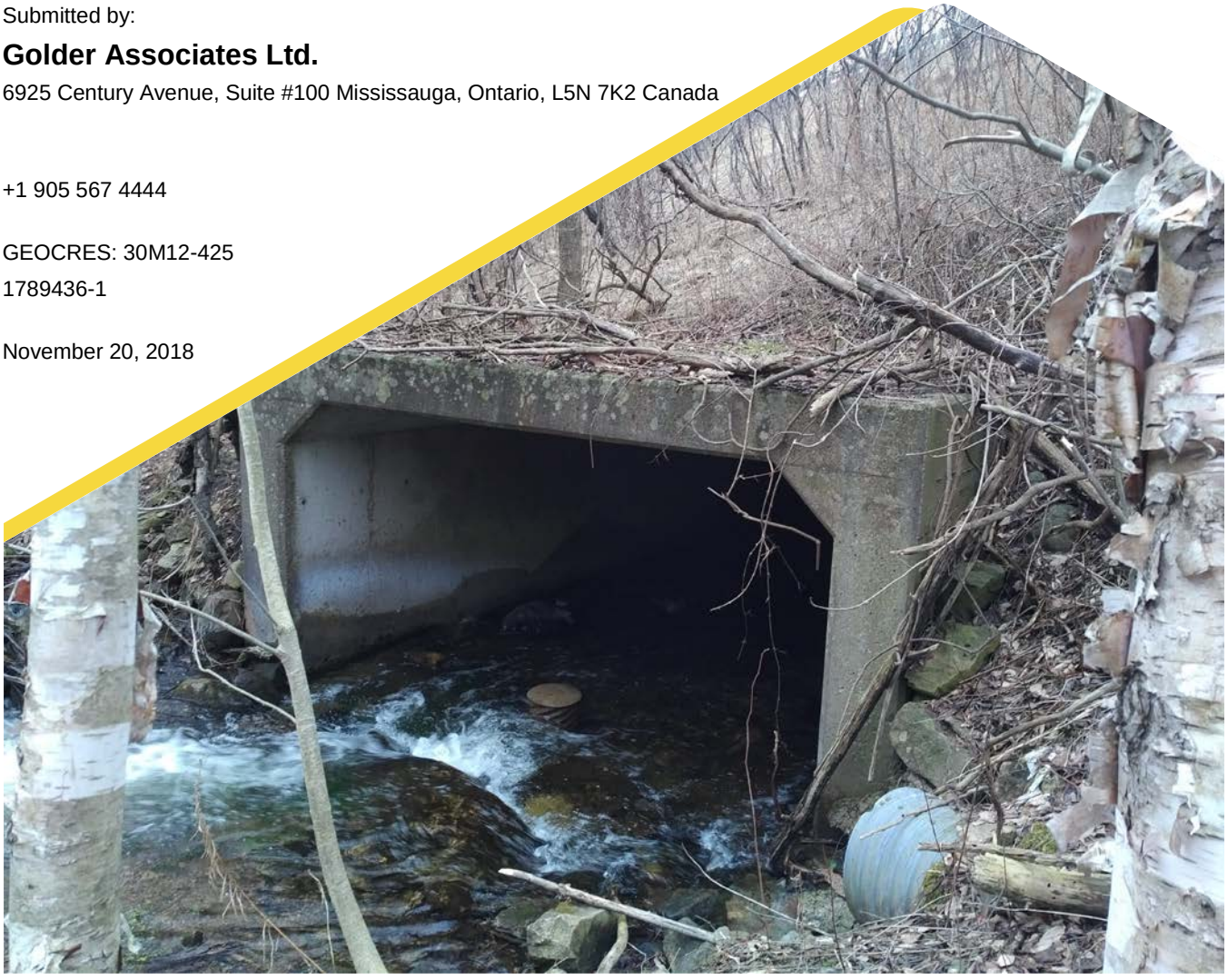
GEOCRES: 30M12-425
1789436-1

November 20, 2018



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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by AIA Engineers Ltd. (AIA) on behalf of the Ministry of Transportation, Ontario (MTO) to provide Foundation Engineering services for the replacement of the Sixteen Mile Creek structural culvert located at about Station (STA) 17+940 on Highway 401 in the Regional Municipality of Halton (MTO Structural Site No. 10-592/C), approximately 450 m east of Appleby Line in Milton, Ontario (see key plan on Drawing 1).

The Terms of Reference and the Scope of Work for the foundation investigation are outlined in MTO's Request for Quotation, dated September 2017. Golder's proposal for the foundation engineering services associated with the culvert replacement is contained in Section 3.5 of AIA's Technical Proposal for this assignment.

2.0 SITE DESCRIPTION

The existing open box concrete culvert is about 122 m in total length, about 3.1 m wide and 1.6 m high. The upstream and downstream invert elevations of the existing culvert are at about Elevation 238.9 m and 234.5 m. The structure is located below the Highway 401 embankment that is up to approximately 11 m high, with up to about 10.2 m of soil cover above the existing culvert. Details of the existing culvert are summarized in Table 1 following the text of this report.

In general, the culvert is located along the Niagara Escarpment and the topography in the area varies from rolling terrain to nearby exposed bedrock faces (i.e. cliffs) and lakes. The area is generally used for agriculture and recreational purposes with the outlet end of the culvert located within the Region of Halton's Kelso Conservation Area. Sixteen Mile Creek flows through the culvert from northwest to southeast and is formed within a valley incised into the natural terrain and eventually drains into Kelso Lake just beyond the outlet of the culvert. The lands adjacent to the creek are generally well vegetated with trees. The ground surface at the borehole locations advanced for the culvert investigation, including through the existing Highway 401 embankment, varies between about Elevation 234.6 m to 249.4 m, referenced to Geodetic datum. The Highway 401 alignment in the project area is generally oriented in a southwest-northeast direction; for the purposes of this report, the direction of east-west along the highway, and north and south for the upstream and downstream ends of the culvert, respectively have been assumed.

3.0 INVESTIGATION PROCEDURES

The fieldwork for the foundations investigation associated with the structural culvert Site No.10-592/C was carried out between March 11 and April 4, 2018, during which time a total of six boreholes were advanced in the immediate vicinity of the culvert alignment as shown in plan on Drawing 1.

The field investigation was carried out using a variety of drilling equipment due to the varying levels of accessibility and restrictions associated with the terrain at the culvert site. The details of the drilling equipment and suppliers are listed below.

Drilling Equipment	Supplied and Operated By
Truck-Mounted Diedrich D90	Walker Drilling Ltd. of Utopia, Ontario
Portable Equipment	OGS Drilling Inc. of Almonte, Ontario

The boreholes drilled by the truck-mounted D90 drill rig were advanced through the overburden using 210 mm outer diameter (O.D.), 108 mm inner diameter (I.D.) hollow stem augers. The boreholes completed with the portable equipment were advanced through the overburden using BW sized casing (73 mm O.D.) with wash boring techniques utilizing AW (57 mm O.D.) casing with a diamond casing shoe to advance between samples. As a result, the recovery within the AW casing between SPT sampling intervals was collected and placed in core boxes and photographs taken to supplement the investigation results (see Figure 1). Soil samples were obtained at intervals of depth of about 0.75 m and 1.5 m using a 50 mm O.D. split-spoon sampler operated by an automatic hammer on the drill rigs, performed in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586). Boreholes advanced by portable equipment employed a full-weight hammer lifted manually and dropped from the SPT height.

The results of the SPT testing as presented on the Record of Borehole Sheets are unmodified (not standardized for hammer efficiency, borehole diameter, rod length, etc.). The samplers used in the investigation limit the maximum particle size that can be sampled and tested to about 40 mm. Therefore, particles that may exist within the soils that are larger than this dimension will not be sampled or represented in the grain size distributions. For the site stratigraphy, these larger sized particles may include glacial erratics such as cobbles and boulders.

A piezometer was installed in Boreholes 18-1 and 18-4 to allow monitoring of the groundwater level at this site. The piezometer consists of a 25 mm diameter PVC pipe, with a slotted screen sealed within the sandy clayey silt and sand deposit in Borehole 18-1 and within the sand and gravel and silty sand till deposits in Borehole 18-4. The borehole and annulus surrounding the piezometer pipe above the screen and sand pack were backfilled with bentonite pellets to ground surface. The piezometer installation details and water level readings are noted on the Record of Boreholes in Appendix A. All other boreholes were backfilled with bentonite upon completion of drilling in accordance with Ontario Regulation 903 (Wells) (as amended). The groundwater conditions and water levels in the open boreholes were observed during and immediately following the drilling operations and are described on the Record of Borehole sheets in Appendix A.

The fieldwork was observed by members 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 soil samples were identified in the field, placed in appropriate containers, labelled and transported to our Mississauga geotechnical laboratory where the samples underwent further visual examination and laboratory testing. All of the laboratory tests were carried out to MTO Laboratory Standards and/or ASTM Standards, as appropriate. Classification testing (water content, Atterberg limits and grain size distribution) was carried out on selected soil samples. Where gravel / cobble nests were encountered and sampled, point load strength index tests were carried out, both perpendicular to the core axis (diametral) and along the core axis (axial), to provide an indication of the point load strength index (Is_{50}) of the rock fragment type. The rock strength classification is based on the Is_{50} values as suggested in Table 3.5 of the Canadian Foundation Engineering Manual (CFEM)[1].

The results of the laboratory testing are summarized in Section 4.2, on the Record of Borehole sheets in Appendix A and on the laboratory test sheets in Appendix B.

[1] Canadian Foundation Engineering Manual. 2006. Fourth Edition, Canadian Geotechnical Society.

Four soil samples were submitted to a specialist analytical laboratory under chain of custody procedures for corrosivity package testing. The results of the analytical testing are provided in Appendix C and summarized in Section 4.4.

Borehole locations and Geodetic elevations were surveyed in the field at the as-drilled location using a GPS (Trimble XH 3.5G), having an accuracy of 0.1 m in the vertical and 0.1 m in the horizontal directions and/or relative to a fixed benchmark location on site. Where boreholes were surveyed relative to a fixed benchmark location, the as-drilled borehole locations were measured from this point and subsequently converted into MTM NAD 83 (Zone 10) coordinates and elevations obtained from the digital terrain model provided by AIA. The borehole locations, ground surface elevations and depths drilled are provided below.

Culvert Location	Borehole I.D.	Location		Ground Surface Elevation (m)	Depth of Borehole (m)
		Northing (m) / Latitude (º)	Easting (m) / Longitude (º)		
Highway 401 – STA 17+940 (STA 17+884 to STA17+966)	18-1	4,818,779.1 / 43.508038	268,079.0 / -79.954156	240.0	6.1
	18-2	4,818,791.9 / 43.508154	268,085.2 / -79.954070	239.7	5.5
	18-3	4,818,781.0 / 43.508057	268,109.3 / -79.953772	249.4	20.1
	18-4	4,818,812.1 / 43.508339	268,167.6 / -79.953053	247.7	21.6
	18-5	4,818,804.8 / 43.508276	268,208.6 / -79.952545	234.8	9.8
	18-6	4,818,824.6 / 43.508454	268,214.9 / -79.952469	234.6	9.8

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

The section of Highway 401 where Sixteen Mile Creek crosses is located within the Niagara Escarpment physiographic region, as delineated by *The Physiography of Southern Ontario* (Chapman and Putman, 1984)[2]. This area of the Niagara Escarpment is bordered by the Flamborough Plain and the Peel Plain physiographic regions to the west and east, respectively. The Niagara Escarpment region is characterized by its vertical dolostone cliffs. At the culvert location, Highway 401 crosses an old river valley cut through the escarpment. The Peel Plain physiographic region is located to the east of the Niagara Escarpment and is generally characterized by a thin clay deposit overlying till deposits. The Flamborough Plain physiographic region is located on top of the escarpment to

[2] Chapman, L.J. and Putnam, D.F., 1984: The Physiography of Southern Ontario, Third Edition. Ontario Geological Survey, Special Volume 2.

the west of the site. This region has few drumlins and multiple swamps. It is a limestone plain with shallow cover generally consisting of bouldery glacial tills or sands and gravels.

4.2 General Overview of Local Subsurface Conditions

The detailed subsurface soil and groundwater conditions as encountered in the boreholes advanced during this investigation, together with the results of the laboratory tests carried out on selected soil samples, are presented on the Record of Borehole sheets and the laboratory test sheets in Appendices A and B, respectively. The stratigraphic boundaries shown on the Record of Boreholes are inferred from non-continuous sampling, observations of drilling progress and in situ testing and are approximate. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Further, subsurface conditions will vary between and beyond the borehole locations.

In general, the soil stratigraphy at the culvert site consists of surficial layers of embankment fill (Highway 401) or topsoil underlain by an upper granular deposit primarily consisting of sand to sand and gravel which is in turn underlain by a non-cohesive to cohesive till deposit. The till deposit is typically underlain by a lower granular deposit on the north side of the site. On the south side of the site, closer to Kelso Lake, the topsoil is underlain directly by a clayey silt deposit which is in turn underlain by a cohesive till deposit. A detailed description of the main soil deposits / stratum encountered during the investigation is provided below.

4.2.1 Asphalt

In Boreholes 18-3 and 18-4 advanced at the Highway 401 grade, an asphalt layer approximately 200 mm to 225 mm thick was encountered.

4.2.2 Topsoil to Sandy Clayey Silt containing Organics

A 0.1 m to 0.6 m thick layer of topsoil in Boreholes 18-2 and 18-6 and sandy clayey silt containing organics in Boreholes 18-1 and 18-5 was encountered at ground surface.

The SPT ‘N’-values measured within the surficial organic deposit range between 4 blows and 10 blows per 0.3 m of penetration, suggesting a firm to stiff consistency.

The natural water content measured on two samples of the sandy clayey silt containing organics were about 28 and 29 per cent.

4.2.3 Embankment Fill

Embankment fill, approximately 10.4 m and 11.7 m thick, was encountered below the asphalt in Boreholes 18-3 and 18-4 at Elevations 249.2 m and 247.5 m, respectively. The embankment fill consists of gravelly sand to sand and gravel, with variable amounts of silt. Although not specifically observed in the samples collected, our recent experience with trenchless crossings of major MTO highways suggests that there may be debris consisting of abandoned temporary works associated with the original culvert construction. This debris buried in the fill may consist of logs, stumps, and brush from the clearing and grubbing operations, and cobbles and/or boulders as inferred from auger grinding in Boreholes 18-3 and 18-4 (see Borehole Record for details).

The SPT ‘N’-values measured within the non-cohesive fill range between 10 blows and 64 blows per 0.3 m of penetration, indicating a compact to very dense level of compactness.

The natural water content measured on select samples of the non-cohesive embankment fill ranges between about 4 per cent and 20 per cent.

The results of grain size distribution tests completed on two samples of the sand and gravel fill are shown on Figure B1 in Appendix B.

Atterberg limits tests were carried out on two samples of the embankment fill and measured liquid limits of 21 per cent and 22 per cent, plastic limits of 14 per cent and 16 per cent, corresponding to plasticity indices of 7 per cent and 6 per cent. The test results, which are plotted on a plasticity chart on Figure B2 in Appendix B, indicate that the fines component of the material tested is a clayey silt of low plasticity.

4.2.4 Upper Granular Deposit

An upper granular deposit (1.0 m to 3.3 m thick) consisting of sand, sand and gravel, silty sand and gravel and sandy gravel, was encountered below the topsoil / sandy clayey silt with organics layer in Boreholes 18-1 and 18-2 and below the embankment fill in Boreholes 18-3 and 18-4 between Elevations 239.6 and 235.8 m. The upper 1.1 m of the deposit encountered in Borehole 18-2 contains organics. A 0.6 m to 0.7 m thick layer of sandy clayey silt with gravel was encountered within the upper granular deposit in Boreholes 18-1 and 18-2 at Elevations 238.9 m and 238.5 m, respectively. Auger grinding in Borehole 18-4 suggests the presence of cobbles and/or boulders within the deposit and cobble sized rock fragments (between 75 mm and 150 mm) were recovered in the core samples obtained during advancement of Boreholes 18-1 and 18-2 within this deposit (See Figure 1).

The SPT ‘N’-values measured within the upper granular deposit range between 7 blows and 136 blows per 0.3 m of penetration, and up to 100 blows per 0.05 m of penetration, indicating a loose to very dense level of compactness. The SPT ‘N’-values measured within the sandy clayey silt with gravel layer are 26 blows and 107 blows per 0.3 m of penetration, suggesting a very stiff to hard consistency.

The natural water content measured on select samples of the upper granular deposit are between about 9 per cent and 17 per cent. The natural water content measured on select samples of the sandy clayey silt and gravel layer were about 11 per cent and 15 per cent.

The results of grain size distribution tests completed on five samples of the upper granular deposit are shown on Figure B3 in Appendix B.

Point load strength index tests (axial and diametral) were carried out on cobble sized rock fragment recovered in the core during advancement of Boreholes 18-1 and 18-2. The corrected point load strength index values (Is_{50}) are shown on the Record of Boreholes in Appendix A. The axial and diametral Is_{50} values of 2.6 MPa and 5.0 MPa (axial) and 1.4 MPa and 2.2 MPa (diametral) were measured, respectively. Based on the laboratory Is_{50} values and the field measurement techniques, the estimated intact strength of the cobble sized fragments tested is classified as medium strong (R3, 25 MPa < UCS < 50 MPa) to very strong (R5, 100 MPa < UCS <250 MPa).

4.2.5 Glacial Till

A glacial till deposit about 2.1 m to 6.3 m thick consisting of non-cohesive and cohesive till was encountered below the upper granular deposit in Boreholes 18-1 to 18-4 and below the clayey silt deposit in Borehole 18-5. Auger grinding in Boreholes 18-3 and 18-4 suggests the presence of cobbles and/or boulders within the till deposit and cobbles (between 75 mm and 250 mm in size) were confirmed / recovered during coring to advance Boreholes 18-1, 18-2 and 18-5. Photos of the core recovery from Boreholes 18-1, 18-2 and 18-5 are provided on Figure 1 following the text of the report. Boreholes 18-1 and 18-5 were terminated in this deposit after penetrating it for lengths of 3.3 m and 5.5 m, respectively.

Non-Cohesive Glacial Till

Non-cohesive till comprised of silty sand and silty sand and gravel was encountered in Boreholes 18-1, 18-3 and 18-4.

The SPT 'N'-values measured within the non-cohesive till range between 30 blows per 0.3 m of penetration and 100 blows per 0.05 m of penetration, indicating a compact to very dense level of compactness.

The natural water content measured on samples of the non-cohesive till ranges between about 8 per cent and 17 per cent.

The results of grain size distribution tests completed on three samples of the predominantly non-cohesive till are shown on Figure B4 in Appendix B.

Atterberg limits tests were carried out on three samples of the non-cohesive till and measured liquid limits between 15 per cent and 18 per cent, plastic limits between 11 per cent and 12 per cent, and plasticity indices of 4 per cent and 6 per cent. The test results, which are plotted on a plasticity chart on Figure B5 in Appendix B, indicate that the fines component of the material tested ranges from a silt of slight plasticity to a clayey silt of low plasticity.

Cohesive Glacial Till

Cohesive till comprised of sandy clayey silt to gravelly clayey silt with sand was encountered in Boreholes 18-2, 18-3 and 18-5.

The SPT 'N'-values measured within the cohesive till range between 28 blows per 0.3 m of penetration, and 100 blows per 0.05 m of penetration, suggesting a very stiff to hard consistency.

The natural water content measured on samples of the cohesive till ranges from about 7 per cent to 21 per cent.

The results of a grain size distribution test completed on three samples of the cohesive till are shown on Figure B4 in Appendix B.

Atterberg limits tests were carried out on three samples of the cohesive till and measured liquid limits between 16 per cent and 24 per cent, plastic limits between 11 per cent and 15 per cent, and plasticity indices between 5 per cent and 9 per cent. The test results, which are plotted on a plasticity chart on Figure B5 in Appendix B, indicate that the material tested is a clayey silt of low plasticity.

Point load strength index tests (axial and diametral) were carried out on a sample of the cobble sized rock fragment recovered in the core during advancement of Borehole 18-5. The corrected point load strength index values (Is_{50}) are shown on the Record of Boreholes in Appendix A. The axial and diametral Is_{50} values measured were 12.2 MPa and 11.1 MPa, respectively. Based on the laboratory Is_{50} values and the field measurement techniques, the estimated intact strength of the cobble sized fragment tested is classified as extremely strong (R6, UCS > 250 MPa).

4.2.6 Clayey Silt

A 3.7 m and 8.2 m thick deposit of clayey silt was encountered below the topsoil to sandy clayey silt with organics deposit in Boreholes 18-5 and 18-6 and below the till deposit in Borehole 18-4 between Elevation 234.2 m and 228.5 m. The lower 1.2 m of the deposit encountered in Borehole 18-5 is described as clayey silt with gravel. Auger grinding in Borehole 18-4 suggests the presence of cobbles and/or boulders within the deposit and cobbles (between 75 mm and 100 mm in size) were confirmed during coring in Boreholes 18-5 and 18-6. Photos of the

cored soil retrieved from Boreholes 18-5 and 18-6 are provided on Figure 1 following the text of the report. Borehole 18-4 was terminated in this deposit after penetrating it for a length of 2.4 m.

The SPT 'N'-values measured within the clayey silt deposit range from 18 blows to 132 blows per 0.3 m of penetration, and up to 100 blows for 0.13 m of penetration, suggesting a very stiff to hard consistency.

The natural water content measured on samples of the clayey silt deposit range between about 14 per cent and 27 per cent.

The results of grain size distribution tests completed on six samples of the clayey silt deposit are shown on Figure B6 in Appendix B.

Atterberg limits tests were carried out on seven samples of the clayey silt deposit and measured liquid limits ranging between 24 per cent and 31 per cent, plastic limits ranging between 15 per cent and 18 per cent and plasticity indices ranging between about 6 per cent and 16 per cent. The test results, which are plotted on a plasticity chart on Figure B7 in Appendix B, indicate that the material tested is a clayey silt of low plasticity.

4.2.7 Lower Granular Deposit

A lower granular deposit consisting of sand and gravel to sandy gravel was encountered in Boreholes 18-2, 18-3 and 18-6 between Elevations 234.8 m and 225.8 m. Auger grinding in Borehole 18-3 suggests the presence of cobbles and/or boulders within the deposit. Boreholes 18-2, 18-3 and 18-6 were terminated within this deposit after penetrating it for lengths between 0.6 m and 2.4 m.

The SPT 'N'-values measured within the lower granular deposit range between 41 blows per 0.3 m of penetration to 100 blows per 0.1 m of penetration, indicating a dense to very dense level of compactness.

The natural water content measured on select samples of the lower granular deposit are between about 7 per cent and 10 per cent.

The results of grain size distribution tests completed on two samples of the lower granular deposit are shown on Figure B8 in Appendix B.

4.3 Groundwater Conditions

The water level was measured in Boreholes 18-2, 18-3, 18-5 and 18-6 upon completion of drilling operations at depths between 0.1 m and 12.5 m below ground surface, between Elevations 238.7 m and 233.6 m. The water level observed in the open boreholes during and/or upon completion of drilling may not represent the longer-term, stabilized groundwater level at the site.

Standpipe piezometers were installed in Boreholes 18-1 and 18-4 located on the north and south side of the Highway 401 embankment, respectively. The observed groundwater levels in the standpipe piezometers are shown on the Record of Borehole sheets and summarized below.

Borehole	Depth to Water Level (m)	Groundwater Elevation (m)	Date of Measurement
18-1	1.8	238.2	March 13, 2018
	0.8	239.2	April 12, 2018
18-4	12.5	235.2	March 22, 2018

The water level at the site is expected to fluctuate seasonally in response to changes in precipitation and snow melt, and is expected to be higher during the spring and periods of precipitation. Given the close proximity of the outlet to Lake Kelso, the water level in the lake also has the potential to influence the groundwater level at the culvert outlet. The water level in Lake Kelso is controlled by a dam and as such, the water level in the lake has the potential to change rapidly.

4.4 Analytical Testing of Soil Samples

Analytical testing was carried out on selected soil samples from four boreholes to assess the corrosivity and concrete degradation potential of the soils for the new culvert structure. The analytical test results from the specialist analytical laboratory are presented in Appendix C and are summarized below.

Borehole (Sample)	Depth / Elevation (m)	Parameters				
		Soil Resistivity (ohm-cm)	Soil Conductivity (mS/cm)	Sulphate Concentration (%)	Chloride Concentration (%)	Soil pH
18-2 (SA 4)	2.0 / 237.7	11,100	0.09	<0.01	0.002	8.58
18-3 (SA 16)	15.4 / 234.0	6,250	0.16	0.02	0.003	8.43
18-4 (SA 8)	9.2 / 238.2	2,330	0.43	<0.01	0.026	8.33
18-6 (SA 13)	7.6 / 227.0	3,570	0.28	0.02	0.004	8.13

5.0 CLOSURE

Messrs. Jeremy Lebow and Erik Giles supervised the borehole investigation program. Mr. Matthew Kelly, P.Eng., the project engineer, oversaw the overall field investigation. This report was prepared by Ms. Madison Kennedy, B.A.Sc., and was reviewed by Mr. Matthew Kelly, P.Eng., a geotechnical engineer. Mr. Kevin J. Bentley, P.Eng., an Associate with Golder and Designated MTO Foundations Contact conducted an independent quality control review of this report.

Signature Page

Golder Associates Ltd.

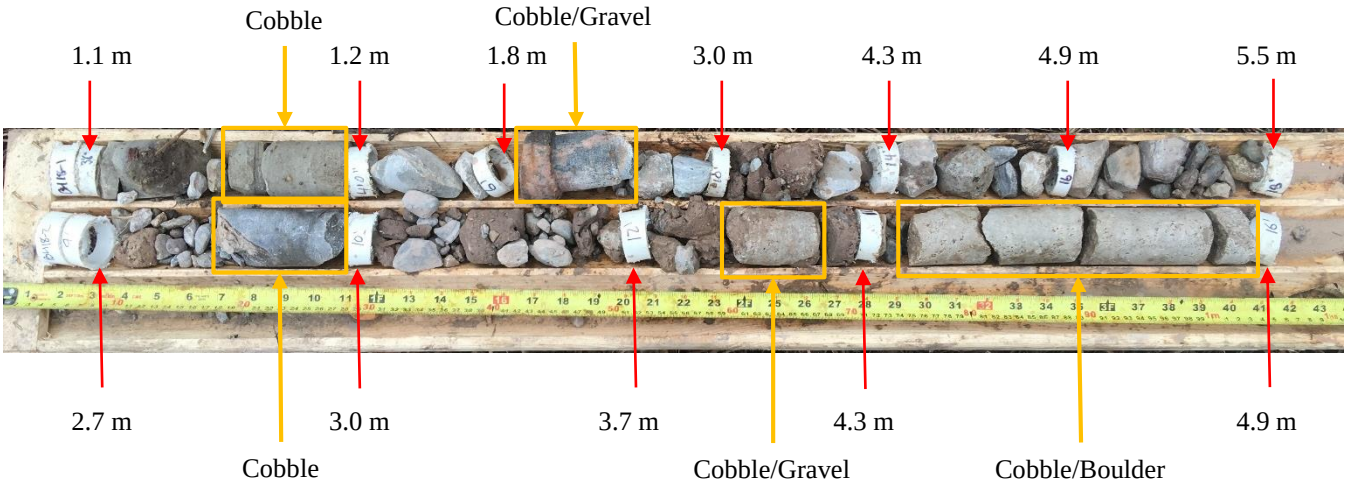
Matthew Kelly, P.Eng.
Geotechnical Engineer

Kevin J. Bentley, P.Eng.
MTO Foundations Designated Contact, Associate

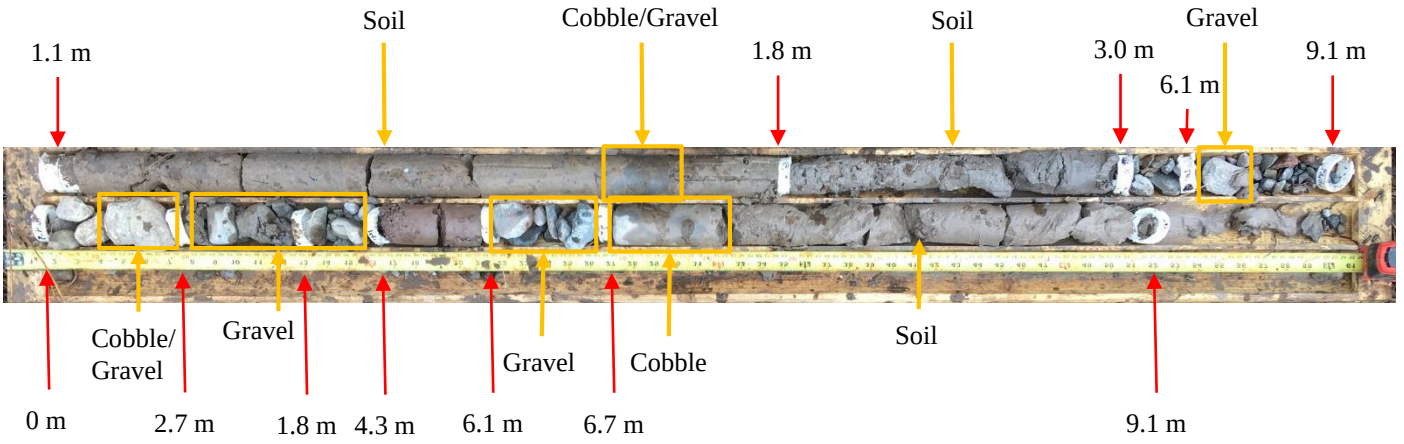
MWK/KJB

FIGURES

Borehole 18-1 (Upper Row) and 18-2 (Lower Row)



Borehole 18-5 (Lower Row) and 18-6 (Upper Row)



Note:
Borehole advancement was carried out with BW casing utilizing washboring techniques with AW casing. The photographs represent the material recovered from the AW casing during borehole advancement.

REVISION DATE: May 16, 2018 BY: MCK Project: 1789436

PROJECT **SIXTEEN MILE CREEK CULVERT REPLACEMENT STRUCTURAL CULVERT REHABILITATION / REPLACEMENT, HIGHWAY 401 G.W.P 2219-14-00**

TITLE

AW Recovery Photographs
Boreholes 18-1, 18-2, 18-5 and 18-6

GOLDER

PROJECT No. 1789436			FILE No. ----	
DESIGN	MCK		SCALE	REV.
CADD	-- --			
CHECK			**FIGURE 1**	
REVIEW				

DRAWINGS

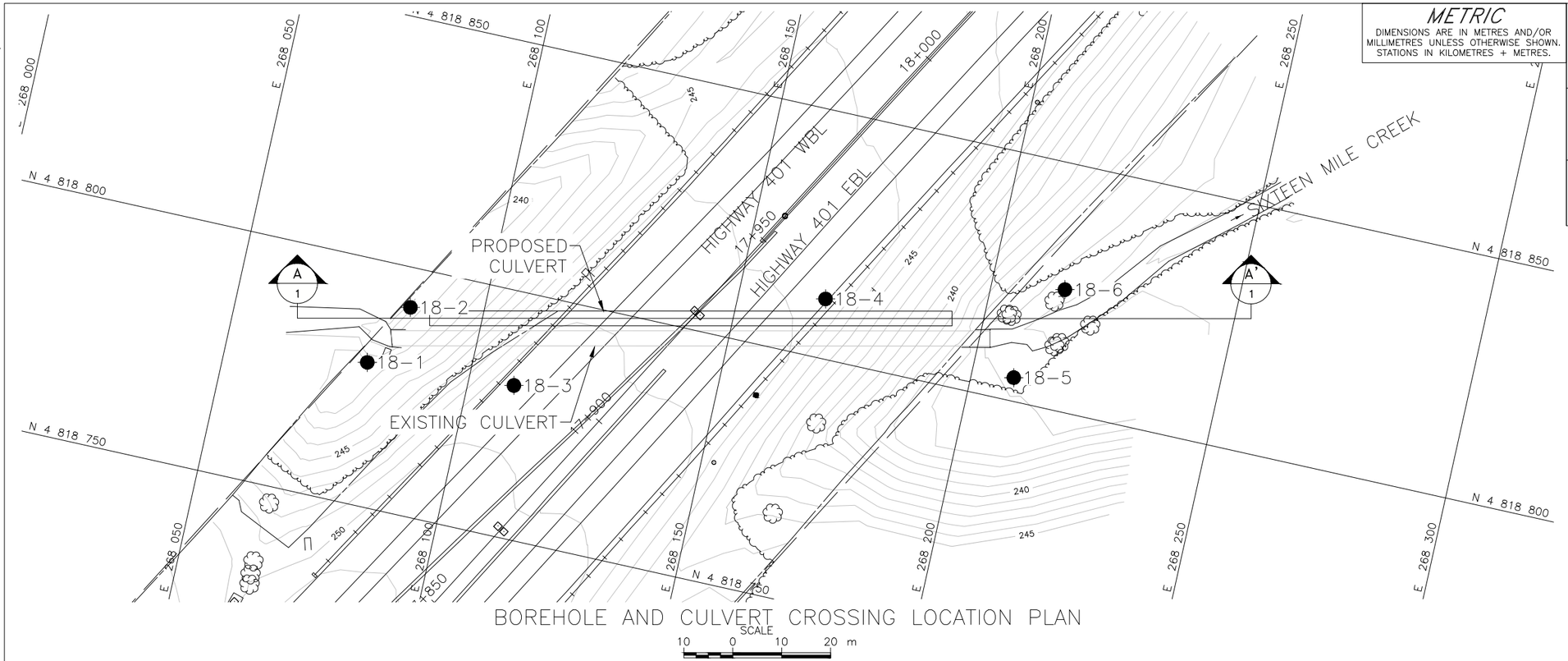
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
GWP No. 2219-14-00

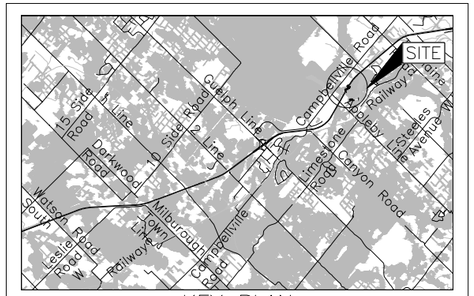
HIGHWAY 401
SIXTEEN MILE CREEK CULVERT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

Golder Associates



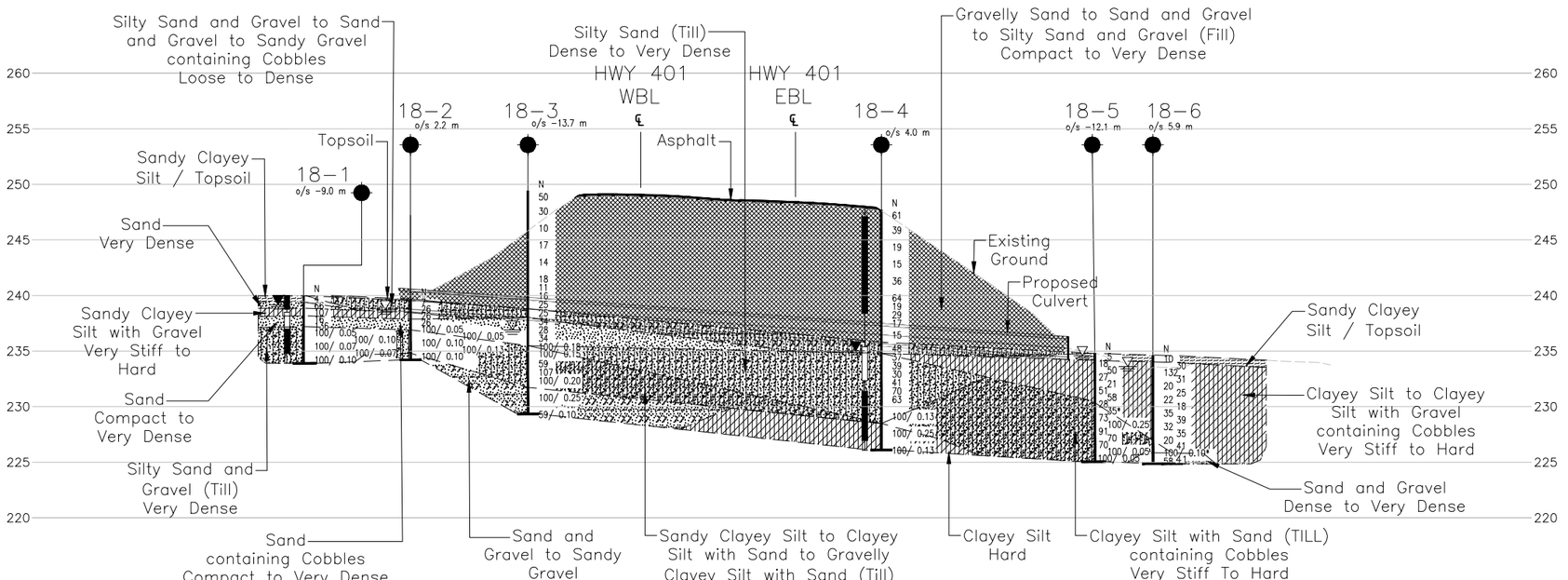
BOREHOLE AND CULVERT CROSSING LOCATION PLAN
SCALE 10 0 10 20 m



KEY PLAN
SCALE 2 0 2 4 km

LEGEND

- Borehole – Current Investigation
- N — Standard Penetration Test Value
- 16 — Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- Seal
- Piezometer
- WL in piezometer, measured on March 22, 2018
- WL upon completion of drilling



A-A' 1 SECTION A-A'
HORIZONTAL SCALE 10 0 10 20 m
VERTICAL SCALE 5 0 5 10 m

BOREHOLE CO-ORDINATES (MTM NAD83, ZONE 10)

No.	ELEVATION	NORTHING	EASTING
18-1	240.0	4818779.1	268079.0
18-2	239.7	4818791.9	268085.2
18-3	249.4	4818781.0	268109.3
18-4	247.7	4818812.1	268167.6
18-5	234.8	4818804.8	268208.6
18-6	234.6	4818824.6	268214.9

NOTES

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

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

REFERENCE

Base plan and surface data provided in digital format by AIA, drawing file no. E1624014_GA_WithoutProfile.dwg, dated , 2018, received May 16, 2018.
Culvert crossing profile general arrangement provided in digital format by AIA, drawing file no. E1624014.dwg, dated March, 2018, received April 18, 2018.
Base Data MNRF 2018.

NO.	DATE	BY	REVISION
.	.	.	.

LICENSED PROFESSIONAL ENGINEER M.W.KELLY Oct. 18, 2018 PROVINCE OF ONTARIO

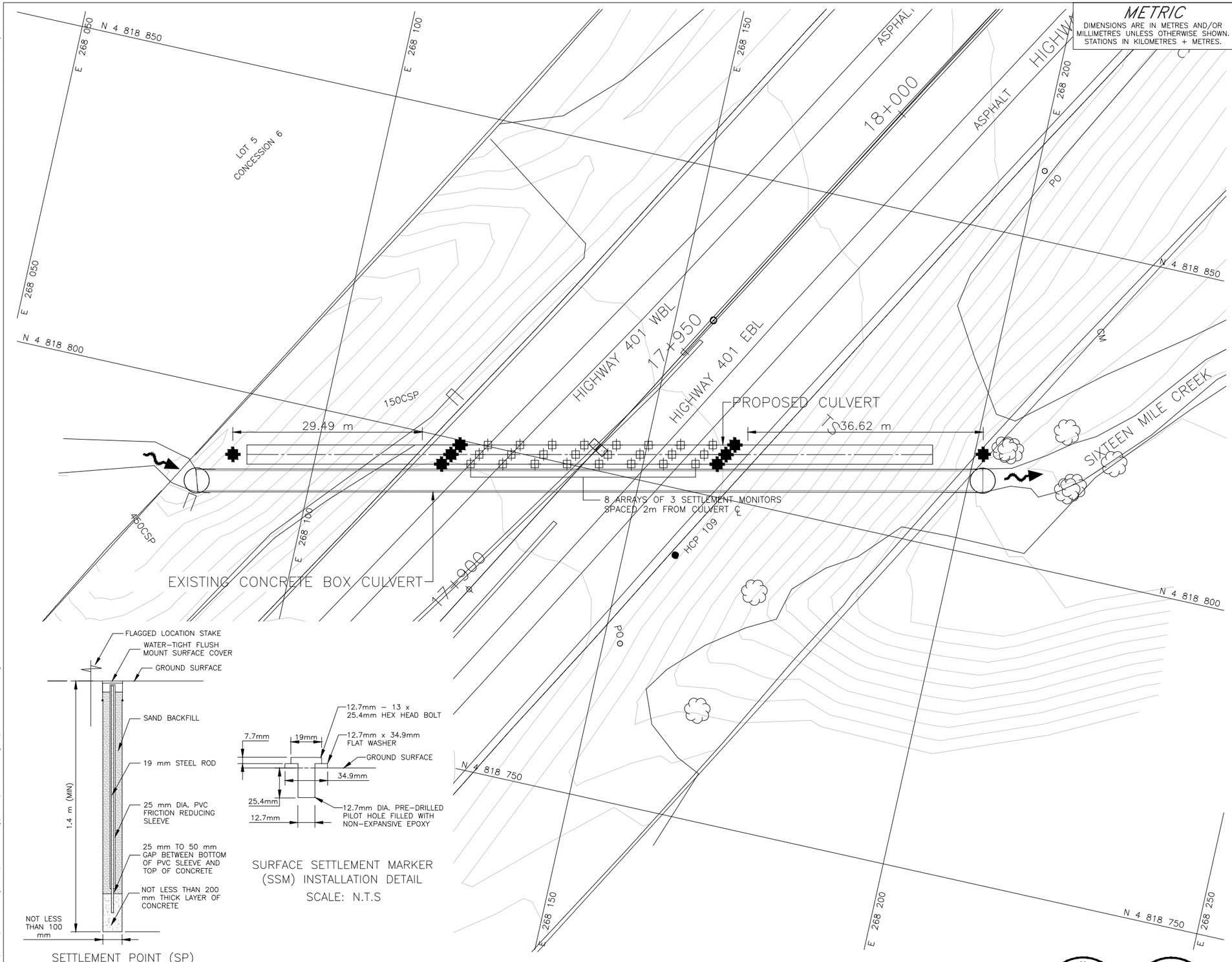
LICENSED PROFESSIONAL ENGINEER K. J. BENTLEY Oct. 18, 2018 PROVINCE OF ONTARIO

Geocres No. 30M12-425

HWY. 401		PROJECT NO. 1789436	DIST. .
SUBM'D. MCK	CHKD. MCK	DATE: 10/18/2018	SITE: 10-592/C
DRAWN: SMD	CHKD. MWK	APPD. KJB	DWG. 1

PLOT DATE: October 18, 2018
FILENAME: S:\Clients\MTO\Hwy_401\99_PRO\1789436_MTO_Hwy401_GuelphLineCulvertCrossing\40_PROD\001_Geotechnicalinvestigation\1789436-0001-BC-0001.dwg

MINISTRY OF TRANSPORTATION, ONTARIO



SETTLEMENT POINT (SP) INSTALLATION DETAIL

SCALE: N.T.S

SURFACE SETTLEMENT MARKER (SSM) INSTALLATION DETAIL

SCALE: N.T.S

SETTLEMENT MONITORING INSTALLATION DETAILS

PLAN

SCALE

6 0 6 12 m

METRIC

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

CONT No.

GWP No2219-14-00

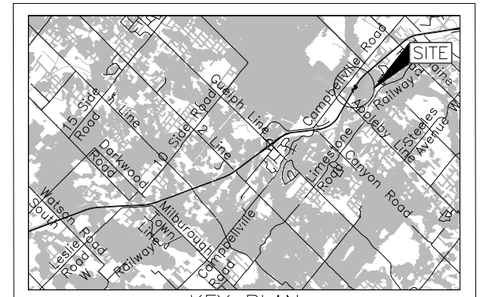
HIGHWAY 401

SIXTEEN MILE CREEK CULVERT

SETTLEMENT MONITORING INSTRUMENTATION LOCATIONS AND DETAILS

SHEET

Golder Associates



KEY PLAN

SCALE

2 0 2 4 km

LEGEND

- Surface Settlement Marker
- Settlement Point

NOTES

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

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

REFERENCE

Base plan and surface data provided in digital format by AIA, drawing file no. E1624014_GA_WithoutProfile.dwg, dated , 2018, received May 16, 2018.
Culvert crossing profile general arrangement provided in digital format by AIA, drawing file no. E1624014.dwg, dated March, 2018, received April 18, 2018.
Base Data MNRF 2018.

NO.	DATE	BY	REVISION
.	.	.	.

LICENSED PROFESSIONAL ENGINEER M.W.KELLY Oct. 18, 2018 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER K. J. BENTLEY Oct. 18, 2018 PROVINCE OF ONTARIO

Geocres No. 30M12-425

HWY. 401	PROJECT NO. 1789436		DIST. .
SUBM'D. MCK	CHKD. MCK	DATE: 10/18/2018	SITE: .
DRAWN: SMD	CHKD. .	APPD. .	DWG. 2

PLOT DATE: October 18, 2018
FILENAME: S:\Clients\MTO\Hwy_401\99_PROJ\1789436_MTO_Hwy401_GuelphLineCulvertCrossing\40_PROD\0001_Geotechnicalnvestigation\1789436-0001-BG-0002.dwg

APPENDIX A

Record of Boreholes

LIST OF SYMBOLS

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

I. GENERAL

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

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
σ_1, σ_2, σ_3	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

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

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

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index = $(w_l - w_p)$
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 δ
c'	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

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

2 shear strength = (compressive strength)/2

LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

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

Dynamic Cone Penetration Resistance; N_d:

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

PH:	Sampler advanced by hydraulic pressure
PM:	Sampler advanced by manual pressure
WH:	Sampler advanced by static weight of hammer
WR:	Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

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

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

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

(b) Cohesive Soils

Consistency

	c_u, s_u kPa	c_u, s_u psf
Very soft	0 to 12	0 to 250
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

GOLDER

RECORD OF BOREHOLE No 18-1

SHEET 1 OF 1

METRIC

PROJECT 1789436

G.W.P. 2219-14-00

LOCATION N 4818779.1; E 268079.0 MTM NAD 83 ZONE 10 (LAT. 43.508038; LONG. -79.954146)

ORIGINATED BY EG

DIST Central HWY 401

BOREHOLE TYPE Portable Equipment (Manual Hammer), BW Casing, Washboring

COMPILED BY BR

DATUM Geodetic

DATE March 12 to 13, 2018

CHECKED BY MCK

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
240.0	GROUND SURFACE										
0.0 / 239.4	Sandy CLAYEY SILT, trace gravel, containing organics and cobbles Firm Dark brown Moist		1	SS	4						
0.6 / 238.9	SAND, some silt Very dense Brown Wet		2A 2B	SS	66	▽	239				
1.1 / 238.2	Sandy CLAYEY SILT with GRAVEL, containing cobbles (75 mm to 150 mm) Hard Grey to dark grey Moist to wet		3	SS	107						
1.8 / 237.2	SAND, some silt, trace to some gravel, trace to some clay, containing cobbles (100 mm) Compact to very dense Red/Brown Wet		4 5A 5B	SS	16 136		238				5 76 14 5
2.8	Silty SAND and GRAVEL, trace clay, containing cobbles (75 mm) (TILL) Very dense Red/brown Wet		6 7 8 9 10	SS	100/ 0.05 100/ 0.10 100/ 0.07 100/ 0.07 100/ 0.10		237 236 235				32 41 22 5
233.9							234				
6.1	END OF BOREHOLE										

NOTES:

1. Groundwater level measurement in piezometer:

Date:	Depth (m)	Elev. (m)
03/13/18	1.8	238.2
04/12/18	0.8	239.2

2. Point load index testing carried out on a sample of cobble collected in core barrel at a depth of 1.1 m (Elev. 238.9 m)

Type	Is(50)
Axial	2.6 MPa
Diametral	1.4 MPa

$+^3, \times^3$: Numbers refer to Sensitivity

$\circ^{3\%}$ STRAIN AT FAILURE

GTA-MTO 001 S:\CLIENTS\MTO\HWY_401\02_DATA\GINT\HWY_401.GPJ GAL-GTA.GDT 07/06/18

GOLDER

RECORD OF BOREHOLE No 18-2

SHEET 1 OF 1 **METRIC**

PROJECT 1789436
G.W.P. 2219-14-00
DIST Central HWY 401
DATUM Geodetic

LOCATION N 4818791.9; E 268085.2 MTM NAD 83 ZONE 10 (LAT. 43.508154; LONG. -79.954070)
BOREHOLE TYPE Portable Equipment (Manual Hammer), BW Casing, Washboring
DATE March 14, 2018

ORIGINATED BY EG
COMPILED BY BR
CHECKED BY MCK

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
239.7	GROUND SURFACE										
0.0	TOPSOIL										
0.1	Silty SAND and GRAVEL, trace to some clay, containing organics and cobbles Loose to compact Dark brown to red/brown		1	SS	7						
			2	SS	26	▽	239				39 30 24 7
238.5	Wet										
1.2	Sandy CLAYEY SILT with GRAVEL Very stiff		3	SS	26						
237.9	Red/Brown						238				
1.8	Wet		4	SS	26						
	SAND, trace to some gravel, trace silt, containing cobbles Compact to very dense		5A 5B	SS	100/ 0.05						
236.9	Red/brown						237				
2.8	Wet										
	CLAYEY SILT with SAND, trace to some gravel, containing cobbles (75 mm to 250 mm) (TILL) Hard Red/Brown Wet		6	SS	100/ 0.05						
			7	SS	100/ 0.10		236				
			8	SS	100/ 0.13						6 36 42 16
234.8											
4.9	Sandy GRAVEL Very dense Red/brown		9	SS	100/ 0.10		235				
234.2	Moist										
5.5	END OF BOREHOLE										

NOTES:

1. Water level recorded in open borehole at a depth of 1.0 m below ground surface (Elev. 238.7 m) upon completion of drilling.
2. Point load index testing carried out on a sample of cobble collected from core barrel at a depth of 2.7 m (Elev. 237.0 m)

Type	Is(50)
Axial	5.0 MPa
Diametral	2.2 MPa

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

GTA-MTO 001 S:\CLIENTS\MTO\HWY_401\02_DATA\GINT\HWY_401.GPJ GAL-GTA.GDT 07/06/18

GOLDER

RECORD OF BOREHOLE No 18-3

SHEET 1 OF 2

METRIC

PROJECT 1789436

G.W.P. 2219-14-00

LOCATION N 4818781.0; E 268109.3 MTM NAD 83 ZONE 10 (LAT. 43.508057; LONG. -79.953772)

ORIGINATED BY JL

DIST Central HWY 401

BOREHOLE TYPE Diedrich D90; 108 mm I.D., 210 mm O.D. Hollow Stem Augers

COMPILED BY BR

DATUM Geodetic

DATE March 11 to 13, 2018

CHECKED BY MCK

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
249.4	GROUND SURFACE										
0.0	ASPHALT (225 mm)										
0.2	Gravelly sand, trace fines (FILL) Dense to very dense Brown and grey Dry		1	SS	50		249				
			2	SS	30		248		○		
	- Containing clayey silt pockets below a depth of 1.5 m										
246.8							247				
2.6	Silty sand and gravel (FILL) Compact Red-brown and grey Moist - Auger grinding at a depth of 3.0 m to 4.6 m - Wet pocket at 3.4 m		3	SS	10		246		○		
			4	SS	17		245				
			5	SS	14		244				
	- Auger grinding at a depth of 7.0 m		6	SS	18		243		○		
			7	SS	11		242		○		
			8	SS	16		241		○		51 31 14 4
	- Auger grinding from 10.4 m to 10.7 m		9	SS	25		240		○		
238.8							239				
10.6	Sandy GRAVEL, trace to some silt, trace clay Compact Grey Wet		10	SS	25		238		○		60 27 10 3
238.0											
11.4	SAND, some gravel, some silt, containing clayey silt pockets Compact to dense Red-brown Wet		11A 11B	SS	34		237		○		
			12	SS	28	▽	236		○		
			13	SS	34		235		○		13 72 12 3
235.5			14	SS	100/ 0.18						
235.1	Sandy CLAYEY SILT, some gravel (TILL)										
14.3	Hard Brown to grey Wet		15	SS	100/ 0.15		235				12 51 28 9
234.5											

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

GOLDER

RECORD OF BOREHOLE No 18-3

SHEET 2 OF 2 **METRIC**

PROJECT 1789436
G.W.P. 2219-14-00
DIST Central HWY 401
DATUM Geodetic

LOCATION N 4818781.0; E 268109.3 MTM NAD 83 ZONE 10 (LAT. 43.508057; LONG. -79.953772)
BOREHOLE TYPE Diedrich D90; 108 mm I.D., 210 mm O.D. Hollow Stem Augers
DATE March 11 to 13, 2018

ORIGINATED BY JL
COMPILED BY BR
CHECKED BY MCK

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
14.9	Silty SAND, some gravel, trace to some clay (TILL) Very dense Brown to grey Wet		16	SS	59		234		○		
	Gravelly CLAYEY SILT with SAND (TILL) Hard Brown to grey Wet - Auger grinding between depths of about 16.2 m to 16.8 m and 17.1 m to 17.7 m		17	SS	107		233		○		22 36 32 10
231.7			18	SS	100/ 0.20				○		
17.7	SAND and GRAVEL, trace to some silt, trace clay Very dense Brown and grey Wet - Auger grinding at a depth of about 17.7 m to 18.0 m and 18.6 m to 19.8 m		19	SS	100/ 0.25		232				
229.3			20	SS	59/ 0.10		231		○		38 52 8 2
20.1	END OF BOREHOLE: NOTE: 1. Water level recorded in open borehole at a depth of about 12.5 m below ground surface (Elev. 236.9 m) on March 13, 2018.						230				

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

GOLDER

RECORD OF BOREHOLE No 18-4

SHEET 1 OF 2

METRIC

PROJECT 1789436

G.W.P. 2219-14-00

LOCATION N 4818812.1; E 268167.6 MTM NAD 83 ZONE 10 (LAT. 43.508339; LONG. -79.953053)

ORIGINATED BY JL

DIST Central HWY 401

BOREHOLE TYPE Diedrich D90; 108 mm I.D., 210 mm O.D. Hollow Stem Augers

COMPILED BY BR

DATUM Geodetic

DATE March 14 to 16 and 18, 2018

CHECKED BY MCK

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
247.7	GROUND SURFACE						
0.0	ASPHALT (200 mm)						
0.4	Sand and gravel, containing asphalt fragments, trace fines (FILL) Very dense Grey to black Dry	1	SS	61	247		
246.5							
1.2	Gravelly sand, trace fines (FILL) Very dense Grey and brown Dry	2	SS	39	246		
	Sand and gravel, some silt, trace clay (FILL) Compact to very dense Brown, grey, red/brown Dry to moist - Auger grinding between a depth of about 1.8 m to 2.4 m	3	SS	19	245		
					244		
	- Wet pocket at 4.6 m - Auger grinding from a depth of about 4.9 m to 5.8 m	4	SS	15	243		
					242		
	- Auger grinding from a depth of about 6.0 m to 8.8 m	5	SS	36	241		
		6	SS	64	240		
		7	SS	19	239		41 42 13 4
	- Auger grinding from a depth of about 9.1 m to 9.8 m	8	SS	29	238		
		9	SS	17	237		
	- Containing clayey silt seams below a depth of 11.2 m	10A 10B	SS	15	236		
235.8							
11.9	SAND and GRAVEL, some silt, trace clay Dense Brown Wet	11	SS	48	235		48 34 14 4
234.8							
12.9	- Auger grinding from a depth of about 12.2 m to 12.8 m Silty SAND, some gravel, trace to some clay (TILL) Dense to very dense Red/brown and grey Wet	12	SS	37	234		
	- Auger grinding from a depth of about 13.7 m to 14.3 m	13	SS	39	233		
		14	SS	30			18 48 27 7

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED; 20 40 60 80 100

PLASTIC LIMIT w_P | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w_L

WATER CONTENT (%): 10 20 30

Continued Next Page

$+^3, \times^3$: Numbers refer to Sensitivity

$\circ^{3\%}$ STRAIN AT FAILURE

GOLDER

RECORD OF BOREHOLE No 18-4

SHEET 2 OF 2 **METRIC**

PROJECT 1789436
G.W.P. 2219-14-00
DIST Central HWY 401
DATUM Geodetic

LOCATION N 4818812.1; E 268167.6 MTM NAD 83 ZONE 10 (LAT. 43.508339; LONG. -79.953053) ORIGINATED BY JL
BOREHOLE TYPE Diedrich D90; 108 mm I.D., 210 mm O.D. Hollow Stem Augers COMPILED BY BR
DATE March 14 to 16 and 18, 2018 CHECKED BY MCK

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
	Silty SAND, some gravel, trace to some clay (TILL) Dense to very dense Red/brown and grey Wet		15	SS	41		232	○	○		
			16	SS	70		231		○		
			17	SS	63		230		○		
228.5			18	SS	100/ 0.13		229				
19.2	CLAYEY SILT, trace to some sand Hard Grey Wet - Auger grinding at a depth about 19.2 m - Auger Grinding at 20.1 m		19	SS	100/ 0.25		228		⊢○⊣		0 7 65 28
226.1			20	SS	100/ 0.13		227				
21.6	END OF BOREHOLE										

NOTES:

1. Water level recorded in borehole at a depth of 12.5 m below ground surface (Elev. 235.2 m) on March 18, 2018.

2. Water level measured in standpipe Piezometer:

Date	Depth (m)	Elev. (m)
03/22/18	12.5	235.2

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

GOLDER

RECORD OF BOREHOLE No 18-5

SHEET 1 OF 1 **METRIC**

PROJECT 1784436

G.W.P. 2219-14-00 LOCATION N 4818804.8; E 268208.6 MTM NAD 83 ZONE 10 (LAT. 43.508276; LONG. -79.952545) ORIGINATED BY EG

DIST Central HWY 401 BOREHOLE TYPE Portable Equipment (Manual Hammer), BW Casing, Washboring COMPILED BY BR

DATUM Geodetic DATE March 29 and April 4, 2018 CHECKED BY MCK

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
234.8	GROUND SURFACE										
0.0	Sandy CLAYEY SILT with organics, some to trace gravel Firm Brown to Red/brown Wet		1	SS	5						
234.2											
0.6	CLAYEY SILT, some sand, trace gravel, containing silt seams and cobbles (100 mm) Very stiff to hard Grey Wet		2A 2B	SS	18		234				
			3	SS	50						3 15 54 28
			4	SS	27		233				
			5	SS	21		232				
231.8											
3.1	CLAYEY SILT with GRAVEL, some sand Hard Brown Wet		6	SS	51						31 18 39 12
230.5			7	SS	58		231				
4.3	CLAYEY SILT with SAND, some gravel, containing cobbles (75 mm to 130 mm) (TILL) Very stiff to hard Red/brown to grey Wet		8	SS	28						
			9	SS	35*		230				
			10A 10B	SS	73		229				
			11	SS	100/ 0.25						
			12	SS	91		228				16 30 38 16
			13	SS	70		227				
			14	SS	70						
			15	SS	100/ 0.05		226				
	- Grey below 9.1 m		16	SS	100/ 0.05						
225.1											
9.8	END OF BOREHOLE										

* - No Recovery

NOTES:

1. Water level recorded in open borehole at a depth of 0.1 m below ground surface (Elev. 234.7 m) upon completion of drilling.
2. Point load index testing carried out on a sample of cobble collected from core barrel at a depth of 6.7 m (Elev. 228.1 m)

Type	Is(50)
Axial	12.2 MPa
Diametral	11.1 MPa

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

GTA-MTO 001 S:\CLIENTS\MTO\HWY_401\02_DATA\GINT\HWY_401.GPJ GAL-GTA.GDT 07/06/18

GOLDER

RECORD OF BOREHOLE No 18-6

SHEET 1 OF 1

METRIC

PROJECT 1789436

G.W.P. 2219-14-00

LOCATION N 4818824.6; E 268214.9 MTM NAD 83 ZONE 10 (LAT. 43.508454; LONG. -79.952469)

ORIGINATED BY EG

DIST Central HWY 401

BOREHOLE TYPE Portable Equipment (Manual Hammer), BW Casing, Washboring

COMPILED BY BR

DATUM Geodetic

DATE March 26 to 28, 2018

CHECKED BY MCK

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
234.6	GROUND SURFACE										
0.0 / 234.0	TOPSOIL		1	SS	10		234				
0.6	CLAYEY SILT, some sand, trace to some gravel, containing cobbles (75 mm) Very stiff to hard Dark brown to grey Wet		2	SS	30	▽			○		
			3	SS	132		233				
			4	SS	31				○		4 15 48 33
			5	SS	20		232				
			6	SS	25						
			7	SS	22		231		○		7 18 48 27
			8	SS	18						
	- Containing silt and clay seams below a depth of 4.9 m		9A / 9B	SS	35		230		○		
			10	SS	39		229				
			11	SS	32				○		
			12	SS	35		228				
			13	SS	20				○		9 10 60 21
			14	SS	41		227				
225.8			15	SS	100/ 0.10*						
8.8	SAND and GRAVEL, some silt, trace clay Dense to very dense Red/brown Wet		16	SS	41		226		○		
224.9			17	SS	58		225		○		53 32 11 4
9.8	END OF BOREHOLE										

* - No Recovery - Split-Spoon Sampler Refusal

NOTES:

1. Water level recorded in borehole at a depth of 1.0 m below ground surface (Elev. 233.6 m) upon completion of drilling.

2. Continuous sampling was carried out to a depth of 1.8 m. An adjacent borehole was advanced using BW casing to carry out continuous sampling below a depth of 1.8 m.

+3, ×3: Numbers refer to Sensitivity

○3% STRAIN AT FAILURE

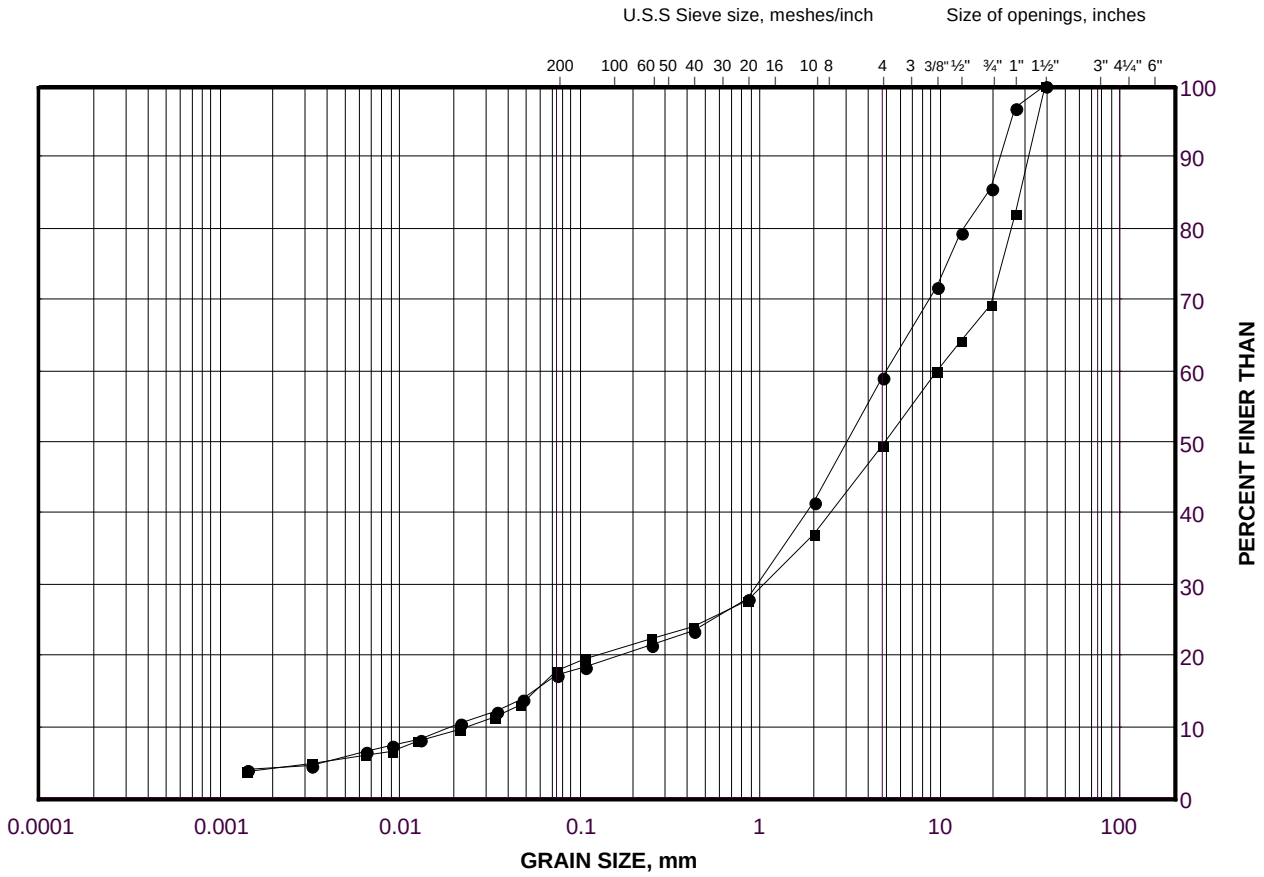
APPENDIX B

Laboratory Test Results

GRAIN SIZE DISTRIBUTION

Silty Sand and Gravel to Sand and Gravel (Fill)

FIGURE B1



LEGEND

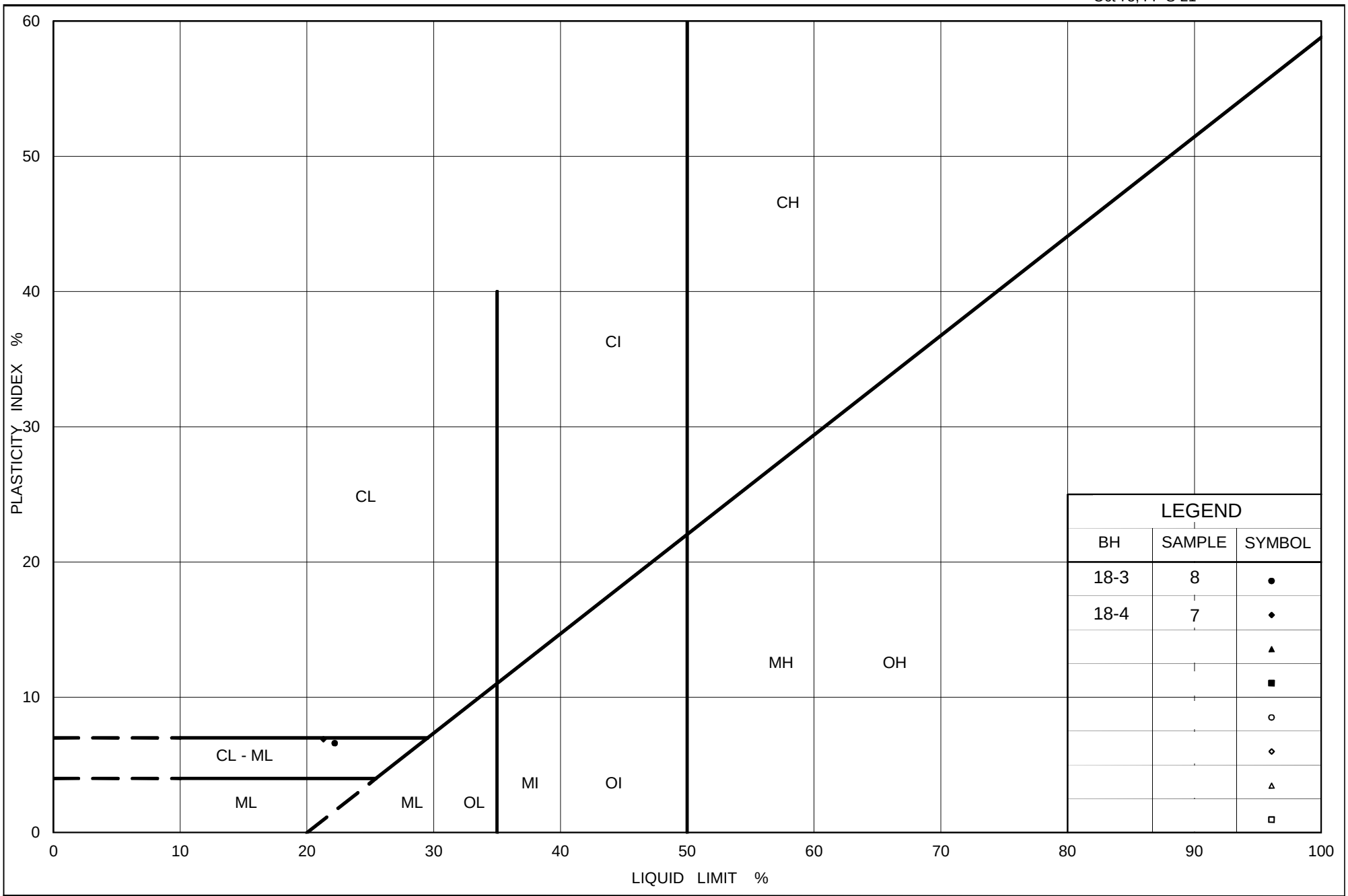
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	18-4	7	239.0
■	18-3	8	240.0

Project Number: 1789436

Checked By: MCK

Golder Associates

Date: 10-May-18



Ministry of Transportation

Ontario

PLASTICITY CHART

Silty Sand and Gravel to Sand and Gravel (Fill)
(Fines Component)

Figure No. B2

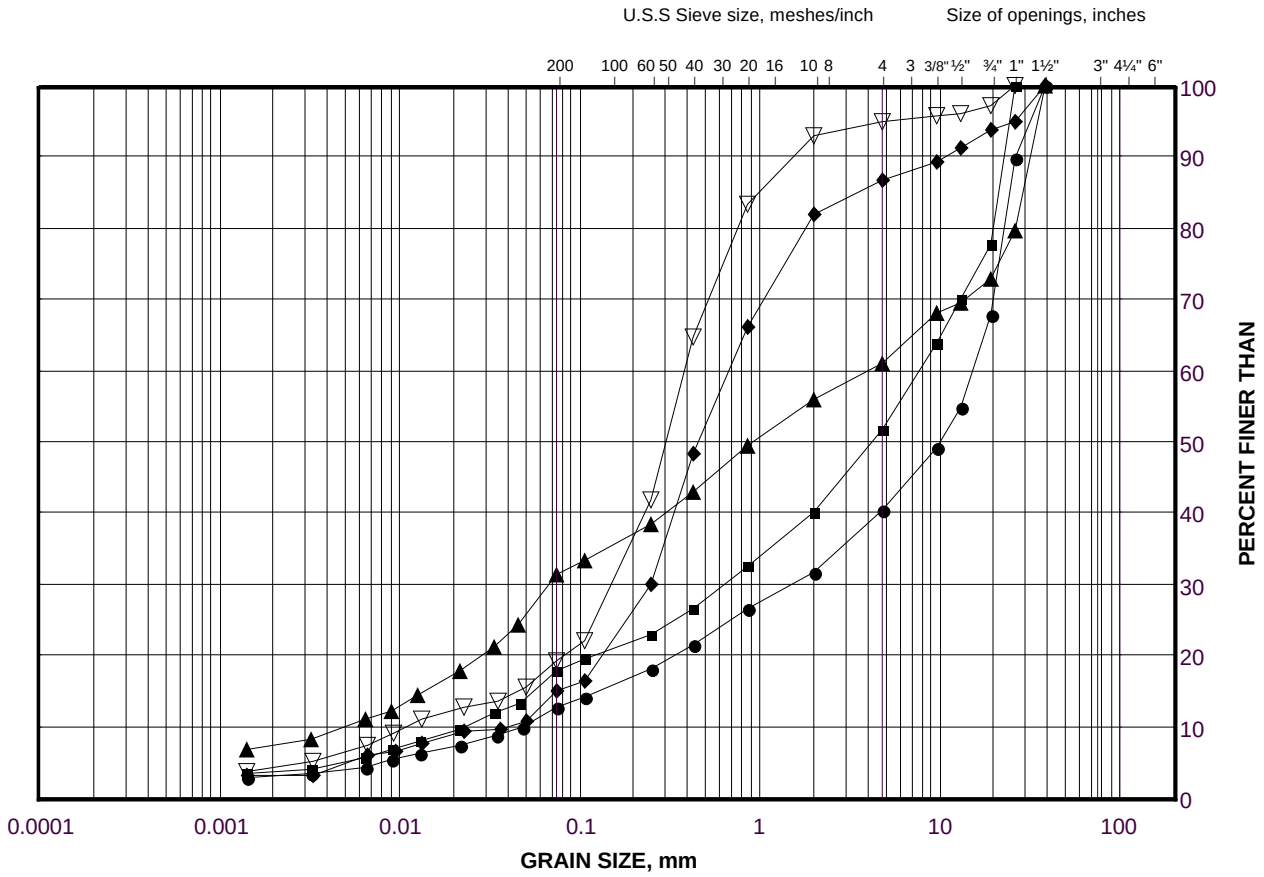
Project No. 1789436

Checked By: MCK

GRAIN SIZE DISTRIBUTION

Sand to Sand and Gravel to Sandy Gravel (Upper Granular Deposit)

FIGURE B3



LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	18-3	10	238.5
■	18-4	11	235.2
◆	18-3	13	236.2
▲	18-2	2	238.8
▽	18-1	4	237.8

Project Number: 1789436

Checked By: MCK

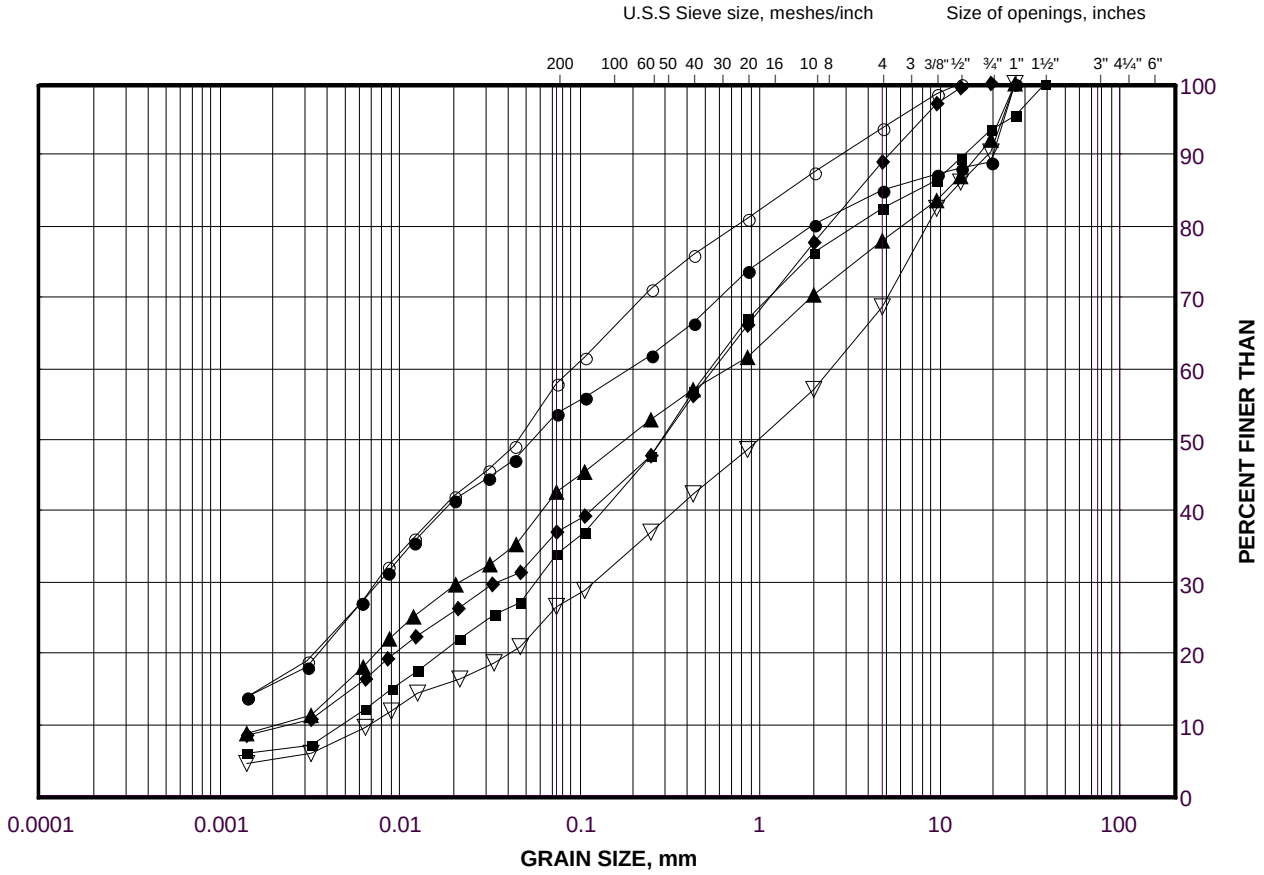
Golder Associates

Date: 10-May-18

GRAIN SIZE DISTRIBUTION

Silty Sand to Silty Sand and Gravel (Till) / Sandy Clayey Silt to Gravelly Clayey Silt with Sand (Till)

FIGURE B4



LEGEND

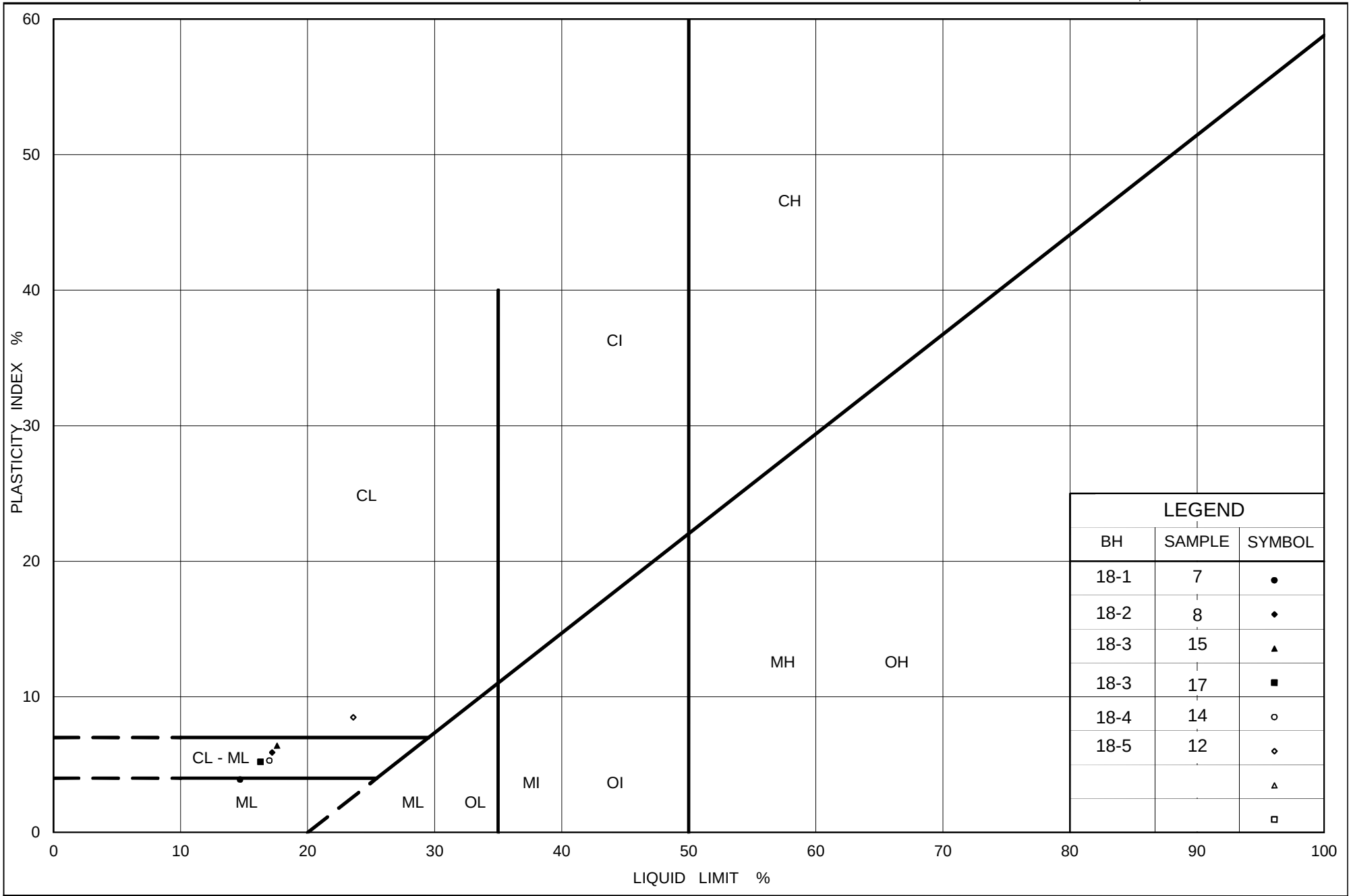
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	18-5	12	227.8
■	18-4	14	233.0
◆	18-3	15	235.1
▲	18-3	17	233.0
▽	18-1	7	236.2
❍	18-2	8	235.3

Project Number: 1789436

Checked By: MCK

Golder Associates

Date: 10-May-18



Ministry of Transportation

Ontario

PLASTICITY CHART

Silty Sand to Silty Sand and Gravel (Till) / Sandy Clayey Silt to Gravelly Clayey Silt with Sand (Till) (Fines Component)

Figure No. B5

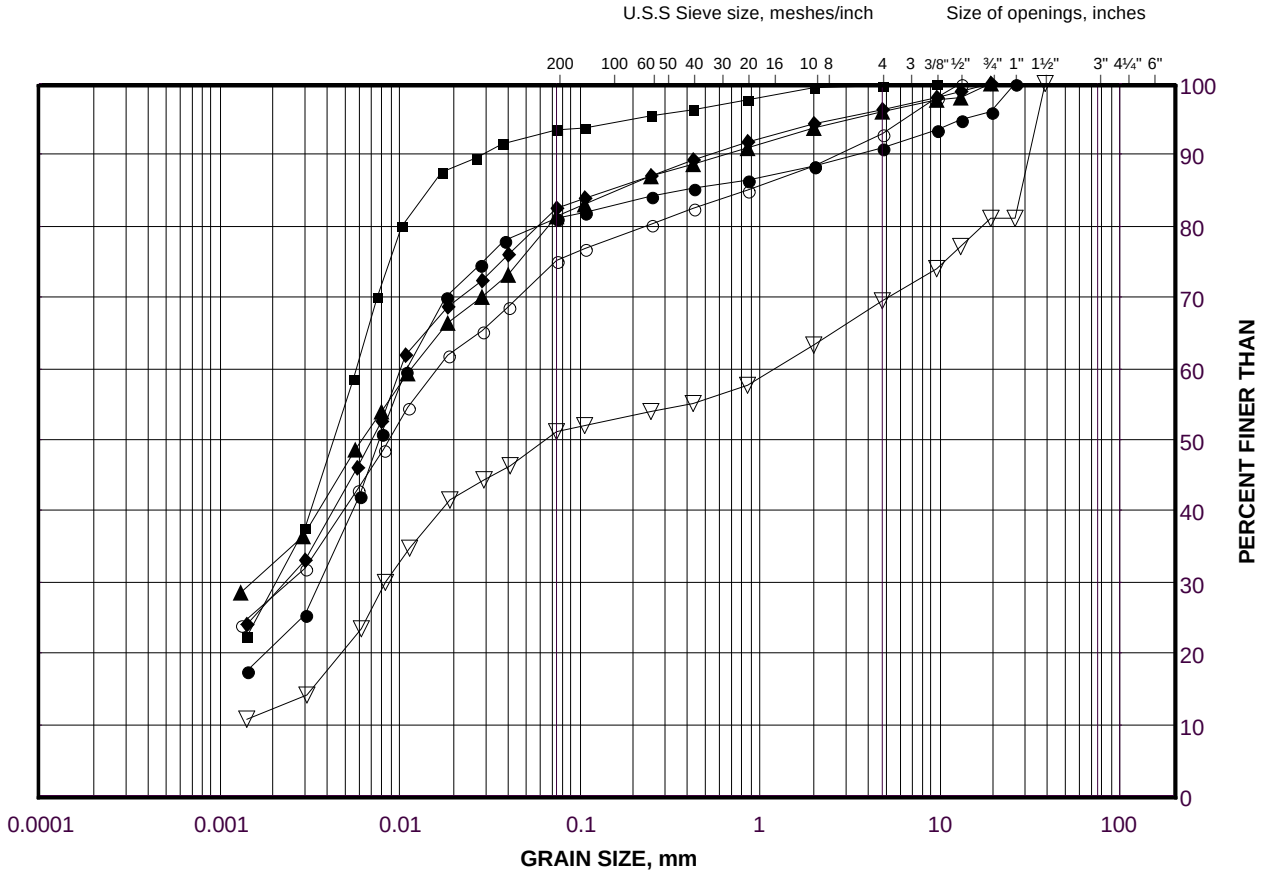
Project No. 1789436

Checked By: MCK

GRAIN SIZE DISTRIBUTION

Clayey Silt to Clayey Silt with Gravel

FIGURE B6



LEGEND

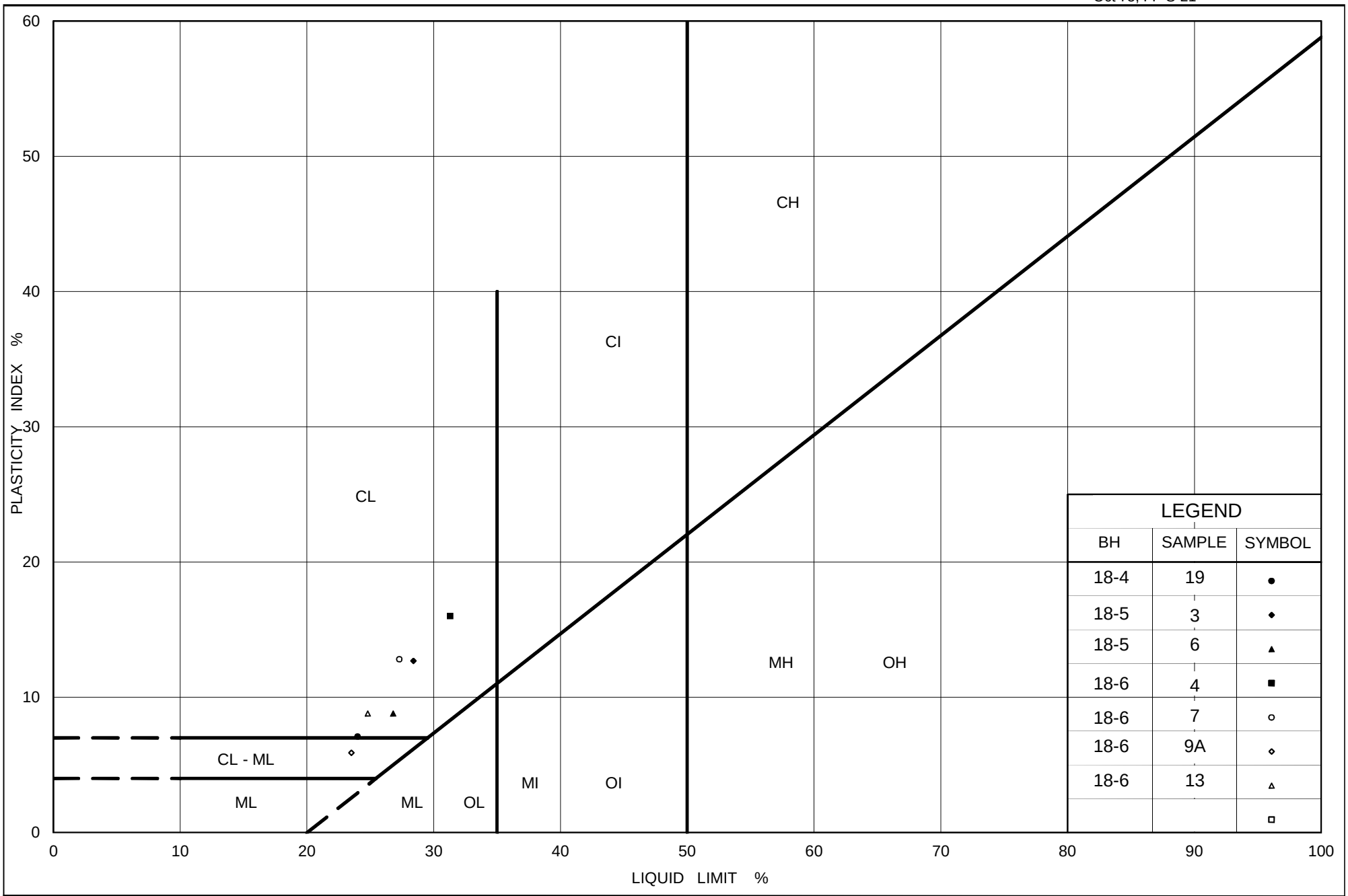
SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	18-6	13	227.0
■	18-4	19	227.8
◆	18-5	3	233.3
▲	18-6	4	232.5
▽	18-5	6	231.5
❍	18-6	7	230.6

Project Number: 1789436

Checked By: MCK

Golder Associates

Date: 10-May-18



Ministry of Transportation

Ontario

PLASTICITY CHART

Clayey Silt to Clayey Silt with Gravel

Figure No. B7

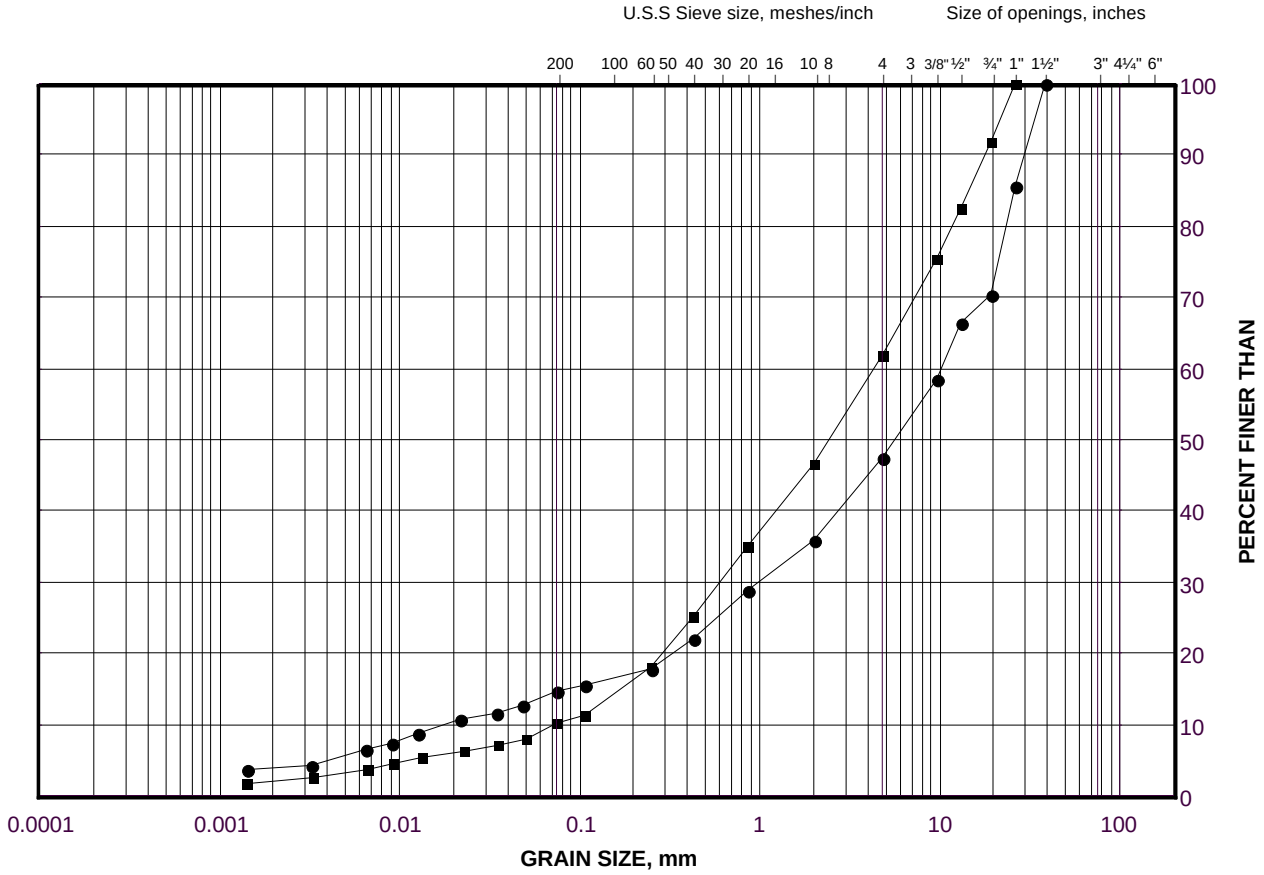
Project No. 1789436

Checked By: MCK

GRAIN SIZE DISTRIBUTION

Sand and Gravel (Lower Granular Deposit)

FIGURE B8



LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	18-6	17	225.8
■	18-3	19	231.0

Project Number: 1789436

Checked By: MCK

Golder Associates

Date: 10-May-18

APPENDIX C

Analytical Test Results

Certificate of Analysis

Client: Golder Associates Ltd. (Mississauga)
6925 Century Avenue
Mississauga, ON
L5N 7K2
Attention: Ms. Madison Kennedy
PO#:
Invoice to: Golder Associates Ltd. (Mississauga)

Report Number: 1805486
Date Submitted: 2018-04-13
Date Reported: 2018-04-20
Project: 1789436
COC #: 197339

Dear Madison Kennedy:

Please find attached the analytical results for your samples. If you have any questions regarding this report, please do not hesitate to call (613-727-5692).

Report Comments:

APPROVAL: _____
Addrine Thomas, Inorganics Supervisor

All analysis is completed in Ottawa, Ontario (unless otherwise indicated).

Eurofins Ottawa is accredited by CALA, Canadian Association for Laboratory Accreditation to ISO/IEC 17025 for tests which appear on our CALA scope of accreditation. It can be found at http://www.cala.ca/scopes/2602.pdf.

Eurofins(Ottawa) is certified and accredited for specific parameters by OMAFRA, Ontario Ministry of Agriculture, Food and Rural Affairs (for farm soils). Licensed by Ontario MOE for specific tests in drinking water.

Please note: Field data, where presented on the report, has been provided by the client and is presented for informational purposes only. Guideline values listed on this report are provided for ease of use (informational purposes) only. Eurofins recommends consulting the official provincial or federal guideline as required.

Certificate of Analysis

Client: Golder Associates Ltd. (Mississauga)
6925 Century Avenue
Mississauga, ON
L5N 7K2
Attention: Ms. Madison Kennedy
PO#:
Invoice to: Golder Associates Ltd. (Mississauga)

Report Number: 1805486
Date Submitted: 2018-04-13
Date Reported: 2018-04-20
Project: 1789436
COC #: 197339

Group	Analyte	MRL	Units	Guideline	Lab I.D. / Sample Matrix / Sample Type / Sampling Date / Sample I.D.			
					1353885 Soil 2018-03-14 BH 18-2 SA4	1353886 Soil 2018-03-12 BH 18-3 SA16	1353887 Soil 2018-03-14 BH 18-4 SA8	1353888 Soil 2018-03-27 BH 18-6 SA13
Agri. - Soil	pH	2.00			8.58	8.43	8.33	8.13
	SO4	0.01	%		<0.01	0.02	<0.01	0.02
General Chemistry	Cl	0.002	%		0.002	0.003	0.026	0.004
	Electrical Conductivity	0.05	mS/cm		0.09	0.16	0.43	0.28
	Resistivity	1	ohm-cm		11100	6250	2330	3570

Guideline = *** = Guideline Exceedence**

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

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

Certificate of Analysis

eurofins | Environment Testing

Client: Golder Associates Ltd. (Mississauga)
6925 Century Avenue
Mississauga, ON
L5N 7K2
Attention: Ms. Madison Kennedy
PO#:
Invoice to: Golder Associates Ltd. (Mississauga)

Report Number: 1805486
Date Submitted: 2018-04-13
Date Reported: 2018-04-20
Project: 1789436
COC #: 197339

QC Summary

Analyte	Blank	QC % Rec	QC Limits
Run No 343852 **Analysis/Extraction Date** 2018-04-19 **Analyst** C F			
Method Ag Soil			
pH	4.74	100	90-110
Method Cond-Soil			
Electrical Conductivity	<0.05 mS/cm	99	85-115
Method Resistivity - soil			
Resistivity			
Run No 343932 **Analysis/Extraction Date** 2018-04-20 **Analyst** C F			
Method C CSA A23.2-4B			
Chloride		101	90-110
Run No 343933 **Analysis/Extraction Date** 2018-04-20 **Analyst** C F			
Method AG SOIL			
SO4	<0.01 %	84	70-130

Guideline = *** = Guideline Exceedence**

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

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

golder.com