

## Foundation Investigation Report

*Trenchless Culvert Installations, Highway 48 and Bloomington Road Roundabout  
(Lat. 44.000847, Long. -79.289013), York Region, Ontario, Ministry of  
Transportation, Ontario, G.W.P. 2086-16-00*

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1671430-O9-2

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**GEOCRE No.: 31D-704**





## Distribution List

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## 1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by AECOM Canada Ltd. (AECOM) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the proposed trenchless culvert installations associated with the proposed Highway 48 / Bloomington Road Roundabout between Bloomington and Lemonville, Ontario, under G.W.P. 2086-16-00 (refer to the Key Plan on Drawing 1).

The Terms of Reference and scope of work are outlined in MTO's Work Item Order No. 2016-E-0029-009, dated December 2017, which forms part of the Consultant's Assignment for the Central Region Large Value Retainer under Agreement No. 2016-E-0029-009.

## 2.0 SITE DESCRIPTION

The proposed culverts are located within 50 m of the Highway 48 and Bloomington Road intersection, in the Town of Whitchurch-Stouffville. Culverts 4 and 15 will cross under Bloomington Road, west and east of Highway 48, respectively; and culvert 11 will cross under Highway 48, south of Bloomington Road.

A gas station is located on the southwest quadrant of the site adjacent to the Bloomington Road side of the intersection. Residential areas and farmland are located on both sides of Highway 48 north and southeast of the intersection. The topography of the site is generally flat-lying but rises from south to north, from about Elevation 314 m at the southernmost project limit to about Elevation 340 m at the northernmost project limit. The road grade at the Highway 48 and Bloomington Road intersection is at about Elevation 325.5 m.

The existing embankments at the Highway 48 / Bloomington Road intersection are about 3 m to 5 m high constructed with side slopes at inclinations of about 2H:1V and grass covered. The embankment side slopes were in good condition showing no signs of instability at the time of the field investigation.

## 3.0 INVESTIGATION PROCEDURES

Field work for the foundation investigation for the trenchless culverts was carried out between March 6 and 20, 2018, during which time eight boreholes (designated as Boreholes C4-1 to C4-3, C11-2, C11-3, and C15-1 to C15-3) were advanced at the site, approximately at the locations shown on Drawing 1.

Boreholes C4-1, C4-2, C11-2, C15-1 and C15-2 were advanced through the overburden using 153 mm outside diameter (O.D.) hollow stem augers using a CME 75 truck mounted drill rig, supplied and operated by Geo-Environmental Drilling Inc. of Acton, Ontario. Boreholes C4-3, C11-3 and C15-3 were advanced through the overburden using 60 mm inner diameter BW casing and wash boring technique with a portable tripod drill rig supplied and operated by OGS Inc. of Almonte, Ontario; water for the wash boring operations was brought to site in a large mobile tank by the drilling subcontractor. Soil samples were obtained at 0.75 m and 1.5 m intervals of depth using a 50 mm outer diameter split-spoon sampler driven by an automatic hammer on the truck-mounted drill rig and driven by a manual hammer on the portable tripod drill rig, in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586)<sup>1</sup>.

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<sup>1</sup> ASTM D1586 – Standard Test Method for Standard Penetration Tests and Split Barrel Sampling of Soils.



Boreholes C4-2, C11-2, C15-1 and C15-2 were advanced through the Highway 48 and Bloomington Road surface and C4-1 was advanced from the Bloomington Road shoulder to depth ranging from 6.1 m to 9.8 m below existing ground surface. Borehole C4-3 was advanced within the grassed area in the southwest quadrant of the highway / road intersection to a depth of 5.5 m, while Boreholes C11-3 and C15-3 were advanced along the road embankment slope within the southeast quadrant of the intersection to depths of 3.1 m and 3.7 m, respectively. Traffic protection was required for all the boreholes and consisted of either a shoulder closure for boreholes advanced in the roadways (ditches) or lane closures for boreholes advanced from the roadways platforms, consistent with Book 7 requirements.

Groundwater conditions in the open boreholes were observed during and immediately following the drilling operations. A standpipe piezometer was installed in each of Boreholes C4-2, C11-2 and C15-2 to permit monitoring of the water level at the site. The installed piezometers consist of a 50 mm diameter PVC pipe, with a 1.5 m to 3 m slotted screen sealed within a filter sand pack. The borehole and annulus surrounding the piezometer pipe above the filter sand pack were backfilled to the ground surface with bentonite pellets, and piezometers installed on the road surface were protected with flush mounted casing. Piezometer installation details and water level readings are described on the borehole records in Appendix A. Boreholes C4-1, C4-3, C11-3, C15-1 and C15-3 were backfilled to ground surface with bentonite in accordance with Ontario Regulation 903, Wells (as amended), and Boreholes C4-2, C15-1 and C15-2 were sealed at the surface with cold patch asphalt upon completion.

Field work was monitored on a full-time basis by a member of Golder's technical staff who located the boreholes in the field, directed the sampling and in situ testing operations, logged the boreholes and examined the soil samples. The soil samples were identified in the field, placed in labelled containers and transported to Golder's laboratory in Mississauga for further visual review and geotechnical laboratory testing on selected samples, consisting of natural moisture content, Atterberg limits and grain size distribution analyses, conducted in accordance with MTO and / or ASTM Standards as applicable.

One soil sample obtained during the field investigation from each three boreholes, using appropriate sampling protocols, were submitted to a specialist analytical laboratory under chain of custody procedures for chemical analysis of conductivity / resistivity, pH, and sulphate and chloride concentrations to assess the potential for the soil to cause deterioration to buried concrete and corrosion to steel.

Borehole locations were marked in the field by Golder personnel relative to the existing road features and using a hand-held GPS. The locations given on the Record of Borehole sheets and shown on Drawing 1 are positioned relative to MTM NAD 83 (Zone 10) northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum. The borehole locations, ground surface elevations and drilled depths are summarized below.

Borehole No.	MTM NAD83 (Zone 10)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing (m) (Latitude)	Easting (m) (Longitude)		
C4-1	4,873,452.1 (44.000869)	321,665.4 (-79.289704)	325.6	6.1
C4-2	4,873,442.1 (44.000779)	321,684.7 (-79.289463)	325.9	6.1



Borehole No.	MTM NAD83 (Zone 10)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing (m) (Latitude)	Easting (m) (Longitude)		
C4-3	4,873,421.2 (44.000590)	321,698.3 (-79.289294)	324.1	5.2
C11-2	4,873,415.5 (44.000539)	321,732.9 (-79.288863)	325.2	7.3
C11-3	4,873,429.9 (44.000667)	321,767.5 (-79.288431)	321.4	3.1
C15-1	4,873,476.8 (44.001089)	321,786.5 (-79.288193)	325.6	9.8
C15-2	4,873,456.8 (44.000909)	321,784.9 (-79.288214)	325.4	9.8
C15-3	4,873,442.5 (44.000780)	321,789.7 (-79.288154)	321.1	3.7

## 4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

### 4.1 Regional Geology

The site is located at the boundary of the Oak Ridges Moraine and South Slope physiographic regions, according to *The Physiography of Southern Ontario* (Chapman and Putnam, 1984)<sup>2</sup>

The Oak Ridges Moraine is hilly, with a knob-and-basin relief typical of end moraines and Rame moraines. The hills are mostly composed of sand and gravel, however; some are formed of till which protrudes above the sand and gravel deposits. The South Slope is a smooth and drumlinized till plain that has formed as a result of glacial action and deposition of till materials just south of the Oak Ridges Moraine.

### 4.2 Subsurface Conditions

Subsurface soil and groundwater conditions as encountered in the boreholes advanced during this investigation and the results of the geotechnical laboratory tests carried out on selected soil samples are presented on the Record of Borehole sheets provided in Appendix A. The results of in situ field tests (i.e., SPT “N”-values) as presented on the Record of Borehole sheets, on the stratigraphic profiles and in Section 4.2 are uncorrected. Results of the geotechnical laboratory testing on soil samples are also presented in Appendix B. Results of the analytical testing of three soil samples are summarized in Section 4.4 and the laboratory test report is provided in Appendix C.

Stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profiles on Drawing 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

<sup>2</sup> 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.



of geological change. Furthermore, subsurface conditions will vary between and beyond the borehole locations; however, the factual data presented in the Record of Borehole sheets governs any interpretation of the site conditions.

In general, the stratigraphy encountered at the various borehole locations typically consists of surficial layers of asphalt / concrete pavement and / or non-cohesive fill underlain by a cohesive till deposit, further underlain by a sand to sand and gravel deposit or a non-cohesive till deposit. The water level at this site was encountered between Elevation 318.1 m and 322.1 m in the open boreholes upon completion of drilling and the stand pipe piezometers installed were found to be dry about one week after installation.

Detailed descriptions of the subsurface conditions are provided in the following sections of this report. Where relatively significant thicknesses of overburden were encountered, the various soil types are described in detail for each main deposit.

#### **4.2.1 Topsoil**

Approximately 25 mm to 50 mm of topsoil was encountered at ground surface in Boreholes C4-3, C11-3 and C15-3, which were advanced away from the highway / roadway.

#### **4.2.2 Asphalt**

An approximately 64 mm to 180 mm of asphalt pavement was encountered at ground surface in Boreholes C4-2, C11-2, C15-1 and C15-2, which were advanced from the highway / roadway.

#### **4.2.3 Fill**

A 0.4 m to 1.5 m thick layer of fill was encountered at ground surface in Borehole C4-1, underlying the topsoil layer in Boreholes C4-3, C11-3 and C15-3, and underlying the asphalt pavement in Boreholes C4-2, C11-2, C15-1 and C15-2. The surface of the fill layer was encountered between Elevations 325.7 m and 321.1 m, and the base of the fill layer was encountered between Elevations 325.3 m and 319.9 m.

The fill is mainly non-cohesive and varies in composition from sand containing trace to some gravel, trace to some silt, trace clay and trace to some rock fragments to gravelly sand containing trace silt to sandy gravel to sand and gravel containing trace to some silt. The cohesive fill was encountered in Boreholes C4-3 and C15-3 and is comprised clayey silt containing some sand and trace gravel to sandy clayey silt containing trace gravel. Trace organics and rootlets were encountered within the cohesive fill in Boreholes C4-3 and C15-3 and within the non-cohesive fill in Borehole C11-3.

The Standard Penetration Test (SPT) "N"-values measured within the non-cohesive fill deposit range from 3 blows to 62 blows per 0.3 m of penetration, indicating a very loose to very dense level of compactness. The SPT "N"-values measured within the cohesive fill range from 3 blows to 11 blows per 0.3 m of penetration, suggesting a soft to stiff consistency.

The natural water content measured on one selected sample of the non-cohesive fill was about 5 per cent. The natural water content measured on one selected sample of the cohesive fill is 28 per cent.

#### **4.2.4 Clayey Silt**

A 2.5 m and 0.3 m thick clayey silt deposit was encountered underlying the fill in Boreholes C4-3 and C15-2, respectively. The surface of the clayey silt deposit was encountered at Elevations 323.5 m and 324.0 m.



The SPT “N”-values measured within the clayey silt deposit range from 13 blows to 125 blows per 0.3 m of penetration, suggesting a stiff to hard consistency.

A grain size distribution test was carried out on one sample of the clayey silt and the result is shown on Figure B-1 in Appendix B. An Atterberg limits test was carried out on one sample of the clayey silt deposit and measured a liquid limit of 30 per cent, a plastic limit of 15 per cent, and a corresponding plasticity index of 15 per cent. The result, which is plotted on a plasticity chart on Figure B-2 in Appendix B, indicates that the deposit consists of clayey silt of low plasticity. The natural water content measured on two selected samples of the clayey silt is about 15 per cent and 18 per cent.

#### **4.2.5 Clayey Silt to Clayey Silt with Sand Till**

A 1.6 m to 6.5 m thick cohesive till deposit was encountered underlying the fill layer in Boreholes C11-2, C11-3, and C15-3, underlying the sand till in Borehole C15-1 and underlying the gravelly sand in Borehole C15-2. The surface of the cohesive till deposit was encountered between Elevations 324.1 m and 319.9 m. The cohesive till is comprised of clayey silt containing some sand to clayey silt with sand, trace gravel and trace cobble/rock fragments, though the sampler could not obtain larger fragments of rock given the sampler size. A hydrocarbon odour was noted in Boreholes C11-2 and C15-2 in select samples from the till deposit. Boreholes C11-2 and C11-3 were terminated within the cohesive till deposit, penetrating it for a thickness of 6.2 m and 2.5 m, respectively.

The SPT “N”-values measured within the cohesive till deposit, generally range from 4 blows to 57 blows per 0.3 m of penetration, with discrete “N”-values of 28 blows and 50 blows per 0.15 m of penetration on inferred cobbles, suggesting a generally firm to hard consistency.

Grain size distribution testing was carried out on 10 samples of the cohesive till and the results are shown on Figures B-3A and B-3B in Appendix B. Atterberg limits testing was carried out on 10 samples of the cohesive till deposit and measured liquid limits between 16 per cent and 33 per cent, plastic limits between 11 per cent and 24 per cent, and plasticity indices between 5 per cent and 10 per cent. These results, which are plotted on a plasticity chart on Figures B-4A and B-4B in Appendix B, indicate that the cohesive till consists of clayey silt of low plasticity. An organic content test was carried out on one sample of the cohesive till deposit and measured 5.3 per cent organics. The natural water content measured on selected samples of the cohesive till ranges from about 9 per cent to about 32 per cent.

#### **4.2.6 Sand to Silt and Sand to Silty Gravelly Sand Till**

A 0.9 m to 2.4 m thick non-cohesive till deposit was encountered underlying the fill in Borehole C15-1, underlying the clayey silt deposit in Borehole C4-3, the cohesive till in Borehole C15-3, and the sandy gravel to sand and gravel deposit in Boreholes C4-1 and C4-2. The surface of the non-cohesive till was encountered between Elevations 322.2 m and 318.3 m. Boreholes C4-1, C4-2 and C15-3 were terminated within this deposit, penetrating it for thickness between 0.9 m and 2.4 m. The non-cohesive till is comprised of sand to silt and sand to silty gravelly sand containing trace to some clay. The non-cohesive till contains trace cobble/rock fragments, though the sampler could not obtain larger fragments of rock given the sampler size.

The SPT “N”-values measured within the non-cohesive till deposit, range from 5 blows to 55 blows per 0.3 m of penetration, with discrete “N”-values of 116 blows and 148 blows per 0.3 m of penetration and 100 blows per 0.05 m of penetration in Borehole C4-3 on inferred cobbles, indicating a loose to very dense level of compactness. In general the SPT “N”-values in the non-cohesive till are greater than 20 blows per 0.3 m of penetration.



Grain size distribution testing was carried out on six samples of the non-cohesive till and the results are shown on Figure B-5 in Appendix B. Atterberg limits testing was carried out on two samples of the non-cohesive till deposit and measured liquid limits of 13 per cent and 16 per cent, plastic limits of 11 per cent and 12 per cent, and plasticity indices of 2 per cent and 4 per cent. These results, which are plotted on a plasticity chart on Figure B-6 in Appendix B, indicate that the non-cohesive till is a silt of low plasticity. The natural water content measured on selected samples of the non-cohesive till ranges from about 2 per cent to about 12 per cent.

#### 4.2.7 Sand to Sand and Gravel

A 0.3 m to 3.1 m thick sand to sand and gravel deposit was encountered underlying the fill in Boreholes C4-1 and C4-2, the clayey silt deposit in Borehole C15-2, and was found underlying the till in Boreholes C4-3, C15-1 and C15-2. The surface of the deposit was encountered between Elevations 325.3 m and 316.7 m. Boreholes C4-3, C15-1 and C15-2 were terminated within this deposit, penetrating it for thicknesses between 0.3 m and 1.1 m.

The deposit consists of sand containing trace clay, trace to some silt and some gravel (Borehole C15-2 and C4-2) to gravelly sand to sand and gravel containing trace to some silt, trace clay and trace cobble fragments (Boreholes C4-1, C4-2, C4-3, C15-1 and C15-2). Grinding of the augers was observed within the sandy gravel to sand and gravel layer in Boreholes C4-1, on inferred cobbles or boulders.

The SPT “N”-values measured within the sand to sand and gravel deposit range from 10 blows to 93 blows per 0.3 m of penetration, with one discrete “N”-value of 186 blows per 0.2 m of penetration, indicating a compact to very dense level of compactness.

Grain size distribution testing was carried out on four samples of the sand to silty gravelly sand to sand and gravel deposit and the results are shown on Figures B-7 in Appendix B. The natural water content measured on selected samples of the sand to silty gravelly sand to sand and gravel deposit ranges from about 1 per cent to about 9 per cent.

### 4.3 Groundwater Conditions

The water levels in the open boreholes were measured upon completion of drilling operations. A standpipe piezometer was installed in each of Boreholes C4-2, C11-2 and C15-2 to permit monitoring of the groundwater level at this site; water level recorded in the open boreholes and piezometers are summarized below.

Borehole No.	Ground Surface Elevation (m)	Depth to Water Level (m)	Groundwater Elevation (m)	Date	Comments
C4-1	325.6	Dry	-	Mar. 9, 2018	Open borehole
C4-2	325.9	Dry	-	Mar. 12, 2018	Open borehole
		Dry	-	Mar. 21, 2018	Piezometer
C4-3	324.1	2.0	322.1	Mar. 19, 2018	Open borehole
C11-2	325.2	Dry	-	Mar. 8, 2018	Open borehole
		Dry	-	Mar. 20, 2018	Piezometer



Borehole No.	Ground Surface Elevation (m)	Depth to Water Level (m)	Groundwater Elevation (m)	Date	Comments
C11-3	321.4	Dry	-	Mar. 20, 2018	Open borehole
C15-1	325.6	Dry	-	Mar. 6, 2018	Open borehole (borehole caved to 8.2 m depth)
C15-2	325.4	Dry	-	Mar. 11, 2018	Open borehole
		Dry	-	Mar. 20, 2018	Piezometer
C15-3	321.1	3.0	318.1	Mar. 20, 2018	Open borehole

The water level at this site will be subject to seasonal fluctuations and precipitation events and should be expected to be higher during the spring season or during and following periods of heavy precipitation.

#### 4.4 Analytical Testing Results

Three soil samples were submitted for analysis of parameters used to assess the potential corrosivity of the site soil to steel and concrete. Detailed analytical test results are included in Appendix C and the test results are summarized below:

Borehole No. / Sample No.	pH	Resistivity (ohm-cm)	Electrical Conductivity (umho/cm)	Chlorides (ug/g)	Soluble Sulphates (ug/g)
C4-2 / 4	8.14	1,500	684	340	<20
C11-2 / 5	7.68	420	2,400	1,300	130
C15-1 / 7	7.68	850	1,170	630	<20



## 5.0 CLOSURE

This Foundation Investigation Report was prepared by Ms. Nikol Kochmanová, P.Eng., a geotechnical engineer with Golder. Mr. Jorge Costa, P.Eng., a MTO Foundations Designated Contact and Senior Consultant with Golder, conducted a technical and quality control review of the report.

### Golder Associates Ltd.



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*Geotechnical Engineer*



Jorge M.A. Costa, P.Eng.  
*MTO Foundations Designated Contact, Senior Consultant*

NK/JMAC/rb

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<https://golderassociates.sharepoint.com/sites/15994g/6.deliverables/wo009-hwy48-bloomington/2.culverts/3.final/1671430wo9fir2018jul12bloomingtontrenchlessculverts.docx>



## REFERENCES

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.

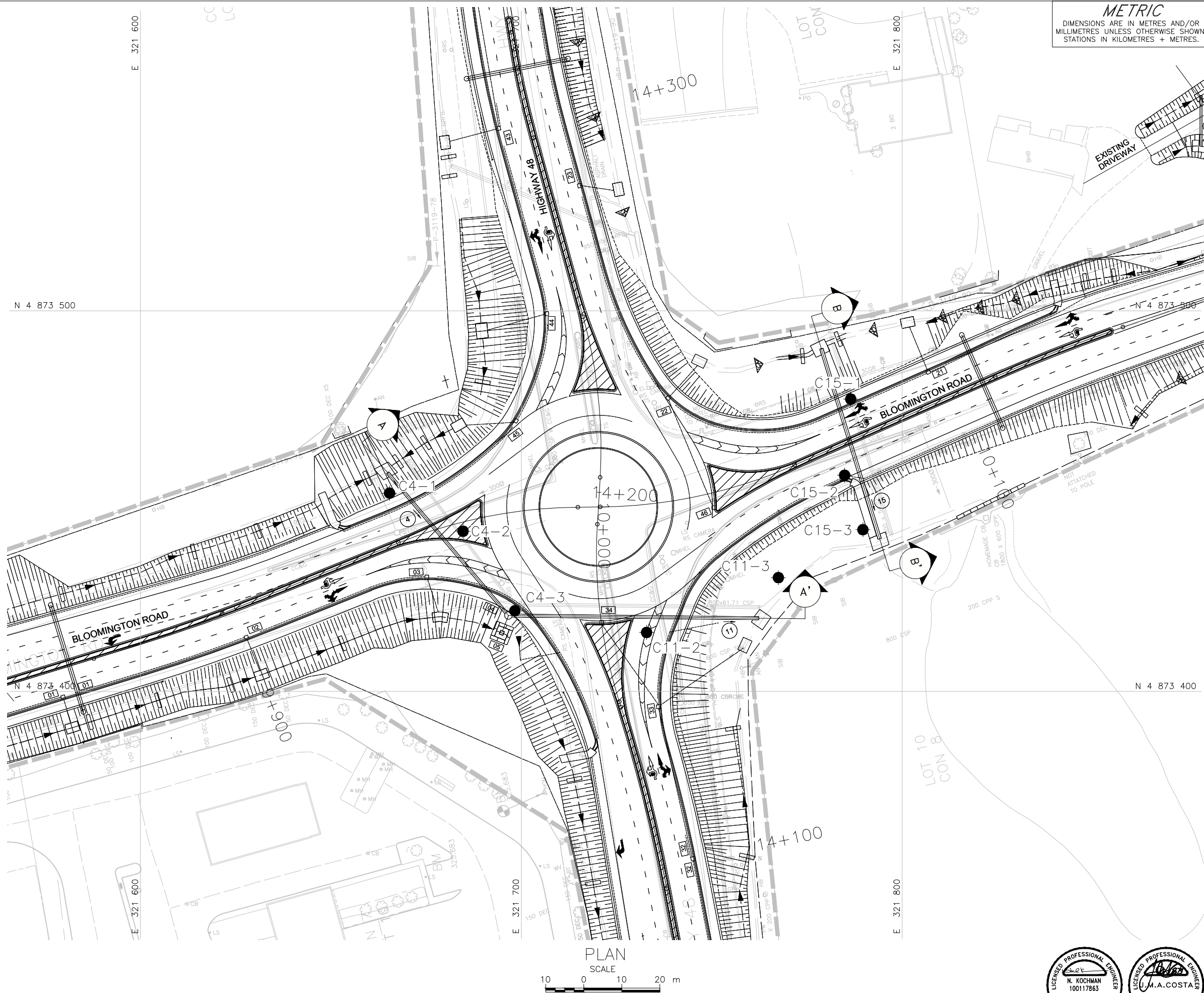
### **ASTM International**

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

### **Ontario Water Resources Act**

Ontario Regulation 903 Wells (as amended)

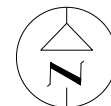




PLAN  
SCALE  
10 0 10 20 m

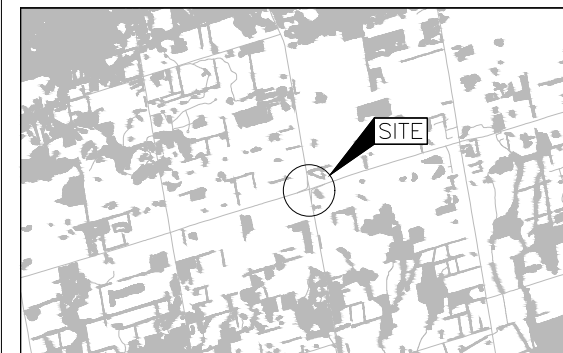
**METRIC**  
DIMENSIONS ARE IN METRES AND/OR  
MILLIMETRES UNLESS OTHERWISE SHOWN.  
STATIONS IN KILOMETRES + METRES.

CONT No. 2017-2042  
GWP No. 2086-16-00



SHEET

HWY 48 AND BLOOMINGTON ROAD ROUNDABOUT  
(LAT. 44.000847, LONG. -79.289013)  
NON-STRUCTURAL CULVERT REPLACEMENTS  
BOREHOLE LOCATIONS



KEY PLAN  
SCALE

1 0 1 2 km

LEGEND

● Borehole - Current Investigation

BOREHOLE CO-ORDINATES (MTM NAD 83 ZONE 10)

No.	ELEVATION	NORTHING	EASTING
C4-1	325.6	4873452.1	321665.4
C4-2	325.9	4873442.1	321684.7
C4-3	324.1	4873421.2	321698.3
C11-2	325.2	4873415.5	321732.9
C11-3	321.4	4873429.9	321767.5
C15-1	325.6	4873476.8	321786.5
C15-2	325.4	4873456.8	321784.9
C15-3	321.1	4873442.5	321789.7

### NOTES

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

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

### REFERENCE

Base plans provided in digital format by AECOM, drawing file nos. Hwy48 Bloom\_bgd\_PH 150409\_Hwy48N.dwg, Hwy48 Bloom\_bgd\_PH 150410\_Hwy48S.dwg and Hwy48 Bloom\_plan.dwg, received February 15, 2018 and Hwy48 Bloom\_bgd.dwg, received April 12, 2018.

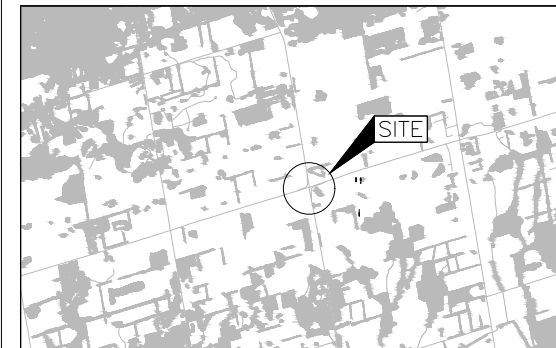


NO.	DATE	BY	REVISION
Geocres No. 31D-704			
HWY. 48	PROJECT NO. 1671430		DIST. .
SUBM'D. NK	CHKD. NK	DATE: 07/12/2018	SITE: .
DRAWN: DD	CHKD. NK	APPD. JMAC	DWG. 1









SHEET



KEY PLAN  
SCALE



### LEGEND

- |   |  |
|---|--|
|  | Borehole – Current Investigation                                   |
| N   | Standard Penetration Test Value                                    |
| 16  | Blows/0.3m unless otherwise stated<br>(Std. Pen. Test, 475 j/blow) |
|  | WL upon completion of drilling                                     |
|  | Seal   |
|  | Piezometer   |

BOREHOLE CO-ORDINATES (MTM NAD 83 ZONE 10)			
No.	ELEVATION	NORTHING	EASTING
C4-1	325.6	4873452.1	321665.4
C4-2	325.9	4873442.1	321684.7
C4-3	324.1	4873421.2	321698.3
C11-2	325.2	4873415.5	321732.9
C11-3	321.4	4873429.9	321767.5
C15-1	325.6	4873476.8	321786.5
C15-2	325.4	4873456.8	321784.9
C15-3	321.1	4873442.5	321789.7

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Base plans provided in digital format by AECOM, drawing file nos. Hwy48Bloom\_bgd\_PH 150409\_Hwy48N.dwg, Hwy48Bloom\_bgd\_PH 150410\_Hwy48S.dwg and Hwy48 Bloom\_plan.dwg, received February 15, 2018 and Hwy48 Bloom\_bgd.dwg, received April 12, 2018.

[illegible]



**APPENDIX A**

# Record of Borehole Sheets



## LIST OF SYMBOLS

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

### I. GENERAL

$\pi$	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

$\gamma$	shear strain
$\Delta$	change in, e.g. in stress: $\Delta \sigma$
$\varepsilon$	linear strain
$\varepsilon_v$	volumetric strain
$\eta$	coefficient of viscosity
$\nu$	Poisson's ratio
$\sigma$	total stress
$\sigma'$	effective stress ( $\sigma' = \sigma - u$ )
$\sigma'_{vo}$	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
$\sigma_{oct}$	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
$\tau$	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
$\gamma'$	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
$C_{\alpha}$	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
$\sigma'_p$	pre-consolidation stress
OCR	over-consolidation ratio = $\sigma'_p / \sigma'_{vo}$

#### (d) Shear Strength

$\tau_p, \tau_r$	peak and residual shear strength
$\phi'$	effective angle of internal friction
$\delta$	angle of interface friction
$\mu$	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  $\rho$ . Unit weight symbol is  $\gamma$  where  $\gamma = \rho g$  (i.e. mass density multiplied by acceleration due to gravity)

Notes: 1  
2

$\tau = c' + \sigma' \tan \phi'$   
shear strength = (compressive strength)/2



## LIST OF ABBREVIATIONS

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

### I. SAMPLE TYPE

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

### II. PENETRATION RESISTANCE

#### Standard Penetration Resistance (SPT), N:

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

#### Dynamic Cone Penetration Resistance; $N_d$ :

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

**PH:** Sampler advanced by hydraulic pressure

**PM:** Sampler advanced by manual pressure

**WH:** Sampler advanced by static weight of hammer

**WR:** Sampler advanced by weight of sampler and rod

#### Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm<sup>2</sup> 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	N
Condition	Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

#### (b) Cohesive Soils Consistency

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

### IV. SOIL TESTS

w	water content
$w_p$	plastic limit
$w_l$	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test <sup>1</sup>
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement <sup>1</sup>
$D_R$	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)
$\gamma$	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



<b>PROJECT</b> 1671430		<b>RECORD OF BOREHOLE No C4-1</b>		SHEET 1 OF 1		<b>METRIC</b>	
G.W.P. 2086-16-00		LOCATION N 4873452.1; E 321665.4 MTM NAD 83 ZONE 10 (LAT. 44.000869; LONG. -79.289704)		ORIGINATED BY JS			
DIST Central HWY 48		BOREHOLE TYPE 153 mm O.D., 70 mm I.D. Hollow Stem Augers		COMPILED BY ACM			
DATUM Geodetic		DATE March 9, 2018		CHECKED BY NK			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT   NATURAL LIQUID   MOISTURE LIMIT   CONTENT   LIMIT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					W <sub>p</sub>	W	W <sub>L</sub>		GR	SA	SI	CL
								○ UNCONFINED   + FIELD VANE ● QUICK TRIAXIAL   × REMOULDED						WATER CONTENT (%)						
325.6	GROUND SURFACE						20	40	60	80	100									
0.0	Gravelly sand, trace silt, trace rootlets (FILL)		1A	SS	14		325													
325.2	Compact Brown Moist		1B																	
0.4	Sand, some gravel, trace silt (FILL)	2	SS	28																
324.2	Compact Brown Moist																			
1.5	Sandy GRAVEL to SAND and GRAVEL, trace silt, trace clay, some rock fragments from 2.9 m to 3.7 m	3	SS	41																
	Dense to very dense Grey to brown Dry to moist - Grinding between depths of about 2.3 m and 2.9 m below ground surface																			
		4	SS	85																
		5	SS	71																
321.4			6A	SS	55															
4.2	SAND, trace to some silt, trace gravel, trace clay (TILL)		6B																	
	Loose to very dense Brown Moist		7	SS	52															
319.5			8	SS	5															
6.1	END OF BOREHOLE																			
	NOTE:  1. Open borehole dry upon completion of drilling.																			

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PROJECT		1671430		RECORD OF BOREHOLE No C4-2		SHEET 1 OF 1		METRIC										
G.W.P.		2086-16-00		LOCATION		N 4873442.1; E 321684.7 MTM NAD 83 ZONE 10 (LAT. 44.000779; LONG. -79.289463)		ORIGINATED BY JS										
DIST		Central HWY 48		BOREHOLE TYPE		153 mm O.D., 70 mm I.D. Hollow Stem Augers		COMPILED BY ACM										
DATUM		Geodetic		DATE		March 12, 2018		CHECKED BY NK										
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	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ	GR SA SI CL
								20 40 60 80 100	20 40 60 80 100	W <sub>p</sub>	W	W <sub>L</sub>	10 20 30	kN/m <sup>3</sup>				
325.9	0.0	GROUND SURFACE ASPHALT (180 mm)		1A	AS	-												
		Gravelly sand, trace silt (FILL)		1B														
	0.6	Brown Moist Sand, trace silt, trace gravel (FILL)		2	SS	93		325										
		Brown Moist SAND, some gravel, trace silt, trace clay		3	SS	44		324										
	323.6	Dense to very dense																
	2.3	Brown Moist SAND and GRAVEL, trace to some silt, trace clay		4	SS	67		323										
		Very dense		5	SS	71											45 46 7 2	
	322.2	Brown Moist SAND, trace to some gravel, trace to some silt, trace clay (TILL)		6	SS	32		322										
	3.7	Dense to very dense		7	SS	39		321									7 85 7 1	
		Brown to grey Moist		8	SS	51		320										
	319.8	END OF BOREHOLE																
	6.1	NOTES:  1. Open borehole dry upon completion of drilling.  2. Water levels measured in standpipe piezometer:  Date Depth(m) Elev.(m) 12/03/18 Dry - 21/03/18 Dry -																



PROJECT		1671430		RECORD OF BOREHOLE No C4-3		SHEET 1 OF 1		METRIC						
G.W.P.		2086-16-00		LOCATION		N 4873421.2; E 321698.3 MTM NAD 83 ZONE 10 (LAT. 44.000590; LONG. -79.289294)		ORIGINATED BY						
DIST		Central HWY 48		BOREHOLE TYPE		73 mm O.D., 60 mm I.D. BW Casing		COMPILED BY						
DATUM		Geodetic		DATE		March 19, 2018		CHECKED BY						
								NK						
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
324.1	GROUND SURFACE							20 40 60 80 100	20 40 60 80 100	10 20 30				
0.0	TOPSOIL (25 mm)		1	SS	11									
323.5	Clayey silt, some sand, trace gravel, trace organics, rootlets (FILL)		2	SS	13						○			
0.6	Stiff Brown Moist		3	SS	35									
	CLAYEY SILT, trace to some sand, trace gravel		4	SS	33									
	Stiff to hard Brown Moist		5	SS	125									
321.0	- Cobbles encountered between 1.8 m and 3.1 m depths													2 10 53 35
	- Sand seam between 2.3 m and 2.9 m depths													
3.1	Silty Gravelly SAND, trace to some clay, trace cobble fragments (TILL)		6	SS	148						○			25 38 29 8
	Very dense Brown to brown/grey mottled Moist to wet		7	SS	100/0.05									
	- Cobbles encountered between 3.1 m and 3.7 m depths													
319.2			8	SS	116						○			26 46 24 4
318.9	SAND and GRAVEL, some silt, cobbles fragments, sand seams, clayey silt pocket		9	SS	186/0.20									
5.2	Very dense Grey/brown, mottled Wet													
	END OF BOREHOLE													
	NOTE:													
	1. Water level in open borehole at a depth of about 2.0 m below ground surface (Elev. 322.1 m) upon completion of drilling.													



PROJECT 1671430		<b>RECORD OF BOREHOLE No C11-2</b>		SHEET 1 OF 1		<b>METRIC</b>							
G.W.P. 2086-16-00		LOCATION N 4873415.5; E 321732.9 MTM NAD 83 ZONE 10 (LAT. 44.000539; LONG. -79.288863)		ORIGINATED BY JS									
DIST Central HWY 48		BOREHOLE TYPE 153 mm O.D., 70 mm I.D. Hollow Stem Augers		COMPILED BY ACM									
DATUM Geodetic		DATE March 8, 2018		CHECKED BY NK									
SOIL PROFILE			SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa		WATER CONTENT (%)			
325.2	GROUND SURFACE						20 40 60 80 100	20 40 60 80 100	10 20 30				
0.0	ASPHALT (152 mm)		1A	AS	-								
324.7	Gravelly sand, trace silt (FILL)		1B										
0.5	Brown Moist												
324.1	Sand, trace to some gravel, trace to some silt (FILL)		2A	SS	23								
1.1	Compact Brown Moist		2B										
	CLAYEY SILT, some sand to with SAND, trace to some gravel (TILL)		3	SS	28/0.15								
	Firm to hard												
	Brown to black at 1.1 m to grey at 6.4 m to 7.3 m		4	SS	17								4 38 45 13
	Moist												
	- Hydrocarbon odour noted at 1.5 m depth		5	SS	8								
	-split spoon refusal at 1.7 m		6	SS	6								
			7	SS	14								3 29 50 18
			8A	SS	22								
			8B										
			9A	SS	35								7 36 44 13
			9B										
317.9	END OF BOREHOLE												
7.3	NOTES:												
	1. Open borehole dry on completion of drilling.												
	2. Water level measured in standpipe piezometer:												
	Date Depth (m) Elev. (m)												
	08/03/18 Dry -												
	20/03/18 Dry -												

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PROJECT		1671430		RECORD OF BOREHOLE No C11-3		SHEET 1 OF 1		METRIC									
G.W.P.		2086-16-00		LOCATION		N 4873429.9; E 321767.5 MTM NAD 83 ZONE 10 (LAT. 44.000667; LONG. -79.288431)		ORIGINATED BY									
DIST		Central HWY 48		BOREHOLE TYPE		73 mm O.D., 60 mm I.D. BW Casing		COMPILED BY									
DATUM		Geodetic		DATE		March 20, 2018		CHECKED BY									
								NK									
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
321.4	GROUND SURFACE																
0.9	TOPSOIL (50 mm)		1A	SS	3												
320.8	Sand, some gravel, some silt, trace organics (FILL) Very loose Brown/grey mottled Moist		1B	SS	3												
0.6	CLAYEY SILT with SAND, trace gravel, trace organics, trace sand seams (TILL) Firm to very stiff Brown Moist		2	SS	6												
			3	SS	6												
			4	SS	10												
			5	SS	20												
318.4	END OF BOREHOLE																
3.1	NOTE:  1. Borehole dry upon completion of drilling.																



PROJECT		1671430		RECORD OF BOREHOLE No C15-1		SHEET 1 OF 1		METRIC					
G.W.P.		2086-16-00		LOCATION		N 4873476.8; E 321786.5 MTM NAD 83 ZONE 10 (LAT. 44.001089; LONG. -79.288193)		ORIGINATED BY JS					
DIST		Central HWY 48		BOREHOLE TYPE		153 mm O.D., 70 mm I.D. Hollow Stem Augers		COMPILED BY ACM					
DATUM		Geodetic		DATE		March 6, 2018		CHECKED BY NK					
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W <sub>p</sub> W W <sub>L</sub>			
325.6	GROUND SURFACE												
0.0	ASPHALT (152 mm)												
0.2	Sand to gravelly sand, trace silt (FILL)		1A	AS	-								
324.9	Brown Moist		1B										
0.7	SAND, trace to some silt, trace to some gravel, trace clay (TILL)		2	SS	48								7 80 11 2
	Compact to dense		3	SS	23								
	Brown Moist		4	SS	20								
322.6													
3.0	Sandy CLAYEY SILT, trace to some gravel (TILL)		5A	SS	57								
	Firm to hard		5B										
	Brown Moist		6	SS	36								3 29 52 16
			7	SS	8								
			8	SS	8								1 25 56 18
			9	SS	10								
316.9													
8.7	SAND and GRAVEL, trace to some silt, trace clay												
	Loose to compact												
	Brown Moist		10	SS	10								49 42 8 1
315.8													
9.8	END OF BOREHOLE												
NOTES:													
1. Borehole caved to a depth of 8.2 m below ground surface on removal of augers.													
2. Open borehole dry upon completion of drilling.													

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PROJECT 1671430		<b>RECORD OF BOREHOLE No C15-2</b>		SHEET 1 OF 1		<b>METRIC</b>																	
G.W.P. 2086-16-00		LOCATION N 4873456.8; E 321784.9 MTM NAD 83 ZONE 10 (LAT. 44.000909; LONG. -79.288214)		ORIGINATED BY JS																			
DIST Central HWY 48		BOREHOLE TYPE 153 mm O.D., 70 mm I.D. Hollow Stem Augers		COMPILED BY ACM																			
DATUM Geodetic		DATE March 11, 2018		CHECKED BY NK																			
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID		UNIT		REMARKS & GRAIN SIZE DISTRIBUTION (%)											
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa		W <sub>p</sub>	W	W <sub>L</sub>	γ	GR SA SI CL									
325.4	GROUND SURFACE							20 40 60 80 100	20 40 60 80 100	10 20 30			kN/m <sup>3</sup>										
0.0	ASPHALT (64 mm)		1A	AS	-		325																
0.3	Sand and gravel, trace silt (FILL) Brown Moist		1B																				
	Sand, trace to some gravel, trace silt (FILL) Very dense Brown Moist		2	SS	62																		
324.0							324																
323.7	CLAYEY SILT, some sand, trace gravel, trace organics/wood fragments Hard Brown Moist		3A	SS	34																		
1.7			3B																				
323.2			4	SS	50/ 0.15		323																
2.2	Gravelly SAND, trace silt Dense Brown Moist to wet		5	SS	37																		
	CLAYEY SILT, trace sand to with SAND, trace to some gravel (TILL) Stiff to hard Brown with oxidation stains Moist to wet -split spoon refusal at 2.4 m  - Hydrocarbon odour between 4.6 m and 5.2 m		6	SS	28		322																
			7	SS	36									7 34 45 14									
							321																
			8	SS	8		320						OC=5.3%	2 16 68 14									
							319																
			9A 9B	SS	14		318							0 7 83 10									
							317																
316.7	SAND, some silt, some gravel Compact Brown Moist		10	SS	18		316																
315.7																							
9.8	END OF BOREHOLE																						
NOTES: 1. Open borehole dry on completion of drilling. 2. Water level measured in standpipe piezometer: <table border="1" style="width:100%; border-collapse: collapse;"> <thead> <tr> <th>Date (m)</th> <th>Depth (m)</th> <th>Elev.</th> </tr> </thead> <tbody> <tr> <td>11/03/18</td> <td>Dry</td> <td>-</td> </tr> <tr> <td>20/03/18</td> <td>Dry</td> <td>-</td> </tr> </tbody> </table>															Date (m)	Depth (m)	Elev.	11/03/18	Dry	-	20/03/18	Dry	-
Date (m)	Depth (m)	Elev.																					
11/03/18	Dry	-																					
20/03/18	Dry	-																					

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PROJECT		1671430		RECORD OF BOREHOLE No C15-3		SHEET 1 OF 1		METRIC										
G.W.P.		2086-16-00		LOCATION		N 4873442.5; E 321789.7 MTM NAD 83 ZONE 10 (LAT. 44.000780; LONG. -79.288154)		ORIGINATED BY										
DIST		Central HWY 48		BOREHOLE TYPE		73 mm O.D., 60 mm I.D. BW Casing		COMPILED BY										
DATUM		Geodetic		DATE		March 20, 2018		CHECKED BY										
								NK										
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)
321.1	GROUND SURFACE							20	40	60	80	100						
0.0	TOPSOIL (25 mm)		1	SS	3													
	Sandy clayey silt, trace gravel, trace organics/rootlets, sand seams (FILL)		2	SS	6													
319.9	Firm Dark brown to brown, black staining Moist		3	SS	4													
1.2	CLAYEY SILT with SAND, trace to some gravel (TILL)		4	SS	4													
	Soft to very stiff Brown Moist to wet		5A	SS	29													
318.3	SILT and SAND, trace to some gravel, trace to some clay (TILL)		5B	SS	29													
2.8	Compact to very dense Brown Moist		6	SS	52													
317.4	- Sand seams and oxidation present below 3.1 m																	
3.7	END OF BOREHOLE																	
NOTE: 1. Water level recorded in open borehole at a depth of about 3.0 m below ground surface (Elev. 318.1 m) upon completion of drilling.																		



**APPENDIX B**

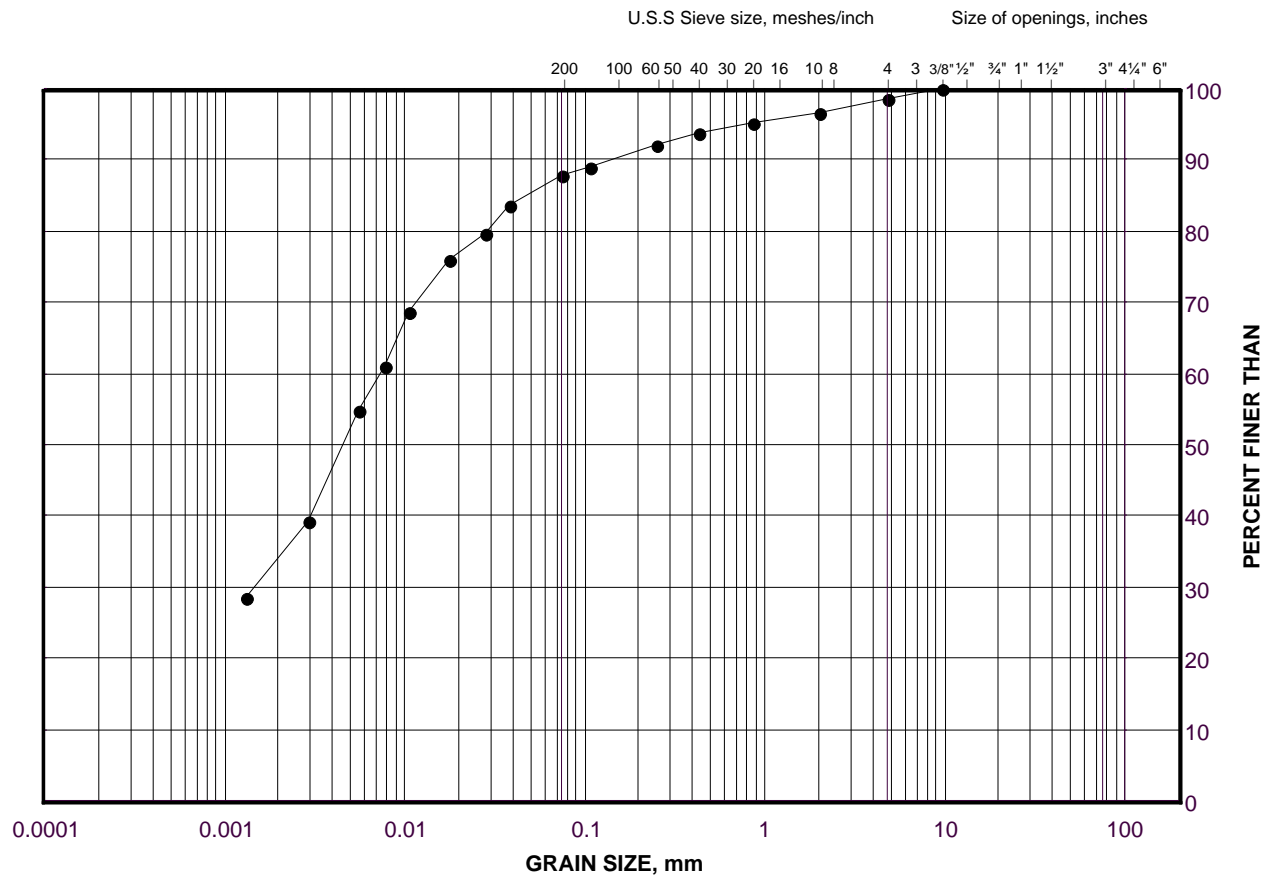
# Geotechnical Laboratory Test Results



# GRAIN SIZE DISTRIBUTION

Clayey Silt

FIGURE B-1



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

## LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
•	C4-3	4	322.0

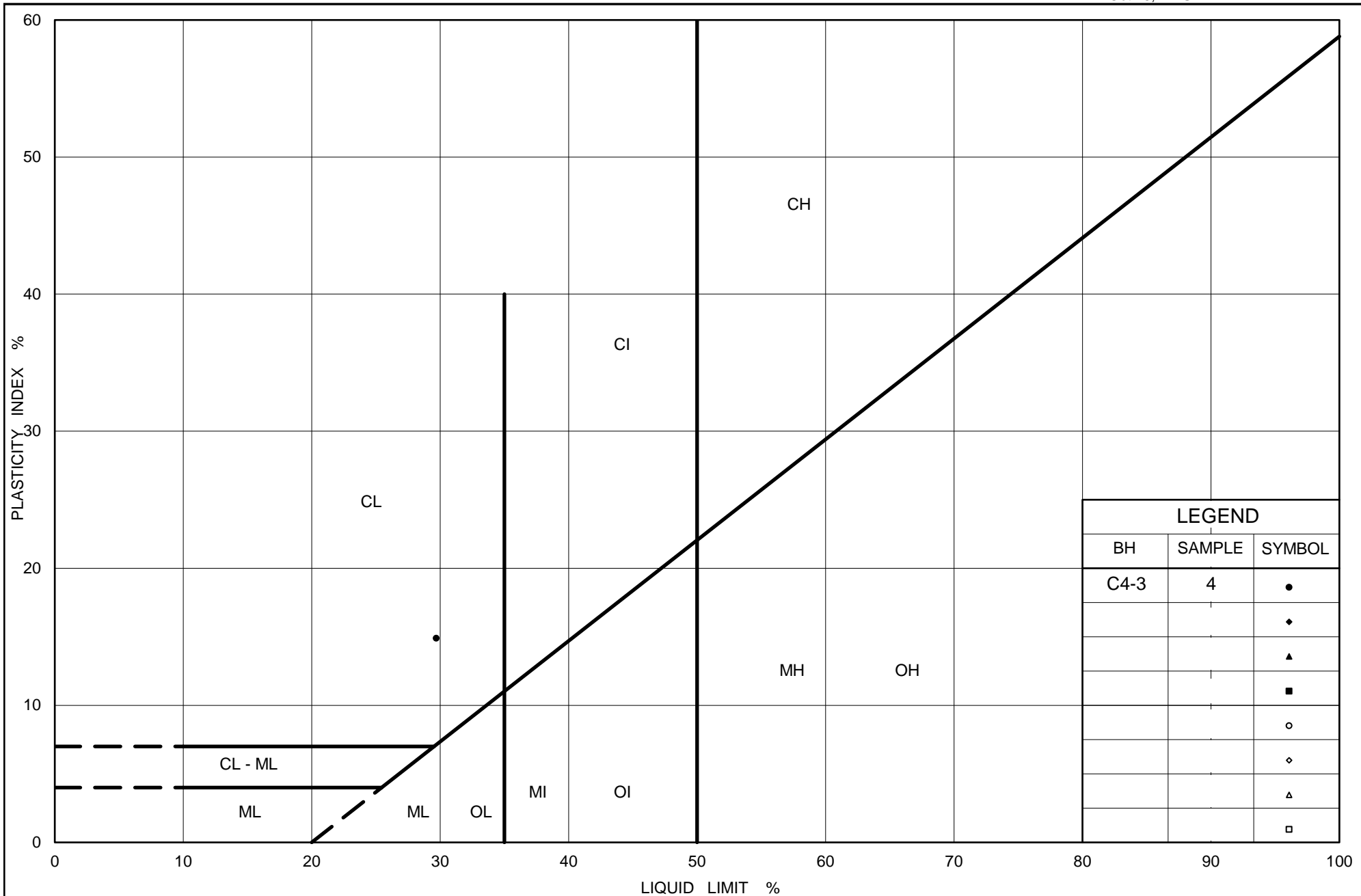
Project Number: 1671430

Checked By: NK

**Golder Associates**

Date: 17-Apr-18





Ministry of Transportation

Ontario

# PLASTICITY CHART Clayey Silt

Figure No. B-2

Project No. 1671430 WO9

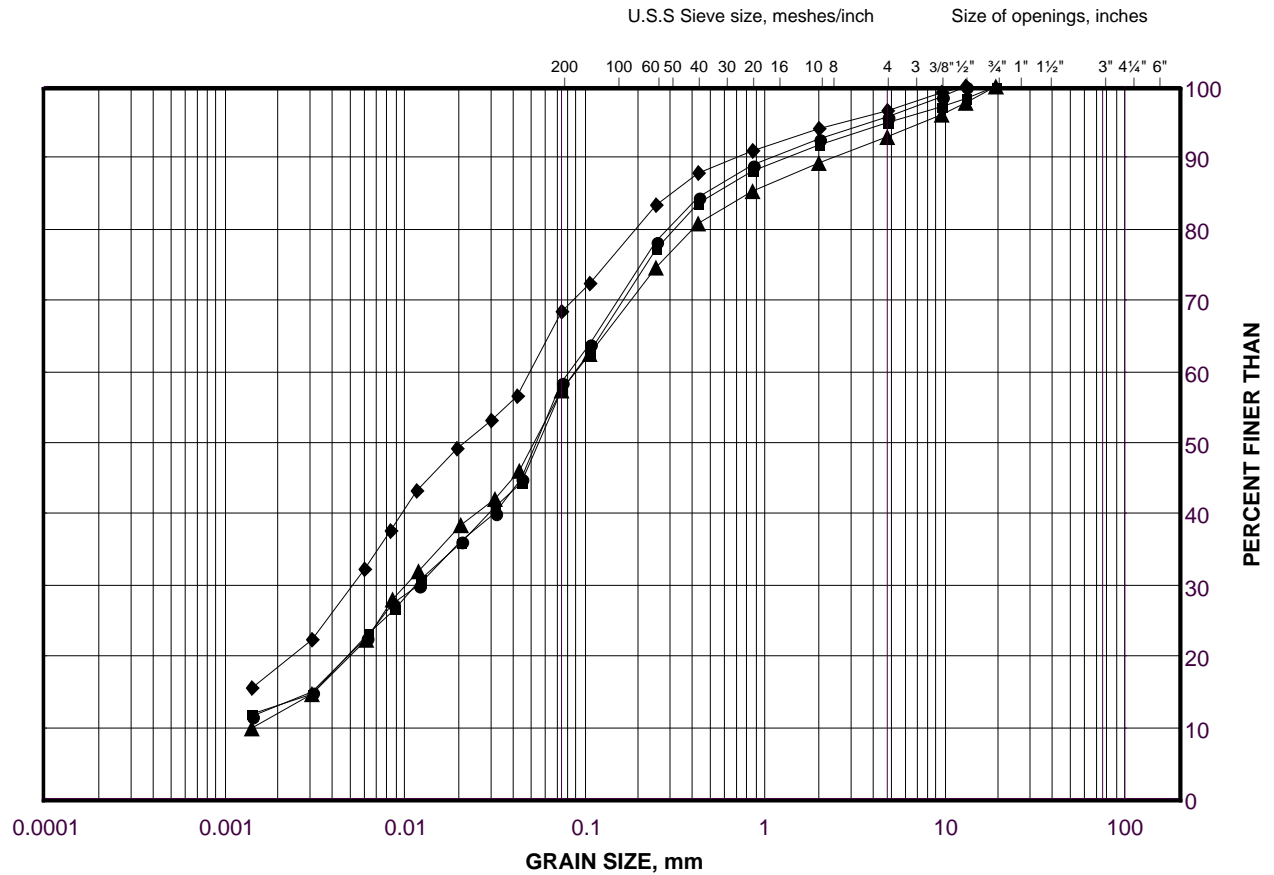
Checked By: NK



# GRAIN SIZE DISTRIBUTION

Sandy Clayey Silt to Clayey Silt with Sand (Till)

FIGURE B-3A



## LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	C11-2	4	322.6
■	C11-3	5	318.7
◆	C11-2	7	320.3
▲	C11-2	9A	318.3

Project Number: 1671430

Checked By: NK

**Golder Associates**

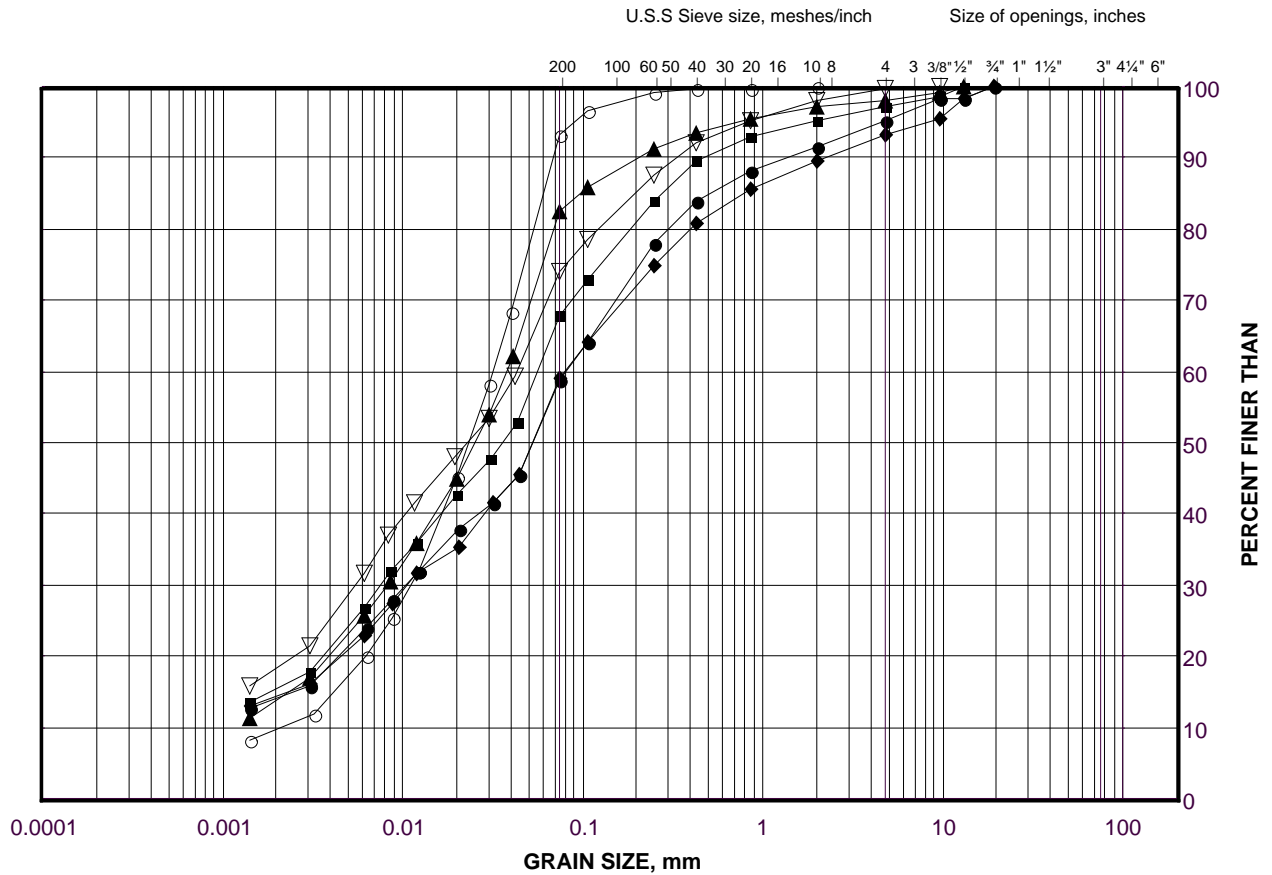
Date: 27-Apr-18



# GRAIN SIZE DISTRIBUTION

Sandy Clayey Silt to Clayey Silt with Sand (Till)

FIGURE B-3B



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

## LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	C15-3	4	319.0
■	C15-1	6	321.5
◆	C15-2	7	320.6
▲	C15-2	8	319.0
▽	C15-1	8	319.2
○	C15-2	9A	317.6

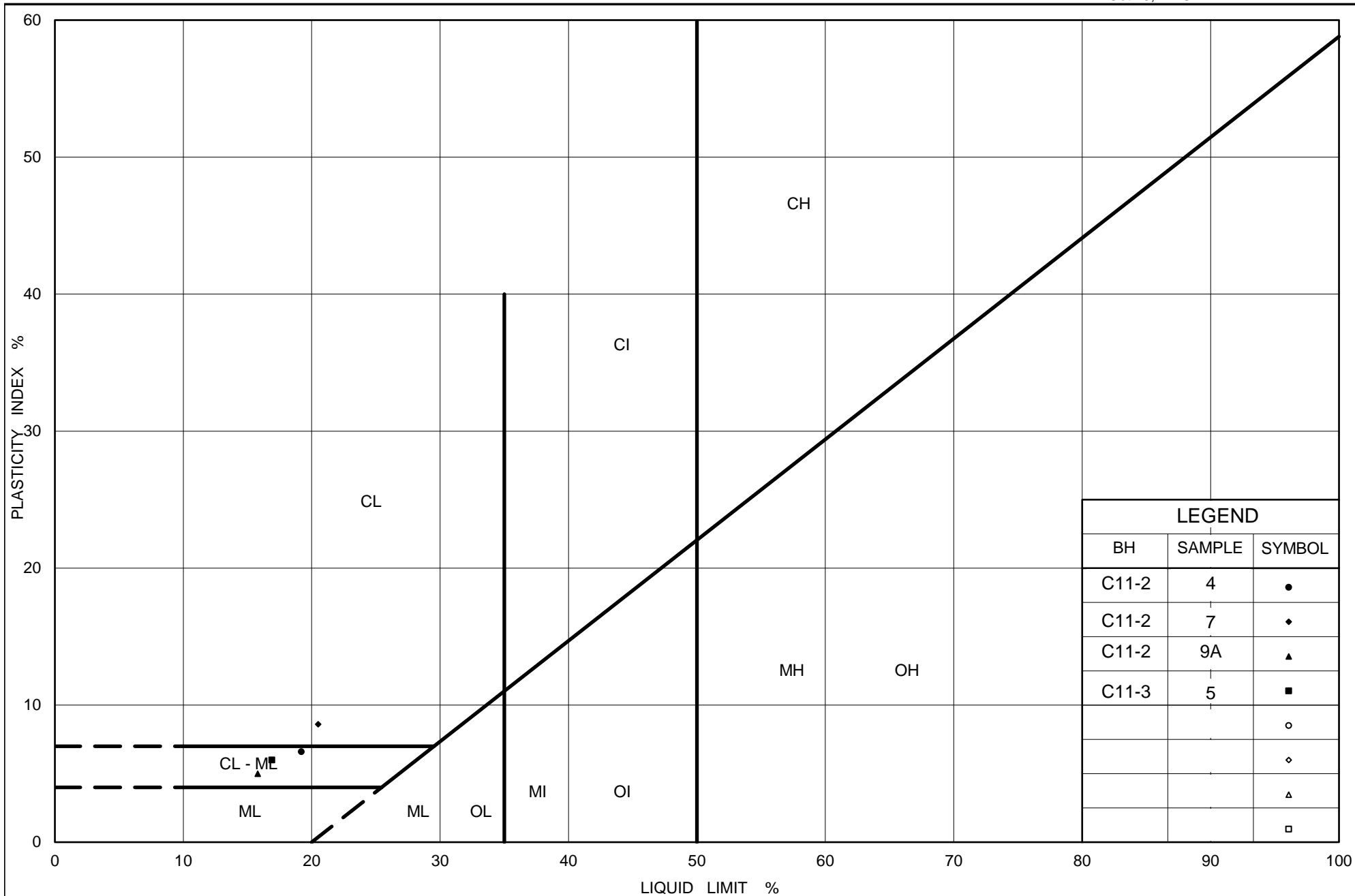
Project Number: 1671430

Checked By: NK

**Golder Associates**

Date: 27-Apr-18





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# PLASTICITY CHART Sandy Clayey Silt to Clayey Silt with Sand (Till)

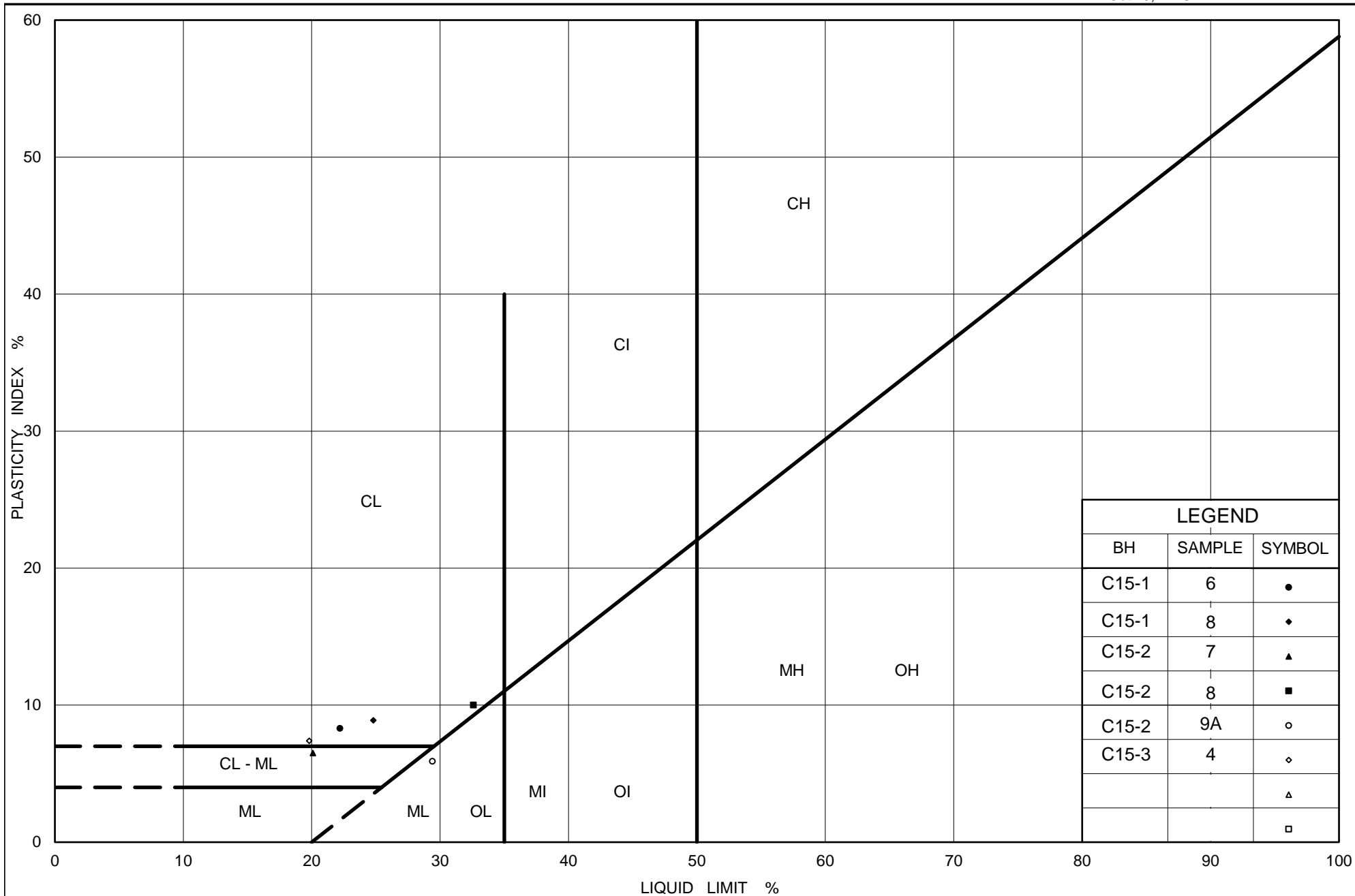
Ontario

Figure No. B-4A

Project No. 1671430 WO9

Checked By: NK





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# **PLASTICITY CHART** Sandy Clayey Silt to Clayey Silt with Sand (Till)

Ontario

Figure No. B-4B

Project No. 1671430 WO9

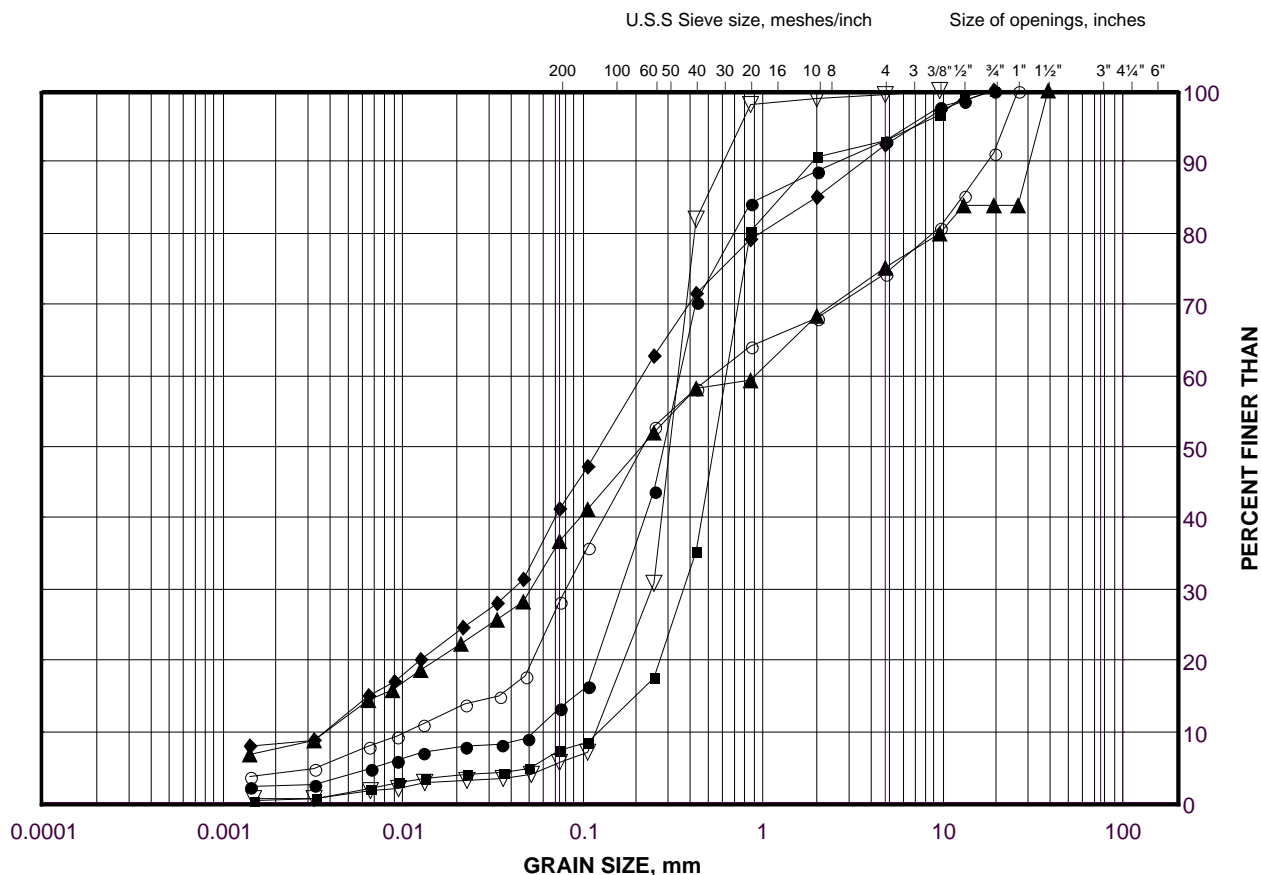
Checked By: NK



# GRAIN SIZE DISTRIBUTION

Sand to Silt and Sand to Gravelly Silty Sand (Till)

FIGURE B-5



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

## LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	C15-1	2	324.6
■	C4-2	6	321.8
◆	C15-3	6	317.8
▲	C4-3	6	320.8
▽	C4-1	7	320.8
○	C4-3	8	319.5

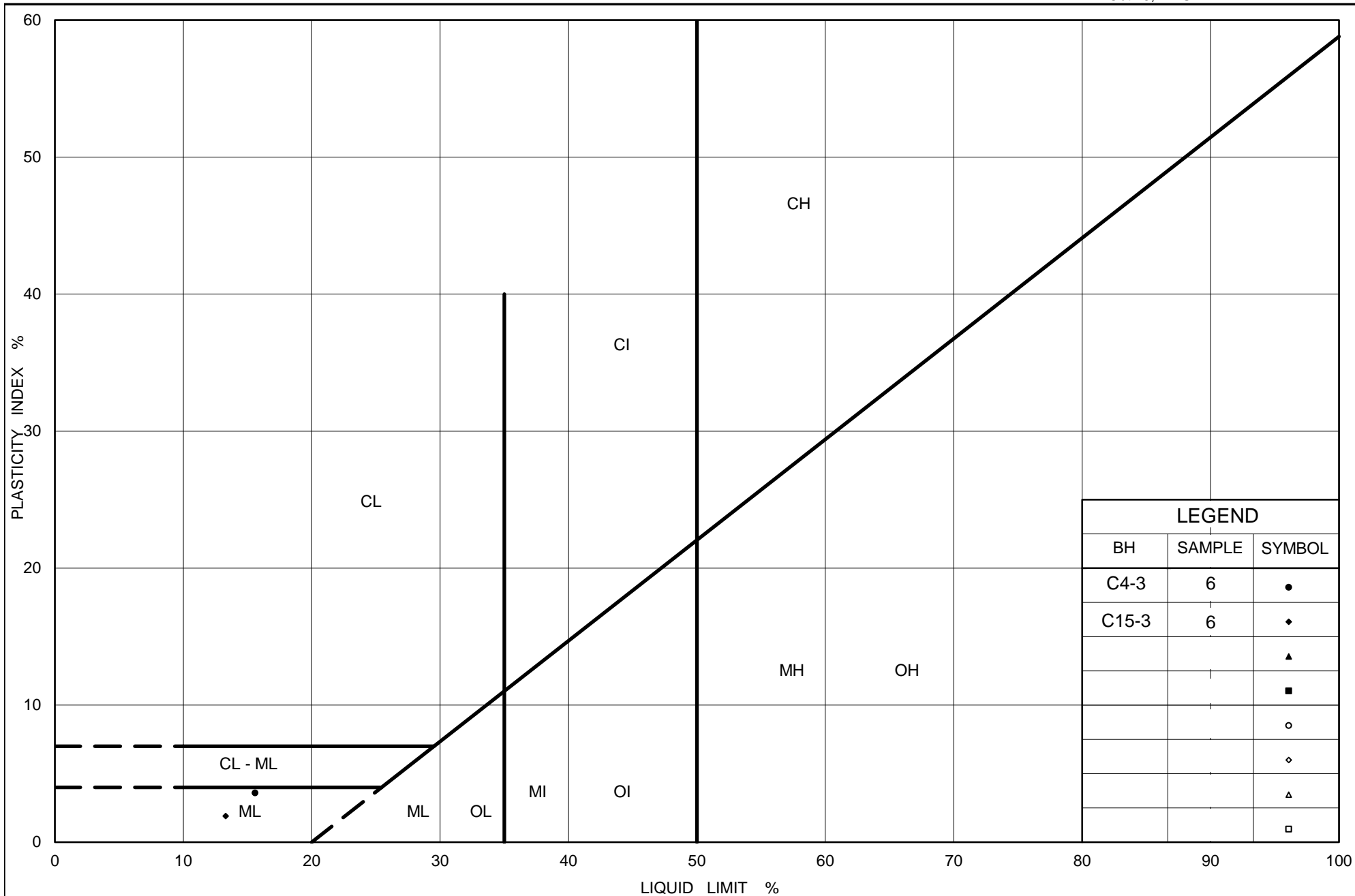
Project Number: 1671430

Checked By: NK

**Golder Associates**

Date: 01-May-18





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# PLASTICITY CHART Silt and Sand to Gravelly Silty Sand (Till)

Figure No. B-6

Project No. 1671430 WO9

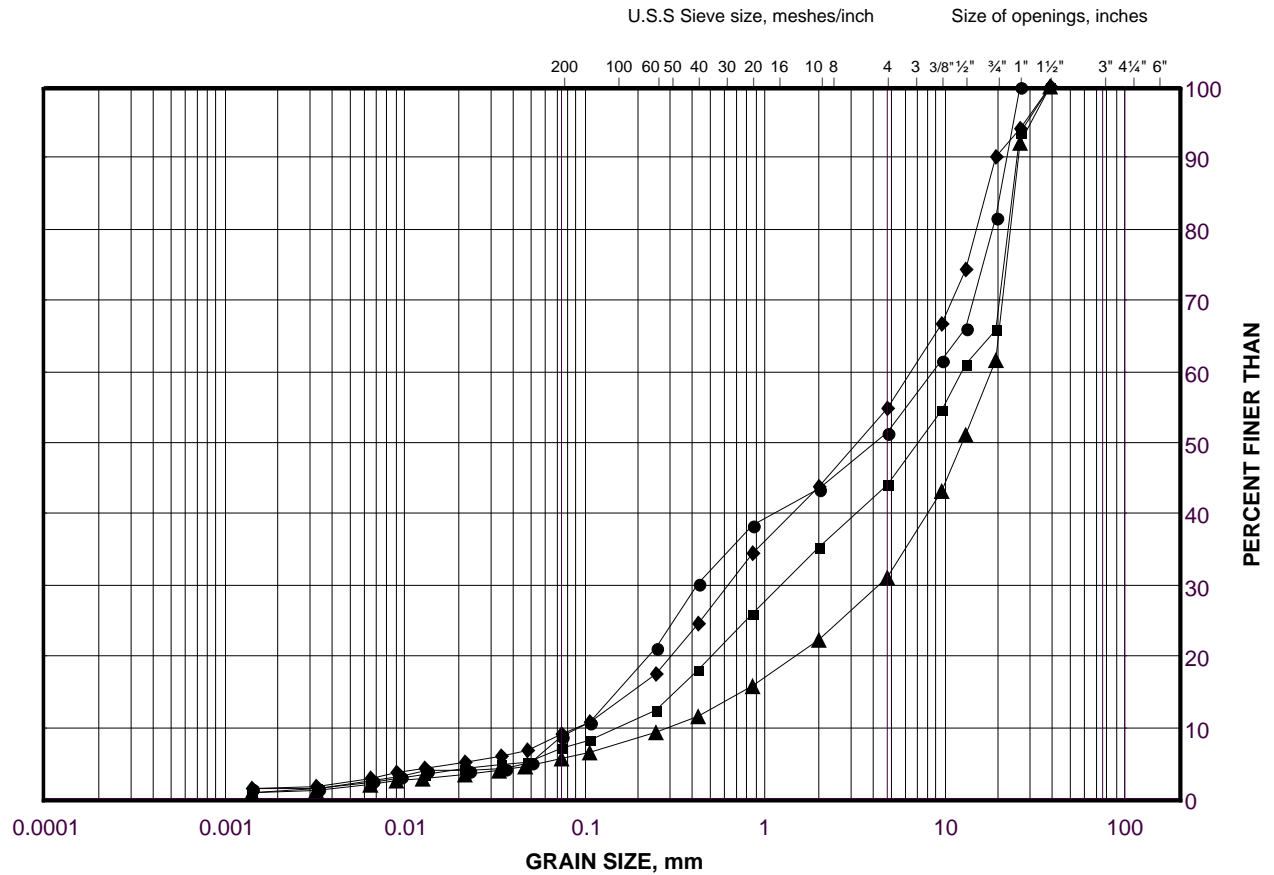
Checked By: NK



# GRAIN SIZE DISTRIBUTION

Silty Gravelly Sand to Sand and Gravel

FIGURE B-7



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

## LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	C15-1	10	316.1
■	C4-1	4	323.0
◆	C4-2	5	322.6
▲	C4-1	5	322.2

Project Number: 1671430

Checked By: NK

**Golder Associates**

Date: 01-May-18



**APPENDIX C**

# Analytical Test Results



Your Project #: 1671430-W09

Site Location: HWY 48

Your C.O.C. #: 107476

**Attention: Nikol Kochmanova**

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

**Report Date: 2018/03/23**

Report #: R5052467

Version: 1 - Final

**CERTIFICATE OF ANALYSIS**

**MAXXAM JOB #: B862098**

**Received: 2018/03/20, 12:06**

Sample Matrix: Soil  
# Samples Received: 3

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Reference
Chloride (20:1 extract)	3	N/A	2018/03/22	CAM SOP-00463	EPA 325.2 m
Conductivity	3	N/A	2018/03/22	CAM SOP-00414	OMOE E3530 v1 m
pH CaCl <sub>2</sub> EXTRACT	3	2018/03/23	2018/03/23	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	3	2018/03/20	2018/03/22	CAM SOP-00414	SM 23 2510 m
Sulphate (20:1 Extract)	3	N/A	2018/03/22	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.



Your Project #: 1671430-W09

Site Location: HWY 48

Your C.O.C. #: 107476

**Attention: Nikol Kochmanova**

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

**Report Date: 2018/03/23**

Report #: R5052467

Version: 1 - Final

**CERTIFICATE OF ANALYSIS**

**MAXXAM JOB #: B862098**

**Received: 2018/03/20, 12:06**

**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

=====

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### SOIL CORROSIVITY PACKAGE (SOIL)

Maxxam ID		GHG284		GHG285		GHG286			GHG286		
Sampling Date		2018/03/12		2018/03/08		2018/03/06			2018/03/06		
COC Number		107476		107476		107476			107476		
	UNITS	C4-2-SA4	RDL	C11-2-SA5	RDL	C15-1-SA7	RDL	QC Batch	C15-1-SA7 Lab-Dup	RDL	QC Batch
Calculated Parameters											
Resistivity	ohm-cm	1500		420		850		5448848			
Inorganics											
Soluble (20:1) Chloride (Cl)	ug/g	340	20	1300	60	630	20	5450392			
Conductivity	umho/cm	684	2	2400	2	1170	2	5451899	1170	2	5451899
Available (CaCl2) pH	pH	8.14		7.68		7.68		5452126			
Soluble (20:1) Sulphate (SO4)	ug/g	<20	20	130	20	<20	20	5450427	<20	20	5450427
RDL = Reportable Detection Limit											
QC Batch = Quality Control Batch											
Lab-Dup = Laboratory Initiated Duplicate											



## TEST SUMMARY

**Maxxam ID:** GHG284  
**Sample ID:** C4-2-SA4  
**Matrix:** Soil

**Collected:** 2018/03/12  
**Shipped:**  
**Received:** 2018/03/20

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5450392	N/A	2018/03/22	Alina Dobreanu
Conductivity	AT	5451899	N/A	2018/03/22	Tahir Anwar
pH CaCl2 EXTRACT	AT	5452126	2018/03/23	2018/03/23	Neil Dassanayake
Resistivity of Soil		5448848	2018/03/22	2018/03/22	Cristina Carriere
Sulphate (20:1 Extract)	KONE/EC	5450427	N/A	2018/03/22	Alina Dobreanu

**Maxxam ID:** GHG285  
**Sample ID:** C11-2-SA5  
**Matrix:** Soil

**Collected:** 2018/03/08  
**Shipped:**  
**Received:** 2018/03/20

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5450392	N/A	2018/03/22	Alina Dobreanu
Conductivity	AT	5451899	N/A	2018/03/22	Tahir Anwar
pH CaCl2 EXTRACT	AT	5452126	2018/03/23	2018/03/23	Neil Dassanayake
Resistivity of Soil		5448848	2018/03/22	2018/03/22	Cristina Carriere
Sulphate (20:1 Extract)	KONE/EC	5450427	N/A	2018/03/22	Alina Dobreanu

**Maxxam ID:** GHG286  
**Sample ID:** C15-1-SA7  
**Matrix:** Soil

**Collected:** 2018/03/06  
**Shipped:**  
**Received:** 2018/03/20

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5450392	N/A	2018/03/22	Alina Dobreanu
Conductivity	AT	5451899	N/A	2018/03/22	Tahir Anwar
pH CaCl2 EXTRACT	AT	5452126	2018/03/23	2018/03/23	Neil Dassanayake
Resistivity of Soil		5448848	2018/03/22	2018/03/22	Cristina Carriere
Sulphate (20:1 Extract)	KONE/EC	5450427	N/A	2018/03/22	Alina Dobreanu

**Maxxam ID:** GHG286 Dup  
**Sample ID:** C15-1-SA7  
**Matrix:** Soil

**Collected:** 2018/03/06  
**Shipped:**  
**Received:** 2018/03/20

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Conductivity	AT	5451899	N/A	2018/03/22	Tahir Anwar
Sulphate (20:1 Extract)	KONE/EC	5450427	N/A	2018/03/22	Alina Dobreanu



### GENERAL COMMENTS

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

Package 1	15.0°C
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**Results relate only to the items tested.**



## QUALITY ASSURANCE REPORT

Golder Associates Ltd  
Client Project #: 1671430-W09  
Site Location: HWY 48  
Sampler Initials: JLS

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
5450392	Soluble (20:1) Chloride (Cl)	2018/03/22	NC	70 - 130	103	70 - 130	<20	ug/g	2.4	35
5450427	Soluble (20:1) Sulphate (SO4)	2018/03/22	114	70 - 130	102	70 - 130	<20	ug/g	NC	35
5451899	Conductivity	2018/03/22			100	90 - 110	<2	umho/cm	0.35	10
5452126	Available (CaCl2) pH	2018/03/23			99	97 - 103			0.89	N/A

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

---

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CHAIN OF CUSTODY RECORD

107476 Page 3 of 3

Invoice Information		Report Information (if differs from invoice)		Project Information (where applicable)		Turnaround Time (TAT) Required	
Company Name: <u>Goldier Associates Ltd.</u>		Company Name:		Quotation #:		<input checked="" type="checkbox"/> Regular TAT (5-7 days) Most analyses	
Contact Name: <u>Nikol Kahmanova</u>		Contact Name:		P.O. # / A/E/R:		PLEASE PROVIDE ADVANCE NOTICE FOR RUSH PROJECTS	
Address: <u>6925 Century Ave #100</u> <u>Mississauga ON</u>		Address:		Project #: <u>1671430-W09</u>		Rush TAT (Surcharges will be applied)	
Phone: <u>905-567-4444</u> Fax:		Phone: Fax:		Site Location:		<input type="checkbox"/> 1 Day <input type="checkbox"/> 2 Days <input type="checkbox"/> 3-4 Days	
Email: <u>Nikol.Kahmanova@goldier.com</u>		Email:		Site #: <u>HWY 48</u>		Date Required:	
				Sampled By: <u>JLS</u>			
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		Rush Confirmation #:	
<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"/> Agr/ Other <input type="checkbox"/> Table _____ FOR RSC (PLEASE CIRCLE) Y / N		<input type="checkbox"/> CCME <input type="checkbox"/> Sanitary Sewer Bylaw <input type="checkbox"/> MISA <input type="checkbox"/> Storm Sewer Bylaw <input type="checkbox"/> PWQO Region <input type="checkbox"/> Other (Specify) <input type="checkbox"/> REG 558 (MIN. 3 DAY TAT REQUIRED)		# OF CONTAINERS SUBMITTED FIELD FILTERED (CIRCLE) Metals / Hg / CrVI BTEX / PHC F1 PHCs P2 - P4 VOCs REG 153 METALS & INORGANICS REG 153 CPMS METALS REG 153 METALS (Hg, Cr VI, CPMS Metals, HWS - B) <u>Corrosivity Package</u>		LABORATORY USE ONLY CUSTODY SEAL Y / N COOLER TEMPERATURES Present Intact <u>N N</u> <u>9/18/19</u> COOLING MEDIA PRESENT: Y / <u>(N)</u> COMMENTS	
Include Criteria on Certificate of Analysis: Y / N							
SAMPLES MUST BE KEPT COOL (< 10 °C) FROM TIME OF SAMPLING UNTIL DELIVERY TO MAXXAM							
SAMPLE IDENTIFICATION		DATE SAMPLED (YYYY/MM/DD)	TIME SAMPLED (HH:MM)	MATRIX	# OF CONTAINERS SUBMITTED	FIELD FILTERED (CIRCLE) Metals / Hg / CrVI	FIELD FILTERED (CIRCLE) Metals / Hg / CrVI
1	<u>C4-2-SA4</u>	<u>2018/3/12</u>	<u>PM</u>	<u>SOIL</u>	<u>1</u>	<u>1</u>	<u>1</u>
2	<u>C11-2-SA5</u>	<u>2018/3/8</u>	<u>PM</u>	<u>SOIL</u>	<u>1</u>	<u>1</u>	<u>1</u>
3	<u>C15-1-SA7</u>	<u>2018/3/6</u>	<u>PM</u>	<u>SOIL</u>	<u>1</u>	<u>1</u>	<u>1</u>
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>Kate Neo Kati</u>		<u>2018/03/20</u>	<u>12:05 PM</u>	<u>Pardeep Pardeep K. Kurew</u>		<u>2018/03/20</u>	<u>12:06</u>

20-Mar-18 12:06

Ema Gitej



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ENV-1226

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