



## FOUNDATION INVESTIGATION REPORT

# Highway 66, Station 17+903, Township of Gauthier Culvert Replacement Ministry of Transportation, Ontario GWP 5210-14-00

Submitted to:

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GEOCRES NO: 32D-29

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**PART A**

FOUNDATION INVESTIGATION REPORT  
HIGHWAY 66, STA 17+903, TOWNSHIP OF GAUTHIER  
CULVERT REPLACEMENT  
MINISTRY OF TRANSPORTATION, ONTARIO  
GWP 5210-14-00

## 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 related to the replacement of the gabion basket walls at each end of the culvert on Highway 66 at Station 17+903, in the Township of Gauthier, approximately 6.3 km east of the Highway 66 and Highway 672 intersection. The Key Plan of the general location of this section of Highway 66 and the location of the investigated area are shown on Drawing 1.

The purpose of this investigation is to establish the subsurface conditions at the culvert site for the gabion basket wall replacement by borehole drilling with laboratory testing carried out on selected soil samples.

The Terms of Reference (TOR) and the scope of work for the foundation investigation are outlined in MTO's Request for Proposal, dated February 2018, and the subsequent clarifications/addenda, which forms part of the Consultant's Assignment Number 5017-E-0039 for this project. The work has been carried out in accordance with Golder's Supplementary Specialty Plan for foundation engineering services for this project dated November 2018.

Investigation of the Pavement Distress Area between about Station 17+886 and 17+928, Gauthier Township is provided in Golder Pavement Design Report under Golder Project 1896349.

## 2.0 SITE DESCRIPTION

It should be noted that the orientation (i.e., north, south, east, west) stated in the text of the report is typically referenced to project north and therefore may differ from magnetic north shown on Drawing 1. For the purpose of this report, Highway 66 is oriented in a west-east direction with the culvert positioned on a skew to the highway generally in a north-south orientation. At the culvert location, the creek flows in a north to south direction.

The existing culvert consists of a 1.9 m wide by 1.2 m high, 40 m long Corrugated Steel Pipe Arch (CSPA), with gabion basket wall around the pipe at the inlet and outlet. The culvert inlet (north end) and outlet (south end) inverts are at approximately Elevations 274.3 m and 273.5 m, respectively. The highway grade at the culvert location is at approximately Elevation 278.5 m and the highway embankment is about 4.2 m and 5.0 m high relative to the culvert invert at the inlet and outlet, respectively. In general, the topography in the vicinity of the culvert is relatively flat, grassy terrain with shrubs and trees. The ground surface conditions at select locations of the culvert area are shown on Photographs 1 to 4.

At the time of the subsurface exploration field work, the embankment side slopes appeared to be grass covered with some local vegetation growing adjacent to the toe of the embankment slopes and exhibit some localized shallow erosion gullies. The gabion basket wall at the toe of the embankment side slope at each end of the culvert shows signs of slight tilting laterally relative to each basket and slight slumping. The highway pavement shows sign of some distress in the form of longitudinal and transverse cracks and appears to be an older section compared to that to the east of the culvert. The embankment appeared to be stable with no signs of slope instability or roadway settlement.

## 3.0 INVESTIGATION PROCEDURES

Field work for this subsurface exploration was carried out between May 24 to 26, 2019, during which time five boreholes (Boreholes C258-1 to C258-5) were advanced at the approximate locations shown on Drawing 1. Boreholes C258-1 to C258-3 were advanced from the highway grade through the roadway embankment and Boreholes C258-4 and C258-5 were advanced near the north and south toes of the highway embankment slopes



adjacent to the culvert inlet and outlet, respectively. The boreholes were advanced using a track mounted CME-55LC drilling rig supplied and operated by George Downing Estate Drilling of Grenville-Sur-La-Rouge, Quebec. Traffic control, where required, was performed in accordance with MTO's Ontario Traffic Control Manual Book 7 – Temporary Conditions.

The boreholes were advanced using NW Casing with wash boring techniques. Soil samples were obtained in the boreholes at 0.75 m and 1.5 m intervals of depth using 50 mm outer diameter split-spoon samplers driven by an automatic hammer in accordance with the Standard Penetration Test (SPT) procedures (ASTM D1586). In-situ vane shear tests were carried out in cohesive soils for determination of undrained shear strengths in accordance with Standard Test Method for Field Vane Shear Test in Saturated Fine Grained Soils (ASTM 2573), using an MTO standard "N"-size vane. The water level inside the NW casing was observed upon completion of drilling operations, but it is noted that water was added into the casing during borehole advancement. The boreholes were backfilled upon completion in accordance with Ontario Regulation 903 (wells) as amended. The boreholes drilled through Highway 66 are capped at the roadway surface using cold patch asphalt.

Field work was supervised on a full-time basis by a member of Golder's technical staff who: located the boreholes in the field; arranged for the clearance of underground services; supervised the drilling and sampling 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 geotechnical laboratory in Sudbury for further examination and laboratory testing. Index and classification testing consisting of water content determinations, grain size distributions, Atterberg limits, and organic content was carried out on selected soil samples. The geotechnical laboratory testing was completed according to ASTM and MTO LS standards, as applicable. In addition, one soil sample was submitted to Bureau Veritas Laboratories (formerly Maxxam) in Sudbury, Ontario, an accredited analytical laboratory, for testing of a suite of corrosivity indicator parameters.

The as-drilled borehole locations were measured relative to highway chainages/station marked on the pavement by a member of our technical staff and converted into northing/easting coordinates on the plan drawing. The ground surface elevation at each borehole location was surveyed by Golder relative to the highway and culvert centreline, with the elevation of the centreline provided by AECOM. The MTM NAD 83-CSRS CBN v6-2010.0 (Zone 12) northing and easting coordinates, geographical coordinates, ground surface elevations referenced to Geodetic datum, and borehole depths at each borehole location are presented on the borehole records in Appendix A and summarized below.

Borehole Number	MTM NAD 83 Northing (m) (Latitude)	MTM NAD 83 Easting (m) (Longitude)	Ground Surface Elevation (m)	Borehole Depth (m)
C258-1	5330483.6 (48.106971)	394108.7 (-79.800632)	278.4	21.0
C258-2	5330481.9 (48.106957)	394092.5 (-79.800851)	278.6	16.5
C258-3	5330478.7 (48.106924)	394123.5 (-79.800435)	278.3	16.5
C258-4	5330496.2 (48.107085)	394099.2 (-79.800757)	276.2	10.4
C258-5	5330462.5 (48.106778)	394122.4 (-79.800453)	274.4	10.4

## 4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

### 4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain Study (NOEGTS)<sup>1</sup> mapping, the culvert site is located within a glaciolacustrine plain, with the subsoils consisting primarily of clay.

Based on geological mapping (MNDM)<sup>2</sup>, the site is underlain by mafic to intermediate metavolcanics rocks.

### 4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the summary results of in situ and laboratory testing are given on the Record of Borehole sheets contained in Appendix A. The plotted results of geotechnical laboratory testing are contained in Appendix B. The results of the in-situ field tests (i.e., SPT 'N'-values and in-situ vane shear strengths) as presented on the Record of Borehole sheets and discussed in Section 4.2 are uncorrected. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profiles shown on Drawing 1 are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The results of the analytical laboratory testing (by Bureau Veritas Laboratories) are summarized in Section 4.4 and the detailed laboratory testing report is included in Appendix B.

The subsurface conditions will vary between and beyond the borehole locations, however, the factual data presented on the Record of Borehole sheets governs any interpretation of the site conditions. A summary description of the soil deposits and groundwater conditions encountered in the boreholes is provided below. It should be noted that the interpreted stratigraphy shown on Drawing 1 is a simplification of the subsurface conditions.

#### 4.2.1 Asphalt / Fill

An approximately 140 mm to 100 mm thick layer of asphalt pavement was encountered at ground surface in Boreholes C258-1 and C258-2 at Elevations 278.4 m and 278.6 m, respectively. A 3.6 m to 5.5 m thick layer of embankment fill, consisting of an upper 0.2 m to 2.1 m thick layer of gravelly sand to gravel to sand, underlain by a 3.4 m to 3.7 m thick layer of sand fill, was encountered below the asphalt in Boreholes C258-1 and C258-2, and from ground surface in Borehole C258-3 at Elevation 278.3 m.

From ground surface in Boreholes C258-4 and C258-5, an approximately 0.4 m and 0.2 m thick layer of organic silty sand fill was encountered at Elevations 276.2 m and 274.4 m, respectively. Below the organic silty sand, an approximately 0.6 m to 1.0 m thick layer of silty sand to sand fill was encountered.

The SPT "N"-values measured within the gravelly sand fill and sand fill ranges from 1 blow to 22 blows per 0.3 m of penetration, indicating a very loose to compact compactness condition.

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<sup>1</sup> Ontario Ministry of Natural Resources and Forestry. Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 41PNE.

<sup>2</sup> Ontario Ministry of Northern Development and Mines. Bedrock Geology of Ontario, East-Central Sheet. Map 2543.

Grain size distribution testing was carried out on one sample of the sand fill and the result is presented on Figure B-1 in Appendix B. The natural moisture content measured on one sample of the sand fill is 8 per cent.

#### 4.2.2 Organic Silt to Organic Silty Sand / Peat

An approximately 0.6 m to 0.8 m thick layer of organic silt to organic silty sand was encountered below the fill in Boreholes C258-2, C258-3, and C258-5 between Elevations 274.9 m and 273.6 m. A 0.8 m thick deposit of peat was encountered below the fill in Borehole C258-4 at Elevation 274.8 m.

The SPT “N”-values measured within the organic deposit range from 2 blows to 7 blows per 0.3 m of penetration indicating a very loose to loose compactness condition.

The natural moisture content and the organic content measured on one sample of the organic silty sand is about 50 per cent and about 7 per cent, respectively.

#### 4.2.3 Sand

An approximately 2.2 m to 3.4 m thick layer of sand, trace to some gravel, trace silt was encountered below the fill in Borehole C258-1 and below the organic deposit in Boreholes C258-2 to C258-5 between Elevations 274.1 m and 272.8 m.

The SPT “N”-values measured within the sand deposit ranges from 0 blows (weight of hammer) to 13 blows per 0.3 m of penetration, indicating a very loose to compact compactness condition.

Grain size distribution testing was carried out on two samples of the sand and the results are presented on Figure B-2 in Appendix B. The natural moisture content measured on two samples of the sand deposit are about 18 per cent and 39 per cent.

#### 4.2.4 Silt

An approximately 1.5 m to 4.8 m thick layer of silt, some clay, trace to some sand was encountered below the sand deposit in Boreholes C258-1, C258-4, and C258-5 and interlayered within the silty clay to clay deposit (discussed below) in Boreholes C258-2 and C258-3 between Elevations 270.6 m and 267.0 m. Borehole C258-4 was terminated within the silt deposit, penetrating into it for a depth of 4.8 m.

The SPT “N”-values measured within the silt deposit range from 2 blows to 8 blows per 0.3 m of penetration, indicating a very loose to loose compactness condition.

Grain size distribution testing was carried out on five samples of the silt deposit and the results are presented on Figure B-3 in Appendix B. Atterberg limit tests were carried out on three samples of the silt deposit and two samples measured liquid limits of about 19 per cent, plastic limits of about 15 per cent and 17 per cent and plasticity indices of about 2 per cent and 4 per cent; and one sample is non-plastic. The results of the Atterberg limit test are presented in Figure B-4 and indicate the deposit is comprised of silt to silt of slight plasticity. The natural moisture content measured on five samples of the deposit are about 18 per cent and 31 per cent.



### 4.2.5 Silty Clay to Clay

A deposit of silty clay to clay was encountered at the following borehole locations:

- Borehole C258-1: at 7.9 m thick deposit of clay with silt laminations below the silt deposit, at Elevation 265.3 m
- Borehole C258-2: an upper 4.4 m thick layer of silty clay below the sand deposit, at Elevation 271.4 m; and a lower 3.4 m thick layer of clay with silt laminations below the silt deposit, at Elevation 265.5 m
- Boreholes C258-3: an upper 2.9 m thick layer of silty clay below the sand deposit, at Elevation 271.1 m; and a lower 3.2 m thick layer of clay with silt laminations below the silt deposit, at Elevation 265.0 m
- Borehole C258-5: a 1.7 m thick layer of silty clay below the silt deposit, at Elevation 265.7 m

The deposit was not penetrated in Boreholes C258-1 to C258-3 and C258-5.

The SPT “N”-values measured within the silty clay to clay deposit range from 0 blows (weight of hammer) to 10 blows per 0.3 m of penetration. In-situ field vane tests carried out within the deposit measured undrained shear strengths ranging from about 48 kPa to 58 kPa, with one test measured greater than 100 kPa, and sensitivity ranging from about 2 to 3. The field vane test results suggest that the deposit generally has a firm to stiff consistency.

Atterberg limit tests were carried out on seven samples of the cohesive deposit and measured liquid limits ranging between about 39 per cent and 58 per cent, plastic limits ranging between about 18 per cent and 25 per cent and plasticity indices ranging between about 21 per cent and 36 per cent. The results of the Atterberg limit test are presented in Figure B-5 and indicate the deposit are comprised of silty clay of medium plasticity to clay of high plasticity. Grain size distribution testing was carried out on two samples of the silty clay deposit and the result is presented on Figure B-6 in Appendix B. The natural moisture content measured on seven samples of the deposit are ranging between about 35 per cent and 57 per cent.

### 4.3 Groundwater Conditions

The unstabilized groundwater levels relative to ground surface measured inside the casing or augers upon completion of drilling are summarized below. Groundwater water levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

Borehole No.	Depth to Unstabilized Groundwater Level (m)	Approximate Groundwater Elevation (m)
C258-1	1.9	276.5
C258-2	2.8	275.8
C258-3	3.1	275.2
C258-4	0.3	275.9
C258-5	0.1	274.3

## 4.4 Analytical Laboratory Testing Results

Analytical testing was carried out on a sample of the sand deposit recovered from Borehole C227-1 (Sample #7). The soil sample was submitted to Bureau Veritas Laboratories of Mississauga, Ontario for corrosivity testing. The analytical laboratory test results are summarized below, and the detailed analytical laboratory test report is included in Appendix B.

Borehole No.	Borehole Sample No.	Depth (m)	Parameters					
			Resistivity (ohm-cm)	Electrical Conductivity (µmho/cm)	Soluble Sulphate (SO <sub>4</sub> ) Content (µg/g)	Chloride (Cl) Content (µg/g)	Sulphide (µg/g)	pH
C258-1	7	6.1 – 6.7	5,400	185	<20 <sup>1</sup>	40	<0.50 <sup>2</sup>	7.7

Note:

1. The sulphate concentration is below the reportable detection limit of 20 µg/g.
2. The sulphide was below the reportable detection limit of 0.50 µg/g.

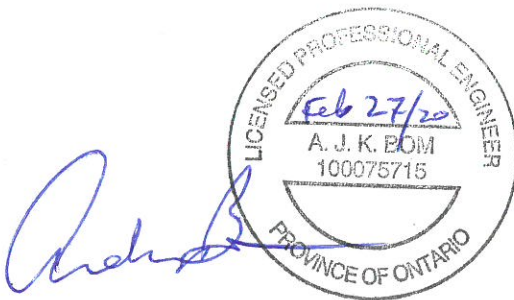
## 5.0 CLOSURE

The field drilling program was carried out under the supervision of Mr. Mathew Riopelle under the overall direction of Mr. André Bom, P. Eng., an Associate of Golder. This Foundation Investigation Report was prepared by Mr. Tibor Berecz, a geotechnical EIT with Golder and Mr. André Bom provided a technical review of the report. Mr. Jorge Costa, P. Eng., an MTO Foundations Designated Contact and Senior Consultant for Golder, conducted an independent quality control review of this report.

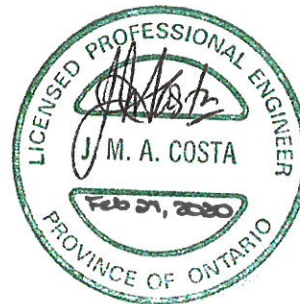
## Signature Page

**Golder Associates Ltd.**

  
Tibor Berecz, EIT  
Geotechnical EIT



André Bom, P.Eng.  
*Senior Geotechnical Engineer, Associate*

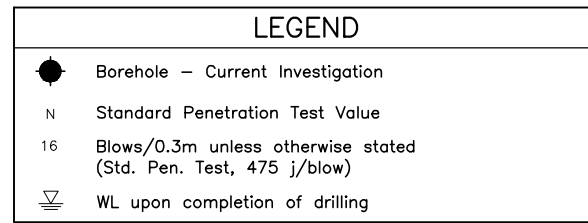


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BOREHOLE CO-ORDINATES (NAD 83 MTM ZONE 12)			
No.	ELEVATION	NORTHING	EASTING
C258-1	278.4	5330483.6	394108.7
C258-2	278.6	5330481.9	394092.5
C258-3	278.3	5330478.7	394123.5
C258-4	276.2	5330496.2	394099.2
C258-5	274.4	5330462.5	394122.4

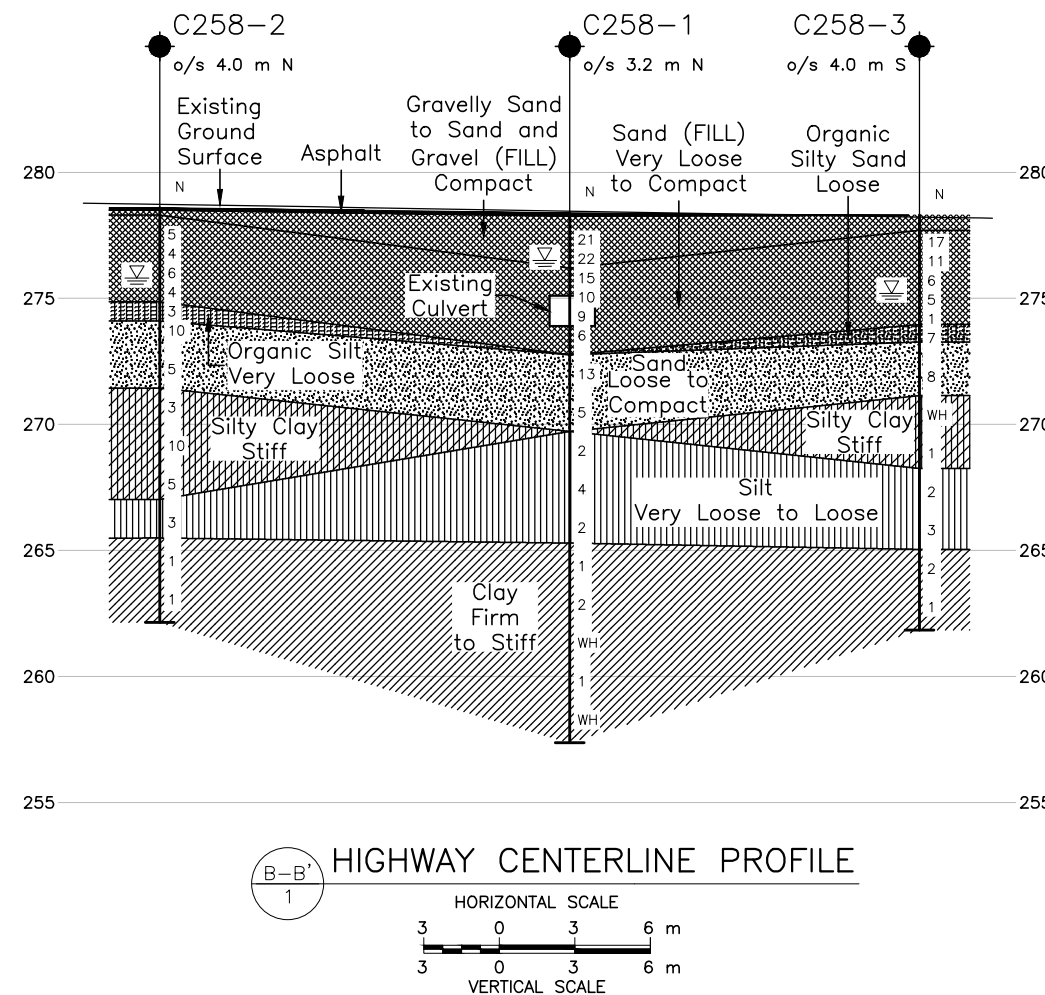


This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

Base plans provided in digital format by CALLON DIETZ LTD., drawing file no. gwp52101400b.dwg, received AUGUST 14, 2019.

NO.		DATE		BY		REVISION	
Geocres No. 32D-29							
HWY. 66			PROJECT NO. 1896349			DIST. .	
SUBM'D. .			CHKD. TB			DATE: 2/18/2020	
DRAWN: TR			CHKD. AB			APPD. JMAC	
						DWG. 1	







**Photograph 1: Road Surface at Culvert Location, Facing East (April 2019)**



**Photograph 2: Embankment North Slope at Culvert Inlet, Facing East (April 2019)**





**Photograph 3: Embankment South Slope at Culvert Outlet, Facing South (April 2019)**



**Photograph 4: Culvert Outlet, South Side of Embankment (April 2019)**



**APPENDIX A**

# Record of Boreholes

# ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

## MINISTRY OF TRANSPORTATION, ONTARIO

### PARTICLE SIZES OF CONSTITUENTS

Soil Constituent	Particle Size Description	Millimetres	Inches (US Std. Sieve Size)
BOULDERS	Not Applicable	>300	>12
COBBLES	Not Applicable	75 to 300	3 to 12
GRAVEL	Coarse Fine	19 to 75 4.75 to 19	0.75 to 3 (4) to 0.75
SAND	Coarse Medium Fine	2.00 to 4.75 0.425 to 2.00 0.075 to 0.425	(10) to (4) (40) to (10) (200) to (40)
FINES	Classified by plasticity	<0.075	< (200)

### MODIFIERS FOR SECONDARY COMPONENTS<sup>1,2</sup>

Percentage by Mass	Modifier
> 35	Use 'and' to combine primary and secondary component ( <i>i.e.</i> , SAND and gravel)
> 20 to 35	Primary soil name prefixed with "gravelly, sandy" as applicable
> 10 to 20	some ( <i>i.e.</i> , some sand)
≤ 10	trace ( <i>i.e.</i> , trace fines)

1. Only applicable to components not described by Primary Group Name.

2. Classification of Primary Group Name based on Unified Soil Classification System (ASTM D2487) for coarse-grained soils; fine-grained soils described per current MTO Soil Classification System.

### 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.) split-spoon sampler for a distance of 300 mm (12 in.). Values reported are as recorded in the field and are uncorrected.

#### Cone Penetration Test (CPT)

An 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<sub>t</sub>*), porewater pressure (*u*) and sleeve friction (*f<sub>s</sub>*) are recorded electronically at 25 mm penetration intervals.

#### Dynamic Cone Penetration Resistance (DCPT); N<sub>d</sub>:

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

### SAMPLES

AS	Auger sample
BS	Block sample
CS	Chunk sample
DD	Diamond Drilling
DO or DP	Seamless open ended, driven or pushed tube sampler – note size
DS	Denison type sample
GS	Grab Sample
MC	Modified California Samples
MS	Modified Shelby (for frozen soil)
RC / SC	Rock core / Soil core
SS	Split spoon sampler – note size
ST	Slotted tube
TO	Thin-walled, open – note size (Shelby tube)
TP	Thin-walled, piston – note size (Shelby tube)
WS	Wash sample
OD / ID	Outer Diameter / Inner Diameter
HSA / SSA	Hollow-Stem Augers / Solid-Stem Augers

### SOIL TESTS

w	water content
PL, w <sub>p</sub>	plastic limit
LL, w <sub>L</sub>	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 <sub>R</sub>	relative density (specific gravity, G <sub>s</sub> )
DS	direct shear test
GS	specific gravity
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 <sub>4</sub>	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V (FV)	field vane (LV-laboratory vane test)
Y	unit weight

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

### COARSE-GRAINED SOILS

#### Compactness<sup>1</sup>

Term	SPT 'N' (blows/0.3m) <sup>2</sup>
Very Loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	➤ 50

3. Definition of compactness terms are based on SPT 'N' ranges as provided in Terzaghi, Peck and Mesri (1996). Many factors affect the recorded SPT 'N' value, including hammer efficiency (which may be greater than 60% in automatic trip hammers), overburden pressure, groundwater conditions, and grain size. As such, the recorded SPT 'N' value(s) should be considered only an approximate guide to the soil compactness. These factors need to be considered when evaluating the results, and the stated compactness terms should not be relied upon for design or construction.

4. SPT 'N' in accordance with ASTM D1586, uncorrected for the effects of overburden pressure.

### FINE-GRAINED SOILS

#### Consistency

Term	Undrained Shear Strength (kPa)	SPT 'N' <sup>1,2</sup> (blows/0.3m)
Very Soft	< 12	0 to 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	> 200	> 30

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.

2. SPT 'N' values should be considered ONLY an approximate guide to consistency; for sensitive clays (e.g., Champlain Sea clays), the N-value approximation for consistency terms does NOT apply. Rely on direct measurement of undrained shear strength or other manual observations.

### Field Moisture Condition

Term	Description
Dry	Soil flows freely through fingers.
Moist	Soils are darker than in the dry condition and may feel cool.
Wet	As moist, but with free water forming on hands when handled.

# LIST OF SYMBOLS

## MINISTRY OF TRANSPORTATION, ONTARIO

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

\* Density symbol is  $\rho$ . Unit weight symbol is  $\gamma$  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 $= (w_l - w_p)$
NP	non-plastic
$w_s$	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



Notes: 1  
2

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



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

PROJECT 1896349		RECORD OF BOREHOLE No C258-1				2 OF 2 METRIC						
G.W.P. 5210-14-00		LOCATION N 5330483.6; E 394108.7 NAD83 MTM ZONE 12 (LAT. 48.106971; LONG. -79.800632)				ORIGINATED BY MR						
DIST _____ HWY 66		BOREHOLE TYPE NW Casing, Wash Boring				COMPILED BY TR						
DATUM GEODETIC		DATE May 24, 2019				CHECKED BY AB						
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT  SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED	PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W <sub>p</sub> — W — W <sub>L</sub> WATER CONTENT (%)	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES							
--- CONTINUED FROM PREVIOUS PAGE ---												
265.3	SILT, trace sand, with clayey silt laminations Very loose to loose Grey Wet		11	SS	2		266					
13.1	CLAY, with silt laminations Firm to stiff Grey Wet						265					
			12	SS	1		264					0 0 35 65
							263					
			13	SS	2		262					
							261					
			14	SS	WH		260					
							259					
			15	SS	1		258					
257.4	END OF BOREHOLE											
21.0	NOTE:  1. Water level inside casing at a depth of 1.9 m below ground surface (Elev. 276.5 m) upon completion of drilling.											

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PROJECT 1896349		RECORD OF BOREHOLE No C258-2		1 OF 2 METRIC									
G.W.P. 5210-14-00		LOCATION N 5330481.9; E 394092.5 NAD83 MTM ZONE 12 (LAT. 48.106957; LONG. -79.800851)		ORIGINATED BY MR									
DIST _____ HWY 66		BOREHOLE TYPE NW Casing, Wash Boring		COMPILED BY TR									
DATUM GEODETIC		DATE May 26, 2019		CHECKED BY AB									
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT $\gamma$	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	W <sub>p</sub> W W <sub>L</sub>	WATER CONTENT (%)		
278.6	GROUND SURFACE												
0.0	ASPHALT (100 mm)												
0.3	Sand and gravel (FILL)												
	Sand, trace gravel (FILL)												
	Very loose to loose												
	Brown												
	Moist to wet												
			1	SS	5								
			2	SS	4								
			3	SS	6								
	- Trace asphalt in Sample 4		4	SS	4								
274.9													
3.7	Organic SILT, trace gravel, trace sand, trace wood												
	Very loose												
	Dark brown												
	Wet												
274.1													
4.5	SAND, trace gravel, trace silt												
	Loose to compact												
	Grey												
	Wet												
			6	SS	10								
			7	SS	5								
271.4													
7.2	SILTY CLAY												
	Very stiff												
	Grey												
	Wet												
			8	SS	3								
			9	SS	10								
			10	SS	5								
267.0													
11.6	SILT, trace sand, trace clay												

Continued Next Page

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

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PROJECT 1896349		RECORD OF BOREHOLE No C258-2				2 OF 2 METRIC															
G.W.P. 5210-14-00		LOCATION N 5330481.9; E 394092.5 NAD83 MTM ZONE 12 (LAT. 48.106957; LONG. -79.800851)				ORIGINATED BY MR															
DIST _____ HWY 66		BOREHOLE TYPE NW Casing, Wash Boring				COMPILED BY TR															
DATUM GEODETIC		DATE May 26, 2019				CHECKED BY AB															
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		
	--- CONTINUED FROM PREVIOUS PAGE ---							20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					W <sub>p</sub> W W <sub>L</sub> 20 40 60			kN/m <sup>3</sup>					
265.5	SILT, trace sand, trace clay Very loose Grey Wet		11	SS	3		266														
13.1	CLAY, with silt laminations Stiff Grey Wet		12	SS	1		265														
							264														
			13	SS	1		263														
262.1	END OF BOREHOLE																				
16.5	NOTE:  1. Water level inside casing at a depth of 2.8 m below ground surface (Elev. 275.8 m) upon completion of drilling.																				

PROJECT 1896349		RECORD OF BOREHOLE No C258-3				1 OF 2 METRIC								
G.W.P. 5210-14-00		LOCATION N 5330478.7; E 394123.5 NAD83 MTM ZONE 12 (LAT. 48.106924; LONG. -79.800435)				ORIGINATED BY MR								
DIST _____ HWY 66		BOREHOLE TYPE NW Casing, Wash Boring				COMPILED BY TR								
DATUM GEODETIC		DATE May 26, 2019				CHECKED BY AB								
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						
278.3 0.0	GROUND SURFACE Sand and gravel (FILL)							20 40 60 80 100	20 40 60					
277.7 0.6	Sand, trace to some gravel (FILL) Very loose to compact Brown Moist to wet		1	SS	17									
	- Trace asphalt in Sample 2		2	SS	11									
			3	SS	6									
			4	SS	5									
			5	SS	1									
274.0 4.3	Organic SILTY SAND, trace gravel Loose Dark brown Wet		A	SS	7								OC=7.2%	
273.3 5.0	SAND, trace to some gravel Loose Grey Wet		6	SS										
			7	SS	8									
271.1 7.2	SILTY CLAY Stiff Grey Wet		8	SS	WH									
			9	SS	1									
268.2 10.1	SILT, some clay, trace sand Very loose Grey Wet		10	SS	2								NP	0 5 79 16

Continued Next Page

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

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PROJECT <u>1896349</u>		<b>RECORD OF BOREHOLE No C258-3</b>				2 OF 2 <b>METRIC</b>											
G.W.P. <u>5210-14-00</u>		LOCATION <u>N 5330478.7; E 394123.5 NAD83 MTM ZONE 12 (LAT. 48.106924; LONG. -79.800435)</u>				ORIGINATED BY <u>MR</u>											
DIST <u>          </u> HWY <u>66</u>		BOREHOLE TYPE <u>NW Casing, Wash Boring</u>				COMPILED BY <u>TR</u>											
DATUM <u>GEODETIC</u>		DATE <u>May 26, 2019</u>				CHECKED BY <u>AB</u>											
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 (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					WATER CONTENT (%)				
	--- CONTINUED FROM PREVIOUS PAGE ---							20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>		
265.0	SILT, some clay, trace sand Very loose Grey Wet		11	SS	3		266										
13.3	CLAY, with silt laminations Stiff Grey Wet		12	SS	2		265			2							
							264										
							263			2							
261.8			13	SS	1		262										
16.5	END OF BOREHOLE  NOTE:  1. Water level inside casing at a depth of 3.1 m below ground surface (Elev. 275.2 m) upon completion of drilling.																

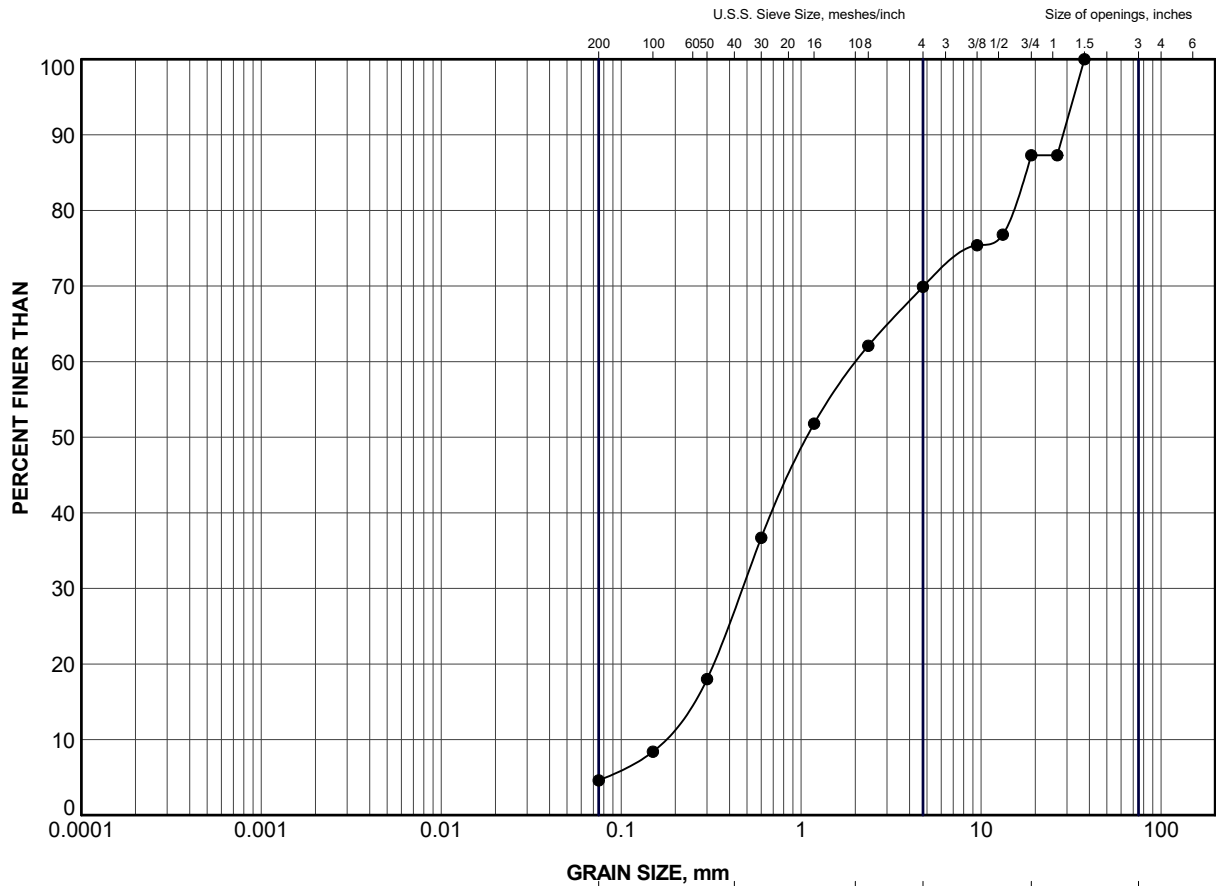
PROJECT 1896349		RECORD OF BOREHOLE No C258-4				1 OF 1 METRIC											
G.W.P. 5210-14-00		LOCATION N 5330496.2; E 394099.2 NAD83 MTM ZONE 12 (LAT. 48.107085; LONG. -79.800757)				ORIGINATED BY MR											
DIST _____ HWY 66		BOREHOLE TYPE NW Casing, Wash Boring				COMPILED BY TR											
DATUM GEODETIC		DATE May 25, 2019				CHECKED BY AB											
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									
276.2	GROUND SURFACE							20	40	60	80	100					
0.0	Organic silty sand (FILL) Dark brown Moist to wet						276										
275.8																	
0.4	Silty sand, trace gravel, trace organics (FILL) Loose Grey Wet		1	SS	6		275										
274.8																	
1.4	PEAT, trace gravel, trace wood Very loose Dark brown Wet		2	SS	2		274										
274.0																	
2.2	SAND, trace gravel, trace silt Very loose to loose Grey Wet		3	SS	7		273										
			4	SS	3												
			5	SS	WH		272										
			6	SS	2												
							271										
270.6																	
5.6	SILT, some sand, some clay Very loose to loose Grey Wet		7	SS	8		270										0 3 81 16
							269										
			8	SS	4		268										0 16 70 14
			9	SS	3		267										
							266										
265.8	END OF BOREHOLE																
10.4	NOTE:  1. Water level inside casing at a depth of 0.3 m below ground surface (Elev. 275.9 m) upon completion of drilling.																

PROJECT 1896349		<b>RECORD OF BOREHOLE No C258-5</b>		1 OF 1 <b>METRIC</b>																										
G.W.P. 5210-14-00		LOCATION N 5330462.5; E 394122.4 NAD83 MTM ZONE 12 (LAT. 48.106778; LONG. -79.800453)		ORIGINATED BY MR																										
DIST _____ HWY 66		BOREHOLE TYPE NW Casing, Wash Boring		COMPILED BY TR																										
DATUM GEODETIC		DATE May 25, 2019		CHECKED BY AB																										
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS			ELEVATION SCALE			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			SHEAR STRENGTH kPa			WATER CONTENT (%)			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV	DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES																								
274.4	0.0	GROUND SURFACE																												
	0.2	Organic silty sand (FILL) Dark brown Moist to wet																												
	0.8	Sand, trace gravel, trace organics (FILL) Dark brown Wet																												
	1.4	Organic SILTY SAND Loose Dark brown Wet		1	SS	6																								
		SAND, trace gravel Very loose to loose Brown Wet		2	SS	3																								
				3	SS	6																								
				4	SS	3																								
				5	SS	5																								
	4.5	SILT, some sand, some clay Very loose to loose Brown Wet		6	SS	5																								
				7	SS	5																								
				8	SS	2																								
	8.7	SILTY CLAY Firm Grey Wet		9	SS	1																								
	10.4	END OF BOREHOLE																												
NOTE: 1. Water level inside casing at a depth of 0.1 m below ground surface (Elev. 274.3 m) upon completion of drilling.																														

**APPENDIX B**

# Laboratory Test Results






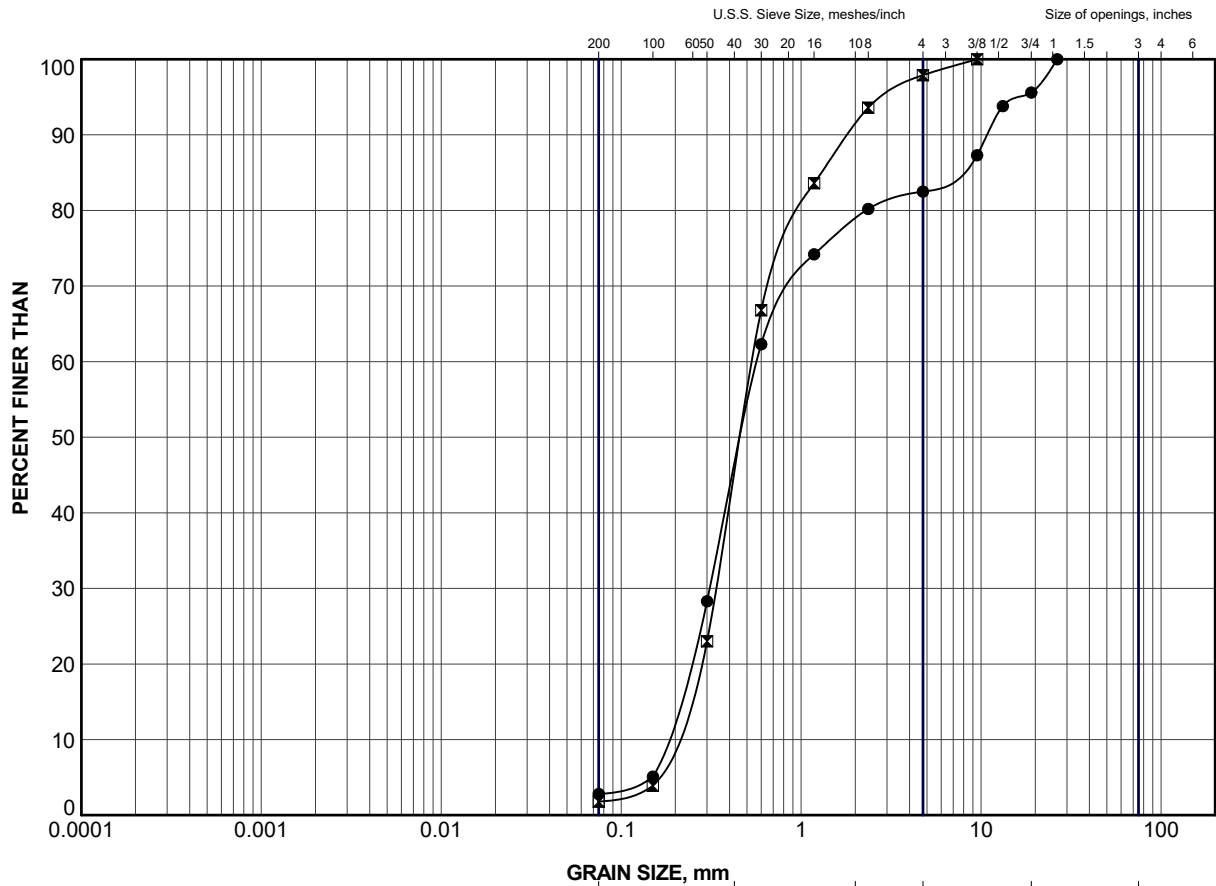
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

**LEGEND**

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C258-1	2	276.6


PROJECT						HIGHWAY 66 STATION 17+903 TOWNSHIP OF GAUTHIER CULVERT					
TITLE						<b>GRAIN SIZE DISTRIBUTION</b> Gravelly Sand (FILL)					
PROJECT No.			1896349			FILE No.			1896349.GPJ		
DRAWN	TR	Nov 2019	SCALE	N/A	REV.	<b>FIGURE B-1</b>					
CHECK	AB	Nov 2019									
APPR	JMAC	Nov 2019									
 <b>GOLDER</b> SUDBURY, ONTARIO											

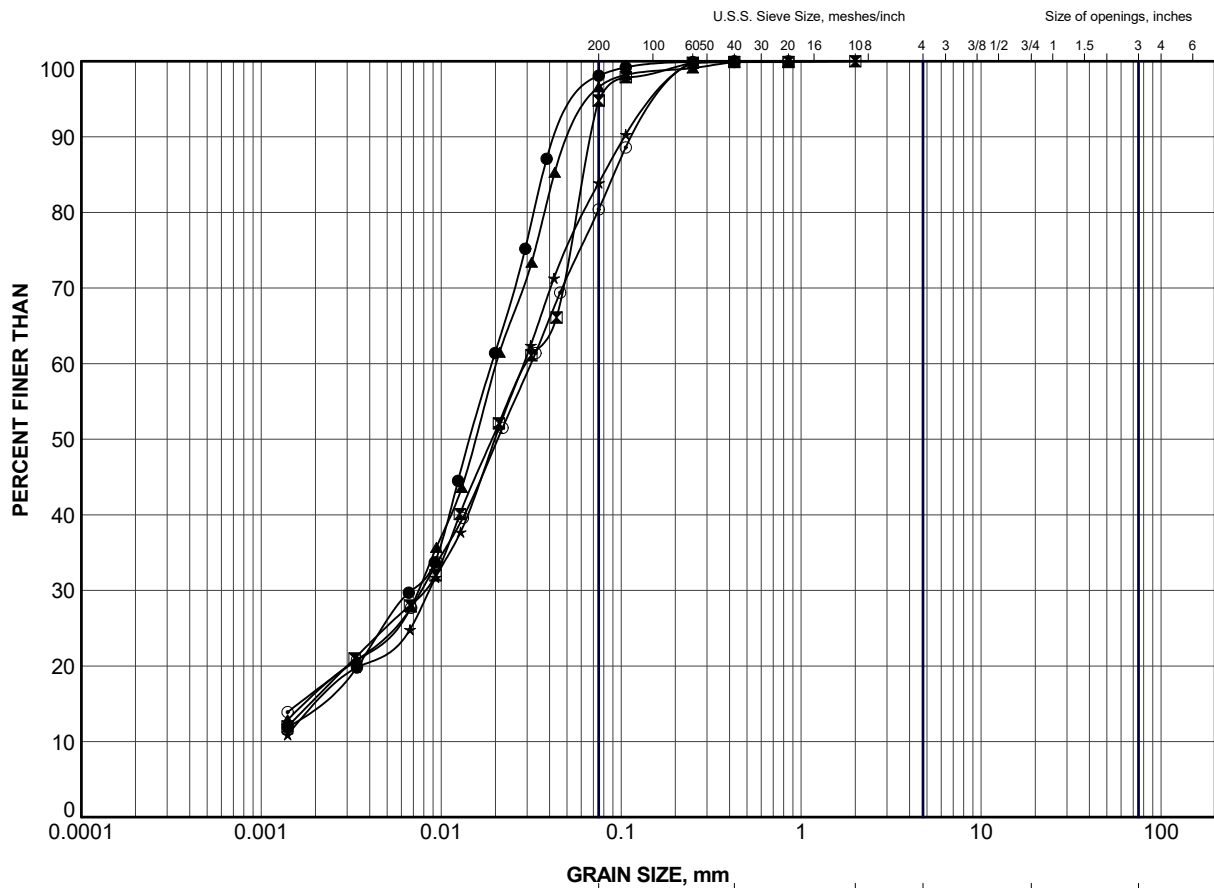
SUD-MTO GSD GLDR\_LDN.GDT



### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C258-1	8	270.5
×	C258-2	7	272.2

PROJECT						HIGHWAY 66 STATION 17+903 TOWNSHIP OF GAUTHIER CULVERT					
TITLE						GRAIN SIZE DISTRIBUTION SAND					
PROJECT No.			1896349			FILE No.			1896349.GPJ		
DRAWN	TR	Nov 2019	SCALE	N/A	REV.						
CHECK	AB	Nov 2019									
APPR	JMAC	Nov 2019									
 <b>GOLDER</b> SUDBURY, ONTARIO						<b>FIGURE B-2</b>					



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

### LEGEND

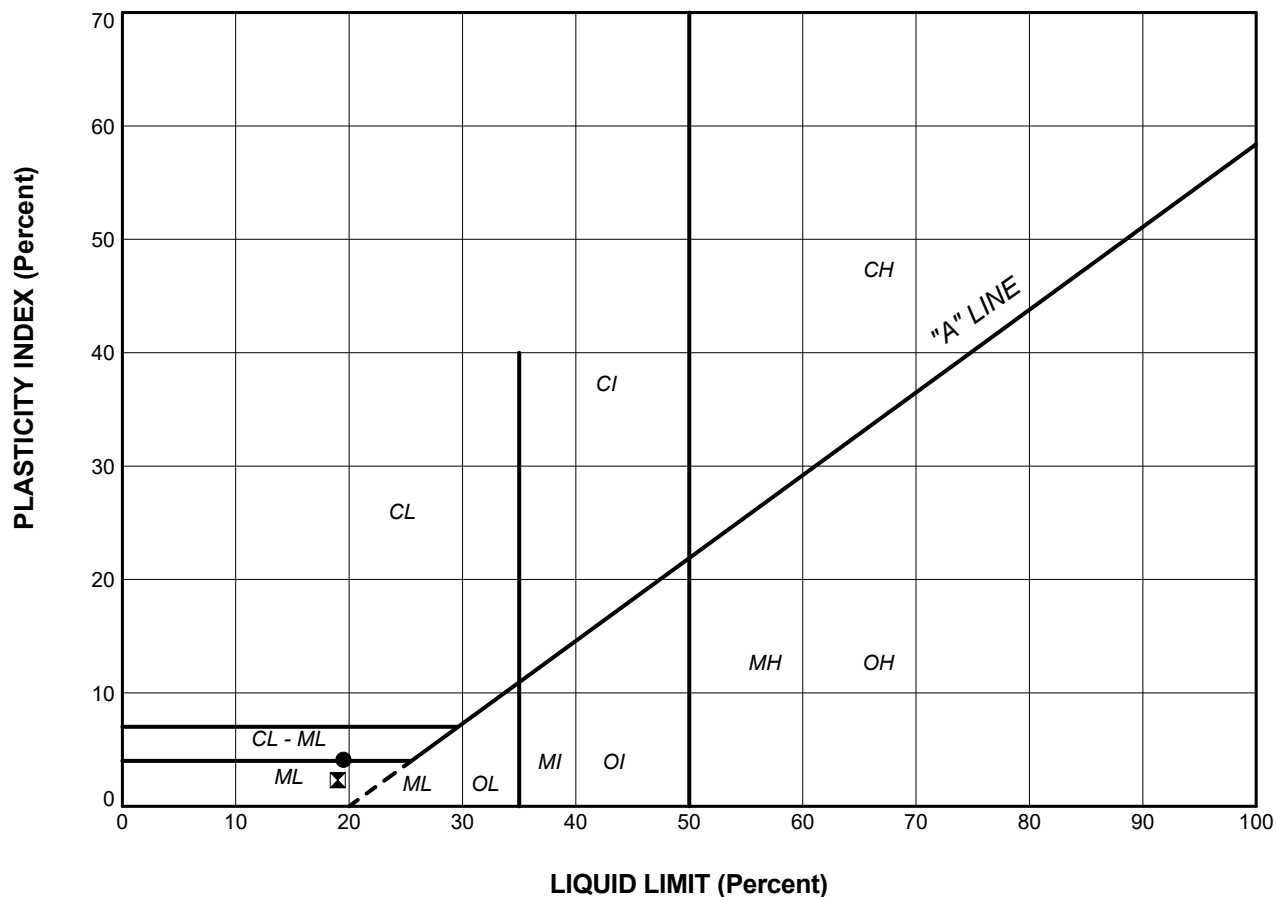
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C258-1	10	267.4
⊠	C258-3	10	267.3
▲	C258-4	7	269.8
★	C258-4	8	268.3
⊙	C258-5	7	268.0

PROJECT						HIGHWAY 66 STATION 17+903 TOWNSHIP OF GAUTHIER CULVERT					
TITLE						GRAIN SIZE DISTRIBUTION SILT					
PROJECT No.			1896349			FILE No.			1896349.GPJ		
DRAWN	TR	Nov 2019	SCALE	N/A	REV.						
CHECK	AB	Nov 2019									
APPR	JMAC	Nov 2019									
						FIGURE B-3					



GOLDER

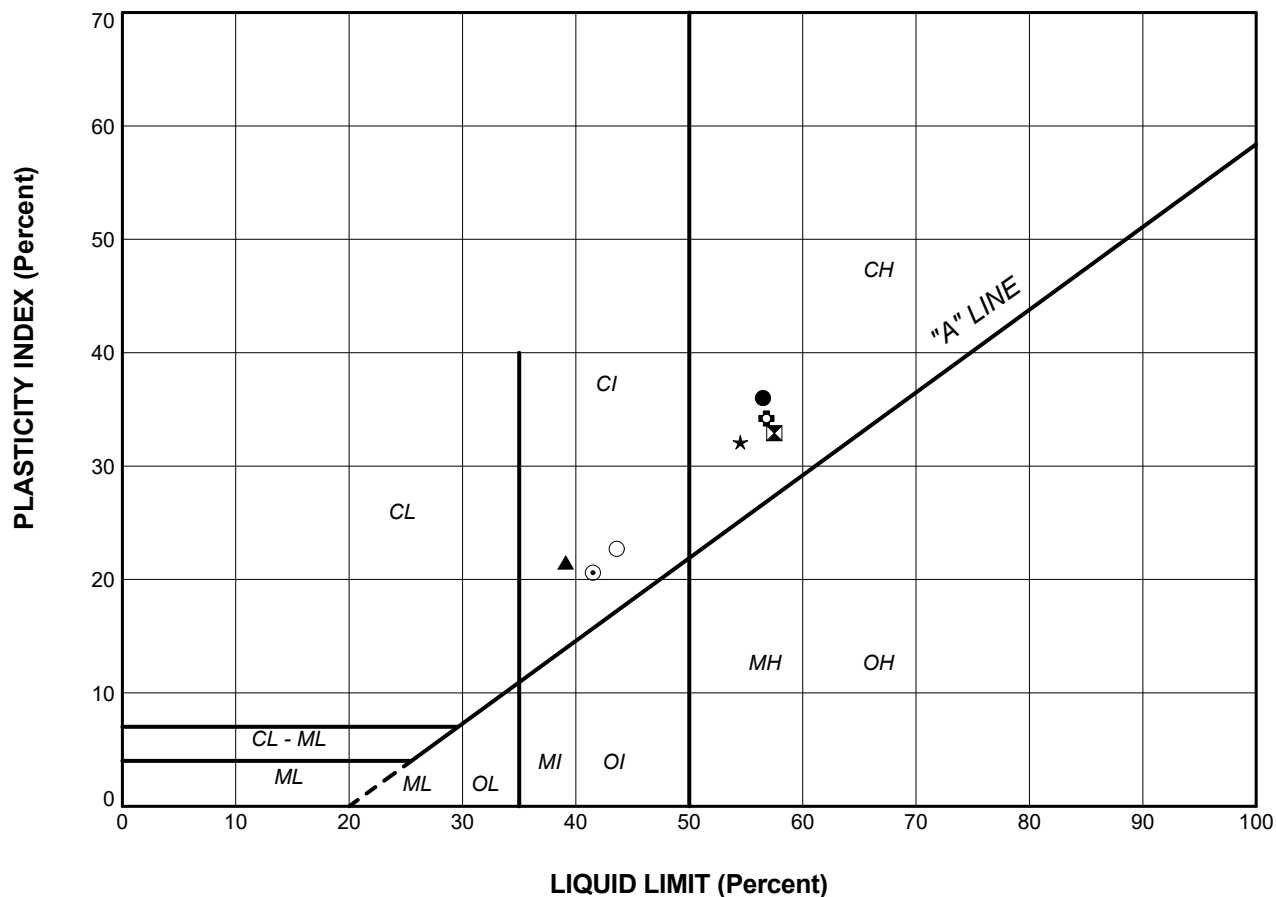
SUDBURY, ONTARIO



### LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	C258-1	10	19.5	15.4	4.1
⊠	C258-4	8	19.0	16.7	2.3

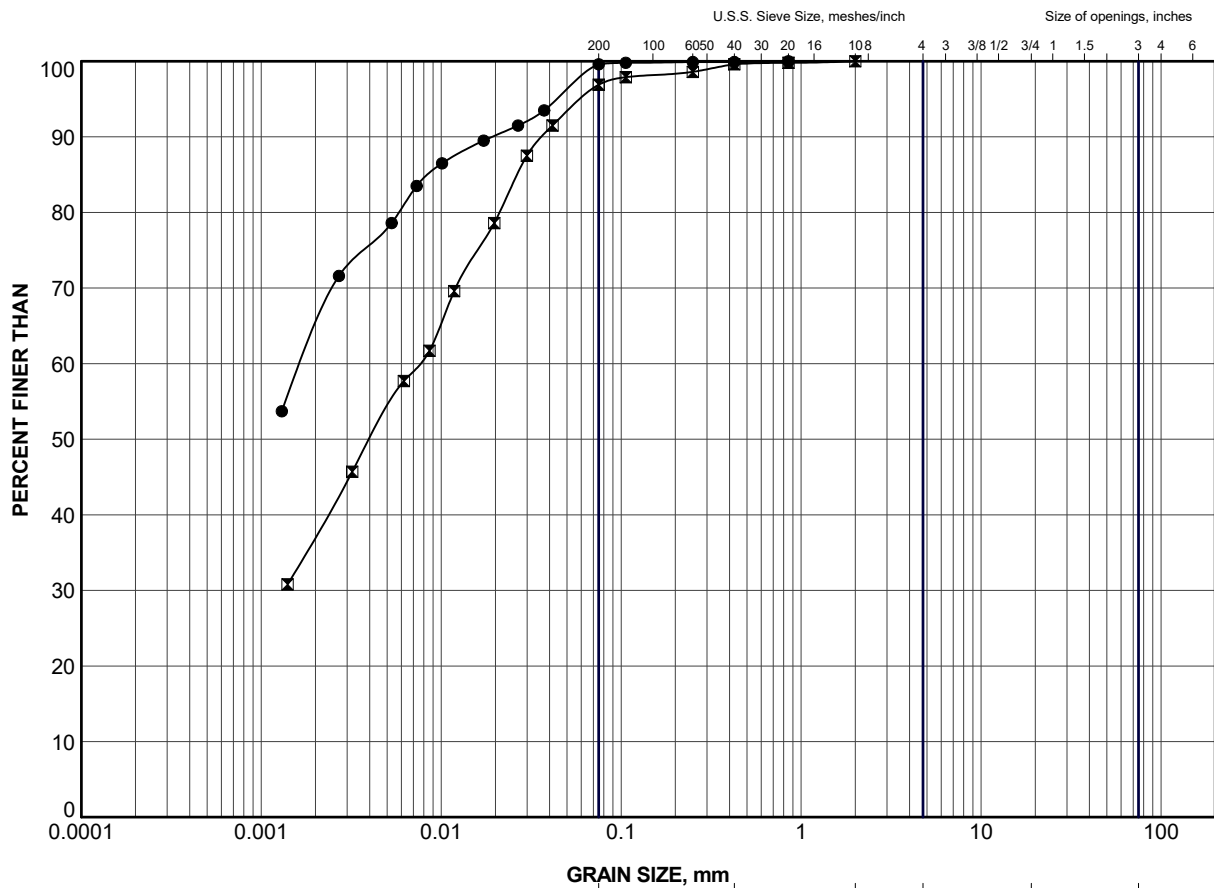
PROJECT						HIGHWAY 66 STATION 17+903 TOWNSHIP OF GAUTHIER CULVERT					
TITLE						PLASTICITY CHART SILT					
PROJECT No.			1896349			FILE No.			1896349.GPJ		
DRAWN	TR	Nov 2019	SCALE	N/A	REV.	FIGURE B-4					
CHECK	AB	Nov 2019									
APPR	JMAC	Nov 2019									
GOLDER						SUDBURY, ONTARIO					



### LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	C258-1	12	56.5	20.5	36.0
⊠	C258-1	14	57.5	24.6	32.9
▲	C258-2	8	39.1	17.6	21.5
★	C258-2	12	54.5	22.4	32.1
⊙	C258-3	8	41.5	20.9	20.6
⊕	C258-3	12	56.8	22.6	34.2
○	C258-5	9	43.6	20.9	22.7

PROJECT		HIGHWAY 66 STATION 17+903 TOWNSHIP OF GAUTHIER CULVERT			
TITLE		<b>PLASTICITY CHART</b> SILTY CLAY to CLAY			
PROJECT No.		1896349		FILE No. 1896349.GPJ	
DRAWN	TR	Nov 2019		SCALE	N/A
CHECK	AB	Nov 2019		REV.	
APPR	JMAC	Nov 2019		<b>FIGURE B-5</b>	
GOLDER		SUDBURY, ONTARIO			



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

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C258-1	12	264.4
□	C258-2	8	270.7

PROJECT						HIGHWAY 66 STATION 17+903 TOWNSHIP OF GAUTHIER CULVERT					
TITLE						GRAIN SIZE DISTRIBUTION SILTY CLAY to CLAY					
PROJECT No.			1896349			FILE No.			1896349.GPJ		
DRAWN	TR	Nov 2019	SCALE	N/A	REV.	FIGURE B-6					
CHECK	AB	Nov 2019									
APPR	JMAC	Nov 2019									
GOLDER						SUDBURY, ONTARIO					

BUREAU  
VERITASBV Labs Job #: B9E6999  
Report Date: 2019/06/10Golder Associates Ltd  
Client Project #: 1896349  
Site Location: HWY 66  
Sampler Initials: MR

## RESULTS OF ANALYSES OF SOIL

BV Labs ID		JWF921			JWF921			JWF922		
Sampling Date		2019/05/21 09:10			2019/05/21 09:10			2019/05/24 12:10		
COC Number		127612			127612			127612		
	UNITS	C212-1	RDL	QC Batch	C212-1 Lab-Dup	RDL	QC Batch	C258-1	RDL	QC Batch
<b>CONVENTIONALS</b>										
Sulphide	ug/g	<0.50	0.50	6165835	<0.50	0.50	6165835	<0.50	0.50	6165835
<b>Calculated Parameters</b>										
Resistivity	ohm-cm	30000		6152340				5400		6152340
<b>Inorganics</b>										
Soluble (20:1) Chloride (Cl-)	ug/g	<20	20	6156490				40	20	6156490
Conductivity	umho/cm	33	2	6158961	32	2	6158961	185	2	6158961
Available (CaCl2) pH	pH	6.11		6156642				7.70		6156642
Soluble (20:1) Sulphate (SO4)	ug/g	<20	20	6156491	<20	20	6156491	<20	20	6156491
<b>Physical Testing</b>										
Moisture-Subcontracted	%	12	0.30	6165834				19	0.30	6165834
RDL = Reportable Detection Limit QC Batch = Quality Control Batch Lab-Dup = Laboratory Initiated Duplicate										



**[golder.com](http://golder.com)**