

FOUNDATION INVESTIGATION REPORT

CONTRACT NO. 2020-5160

REPORT NO. 4



## FOUNDATION INVESTIGATION REPORT

# Highway 66, Station 13+221, Township of Lebel Culvert Replacement Ministry of Transportation, Ontario GWP 5210-14-00

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**PART A**

FOUNDATION INVESTIGATION REPORT  
HIGHWAY 66, STA 13+221, TOWNSHIP OF LEBEL  
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 culvert on Highway 66 at Station 13+221, in the Township of Lebel, approximately 1.8 km west of Main Street in King Kirkland, Ontario. 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 replacement site 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.

## 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 the Drawing 1. For the purpose of this report, Highway 66 is oriented in a west-east direction with the culvert positioned perpendicular to the highway generally in a north-south orientation. At the culvert location, the creek flows in a north-south direction, discharging into Gull Lake.

The existing culvert consists of a 750 mm diameter, 20 m long Corrugated Steel Pipe (CSP). The culvert inlet (north end) and outlet (south end) inverts are approximately Elevations 319.8 m and 319.7 m, respectively. The highway grade at the culvert location is approximately Elevation 322.4 m and the highway embankment is about 2.6 m high relative to the culvert invert, providing a thickness of about 1.9 m soil cover on the culvert. At the time of the subsurface exploration field work the embankment/side slopes appeared to be performing well, with no visible signs of slope instability or roadway settlement issues. The CSP culvert appears to be rust covered along its entire internal wall and the crown at the inlet and outlet is rusted through. In general, the topography in the vicinity of the culvert consists of forested hills and rock outcrops north of the culvert and Gull Lake south of the culvert. The ground surface conditions at select locations near the culvert are shown on Photographs 1 to 4.

## 3.0 INVESTIGATION PROCEDURES

Field work for this subsurface exploration was carried out on May 13, 21, and 27, 2019, during which time three boreholes (Boreholes C212-1 to C212-3) were advanced at the approximate locations shown on Drawing 1. Boreholes C212-1 and C212-3 were advanced using a track mounted CME-55LC drilling rig supplied and operated by George Downing Estate Drilling (Downing) of Grenville-Sur-La-Rouge, Quebec. Borehole C212-2 was advanced using a CME-550 Rubber Tire ATV Mounted Drill supplied and operated by Landcore Drilling (Landcore) of Chelmsford, Ontario. 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, and the bedrock was cored using NQ coring techniques. Water for casing advancement and coring operations was obtained locally from the adjacent creek and Gull Lake.

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 a full weight automatic hammer, in accordance with the Standard Penetration Test (SPT) procedure (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 D2573), using an MTO standard "N"-size vane. The groundwater level in the boreholes upon removal of the casing was observed and recorded after the completion of drilling. The bedrock cored length of the boreholes was backfilled with bentonite pellets to the bedrock surface and the remainder of the borehole was backfilled in accordance with Ontario Regulation 903 (wells), as amended. The roadway surface at the borehole drilled through Highway 66 was capped at ground 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 and bedrock 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, Atterberg limits, grain size distributions and organic content were carried out on selected soil samples. The geotechnical laboratory testing was completed according to ASTM and MTO LS standards, as applicable. One soil sample was submitted to Bureau Veritas Laboratories (formerly Maxxam) of Sudbury, an accredited analytical laboratory, for testing of a suite of corrosivity indicator parameters.

The as-drilled borehole locations were measured relative to highway chainages/stations 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 the borehole locations 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 <sup>1</sup> (m)
C212-1	5336666.8 (48.164329)	380563.2 (-79.981411)	322.6	13.2
C212-2	5336658.0 (48.164251)	380566.8 (-79.981363)	322.1	17.0
C212-3	5336671.5 (48.164371)	380570.5 (-79.981311)	321.4	11.4

Note:

<sup>1</sup> Borehole depth includes 3.3 m, 3.5 m and 3.7 m of bedrock coring in the respective boreholes.

## 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 subsoils in the vicinity of the culvert site are glacially derived ground moraine comprising primarily of till.

Based on geological mapping (MNDM)<sup>2</sup>, the site is underlain by metasedimentary 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 profile 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 240 mm thick layer of asphalt was encountered in Borehole C212-2 drilled through the roadway, at Elevation 322.1 m. A 2.2 m thick layer of embankment fill, consisting of an upper 0.3 m and 0.4 m thick layer of sand and gravel, underlain by sand, was encountered at ground surface in Borehole C212-1 at Elevation 322.6 m and below the asphalt in Borehole C212-2.

The SPT "N"-values measured within the sand fill range from 11 blows to 36 blows per 0.3 m of penetration, indicating a compact to dense compactness condition.

#### 4.2.2 Silty Sandy Topsoil

An approximately 0.4 m thick layer of silty sandy topsoil was encountered from ground surface in Borehole C212-3 at Elevation 321.4 m.

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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



### 4.2.3 Silt (Upper)

An upper, 1.0 m thick layer of silt was encountered below the organic soil in Borehole C212-3 at Elevation 321.0 m.

An SPT “N”-value measured within the upper layer of silt is 5 blows per 0.3 m of penetration indicating a loose compactness condition.

### 4.2.4 Clayey Silt to Silty Clay

A 2.4 m to 3.9 m thick deposit of clayey silt to silty clay was encountered in all three boreholes between Elevations 320.4 m and 319.7 m.

SPT “N”-values measured within the clayey silt to silty clay deposit range from 0 blows (weight of hammer) to 18 blows per 0.3 m of penetration. In-situ field vane tests carried out within the cohesive deposit measured undrained shear strengths ranging from about 28 kPa to 58 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 four samples of the clayey silt to silty clay deposit and measured liquid limits ranging between about 27 per cent and 40 per cent, plastic limits ranging between about 18 per cent and 21 per cent and plasticity indices ranging between about 10 per cent and 20 per cent. The results of the Atterberg limit test are presented on Figure B-1 and indicate the deposit is comprised of clayey silt of low plasticity to silty clay of intermediate plasticity. The natural moisture content measured on the samples of the deposit range between about 19 per cent and 42 per cent.

Grain size distribution analysis was carried out on five samples of the clayey silt to silty clay deposits and the results are presented on Figure B-2 in Appendix B.

### 4.2.5 Silt (Lower)

A lower, 0.6 m thick layer of silt was encountered in Borehole C212-3 below the silty clay deposit at Elevation 317.6 m.

### 4.2.6 Till

A 3.3 m to 8.2 m thick deposit of granular till ranging in composition from silt some sand some gravel to silt and sand to silty sand to silty sand and gravel, was encountered in the three boreholes underlying the clayey silt and silt deposits, between Elevations 317.0 m and 316.5 m. Cobbles and boulders (of about 400 mm to 500 mm sizes) were encountered within the till at various depths as noted on the borehole records.

The SPT “N”-values measured within the till deposit range between 15 blows to 109 blows per 0.3 m of penetration, with ‘N’-values of 26 blows for 0.15 m of penetration and 100 blows for 0.13 m of penetration recorded in the lower section of the deposit, indicating a compact to very dense compactness condition.

Grain size distribution analysis was carried out on three samples of the till deposit and the results are presented on Figure B-3 in Appendix B. The natural moisture content measured on three samples of the till deposit ranges between about 8 per cent and about 27 per cent.

#### 4.2.6 Bedrock

Bedrock was encountered in the three boreholes at depths ranging from 7.7 m to 13.5 m below ground surface, between Elevations 313.7 m and 308.6 m, and was cored for lengths between 3.3 m and 3.7 m.

The retrieved bedrock core samples are described as very fine to medium grained, fresh, dark grey, metasedimentary, as described on the Record of Drillholes presented in Appendix A. Photographs of the retrieved bedrock core samples are shown on Figures B-4A to B-4C in Appendix B. The Total Core Recovery (TCR) of the bedrock samples is 100 per cent and the Solid Core Recovery (SCR) ranges from about 70 per cent to 100 per cent. The Rock Quality Designation (RQD) of the bedrock core samples ranges between 56 per cent and 100 per cent, and based on the Classification of rock with respect to RQD value in Table 3.10 of CFEM (2006)<sup>3</sup>, the bedrock is considered of fair to excellent quality.

### 4.3 Groundwater Conditions

The unstabilized groundwater levels measured in the open boreholes upon completion of casing removed (after bedrock coring) are summarized below. The water level of Gull Lake, surveyed by Callon Dietz in June 2019, was approximately Elevation 320.4 m. Groundwater and lake 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)
C212-1	0.7	321.9
C212-2	0.7	321.4
C212-3	0.0	321.4

### 4.4 Analytical Laboratory Testing Results

Analytical testing was carried out on a sample of clayey silt recovered from Borehole C212-1. The soil sample was submitted to Bureau Veritas Laboratories for corrosivity testing. The analytical laboratory test results are summarized below, and the detailed analytical laboratory test report is included in Appendix B.

<sup>3</sup> Canadian Geotechnical Society. 2006. Canadian Foundation Engineering Manual (CFEM), 4<sup>th</sup> Edition.

Borehole No.	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
C212-1	4	3.0 – 3.6	30,000	33	<20 <sup>1</sup>	<20 <sup>1</sup>	<0.50 <sup>1</sup>	6.11

Note:

<sup>1</sup>. The sulphate, chloride, and sulphide concentrations are below the reportable detection limits of 20 µg/g, 20 µg/g, and 0.50 µg/g, respectively.

## 5.0 CLOSURE

The field drilling program was carried out under the supervision of Mr. Mathew Riopelle and Mr. Yusuf Soliman, under the overall direction of Mr. André Bom, P.Eng., an Associate of Golder. This Foundation Investigation Report was prepared by Mr. Mahmoud Hussein, PhD/Geotechnical Consultant, and Mr. André Bom, P.Eng., an Associate of Golder, 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.



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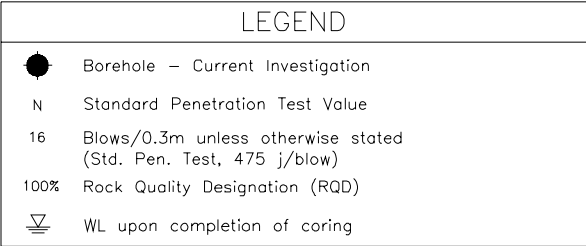
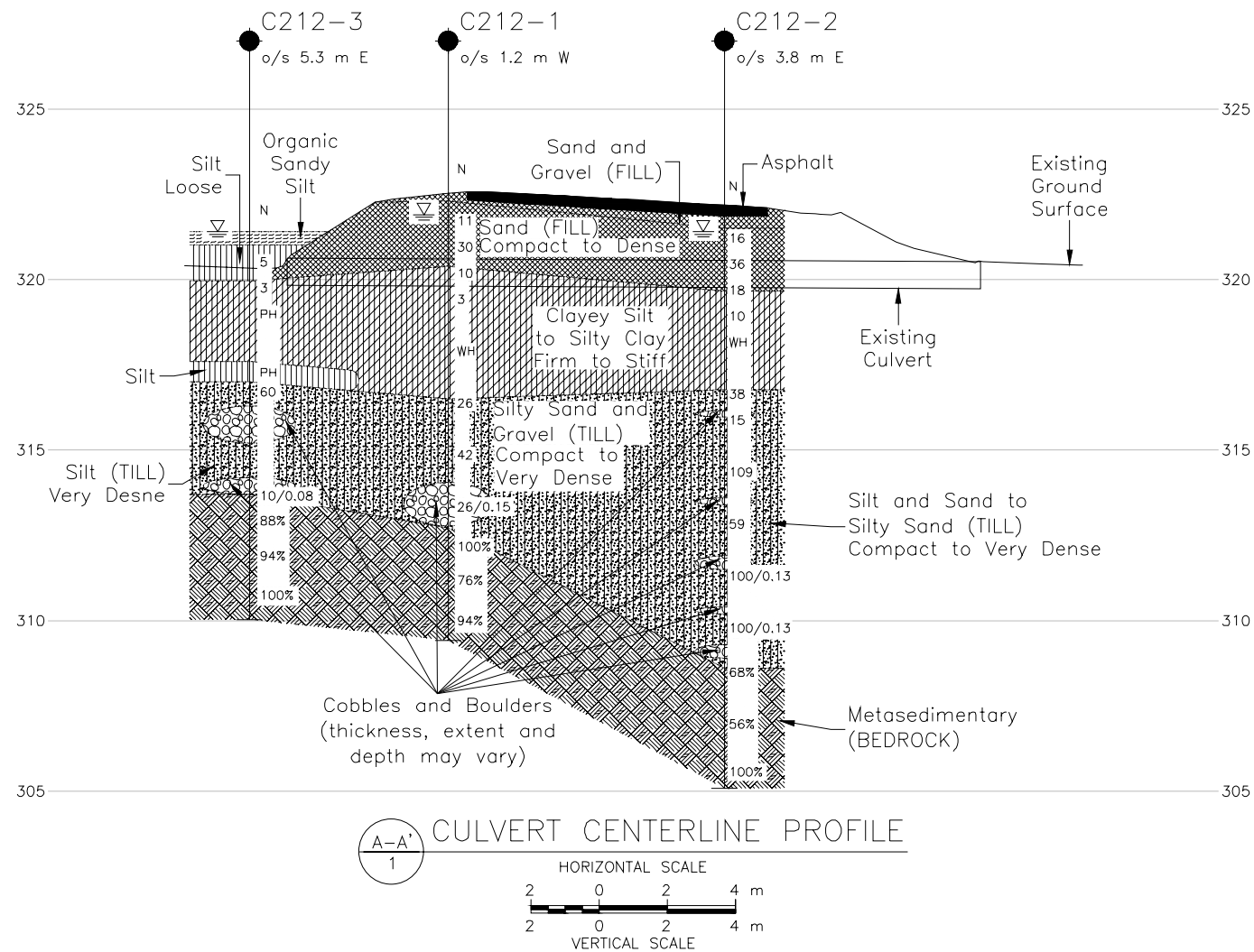


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BOREHOLE CO-ORDINATES (NAD 83 MTM ZONE 12)			
No.	ELEVATION	NORTHING	EASTING
C212-1	322.6	5336666.8	380563.2
C212-2	322.1	5336658.0	380566.8
C212-3	321.4	5336671.5	380570.5



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. qwp52101400a.dwg, received AUGUST 14, 2019.

NO.	DATE	BY	REVISION	
Geocres No. 32D--33				
HWY. 66		PROJECT NO. 1896349		DIST.
SUBM'D.	CHKD. TB	DATE: 3/10/2020	SITE:	
DRAWN: TR	CHKD. AB	APPD. JMAC	DWG. 1	





**Photograph 1:** Highway 66 North End (Inlet) of Culvert, Facing East (May 2018)



**Photograph 2:** Borehole C212-2 and Gull Lake, Facing East (May 2019)





**Photograph 3:** Highway 66 EBL and Gull Lake, Facing East (May 2019)



**Photograph 4:** Highway 66 North Embankment Slope at Culvert inlet, Facing Northwest (May 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.e., SAND and gravel)
> 20 to 35	Primary soil name prefixed with "gravelly, sandy" as applicable
> 10 to 20	some (i.e., some sand)
≤ 10	trace (i.e., 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

## WEATHERINGS STATE

**Fresh:** no visible sign of weathering

**Faintly weathered:** weathering limited to the surface of major discontinuities.

**Slightly weathered:** penetrative weathering developed on open discontinuity surfaces but only slight weathering of rock material.

**Moderately weathered:** weathering extends throughout the rock mass but the rock material is not friable.

**Highly weathered:** weathering extends throughout rock mass and the rock material is partly friable.

**Completely weathered:** rock is wholly decomposed and in a friable condition but the rock and structure are preserved.

## BEDDING THICKNESS

Description	Bedding Plane Spacing
Very thickly bedded	Greater than 2 m
Thickly bedded	0.6 m to 2 m
Medium bedded	0.2 m to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 mm to 60 mm
Laminated	6 mm to 20 mm
Thinly laminated	Less than 6 mm

## JOINT OR FOLIATION SPACING

Description	Spacing
Very wide	Greater than 3 m
Wide	1 m to 3 m
Moderately close	0.3 m to 1 m
Close	50 mm to 300 mm
Very close	Less than 50 mm

## GRAIN SIZE

Term	Size*
Very Coarse Grained	Greater than 60 mm
Coarse Grained	2 mm to 60 mm
Medium Grained	60 microns to 2 mm
Fine Grained	2 microns to 60 microns
Very Fine Grained	Less than 2 microns

Note: \* Grains greater than 60 microns diameter are visible to the naked eye.

## CORE CONDITION

### Total Core Recovery (TCR)

The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

### Solid Core Recovery (SCR)

The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

### Rock Quality Designation (RQD)

The percentage of solid drill core, greater than 100 mm length, recovered at full diameter, measured relative to the length of the total core run. RQD varied from 0% for completely broken core to 100% for core in solid sticks.

## DISCONTINUITY DATA

### Fracture Index

A count of the number of discontinuities (physical separations) in the rock core, including both naturally occurring fractures and mechanically induced breaks caused by drilling.

### Dip with Respect to Core Axis

The angle of the discontinuity relative to the axis (length) of the core. In a vertical borehole a discontinuity with a 90° angle is horizontal.

### Description and Notes

An abbreviation description of the discontinuities, whether naturally occurring separations such as fractures, bedding planes and foliation planes or mechanically induced features caused by drilling such as ground or shattered core and mechanically separated bedding or foliation surfaces. Additional information concerning the nature of fracture surfaces and infillings are also noted.

### Abbreviations

JN Joint	PL Planar
FLT Fault	CU Curved
SH Shear	UN Undulating
VN Vein	IR Irregular
FR Fracture	K Slickensided
SY Stylolite	PO Polished
BD Bedding	SM Smooth
FO Foliation	SR Slightly Rough
CO Contact	RO Rough
AXJ Axial Joint	VR Very Rough
KV Karstic Void	
MB Mechanical Break	

SUD-MTO 001 S:\CLIENTS\MTO\HWY65&66\02 DATA\GINT\1896349.GPJ GAL-MISS.GDT 1-6-20 TR

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○<sup>3%</sup> STRAIN AT FAILURE

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○<sup>3</sup>% STRAIN AT FAILURE

SUD-MTO 001 S:\CLIENTS\MTO\HWY65&66\02 DATA\GINT\1896349.GPJ GAL-MISS.GDT 1-6-20 TR

PROJECT: 1896349

LOCATION: N 5336666.8; E 380563.2

NAD83 MTM ZONE 12 (LAT. 48.164329; LONG. -79.981411)

INCLINATION: -90° AZIMUTH: —

## RECORD OF DRILLHOLE: C212-1

SHEET 1 OF 1

DRILLING DATE: May 21, 2019

DATUM: GEODETIC

DRILL RIG: CME55 LC Track Mount

DRILLING CONTRACTOR: Downing Drilling

DEPTH SCALE METRES	DRILLING RECORD		DESCRIPTION	SYMBOLIC LOG	ELEV.	RUN No.	COLOUR % RETURN	FLUSH	RECOVERY				R.Q.D. %	FRACT. INDEX METRES	DISCONTINUITY DATA						HYDRAULIC CONDUCTIVITY				Diametral Point Load Index (MPa)	RMC -Q AVG.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
									TOTAL CORE %	SOLID CORE %	B Angle	DF w/z CORE AXIS			TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	10 <sup>0</sup>	10 <sup>1</sup>	10 <sup>2</sup>	10 <sup>3</sup>																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
	THICKNESS	PERCENTAGE			PLANAR																		CURVED	UNDULATING			STEPPED	IRREGULAR	PLANAR	CURVED	UNDULATING	STEPPED	IRREGULAR	PLANAR	CURVED	UNDULATING	STEPPED	IRREGULAR																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
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DEPTH SCALE

1 : 60



GOLDER

LOGGED: MR

CHECKED: AB

SUD-MTO-ROCK S:\CLIENTS\MTOWHY\65866\02\_DATA\GINTV1896349.GPJ GAL-MISS.GDT 12-5-19 TR



PROJECT 1896349			RECORD OF BOREHOLE No C212-2			1 OF 2 METRIC																				
G.W.P. 5210-14-00			LOCATION N 5336658.0; E 380566.8 NAD83 MTM ZONE 12 (LAT. 48.164251; LONG. -79.981363)			ORIGINATED BY YS																				
DIST _____ HWY 66			BOREHOLE TYPE NW Casing, Wash boring and NQ Coring			COMPILED BY TR																				
DATUM GEODETIC			DATE May 13, 2019			CHECKED BY AB																				
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS			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		ELEVATION SCALE	20 40 60 80 100	20 40 60 80 100	W <sub>p</sub>	W	W <sub>L</sub>	γ	GR	SA	SI	CL									
322.1	GROUND SURFACE																									
0.0	ASPHALT (240 mm)																									
0.2	Sand and gravel (FILL)																									
321.5	Sand, some gravel (FILL)																									
0.6	Compact to dense Brown Frozen to wet		1	SS	16																					
			2	SS	36																					
319.7	CLAYEY SILT, trace sand Firm to stiff Dark brown to grey w>PL		3A	SS	18																					
2.4			3B	SS																						
			3C	SS																						
			4	SS	10																					
			5	SS	WH																					
316.8	SILT and SAND to Silty SAND, trace to some gravel, trace to some clay (TILL) Compact to very dense Grey Moist to wet		6	SS	38																					
5.3			7	SS	15																					
	- Cobble encountered from 5.9 m to 6.1 m depth		8	SS	109																					
	- Cobble encountered from 8.5 m to 8.7 m depth		9	SS	59																					
	- 400 mm diameter boulder encountered from 10.2 m to 10.6 m depth		10	SS	100/0.13																					
	- Cobble encountered from 11.7 m to 11.9 m depth																									

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

SUD-MTO 001 S:\CLIENTS\MTOT\HWY65&amp;66\02\_DATA\GINT\1896349.GPJ GAL-MISS.GDT 1-6-20 TR

PROJECT 1896349		<b>RECORD OF BOREHOLE No C212-2</b>				2 OF 2 <b>METRIC</b>							
G.W.P. 5210-14-00		LOCATION N 5336658.0; E 380566.8 NAD83 MTM ZONE 12 (LAT. 48.164251; LONG. -79.981363)				ORIGINATED BY YS							
DIST _____ HWY 66		BOREHOLE TYPE NW Casing, Wash boring and NQ Coring				COMPILED BY TR							
DATUM GEODETIC		DATE May 13, 2019				CHECKED BY AB							
SOIL PROFILE			SAMPLES			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	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)
	--- CONTINUED FROM PREVIOUS PAGE ---							20 40 60 80 100	20 40 60	20 40 60			
310	SILT and SAND to Silty SAND, trace to some gravel, trace to some clay (TILL) Compact to very dense Grey Moist to wet		11	SS	100/0.13								
308.6	- 400 mm diameter boulder encountered from 12.8 m to 13.2 m depth												
13.5	Metasedimentary (BEDROCK)  For coring details see Record of Drillhole C212-2.		1	RC	REC 100%								RQD = 68%
			2	RC	REC 100%								RQD = 56%
			3	RC	REC 100%								RQD = 100%
305.1	END OF BOREHOLE												
17.0	NOTE:  1. Water level in the open borehole was measured at a depth of 0.7 m below ground surface (Elev. 321.4 m) upon completion of casing removal.												

PROJECT: 1896349

LOCATION: N 5336658.0; E 380566.8

NAD83 MTM ZONE 12 (LAT. 48.164251; LONG. -79.981363)

INCLINATION: -90° AZIMUTH: —

**RECORD OF DRILLHOLE: C212-2**

SHEET 1 OF 1

DRILLING DATE: May 13, 2019

DATUM: GEODETIC

DRILL RIG: CME550 Buggy

DRILLING CONTRACTOR: Landcore Drilling

DEPTH SCALE METRES	DRILLING RECORD		DESCRIPTION	SYMBOLIC LOG	ELEV.	RUN No.	COLOUR	FLUSH	RECOVERY			R.Q.D. %	FRACT. INDEX METRES	DISCONTINUITY DATA						HYDRAULIC CONDUCTIVITY				Diametral Point Load Index (MPa)	RMC -Q AVG.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
									TOTAL CORE %	SOLID CORE %	B Angle			DP w/z CORE AXIS	TYPE AND SURFACE DESCRIPTION			Jr	Ja	Jn	10 <sup>0</sup>	10 <sup>1</sup>	10 <sup>2</sup>			10 <sup>3</sup>																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
	JN - Joint	BD - Bedding			PL - Planar										PO - Polished	BR - Broken Rock																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
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DEPTH SCALE

1 : 60

**GOLDER**

LOGGED: YS

CHECKED: AB

SUD-MTO-ROCK S:\CLIENTS\MTOWHY\65866\02\_DATA\GINTV\1896349.GPJ GAL-MISS.GDT 12-5-19 TR

PROJECT 1896349		RECORD OF BOREHOLE No C212-3				1 OF 2 METRIC						
G.W.P. 5210-14-00		LOCATION N 5336671.5; E 380570.5 NAD83 MTM ZONE 12 (LAT. 48.164371; LONG. -79.981311)				ORIGINATED BY MR						
DIST _____ HWY 66		BOREHOLE TYPE NW Casing, Wash Boring and NQ Coring				COMPILED BY TR						
DATUM GEODETIC		DATE May 27, 2019				CHECKED BY AB						
SOIL PROFILE			SAMPLES			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	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	W <sub>p</sub> W W <sub>L</sub>			20 40 60
321.4	GROUND SURFACE											
0.0	Organic sandy SILT, trace gravel Dark brown Wet											
321.0												
0.4	SILT, trace clay Loose Grey Wet		1	SS	5		321					
320.0							320					
1.4	SILTY CLAY, trace sand Firm Grey w>PL		2	SS	3							
			3	TO	PH		319					
							318					
317.6												
3.8	SILT Grey Wet		4	SS	PH		317					
317.0												
4.4	SILT, some gravel (TILL) Very dense Grey Wet		5	SS	60							
	- Cobble encountered from 5.1 m to 5.3 m depth.						316					
	- 500 mm diameter boulder encountered from 5.3 m to 5.8 m depth.						315					
	- 400 mm diameter boulder encountered from 5.8 m to 6.2 m depth.						314					
	- 400 mm diameter boulder encountered from 7.2 m to 7.6 m depth.											
313.7			6	SS	10/0.06							
7.7	Metasedimentary (BEDROCK)											
	For coring details see Record of Drillhole C212-3.		1	RC	REC 100%		313					RQD = 88%
			2	RC	REC 100%		312					RQD = 94%
			3	RC	REC 100%		311					RQD = 100%
310.0												
11.4	END OF BOREHOLE											

Continued Next Page

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

SUD-MTO 001 S:\CLIENTS\MTOT\HWY65&amp;66\02\_DATA\GINT\1896349.GPJ GAL-MISS.GDT 1-6-20 TR



+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○<sup>3</sup>% STRAIN AT FAILURE

SUD-MTO 001 S:\CLIENTS\MTO\HWY65&66\02 DATA\GINT\1896349.GPJ GAL-MISS.GDT 1-6-20 TR

PROJECT: 1896349

LOCATION: N 5336671.5; E 380570.5

NAD83 MTM ZONE 12 (LAT. 48.164371; LONG. -79.981311)

INCLINATION: -90° AZIMUTH: —

**RECORD OF DRILLHOLE: C212-3**




















SHEET 1 OF 1

DRILLING DATE: May 27, 2019

DATUM: GEODETIC

DRILL RIG: CME55 LC Track Mount

DRILLING CONTRACTOR: Downing Drilling

DEPTH SCALE METRES	DRILLING RECORD		DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	RECOVERY		R.O.D. %	FRACT. INDEX METRES	DISCONTINUITY DATA					HYDRAULIC CONDUCTIVITY			Diametral Point Load Index (MPa)	RMC -Q AVG.				
	FLUSH	TOTAL CORE %						SOLID CORE %	B Angle			DIP w/L CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	k, cm/s	10 <sup>-5</sup>	10 <sup>-4</sup>			10 <sup>-3</sup>			
		JN - Joint						BD - Bedding															PL - Planar	PO - Polished	BR - Broken Rock
		FLT - Fault						FO - Foliation															CU - Curved	K - Slickensided	
		SHR - Shear						CO - Contact															UN - Undulating	SM - Smooth	
VN - Vein	OR - Orthogonal	ST - Stepped	Ro - Rough																						
CJ - Conjugate	CL - Cleavage	IR - Irregular	MB - Mechanical Break																						
NOTE: For additional abbreviations refer to list of abbreviations & symbols.																									
8	NW	Metasedimentary Fresh Dark grey Fine to medium grained		313.7 7.7	1	Grey 100							JNIRRo												
9	NQ Coring May 27, 2019			2	Grey 100							JNIRRo JNIRRo													
11				3	Grey 100							JNIRRo													
12	END OF DRILLHOLE			310.0 11.4																					
13																									
14																									
15																									
16																									
17																									
18																									
19																									

DEPTH SCALE

1 : 60

**GOLDER**

LOGGED: MR

CHECKED: AB

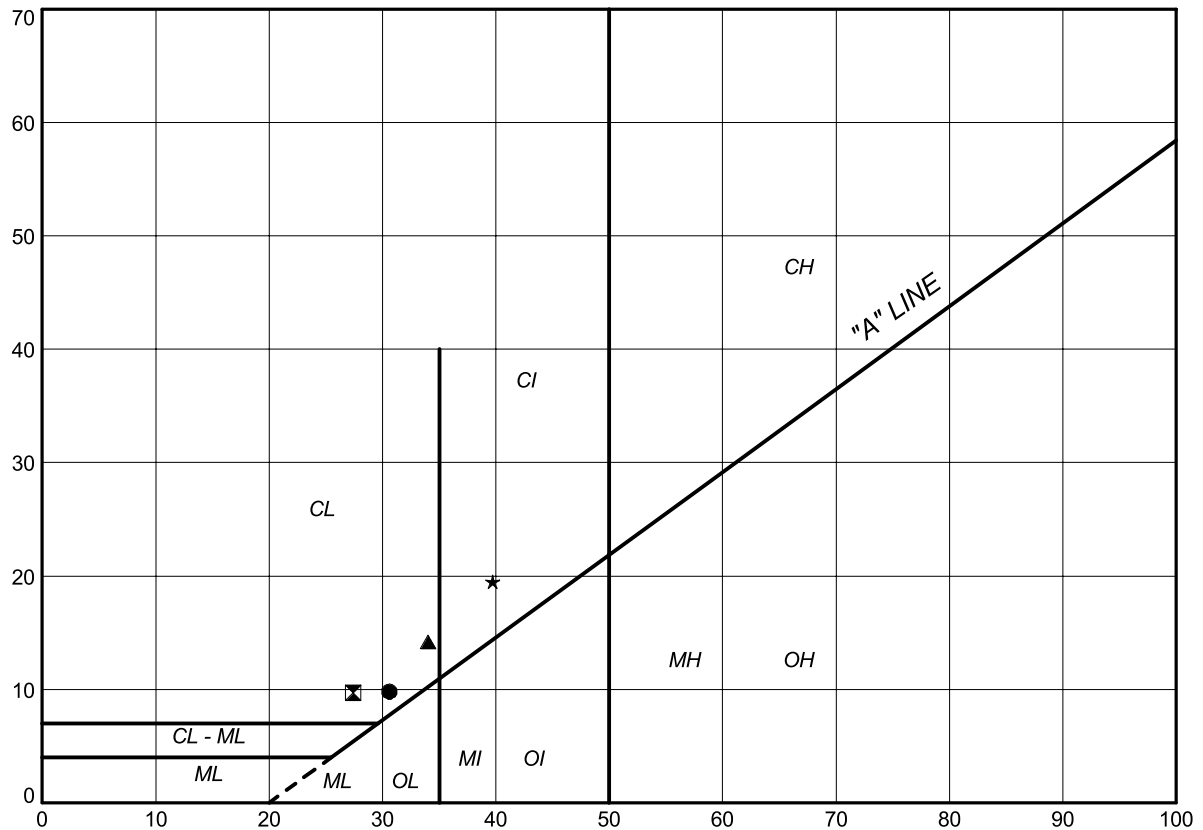
SUD-MTO-ROCK S:\CLIENTS\MTOWHY65866\02\_DATA\GINTV1896349.GPJ GAL-MISS.GDT 12-5-19 TR

**APPENDIX B**

# Laboratory Test Results



PLASTICITY INDEX (Percent)



LIQUID LIMIT (Percent)

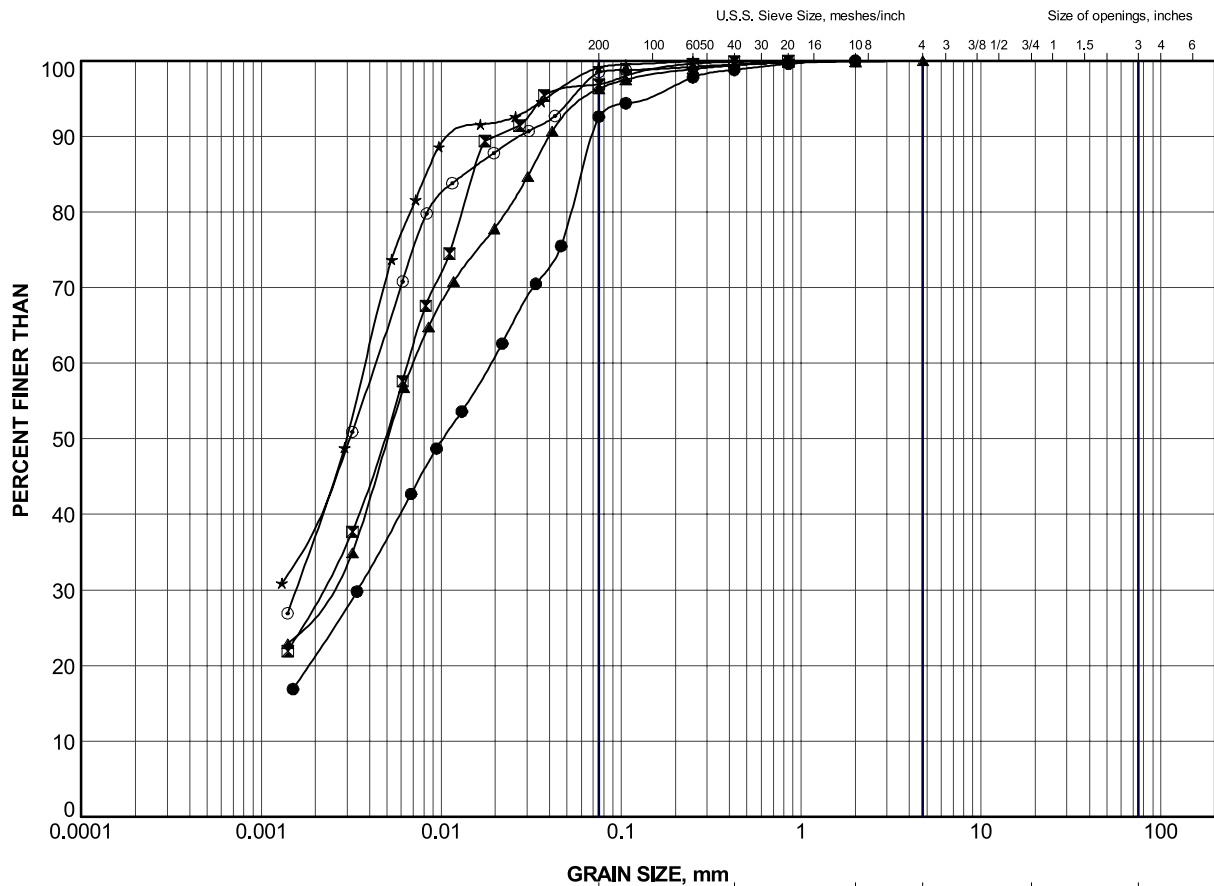
**SOIL TYPE**  
C = Clay  
M = Silt  
O = Organic

**PLASTICITY**  
L = Low  
I = Intermediate  
H = High

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	C212-1	5	30.6	20.8	9.8
⊠	C212-2	3B	27.4	17.7	9.7
▲	C212-2	5	34.0	19.8	14.2
★	C212-3	2	39.7	20.2	19.5


PROJECT		HIGHWAY 66 STATION 13+221 TOWNSHIP OF LEBEL CULVERT			
TITLE		<b>PLASTICITY CHART</b> CLAYEY SILT to SILTY CLAY			
PROJECT No.		1896349		FILE No.	
DRAWN		TR		Dec 2019	
CHECK		AB		Dec 2019	
APPR		JMAC		Dec 2019	
GOLDER		SUDBURY, ONTARIO		SCALE N/A REV.	
				<b>FIGURE B-1</b>	

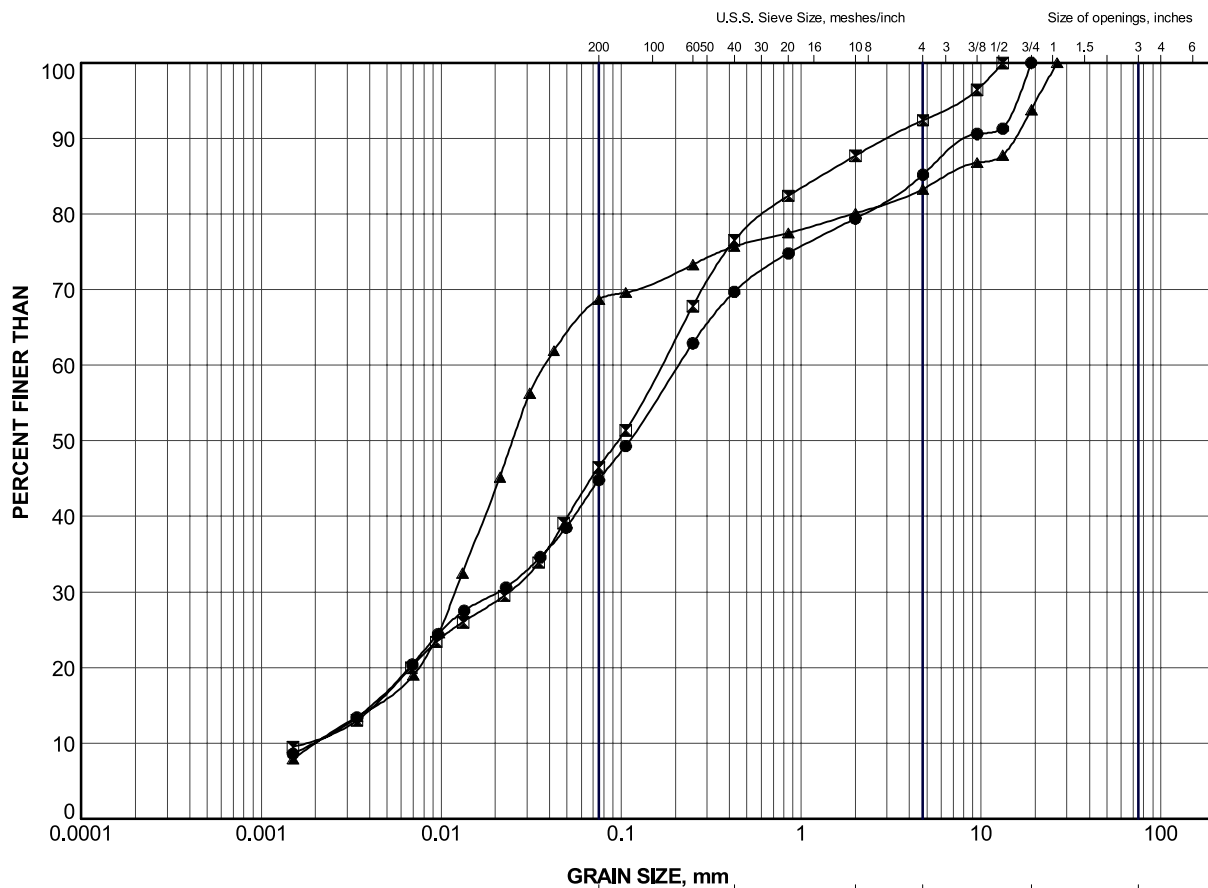


GRAVEL SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C212-1	3	320.0
⊠	C212-1	5	317.7
▲	C212-2	3B	319.5
★	C212-2	5	318.0
⊙	C212-3	2	319.6


PROJECT		HIGHWAY 66 STATION 13+221 TOWNSHIP OF LEBEL CULVERT			
TITLE		<b>GRAIN SIZE DISTRIBUTION</b> CLAYEY SILT to SILTY CLAY			
PROJECT No.		1896349		FILE No.	
DRAWN		TR	Dec 2019	SCALE N/A	
CHECK		AB	Dec 2019	REV.	
APPR		JMAC	Dec 2019	<b>FIGURE B-2</b>	
 <b>GOLDER</b> SUDBURY, ONTARIO					



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

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C212-2	8	314.2
■	C212-2	10	311.4
▲	C212-3	5	316.6

PROJECT						HIGHWAY 66 STATION 13+221 TOWNSHIP OF LEBEL CULVERT					
TITLE						GRAIN SIZE DISTRIBUTION SILT to SILT and SAND (TILL)					
PROJECT No.						1896349					
FILE No.						1896349.GPJ					
DRAWN		TR		Dec 2019		SCALE		N/A		REV.	
CHECK		AB		Dec 2019							
APPR		JMAC		Dec 2019							
 <b>GOLDER</b> SUDBURY, ONTARIO						<b>FIGURE B-3</b>					



BUREAU  
VERITAS

BV Labs Job #: B9E6999  
Report Date: 2019/06/10

Golder 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										

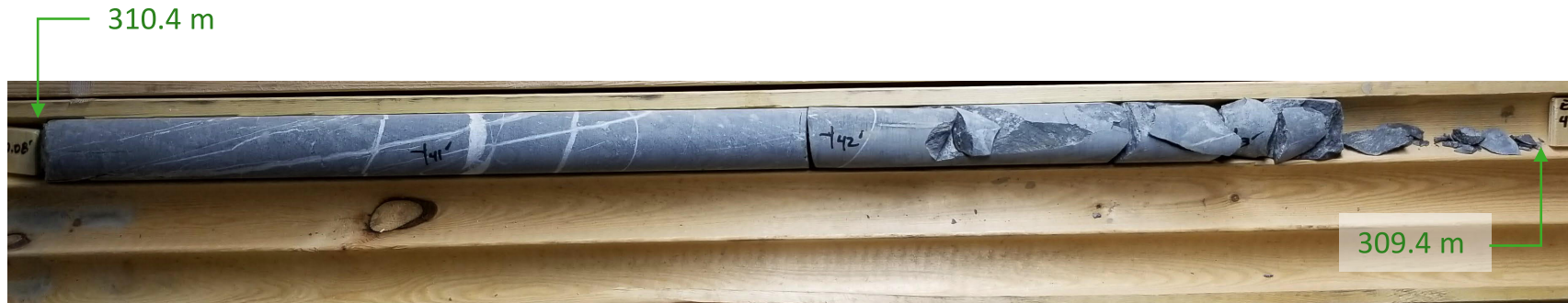
# Bedrock Core Photographs

Figure B-4A

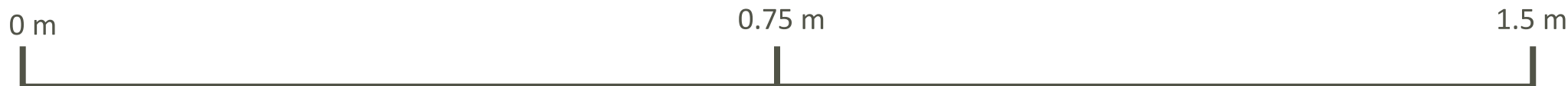
Highway 66, Station 13+221, Township of Lebel Culvert



**Borehole C212-1**  
Elevations 312.7 m to 310.4 m



**Borehole C212-1**  
Elevations 310.4 m to 309.4 m



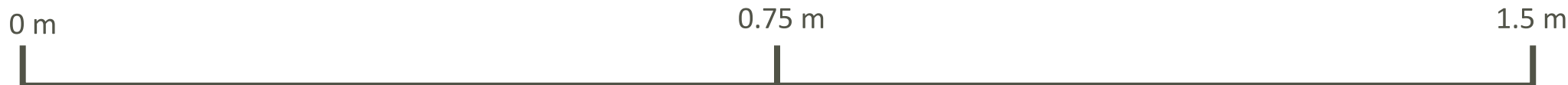
# Bedrock Core Photographs

**Figure B-4B**

Highway 66, Station 13+221, Township of Lebel Culvert



**Borehole C212-2**  
**Elevations 308.6 m to 305.1 m**

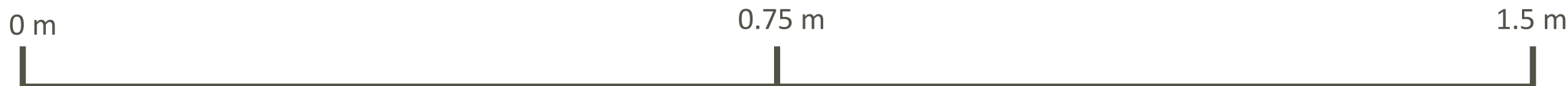




# Bedrock Core Photographs

**Figure B-4C**

Highway 66, Station 13+221, Township of Lebel Culvert







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