

FOUNDATION INVESTIGATION REPORT

CONTRACT NO. 2020-5140

REPORT NO. 5



FOUNDATION INVESTIGATION REPORT

Highway 66, Station 13+315, Township of Lebel Culvert Replacement Ministry of Transportation, Ontario GWP 5210-14-00

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GEOCRES NO: 32D-34

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PART A

FOUNDATION INVESTIGATION REPORT
HIGHWAY 66, STA 13+315, 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+315, in the Township of Lebel, Ontario, approximately 1.7 km northwest 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.

The existing culvert consists of a 0.8 m diameter, 19.8 m long Corrugated Steel Pipe (CSP). The culvert inlet (north end) and outlet (south end) inverts are approximately Elevations 320.0 m and 319.7 m, respectively. The highway grade at the centreline at the culvert location is at approximately Elevation 322.1 m. The existing north slope of the embankment at the culvert location is inclined at about 1.5 Horizontal to 1 Vertical (1.5H:1V) and the embankment is about 2.5 m high relative to the culvert invert at the inlet. The existing south slope of the embankment at the culvert location is inclined at about 1.5H:1V to 2.6H:1V and is about 2.0 m high relative to the culvert invert at the outlet. The thickness of soil cover over the culvert is between about 1.3 m and 1.5 m. In general, the topography within 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.

At the time of the June 2019 subsurface exploration field work, the embankment side slopes appeared to be partially grass-covered and the south embankment was partially submerged below the Gull Lake.

3.0 INVESTIGATION PROCEDURES

Field work for this subsurface exploration was carried out on May 14 and 15, and June 5, 2019, during which time three boreholes (Boreholes C213-1 to C213-3) were advanced at the approximate locations shown on Drawing 1. Boreholes C213-1 and C213-2 were advanced through the roadway embankment using a track mounted CME-55 drilling rig supplied and operated by Landcore Drilling (Landcore) of Chelmsford, Ontario. Borehole C213-3 was advanced near the north toe of the highway embankment adjacent to the culvert inlet, using a portable tripod rig supplied and operated by Landcore. Traffic control, where required, was performed in accordance with MTO's Ontario Traffic Control Manual Book 7 – Temporary Conditions.

Boreholes C213-1 and C213-2 were advanced through the roadway using NW casing with wash boring techniques, and the bedrock was cored using NQ coring techniques. Water for drilling operations was obtained from Gull Lake. Borehole C213-3 was advanced near north toe of the highway embankment using portable NW casing equipment. 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 on the drilling rig and a cathead hammer on the portable equipment, in accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586). The groundwater level inside the boreholes upon removal of the casing was observed and recorded after the completion of drilling. The boreholes were backfilled in accordance with Ontario Regulation 903 (wells), as amended. The roadway surface at the boreholes drilled through Highway 66 were 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 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, 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 Vertas 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 (m)
C213-1	5336643.3 (48.164108)	380646.9 (-79.980289)	322.3	8.7 ¹
C213-2	5336633.8 (48.164021)	380654.9 (-79.980183)	322.0	9.3 ¹
C213-3	5336650.1 (48.164169)	380649.8 (-79.980249)	320.7	3.8

Notes:

¹ Borehole depths include 3.5 m and 3.3 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)¹ mapping, the subsoils in the vicinity of the culvert site are glacially derived ground moraine comprising primarily of till.

Based on geological mapping (MNDM)², the site is underlain by coarse clastic 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), 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 170 mm and 200 mm thick layer of asphalt pavement was encountered in Boreholes C213-1 and C213-2 drilled from the roadway platform, at Elevations 322.3 m and 322.0 m. A 1.4 m to 3.5 m thick layer of embankment fill, consisting of an upper 0.4 m to 0.7 m thick layer of sand and gravel underlain by sand to silt and sand, was encountered below the asphalt in Boreholes C213-1 and C213-2 and at ground surface in Borehole C213-3.

The SPT "N"-values measured within the sand fill generally range from 45 blows to 71 blows per 0.3 m of penetration, indicating a generally dense to very dense compactness condition. An "N"-value of 100 blows for 0.1 m of penetration was measured within the sand fill in Borehole C213-1 and is inferred to be the result of driving the split spoon on the underlying 1,400 mm size boulder. The SPT "N"-values measured within the sand and gravel fill and silt and sand fill in Borehole C213-3 were 4 blow and 3 blows per 0.3 m of penetration, respectively, indicating a very loose compactness condition at this location.

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

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

Grain size distribution analysis was carried out on one sample of the sand and gravel fill, three samples of the sand fill, and one sample of the silt and sand fill, and the results are presented on Figures B-1A to B-1C in Appendix B, respectively. The natural moisture content measured on one sample of the sand and gravel fill was about 24 per cent, the natural moisture content measured on the sand fill samples ranges from about 12 per cent to 19 per cent, and the natural moisture content measured on one sample of the silt and sand fill is about 27 per cent. The organic content measured on one sample of the silt and sand fill is about 3 per cent.

4.2.2 Gravel and Sand Till

A 1.3 m to 2.4 m thick deposit of till, comprised of sand and gravel, trace to some silt, was encountered underlying the fill in Boreholes C213-1, C213-2, and C213-3 between Elevations 319.3 m and 318.3 m. Cobbles ranging in size from 100 mm to 200 mm were encountered within the till deposit in Borehole C213-2.

The SPT “N”-values measured within the till deposit range between 11 blows and 67 blows per 0.3 m of penetration indicating a compact to very dense compactness condition.

Grain size distribution analysis was carried out on one sample of the till deposit and the result is presented on Figure 2 in Appendix B. The natural moisture content measured on one sample of the till deposit is about 8 per cent.

4.2.6 Bedrock

Bedrock was encountered in Boreholes C213-1 and C213-2 at depths of 5.2 m and 6.0 m below the road grade (Elevations 317.1 m and 316.0 m, respectively) and was cored for 3.5 m and 3.3 m lengths in the respective boreholes. Refusal to further casing advancement was encountered in Borehole C213-3 at a depth of 3.8 m (Elevation 316.9 m) on inferred bedrock.

The retrieved bedrock core samples are described as very fine grained, fresh, dark grey, metasedimentary bedrock, as described on the Record of Drillholes presented in Appendix A. Photographs of the retrieved bedrock core samples are shown on Figure B-3 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 69 per cent and 100 per cent and based on the Quality Classification from Table 3.10 of CFEM 2006³, the bedrock is considered of fair to excellent quality.

4.3 Groundwater Conditions

The unstabilized groundwater levels measured in the open boreholes upon removal of the casing relative to ground surface are summarized below. Groundwater and creek/lake water levels in the area are subject to seasonal fluctuations and variations due to precipitation events. The water level of Gull Lake, surveyed by Callon Dietz in June 2019, is approximately 320.4 m.

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

Borehole No.	Depth to Unstabilized Groundwater Level (m)	Approximate Groundwater Elevation (m)
C213-1	1.3	321.0
C213-2	1.5	320.5
C213-3	0.0	320.7

4.4 Analytical Laboratory Testing Results

Analytical testing was carried out on a sample of sand fill recovered from Borehole C213-1. The soil sample was submitted to Bureau Veritas Laboratories for analysis of a suite of corrosivity indicator parameters. The analytical laboratory test results are summarized below, and the detailed analytical laboratory test report is included in Appendix B.

Borehole No.	Sample No.	Depth (m)	Parameters					
			Resistivity (ohm-cm)	Electrical Conductivity (µmho/cm)	Soluble Sulphate (SO ₄) Content (µg/g)	Chloride (Cl) Content (µg/g)	Sulphide (µg/g)	pH
C213-1	2	1.5 – 2.1	11,000	88	<20 ¹	<20 ¹	<0.30 ¹	7.60

Notes:

¹ The sulphate, chloride, and sulphide concentrations are below the reportable detection limits of 20 µg/g, 20 µg/g, and 0.30 µg/g, respectively.

5.0 CLOSURE

The field drilling program was carried out under the supervision of Mr. Yusuf Soliman, under the overall direction of Mr. André Bom, P.Eng., an Associate of Golder. This Foundation Investigation Report was prepared by Ms. Anastasia Poliacik, P.Eng. Mr. André Bom, P.Eng., a senior geotechnical engineer with Golder, carried out a 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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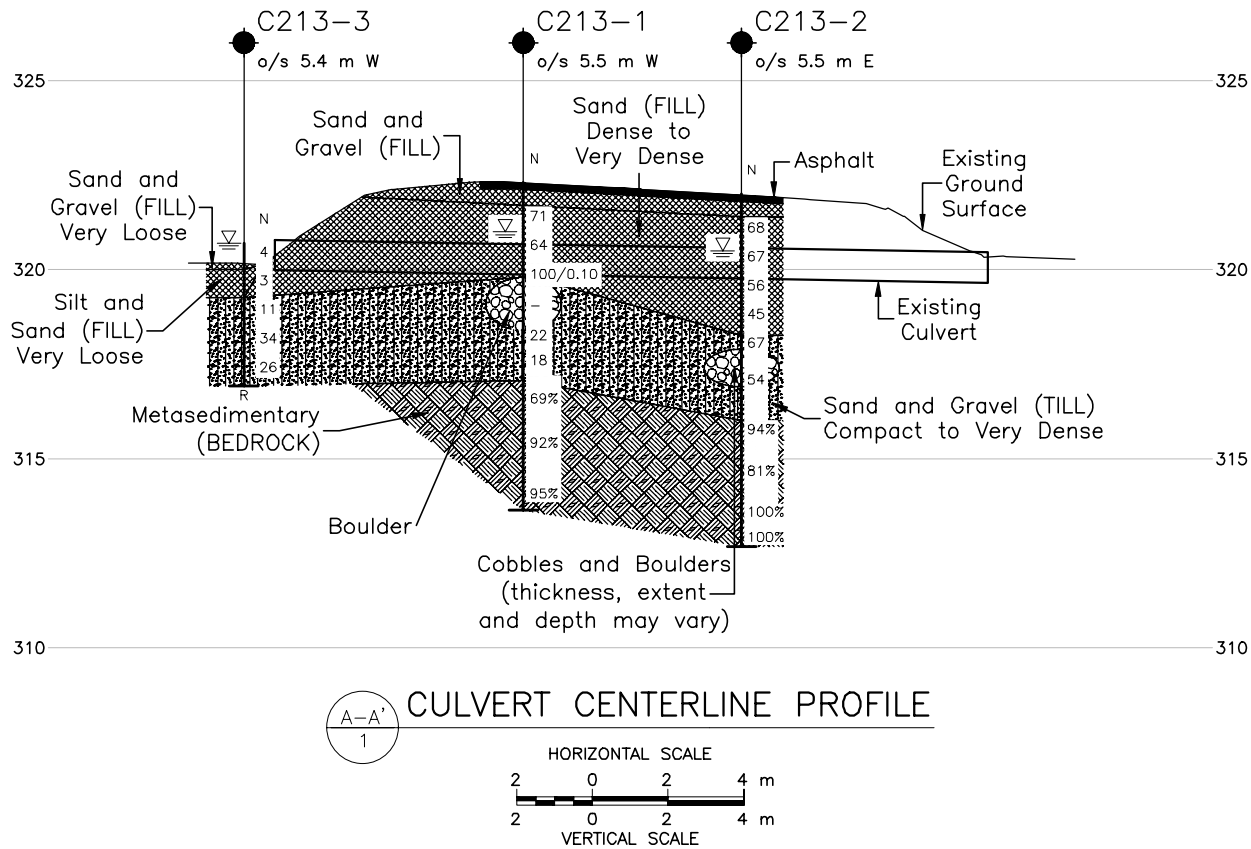
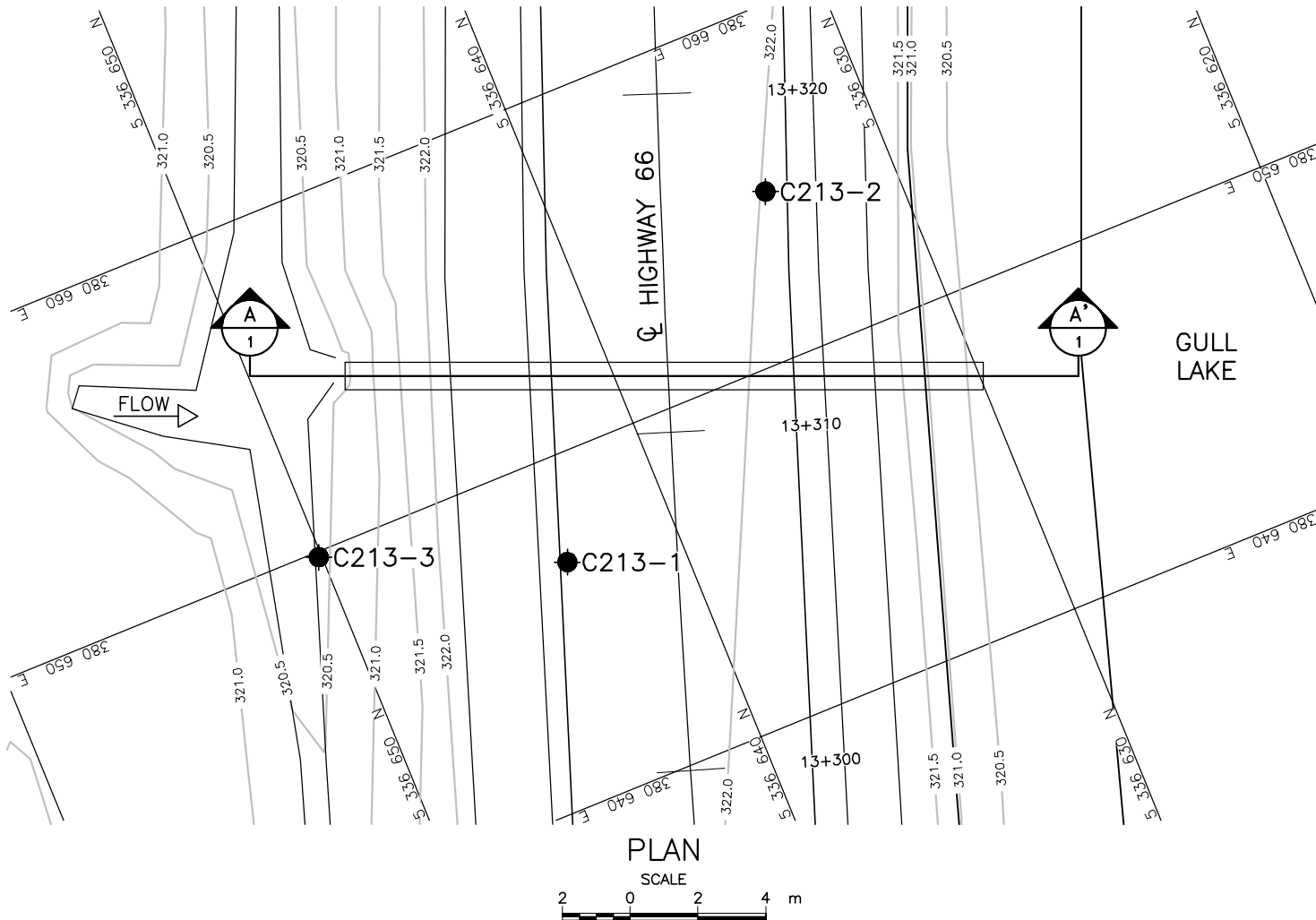


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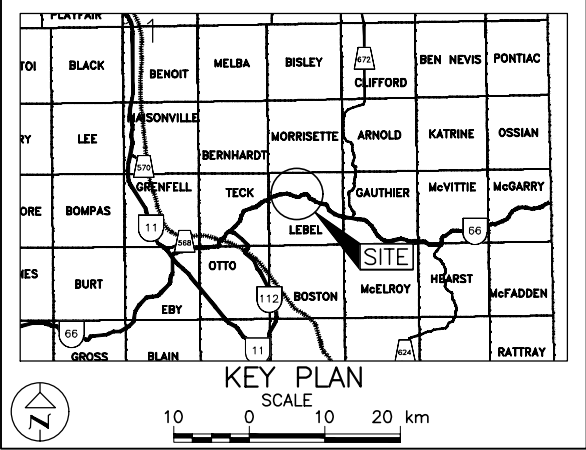
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METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

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GWP No. 5210-14-00

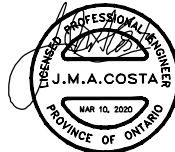
HIGHWAY 66
STATION 13+315
TOWNSHIP OF LEBEL CULVERT
BOREHOLE LOCATIONS AND SOIL STRATA



LEGEND

- Borehole - Current Investigation
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- R Refusal
- 100% Rock Quality Designation (RQD)
- WL upon completion of drilling

BOREHOLE CO-ORDINATES (NAD 83 MTM ZONE 12)			
No.	ELEVATION	NORTHING	EASTING
C213-1	322.3	5336643.3	380646.9
C213-2	322.0	5336633.8	380654.9
C213-3	320.7	5336650.1	380649.8



NOTES

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

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

REFERENCE

Base plans provided in digital format by CALLON DIETZ LTD. drawing file no. gwp52101400a.dwg, received AUGUST 14, 2019.

NO.	DATE	BY	REVISION

Geocres No. 32D-34

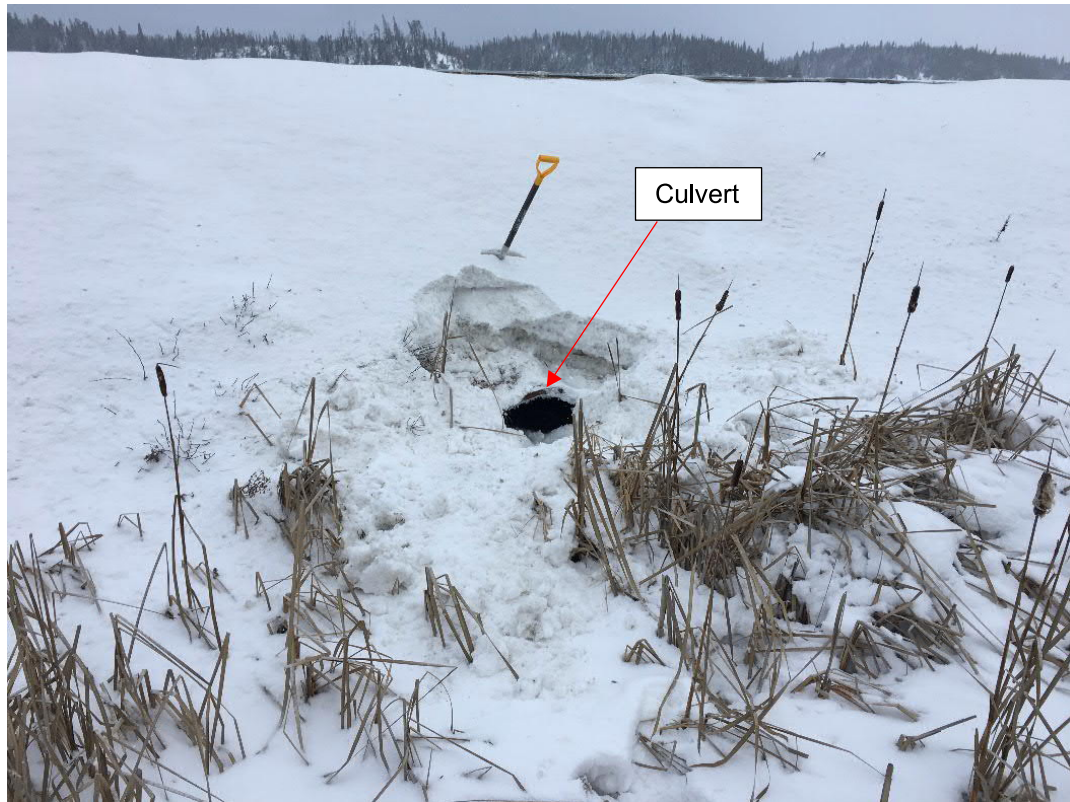
HWY. 66	PROJECT NO. 1896349	DIST. .
SUBM'D. .	CHKD. AMP/TB	DATE: 3/10/2020
DRAWN: TR	CHKD. AB	APPD. JMAC
		DWG. 1



Photograph 1: Borehole C213-2 and Gull Lake, Facing East (May 2019)



Photograph 2: Highway 66 at Culvert Location, Facing East (December 2018)



Photograph 3: Culvert Inlet (North End), Facing South (December 2018)



Photograph 4: Highway 66 at South End (Outlet) of Culvert Site, Facing West (December 2018)

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^{1,2}

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 cm² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (q_t), porewater pressure (u) and sleeve friction (f_s) are recorded electronically at 25 mm penetration intervals.

Dynamic Cone Penetration Resistance (DCPT); N_d:

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

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

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 _p	plastic limit
LL, w _L	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D _R	relative density (specific gravity, G _s)
DS	direct shear test
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 ₄	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

Compactness¹

Term	SPT 'N' (blows/0.3m) ²
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' ^{1,2} (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

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

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)

σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
U	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

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

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

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index = $(w_l - w_p)$
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_α	secondary compression index
m_v	coefficient of volume change
c_v	coefficient of consolidation (vertical direction)
c_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

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

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	

PROJECT 1896349		RECORD OF BOREHOLE No C213-1				1 OF 1 METRIC											
G.W.P. 5210-14-00		LOCATION N 5336643.3; E 380646.9 NAD83 MTM ZONE 12 (LAT. 48.164108; LONG. -79.980289)				ORIGINATED BY YS											
DIST _____ HWY 66		BOREHOLE TYPE NW Casing, Wash Boring and NQ Coring				COMPILED BY TR											
DATUM GEODETIC		DATE May 14 & 15, 2019				CHECKED BY AB											
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
322.3	GROUND SURFACE																
0.0	ASPHALT (170 mm)																
0.2	Sand and gravel (FILL)																
321.7																	
0.6	Sand, trace to some gravel, trace to some silt (FILL) Very dense Brown Moist to wet		1	SS	71												
			2	SS	64												
			3	SS	100/0.10												
319.8	BOULDER (1400 mm)		-	NQ	-												
2.5																	
318.4	SAND and GRAVEL, trace to some silt (TILL) Compact Grey Wet		4	SS	22												
			5	SS	18												
317.1	METASEDIMENTARY BEDROCK																
5.2	For coring details see Record of Drillhole C213-1.		1	RC	REC 100%												RQD = 69%
			2	RC	REC 100%												RQD = 92%
			3	RC	REC 100%												RQD = 95%
314																	
313.6	END OF BOREHOLE																
8.7	NOTES: 1. Water level measured in open borehole at a depth of 1.3 m below ground surface (Elev. 321.0 m) upon removal of casing. 2. Borehole caved to a depth of 2.7 m below ground surface (Elev. 319.6 m) upon removal of casing.																

PROJECT: 1896349

LOCATION: N 5336643.3; E 380646.9

NAD83 MTM ZONE 12 (LAT. 48.164108; LONG. -79.980289)

INCLINATION: -90° AZIMUTH: —

RECORD OF DRILLHOLE: C213-1

SHEET 1 OF 1

DRILLING DATE: May 15, 2019

DATUM: GEODETIC

DRILL RIG: CME550 Buggy

DRILLING CONTRACTOR: Landcore Drilling

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	JN - Joint FLT - Fault SHR - Shear VN - Vein CJ - Conjugate				BD - Bedding FO - Foliation CO - Contact OR - Orthogonal CL - Cleavage				PL - Planar CU - Curved UN - Undulating ST - Stepped IR - Irregular				PO - Polished K - Slickensided SM - Smooth Ro - Rough MB - Mechanical Break				NOTE: For additional abbreviations refer to list of abbreviations & symbols.	BR - Broken Rock																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
							RECOVERY		R.Q.D. %	FRACT. INDEX METRES	DISCONTINUITY DATA				HYDRAULIC CONDUCTIVITY		Diametral Point Load Index (MPa)	RMC -Q AVG.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
							FLUSH	TOTAL CORE %			SOLID CORE %	B Angle	DP w/z CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja			Jn	k, cm/s																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
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DEPTH SCALE

1 : 60



GOLDER

LOGGED: YS

CHECKED: AB

SUD-MTO-ROCK S:\CLIENTS\MTOWHY\65866\02_DATA\GINT\1896349.GPJ GAL-MISS.GDT 12-18-19 TR

PROJECT 1896349		RECORD OF BOREHOLE No C213-2				1 OF 1 METRIC											
G.W.P. 5210-14-00		LOCATION N 5336633.8; E 380654.9 NAD83 MTM ZONE 12 (LAT. 48.164021; LONG. -79.980183)				ORIGINATED BY ys											
DIST _____ HWY 66		BOREHOLE TYPE NW Casing, Wash Boring and NQ Coring				COMPILED BY TR											
DATUM GEODETIC		DATE May 14, 2019				CHECKED BY AB											
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
322.0	GROUND SURFACE																
0.0	ASPHALT (200 mm)																
0.2	Sand and gravel (FILL)																
321.4																	
0.6	Sand, trace to some silt, trace gravel (FILL) Dense to very dense Moist to wet Brown		1	SS	68												
			2	SS	67												1 87 (12)
			3	SS	56												
			4	SS	45												0 97 (3)
318.3																	
3.7	SAND and GRAVEL, trace to some silt (TILL) Very dense Moist to wet Brown		5	SS	67												
317.9																	
4.1	- 100 mm cobble encountered at 3.7 m depth COBBLES and BOULDERS																
316.9			6	SS	54												
5.1	SAND and GRAVEL, trace to some silt (TILL) Very dense Wet Brown																
316.0																	
6.0	- 200 mm cobble encountered at 5.6 m depth METASEDIMENTARY BEDROCK		1	RC	REC 100%												RQD = 94%
			2	RC	REC 100%												RQD = 81%
			3	RC	REC 100%												RQD = 100%
			4	RC	REC 100%												RQD = 100%
312.7	END OF BOREHOLE																
9.3	NOTES: 1. Water level measured in open borehole at a depth of 1.5 m below ground surface (Elev. 320.5 m) upon removal of casing. 2. Borehole caved to a depth of 3.2 m below ground surface (Elev. 318.8 m) upon removal of casing.																

SHEET 1 OF 1



DATUM: GEODETIC

DRILLING CONTRACTOR: Landcore Drilling

- Joint	BD- Bedding	PL - Planar	PO- Polished	BR - Broken Rock
- Fault	FO- Foliation	CU- Curved	K - Slickensided	NOTE: For additional abbreviations refer to list of abbreviations & symbols.
- Shear	CO- Contact	UN- Undulating	SM- Smooth	
- Vein	OR- Orthogonal	ST - Stepped	Ro - Rough	
- Conjugate	CL - Cleavage	IR - Irregular	MB- Mechanical Break	

CHECKED: AB

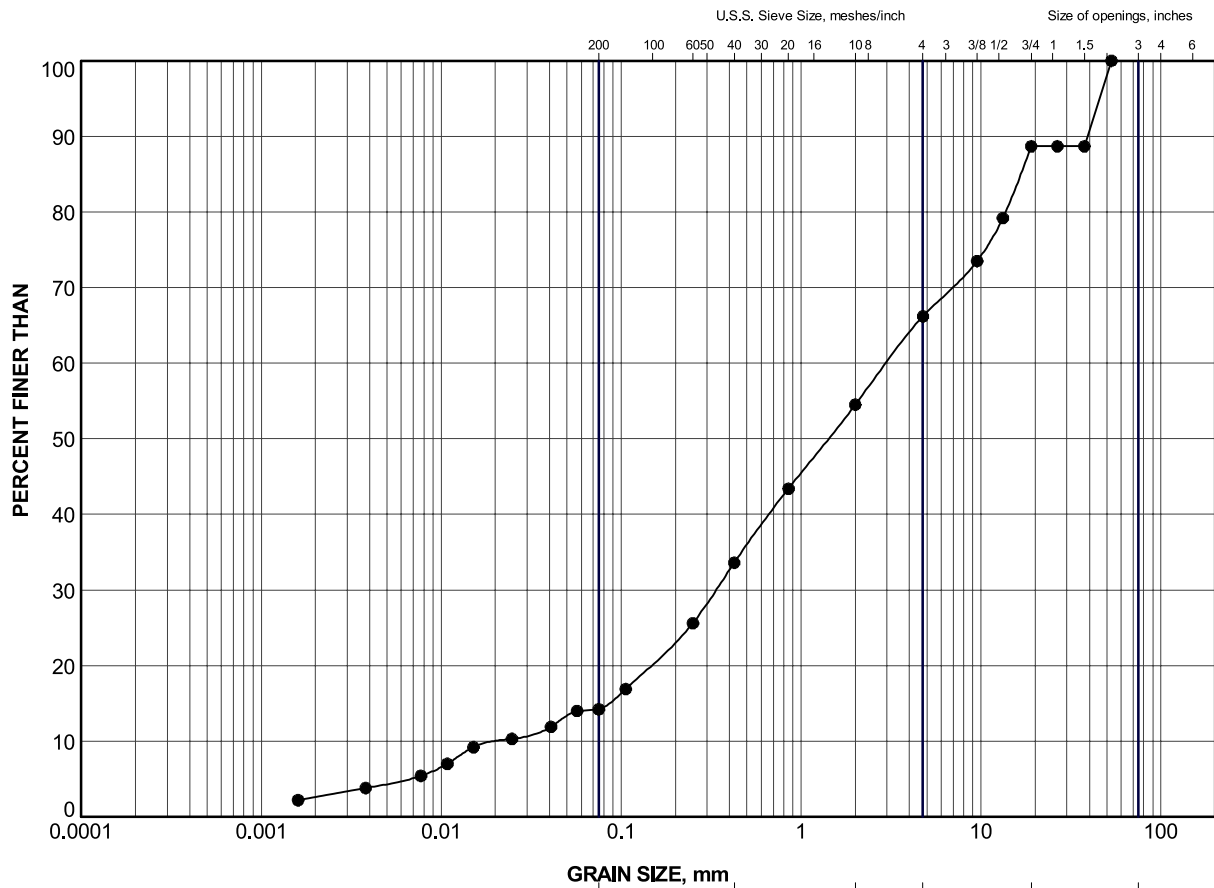
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PROJECT 1896349		RECORD OF BOREHOLE No C213-3				1 OF 1 METRIC												
G.W.P. 5210-14-00		LOCATION N 5336650.1; E 380649.8 NAD83 MTM ZONE 12 (LAT. 48.164169; LONG. -79.980249)				ORIGINATED BY MR												
DIST _____ HWY 66		BOREHOLE TYPE Portable Equipment, NW Casing				COMPILED BY TR												
DATUM GEODETIC		DATE June 5, 2019				CHECKED BY AB												
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)
320.7	GROUND SURFACE																	
0.0	Sand and gravel, some silt, trace clay, trace organics (FILL) Very loose Wet Grey		1	SS	4		320									OC=2.9%	33 53 11 3	
320.0	Silt and sand, trace to some gravel, trace organics (FILL) Very loose Wet Grey		2	SS	3													7 35 (58)
319.3	SAND and GRAVEL, trace to some silt (TILL) Compact to dense Wet Grey		3	SS	11		319											
1.4			4	SS	34			318										
			5	SS	26													
316.9	END OF BOREHOLE REFUSAL TO FURTHER CASING PENETRATION ON INFERRED BEDROCK						317											
3.8	NOTES: 1. Water level in open borehole at ground surface (Elev. 320.7 m) upon removal of casing. 2. Borehole caved to a depth of 2.4 m below ground surface (Elev. 318.3 m) upon removal of casing.																	

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APPENDIX B


Laboratory Test Results

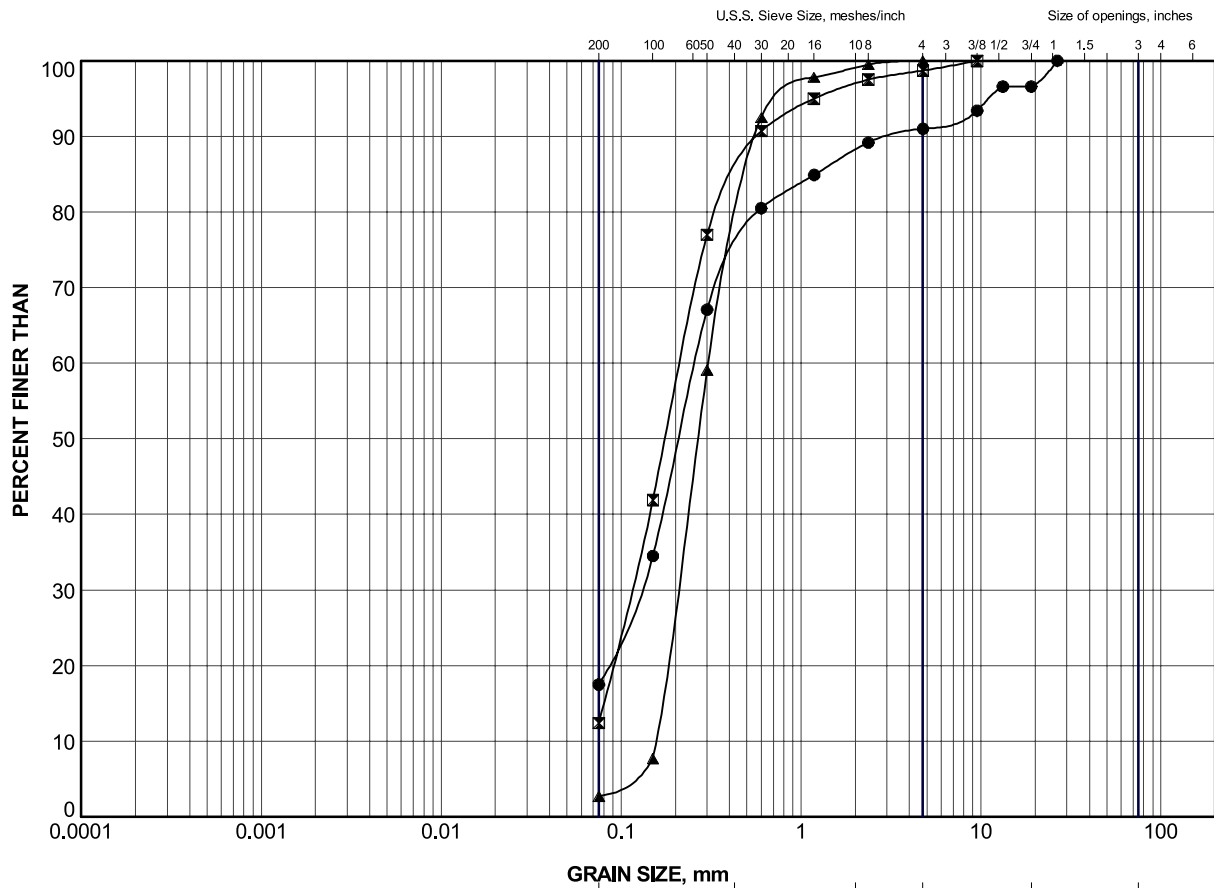


GRAVEL SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C213-3	1	320.4

PROJECT						HIGHWAY 66 STATION 13+315 TOWNSHIP OF LEBEL CULVERT					
TITLE						GRAIN SIZE DISTRIBUTION Sand and Gravel (FILL)					
PROJECT No.				1896349		FILE No.				1896349.GPJ	
DRAWN	TR	Dec 2019		SCALE	N/A	REV.					
CHECK	AB	Dec 2019									
APPR	JMAC	Dec 2019									
 GOLDER				FIGURE B-1A							
SUDBURY, ONTARIO											

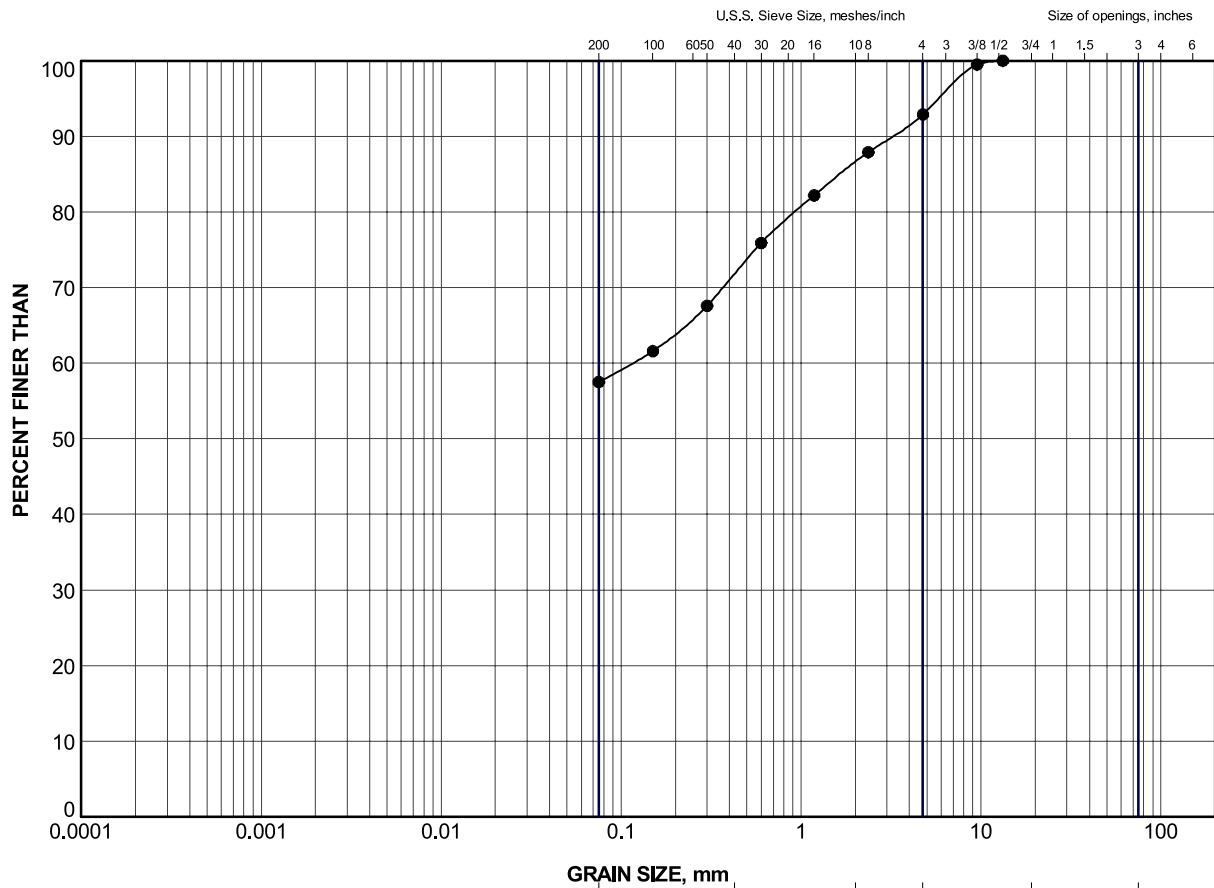


CLAY AND SILT	GRAVEL SIZE, mm						Cobble Size
	fine	medium	coarse	fine	coarse		
	SAND SIZE			GRAVEL SIZE			

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C213-1	3	319.9
■	C213-2	2	320.2
▲	C213-2	4	318.7

PROJECT						HIGHWAY 66 STATION 13+315 TOWNSHIP OF LEBEL CULVERT					
TITLE						GRAIN SIZE DISTRIBUTION Sand (FILL)					
PROJECT No.				1896349		FILE No.				1896349.GPJ	
DRAWN	TR	Dec 2019		SCALE	N/A	REV.					
CHECK	AB	Dec 2019									
APPR	JMAC	Dec 2019									
GOLDER				FIGURE B-1B							
SUDBURY, ONTARIO											

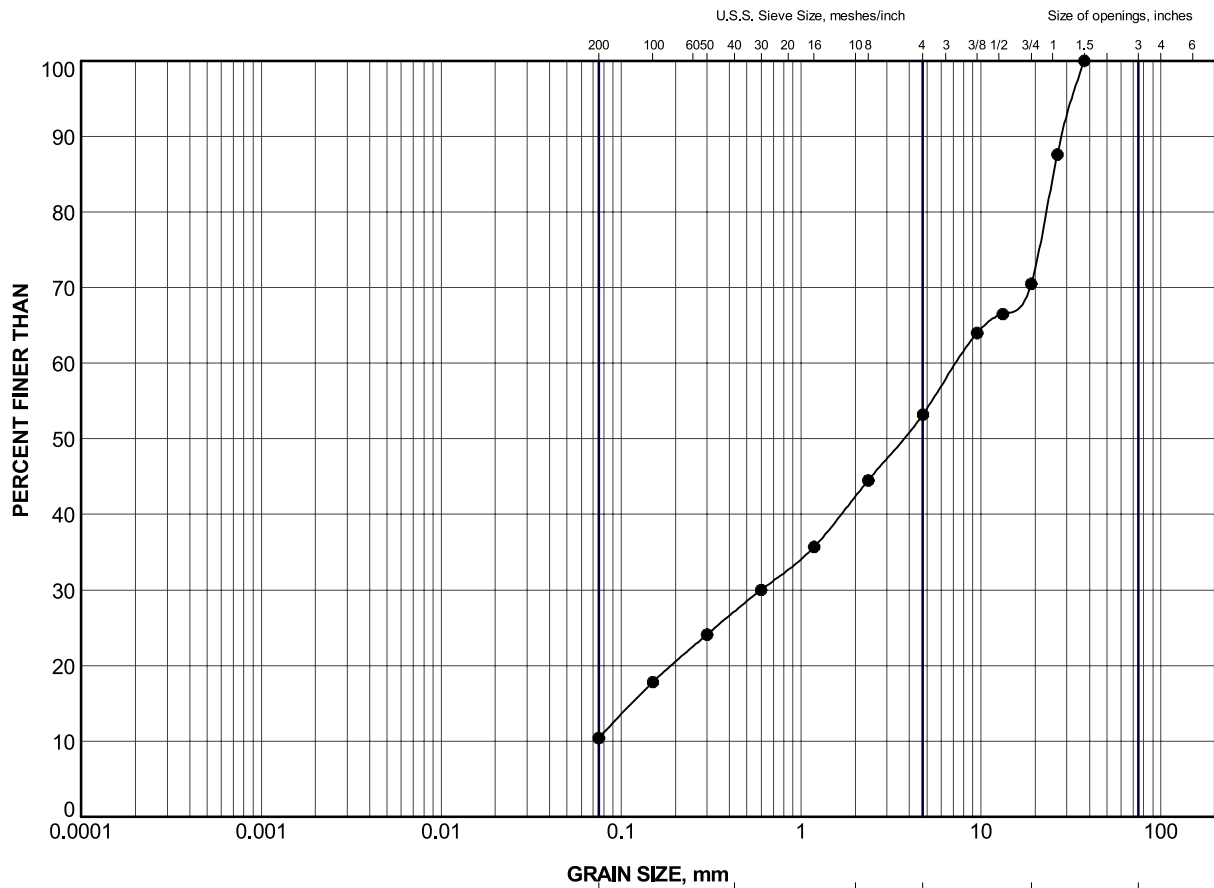


GRAVEL SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C213-3	2	319.6


PROJECT						HIGHWAY 66 STATION 13+315 TOWNSHIP OF LEBEL CULVERT					
TITLE						GRAIN SIZE DISTRIBUTION Silt and Sand (FILL)					
PROJECT No.				1896349		FILE No.				1896349.GPJ	
DRAWN		TR		Dec 2019		SCALE		N/A		REV.	
CHECK		AB		Dec 2019							
APPR		JMAC		Dec 2019							
GOLDER SUDBURY, ONTARIO						FIGURE B-1C					



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C213-3	5	317.4

PROJECT						HIGHWAY 66 STATION 13+315 TOWNSHIP OF LEBEL CULVERT					
TITLE						GRAIN SIZE DISTRIBUTION SAND and GRAVEL (TILL)					
PROJECT No.				1896349		FILE No.				1896349.GPJ	
DRAWN		TR		Dec 2019		SCALE		N/A		REV.	
CHECK		AB		Dec 2019		FIGURE B-2					
APPR		JMAC		Dec 2019							
 GOLDER SUDBURY, ONTARIO											

Bedrock Core Photographs

Figure B-3

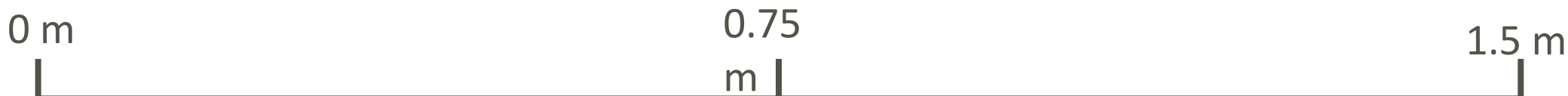
Highway 66, Station 13+315, Township of Lebel Culvert



Borehole C213-1
Elevation 317.1 m to 313.6 m



Borehole C213-2
Elevation 316.0 m to 312.7 m





BUREAU
VERITAS

BV Labs Job #: B9D3975
Report Date: 2019/06/03

Golder Associates Ltd
Client Project #: 1896349(2100)
Site Location: HWY 66
Sampler Initials: MR

RESULTS OF ANALYSES OF SOIL

BV Labs ID		JTI437			JTI437		
Sampling Date		2019/05/14 15:03			2019/05/14 15:03		
COC Number		127611			127611		
	UNITS	C213-1 SA2	RDL	QC Batch	C213-1 SA2 Lab-Dup	RDL	QC Batch
CONVENTIONALS							
Sulphide	ug/g	<0.30 (1)	0.30	6150574	<0.30	0.30	6150574
Calculated Parameters							
Resistivity	ohm-cm	11000		6129977			
Inorganics							
Soluble (20:1) Chloride (Cl-)	ug/g	<20	20	6133046			
Conductivity	umho/cm	88	2	6135430			
Available (CaCl2) pH	pH	7.60		6133358			
Soluble (20:1) Sulphate (SO4)	ug/g	<20	20	6133048			
Physical Testing							
Moisture-Subcontracted	%	15	0.30	6150575			
RDL = Reportable Detection Limit QC Batch = Quality Control Batch Lab-Dup = Laboratory Initiated Duplicate (1) Matrix Spike exceeds acceptance limits due to matrix interference. Reanalysis yields similar results.							



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