



FOUNDATION INVESTIGATION REPORT

Highway 66, Station 10+172, Township of McVittie Culvert Replacement Ministry of Transportation, Ontario GWP 5210-14-00

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GEOCRES NO: 32D-30

LAT: 48.106316

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PART A

FOUNDATION INVESTIGATION REPORT
HIGHWAY 66, STA 10+172, TOWNSHIP OF MCVITTIE
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 10+172, in the Township of McVittie, Ontario, approximately 30 m west of the intersection with Diamond Lake Road. 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

The existing culvert consists of an approximately 1.3 m span by 1.2 m high and 22 m long double box timber structure. The culvert south end and north end inverts are approximately Elevations 277.0 m and 276.9 m, respectively. The culvert connects Fork Lake to the north and south of Highway 66. The topography within the vicinity of the culvert is generally undulating with thick forested vegetation beyond the right of way of the highway. The highway grade at the culvert centreline is approximately Elevation 279.9 m. The embankment is approximately 3.0 m high relative to the culvert invert at the south end and provides approximately 1.8 m of soil cover relative to the highway grade. The embankment side slopes are inclined at approximately 3.4 Horizontal to 1 Vertical (3.4H: 1V) and appear to be performing well, with no visible signs of slope instability or roadway settlement issues. At the time of the subsurface exploration field program, the south end of the culvert was damaged as evidenced by the southward leaning timber posts and misaligned top beam; and piles of vegetation debris had been cleared from the culvert south end and placed on the embankment side slope. The north end of the culvert did not show evidence of similar damage. The ground surface conditions at select locations near the culvert are shown on Photographs 1 to 4.

Recommendations for treatment of Pavement Distress Area between about station 10+172 and 10+186, McVittie township is provided in Golder Pavement Design Report.

3.0 INVESTIGATION PROCEDURES

Field work for this subsurface exploration was carried out on May 4, 5, 15, and 31, 2019, during which time five boreholes (Boreholes C267-1 to C267-5) were advanced at the approximate locations shown on Drawing 1. Boreholes C267-1 to C267-3 were advanced through the roadway embankment and Borehole C267-5 was advanced near the north toe of the highway embankment using a track mounted CME-55LC drilling rig supplied and operated by George Downing Estate Drilling (Downing) of Grenville-Sur-La-Rouge, Quebec. Borehole C267-4 was advanced near the south toe of the highway embankment, using a portable tripod rig 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. Water for wash boring operation was obtained from the adjacent lake/open water.

Boreholes C267-1 to C267-3 were advanced using 76 mm I.D. Hollow Stem Augers, NW casing with wash boring techniques. Borehole C267-5 was advanced using 108 mm I.D. Hollow Stem Augers, NW casing with wash boring techniques. Borehole C267-4 was advanced using NW casing with wash boring techniques. Soil samples were obtained in the boreholes at 0.75 m and 1.5 m intervals of depth using 50 mm outer diameter split-spoon samplers driven by a full weight automatic or cathead hammer, in accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586). The groundwater level inside the augers/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 was 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 Mississauga, an accredited analytical laboratory, for testing a suite of corrosivity indicator parameters.

The as-drilled borehole locations were measured by a member of our technical staff relative to highway chainages/stations marked on the pavement by AECOM's surveyors 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)
C267-1	5330464.9 (48.106347)	397300.4 (-79.757784)	280.1	17.4
C267-2	5330462.7 (48.106329)	397285.6 (-79.757983)	280.0	15.9
C267-3	5330460.2 (48.106303)	397309.2 (-79.757667)	279.9	15.9
C267-4	5330452.7 (48.106236)	397305.1 (-79.757723)	278.7	9.8
C267-5	5330475.0 (48.106437)	397301.9 (-79.757761)	278.6	9.8

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain Study (NOEGTS)¹ mapping, the culvert site is located within a low trough of a bedrock ridge, covered generally by shallow deposits of sand and sand and gravel.

Based on geological mapping (MNDM)², 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), as presented on the Record of Borehole sheets and discussed in Section 4.2, are uncorrected. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profiles shown on Drawing 1 are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The results of the analytical laboratory testing (by Bureau Veritas Laboratories) are summarized in Section 4.4 and the detailed laboratory testing report is included in Appendix B.

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

4.2.1 Asphalt/Fill

An approximately 100 mm thick layer of asphalt was encountered in the roadway Boreholes C267-1 to C267-3, between Elevations 279.9 m and 280.1 m. A 2.1 m to 3.6 m thick layer of embankment fill consisting of an approximately 0.3 m thick upper layer of sand and gravel underlain by a 1.8 m to 3.3 m thick layer of sand, and sandy gravel at one borehole location, was encountered below the asphalt in Boreholes C267-1 to C267-3. Asphalt coated particles were encountered in all three road boreholes at between depths of 0.1 m to 0.3 m below the road surface. In Borehole C267-4, a 3.0 m thick layer of sand fill with trace rootlets/organics was encountered from ground surface (Elevation 278.7 m). In Borehole C267-5, a 0.3 m thick layer of topsoil fill was encountered at ground surface underlain by a 0.4 m thick layer of sand and gravel fill.

The SPT "N"-values measured within the fill range between 2 blows and 64 blows per 0.3 m of penetration with one "N"- value of 108 blows per 0.3 m of penetration on inferred frozen soil, indicating a very loose to very dense compactness condition.

¹ Ontario Ministry of Natural Resources and Forestry. Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 32DSW

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 fill and the result is presented on Figure B-1 in Appendix B. The natural moisture content measured on one sample of the fill is 20 per cent.

4.2.2 Organic Sand and Organic Silt

A 0.2 m and 0.1 m thick layer of organic sand some silt, some gravel, and organic silt was encountered in Boreholes C267-3 and C267-5, respectively, at Elevations 277.7 m and 277.9 m.

An organic content test was carried out on one sample of the organic sand layer in Borehole C267-3 and measured and organic content of about 6 per cent. Grain size distribution analysis was carried out on one sample of the organic sand deposit and the result is presented on Figure B-2 in Appendix B. The natural moisture content measured on one sample of the deposit is 32 per cent.

4.2.3 Sand to Gravelly Sand

A 6.8 m to 13.7 m thick layer of sand to gravelly sand (including the sand and gravel interlayers in Boreholes C267-1 and C267-3 described on Section 4.2.4) was encountered below the fill in Borehole C267-1, C267-2, and C267-4 and below the organic layer in Boreholes C267-3 and C267-5 at between Elevations 277.8 m and 275.7 m. Boreholes C267-1 and C267-3 to C267-5 were terminated within the sand deposit.

The SPT “N”-values measured within this deposit range between 2 blows to 48 blows per 0.3 m of penetrating with one “N” – value of 106 blows per 0.3 m of penetration, indicating that the deposit has a very loose to very dense compactness condition.

Grain size distribution testing was carried out on twelve samples of the deposit and the results are presented on Figure B-3 of Appendix B. The natural moisture content measured on twelve samples of the deposit ranges from 17 per cent to 24 per cent.

4.2.4 Sand and Gravel

A 1.5 m to 2.6 m thick deposit of sand and gravel was encountered interlayered within the sand deposit in Boreholes C267-1 and C267-3 and underlying the sand deposit in Borehole C267-2, at between Elevations 268.4 m and 266.6 m.

The SPT“N” values measured within the sand and gravel deposit / interlayers range between 19 blows and 31 blows per 0.3 m of penetration, indicating a compact to dense compactness condition.

A grain size distribution test was carried out on one sample of the sand and gravel deposit and the result is presented in Figure B-4 in Appendix B.

4.3 Groundwater Conditions

The unstabilized groundwater levels, relative to ground surface measured inside the casing or augers upon completion of drilling are summarized below. Groundwater and lake water levels in the area are subject to

seasonal fluctuations and variations due to precipitation events. The lake water level was surveyed by AECOM's surveyors at Elevation 277.1 m in June 2019.

Borehole No.	Depth to Unstabilized Groundwater Level (m)	Approximate Groundwater Elevation (m)
C267-1	2.3	277.8
C267-2	2.0	278.0
C267-3	1.8	278.1
C267-4	0.9	277.8
C267-5	0.1	278.5

4.4 Analytical Laboratory Testing Results

Analytical testing was carried out on a sample of native sand deposit recovered from Borehole C267-1. 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.

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
C267-1	5	3.8 – 4.4	23,000	43	<20 ¹	<20 ²	<0.30 ³	7.74

Note:

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. Mathew Riopelle, under the overall direction of Mr. André Bom, P.Eng., an Associate of Golder. This Foundation Investigation Report was prepared by Ms. Aronne-Kay De Souza, 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

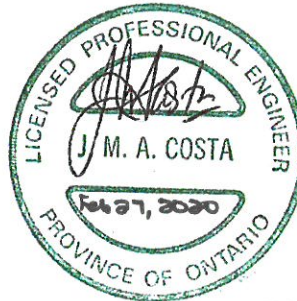
Golder Associates Ltd.

Aronne-Kay De Souza

Aronne-Kay De Souza, EIT, PMP
Geotechnical EIT



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

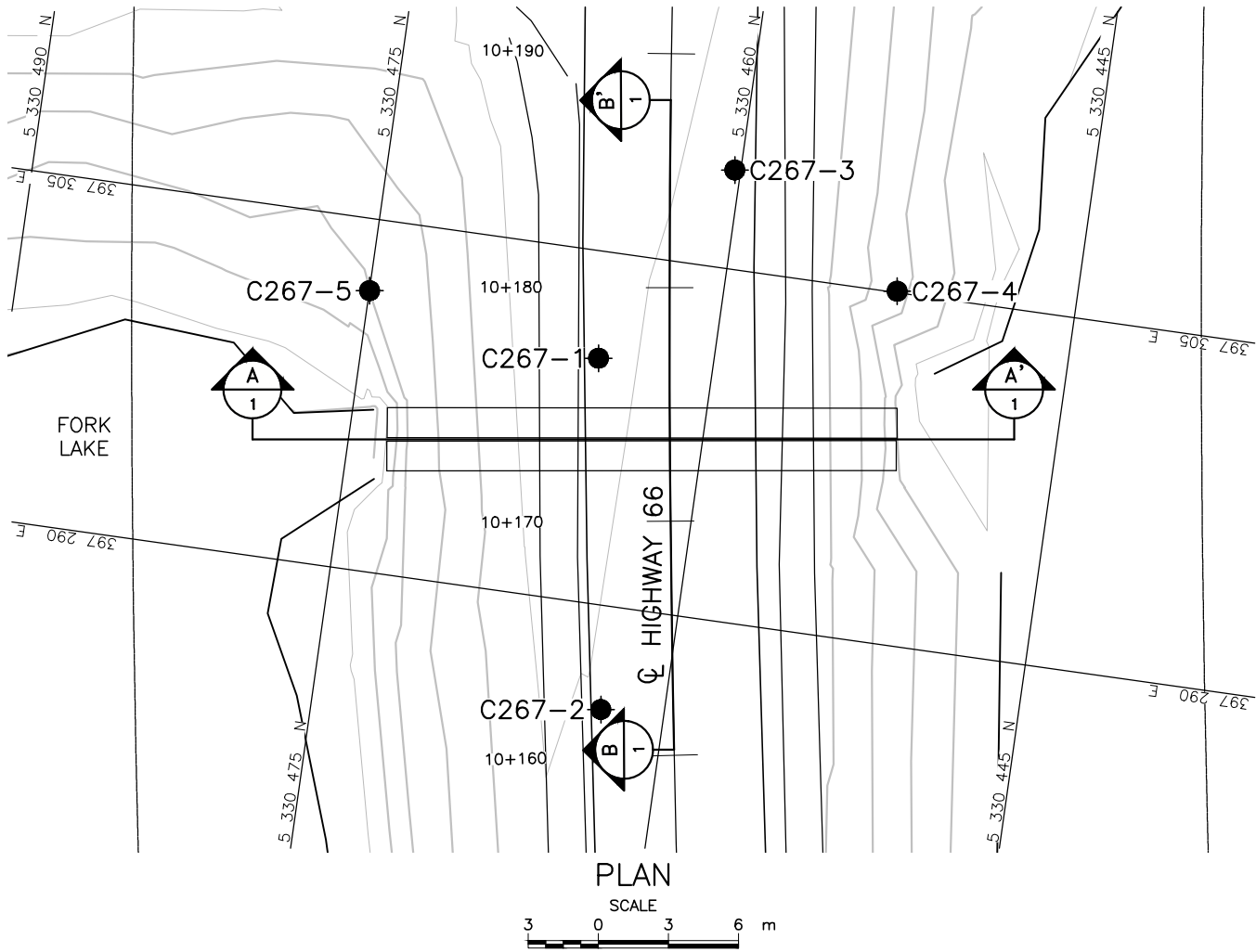


Jorge M. A. Costa, P.Eng.
MTO Foundations Designated Contact, Senior Consultant

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https://golderassociates.sharepoint.com/sites/1809001/deliverables/foundations/2_reporting/r14-mcv-267/3_final/1896349-r14-r-rev0_aecom-culvert-mcv-267-hwy-66-fir-27feb_2020.docx



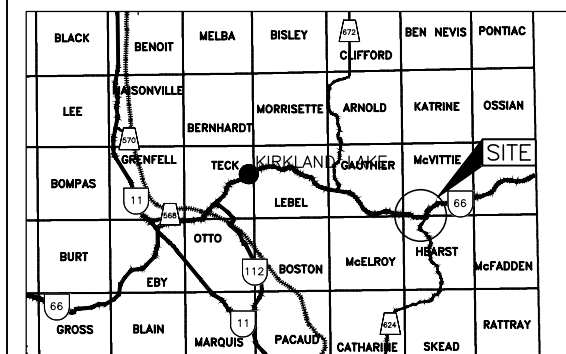
METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
GWP No. 5210-14-00



HIGHWAY 66
STATION 10+172
TOWNSHIP OF MCVITTIE CULVERT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



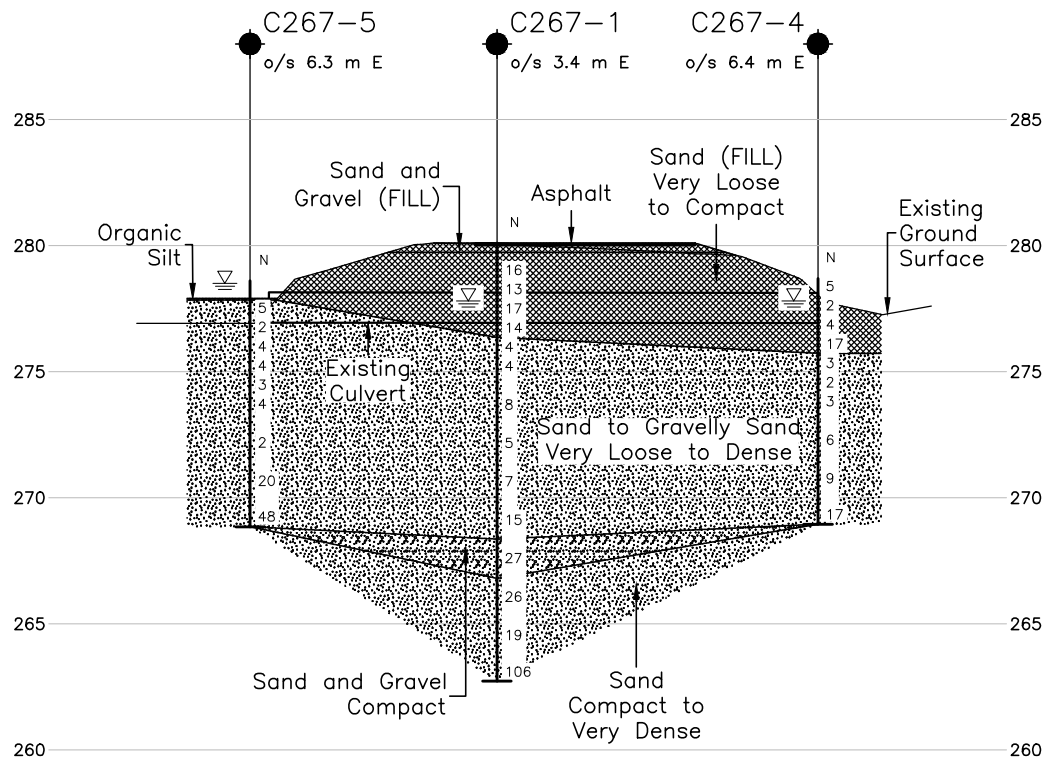
KEY PLAN
SCALE
10 0 10 20 km

LEGEND

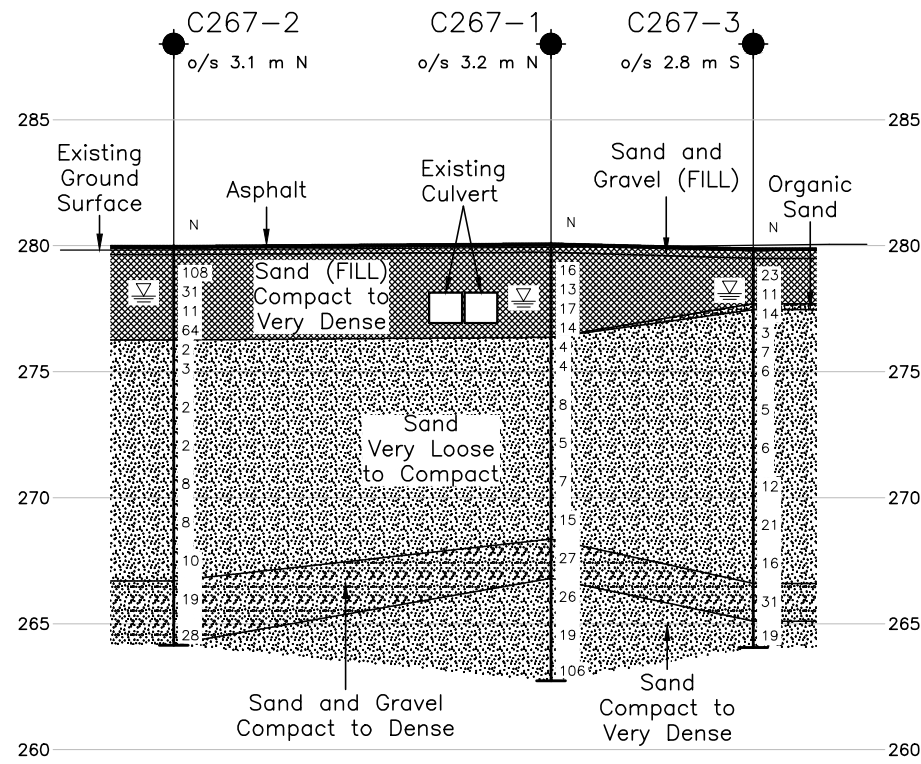
- Borehole - Current Investigation
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL upon completion of drilling

BOREHOLE CO-ORDINATES (NAD 83 MTM ZONE 12)

No.	ELEVATION	NORTHING	EASTING
C267-1	280.1	5330464.9	397300.4
C267-2	280.0	5330462.7	397285.6
C267-3	279.9	5330460.2	397309.2
C267-4	278.7	5330452.7	397305.1
C267-5	278.6	5330475.0	397301.9



A-A'
1
HORIZONTAL SCALE
3 0 3 6 m
VERTICAL SCALE
3 0 3 6 m



B-B'
1
HORIZONTAL SCALE
3 0 3 6 m
VERTICAL SCALE
3 0 3 6 m



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. gwp521001400c.dwg, received AUGUST 14, 2019.

NO.	DATE	BY	REVISION
Geocres No. 32D-30			
HWY. 66	PROJECT NO. 1896349	DIST. .	
SUBM'D.	CHKD. TB	DATE: 2/18/2020	SITE: .
DRAWN: TR	CHKD. AB	APPD. JMAC	DWG. 1



Photograph 1: East Approach at Culvert Location, Facing West (May 2019)



Photograph 2: Embankment South Slope at Culvert Location, Facing west (May 2019)



Photograph 3: Embankment North Slope (October 2018)



Photograph 4: Internal View of Culvert facing south (October 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)

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

- 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

- 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.
- 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

- SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.
- 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 $= \sigma'_p / \sigma'_{vo}$

(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

PROJECT <u>1896349</u>		RECORD OF BOREHOLE No C267-1		1 OF 2 METRIC	
G.W.P. <u>5210-14-00</u>		LOCATION <u>N 5330464.9; E 397300.4 NAD83 MTM ZONE 12 (LAT. 48.106347; LONG. -79.757784)</u>		ORIGINATED BY <u>MR</u>	
DIST <u> </u> HWY <u>66</u>		BOREHOLE TYPE <u>76 mm I.D. Hollow Stem Augers, NW Casing, Wash Boring</u>		COMPILED BY <u>TR</u>	
DATUM <u>GEODETIC</u>		DATE <u>May 4, 2019</u>		CHECKED BY <u>AB</u>	

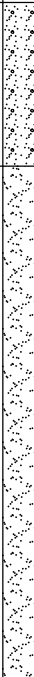
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL
								20	40	60	80	100	W _p	W	W _L					
280.1	GROUND SURFACE																			
0.0	ASPHALT (100 mm)																			
279.7	Sand and gravel (FILL)																			
0.4	Asphalt coated particles from 0.16 m to 0.23 m depth Sand, trace gravel, trace silt (FILL) Compact Brown to grey Moist to wet		1	SS	16															
			2	SS	13															
			3	SS	17															
	- Several gravel sizes in Sample 3		4	SS	14															
276.4																				
3.7	SAND, trace gravel, trace silt Very loose to compact Grey/brown Wet		5	SS	4															
			6	SS	4															
			7	SS	8															
			8	SS	5															
			9	SS	7															
			10	SS	15															
268.4																				
11.7	SAND and GRAVEL																			

Continued Next Page

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

SUD-MTO 001 S:\CLIENTS\MTOWHY\65866\02_DATAGINT\1896349.GPJ GAL-MISS.GDT 19-12-11 TR

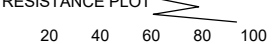
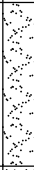
PROJECT <u>1896349</u>			RECORD OF BOREHOLE No C267-1				2 OF 2 METRIC	
G.W.P. <u>5210-14-00</u>			LOCATION <u>N 5330464.9; E 397300.4 NAD83 MTM ZONE 12 (LAT. 48.106347; LONG. -79.757784)</u>				ORIGINATED BY <u>MR</u>	
DIST <u> </u> HWY <u>66</u>			BOREHOLE TYPE <u>76 mm I.D. Hollow Stem Augers, NW Casing, Wash Boring</u>				COMPILED BY <u>TR</u>	
DATUM <u>GEODETIC</u>			DATE <u>May 4, 2019</u>				CHECKED BY <u>AB</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					W _p	W	W _L			
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					WATER CONTENT (%)					
						20 40 60 80 100 20 40 60 80 100					20 40 60							
266.8	SAND and GRAVEL Compact Grey/brown Wet		11	SS	27		268											
							267											
13.3	SAND, trace gravel, trace silt Compact to very dense Grey/brown Wet		12	SS	26		266											
							265											
			13	SS	19		264											
							263											
262.7	END OF BOREHOLE NOTE: 1. Water level at a depth of 2.3 m below ground surface (Elev. 277.8 m) upon completion of drilling.																	
17.4																		

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S:\CLIENTS\MT0\HWY65&66\02 DATA\GINT\1896349.GPJ GAL-MISS.GDT 19-12-11 TR

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

PROJECT 1896349			RECORD OF BOREHOLE No C267-2				2 OF 2 METRIC					
G.W.P. 5210-14-00			LOCATION N 5330462.7; E 397285.6 NAD83 MTM ZONE 12 (LAT. 48.106329; LONG. -79.757983)				ORIGINATED BY MR					
DIST _____ HWY 66			BOREHOLE TYPE 76 mm I.D. Hollow Stem Augers, NW Casing, Wash Boring				COMPILED BY TR					
DATUM GEODETIC			DATE May 4, 2019				CHECKED BY AB					
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT  SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED	PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W _p — W — W _L WATER CONTENT (%)	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES							
266.7	SAND, trace gravel, trace silt Very loose to loose Grey/brown Wet		11	SS	10		267					46 52 (2)
13.3	SAND and GRAVEL Compact Grey/brown Wet		12	SS	19		266					
							265					
264.1			13	SS	28							
15.9	END OF BOREHOLE NOTE: 1. Water level at a depth of 2.0 m below ground surface (Elev. 278.0 m) upon completion of drilling.											

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PROJECT <u>1896349</u>		RECORD OF BOREHOLE No C267-3		1 OF 2 METRIC	
G.W.P. <u>5210-14-00</u>		LOCATION <u>N 5330460.2; E 397309.2 NAD83 MTM ZONE 12 (LAT. 48.106303; LONG. -79.757667)</u>		ORIGINATED BY <u>MR</u>	
DIST <u> </u> HWY <u>66</u>		BOREHOLE TYPE <u>76 mm I.D. Hollow Stem Augers, NW Casing, Wash Boring</u>		COMPILED BY <u>TR</u>	
DATUM <u>GEODETIC</u>		DATE <u>May 5, 2019</u>		CHECKED BY <u>AB</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL
								20	40	60	80	100	20	40	60					
279.9	GROUND SURFACE																			
0.0	ASPHALT (100 mm)																			
279.5	Sand and gravel (FILL)																			
0.4	Asphalt coated particles from 0.16 m to 0.28 m depth																			
	Sand, some gravel (FILL)		1	SS	23															
	Compact																			
	Brown		2	SS	11															
	Moist to wet																			
277.7																				
277.5	Organic SAND, some gravel, some silt																			
2.4	Dark brown		A																	
	Frozen		3	SS	14															
	SAND, trace gravel, trace silt		B																	
	Very loose to compact																			
	Grey/brown		4	SS	3															
	Wet																			
			5	SS	7															
			6	SS	6															
			7	SS	5															
			8	SS	6															
			9	SS	12															
			10	SS	21															

Continued Next Page

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

SUD-MTO 001 S:\CLIENTS\MTOWHY\6586602_DATAGINT\1896349.GPJ GAL-MISS.GDT 19-12-11 TR

PROJECT <u>1896349</u>		RECORD OF BOREHOLE No C267-3				2 OF 2 METRIC									
G.W.P. <u>5210-14-00</u>		LOCATION <u>N 5330460.2; E 397309.2 NAD83 MTM ZONE 12 (LAT. 48.106303; LONG. -79.757667)</u>				ORIGINATED BY <u>MR</u>									
DIST <u> </u> HWY <u>66</u>		BOREHOLE TYPE <u>76 mm I.D. Hollow Stem Augers, NW Casing, Wash Boring</u>				COMPILED BY <u>TR</u>									
DATUM <u>GEODETIC</u>		DATE <u>May 5, 2019</u>				CHECKED BY <u>AB</u>									
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	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	○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED			W _p W W _L			
266.6	SAND, trace gravel, trace silt Very loose to compact Grey/brown Wet		11	SS	16		267								
13.3	SAND and GRAVEL Dense Grey/brown Wet		12	SS	31		266								
265.1															
14.8	SAND, trace to some gravel Compact Grey/brown Wet		13	SS	19		265								
264.0															
15.9	END OF BOREHOLE NOTE: 1. Water level at a depth of 1.8 m below ground surface (Elev. 278.1 m) upon completion of drilling.														

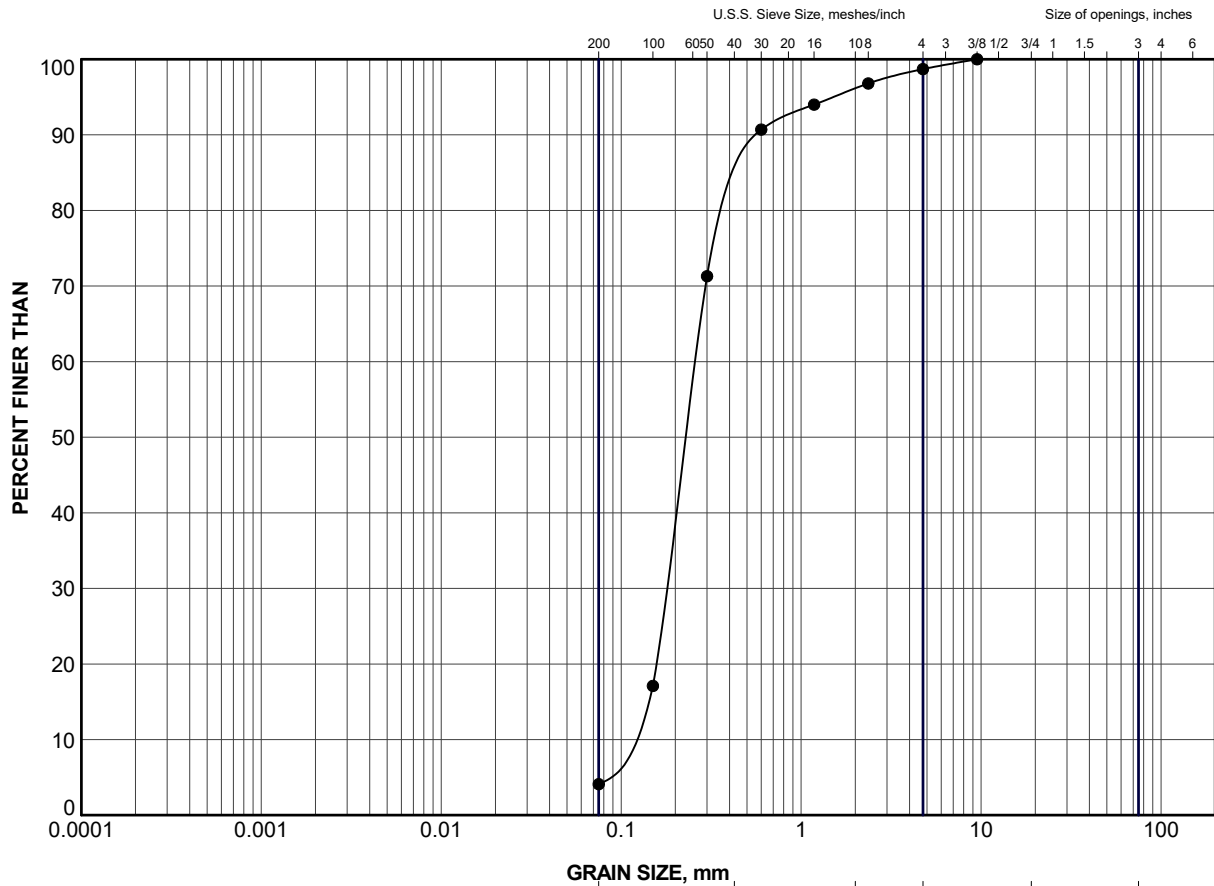
PROJECT <u>1896349</u>		RECORD OF BOREHOLE No C267-4				1 OF 1 METRIC												
G.W.P. <u>5210-14-00</u>		LOCATION <u>N 5330452.7; E 397305.1 NAD83 MTM ZONE 12 (LAT. 48.106236; LONG. -79.757723)</u>				ORIGINATED BY <u>YS</u>												
DIST <u> </u> HWY <u>66</u>		BOREHOLE TYPE <u>Portable Equipment, NW Casing, Wash Boring</u>				COMPILED BY <u>TR</u>												
DATUM <u>GEODETIC</u>		DATE <u>May 31, 2019</u>				CHECKED BY <u>AB</u>												
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 (%)
278.7	GROUND SURFACE							20	40	60	80	100						
0.0	Sand, some gravel, trace rootlets, trace organics (FILL) Very loose to compact Brown Moist to wet		1	SS	5	▽	278											
			2	SS	2		277											
			3	SS	4		276											
			4	SS	17		275											
275.7	SAND to gravelly SAND, trace silt Very loose to compact Brown Wet		5	SS	3		274											
3.0			6	SS	2	273												
			7	SS	3	272												
			8	SS	6	271												
			9	SS	9	270												
			10	SS	17	269												
268.9	END OF BOREHOLE																	
9.8	NOTE: 1. Water level at a depth of 0.9 m below ground surface (Elev. 277.8 m) upon completion of drilling.																	

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PROJECT 1896349		RECORD OF BOREHOLE No C267-5				1 OF 1 METRIC											
G.W.P. 5210-14-00		LOCATION N 5330475.0; E 397301.9 NAD83 MTM ZONE 12 (LAT. 48.106437; LONG. -79.757761)				ORIGINATED BY MR											
DIST _____ HWY 66		BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers, NW Casing, Wash Boring				COMPILED BY TR											
DATUM GEODETIC		DATE May 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									
278.6	GROUND SURFACE																
0.0	Topsoil (FILL)																
278.3																	
0.3	Sand and gravel (FILL)																
277.9	Brown																
0.8	Organic SILT Black Wet SAND, trace gravel, trace silt Very loose to dense Grey/brown Wet		1	SS	5												
			2	SS	2												
			3	SS	4												
			4	SS	4												
			5	SS	3												
			6	SS	4												
			7	SS	2												
			8	SS	20												
			9	SS	48												
268.8	END OF BOREHOLE																
9.8	NOTE: 1. Water level at a depth of 0.1 m below ground surface (Elev. 278.5 m) upon completion of drilling.																

APPENDIX B


Laboratory Test Results

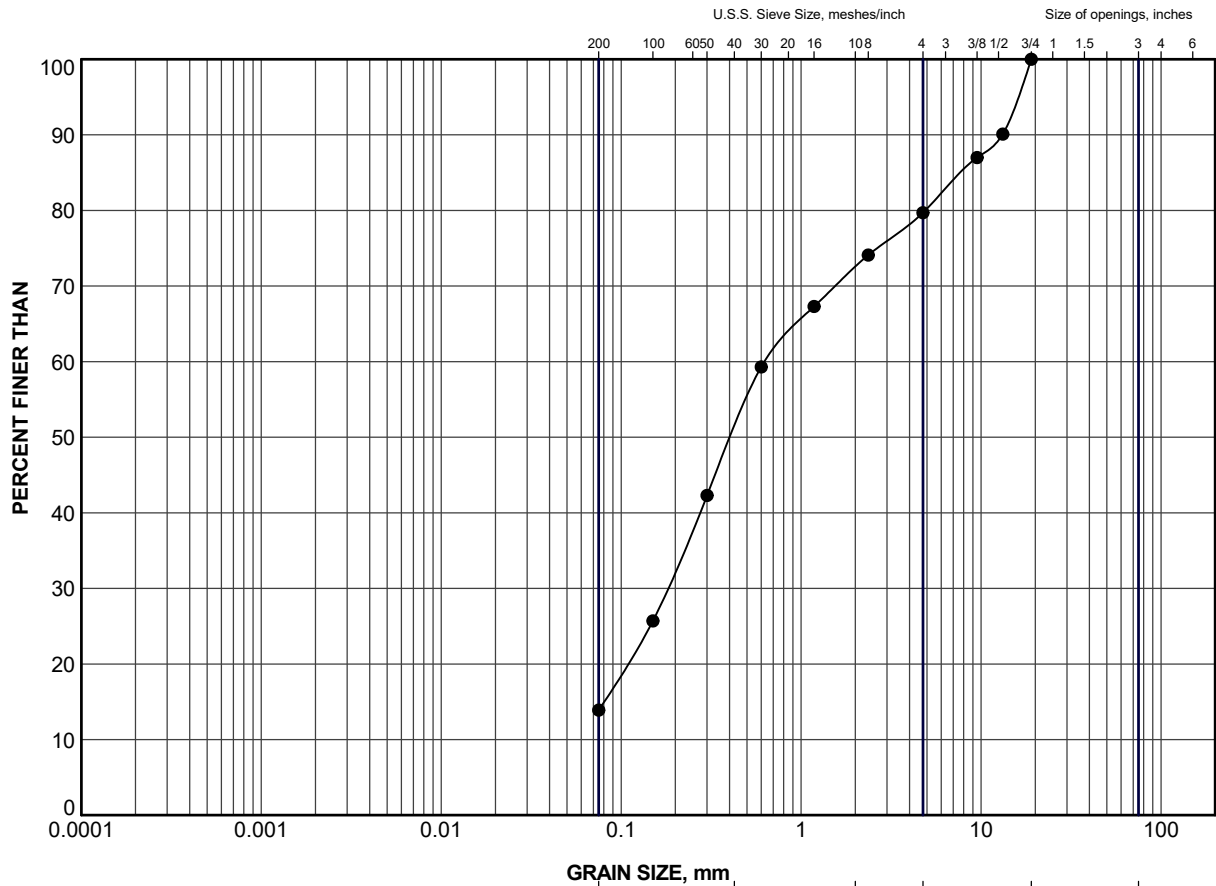


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C267-1	4	276.8


PROJECT						HIGHWAY 66 STATION 10+172 TOWNSHIP OF MCVITTIE CULVERT					
TITLE						GRAIN SIZE DISTRIBUTION Sand (FILL)					
PROJECT No.			1896349			FILE No.			1896349.GPJ		
DRAWN	TR	Nov 2019		SCALE	N/A	REV.					
CHECK	AB	Nov 2019									
APPR	JMAC	Nov 2019									
 GOLDER SUDBURY, ONTARIO						FIGURE B-1					

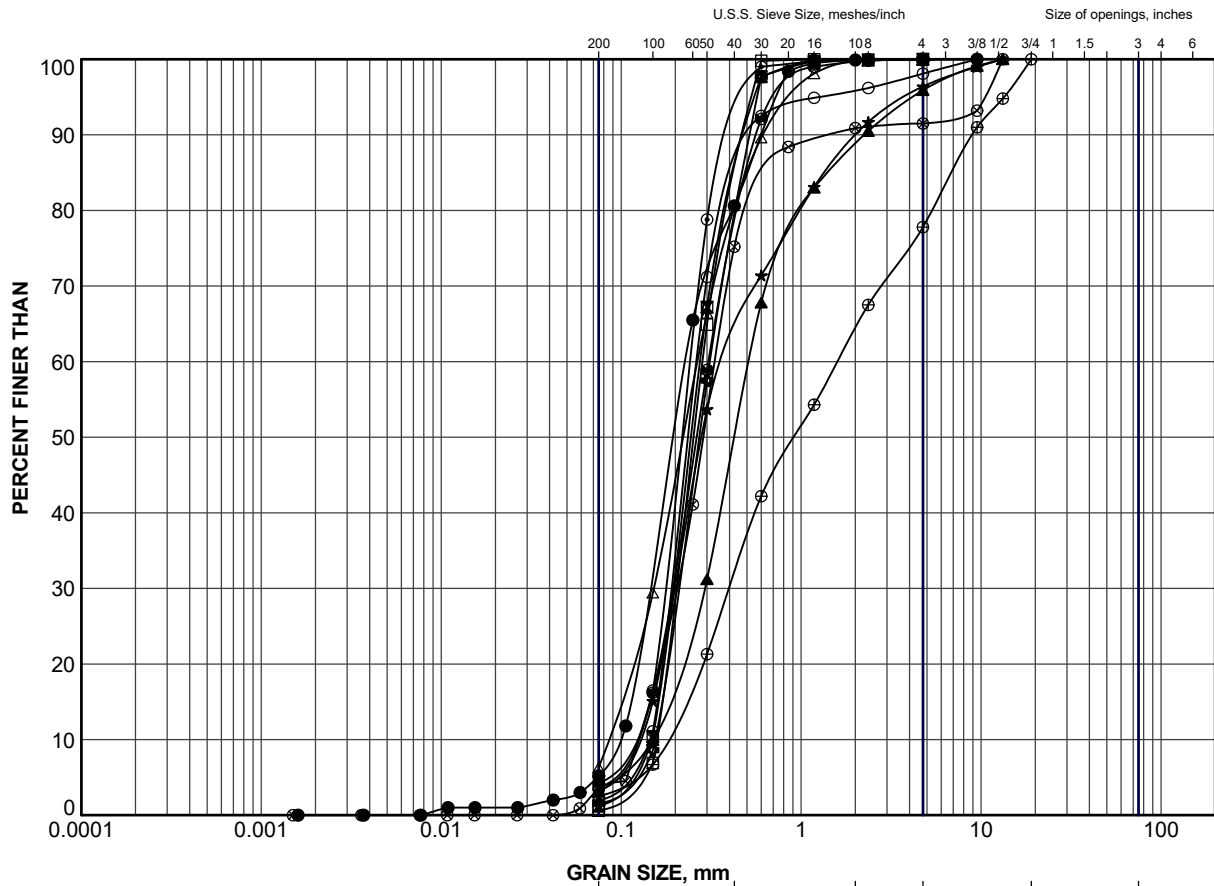


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C267-3	3A	277.5

PROJECT						HIGHWAY 66 STATION 10+172 TOWNSHIP OF MCVITTIE CULVERT					
TITLE						GRAIN SIZE DISTRIBUTION ORGANIC SAND					
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-2					

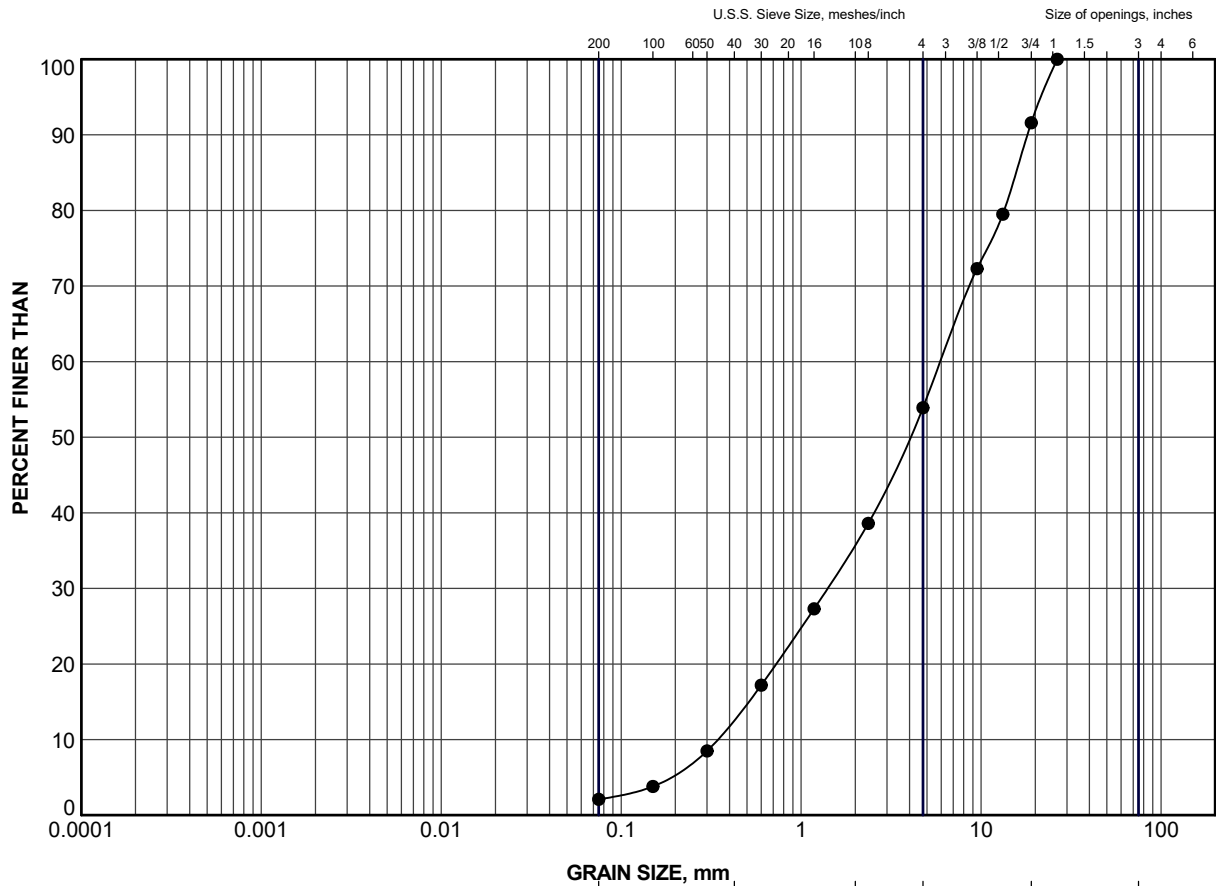


CLAY AND SILT	GRAIN SIZE, mm			Cobble Size
	fine	medium	coarse	
	SAND SIZE			
			GRAVEL SIZE	

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C267-1	6	275.2
⊠	C267-1	9	270.7
▲	C267-1	13	264.6
★	C267-2	5	275.9
⊙	C267-2	7	273.6
⊕	C267-2	10	269.0
○	C267-3	6	275.0
△	C267-3	9	270.5
⊗	C267-4	5	275.4
⊕	C267-4	8	272.3
□	C267-5	3	276.0
⊗	C267-5	7	272.2


PROJECT						HIGHWAY 66 STATION 10+172 TOWNSHIP OF MCVITTIE CULVERT					
TITLE						GRAIN SIZE DISTRIBUTION SAND to Gravelly SAND					
PROJECT No.			1896349			FILE No.			1896349.GPJ		
DRAWN	TR	Dec 2019	SCALE	N/A	REV.						
CHECK	AB	Dec 2019				FIGURE B-3					
APPR	JMAC	Dec 2019									
GOLDER						SUDBURY, ONTARIO					



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C267-2	12	266.0

PROJECT						HIGHWAY 66 STATION 10+172 TOWNSHIP OF MCVITTIE CULVERT					
TITLE						GRAIN SIZE DISTRIBUTION SAND and GRAVEL					
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-4					



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		JTI432			JTI433	JTI434	JTI435	JTI436		
Sampling Date		2019/05/03 10:45			2019/05/04 14:47	2019/05/08 12:39	2019/05/11 16:36	2019/05/14 08:49		
COC Number		127611			127611	127611	127611	127611		
	UNITS	C236-1 Lab-Dup	RDL	QC Batch	C267-1	C228-1	C227-1	C256-1	RDL	QC Batch

CONVENTIONALS										
Sulphide	ug/g				<0.30	<0.30	<0.30	<0.30	0.30	6150574
Calculated Parameters										
Resistivity	ohm-cm				23000	12000	2500	22000		6129977
Inorganics										
Soluble (20:1) Chloride (Cl ⁻)	ug/g				<20	29	250	<20	20	6133046
Conductivity	umho/cm				43	84	405	46	2	6135430
Available (CaCl ₂) pH	pH				7.74	6.56	7.00	6.30		6133358
Soluble (20:1) Sulphate (SO ₄)	ug/g				<20	<20	<20	<20	20	6133048
Physical Testing										
Moisture-Subcontracted	%	15	0.30	6150575	21	20	20	20	0.30	6150575
RDL = Reportable Detection Limit QC Batch = Quality Control Batch Lab-Dup = Laboratory Initiated Duplicate										



golder.com