



January 17, 2014

## FOUNDATION INVESTIGATION REPORT

HIGHWAY 540 MUD CREEK CULVERT, SITE 49-68/C  
TOWNSHIP OF BILLINGS, MANITOULIN ISLAND, ONTARIO  
MINISTRY OF TRANSPORTATION, ONTARIO  
GWP 5465-09-00, WP 5466-09-01

**Submitted to:**

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- 1 copy - McIntosh Perry, Kingston, Ontario
- 1 e-copy - Golder Associates Ltd., Sudbury, Ontario

REPORT







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# **PART A**

**FOUNDATION INVESTIGATION REPORT**  
**HIGHWAY 540 MUD CREEK CULVERT, SITE 49-68/C**  
**TOWNSHIP OF BILLINGS, MANITOULIN ISLAND, ONTARIO**  
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## FOUNDATION REPORT HIGHWAY 540 MUD CREEK CULVERT, SITE 49-68/C

### 1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by McIntosh Perry Consulting Engineers Ltd. (McIntosh Perry) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the replacement of the east end of the existing culvert at Mud Creek (Site 49-68/C) located at STA 20+045 on Highway 540, in the Township of Billings on Manitoulin Island, Ontario. The Key Plan showing the general location of this section of Highway 540 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 location of the culvert by borehole drilling, in situ testing and laboratory testing on selected samples.

### 2.0 SITE DESCRIPTION

The Mud Creek culvert is located in the Township of Billings on Highway 540, approximately 5.8 km west of Highway 551. The land use in the area is generally rural with a few residences in the vicinity of the site.

The topography in the area of the overall project limits is generally flat. The creek banks are vegetated with grass and small trees. The creek was dry at the time of our investigation.

The existing highway grade at the culvert is at about Elevations 220.8 m with the bottom of Mud Creek located about 2.1 m below the existing highway grade. The existing structure is a 3.0 m span by 0.8 m high by 15.8 m long open footing concrete culvert under approximately 0.8 m of fill. We understand the original open footing culvert, which was constructed in 1964, was approximately 6.2 m in length. Since the original construction, the culvert has been extended about 7.7 m to the west and 1.9 m the east. The construction date of the extensions is not known. The existing inlet (west) and outlet (east) inverts are at Elevation 218.7 m and 218.8 m, respectively.

A 2010 structural inspection indicated severe scaling, delaminations and medium stained cracks. The base of the south wall of the east culvert extension was noted to be rotating inwards. Based on the 2012 inspection performed by McIntosh Perry, the north side of the east culvert extension has also rotated inward at the base of the wall.

Photographs taken at the site are included following the text of the report.

### 3.0 INVESTIGATION PROCEDURES

The fieldwork for the investigation was carried out on July 8 and 9, 2013, during which time a total of four boreholes (M1 to M4) were advanced at the culvert location. The locations of the boreholes are shown on Drawing 1.

The field investigation was carried out using a track-mounted CME-850 drill rig supplied and operated by Landcore Drilling Inc. of Sudbury, Ontario. The boreholes were advanced through the overburden using 108 mm inside diameter hollow-stem augers. Soil samples were obtained at intervals of depth of about 0.75 m, using a 50 mm outer diameter split-spoon sampler, operated by an automatic hammer on the drill rig, in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586-08a). Samples of the bedrock were obtained using





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NW casing and NQ size rock core barrels in each of the boreholes. The groundwater levels in the open boreholes were observed during the drilling operations as described on the Record of Borehole sheets in Appendix A. The boreholes were backfilled with bentonite upon completion in accordance with Ontario Regulation 903 (as amended by Ontario Regulation 372).

The fieldwork was supervised throughout by members of our technical staff who: located the boreholes; arranged for the clearance of underground services; supervised the drilling, sampling operations; logged the boreholes; and examined and cared for the soil and bedrock samples. The samples were identified in the field, placed in appropriate containers, labelled and transported to our Sudbury geotechnical laboratory where the samples underwent further visual examination and laboratory testing. All of the laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate. Classification testing (water contents and grain size distributions) was carried out on selected soil samples and uniaxial compressive strength (UCS) testing was carried out on specimens of the recovered bedrock core. The geotechnical laboratory testing was completed according to applicable MTO LS standards. The results of the laboratory testing are included on the Record of Borehole sheets in Appendix A and in Appendix B.

The as-drilled borehole locations and ground surface elevations were measured and surveyed by members of our technical staff, referenced to stations on the highway. The MTM NAD 83 northing and easting coordinates, ground surface elevations referenced to Geodetic datum and borehole depths at each borehole location are presented on the Record of Borehole sheets in Appendix A and are summarized below.

Borehole	Location (m)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing	Easting		
M1	5078730.0	326590.3	220.5	5.6
M2	5078736.4	326590.3	220.6	5.5
M3	5078730.0	326598.7	220.6	4.7
M4	5078736.7	326605.3	218.8	3.3

As part of the foundation investigation, an excavator was used to expose the foundation at the northeast corner of the culvert extension. As shown in Photograph #3 following the text of the report, the wall of the culvert extension is bearing directly on the exposed bedrock.

## 4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

### 4.1 Regional Geology

Based on the Physiography of Southern Ontario (Ministry of Northern Development and Mines)<sup>1</sup>, the site is located within limestone plains bordering with clay plains and drumlin formations.

<sup>1</sup> Ministry of Northern Development and Mines, 2007, Physiography of Southern Ontario, MRD228.





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Based on geological mapping in the area (Ministry of Northern Development and Mines)<sup>2</sup>, the bedrock in the area consists typically of sandstone, shale, dolostone and siltstone from the Amabel Formation from the Silurian Period of the Paleozoic Era.

### 4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions as encountered in the boreholes advanced for this investigation, together with the results of the laboratory tests carried out on selected soil samples, are given on the attached Record of Borehole and Drillhole sheets in Appendix A. The results of the laboratory testing are provided in Appendix B. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling, observations of drilling progress and the results of SPTs. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Further, subsurface conditions will vary between and beyond the borehole locations. The inferred soil stratigraphy based on the results of the boreholes is shown in profile on Drawing 1.

In general, the subsurface conditions encountered at the site generally consist of embankment fill overlying bedrock. A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

#### 4.2.1 Sand and Gravel Fill

A 1.8 m to 2.1 m thick layer of brown, moist, sand and gravel fill, trace to some silt, trace clay was encountered from ground surface (between Elevation 220.6 and 220.5 m) in Boreholes M1 to M3, which were advanced from the existing highway shoulders. The augers were noted to be grinding on cobbles within the fill generally at a depth of about 0.6 m below the existing ground surface (about Elevation 220.0 m).

Standard Penetration Test (SPT) 'N'-values measured within the sand and gravel fill range from 11 blows to 38 blows per 0.3 m of penetration indicating a compact to dense relative density.

Grain size distribution tests were carried out on five samples of the sand and gravel fill and the results are shown on Figure B1 in Appendix B.

The natural water content measured on five samples of the sand and gravel fill ranges from 3 per cent to 5 per cent.

#### 4.2.2 Silty Organics

A 0.2 m thick layer of brown, moist, silty organics, trace to some sand, trace gravel was encountered from ground surface (Elevation 218.8 m) in Borehole M4, which was advanced beyond the embankment toe of slope near the culvert inlet.

<sup>2</sup> Ministry of Northern Development and Mines, 1991. *Bedrock Geology of Ontario*, Southern Sheet, Map 2544.





### 4.2.3 Gravelly Silty Sand

A 0.4 m thick deposit of brown, wet gravelly silty sand, trace organics, was encountered below the sand and gravel fill in Borehole M1. The surface of this deposit was encountered at Elevation 218.7 m.

The SPT 'N'-value measured within the gravelly silty sand deposit is 14 blows per 0.3 m penetration, indicating a compact relative density.

The natural water content measured on one sample of the gravelly silty sand is 20 per cent.

A grain size distribution test was carried out on a sample of the gravelly silty sand and the results are shown on Figure B2 in Appendix B.

### 4.2.4 Bedrock

Bedrock was cored in Boreholes M1 to M4. The bedrock surface/refusal depths and elevations are presented below.

Borehole No.	Depth to Bedrock (m)	Bedrock Surface Elevation (m)	Notes
M1	2.2	218.3	Bedrock Cored for 3.4 m
M2	2.1	218.5	Bedrock Cored for 3.4 m
M3	1.8	218.8	Bedrock Cored for 2.9 m
M4	0.2	218.6	Bedrock Cored for 3.1 m

The retrieved bedrock core is described as a fine grained, fresh to slightly weathered, grey, dolomitic limestone, as presented in the Record of Drillhole sheets in Appendix A. Photographs of the retrieved bedrock core samples are shown on Figure B3 in Appendix B.

The Total Core Recovery (TCR) during bedrock coring ranged from 97 per cent to 100 per cent. The Rock Quality Designation (RQD) measured on the core samples ranges from 58 per cent to 100 per cent, indicating a rock mass of fair to excellent quality as per Table 3.10 of the Canadian Foundation Engineering Manual (CFEM, 2006).

Laboratory UCS testing was carried out on two core samples of the bedrock. The UCS values are presented below and the test results indicate the bedrock is very strong as per Table 3.5 of the CFEM (2006).

Borehole	Elevation (m)	UCS (MPa)
M2	217.9	229
M3	216.8	183





#### **4.2.5 Groundwater Conditions**

The boreholes were noted to be dry upon completion of drilling prior to bedrock coring.

The creek was dry at the time of the investigation in July 2013. Groundwater levels in the area are subject to seasonal fluctuations and to fluctuations after precipitation events and snowmelt.

### **5.0 CLOSURE**

The field personnel supervising the drilling program was Mr. Mathew Riopelle. This report was prepared by Mr. David Muldowney, P.Eng., and the technical aspects were reviewed by Mr. André Bom, P.Eng. Mr. Fintan Heffernan, P.Eng., Golder's Designated MTO Contact for this project, carried out a quality control review and reviewed the technical aspects of the report.




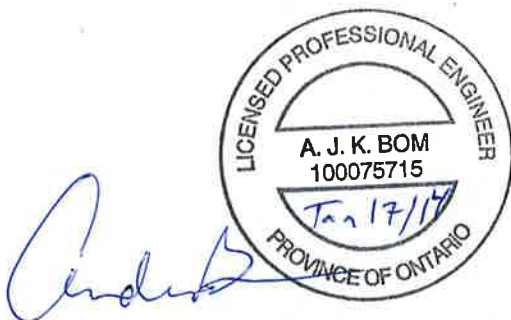


## FOUNDATION REPORT HIGHWAY 540 MUD CREEK CULVERT, SITE 49-68/C

### Report Signature Page

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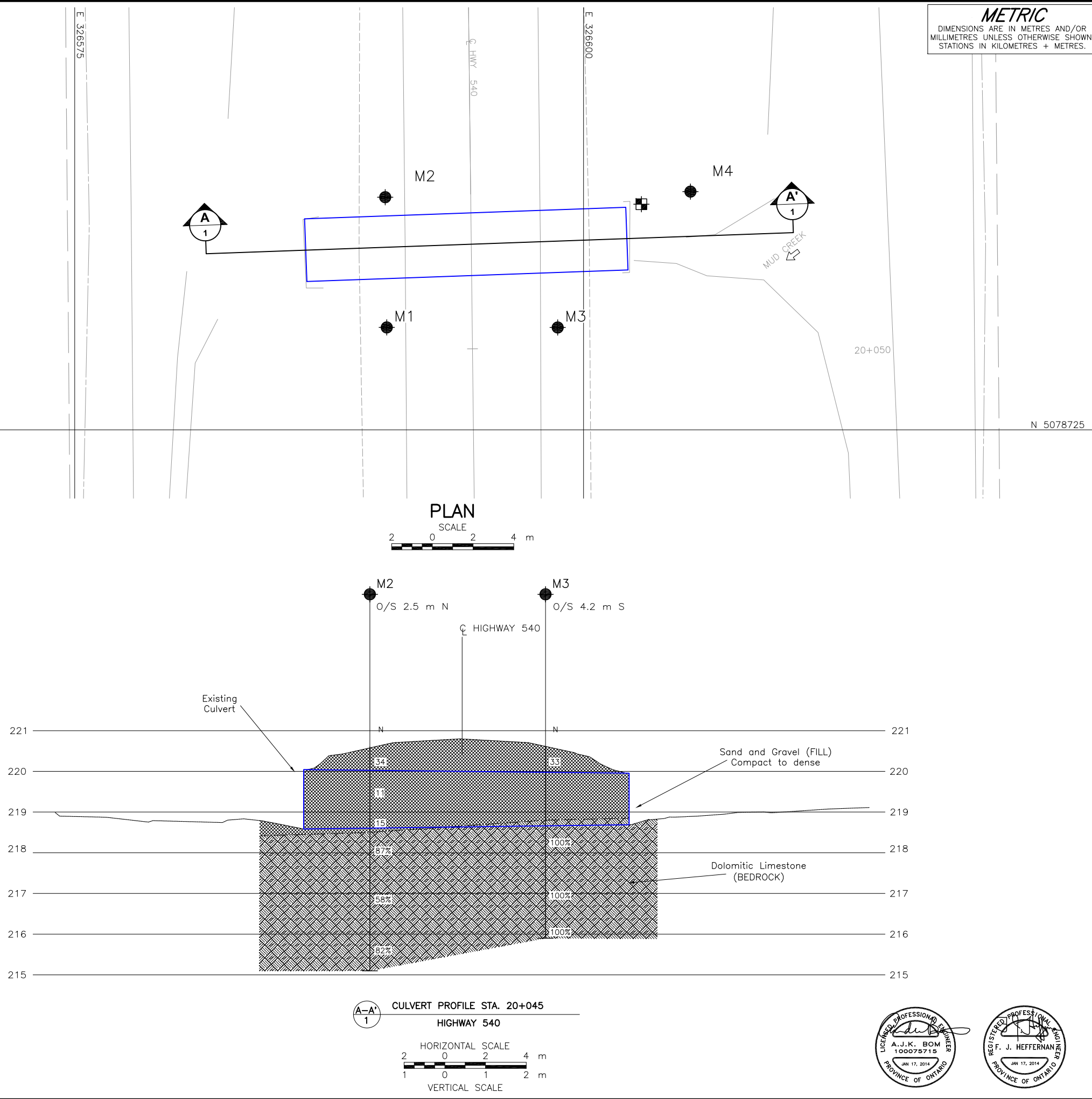
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[http://capws.golder.com/sites/p211910014mtohw542and655manislandlimins/reports/final/mud creek site 49-68/12-1191-0014-r06 rpt 14jan17 mud creek site 49-68 - fir.docx](http://capws.golder.com/sites/p211910014mtohw542and655manislandlimins/reports/final/mud%20creek%20site%2049-68/12-1191-0014-r06%20rpt%2014jan17%20mud%20creek%20site%2049-68%20-fir.docx)





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

CONT No.  
WP No. 5466-09-01

HIGHWAY 540  
MUD CREEK CULVERT SITE 49-68/C  
BOREHOLE LOCATIONS AND  
SOIL STRATA

SHEET

**Golder Associates**

**Golder Associates Ltd.**  
SUDBURY, ONTARIO, CANADA

KEY PLAN

LEGEND

Borehole  
 Test Pit  
N Standard Penetration Test Value  
16 Blows/0.3m unless otherwise stated  
(Std. Pen. Test, 475 j/blow)  
100% Rock Quality Designation (RQD)

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
M1	220.5	5078730.0	326590.3
M2	220.6	5078736.4	326590.3
M3	220.6	5078730.0	326598.7
M4	218.8	5078736.7	326605.3

**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.

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

**REFERENCE**

Base plans provided in digital format by McIntosh Perry, drawing file no. 11-684-Mud Creek Xref.dwg, received Aug 20, 2013. Cross-section file no. 11-684-Mud Creek - Typical Sections - C3D.dwg, received July 19, 2013. Key plan drawing file no. KM11684 - 49-68 and 49-67 Location Map - June 26 2012.jpg, received August 24, 2012.

NO.	DATE	BY	REVISION
Geocres No. 41G-16			
HWY. 540	PROJECT NO. 12-1191-0014		DIST.
SUBM'D. DAM	CHKD.	DATE: JAN 2014	SITE: 49-68/C
DRAWN: TB	CHKD. AB	APPD. FJH	DWG. 1





## **SITE PHOTOGRAPHS (Site 49-68/C)**

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**Photograph 1: Looking southeast from culvert inlet (October 2012)**



**Photograph 2: Looking south at east culvert extension  
(From McIntosh Perry by email Feb 25, 2013)**







## SITE PHOTOGRAPHS (Site 49-68/C)

**Photograph 3: Looking north at exposed east culvert extension following excavation of test pit (July 2013)**



**Photograph 4: Looking at north wall of east extension  
(From McIntosh Perry by email Feb 25, 2013)**







# **APPENDIX A**

## **Record of Boreholes and Drillholes**





## LIST OF SYMBOLS

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

### I. GENERAL

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

### II. STRESS AND STRAIN

$\gamma$	shear strain
$\Delta$	change in, e.g. in stress: $\Delta \sigma$
$\varepsilon$	linear strain
$\varepsilon_v$	volumetric strain
$\eta$	coefficient of viscosity
$\nu$	Poisson's ratio
$\sigma$	total stress
$\sigma'$	effective stress ( $\sigma' = \sigma - u$ )
$\sigma'_{vo}$	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
$\sigma_{oct}$	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
$\tau$	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

### III. SOIL PROPERTIES

#### (a) Index Properties

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

#### (a) Index Properties (continued)

w	water content
$w_l$ or LL	liquid limit
$w_p$ or PL	plastic limit
$I_p$ or PI	plasticity index = $(w_l - w_p)$
$w_s$	shrinkage limit
$I_L$	liquidity index = $(w - w_p) / I_p$
$I_C$	consistency index = $(w_l - w) / I_p$
$e_{max}$	void ratio in loosest state
$e_{min}$	void ratio in densest state
$I_D$	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

#### (b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

#### (c) Consolidation (one-dimensional)

$C_c$	compression index (normally consolidated range)
$C_r$	recompression index (over-consolidated range)
$C_s$	swelling index
$C_\alpha$	secondary compression index
$m_v$	coefficient of volume change
$C_v$	coefficient of consolidation (vertical direction)
$C_h$	coefficient of consolidation (horizontal direction)
$T_v$	time factor (vertical direction)
U	degree of consolidation
$\sigma'_p$	pre-consolidation stress
OCR	over-consolidation ratio = $\sigma'_p / \sigma'_{vo}$

#### (d) Shear Strength

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

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

Notes: 1  
2

$$\tau = c' + \sigma' \tan \phi'$$

$$\text{shear strength} = (\text{compressive strength})/2$$





## LIST OF ABBREVIATIONS

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

### I. SAMPLE TYPE

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

### II. PENETRATION RESISTANCE

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

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

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

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

**PH:** Sampler advanced by hydraulic pressure

**PM:** Sampler advanced by manual pressure

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

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

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

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm<sup>2</sup> pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance ( $Q_t$ ), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

### III. SOIL DESCRIPTION

#### (a) Non-Cohesive (Cohesionless) Soils

Density Index	N
Relative Density	Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

#### (b) Cohesive Soils Consistency

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

### IV. SOIL TESTS

w	water content
$w_p$	plastic limit
$w_l$	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test <sup>1</sup>
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement <sup>1</sup>
$D_R$	relative density (specific gravity, $G_s$ )
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO <sub>4</sub>	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
$\gamma$	unit weight

**Note:** 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

### V. MINOR SOIL CONSTITUENTS

Per cent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (non-cohesive (cohesionless)) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand





## LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

### 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		RECORD OF BOREHOLE No M1				1 OF 1 METRIC											
W.P. 5466-09-01		LOCATION N 5078730.0; E 326590.3				ORIGINATED BY MR											
DIST HWY 540		BOREHOLE TYPE 108 mm ID Continuous Flight Hollow Stem Augers, NW Casing, NQ Coring				COMPILED BY DAM											
DATUM GEODETIC		DATE July 8, 2013				CHECKED BY AB											
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)
220.5	GROUND SURFACE																
0.0	Sand and gravel, some silt, trace clay (FILL) Compact to dense Brown Moist		1	SS	38											38 44 16 2	
	Augers grinding on cobbles between 0.6 m and 0.9 m depth and between 1.4 m and 1.5 m depth.		2	SS	11												43 39 15 3
218.7			3a	SS	14												28 41 28 3
218.3	Gravelly Silty SAND, trace clay, trace organics Compact Brown Wet	3b															
2.2	DOLOMITIC LIMESTONE (BEDROCK)  Bedrock cored from 2.2 m depth to 5.6 m depth.  For coring details see Record of Drillhole M1.		1	RC	REC 97%												RQD = 78%
			2	RC	REC 100%												RQD = 96%
			3	RC	REC 100%												RQD = 99%
214.9																	
5.6	END OF BOREHOLE  Note: 1. Borehole dry upon completion of drilling.																

SUD\_MTO 003 1211910014.5000.GPJ GAL-MISS.GDT 22/08/13 DATA INPUT:



PROJECT: 12-1191-0014

**RECORD OF DRILLHOLE: M1**

SHEET 1 OF 1

LOCATION: N 5078730.0 ; E 326590.3

DRILLING DATE: July 8, 2013

DATUM: GEODETIC

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 850

DRILLING CONTRACTOR: Landcore Drilling Ontario Inc.

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										BR - Broken Rock	NOTE: For additional abbreviations refer to list of abbreviations & symbols.	NOTES WATER LEVELS INSTRUMENTATION																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
							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	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	k, cm/s	10°	10°	10°																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
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DEPTH SCALE

1 : 50



LOGGED: MR

CHECKED: AB

SUD-RCK 1211910014 5000.GPJ GAL-MISS.GDT 22/08/13 DATA INPUT:



PROJECT 12-1191-0014		<b>RECORD OF BOREHOLE No M2</b>				1 OF 1 <b>METRIC</b>												
W.P. 5466-09-01		LOCATION N 5078736.4; E 326590.3				ORIGINATED BY MR												
DIST HWY 540		BOREHOLE TYPE 108 mm ID Continuous Flight Hollow Stem Augers, NW Casing, NQ Coring				COMPILED BY DAM												
DATUM GEODETIC		DATE July 8, 2013				CHECKED BY AB												
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										
220.6	GROUND SURFACE							20	40	60	80	100						
0.0	Sand and gravel, trace to some silt (FILL) Compact to dense Brown Moist		1	SS	34													
	Augers grinding on cobbles between 0.6 m and 0.8 m depth and between 1.2 m and 1.5 m depth.		2	SS	11													56 33 (11)
			3	SS	15													39 49 (12)
218.5	DOLOMITIC LIMESTONE (BEDROCK)		1	RC	REC 100%													
2.1	Bedrock cored from 2.1 m depth to 5.5 m depth.  For coring details see Record of Drillhole M2.		2	RC	REC 100%													RQD = 87%
			3	RC	REC 100%													RQD = 58%
																		RQD = 82%
215.1	END OF BOREHOLE																	
5.5	Note:  1. Borehole dry upon completion of drilling.																	



PROJECT: 12-1191-0014

**RECORD OF DRILLHOLE: M2**

SHEET 1 OF 1

LOCATION: N 5078736.4 ; E 326590.3

DRILLING DATE: July 8, 2013

DATUM: GEODETIC

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 850

DRILLING CONTRACTOR: Landcore Drilling Ontario Inc.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR FLUSH % 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										BR - Broken Rock	NOTES WATER LEVELS INSTRUMENTATION																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
							RECOVERY		R.Q.D. %	FRACT. INDEX METRES	DISCONTINUITY DATA										HYDRAULIC CONDUCTIVITY		Diametral Point Load Index (MPa)	RMC -Q' AVG.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
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							FLUSH	FLUSH			B Angle	DIP w.r.t. CORE AXIS	Jr	Ja	Jn	Jr	Ja	Jn	Jr	Ja	Jn	Jr			Ja	Jn																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
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DEPTH SCALE

1 : 50



LOGGED: MR

CHECKED: AB

SUD-RCK 1211910014.5000.GPJ GAL-MISS.GDT 22/08/13 DATA INPUT:



PROJECT		RECORD OF BOREHOLE No M3				1 OF 1 METRIC																		
W.P. 5466-09-01		LOCATION N 5078730.0; E 326598.7				ORIGINATED BY MR																		
DIST HWY 540		BOREHOLE TYPE 108 mm ID Continuous Flight Hollow Stem Augers, NW Casing, NQ Coring				COMPILED BY DAM																		
DATUM GEODETIC		DATE July 9, 2013				CHECKED BY AB																		
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)									
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ			GR	SA	SI	CL		
220.6	GROUND SURFACE							20 40 60 80 100	20 40 60 80 100	20 40 60														
0.0	Sand and gravel, some silt, trace clay (FILL) Dense Brown Moist		1	SS	33		220																	34 46 17 3
218.8	Augers grinding on cobbles between 0.5 m and 0.8 m depth.						219																	
1.8	Split spoon attempted at 0.8 m depth, hammer bouncing on cobbles. Switched to NW Casing.																							
	A 150 mm coble encountered at 0.9 m and 1.3 m depths, respectively.		1	RC	REC 100%		218																	RQD = 100%
	DOLOMITIC LIMESTONE (BEDROCK)																							
	Bedrock cored from 1.8 m depth to 4.7 m depth.		2	RC	REC 100%		217																	RQD = 100%
	For coring details see Record of Drillhole M3.																							
215.9	END OF BOREHOLE		3	RC	REC 100%		216																	RQD = 100%
4.7	Note: 1. Borehole dry upon completion of drilling.																							

SUD\_MTO 003 1211910014.5000.GPJ GAL-MISS.GDT 22/08/13 DATA INPUT:



PROJECT: 12-1191-0014

**RECORD OF DRILLHOLE: M3**

SHEET 1 OF 1

LOCATION: N 5078730.0 ; E 326598.7

DRILLING DATE: July 9, 2013

DATUM: GEODETIC

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 850

DRILLING CONTRACTOR: Landcore Drilling Ontario Inc.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH	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	BR - Broken Rock	NOTES WATER LEVELS INSTRUMENTATION
DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH	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	BR - Broken Rock	NOTES WATER LEVELS INSTRUMENTATION
		TOP OF ROCK		218.8									
2	NW	DOLOMITIC LIMESTONE Fine grained Very strong Grey Fresh		1.8	1	GREY	100%						
3	July 9, 2013 NQ Coring				2	GREY	100%						
4					3	GREY	100%						
5		END OF DRILLHOLE		215.9	4.7								
6													
7													
8													
9													
10													
11													

DEPTH SCALE

1 : 50




LOGGED: MR

CHECKED: AB

SUD-RCK 1211910014 5000.GPJ GAL-MISS.GDT 22/08/13 DATA INPUT:



PROJECT 12-1191-0014		<b>RECORD OF BOREHOLE No M4</b>				1 OF 1 <b>METRIC</b>												
W.P. 5466-09-01		LOCATION N 5078736.7; E 326605.3				ORIGINATED BY MR												
DIST _____ HWY 540		BOREHOLE TYPE 108 mm ID Continuous Flight Hollow Stem Augers, NW Casing, NQ Coring				COMPILED BY DAM												
DATUM GEODETIC		DATE July 9, 2013				CHECKED BY AB												
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)
218.8	GROUND SURFACE							20	40	60	80	100						
0.0	Silty ORGANICS, trace to some sand, trace gravel																	
0.2	Brown Moist DOLOMITIC LIMESTONE (BEDROCK)		1	RC	REC 100%	218											RQD = 84%	
	Bedrock cored from 0.2 m depth to 3.3 m depth.																	
	For coring details see Record of Drillhole M4.		2	RC	REC 100%	217											RQD = 100%	
215.5			3	RC	REC 100%	216										RQD = 100%		
3.3	END OF BOREHOLE																	
	Note: 1. Borehole dry upon completion of drilling.																	

SUD\_MTO 003 1211910014.5000.GPJ GAL-MISS.GDT 22/08/13 DATA INPUT:

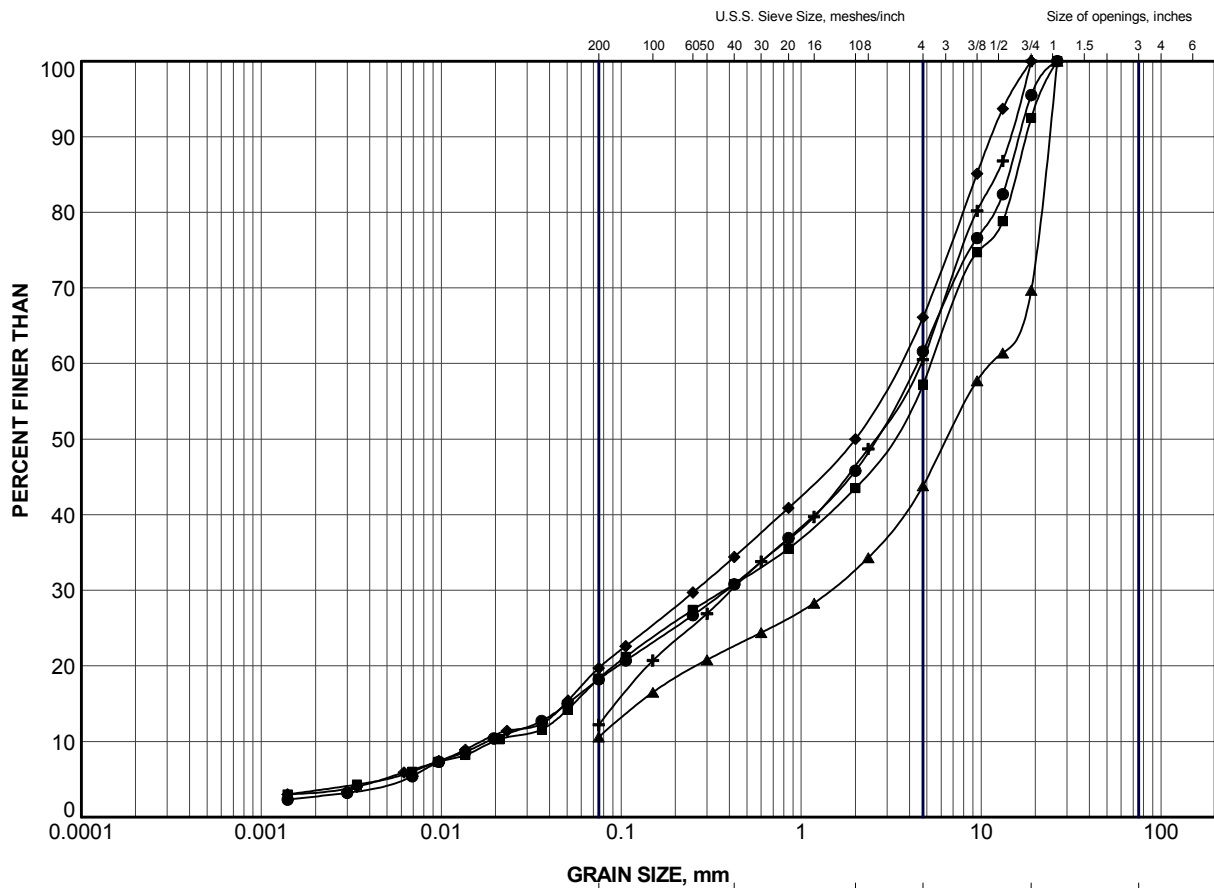




# **APPENDIX B**

## **Laboratory Test Results**





### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	M1	1	220.2
■	M1	2	219.4
▲	M2	2	219.5
+	M2	3	218.8
◆	M3	1	220.3

PROJECT

HIGHWAY 540  
MUD CREEK CULVERT

TITLE

## GRAIN SIZE DISTRIBUTION

SAND and GRAVEL (FILL)

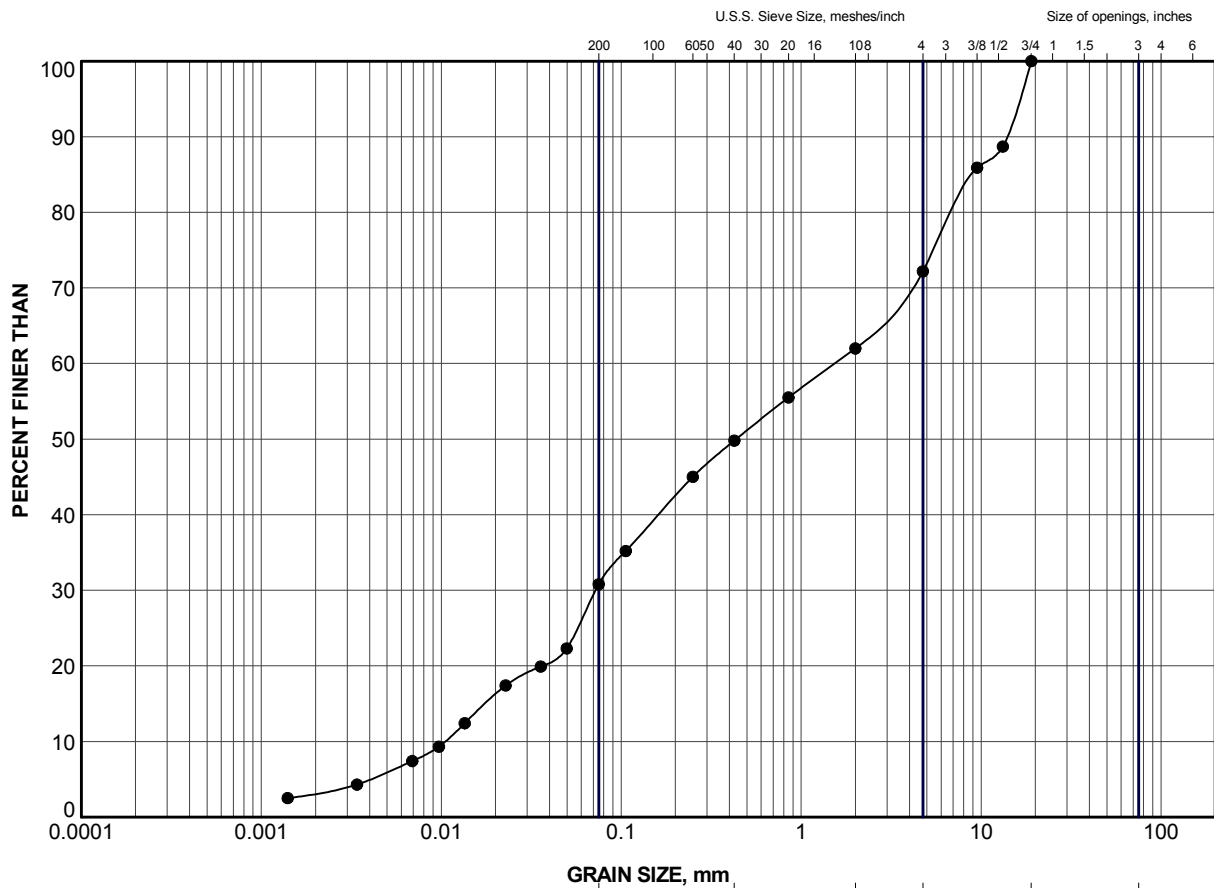


**Golder  
Associates**  
SUDBURY, ONTARIO

PROJECT No.	12-1191-0014	FILE No.	1211910014.5000.GPJ
DRAWN	JJL	Aug 2013	SCALE N/A
CHECK	AB	Aug 2013	REV.
APPR		Aug 2013	

**FIGURE B1**






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

#### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	M1	3b	218.5

PROJECT					HIGHWAY 540 MUD CREEK CULVERT				
TITLE					GRAIN SIZE DISTRIBUTION GRAVELLY SILTY SAND				
PROJECT No.		12-1191-0014			FILE No.		1211910014.5000.GPJ		
DRAWN	JJL	Aug 2013			SCALE	N/A	REV.		
CHECK	AB	Aug 2013			FIGURE B2				
APPR		Aug 2013							
 <b>Golder Associates</b> SUDBURY, ONTARIO									



Borehole M1  
Elevation 218.3 m to 214.9 m



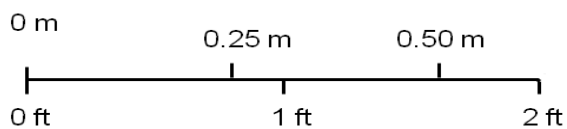
Borehole M2  
Elevation 218.5 m to 215.1 m




Borehole M3  
Elevation 218.8 m to 215.9 m



Borehole M4  
Elevation 218.6 m to 215.5 m



PROJECT		HWY 540 MUD CREEK CULVERT			
TITLE		BEDROCK CORE			
		PROJECT No. 12-1191-0014		FILE No. ----	
		DESIGN	DAM	Aug. 2013	SCALE AS SHOWN
		CADD	--		REV.
		CHECK	AB	Aug. 2013	
		REVIEW			
					<b>FIGURE B3</b>



At Golder Associates we strive to be the most respected global company providing consulting, design, and construction services in earth, environment, and related areas of energy. Employee owned since our formation in 1960, our focus, unique culture and operating environment offer opportunities and the freedom to excel, which attracts the leading specialists in our fields. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees who operate from offices located throughout Africa, Asia, Australasia, Europe, North America, and South America.

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Europe	+ 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 55 21 3095 9500

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