



November 27, 2014

FOUNDATION INVESTIGATION REPORT

**BEAR CREEK CULVERT AT STA 14+960, SITE 43-231/C
HIGHWAY 17 REHABILITATION BETWEEN WARREN AND VERNER
FROM HIGHWAY 539 EASTERLY TO 0.2 KM EAST
OF WEST JUNCTION OF HIGHWAY 64
TOWNSHIP OF KIRKPATRICK, ONTARIO
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 300-8-00, WP300-98-01**

Submitted to:

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Distribution:

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REPORT





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PART A

FOUNDATION INVESTIGATION REPORT
BEAR CREEK CULVERT AT STA 14+960, SITE 43-231/C
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Morrison Hershfield Limited (MH), on behalf of the Ministry of Transportation, Ontario (MTO), to provide foundation engineering services for the replacement of the Highway 17 Bear Creek culvert (Site 43-231/C) at STA 14+960 in the Township of Kirkpatrick, Municipality of West Nipissing, Ontario. The Key Plan showing the general location of this section of Highway 17 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 soil samples.

2.0 SITE DESCRIPTION

The Bear Creek culvert is located on Highway 17 east of Warren, approximately 7 km east of the junction of Highway 539. In general, the topography in the area of the overall project limits consists of flat terrain primarily utilized as farmland, with moderate tree cover. The existing highway grade is at about Elevation 208 m with Bear Creek crossing under the embankment about 7 m below the existing highway grade. The side slopes of the existing embankment are inclined at about 2 Horizontal to 1 Vertical (2H:1V) and are vegetated with various grasses. The existing structure is a twin cell reinforced concrete culvert constructed in 1948. The culvert is 40 m long and each cell has a span of 5.3 m and an opening of 3.2 m high.

3.0 INVESTIGATION PROCEDURES

The fieldwork for the investigation was carried out on December 10, 2013, January 13 and 20, February 3 and 4 and March 4 to 12, 2014, during which time a total of six boreholes and one Dynamic Cone Penetration Test (DCPT) were advanced at the approximate locations shown on Drawing 1:

- three boreholes for the culvert alignment (Boreholes BE-1, BE-4 and BE-5 with an adjacent DCPT);
- one borehole for the proposed roadway protection (Borehole BE-2); and
- two boreholes for the proposed cofferdam (Boreholes BE-3 and BE-6).

Boreholes BE-1 and BE-2, located on the existing highway embankment, were advanced using a truck-mounted CME 55 drill rig outfitted with 108 mm inside diameter continuous flight hollow-stem augers and NW casing, supplied and operated by Landcore Drilling Inc. (Landcore) of Sudbury, Ontario. Boreholes BE-3, BE-5 and BE-6, were advanced by portable equipment using wash boring methods with NQ casing, supplied and operated by Landcore or George Downing Estate Drilling Ltd. of Grenville-Sur-La-Rouge, Quebec. Borehole BE-4 was advanced using a track mounted CME 55 drill rig operated by Landcore. At Borehole BE-6, an excavator was used to remove about 2.0 m of cobble and boulder sized rock fill material mixed with sand and gravel prior to advancing the borehole with the portable equipment. A DCPT was advanced adjacent to Borehole BE-5 using portable equipment.

Soil samples were obtained at intervals of depths of about 0.75 m and 1.5 m, using a 50 mm outer diameter (O.D.) split-spoon sampler driven by an automatic hammer at Boreholes BE-1, BE-2 and BE-4 and a manual hammer at Boreholes BE-3, BE-5 and BE-6, and performed in accordance with Standard Penetration Test (SPT)



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procedure (ASTM D1586). The DCPT was driven by a manual hammer. Selected samples of the cohesive soils were obtained using 76 mm O.D. thin-walled 'Shelby' tubes (ASTM D1587, Standard Practice for Thin-Walled Tube Sampling) for relatively undisturbed samples. Field vane shear tests were conducted in cohesive soils for determination of undrained shear strengths (ASTM D2573, Standard Test Method for Field Vane Strength Shear Test) using MTO Standard 'N' size vanes. The groundwater conditions and water levels in the open boreholes were observed during the drilling operations and are described on the Record of Borehole sheets in Appendix A. All boreholes were backfilled with bentonite upon completion of drilling in accordance with Ontario Regulation 903 (as amended).

The fieldwork was supervised throughout by members of our technical staff, who located the boreholes and DCPT, arranged for the clearance of underground services, observed the drilling, sampling and in situ testing operations, logged the boreholes, and examined and cared for the soil samples. The samples were identified in the field, placed in appropriate containers, labelled and transported to our Sudbury 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 content, organic content, Atterberg limits and grain size distribution) was carried out on selected soil samples. The results of the laboratory testing are presented on the Record of Borehole sheets in Appendix A and are also included in Appendix B.

A sample of the creek water was obtained on March 10, 2014, using appropriate sampling protocols and submitted to a specialist analytical laboratory under chain of custody procedures for testing for a suite of parameters. The results of the analytical testing are summarized in Table B1 in Appendix B, together with the detailed analytical laboratory test results.

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

Borehole	Borehole Location		Ground/Ice Surface Elevation (m)	Borehole/DCPT Depth Below Ground/Ice Surface (m)
	Northing	Easting		
BE-1	5 143 672.4	248 753.9	207.6	18.3
BE-2	5 143 666.4	248 728.6	207.4	16.3
BE-3	5 143 691.3	248 722.7	200.9	14.2*
BE-4	5 143 685.2	248 742.9	203.4	14.3
BE-5	5 143 655.6	248 749.4	202.1	20.7/14.6
BE-6	5 143 649.4	248 769.8	202.7	14.7

*includes 1.5 m column of water



4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on terrain mapping (Ontario Geological Survey¹), the site is located on a glaciolacustrine plain in an area of sand and silt deposits with bedrock knobs/outcrops located approximately 100 m to the south of the site.

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 core samples, are given on the Record of Borehole sheets in Appendix A. The results of the in situ tests (i.e., SPT “N”-values and undrained shear strengths from the field vanes) as presented on the Record of Borehole sheets and in Section 4 are uncorrected. Detailed results of the laboratory testing of the soil samples are provided in Appendix B. The stratigraphic boundaries shown on the Record of Borehole sheets and on the stratigraphic profile and cross-section shown on Drawing 1 are inferred from non-continuous sampling, observations of drilling progress and the results of SPTs and in situ testing. 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.

4.2.1 Ice/Water

Borehole BE-3 was advanced from a wooden platform extending across the creek. At the time of drilling, the ice/water column was 1.5 m deep and the creek water surface was at Elevation 200.9 m.

4.2.2 Fill

Boreholes BE-1 and BE-2 penetrated a layer of asphalt 250 mm and 175 mm thick at Elevation 207.6 m and 207.4 m, respectively. Underlying the asphalt, the boreholes encountered 7.1 m and 7.2 m of fill comprised of sand and gravel and blast rock of cobble and boulder size; ranging from 90 mm to 910 mm in diameter. In Borehole BE-4, a 2.1 m thick layer of blast rock fill was encountered from ground surface at Elevation 203.4 m. In Borehole BE-5, a 4.6 m thick layer of fill was encountered from ground surface at Elevation 202.1 m, consisting of an upper thick layer of 1.2 m of sandy silt with trace organics and a lower layer 3.4 m thick clayey silt to silty clay mixed in places with sand or sand and gravel. In Borehole BE-6, a 2.0 m thick layer of blast rock fill consisting of cobble and boulder sites mixed with sand and gravel was encountered at ground surface at Elevation 202.7 m underlain by a 1.9 m thick layer of clayey silt to silty clay fill.

SPT ‘N’-values measured within the fill are as follows:

- Sand and gravel and blast rock: 9 blows to 65 blows per 0.3 m of penetration, indicating a loose to very dense relative density, with two SPT penetrating only up to 0.1 m, indicative of the blast rock fill;

¹ Southern Ontario Engineering Geology Terrain Study, 1980. Ontario Geological Survey.



- Sandy silt: 3 blows per 0.3 m of penetration indicating a very loose relative density; and
- Clayey silt to silty clay: between 2 blows and 34 blows per 0.3 m of penetration. Two situ field vane tests within the clayey silt to silty clay measured undrained shear strengths of 15 kPa and 30 kPa, with sensitivities of 3 and 5. The SPT N-values together with the in situ vane test results indicate that the deposit has a soft to hard consistency.

4.2.3 Gravelly Sand to Silty Sand

Underlying the fill in Boreholes BE-1, BE-4, to BE-6 a deposit of gravelly sand to silty sand was encountered about Elevation 201.3 m and 197.5 m, and the thickness of the deposit is between 0.7 m and 3.0 m.

SPT 'N'-values measured within this deposit range between 11 blows and 29 blows per 0.3 m of penetration, indicating a compact relative density.

Grain size distribution analyses were carried out on two samples of this deposit and the results are presented on Figure B1 in Appendix B.

The natural moisture content measured on two samples of this deposit is about 18 per cent.

4.2.4 Sand and Silt to Silt

Underlying the gravelly sand in Borehole BE-1 at about Elevation 198.9 m and underlying the fill in Borehole BE-2 at about Elevation 200.1 m, a 1.5 m and 1.3 m thick deposit of sand and silt to silt was encountered in the respective boreholes.

Two SPT 'N'-values measured within this deposit are 5 blows and 6 blows per 0.3 m of penetration, indicating a loose relative density.

Grain size distribution analyses were carried out on two samples of this deposit and the results are presented on Figure B2 in Appendix B.

An Atterberg limits test was carried out on a sample of the sand and silt deposit and measured a liquid limit of about 37 per cent, a plastic limit of about 26 per cent, and a plasticity index of about 11 per cent. The results, which are plotted on a plasticity chart on Figures B3, indicate that the tested sample consist of silt of intermediate plasticity. One Atterberg limits test carried out on a select sample of the silt deposit indicates that the material is non-plastic.

The natural moisture content measured on samples of this deposit range from about 27 per cent and 39 per cent.

4.2.5 Clayey Silt to Silty Clay

A deposit of clayey silt to silty clay was encountered in all of the boreholes between Elevation 200.5 m and 195.8 m and was explored for a thickness between 7.7 m and 15.4 m without fully penetrating the deposit. Silt laminations/layers were observed in numerous samples of this deposit.



The SPT 'N'-values measured within the clayey silt to silty clay deposit range between 0 blows (weight of hammer) and 11 blows per 0.3 m of penetration. In situ field vane testing at various depths within the deposit measured undrained shear strengths ranging from 15 kPa to 72 kPa with sensitivities between 1 and 5. The in situ vane test results indicate that the deposit has a soft to stiff consistency with the majority of the undrained shear strengths generally in the firm range.

The results of the grain size distribution tests completed on three samples of this deposit are shown on Figure B4; one sample of the silt layer in Borehole BE-4 is shown on Figure B2.

Atterberg limits tests were carried out on sixteen samples of the cohesive deposit and measured liquid limits ranging from about 28 per cent to 44 per cent with one result of about 5 per cent, plastic limits ranging from about 19 per cent to 23 per cent, and plasticity indices ranging from about 8 per cent to 28 per cent. The results, which are plotted on a plasticity chart on Figures B5, indicate that the tested samples of the overall deposit consist of clayey silt of low plasticity to silty clay of intermediate plasticity with one result indicating a clay of high plasticity. One Atterberg limits test carried out on a sample of the silt layer indicates that the material is non-plastic.

The natural moisture content measured on selected samples of this deposit generally ranges between about 24 per cent and 48 per cent.

4.2.6 Groundwater Conditions

The depth to the water level in Boreholes BE-1, BE-2, BE-4 to BE-6 upon completion of drilling was measured at depths between 0.9 m and 5.2 m below ground surface, between Elevation 206.7 m and 198.7 m. The creek ice/water surface at Borehole BE-3 was Elevation 200.9 m on March 4, 2014.

Groundwater levels encountered in the boreholes during and shortly after drilling may not be representative of static groundwater levels since the groundwater levels in the boreholes may not have stabilized on completion of drilling. Groundwater levels are subject to seasonal fluctuations and to fluctuations due to precipitation events and snowmelt.

5.0 CLOSURE

The drilling program was supervised by Messrs. Trevor Moxam, Mat Riopelle, Gabriel Mathieu and Shane Albert. This report was prepared by Mr. Adam Core, E.I.T. The technical aspects were reviewed by Mr. André Bom, P.Eng., and Mr. Jorge M. A. Costa, P.Eng., Principal and Golder's Designated MTO Contact for this project, conducted an independent quality control review of the report.



FOUNDATION REPORT HIGHWAY 17 BEAR CREEK CULVERT, SITE 43-231/C

Report Signature Page

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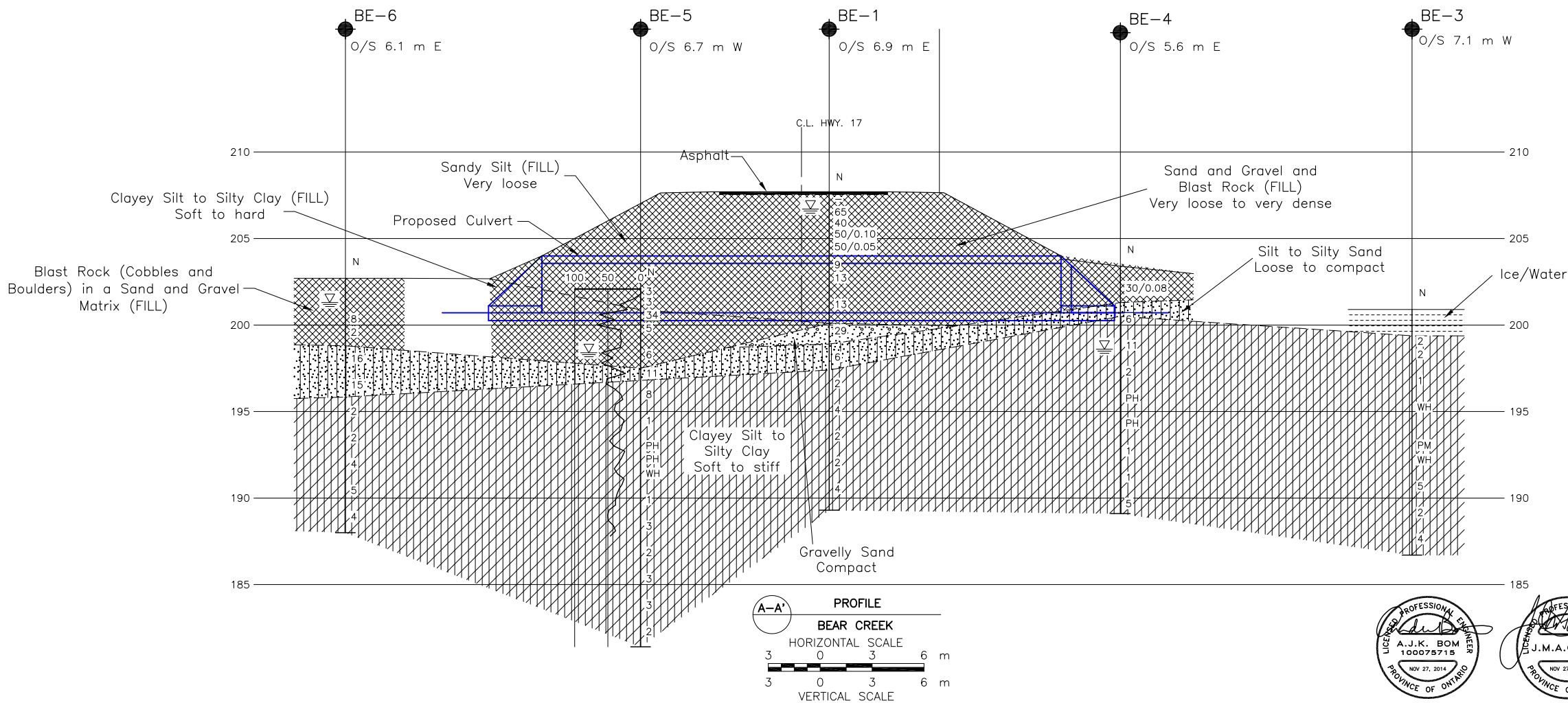
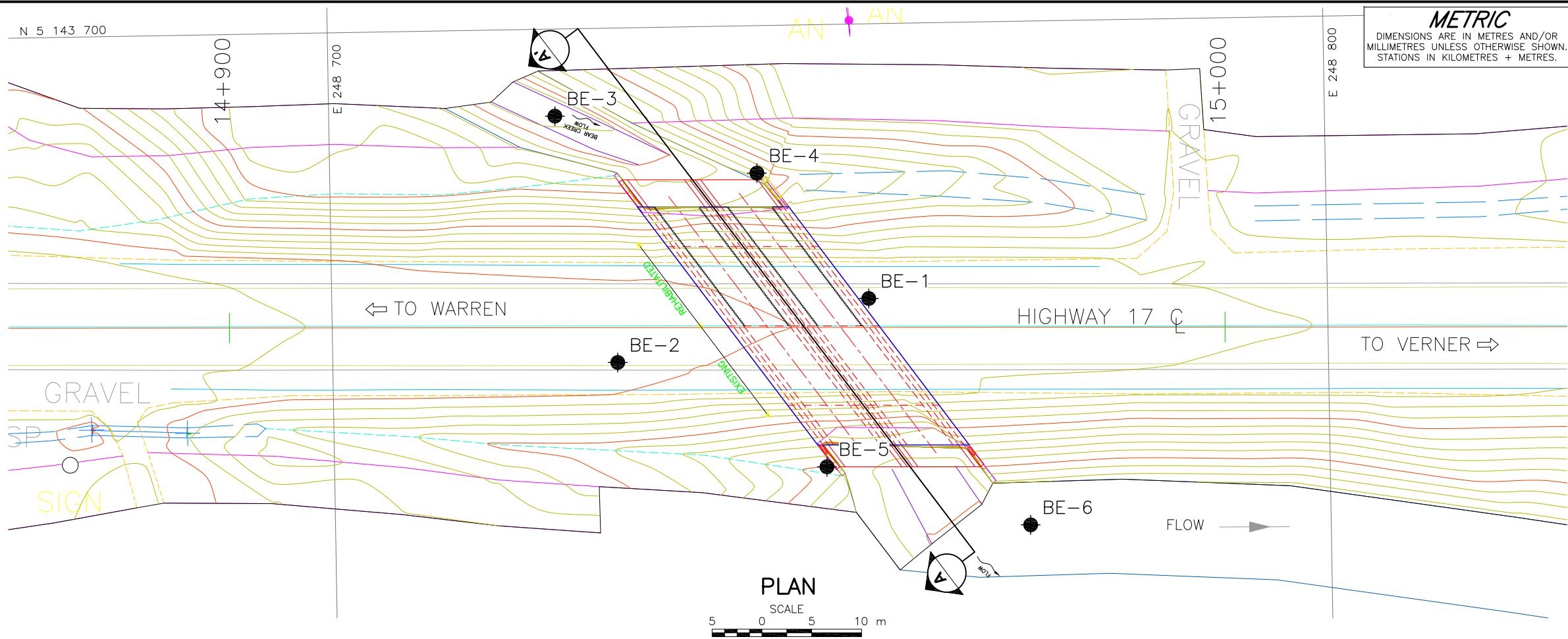


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fidr bear creek.docx



CONT No.
WP No. 300-98-01

HIGHWAY 17
BEAR CREEK CULVERT - STA 14+960
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

Golder Associates Ltd.
SUDBURY, ONTARIO, CANADA



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			
No.	ELEVATION	NORTHING	EASTING
BE-1	207.6	5143672.4	248753.9
BE-2	207.4	5143666.4	248728.6
BE-3	200.9	5143691.3	248722.7
BE-4	203.4	5143685.2	248742.9
BE-5	202.1	5143655.6	248749.4
BE-6	202.7	5143649.4	248769.8

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.

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 Morrison Hershfield, drawing file no. X-1130113_Base Plan.dwg, received NOV 13, 2014 and 43-231C_01.dwg, received NOV 13, 2014.

NO.	DATE	BY	REVISION
Geocres No. 411-321			
HWY. 17	PROJECT No. 13-1184-0074		DIST.
SUBM'D. MT	CHKD.	DATE: NOV 2014	SITE: 43-231/C
DRAWN: TB	CHKD. AB	APPD. JMAC	DWG. 1



APPENDIX A

Record of Boreholes



LIST OF SYMBOLS

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

(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_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

* Density symbol is ρ . Unit weight symbol is γ 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 cm² 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

	kPa	C_u, S_u	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 ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
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_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	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

PROJECT 13-1184-0074			RECORD OF BOREHOLE No BE-1			1 OF 2 METRIC															
W.P. 300-98-01			LOCATION N 5143672.4; E 248753.9			ORIGINATED BY SA															
DIST _____ HWY 17			BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers, NW Casing, Wash Boring			COMPILED BY MT															
DATUM GEODETIC			DATE December 10, 2013			CHECKED BY DAM															
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ			GR SA SI CL		
207.6	GROUND SURFACE							20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					W _p — W — W _L 20 40 60			kN/m ³					
0.0	ASPHALT (250 mm)																				
0.3	Sand and gravel and blast rock (FILL) Loose to very dense Brown Moist to wet		1	AS	-		207														
			2	SS	65		206														
			3	SS	40		205														
			4	SS	50/0 10		204														
			5	SS	50/0 05		203														
	Switched to casing at 3.0 m depth. Cobbles recovered in casing barrel as follows:		6	SS	9		202														
	Depth (m) Thickness (mm) 3.1 150 3.5 100 7.3 200		7	SS	13		201														
			8	SS	13		200														
200.1			9	SS	29		199														
7.5	Gravelly SAND, some silt, trace to some clay Compact Grey Wet		10	SS	6		198														
198.9	SILT, trace to some clay Loose Grey Wet		11	SS	2		197														
197.4	CLAYEY SILT to SILTY CLAY Firm to stiff Grey Wet		12	SS	4		196														
10.2			13	SS	2		195														
							194														
							193														

Continued Next Page

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

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 28/10/14 DATA INPUT:

PROJECT <u>13-1184-0074</u>				RECORD OF BOREHOLE No BE-1				2 OF 2 METRIC									
W.P. <u>300-98-01</u>				LOCATION <u>N 5143672.4; E 248753.9</u>				ORIGINATED BY <u>SA</u>									
DIST <u> </u> HWY <u>17</u>				BOREHOLE TYPE <u>108 mm I.D. Continuous Flight Hollow Stem Augers, NW Casing, Wash Boring</u>				COMPILED BY <u>MT</u>									
DATUM <u>GEODETIC</u>				DATE <u>December 10, 2013</u>				CHECKED BY <u>DAM</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 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	--- CONTINUED FROM PREVIOUS PAGE ---							20	40	60	80	100					
	CLAYEY SILT to SILTY CLAY Firm to stiff Grey Wet		14	SS	2		192										0 0 62 38
	Silt laminations encountered below 16.8 m depth.						191			4							
			15	SS	4												
							190			4							
189.3 18.3	END OF BOREHOLE Note: 1. Water level at a depth of 0.9 m below ground surface (Elev. 206.7 m) upon completion of drilling.																

PROJECT 13-1184-0074			RECORD OF BOREHOLE No BE-2			1 OF 2 METRIC													
W.P. 300-98-01			LOCATION N 5143666.4; E 248728.6			ORIGINATED BY SA/TM													
DIST _____ HWY 17			BOREHOLE TYPE NW Casing, Wash Boring			COMPILED BY MT													
DATUM GEODETIC			DATE January 14 and February 3 and 4, 2014			CHECKED BY DAM													
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa			WATER CONTENT (%)			γ					
207.4	GROUND SURFACE							20 40 60 80 100	○ UNCONFINED	+	FIELD VANE	W _p	W	W _L					
0.0	ASPHALT (175 mm)							20 40 60 80 100	● QUICK TRIAXIAL	×	REMOULDED								
0.2	Sand and gravel and blast rock (FILL) Compact Brown Wet Inferred cobbles and boulders as follows: Depth (m) Thickness (mm) 0.8 90 0.9 150 1.1 150 1.5 200 2.0 85 2.3 460 3.0 100 3.2 100 3.7 360 4.7 700 5.4 300 5.8 230 6.9 125		1	SS	50/0.13			207											
							206												
							205												
							204												
							203												
							202												
			2	SS	19		201												
200.1							200												
7.3	SILT and SAND, trace to some clay Loose Grey Wet		3	SS	5		199												
198.8							198												
8.6	CLAYEY SILT to SILTY CLAY Soft to stiff Grey Wet		4	SS	7		197												
							196												
			5	SS	1		195												
							194												
			6	SS	WH		193												
			7	SS	2														

Continued Next Page

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

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 28/10/14 DATA INPUT:

PROJECT 13-1184-0074				RECORD OF BOREHOLE No BE-2				2 OF 2 METRIC								
W.P. 300-98-01				LOCATION N 5143666.4; E 248728.6				ORIGINATED BY SA/TM								
DIST _____ HWY 17				BOREHOLE TYPE NW Casing, Wash Boring				COMPILED BY MT								
DATUM GEODETIC				DATE January 14 and February 3 and 4, 2014				CHECKED BY DAM								
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					WATER CONTENT (%)			
	--- CONTINUED FROM PREVIOUS PAGE ---						20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					W _p W W _L 20 40 60				
191.1	CLAYEY SILT to SILTY CLAY Soft to stiff Grey Wet		8	SS	3	192										
16.3	END OF BOREHOLE Note: 1. Water level at a depth of 5.2 m below ground surface (Elev. 202.2 m) on February 4, 2014 prior to advancing borehole into native soils.															

PROJECT 13-1184-0074			RECORD OF BOREHOLE No BE-3			1 OF 1 METRIC											
W.P. 300-98-01			LOCATION N 5143691.3; E 248722.7			ORIGINATED BY MR											
DIST HWY 17			BOREHOLE TYPE NW Casing, Wash Boring			COMPILED BY MT											
DATUM GEODETIC			DATE March 4, 2014			CHECKED BY DAM											
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					WATER CONTENT (%) W _p — W — W _L			γ	GR SA SI CL
200.9 0.0	ICE SURFACE ICE/WATER							20 40 60 80 100									
199.4 1.5	CLAYEY SILT to SILTY CLAY Firm to stiff Grey Wet		1	SS	2			200									
			2	SS	2			199									
								198									
			3	SS	1			197									
								196									
			4	SS	WH			195									
								194									
								193									
			5	TO	PM			192									
			6	SS	WH			191									
								190									
			7	SS	5			189									
								188									
			8	SS	2			187									
			9	SS	4												
186.7 14.2	END OF BOREHOLE																

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 28/10/14 DATA INPUT:

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

PROJECT <u>13-1184-0074</u>				RECORD OF BOREHOLE No BE-4				1 OF 2 METRIC						
W.P. <u>300-98-01</u>		LOCATION <u>N 5143685.2; E 248742.9</u>				ORIGINATED BY <u>GM</u>								
DIST <u> </u> HWY <u>17</u>		BOREHOLE TYPE <u>NW Casing, Wash Boring</u>				COMPILED BY <u>MT</u>								
DATUM <u>GEODETIC</u>		DATE <u>March 10 and 11, 2014</u>				CHECKED BY <u>DAM</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 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
203.4	GROUND SURFACE													
0.0	Blast rock (FILL)													
201.3														
2.1	Silty SAND, trace clay Brown Wet													
200.5			2A											
2.9	CLAYEY SILT to SILTY CLAY, trace sand Firm to stiff Brown to grey Wet Approximately 0.6 m thick silt layer at 4.0 m depth.		2B	SS	6									
			3	SS	11									
			4	SS	2									
			5	TO	PH									
			6	TO	PH									
			7	SS	1									
			8	SS	1									
			9	SS	5									
189.1														
14.3														

Continued Next Page

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

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 28/10/14 DATA INPUT:

PROJECT <u>13-1184-0074</u>		RECORD OF BOREHOLE No BE-4				2 OF 2 METRIC										
W.P. <u>300-98-01</u>		LOCATION <u>N 5143685.2; E 248742.9</u>				ORIGINATED BY <u>GM</u>										
DIST <u> </u> HWY <u>17</u>		BOREHOLE TYPE <u>NW Casing, Wash Boring</u>				COMPILED BY <u>MT</u>										
DATUM <u>GEODETIC</u>		DATE <u>March 10 and 11, 2014</u>				CHECKED BY <u>DAM</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 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa								
	--- CONTINUED FROM PREVIOUS PAGE ---															
	END OF BOREHOLE Note: 1. Water level at a depth of 2.3 m below ground surface (Elev. 201.1 m) upon completion of drilling.															

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 28/10/14 DATA INPUT:

PROJECT			RECORD OF BOREHOLE No BE-5			1 OF 2 METRIC		
W.P.			LOCATION			ORIGINATED BY GM		
DIST HWY			BOREHOLE TYPE NW Casing, Wash Boring			COMPILED BY MT		
DATUM GEODETIC			DATE January 13 and 20, 2014			CHECKED BY DAM		
ELEV DEPTH	DESCRIPTION	STRAT PLOT						
202.1	GROUND SURFACE							
0.0	Sandy silt, trace organics, trace to some clay (FILL) Very loose Brown Wet							
200.9								
1.2	Clayey silt to silty clay, trace to some sand, trace gravel (FILL) Soft to hard Grey Wet							
	Approximately 150 mm thick layer of sand and 1.4 m depth. Refusal to further casing advancement at 1.7 m depth. Approximately 0.5 m and 0.3 m thick sand and gravel layer at 2.3 m and 3.5m depth respectively.							
197.5								
4.6	SILTY SAND Compact Brown Wet							
196.8								
5.3	CLAYEY SILT to SILTY CLAY Soft to stiff Grey Wet							
	Silt laminations between 7.3 m and 8.4 m depth.							
	Silt laminations between 10.7 m and 11.4 m depth.							
	Silt laminations encountered between 13.8 m and 17.5 m depth.							
NUMBER	TYPE	"N" VALUES						
1	SS	3						
2	SS	3						
3	SS	34						
4	SS	5						
5	SS	6						
6	SS	11						
7	SS	8						
8	SS	1						
9	TO	PH						
10	TO	PH						
11	SS	WH						
12	SS	1						
13	SS	3						

PROJECT 13-1184-0074				RECORD OF BOREHOLE No BE-5				2 OF 2 METRIC									
W.P. 300-98-01				LOCATION N 5143655.6; E 248749.4				ORIGINATED BY GM									
DIST _____ HWY 17				BOREHOLE TYPE NW Casing, Wash Boring				COMPILED BY MT									
DATUM GEODETIC				DATE January 13 and 20, 2014				CHECKED BY DAM									
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 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	--- CONTINUED FROM PREVIOUS PAGE ---																
	CLAYEY SILT to SILTY CLAY Soft to stiff Grey Wet		14	SS	2		187										
	Silt laminations between 16.5 m and 17.5 m depth.		15	SS	3		186										
							185										
			16	SS	3		184										
							183										
			17	SS	2		182										
181.4 20.7	END OF BOREHOLE																
	Note: 1. Refusal to further casing advancement encountered at 1.7 m depth. 2. Water level at a depth of 3.4 m below ground surface (Elev. 198.7 m) upon completion of drilling.																

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

PROJECT 13-1184-0074		RECORD OF BOREHOLE No BE-6		1 OF 2 METRIC	
W.P. 300-98-01		LOCATION N 5143649.4; E 248769.8		ORIGINATED BY MR	
DIST _____ HWY 17		BOREHOLE TYPE Excavator, NW Casing, Wash Boring		COMPILED BY MT	
DATUM GEODETIC		DATE March 12, 2014		CHECKED BY DAM	

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						
								UNCONFINED ○	FIELD VANE +					
202.7	GROUND SURFACE													
0.0	Blast rock (cobbles and boulders) in a sand and gravel matrix (FILL)													
200.7														
2.0	Clayey silt to silty clay trace to some sand (FILL) Soft to firm Grey Wet		1	SS	8									
			2	SS	2									
198.8														
3.9	SILTY SAND, some gravel, trace clay Compact Grey Wet		3	SS	16									
			4	SS	15									
195.8														
6.9	CLAYEY SILT to SILTY CLAY Firm to stiff Grey Wet Silt laminations between 6.9 and 8.4 m depth.		5	SS	2									
			6	SS	2									
			7	SS	4									
			8	SS	5									
			9	SS	4									
188.0														
14.7														

Continued Next Page

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

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 28/10/14 DATA INPUT:

PROJECT <u>13-1184-0074</u>		RECORD OF BOREHOLE No BE-6				2 OF 2 METRIC	
W.P. <u>300-98-01</u>		LOCATION <u>N 5143649.4; E 248769.8</u>				ORIGINATED BY <u>MR</u>	
DIST <u> </u> HWY <u>17</u>		BOREHOLE TYPE <u>Excavator, NW Casing, Wash Boring</u>				COMPILED BY <u>MT</u>	
DATUM <u>GEODETIC</u>		DATE <u>March 12, 2014</u>				CHECKED BY <u>DAM</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 (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					W _p	W			W _L
	--- CONTINUED FROM PREVIOUS PAGE ---						<div style="display: flex; justify-content: space-between;"> 20 40 60 80 100 </div> <div style="display: flex; justify-content: space-between;"> 20 40 60 80 100 </div>										
	END OF BOREHOLE Note: 1. Excavated blast rock fill to a depth 2.0 m. 2. Water level at a depth of 1.4 m below ground surface (Elev. 201.3 m) upon completion of drilling.																



APPENDIX B

Laboratory Test Results



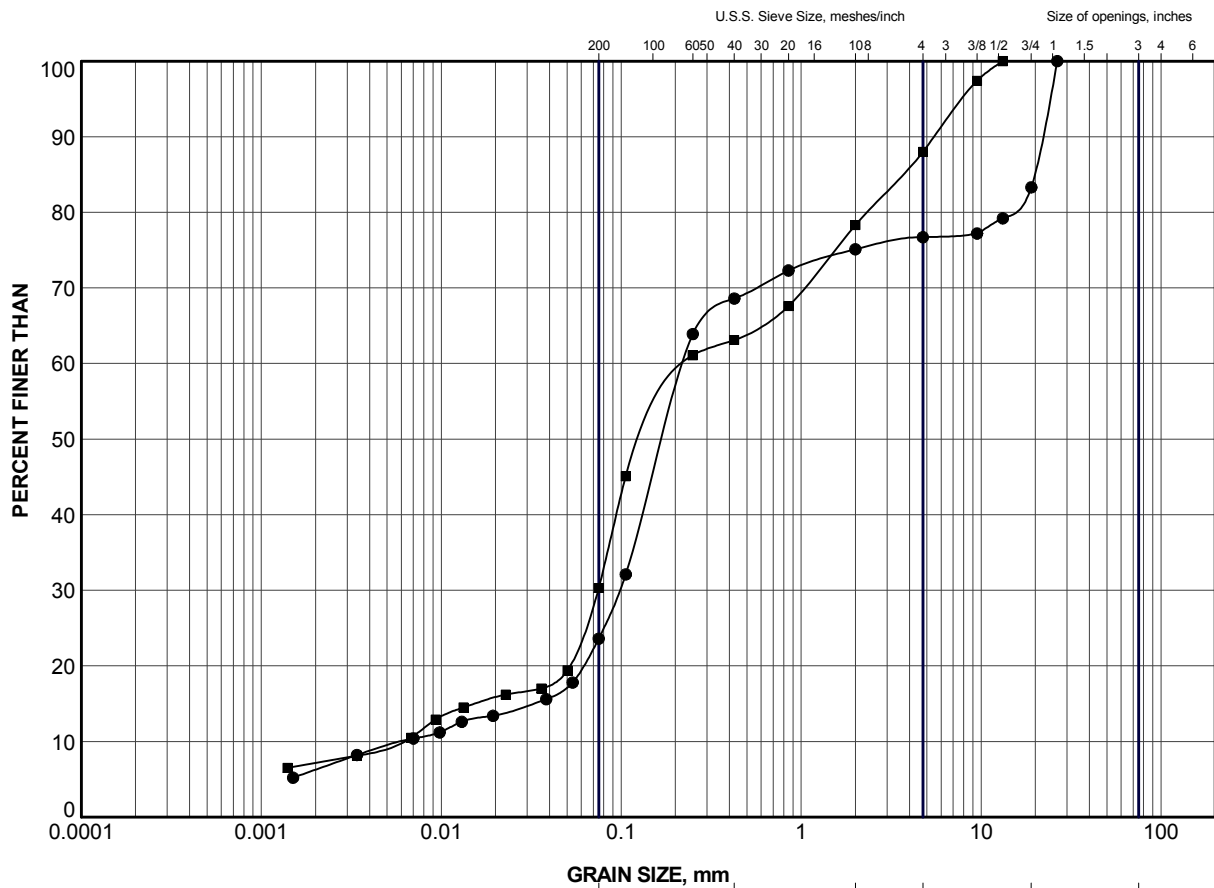
**FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 17 BEAR CREEK CULVERT, SITE 43-231C**

Table B1 - Summary of Analytical Testing of Bear Creek Water Sample

Parameter	Units	Reportable Detection Limit	Result
Dissolved Chloride	mg/L	1	4
Dissolved Sulphate	mg/L	1	2
Conductivity	µohm/cm	1	95
Resistivity	ohm-cm	n/a	11,000
pH	n/a	n/a	7.21


Notes: 1. Sample obtained on March 10, 2014.
2. Analytical testing carried out by Maxxam Analytics.

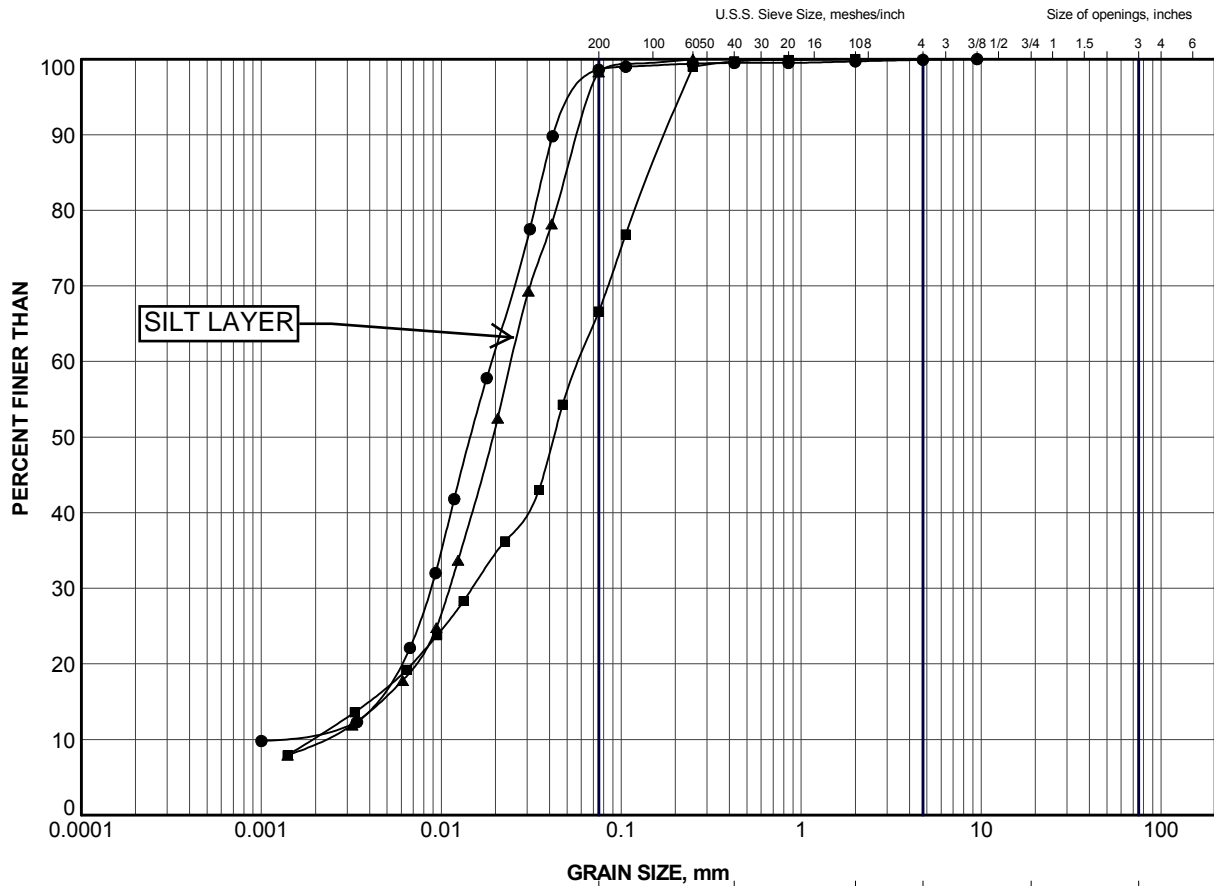
Checked by: AB



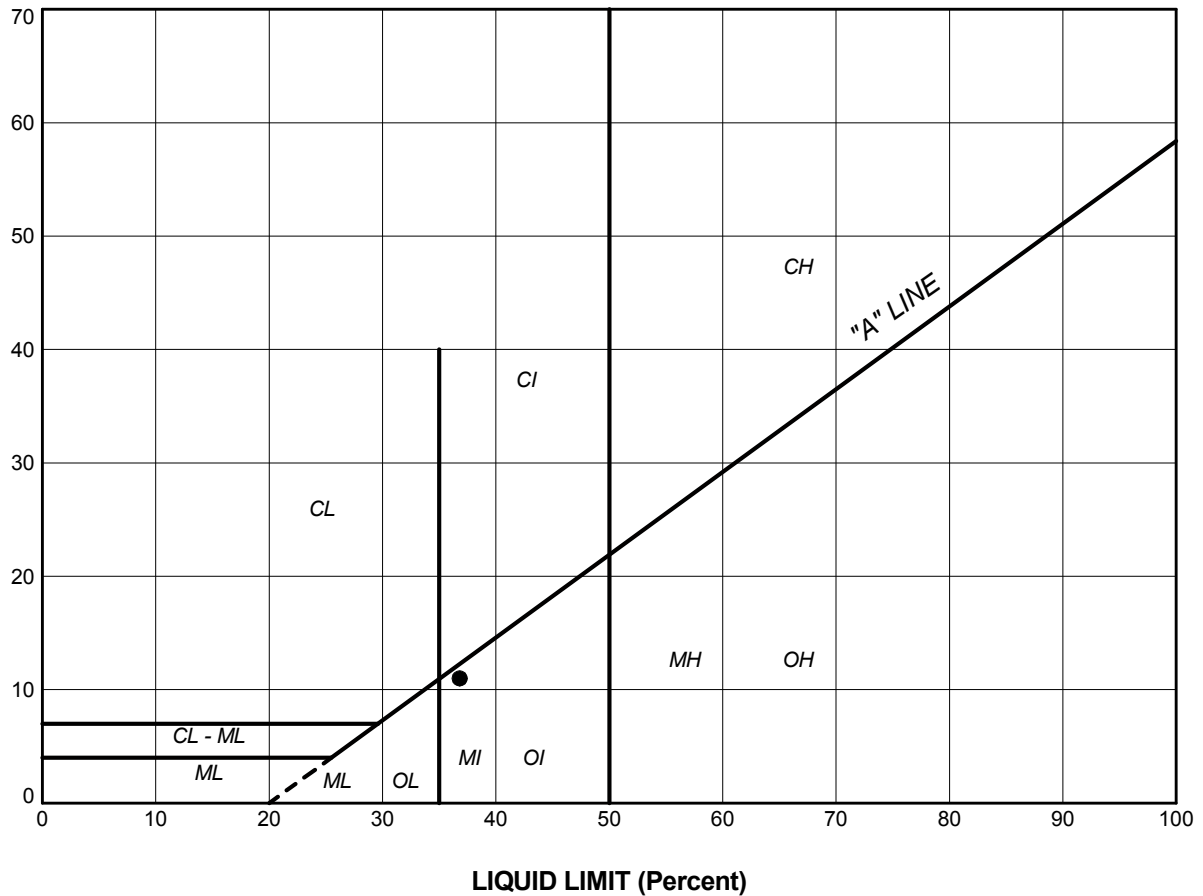
LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BE-1	9	199.7
■	BE-6	3	198.1

PROJECT					
HIGHWAY 17 BEAR CREEK CULVERT - STA 14+960					
TITLE					
GRAIN SIZE DISTRIBUTION GRAVELLY SAND to SILTY SAND					
PROJECT No.		13-1184-0074		FILE No. 13-1184-0074.GPJ	
DRAWN	TB	Oct 2014	SCALE	N/A	REV.
CHECK	AB	Oct 2014			
APPR	JMAC	Oct 2014			
 Golder Associates SUDBURY, ONTARIO			FIGURE B1		



PLASTICITY INDEX (Percent)




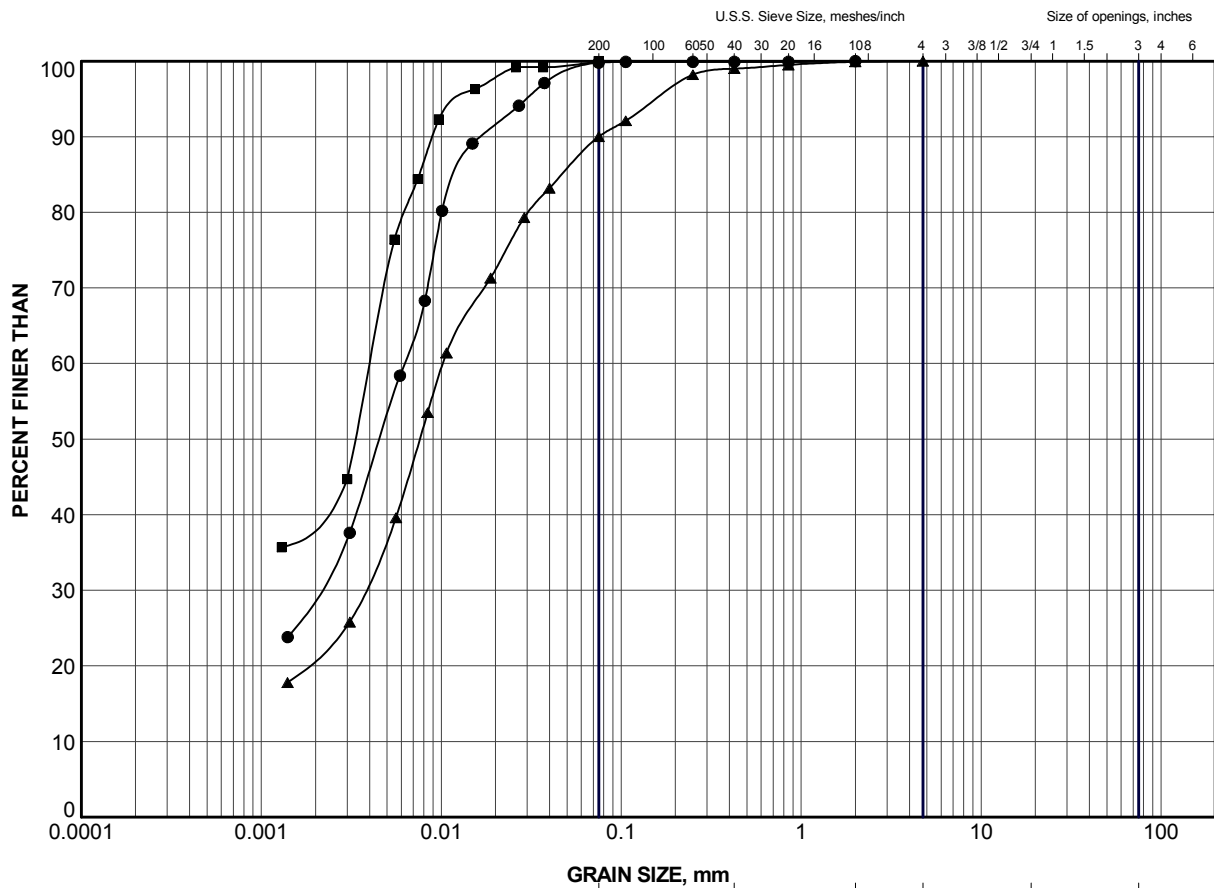
SOIL TYPE
 C = Clay
 M = Silt
 O = Organic

PLASTICITY
 L = Low
 I = Intermediate
 H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	BE-2	3	36.8	25.8	11.0

PROJECT					
HIGHWAY 17 BEAR CREEK CULVERT - STA 14+960					
TITLE					
PLASTICITY CHART SILT and SAND					
PROJECT No.		13-1184-0074		FILE No.	
DRAWN		TB		Oct 2014	
CHECK		AB		Oct 2014	
APPR		JMAC		Oct 2014	
SCALE		N/A		REV.	
 Golder Associates SUDBURY, ONTARIO		FIGURE B3			



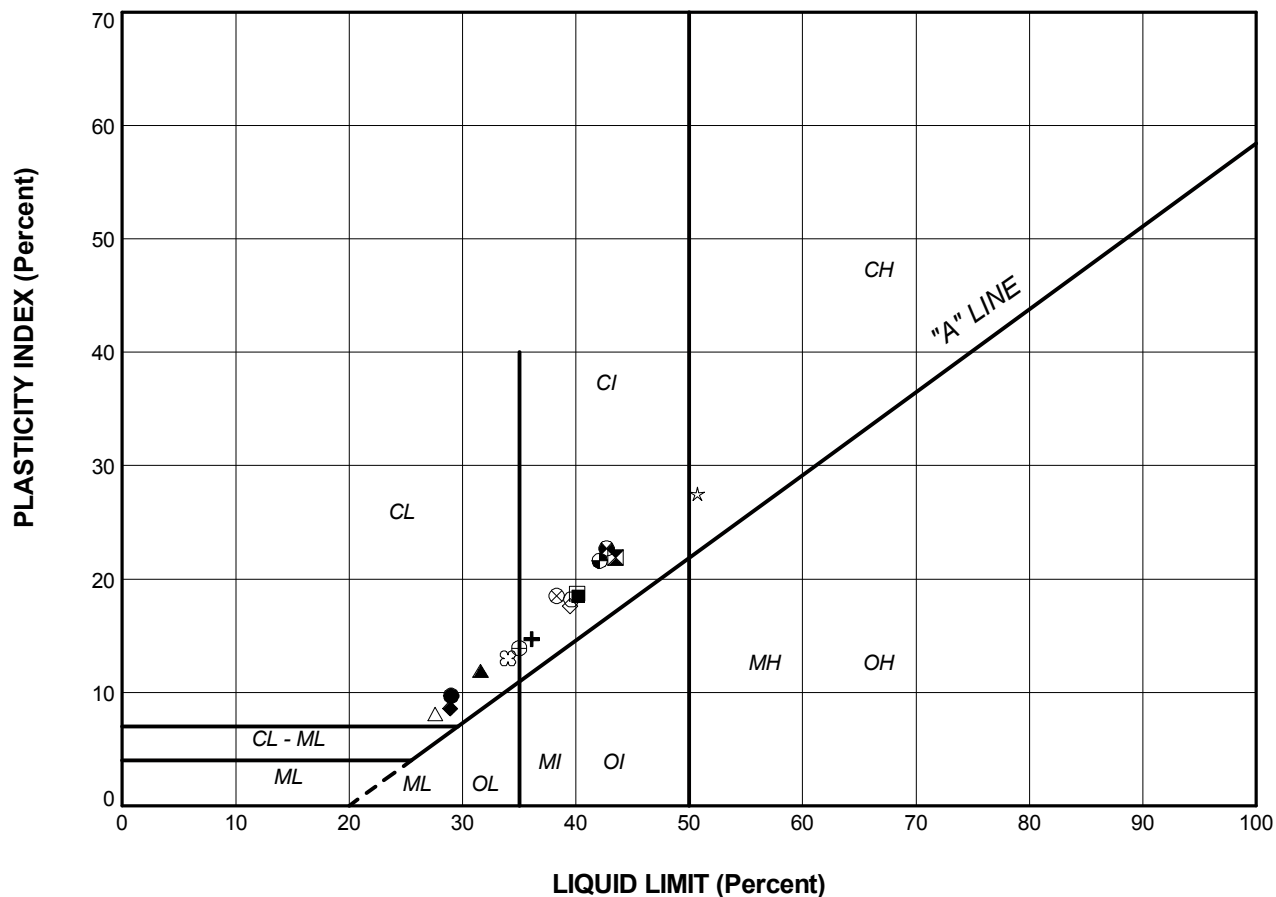
GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BE-1	12	195.1
■	BE-1	14	192.1
▲	BE-4	2B	200.3


PROJECT						HIGHWAY 17 BEAR CREEK CULVERT - STA 14+960					
TITLE						GRAIN SIZE DISTRIBUTION CLAYEY SILT to SILTY CLAY					
PROJECT No.			13-1184-0074			FILE No.			13-1184-0074.GPJ		
DRAWN	TB	Oct 2014	SCALE	N/A	REV.						
CHECK	AB	Oct 2014									
APPR	JMAC	Oct 2014									
						FIGURE B4					





LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	BE-1	12	29.0	19.3	9.7
■	BE-1	14	40.2	21.7	18.5
▲	BE-2	5	31.6	19.7	11.9
+	BE-2	7	36.1	21.4	14.7
◆	BE-3	3	28.9	20.3	8.6
◇	BE-3	7	39.5	21.9	17.6
○	BE-3	9	39.6	21.4	18.2
△	BE-4	2B	27.6	19.5	8.1
⊗	BE-4	6	38.3	19.8	18.5
⊕	BE-4	7	35.0	21.1	13.9
□	BE-5	11	40.1	21.4	18.7
⊗	BE-5	12	42.7	20.0	22.7
⊕	BE-5	13	42.1	20.5	21.6
☆	BE-5	16	50.7	23.2	27.5
⊗	BE-6	6	34.0	21.0	13.0
⊗	BE-6	8	43.5	21.6	21.9

PROJECT				
HIGHWAY 17 BEAR CREEK CULVERT - STA 14+960				
TITLE				
PLASTICITY CHART CLAYEY SILT to SILTY CLAY				
PROJECT No.		13-1184-0074		FILE No.
DRAWN		TB	Oct 2014	SCALE
CHECK		AB	Oct 2014	REV.
APPR		JMAC	Oct 2014	
 Golder Associates SUDBURY, ONTARIO				FIGURE B5

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

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