



May 3, 2016

DETAIL FOUNDATION INVESTIGATION REPORT

**BRULE CREEK CULVERT - SITE NO. 48W-249
HIGHWAY 11/17, DISTRICT OF THUNDER BAY
TOWNSHIP OF CONMEE
MINISTRY OF TRANSPORTATION, ONTARIO
G.W.P 6943-10-00 WP 6943-10-01**

Submitted to:

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REPORT





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PART A

**DETAIL FOUNDATION INVESTIGATION REPORT
BRULE CREEK CULVERT – SITE NO. 48W-249
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G.W.P. 6943-10-00, WP 6943-10-01**



1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Hatch, on behalf of the Ministry of Transportation, Ontario (MTO) to provide detail foundation engineering services for the replacement of the twin Brule Creek culvert (Site No. 48W-249). The Brule Creek culverts are located in the District of Thunder Bay in the Township of Conmee on Highway 11/17 at about STA 15+304, approximately 30 m south of the Highway 17 and Mokomon Road junction in Mokomon, Ontario (approximately 39 km Northwest of Thunder Bay, 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.

2.0 SITE DESCRIPTION

The existing Brule Creek culvert consists of two Structural Plate Corrugated Steel Pipes (SP CSP), the details of which (i.e., diameter, length, etc.) are summarized in Table 1 following the text of the report.

It should be noted that the orientation (i.e., north, south, east, west) stated in the text of the report is typically referenced to project north and therefore may differ from magnetic north shown on the drawing. For the purposes of this report Highway 11/17 is oriented in a north-south direction for this section of roadway and the culvert is oriented perpendicular to the highway in an east-west orientation.

In general, the topography in the area of the culvert is undulating terrain with moderate to dense tree cover beyond the highway right-of-way, and the land use is essentially rural with some rural residences located on the southwest side of site. The highway to the west of Mokomon Road and to the east of the culvert site appears to be within a cut section, and the culvert site is within a fill section. Brule Creek parallels Mokomon Road at the culvert location and flows west-east, draining into the Kaministiquia River which flows southeast and drains into Lake Superior. At the culvert location, the highway grade is at approximately Elevation 382.5 m. The existing culvert inverts, as provided by MTO, are approximately Elevation 374.3 m at the inlet and Elevation 374.2 m at the outlet. The existing embankment is approximately 8.2 m to 8.3 m high, with side slopes inclined at approximately 1.5 Horizontal to 1 Vertical (1.5H:1V) on the west side and approximately 2H:1V on the east side. The creek water level was at Elevation 375.6 m at the inlet (west), as measured by others on May 6, 2013, and measured at Elevations 375.4 m and 374.6 at the inlet and outlet ends, respectively, on December 17, 2015. Surface conditions in the culvert inlet and outlet areas are shown on Photographs 1 to 4, attached.

3.0 INVESTIGATION PROCEDURES

The field work for this subsurface investigation was carried out between December 8 and 21, 2015, January 16, and February 20, 2016, during which time eight boreholes (Boreholes BR-1 to BR-7 and BR-6A) were advanced at approximately the locations shown on Drawing 1.

The field investigation was carried out using a variety of drilling equipment due to the nature of the terrain and access constraints at the Brule creek site. The details of the drilling equipment and suppliers are listed below.



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Drilling Equipment	Borehole (s)	Supplied and Operated By
Track Mounted - CME 55	BR-1, BR-3 and BR-6	RPM Drilling Ltd. of Thunder Bay, Ontario
All-Terrain Vehicle - CME 75	BR-7	
Simco SK1 – 2400	BR-2	
Portable Tripod Equipment	BR-4	
Track Mounted - CME 850	BR-5, BR-6A	Cartwright Drilling Ltd. of Thunder Bay, Ontario

The boreholes were advanced using 83 mm or 108 mm inside diameter hollow stem augers and/or and using NW casing and wash boring techniques. In general, 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 an automatic and cathead hammers, in accordance with the Standard Penetration Test (SPT) procedures (ASTM D1586). The borehole advanced with portable equipment (Borehole BR-4) employed the use of a half weight hammer and the 'N'-values were corrected for the lower energy drive. Samples of the cohesive soils were obtained using 76 mm O.D. thin walled Shelby Tubes (ASTM D1587) for relatively undisturbed samples. Field vane shear tests were conducted in cohesive soils for determination of undrained shear strengths (ASTM D2573) using MTO Standard 'N' size vanes. The groundwater level in the open boreholes was observed during the drilling operations as described on the Record of Borehole sheets in Appendix A. The boreholes were backfilled upon completion in accordance with Ontario Regulation 903 Wells (as amended).

The field work was monitored on a full-time basis by members 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 and cared for 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 Atterberg limits were carried out on selected soil samples. The geotechnical laboratory testing was completed according to MTO LS standards.

A sample of the creek water was obtained during the field investigation (on December 17, 2015) using appropriate sampling protocols and submitted to a specialist analytical laboratory under chain of custody procedures for testing for a suite of parameters including pH, resistivity, conductivity, sulphates and chlorides.

The as-drilled borehole locations and ground surface elevations were measured and surveyed by members of our technical staff, referenced to the highway centerline and existing culvert and converted into northing/easting coordinates on the plan drawing. The ground surface elevation of the highway centerline was obtained from the profile drawing provided by MTO (drawing E47311172.dwg). The MTM NAD83 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 summarized below.

Borehole Number	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)
BR-1	5 371 776.2	331 572.8	375.1	9.8
BR-2	5 371 757.9	331 570.9	374.7	9.8



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Borehole Number	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)
BR-3	5 371 766.7	331 550.2	382.6	18.4
BR-4	5 371 789.7	331 521.5	375.9	7.7
BR-5	5 371 773.5	331 526.6	375.9	9.4
BR-6	5 371 789.9	331 539.7	382.8	10.4
BR-6A	5 371 788.4	331 539.3	382.8	12.7
BR-7	5 371 739.0	331 577.9	375.9	9.8

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain (NOEGTS)¹ mapping, the subsoils in the vicinity of the Brule Creek culverts site generally consist of glaciolacustrine plain deposits consisting primarily of clay bordered closely by bedrock to the west and a hummocky ground moraine of silt and tills to the south.

Based on geological mapping by the Ministry of Northern Development and Mines (MNDM)², the site is underlain by metasedimentary rocks; more specifically wacke, arkose, slate, marble, chert, iron formations and bordered by massive granodiorite to granite formations to the northeast.

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of in situ and laboratory testing are given on the Record of Borehole sheets contained in Appendix A. The detailed results of geotechnical laboratory testing are contained in Appendix B. The results of the in situ field tests (i.e., SPT 'N' values and undrained shear strengths from field vanes) as presented on the Record of Borehole sheets and in Section 4 are uncorrected, except that the 'N'-values obtained by the use of the half-weight hammer have been corrected as noted in Section 3.0. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profile on Drawing 1 are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

In summary, the subsoil conditions encountered at the site consist of asphalt and fill soils of granular, clayey gravel and clay composition (for boreholes advanced through the embankment), peat/topsoil (for boreholes advanced along the toe of slope) underlain by deposits of sand and gravel to sandy gravel, silty clay to clay, silty sand to silt, and sandy silt (Till). A more detailed description of the soil deposits and groundwater conditions encountered in the boreholes is provided below.

¹ Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 42DNE

² Ministry of Northern Development of Mines. Bedrock Geology of Ontario – West Central Sheet, Ontario Geological Survey – Map 2542



DETAIL FOUNDATION REPORT BRULE CREEK CULVERT - SITE NO. 48W-249

Deposit/Layer Description	Boreholes	Deposit Thickness (m)	Deposit Surface Elevation (m)	N Values (blows)/ S_u Shear Strength (kPa)	Laboratory Testing
				Relative Density or Consistency	
Asphalt	BR-3, BR-6 and BR-6A	0.2	382.8 – 382.6	n/a	n/a
(FILL) Sand¹ , trace gravel, trace silt; brown; moist to wet		1.2 – 1.4	382.6 – 382.4	N = 11 Compact	w = 3%, 24% 1 – M (Fig. B1)
(FILL) Clayey Gravel¹ trace to some sand; brown; wet		1.7 – 3.0	381.4 – 381.0	N = 4 – 37 Loose to Dense/ Firm to Hard	n/a
(FILL) Clay , trace to some sand some gravel; reddish brown; wet		2.6 – 4.1	379.7 – 378.0	N = 4 – 21 $S_u = 91$ S = 4 Firm to Stiff	w = 35% - 39% $w_p = 66\%$ $w_L = 27\%$ $I_p = 38\%$ 2 – MH (Fig. B2) 2 – AL (Fig. B3)
Silty Peat/Peat/Topsoil ; brown to black, wet	BR-1, BR-2, BR-4, BR-5 and BR-7	0.7 – 1.4	375.9 – 374.7	N = 2 Very Soft	w = 61% to 70%
Sand and Gravel to Sandy Gravel ; brown; wet	BR-2, BR-5 and BR-7	0.7 – 1.1	375.2 – 373.9	N = 8 – 100 / 0.13 Loose to Very Dense	n/a
Silty Clay to Clay^{2, 3} , trace sand; reddish brown; wet	BR-1 to BR-7 and BR6-A	2.5 – >7.6	375.6 – 373.2	N = 1 – 19 ⁴ $S_u = 51 - > 100$ S = 2 – 3 Stiff to Very Stiff	w = 20% - 63% $w_L = 38\% - 83\%$ $w_I = 16\% - 31\%$ $I_p = 22\% - 53\%$ 9 – MH (Fig. B4) 14 – AL (Fig. B5)
Silt to Silty Sand , trace to some gravel, trace clay; grey; wet	BR-1, BR-2 and BR-7	>3.4 – >5.5 where fully penetrated	371.9 – 369.5	N = 37 – 111/0.23 Dense to Very Dense	w = 21% - 27% 3 – MH (Fig. B6) 2 – AL – N.P.
Sandy Silt (TILL) to Sand and Gravel (TILL)⁵ ; trace to some gravel, trace to some clay; grey; wet	BR-1, BR-3 and BR-6A	>1.1 – >3.6, 1.4	371.5 – 366.4	N = 64 – 111 Very Dense	w = 15% 2 – MH (Fig. B7)

Where:

N = SPT 'N'-value; number of blows for 0.3 m of penetration

S_u = Undrained Shear Strength (kPa)

S = Sensitivity

M = Sieve analysis

MH = Combined Sieve and Hydrometer analysis

w = Natural Moisture Content (%)

w_p = Plastic Limit (%)



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w_L = Liquid Limit (%)
I_p = Plasticity Index (%)
AL = Atterberg Limits Test
N.P. = Non-Plastic Atterberg Limits Test Result

Notes:

¹ 75 mm cobbles were encountered within the sand and clayey gravel portions of the fill deposit in Boreholes BR-3 and BR-6.

² Trace organics (wood and roots) were encountered in Borehole BR-1 within the upper portion of the silty clay to clay deposit.

³ A 0.6 m thick clayey silt seam was encountered within the Silty Clay to Clay deposit at 7.0 m depth in Borehole BR-5. One Atterberg Test result on the clayey silt seam indicated a liquid limit of 24 per cent, a plastic limit of 14 per cent and a plasticity index of 10 per cent, indicating the material is a clayey silt of low plasticity. The results of the Atterberg Limit test are shown on Figure B5 in Appendix B.

⁴ SPT "N"-values of 50 blows per 0.08 m and 100 blows per 0.08 m of penetration inferred to be indicative of the split-spoon refusing on an obstruction or bedrock and not representative of the consistency of the clay deposit.

⁵ 120 mm and 230 mm size cobbles were encountered at 16.6 m and 18.1 m depth within the sandy silt till deposit in Borehole BR-3.

Groundwater Conditions

Unstabilized groundwater levels measured in the open boreholes upon completion of drilling are summarized below. The creek water level was measured at Elevation 375.4 m and 374.6 m at the inlet and outlet, respectively, on December 17, 2015. Groundwater and creek water levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

Borehole No.	Depth to Groundwater Level (m)	Groundwater Elevation (m)
BR-1	0.3	374.8
BR-2	0.1	374.6 ¹
BR-3	3.8	378.8 ¹
BR-4	Dry	Inferred ~ 375.4 ²
BR-5	0.4	375.4
BR-6	2.5	380.3 ¹
BR-6A	7.5	375.3
BR-7	0.7	375.2 ¹

Notes:

¹ Borehole was advanced using NW casing and wash boring techniques; water level likely not representative of stabilized groundwater conditions.

² Adjacent creek water level.



Analytical Testing of Creek Water

The results of an analytical test on a sample of creek water taken at the culvert site are presented in Table B1 in Appendix B. The suite of parameters tested include pH, sulphate, chloride, resistivity and conductivity.

5.0 CLOSURE

The field drilling program was carried out under the supervision of Mr. Randy Axford and Mr. Mathew Riopelle, under the overall direction of Mr. Adam Core, P.Eng. This Preliminary Foundation Investigation Report was prepared by Mr. Adam Core, P.Eng. and Ms. Sarah E. M. Poot, P.Eng. and Associate of Golder provided a technical review of the report. Mr. Jorge M. A. Costa, P.Eng., the Designated MTO Foundations Contact and Principal of Golder, conducted an independent quality control review of this report.



DETAIL FOUNDATION REPORT BRULE CREEK CULVERT - SITE NO. 48W-249

Report Signature Page

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BRULE CREEK CULVERT - SITE NO. 48W-249

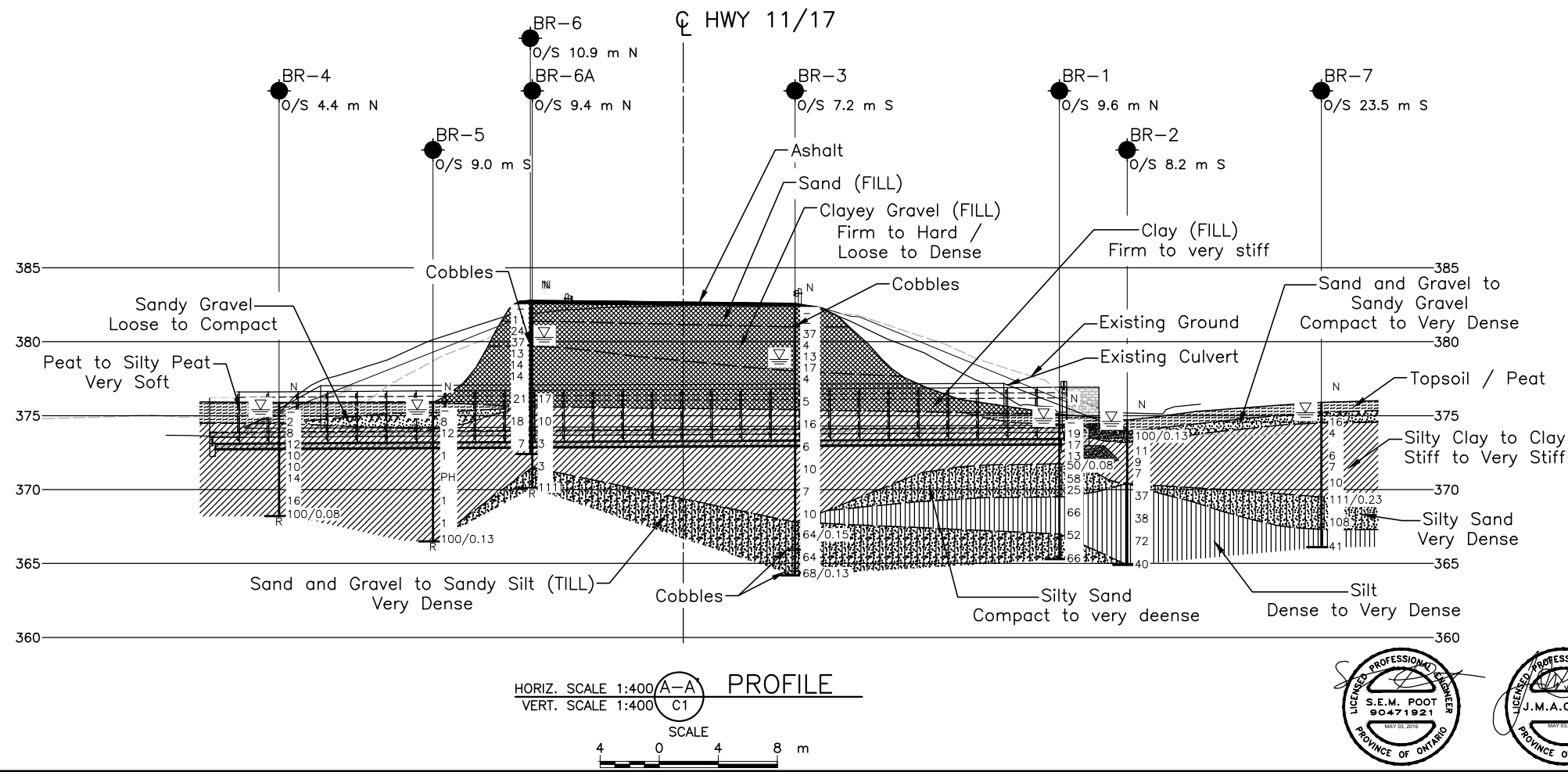
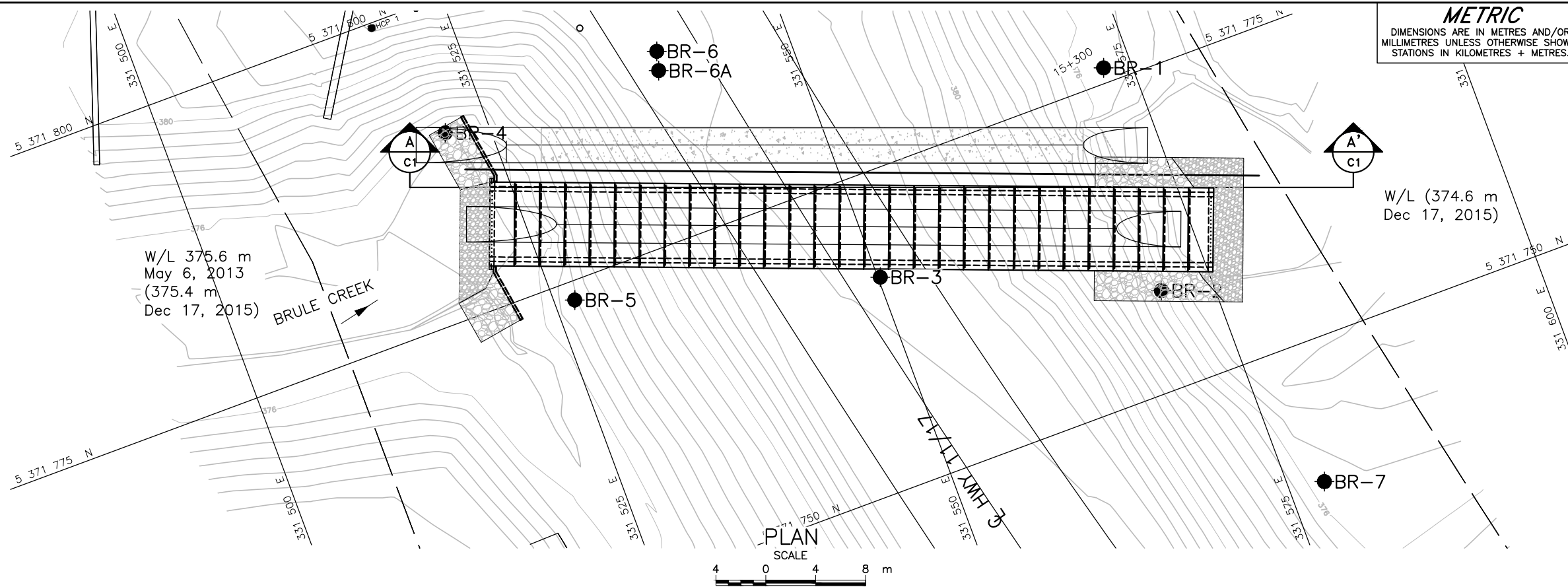
Table 1: Summary Details of Existing Culvert

Culvert Location (Twp)	Site #	Approximate Height of Embankment ¹ (m)	Existing Culvert			Approximate Invert Elevation ²	
			Type	Approximate Dimension ²	Approximate Length (m)	West (Inlet) End of Culvert (m)	East (Outlet) End of Culvert (m)
Hwy 11/17 STA 15+304 (Township of Conmee)	48W-249	8.1 – 8.3	Twin CSP	2.7 m diameter	45 – 46	374.3	374.2

Notes:

1. Embankment height is relative to existing ground surface at the centreline of the roadway and the ground surface at the toe of the embankment slope (i.e., original ground surface).
2. Culvert dimensions and invert elevations are based on the plan and profile drawings provided by MTO (Drawing E47311172.dwg).

Prepared by: AC
Checked by: SEMP
Reviewed by: JMAC



CONT No.
GWP No.6943-10-00

HIGHWAY 11/17
BRULE CREEK CULVERT STA 15+304
BOREHOLE LOCATIONS AND
SOIL STRATA

LEGEND

Borehole - Current Investigation

Standard Penetration Test Value

Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)

Refusal

WL upon completion of drilling

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
BR-1	375.1	5371776.2	331572.8
BR-2	374.7	5371757.9	331570.9
BR-3	382.6	5371766.7	331550.2
BR-4	375.9	5371789.7	331521.5
BR-5	375.9	5371773.5	331526.6
BR-6	382.8	5371789.9	331539.7
BR-6A	382.8	5371788.4	331539.3
BR-7	375.9	5371739.0	331577.9

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 MTO, drawing file nos. E47311172.dwg received Dec. 11, 2015. GA provided in digital format by MTO file nos. ST-358767-BRULE CREEK CULVERT-01-GENERAL ARRANGEMENT.dwg received Apr. 6, 2016.

NO.

DATE

BY

REVISION

Geocres No. 52A-219

HWY.

PROJECT NO. 1533879

DIST.

SUBM'D. AC

CHKD.

DATE: 5/19/2016

SITE: 48W-249

DRAWN: JJL

CHKD. SEMP

APPD. JMAC

DWG. 1

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PHOTOGRAPHS

**Photograph 1: Brule Creek Culvert
Looking North at Culvert (December 2015)**



**Photograph 2: Brule Creek Culvert
Looking South at Culvert (December 2015)**





PHOTOGRAPHS

**Photograph 3: Brule Creek Culvert
Looking South at West Side Inlet (December 2015)**



**Photograph 4: Brule Creek Culvert
Looking West at East Side Outlet (December 2015)**





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

	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 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 1533879		RECORD OF BOREHOLE No BR-1				1 OF 1 METRIC								
G.W.P. 6943-10-00		LOCATION N 5371776.2; E 331572.8				ORIGINATED BY MR								
DIST _____ HWY 11/17		BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers				COMPILED BY AC								
DATUM GEODETIC		DATE December 8, 2015				CHECKED BY SEMP								
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						
375.1	GROUND SURFACE							20 40 60 80 100	20 40 60					
0.0	TOPSOIL, some clay, trace sand, trace gravel Brown Wet		1	AS	-		375							
374.4														
0.7	SILTY CLAY to CLAY, trace to some sand, trace to some gravel Stiff to very stiff Reddish brown Wet		2	SS	19		374							
	Trace organics (wood / roots) in Samples 2 and 3.		3	SS	17		373							
			4	SS	13		372							
371.9			5	SS	50/0.08		371							
3.2	SILTY SAND, trace to some gravel Compact to very dense Grey Wet		6	SS	58		370							
			7	SS	25		369							
369.5							368							
5.6	SILT, trace to some clay, trace sand Very dense Grey Wet		8	SS	66		367							
			9	SS	52		366							
366.4														
8.7	Sandy SILT, trace to some gravel, trace to some clay (TILL) Very dense Grey Wet		10	SS	66									
365.3														
9.8	END OF BOREHOLE													
	Note: 1. Water level at a depth of 0.3 m below ground surface (Elev. 374.8 m) upon completion of drilling.													

SUD-MTO 001 1533879.GPJ GAL-MISS.GDT 23/03/16 DATA INPUT:

PROJECT		1533879		RECORD OF BOREHOLE No BR-2		1 OF 1		METRIC	
G.W.P.		6943-10-00		LOCATION		N 5371757.9; E 331570.9		ORIGINATED BY	
DIST		HWY 11/17		BOREHOLE TYPE		108 mm I.D. Hollow Stem Augers, NW Casing and Wash Boring		COMPILED BY	
DATUM		GEODETIC		DATE		December 18, 2015		CHECKED BY	
SEMP		SEMP		SEMP		SEMP		SEMP	
SOIL PROFILE		SAMPLES		GROUND WATER CONDITIONS		DYNAMIC CONE PENETRATION RESISTANCE PLOT		UNIT WEIGHT	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L
374.7	GROUND SURFACE								
0.0	TOPSOIL, some peat, trace sand, trace gravel Brown Wet								
373.9									
0.8	SAND and GRAVEL Very dense Brown Wet		1	SS	100/0.13				
373.2									
1.5	CLAY, trace sand, trace gravel Stiff Reddish brown Wet		2	SS	11				
			3	SS	9				
			4	SS	7				
370.4									
4.3	SILT, trace sand, trace to some gravel, trace clay Dense to very dense Grey Wet One piece of gravel recovered in Sample 5. One piece of gravel in Sample 6.		5	SS	37				
			6	SS	38				
			7	SS	72				
			8	SS	40				
364.9									
9.8	END OF BOREHOLE Note: 1. Water level at a depth of 0.1 m below ground surface (Elev. 374.6 m) upon completion of drilling.								

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


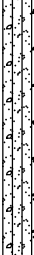

PROJECT 1533879		RECORD OF BOREHOLE No BR-3		1 OF 2		METRIC	
G.W.P. 6943-10-00		LOCATION N 5371766.7; E 331550.2		ORIGINATED BY		MR	
DIST HWY 11/17		BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers, NW Casing and Wash Boring		COMPILED BY		AC	
DATUM GEODETIC		DATE December 11 and 12, 2015		CHECKED BY		SEMP	

[illegible]

Continued Next Page

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

SUD-MTO 001 1533879.GPJ GAL-MISS.GDT 23/03/16 DATA INPUT:

PROJECT 1533879		RECORD OF BOREHOLE No BR-3				2 OF 2 METRIC								
G.W.P. 6943-10-00		LOCATION N 5371766.7; E 331550.2				ORIGINATED BY MR								
DIST _____ HWY 11/17		BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers, NW Casing and Wash Boring				COMPILED BY AC								
DATUM GEODETIC		DATE December 11 and 12, 2015				CHECKED BY SEMP								
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 ---							20 40 60 80 100	20 40 60					
367.8	CLAY, trace to some sand, trace gravel Stiff to very stiff Reddish brown Wet		12	SS	7									0 3 36 61
14.8	Sandy SILT, trace to some gravel, trace to some clay (TILL) Very dense Grey Wet		14	SS	64/0.15									
	A 120 mm cobble encountered at 16.6 m depth.		15	SS	64									
364.2	A 230 mm cobble encountered at 18.1 m depth.		16	SS	68/0.13									13 27 53 7
18.4	END OF BOREHOLE													
	Note: 1. Water level at a depth of 3.8 m below ground surface (Elev. 378.8 m) upon completion of drilling.													

PROJECT 1533879		RECORD OF BOREHOLE No BR-4				1 OF 1 METRIC												
G.W.P. 6943-10-00		LOCATION N 5371789.7; E 331521.5		ORIGINATED BY MR/RA														
DIST _____ HWY 11/17		BOREHOLE TYPE Portable Equipment		COMPILED BY AC														
DATUM GEODETIC		DATE December 20 and 21, 2015		CHECKED BY SEMP														
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		
375.9	GROUND SURFACE							20 40 60 80 100	20 40 60 80 100	20 40 60	W _p W W _L	83	GR SA SI CL					
0.0	PEAT (Fibrous), trace sand Very soft Black Wet		1	AS	-	▽	375											
			2	SS	2													
374.5	CLAY, trace sand, trace gravel Stiff to very stiff Reddish brown Wet		3	SS	8		374											
1.4			4	SS	12		373											
			5	SS	10													
			6	SS	10		372											
			7	SS	14		371											
			8	SS	16		370											
							369											
368.2	END OF BOREHOLE SPLIT-SPOON REFUSAL		9	SS	100/10.08													
7.7	Note: 1. Borehole dry upon completion of drilling, inferred water level at about 0.5 m (Elev. 375.4 m) below ground surface as per adjacent creek water level on December 17, 2015. 2. Split Spoon samples obtained by driving with a 1/2 weight hammer. SPT 'N' values have been adjusted to the inferred values that would be obtained using a standard weight hammer.																	

SUD-MTO 001 1533879.GPJ GAL-MASS.GDT 23/03/16 DATA INPUT:

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

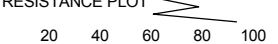

PROJECT 1533879		RECORD OF BOREHOLE No BR-6				1 OF 1 METRIC								
G.W.P. 6943-10-00		LOCATION N 5371789.9; E 331539.7				ORIGINATED BY MR								
DIST _____ HWY 11/17		BOREHOLE TYPE 83 mm I.D. Hollow Stem Augers, NW Casing and Wash Boring				COMPILED BY AC								
DATUM GEODETIC		DATE December 12, 2015				CHECKED BY SEMP								
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						
382.8	GROUND SURFACE							20 40 60 80 100	20 40 60					
0.0	ASPHALT (200 mm)							20 40 60 80 100	20 40 60					
0.2	Sand, trace to some gravel (FILL) Compact Brown Moist		1	AS	-									
			2	SS	11									
381.4														
1.4	Clayey gravel, trace to some sand (FILL) Very stiff to hard / compact to dense Reddish brown Moist to wet		3	SS	24									
			4	SS	37									
379.7	A 75 mm cobble encountered at 3.0 m depth.													
3.1	Clay, some sand, trace gravel (FILL) Stiff to very stiff Reddish brown Wet		5	SS	13									
			6	SS	14									
			7	SS	14									
			8	SS	21									
375.6														
7.2	CLAY, trace sand, trace gravel Firm to very stiff Reddish brown Wet		9	SS	18									
			10	SS	7									
372.4														
10.4	END OF BOREHOLE													
	Note: 1. Water level at a depth of 2.5 m below ground surface (Elev. 380.3 m) upon completion of drilling.													

SUD-MTO 001 1533879.GPJ GAL-MISS.GDT 23/03/16 DATA INPUT:



SUD-MTO 001 1533879.GPJ GAL-MISS.GDT 06/04/16 DATA INPUT:

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

PROJECT 1533879		RECORD OF BOREHOLE No BR-6A				2 OF 2 METRIC																
G.W.P. 6943-10-00		LOCATION N 5371788.4; E 331539.3				ORIGINATED BY MR																
DIST _____ HWY 11/17		BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers				COMPILED BY AC																
DATUM GEODETIC		DATE February 20, 2016				CHECKED BY SEMP																
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	 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED			W _p	W	W _L	γ	GR SA SI CL							
--- CONTINUED FROM PREVIOUS PAGE ---																						
370.1			5	SS	111											o						47 36 14 3
12.7	END OF BOREHOLE SPOON AND AUGER REFUSAL Note: 1. Water level at a depth of 7.5 m below ground surface (Elev. 375.3 m) upon completion of drilling.																					

PROJECT 1533879		RECORD OF BOREHOLE No BR-7				1 OF 1 METRIC								
G.W.P. 6943-10-00		LOCATION N 5371739.0; E 331577.9				ORIGINATED BY RA								
DIST _____ HWY 11/17		BOREHOLE TYPE Solid Stem Augers, NW Casing and Wash Boring				COMPILED BY AC								
DATUM GEODETIC		DATE December 16, 2015				CHECKED BY SEMP								
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	W _p W W _L	WATER CONTENT (%)	20 40 60		
375.9	GROUND SURFACE													
0.0	PEAT (Fibrous) Black Wet													
375.2														
0.7	Sandy GRAVEL, some organics Compact Brown Wet		1	SS	16									
374.5														
1.4	SILTY CLAY to CLAY, some sand, trace gravel Firm to very stiff Reddish brown Wet		2	SS	4									
			3	SS	6									
			4	SS	7									
			5	SS	10									
369.5			6A	SS	111/0.23									
6.4	SILTY SAND, some gravel Very dense Grey Wet		6B											
			7	SS	108									
367.3														
8.6	SILT, trace to some clay, trace sand Dense Grey Wet													
			8	SS	41									
366.1														
9.8	END OF BOREHOLE													
	Note: 1. Water level at a depth of 0.7 m below ground surface (Elev. 375.2 m) upon completion of drilling.													

SUD-MTO 001 1533879.GPJ GAL-MISS.GDT 23/03/16 DATA INPUT:

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



APPENDIX B

Laboratory Test Results



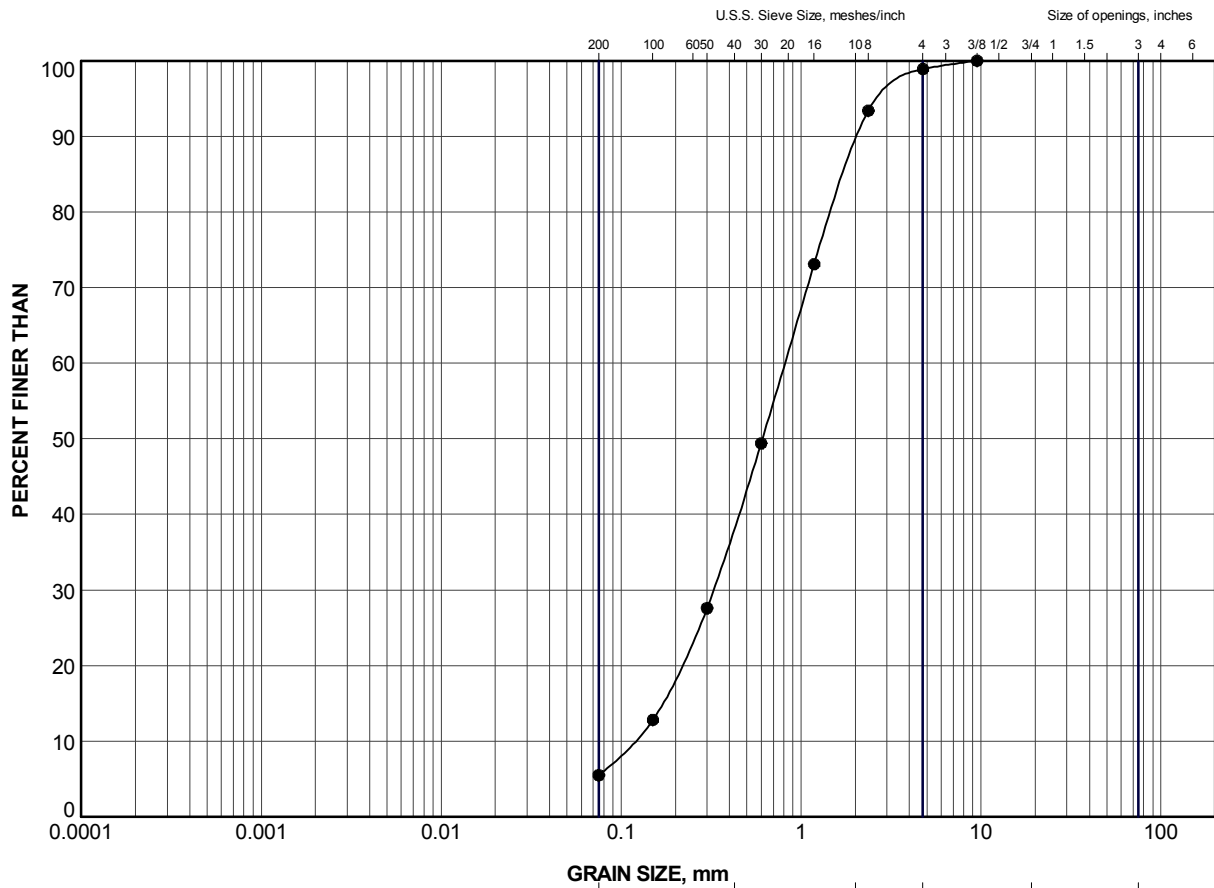
DETAIL FOUNDATION REPORT BRULE CREEK CULVERT - SITE NO. 48W-249

Table B1: Summary of Analytical Testing of Brule Creek Water Sample

Parameter	Units	Result
Chloride (CL)	mg/L	1.59
Sulphate (SO4)	mg/L	3.19
Conductivity (EC)	µS/cm	170
Resistivity	ohm-cm	5882
pH	n/a	8.00

Notes: 1. Sample obtained on December 17, 2015.
2. Analytical testing carried out by ALS Canada Ltd.


Prepared by: AC
Checked by: SEMP
Reviewed by: JMAC

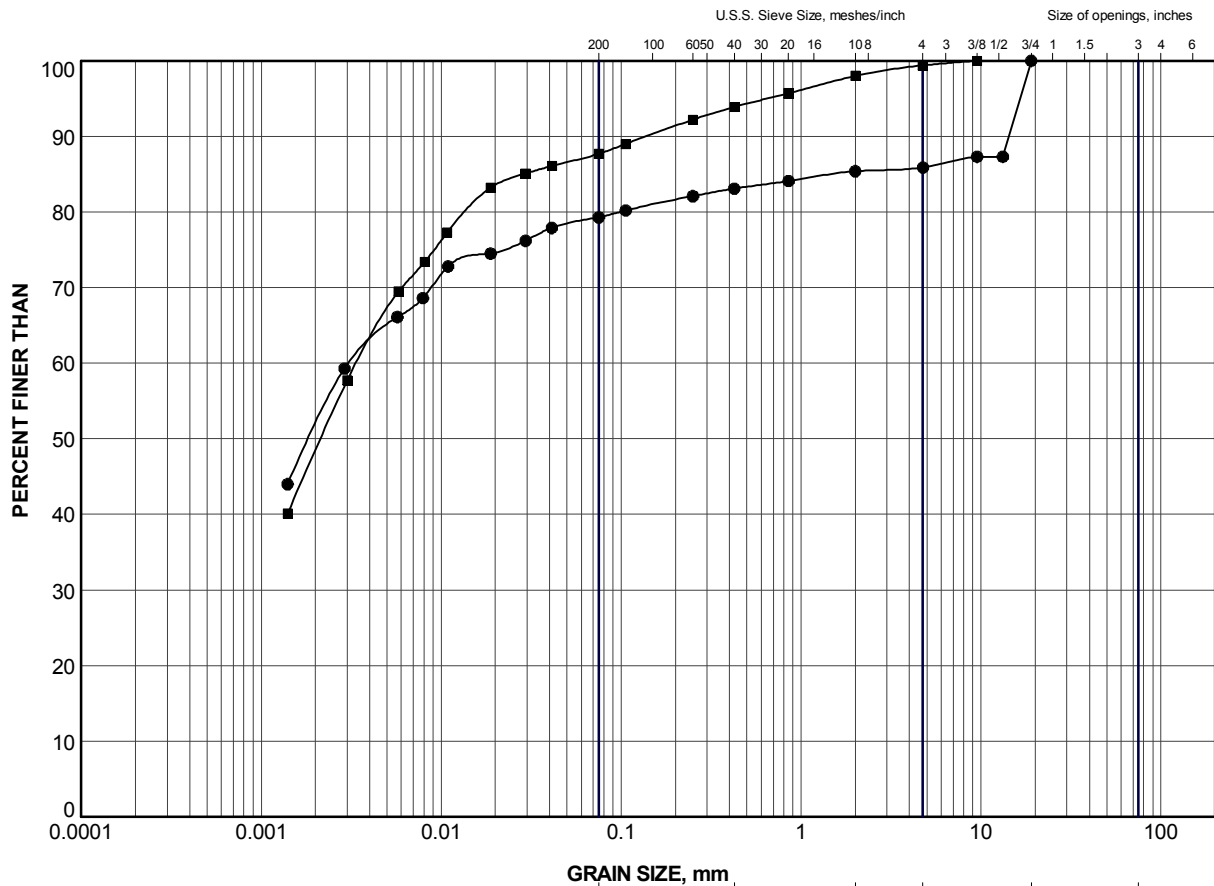


GRAVEL SIZE, mm							Cobble Size
CLAY AND SILT	fine	medium	coarse	fine	coarse		
	SAND SIZE			GRAVEL SIZE			

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BR-3	2	381.5

PROJECT					
HIGHWAY 11/17 BRULE CREEK CULVERT STA 15+304					
TITLE					
GRAIN SIZE DISTRIBUTION SAND (FILL)					
PROJECT No.		1533879		FILE No. 1533879.GPJ	
DRAWN	JJL	Feb 2016	SCALE	N/A	REV.
CHECK	SEMP	Feb 2016			
APPR	JMAC	Feb 2016			
 Golder Associates SUDBURY, ONTARIO			FIGURE B1		



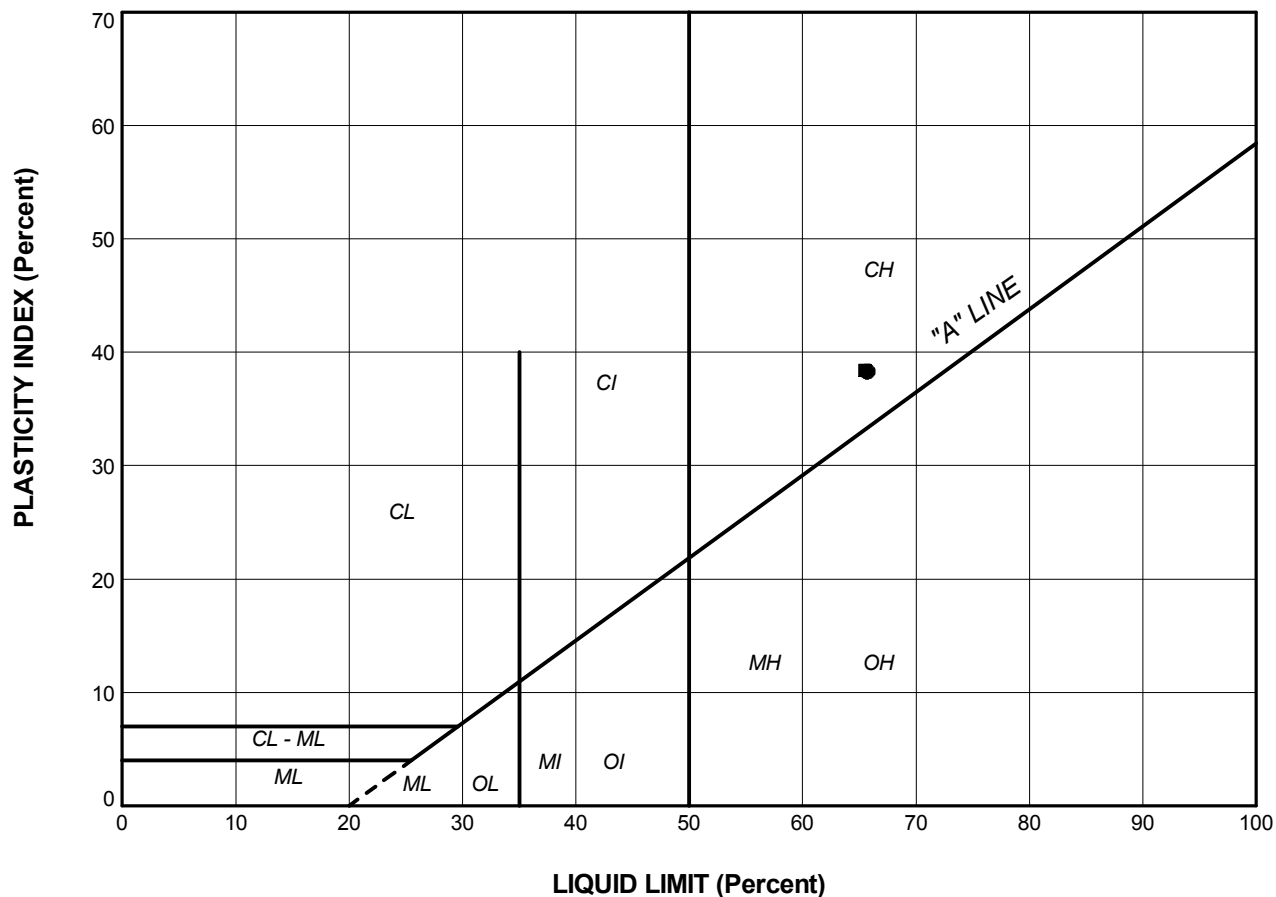
GRAVEL SIZE, mm							Cobble Size
CLAY AND SILT	fine	medium	coarse	fine	coarse		
	SAND SIZE			GRAVEL SIZE			

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BR-3	7	377.7
■	BR-6	6	378.7

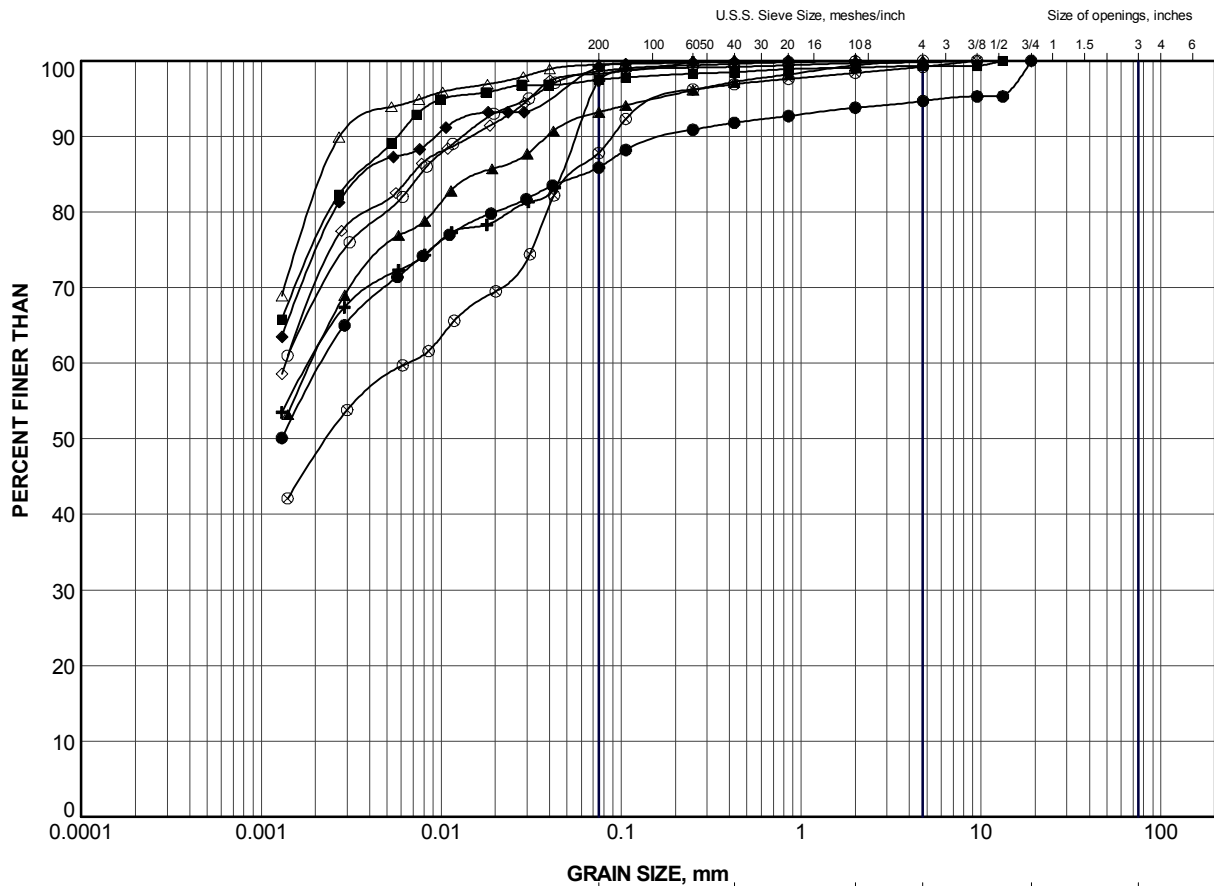
PROJECT					
HIGHWAY 11/17 BRULE CREEK CULVERT STA 15+304					
TITLE					
GRAIN SIZE DISTRIBUTION CLAY (FILL)					
PROJECT No.		1533879		FILE No. 1533879.GPJ	
DRAWN	JJL	Feb 2016	SCALE	N/A	REV.
CHECK	SEMP	Feb 2016			
APPR	JMAC	Feb 2016			
			FIGURE B2		





PROJECT					
HIGHWAY 11/17 BRULE CREEK CULVERT STA 15+304					
TITLE					
PLASTICITY CHART CLAY (FILL)					
PROJECT No. 1533879			FILE No. 1533879.GPJ		
DRAWN	JJL	Feb 2016	SCALE	N/A	REV.
CHECK	SEMP	Feb 2016	FIGURE B3		
APPR	JMAC	Feb 2016			





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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BR-1	4	372.5
■	BR-2	2	372.9
▲	BR-3	10	373.2
+	BR-3	12	370.1
◆	BR-4	4	373.3
◇	BR-4	7	371.0
○	BR-5	4	372.6
△	BR-6	9	374.9
⊗	BR-7	5	370.7

PROJECT

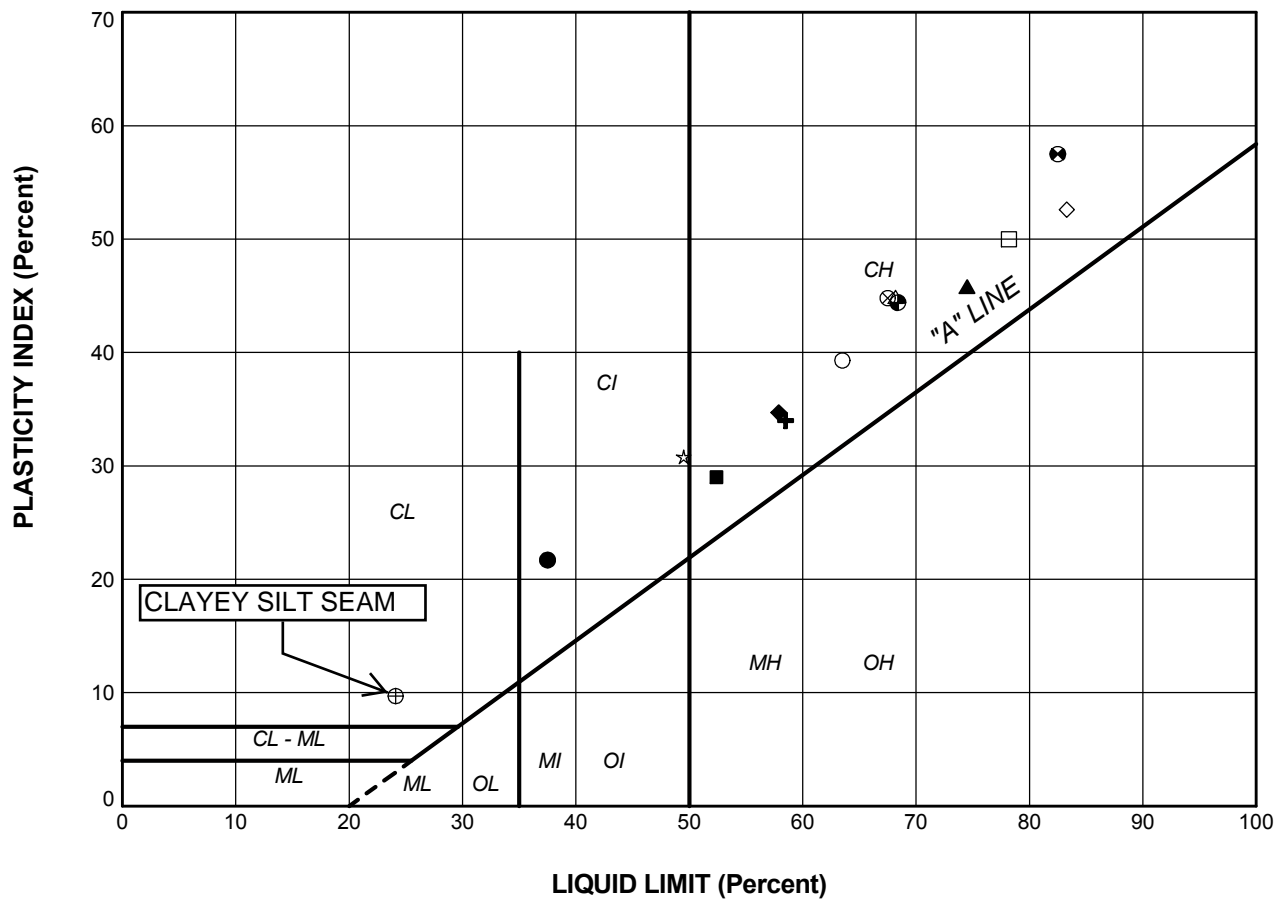
HIGHWAY 11/17
BRULE CREEK CULVERT STA 15+304

TITLE

GRAIN SIZE DISTRIBUTION
SILTY CLAY to CLAY




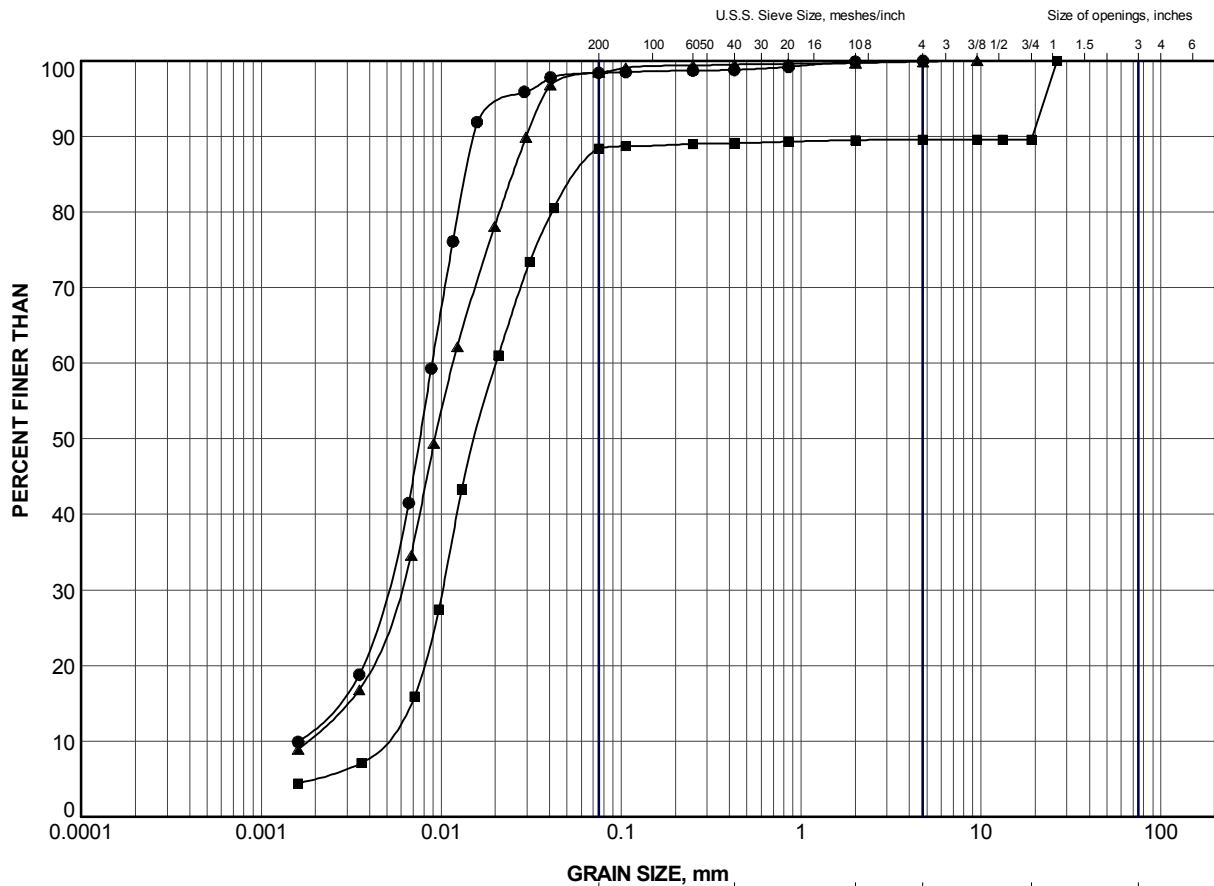
PROJECT No. 1533879			FILE No. 1533879.GPJ		
DRAWN	JJL	Feb 2016	SCALE	N/A	REV.
CHECK	SEMP	Feb 2016	FIGURE B4		
APPR	JMAC	Feb 2016			



LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	BR-1	2	37.5	15.8	21.7
■	BR-1	4	52.4	23.4	29.0
▲	BR-2	2	74.5	28.7	45.8
+	BR-3	10	58.5	24.5	34.0
◆	BR-3	12	57.9	23.2	34.7
◇	BR-4	4	83.3	30.7	52.6
○	BR-4	7	63.5	24.2	39.3
△	BR-5	3B	68.2	23.3	44.9
⊗	BR-5	4	67.5	22.7	44.8
⊕	BR-5	7	24.1	14.4	9.7
□	BR-6	9	78.2	28.2	50.0
⊗	BR-6A	4	82.5	25.0	57.5
●	BR-7	2	68.4	24.0	44.4
☆	BR-7	5	49.5	18.7	30.8


PROJECT					
HIGHWAY 11/17 BRULE CREEK CULVERT STA 15+304					
TITLE					
PLASTICITY CHART SILTY CLAY to CLAY					
PROJECT No.		1533879		FILE No.	
DRAWN		JJL	Apr 2016	SCALE N/A REV.	
CHECK		SEMP	Apr 2016		
APPR		JMAC	Apr 2016		
 Golder Associates SUDBURY, ONTARIO			FIGURE B5		

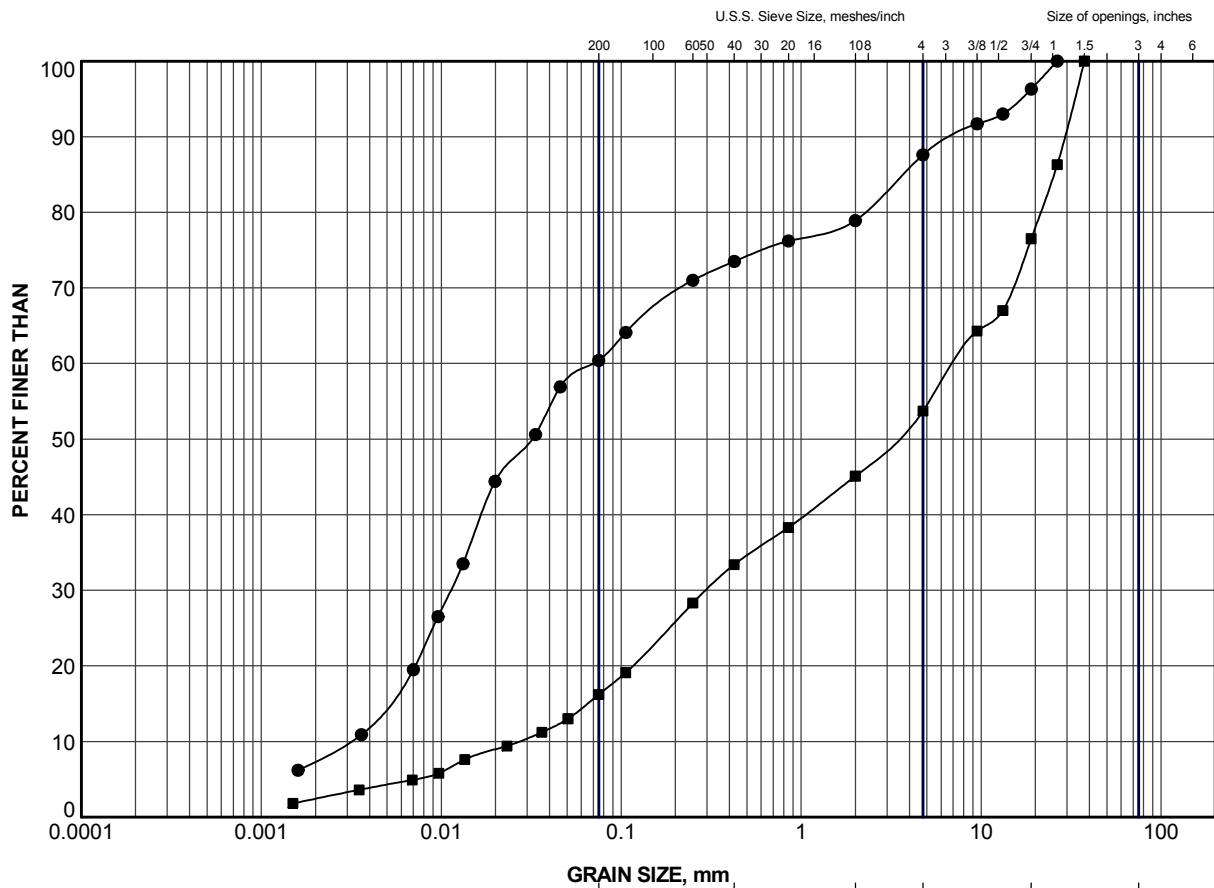


GRAVEL SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BR-1	9	367.2
■	BR-2	6	368.3
▲	BR-7	8	366.4

PROJECT						HIGHWAY 11/17 BRULE CREEK CULVERT STA 15+304					
TITLE						GRAIN SIZE DISTRIBUTION SILT					
PROJECT No.				1533879		FILE No.				1533879.GPJ	
DRAWN		JJL		Feb 2016		SCALE		N/A		REV.	
CHECK		SEMP		Feb 2016							
APPR		JMAC		Feb 2016							
 Golder Associates SUDBURY, ONTARIO						FIGURE B6					



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BR-3	16	364.3
■	BR-6A	5	370.3

PROJECT					
HIGHWAY 11/17 BRULE CREEK CULVERT STA 15+304					
TITLE					
GRAIN SIZE DISTRIBUTION SANDY SILT (TILL) to SAND AND GRAVEL (TILL)					
PROJECT No.		1533879		FILE No. 1533879.GPJ	
DRAWN	JJL	Apr 2016	SCALE	N/A	REV.
CHECK	SEMP	Apr 2016	FIGURE B7		
APPR	JMAC	Apr 2016			



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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