



April 17, 2015

## FOUNDATION INVESTIGATION REPORT

**CULVERT AT STATION 13+210, TOWNSHIP OF LOUISE  
HIGHWAY 17 FOUR-LANING EXTENSION FROM 20.5 KM  
WEST OF HIGHWAY 144, EASTERLY FOR 6.5 KM  
MINISTRY OF TRANSPORTATION, ONTARIO  
GWP 156-98-00**

**Submitted to:**

D.M. Wills Associates Ltd.  
150 Jameson Drive  
Peterborough, Ontario  
K9J 0B9



**GEOCRES NO. 41I-328**

**Report Number:** 11-1191-0007-04

**Distribution:**

- 1 PDF copy - Ministry of Transportation, Ontario, North Bay, ON (Northeastern Region)
- 1 PDF copy - Ministry of Transportation, Ontario, Downsview, ON (Foundations Section)
- 1 copy - D. M. Wills Associates Ltd., Peterborough, ON
- 1 PDF copy - Golder Associates Ltd., Sudbury, ON

REPORT





## Table of Contents

### PART A – FOUNDATION INVESTIGATION REPORT

1.0	INTRODUCTION.....	1
2.0	SITE DESCRIPTION.....	1
3.0	INVESTIGATION PROCEDURES .....	2
4.0	SITE GEOLOGY AND SUBSURFACE CONDITIONS .....	3
4.1	Regional Geology .....	3
4.2	General Overview of Local Subsurface Conditions .....	3
4.2.1	Peat .....	4
4.2.2	Cohesive Deposit.....	4
4.2.3	Silt.....	5
4.2.4	Sand and Silt to Sand .....	6
4.2.5	Sand and Gravel.....	6
4.2.6	Refusal.....	6
4.2.7	Groundwater Conditions .....	6
5.0	CLOSURE .....	6

### DRAWINGS

Drawing 1	Site Location Plan
Drawing 2	Borehole Locations and Soil Strata

### APPENDICES

#### Appendix A Record of Boreholes

List of Symbols and Abbreviations

Record of Boreholes	H2-4 to H2-6, H2-28 to H2-30
---------------------	------------------------------

#### Appendix B Figures

Figure B1	Plasticity Chart – Clayey Silt
Figure B2	Grain Size Distribution – Silty Clay to Clay
Figure B3	Plasticity Chart – Silty Clay to Clay
Figure B4	Grain Size Distribution – Silt
Figure B5	Grain Size Distribution – Sand and Silt
Figure B6	Grain Size Distribution – Sand and Gravel



# PART A

FOUNDATION INVESTIGATION REPORT  
CULVERT AT STATION 13+210, TOWNSHIP OF LOUISE  
HIGHWAY 17 FOUR-LANING EXTENSION FROM 20.5 KM  
WEST OF HIGHWAY 144, EASTERLY 6.5 KM  
MINISTRY OF TRANSPORTATION, ONTARIO  
GWP 156-98-00



## **1.0 INTRODUCTION**

Golder Associates Ltd. (Golder) has been retained by D.M. Wills Associates Ltd. (DMW) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the proposed culvert which will cross the future Highway 17 four-laning alignment at STA 13+210 in the Township of Louise. The proposed work is part of the four-laning extension of the existing Highway 17 at the West Junction of Sudbury Municipal Road 55, from 20.5 km West of Highway 144, easterly for 6.5 km, and which includes a new interchange. The proposed culvert is located within the area designated as High Fill H2. The general location of the culvert is shown on the Site Location Plan on Drawing 1.

The Terms of Reference and the Scope of Work for the foundation investigation are outlined in MTO's Request for Proposal (RFP), dated March 2011. Golder's proposal for the associated foundation engineering services is contained in Section 6.8 of DMW's Technical Proposal for this assignment. The work has been carried out in accordance with Golder's Supplementary Specialty Plan for foundation engineering services for this project, dated November 11, 2011. The base plan showing the proposed horizontal alignment and a drawing showing the proposed vertical alignment for the Highway 17 four-laning extension were provided to Golder by DMW in January 2012.

This report addresses the investigation carried out for proposed Culvert at STA 13+210 in the Township of Louise only. Separate reports address the foundations investigations for the remaining culverts, High Fill embankments over swamps and bridge structures.

Preliminary subsurface information for this project is available and was supplied by MTO, in the reports and subsequent appendices titled:

- Planning, Preliminary Design, and Environmental Assessment Report, Highway 17, Town of Walden, GWP 156-98-00, dated August 2008 by Stantec Consulting Limited
  - Appendix N: Alternate Route Geotechnical Assessment Report, Highway 17, Town of Walden, GWP 156-98-00, Index No: 080FGR, PML Ref: 05TF059G dated July 29, 2008 by Peto MacCallum Ltd.
  - Appendix O: Alternate Route Foundation Assessment Report, Highway 17, Town of Walden, GWP 156-98-00, Index No: 072FFR, PML Ref: 05TF059F, dated May 20, 2008 by Peto MacCallum Ltd.
- Planning, Preliminary Design, and Environmental Supplementary Report, Highway 17, Town of Walden, GWP 156-98-00, dated March 2009 by Stantec Consulting Limited
  - Preliminary Geotechnical Investigation Report, Highway 17, Town of Walden, GWP 156-98-00, Index No: 102FGIR, PML Ref: 05TF059G1 dated March 3, 2009 by Peto MacCallum Ltd.

## **2.0 SITE DESCRIPTION**

The overall project consists of the detail design for the four-laning of Highway 17 from the end of the existing four lanes at the west junction of Sudbury Municipal Road 55, from approximately 20.5 km west of Highway 144, easterly for 6.5 km, including a new interchange. The proposed highway alignment is south of and approximately follows the existing alignment of Highway 17, within the project limits. The proposed culvert will be approximately 88 m long, extending across the proposed realigned Highway 17 eastbound and westbound lane embankments at about STA 13+210.



In general, the topography of this area consists of a low-lying swamp with areas of standing water and various vegetation types and organic soils, with sparsely populated treed areas separated by bedrock out crops to the north and west. The land use in the general vicinity of the culvert location is rural with scattered residential development and rural farm use. The ground surface within the limits of the study area varies between about Elevations 239.8 m and Elevation 239.7 m. A detailed description of the subsurface conditions along the culvert alignment is presented in Section 4.0.

### **3.0 INVESTIGATION PROCEDURES**

The investigation for the culvert at STA 13+210 was carried out between April 3 and April 16, 2012, during which time a total of six (6) boreholes were advanced along the proposed culvert alignment. The locations of the boreholes are summarized below and are shown on Drawing 2.

The field investigation was carried out using a track mounted drill rig supplied and operated by Landcore Drilling of Sudbury, Ontario. The boreholes were advanced through the overburden using 108 mm inner diameter hollow-stem augers and/or NW casing with wash boring techniques. In general, soil samples were obtained at intervals of depth of about 0.75 m and 1.5 m, using a 50 mm outer diameter (O.D.) split-spoon sampler (operated by automatic hammers on the drill rigs), in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586, Standard Test Method for Standard Penetration Test and Split-Barrel Sampling of Soils). Relatively undisturbed 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). Field vane shear tests were conducted in cohesive soils for assessment of undrained shear strengths (ASTM D2573, Standard Test Method for Field Vane Shear Test) using a MTO Standard 'N' size vanes. All boreholes were backfilled upon completion in accordance with Ontario Regulation 903 Wells (as amended).

The culvert boreholes were advanced to depths up to 25 m below existing ground surface. The boreholes were terminated on refusal to further dynamic cone penetration, casing and/or split-spoon advancement. These depths to refusal do not confirm bedrock surface elevations, but may be inferred to indicate the potential proximity to the bedrock surface.

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 provided in Appendix A. Groundwater elevations as encountered in the boreholes may not be representative of static groundwater levels since the groundwater levels in the boreholes may not have stabilized upon completion of drilling. Furthermore, groundwater elevations will vary depending on seasonal fluctuations, precipitation and local soil permeability.

The field work was observed by members of our engineering and technical staff, who located the boreholes, 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 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 content, Atterberg limits and grain size distribution) was carried out on selected representative samples. The results of the laboratory testing on samples from the culvert boreholes are included in Appendix B.

The proposed centreline of the new Highway 17 alignment was staked in the field by exp. prior to drilling. The as-drilled borehole locations, in stations and offsets, were measured in reference to the centreline alignment and



## FOUNDATION REPORT – CULVERT AT STA 13+210, TOWNSHIP OF LOUISE HWY 17 FOUR-LANING, GWP 156-98-00

were subsequently converted into MTM NAD 83 coordinates in AutoCAD. Borehole elevations were surveyed by members of our technical staff in reference to the ground surface elevations at the temporary benchmarks installed by exp. prior to the commencement of fieldwork. The borehole locations given in the Record of Borehole sheets and shown on Drawing 2 are positioned relative to MTM NAD 83 northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum. The borehole locations, ground surface elevations and drilled depths are as follows:

Borehole	Location (MTM NAD 83)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing	Easting		
H2-4	5 136 319.3	273 911.6	239.7	8.9
H2-5	5 136 309.9	273 929.2	239.8	12.9
H2-6	5 136 305.7	273 942.7	239.8	17.7
H2-28	5 136 292.2	273 957.6	239.8	16.1
H2-29	5 136 285.6	273 970.8	239.8	18.6
H2-30	5 136 283.3	273 985.8	239.7	25.0

## 4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

### 4.1 Regional Geology

As delineated in the NOEGTS<sup>1</sup> Mapping, the ground terrain in this section of Highway 17 is comprised of bedrock knobs, outcrops and ridges with undulating to rolling glaciolacustrine plain, alluvial plain and organic/swamp soil deposits. In the lower-lying glaciolacustrine plain and alluvial plain areas, the primary materials consist of wet silts, sands and clays, and the organic terrain deposit primarily consists of peat. The surface water drainage in the area varies from dry to wet, corresponding to areas of moderate to low relief.

Based on geological mapping by the Ministry of Natural Resources (Map 2542)<sup>2</sup>, the site is underlain by rocks of the Paleoproterozoic Era belonging to the Huronian Supergroup and Elliot Lake Group consisting of conglomerate, wacke, arkose, quartz arenite, argillite, limestone and dolostone. Areas of mafic and related intrusive rocks comprised of diabase sills, dykes and related granophyre are also present in the vicinity of the site. Based on geological mapping by the Ontario Department of Mines (Map 2170)<sup>3</sup> this site area is characterized by extensive faults from distinct time periods. The Murray Fault has been identified to run parallel to the proposed approximately alignment of Highway 17.

### 4.2 General Overview of Local Subsurface Conditions

The detailed subsurface soil and groundwater conditions as encountered in the borings advanced during this investigation together with the results of the laboratory tests carried out on selected soil samples are presented on the attached Record of Borehole sheets and the laboratory test figures provided in Appendices A and B, respectively. The results of the in situ field tests (i.e., SPT 'N'-values and undrained shear strengths from the

<sup>1</sup>Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Digital Map Reference Number 411SW.

<sup>2</sup>Ministry of Natural Resources, (1981). Bedrock Geology of Ontario – West Central Sheet, Ontario Geological Survey - Map 2542

<sup>3</sup>Ontario Department of Mines (1969). Sudbury Mining Area, Sudbury District, Map 2170.



field vanes) as presented on the Record of Borehole sheets and in Section 4.0 are uncorrected. 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 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.

The inferred soils stratigraphy based on the result of the boreholes is shown in profile on Drawing 2. It should be noted that the orientation (i.e., north, south, east, west) stated in the text of the report is referenced to project north and therefore may differ from the Magnetic North shown on the drawings. The Highway 17 section of the proposed four-laning is oriented essentially east-west.

The stratigraphy encountered at the site generally consists of peat at the ground surface underlain by a cohesive deposit comprised of a zone of clayey silt (in some areas) transitioning into silty clay to clay. Underlying the cohesive deposit, cohesionless deposits of silt, sand and silt to sand and sand and gravel were encountered.

Detailed descriptions of the subsurface conditions encountered along the investigated culvert alignment are provided in the following sections of this report. Where relatively significant thicknesses of overburden were encountered, the various soil types are described in detail for each main deposit or stratum.

#### **4.2.1 Peat**

A 3.4 m to 3.7 m thick deposit of black, fibrous to amorphous peat was encountered at the ground surface in all boreholes. The surface of the peat deposit varies between Elevations 239.8 m and 239.7 m.

The SPT 'N'-values measured within the peat deposit are typically 0 blows (weight of hammer) to 1 blows per 0.3 m of penetration, suggesting a very soft consistency, however 'N'-values up to 9 blows per 0.3 m of penetration were noted through upper frozen peat materials.

The natural water content measured on six samples of the peat ranges from about 404 per cent to 661 per cent.

#### **4.2.2 Cohesive Deposit**

In all boreholes, a cohesive deposit was encountered beneath the peat. In general the cohesive deposit consisted of clayey silt transitioning into silty clay to clay. The top of the cohesive deposit was encountered between Elevations 236.4 m and 236.1 m and the overall deposit ranged between 3.5 m and 8.5 m in thickness.

#### **Clayey Silt**

In Borehole H2-30, a 2.1 m thick stratum of clayey silt was encountered underlying the peat at Elevation 236.2 m.

The SPT 'N'-values measured within this portion of the deposit are 3 blows and 5 blows per 0.3 m of penetration, suggesting a soft to firm consistency. One in situ field vane test carried out within this portion of the deposit measured an undrained shear strength of about 24 kPa with a calculated sensitivity is of 13. The field test results indicate that this portion of the deposit has a soft consistency.





Atterberg limits tests were carried out on one sample of the clayey silt. The test results indicate a liquid limit of about 30 per cent, a plastic limit of about 18 per cent and a plasticity index of about 12 per cent. The result of the Atterberg limits test is shown on the plasticity chart on Figure B1 in Appendix B and indicate that the material is classified as clayey silt of low plasticity.

The natural water content measured on one sample of this portion of the deposit is about 31 per cent.

### ***Silty Clay to Clay***

A deposit of grey, silty clay to clay was encountered underlying the peat deposit and/or the clayey silt stratum in all boreholes. In the majority of the boreholes, the silty clay to clay portion of the deposit was observed to be varved consisting of irregular layers of clayey silt/silty clay and silty clay/clay. The surface of this portion of the deposit was encountered between Elevations 236.4 m and 234.1 m and the thickness of the deposit ranges from 3.5 m to 8.5 m.

The SPT 'N'-values measured within this portion of the deposit range between 0 blows (weight of hammer) and 5 blows per 0.3 m of penetration, suggesting a very soft to firm consistency. In situ field vane tests carried out within this portion of the deposit measured undrained shear strengths ranging from about 18 kPa and 91 kPa and the sensitivity calculated to range from 3 to 16. The field test results indicate that this portion of the deposit has a soft to stiff consistency, with the stiffer vanes recorded near the surface or bottom of the cohesive deposit near the interface with other deposits. Typically, the deposit has a soft to firm consistency.

The grain size distributions of two samples of this deposit are presented on Figures B2 in Appendix B.

Atterberg limits tests were carried out on seven samples of the clayey silt and indicate liquid limits ranging from about 36 per cent to 71 per cent, plastic limits ranging from about 22 per cent to 27 per cent and plasticity indices ranging from about 14 per cent to 45 per cent. The results of the Atterberg limits tests are shown on the plasticity chart on Figure B3 in Appendix B and indicate that the material is classified as silty clay of medium plasticity to clay of high plasticity.

The natural water content measured on twelve samples of this portion of the deposit range between about 34 per cent and 70 per cent.

### **4.2.3 Silt**

A deposit of grey silt, trace to some clay, trace to some sand was encountered in all Boreholes beneath the cohesive deposit. The surface of this deposit ranges from Elevations 232.8 m to 227.7 m and its thickness ranges from 2.0 m to 10.4 m.

The SPT 'N'-values measured within this deposit range between 0 blows (weight of hammer) and 28 blows per 0.3 m of penetration, indicating a very loose to compact relative density.

The grain size distributions of five samples of this deposit are presented on Figures B4 in Appendix B. The results of Atterberg limits testing on four samples of the silt deposit indicated that the material is classified as non-plastic.

The natural water content measured on nine samples of this deposit ranges between about 28 per cent and 37 per cent.





#### **4.2.4 Sand and Silt to Sand**

A deposit of grey sand and silt to sand, trace to some gravel, trace clay was encountered underlying the silt deposit in Boreholes H2-5, H2-6, H2-28 and H2-30. The surface of this deposit ranges from Elevations 229.6 m to 217.3 m and its thickness ranges from 1.1 m to 6.0 m. A DCPT was advanced below the borehole termination depth in Borehole H2-5. Borehole H2-20 was terminated in this deposit after exploring the deposit for 2.6 m.

The SPT 'N'-values measured within this deposit range between 2 blows and 18 blows per 0.3 m of penetration, indicating a very loose to compact relative density.

The grain size distributions of two samples of this deposit are presented on Figure B5 in Appendix B.

The natural water content measured on two samples of this deposit are about 25 per cent.

#### **4.2.5 Sand and Gravel**

In Borehole H2-29, a 0.8 m thick stratum of sand and gravel was encountered underlying the silt deposit at Elevation 222.2 m.

Refusal was encountered in Borehole H2-29 and recorded an SPT 'N'-value of 10 blows per 0.15 m, likely indicative of an obstruction (i.e. cobble/boulder) or the proximity to bedrock surface.

#### **4.2.6 Refusal**

Refusal to split-spoon, auger or casing advancement or dynamic cone penetration, indicating close proximity to the inferred bedrock surface was encountered in Boreholes H2-4, H2-5, H2-6, H2-28 and H2-29 at depths ranging from 8.9 m to 18.6 m below the ground surface or between Elevations 230.8 m and 221.2 m.

#### **4.2.7 Groundwater Conditions**

In general, the samples taken in the boreholes were wet. Artesian groundwater levels were measured in Borehole H2-6, H2-28, H2-29 and H2-30 and the groundwater level upon completion of drilling was measured between 0.5 m and 1.4 m above ground surface corresponding to Elevations 240.2 m to 241.2 m. In Boreholes H2-4 and H2-5, the groundwater levels observed upon completion of drilling are about Elevation 239.4 m and 239.0 m, measured from 0.3 m to 0.8 m below ground surface, respectively. It should be noted that the groundwater levels in the area fluctuate seasonally as well as during precipitation events and snowmelt.

### **5.0 CLOSURE**

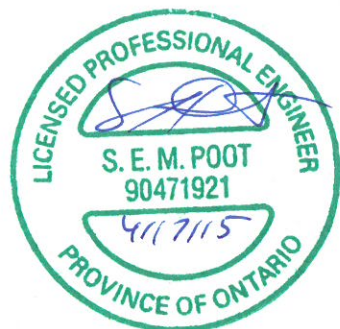
The field personnel supervising the drilling program were Messrs. Ed Savard and Adam Core, under the direction of Mr. Evan Childerhose P.Eng. This report was prepared by Mr. Adam Core, E.I.T. and the technical aspects were reviewed by Ms. Sarah E. M. Poot, P.Eng., a senior geotechnical engineer and Associate with Golder. Mr. Jorge M. A. Costa, P.Eng., Golder's Designated MTO Contact for this project and Principal with Golder, conducted an independent quality control review of the report.



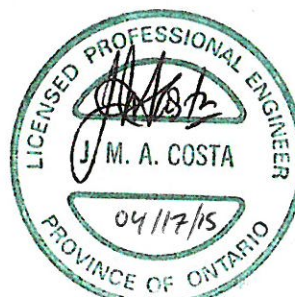
## Report Signature Page

GOLDER ASSOCIATES LTD.

Adam Core E.I.T.  
Geotechnical Engineering Intern



Sarah E. M. Poot, P. Eng.  
Senior Geotechnical Engineer, Associate



Jorge M. A. Costa, P. Eng.  
Designated MTO Contact, Principal

AC/SEMP/JMAC/kp

N:\Active\2011\1190 Sudbury\1191\Temp folder 11-1191-0007\Report\Culverts\R04 - Culvert STA 13+210 Twp Louise (H2 Area)\Final\11-1191-0007-04 RPT 15Apr17 FIDR Culvert  
13+210 Louise.docx

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

CONT No.  
GWP No. 156-98-00

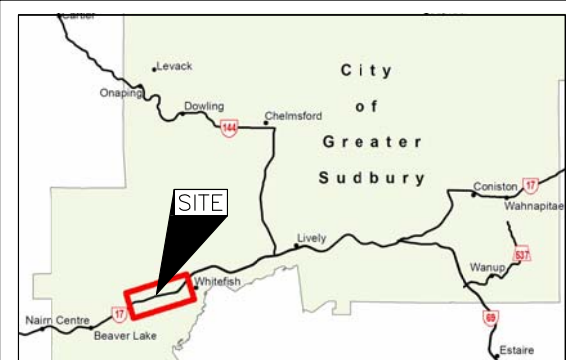


HIGHWAY 17  
SITE LOCATION PLAN

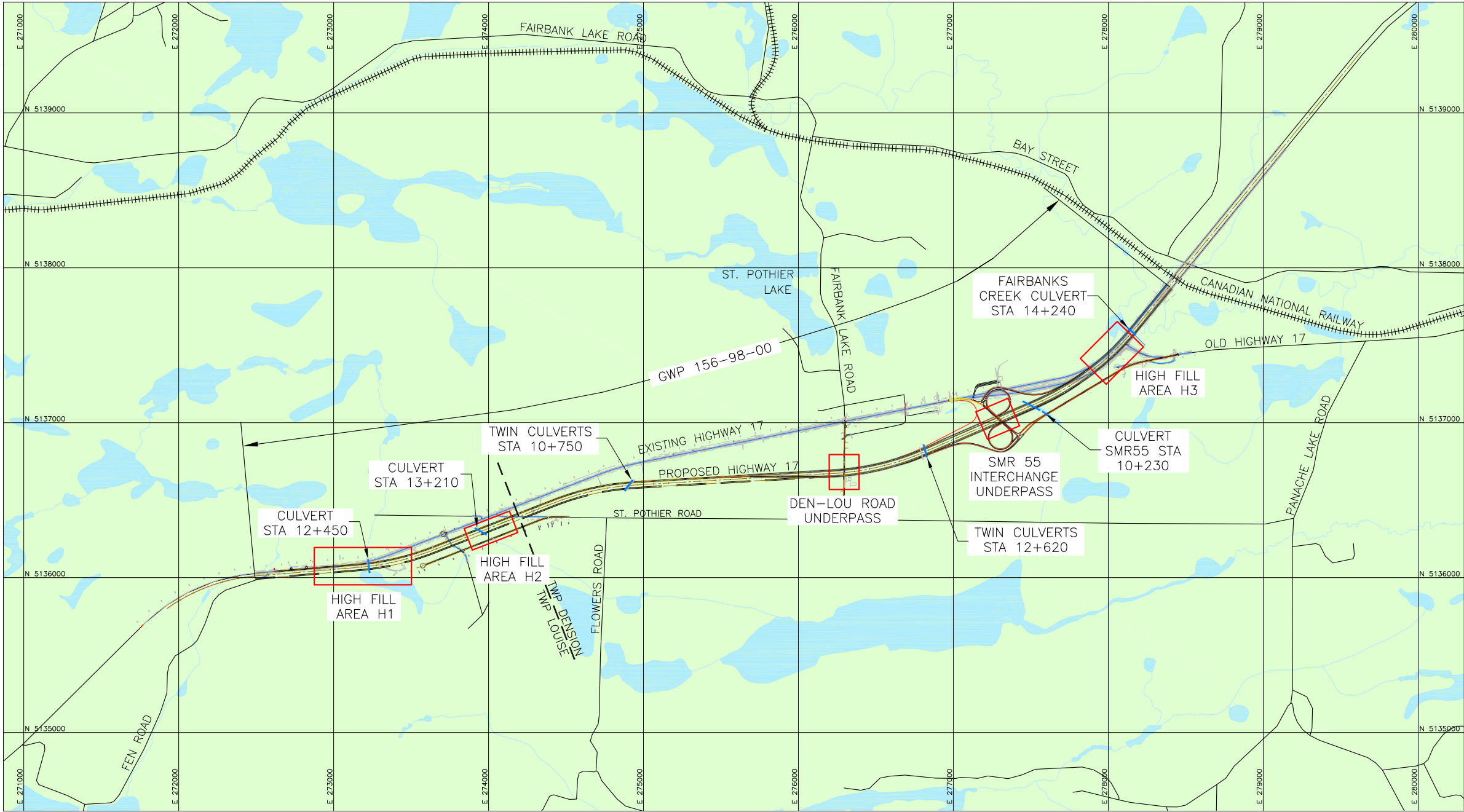
SHEET



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



**KEY PLAN**  
10 0 10 20 km



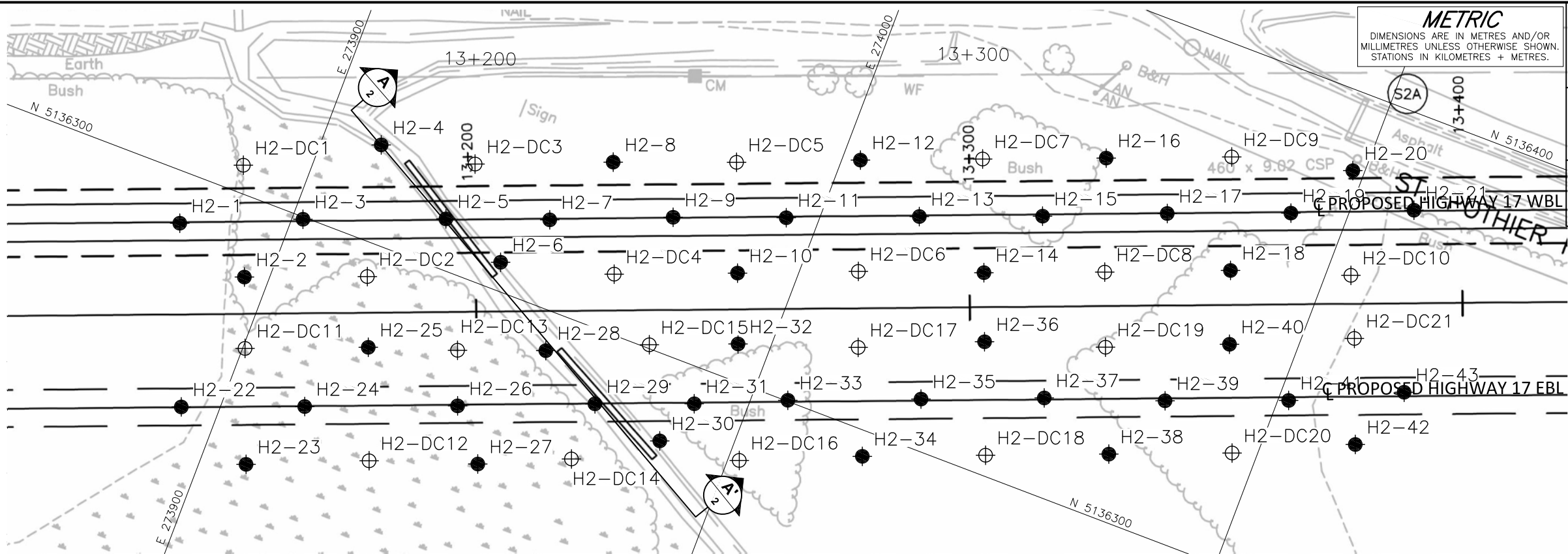
**PLAN**

SCALE  
300 0 300 600 m

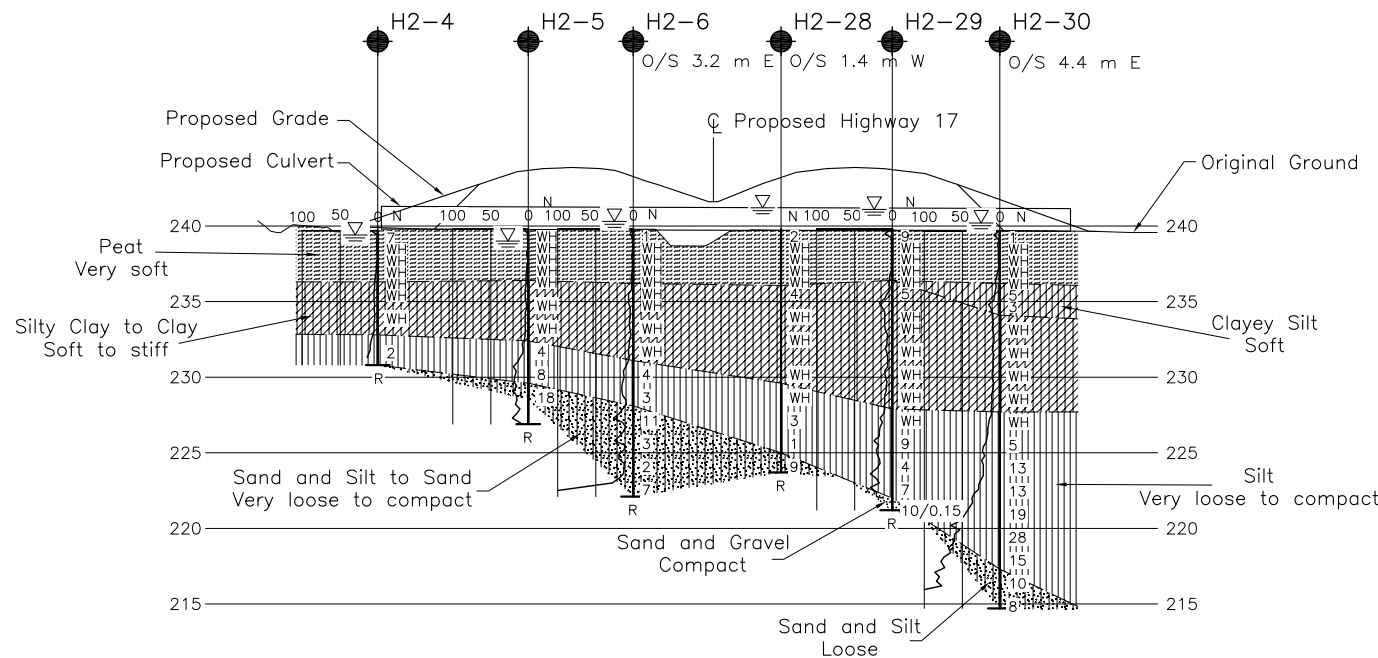
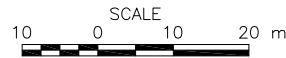
**REFERENCE**

Base plans provided by Golder GIS and highway alignment provided in digital format by DM Wills, drawing file EBL & WBL PROFILES.dwg received Feb 28, 2013.

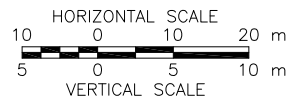
NO.	DATE	BY	REVISION
HWY. 17	PROJECT NO. 11-1191-0007		DIST.
SUBM'D. MT	CHKD.	DATE: APR 2015	SITE:
DRAWN: TB	CHKD. SEMP	APPD. JMAC	DWG. 1



PLAN



A-A'  
2 CULVERT AT STA 13+210  
HIGHWAY 17



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

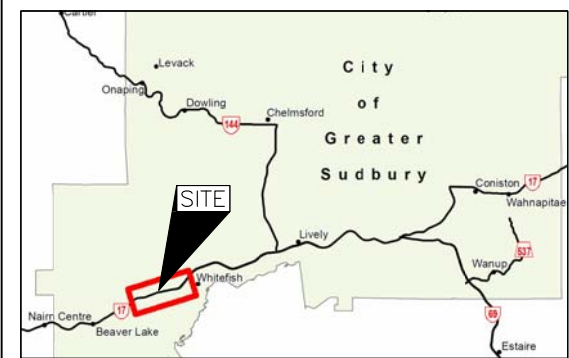
CONT No.  
GWP No. 156-98-00

HIGHWAY 17 4 LANING  
CULVERT - STA 13+210

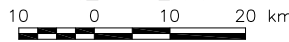
BOREHOLE LOCATIONS AND SOIL STRATA



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



KEY PLAN



LEGEND

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

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
H2-4	239.7	5136319.3	273911.6
H2-5	239.8	5136309.9	273929.2
H2-6	239.8	5136305.7	273942.7
H2-28	239.8	5136292.2	273957.6
H2-29	239.8	5136285.6	273970.8
H2-30	239.7	5136283.3	273985.8

NOTES

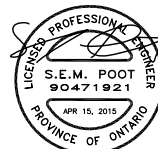
This drawing is for subsurface information only. The proposed details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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 DM Wills, drawing files 581\_base.dwg, GWP156-98-00\_B & C Plans.dwg and 581\_contours.dwg received Jan 17, 2012. Hwy 17 x-sections to Golder (v 2009).dwg provided in digital format by DMWills received on NOV 15, 2013.



NO.	DATE	BY	REVISION
Geocres No. 411-328			
HWY. 17		PROJECT NO. 11-1191-0007	DIST.
SUBM'D. AC	CHKD.	DATE: APR 2015	SITE:
DRAWN: TB	CHKD. SEMP	APPD. JMAC	DWG. 2





# APPENDIX A

## Record of Boreholes



## 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

<b>(a)</b>	<b>Index Properties</b>
$\rho(\gamma)$	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
$SO_4$	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 11-1191-0007			RECORD OF BOREHOLE No H2-4			1 OF 1 METRIC															
G.W.P. 156-98-00			LOCATION N 5136319.3; E 273911.6			ORIGINATED BY EHS															
DIST _____ HWY 17			BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers, NW Casing, Wash Boring			COMPILED BY EC															
DATUM GEODETIC			DATE April 11, 2012			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			GR SA SI CL		
239.7	GROUND SURFACE							20 40 60 80 100	20 40 60 80 100	20 40 60	W <sub>p</sub> W W <sub>L</sub>	66%									
0.0	PEAT (Fibrous) Very soft Black Frozen to wet		1	SS	7	▽	239														
			2	SS	WH		238														
			3	SS	WH		237														
			4	SS	WH		236														
236.3	SILTY CLAY Soft Grey Wet		5	SS	WH		235														
3.4			6	SS	WH		234														
			7	SS	WH		233														
							232														
232.8	SILT, trace to some clay Very loose Grey to brown Wet		8	SS	2		231														
6.9																					
	Spoon attempted at 8.9 m depth, spoon bouncing.																				
230.8	END OF BOREHOLE SPOON REFUSAL (HAMMER BOUNCING)																				
8.9	Notes:  1. Water level at a depth of 0.3 m below ground surface (Elev. 239.4 m) upon completion of drilling.																				

SUD-MTO 001 1111910007 CULVERTS.GPJ GAL-MISS.GDT 20/10/14 DATA INPUT:

PROJECT 11-1191-0007			RECORD OF BOREHOLE No H2-5			1 OF 2 METRIC		
G.W.P. 156-98-00			LOCATION N 5136309.9; E 273929.2			ORIGINATED BY EHS		
DIST _____ HWY 17			BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers, NW Casing, Wash Boring			COMPILED BY EC		
DATUM GEODETIC			DATE April 11 and 12, 2012			CHECKED BY SEMP		
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	
239.8	GROUND SURFACE						<div style="display: flex; justify-content: space-between;"> <div> <p>20 40 60 80 100</p> <p>SHEAR STRENGTH kPa</p> <p>○ UNCONFINED + FIELD VANE</p> <p>● QUICK TRIAXIAL × REMOULDED</p> <p>20 40 60 80 100</p> </div> <div> <p>20 40 60</p> <p>WATER CONTENT (%)</p> <p>W<sub>p</sub> W W<sub>L</sub></p> </div> </div>	
0.0	PEAT (Fibrous to amorphous) Very soft Black Frozen to wet		1	SS	WH	239	<div style="display: flex; justify-content: space-between;"> <div> <p>20 40 60 80 100</p> <p>SHEAR STRENGTH kPa</p> <p>○ UNCONFINED + FIELD VANE</p> <p>● QUICK TRIAXIAL × REMOULDED</p> <p>20 40 60 80 100</p> </div> <div> <p>20 40 60</p> <p>WATER CONTENT (%)</p> <p>W<sub>p</sub> W W<sub>L</sub></p> </div> </div>	
			2	SS	WH	238		
			3	SS	WH	237		
			4	SS	WH	236		
236.4	CLAY Soft to firm Black Wet		5	SS	WH	235		
3.4	Varved below 4.9 m depth.		6	SS	WH	234		
			7	SS	WH	233		
232.4	SILT, some clay Loose Grey Wet		8	SS	4	232		
7.4			9	SS	8	231		
			10	SS	18	230		
229.6	SAND and SILT, trace gravel Compact Grey Wet					229		
10.2						228.5		
228.5	END OF BOREHOLE					228		
11.3								


Continued Next Page

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

SUD-MTO 001 1111910007 CULVERTS.GPJ GAL-MISS.GDT 20/10/14 DATA INPUT:

PROJECT <u>11-1191-0007</u>		<b>RECORD OF BOREHOLE No H2-5</b>				2 OF 2 <b>METRIC</b>	
G.W.P. <u>156-98-00</u>		LOCATION <u>N 5136309.9; E 273929.2</u>				ORIGINATED BY <u>EHS</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>EC</u>	
DATUM <u>GEODETIC</u>		DATE <u>April 11 and 12, 2012</u>				CHECKED BY <u>SEMP</u>	

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT  $\gamma$ 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					W <sub>p</sub>	W			W <sub>L</sub>
	--- CONTINUED FROM PREVIOUS PAGE ---						<div style="display: flex; justify-content: space-between;"> <span>20 40 60 80 100</span> <span>20 40 60 80 100</span> </div> <div style="display: flex; justify-content: space-between;"> <span>○ UNCONFINED   + FIELD VANE</span> <span>● QUICK TRIAXIAL   × REMOULDED</span> </div>										
226.9	END OF BOREHOLE					227											
12.9	END OF DCPT REFUSAL TO FURTHER PENETRATION (HAMMER BOUNCING)  Notes:  1. Water level at a depth of 0.8 m below ground surface (Elev. 239.0 m) upon completion of drilling.																

PROJECT <u>11-1191-0007</u>			<b>RECORD OF BOREHOLE No H2-6</b>			1 OF 2 <b>METRIC</b>		
G.W.P. <u>156-98-00</u>			LOCATION <u>N 5136305.7; E 273942.7</u>			ORIGINATED BY <u>AC</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>EC</u>		
DATUM <u>GEODETIC</u>			DATE <u>April 3 and 4, 2012</u>			CHECKED BY <u>SEMP</u>		
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa ○ UNCONFINED    + FIELD VANE ● QUICK TRIAXIAL    × REMOULDED 20 40 60 80 100
239.8	GROUND SURFACE							PLASTIC LIMIT    NATURAL MOISTURE CONTENT    LIQUID LIMIT W <sub>p</sub> W                      W <sub>L</sub> WATER CONTENT (%)
0.0	PEAT (Fibrous) Very soft Black Frozen to wet		1	SS	1		239	
			2	SS	WH			
			3	SS	WH		238	
			4	SS	WH			
			5	SS	WH		237	
236.2								
3.6	CLAY, varved Soft Grey to brown Wet		6	SS	WH		236	
			7	SS	WH		235	
			8	SS	WH		234	
			9	SS	WH		233	
231.1								
8.7	SILT, trace sand, trace clay Very loose Grey Wet		10	SS	4		232	
			11	SS	3		231	
							230	
							229	
228.1								
11.7							228	

SUD-MTO 001 111910007 CULVERTS.GPJ GAL-MISS.GDT 20/10/14 DATA INPUT:

Continued Next Page

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

PROJECT <u>11-1191-0007</u>			RECORD OF BOREHOLE <b>No H2-6</b>			2 OF 2 <b>METRIC</b>		
G.W.P. <u>156-98-00</u>			LOCATION <u>N 5136305.7; E 273942.7</u>			ORIGINATED BY <u>AC</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>EC</u>		
DATUM <u>GEODETIC</u>			DATE <u>April 3 and 4, 2012</u>			CHECKED BY <u>SEMP</u>		
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT		
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 20 40 60 80 100
	--- CONTINUED FROM PREVIOUS PAGE ---							PLASTIC LIMIT W <sub>p</sub> NATURAL MOISTURE CONTENT W LIQUID LIMIT W <sub>L</sub> WATER CONTENT (%) 20 40 60
	SAND and SILT, trace clay Very loose to compact Grey Wet		12	SS	11		227	○
			13	SS	3		226	
	Casing grinding was noted at 14.9 m depth.		14	SS	2		225	
			15	SS	7		223	
223.5 16.3	SAND, some silt Loose Grey Wet  Spoon attempted at 17.7 m depth, spoon bouncing.							
222.1 17.7	END OF BOREHOLE REFUSAL TO FURTHER CASING ADVANCEMENT  Notes:  1. Water level 0.5 m above ground surface (Elev. 240.3 m) upon completion of drilling.  2. On April 5, 2012, the water level was measured in the casing at 0.5 m above ground surface (Elev. 240.3 m); approximately 3.7 m of sand and silt heave was measured in casing.							

SUD-MTO 001 1111910007 CULVERTS.GPJ GAL-MISS.GDT 20/10/14 DATA INPUT:

PROJECT 11-1191-0007			RECORD OF BOREHOLE No H2-28			1 OF 2 METRIC															
G.W.P. 156-98-00			LOCATION N 5136292.2; E 273957.6			ORIGINATED BY EHS															
DIST _____ HWY 17			BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers, NW Casing, Wash Boring			COMPILED BY EC															
DATUM GEODETIC			DATE April 12 and 13, 2012			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			GR SA SI CL		
239.8	GROUND SURFACE							20 40 60 80 100	20 40 60 80 100	20 40 60	W <sub>p</sub> W W <sub>L</sub>										
0.0	PEAT (Fibrous) Very soft Black Frozen to wet		1	SS	2		239														
			2	SS	WH		238														
			3	SS	WH		237														
			4	SS	WH		236														
			5	SS	WH		235														
236.1	CLAY to SILTY CLAY Soft to stiff Grey to brown Wet Varved between 3.7 m depth and 5.9 m depth.		6	SS	4		234														
							233														
			7	SS	WH		232														
							231														
			8	SS	WH		230														
							229														
							228														
229.6	SILT, trace to some clay, trace sand Very loose Grey Wet		9	SS	WH																
10.2			10	SS	WH																

Continued Next Page

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

SUD-MTO 001 1111910007 CULVERTS.GPJ GAL-MISS.GDT 20/10/14 DATA INPUT:





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

SUD-MTO 001 111910007 CULVERTS.GPJ GAL-MISS.GDT 20/10/14 DATA INPUT:

PROJECT 11-1191-0007			RECORD OF BOREHOLE No H2-29			1 OF 2 METRIC		
G.W.P. 156-98-00			LOCATION N 5136285.6; E 273970.8			ORIGINATED BY EHS		
DIST _____ HWY 17			BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers, NW Casing, Wash Boring			COMPILED BY EC		
DATUM GEODETIC			DATE April 13 and 16, 2012			CHECKED BY SEMP		
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100 PLASTIC LIMIT W <sub>p</sub> NATURAL MOISTURE CONTENT W LIQUID LIMIT W <sub>L</sub> WATER CONTENT (%) 20 40 60 UNIT WEIGHT γ kN/m <sup>3</sup>
239.8	GROUND SURFACE							
0.0	PEAT (Fibrous) Very soft Black Frozen to wet		1	SS	9		239	
			2	SS	WH			
			3	SS	WH		238	
			4	SS	WH		237	
236.4			5	SS	WH		236	
3.4	SILTY CLAY Soft to stiff Grey to brown Wet		6	SS	5		235	
			7	SS	WH		234	
			8	TO	WH		233	
			9	SS	WH		232	
			10	SS	WH		231	
			11	SS	WH		230	
							229	
							228	
227.9								

Continued Next Page

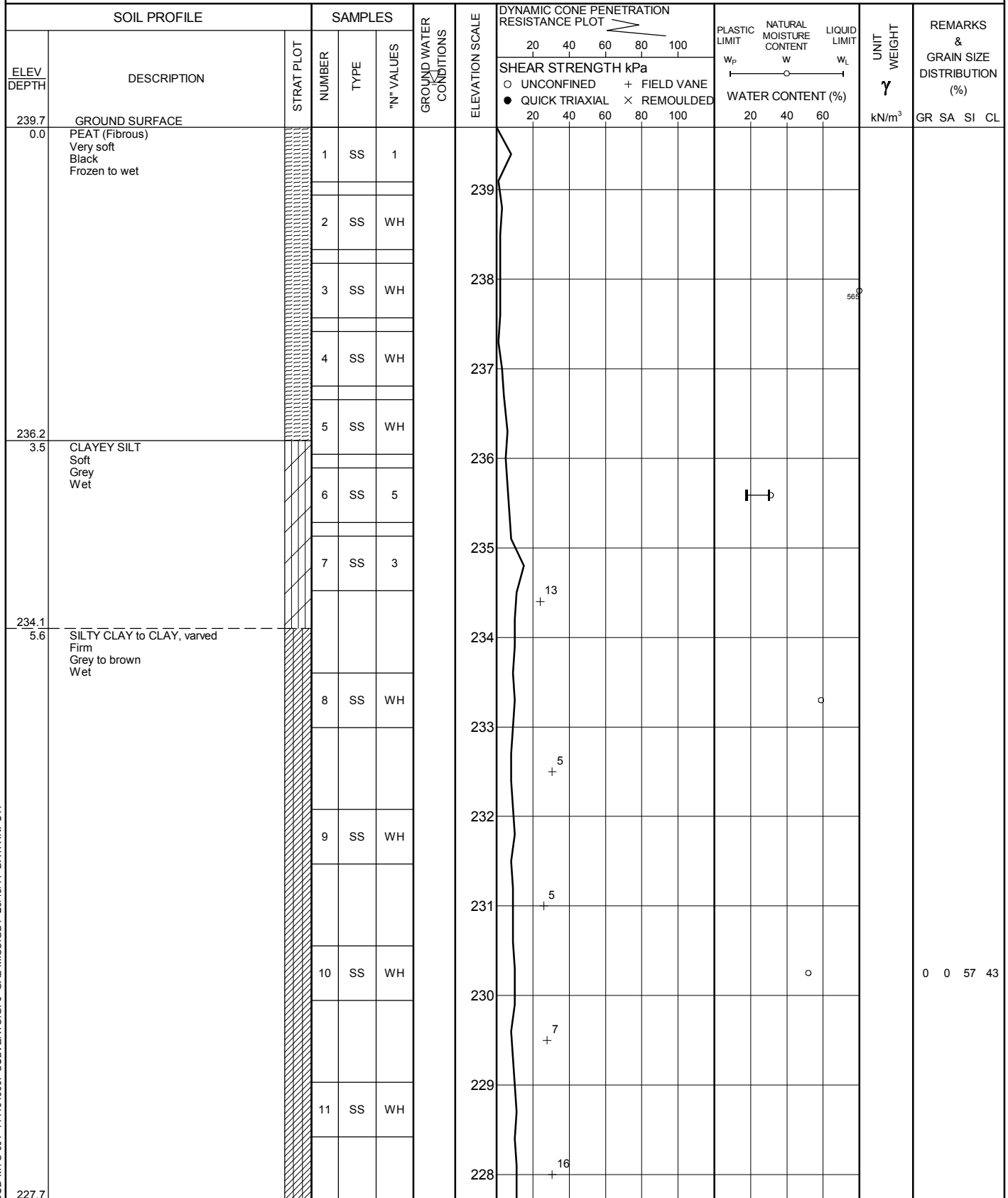
+ 3, × 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

SUD-MTO 001 1111910007 CULVERTS.GPJ GAL-MISS.GDT 20/10/14 DATA INPUT:

PROJECT <u>11-1191-0007</u>		<b>RECORD OF BOREHOLE No H2-29</b>				2 OF 2 <b>METRIC</b>											
G.W.P. <u>156-98-00</u>		LOCATION <u>N 5136285.6; E 273970.8</u>				ORIGINATED BY <u>EHS</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>EC</u>											
DATUM <u>GEODETIC</u>		DATE <u>April 13 and 16, 2012</u>				CHECKED BY <u>SEMP</u>											
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 (%)
--- CONTINUED FROM PREVIOUS PAGE ---																	
11.9	SILT, trace to some clay, trace sand Very loose to loose Grey Wet		12	SS		WH										NP	0 2 90 8
			13	SS		9											
			14	SS		4											
			15	SS		7											
222.0																	
17.8	SAND and GRAVEL Compact Grey Wet																
221.2			16	SS		10/0.15											31 48 19 2
18.6	END OF BOREHOLE SPOON REFUSAL (HAMMER BOUNCING)  Notes:  1. Water level measured in casing at 1.3 m above ground surface (Elev. 241.4 m) upon completion of drilling.																

SUD-MTO-001 1111910007 CULVERTS.GPJ GAL-MISS.GDT 20/10/14 DATA INPUT:

<b>PROJECT</b> 11-1191-0007		<b>RECORD OF BOREHOLE No H2-30</b>		1 OF 3 <b>METRIC</b>	
<b>G.W.P.</b> 156-98-00		<b>LOCATION</b> N 5136283.3; E 273985.8		<b>ORIGINATED BY</b> AC	
<b>DIST</b> _____ <b>HWY</b> 17		<b>BOREHOLE TYPE</b> 108 mm I.D. Continuous Flight Hollow Stem Augers, NW Casing, Wash Boring		<b>COMPILED BY</b> EC	
<b>DATUM</b> GEODETIC		<b>DATE</b> April 4 and 5, 2012		<b>CHECKED BY</b> SEMP	



SUD-MTO 001 1111910007 CULVERTS.GPJ GAL-MISS.GDT 20/10/14 DATA INPUT:

Continued Next Page

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

PROJECT <u>11-1191-0007</u>		<b>RECORD OF BOREHOLE No H2-30</b>		2 OF 3 <b>METRIC</b>	
G.W.P. <u>156-98-00</u>		LOCATION <u>N 5136283.3; E 273985.8</u>		ORIGINATED BY <u>AC</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>EC</u>	
DATUM <u>GEODETIC</u>		DATE <u>April 4 and 5, 2012</u>		CHECKED BY <u>SEMP</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT   NATURAL MOISTURE   LIQUID CONTENT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W <sub>p</sub>	W	W <sub>L</sub>		WATER CONTENT (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
								○ UNCONFINED   + FIELD VANE																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
						● QUICK TRIAXIAL   × REMOULDED																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
12.0	--- CONTINUED FROM PREVIOUS PAGE ---  SILT, trace to some sand, trace clay Very loose to compact Grey Wet																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				</

Continued Next Page

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

SUD-MTO 001 1111910007 CULVERTS.GPJ GAL-MISS.GDT 20/10/14 DATA INPUT:

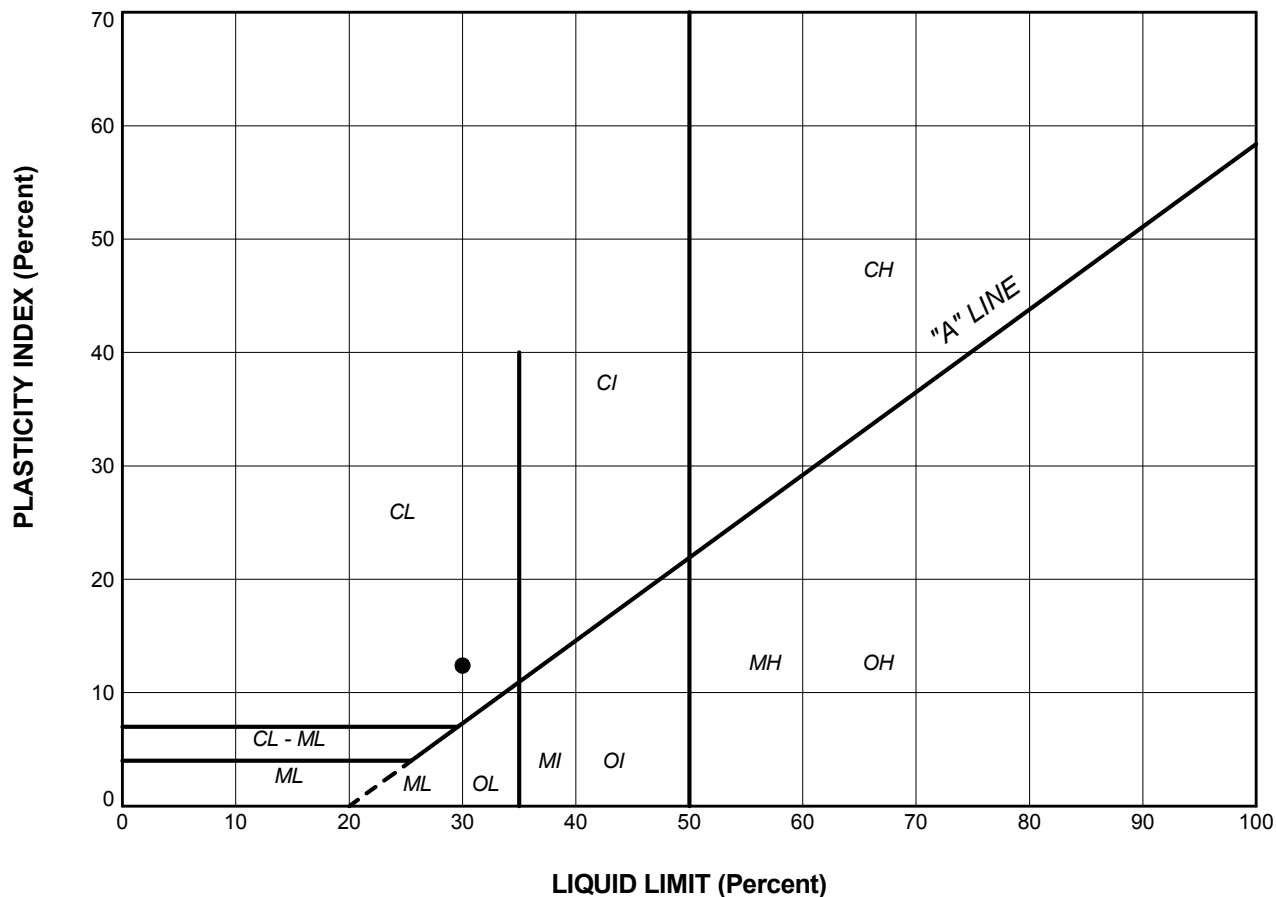
PROJECT <u>11-1191-0007</u>		<b>RECORD OF BOREHOLE No H2-30</b>				3 OF 3 <b>METRIC</b>										
G.W.P. <u>156-98-00</u>		LOCATION <u>N 5136283.3; E 273985.8</u>				ORIGINATED BY <u>AC</u>										
DIST <u>          </u> HWY <u>17</u>		BOREHOLE TYPE <u>108 mm I.D. Continuous Flight Hollow Stem Augers, NW Casing, Wash Boring</u>				COMPILED BY <u>EC</u>										
DATUM <u>GEODETIC</u>		DATE <u>April 4 and 5, 2012</u>				CHECKED BY <u>SEMP</u>										
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					W <sub>p</sub> W   W <sub>L</sub>			
	--- CONTINUED FROM PREVIOUS PAGE ---						<div style="display: flex; justify-content: space-between;"> <span>20   40   60   80   100</span> </div> <div style="display: flex; justify-content: space-between;"> <span>○ UNCONFINED   + FIELD VANE</span> </div> <div style="display: flex; justify-content: space-between;"> <span>● QUICK TRIAXIAL   × REMOULDED</span> </div> <div style="display: flex; justify-content: space-between;"> <span>20   40   60   80   100</span> </div>					<div style="display: flex; justify-content: space-between;"> <span>20   40   60</span> </div>				
214.7	SAND and SILT, trace clay Loose Grey Wet	[Strat Plot]	20	SS	8	215										
25.0	END OF BOREHOLE  Notes:  1. Water level at 0.5 m above ground surface (Elev. 239.7 m) upon completion of drilling.  2. Prior to resuming drilling on April 5, 2012, water level was measured in casing at 0.5 m above existing ground surface (Elev. 240.2 m).															



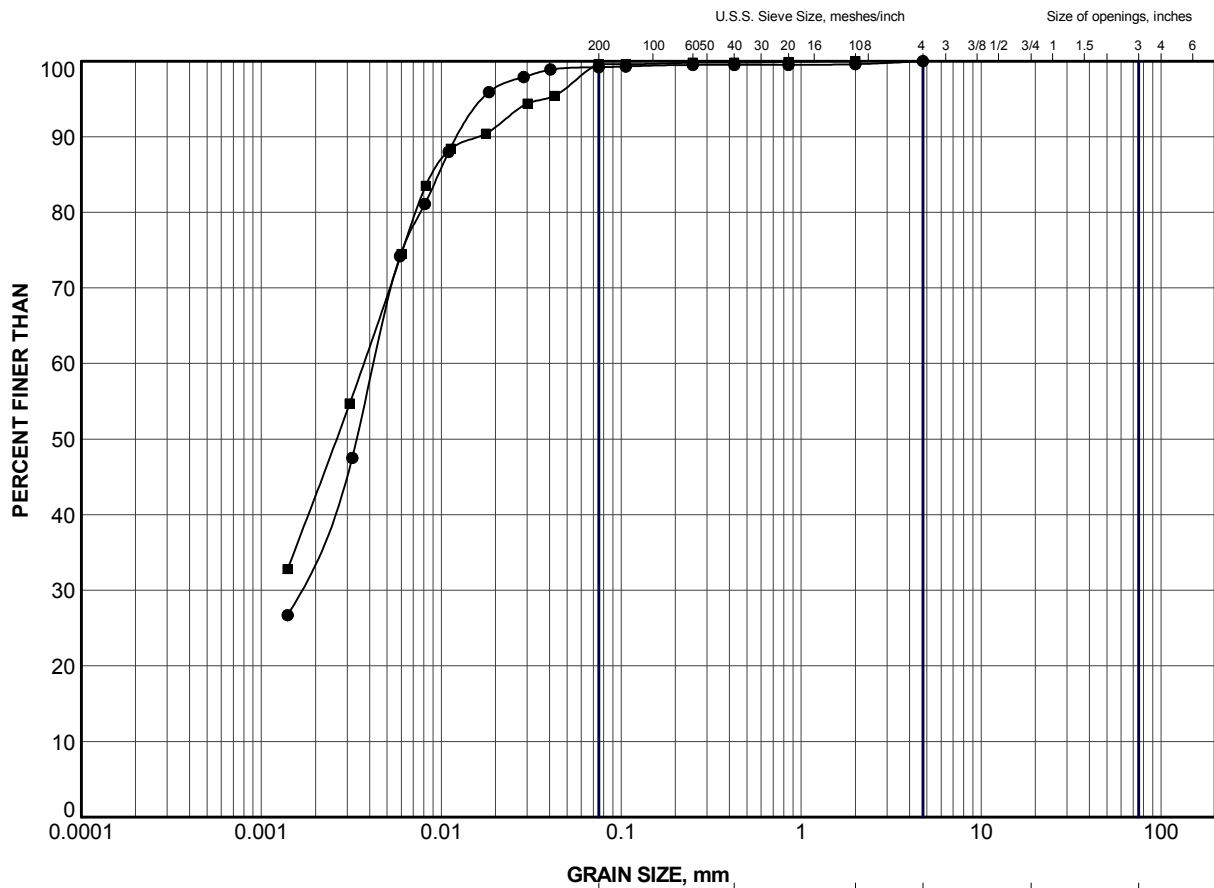
# APPENDIX B

## Laboratory Tests Results






PROJECT			HIGHWAY 17 CULVERT STA 13+210		
TITLE			PLASTICITY CHART CLAYEY SILT		
PROJECT No.		11-1191-0007	FILE N0111910007 CULVERTS.GPJ		
DRAWN	TB	Oct 2014	SCALE	N/A	REV.
CHECK	SEMP	Oct 2014	FIGURE B1		
APPR		Oct 2014			

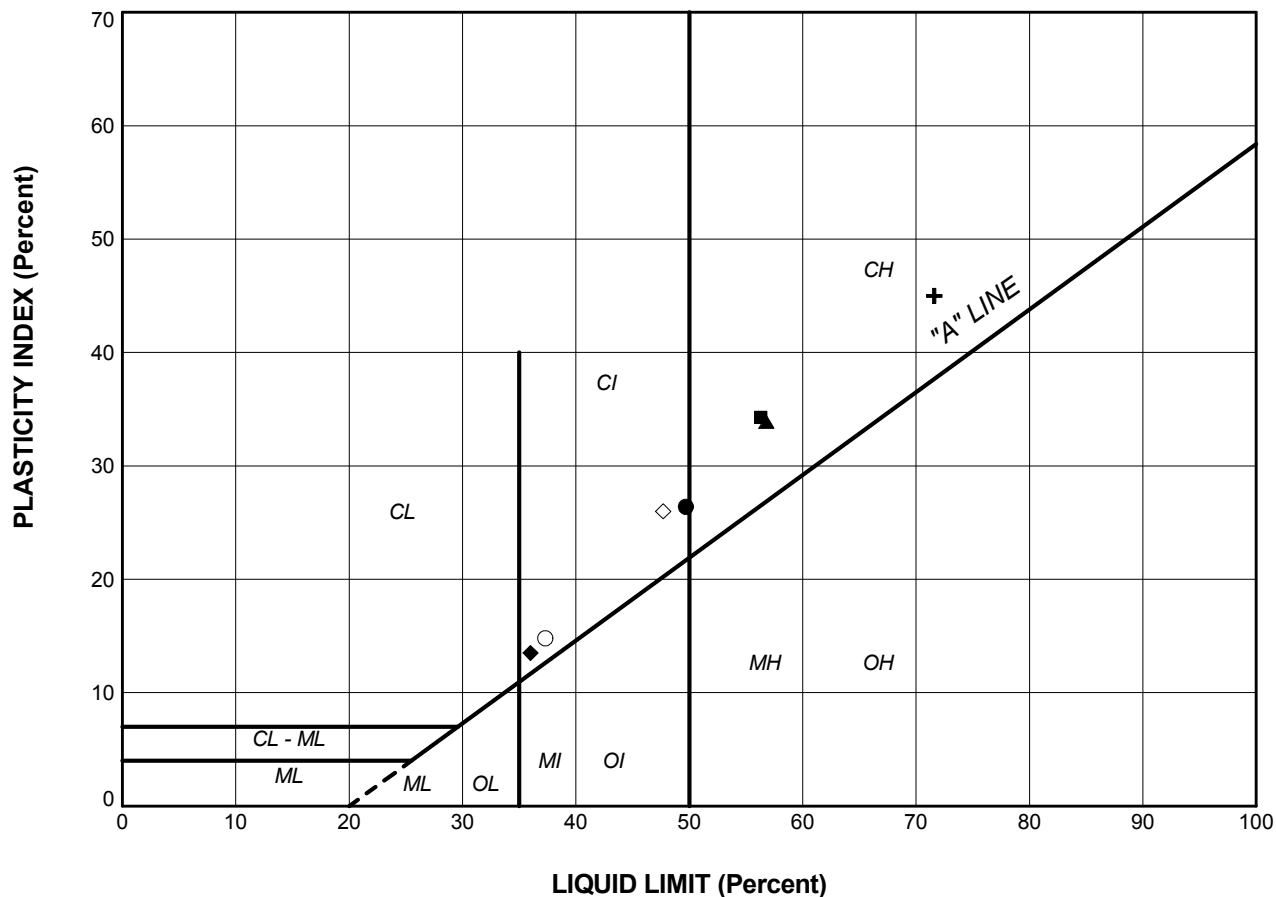


GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

### LEGEND


SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	H2-28	9	230.3
■	H2-30	10	230.2

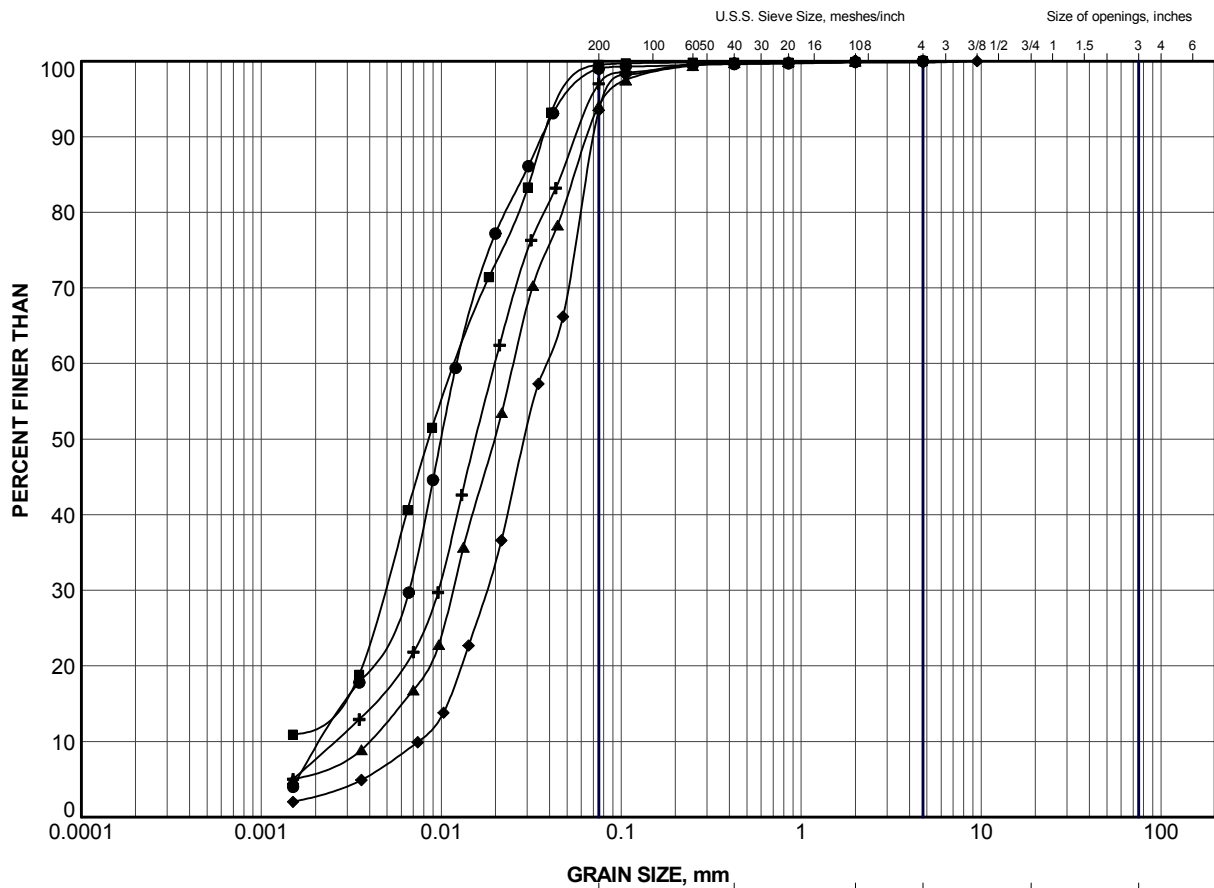
PROJECT						HIGHWAY 17 CULVERT STA 13+210					
TITLE						GRAIN SIZE DISTRIBUTION SILTY CLAY to CLAY					
PROJECT No. 11-1191-0007						FILE # 11-1191-0007 CULVERTS.GPJ					
DRAWN		TB		Oct 2014		SCALE		N/A		REV.	
CHECK		SEMP		Oct 2014							
APPR				Oct 2014							
 <b>Golder Associates</b> SUDBURY, ONTARIO						<b>FIGURE B2</b>					



### LEGEND


SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	H2-4	6	49.7	23.3	26.4
■	H2-5	6	56.3	22.0	34.3
▲	H2-6	7	56.8	22.9	33.9
+	H2-28	7	71.6	26.6	45.0
◆	H2-28	9	36.0	22.5	13.5
◇	H2-29	6	47.7	21.7	26.0
○	H2-29	10	37.3	22.5	14.8

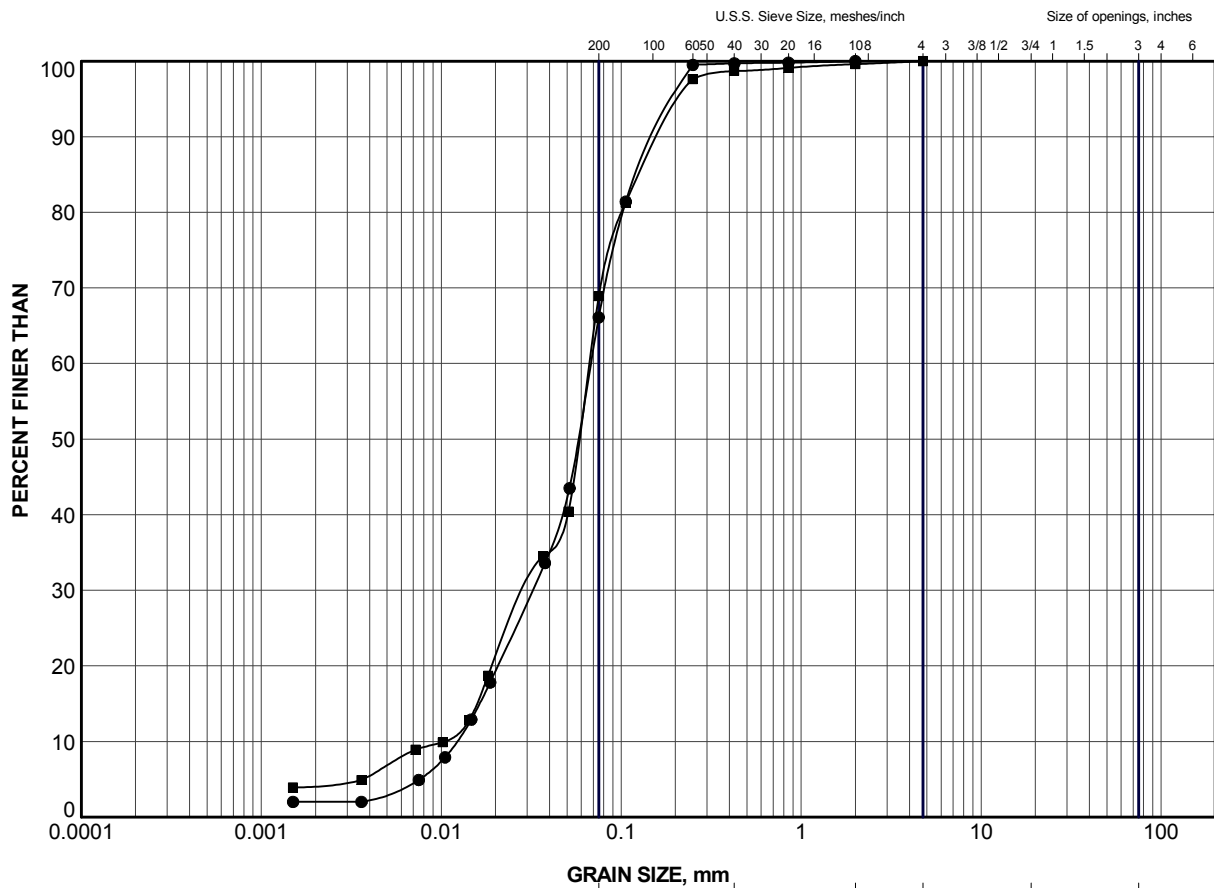
PROJECT					HIGHWAY 17 CULVERT STA 13+210				
TITLE					<b>PLASTICITY CHART</b> SILTY CLAY to CLAY				
PROJECT No.			11-1191-0007		FILE N0111910007 CULVERTS.GPJ				
DRAWN	TB	Oct 2014		SCALE	N/A		REV.		
CHECK	SEMP	Oct 2014							
APPR		Oct 2014							
 <b>Golder Associates</b> SUDBURY, ONTARIO				<b>FIGURE B3</b>					



### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	H2-4	8	231.8
■	H2-5	8	231.9
▲	H2-28	11	227.3
+	H2-29	13	225.8
◆	H2-30	16	221.1

PROJECT					
HIGHWAY 17 CULVERT STA 13+210					
TITLE					
GRAIN SIZE DISTRIBUTION SILT					
PROJECT No.		11-1191-0007		FILE# 11-1191-0007 CULVERTS.GPJ	
DRAWN	TB	Oct 2014	SCALE	N/A	REV.
CHECK	SEMP	Oct 2014			
APPR		Oct 2014			
 <b>Golder Associates</b> SUDBURY, ONTARIO			<b>FIGURE B4</b>		



### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	H2-6	12	227.3
■	H2-30	19	216.5

PROJECT

HIGHWAY 17  
CULVERT STA 13+210

TITLE

## GRAIN SIZE DISTRIBUTION

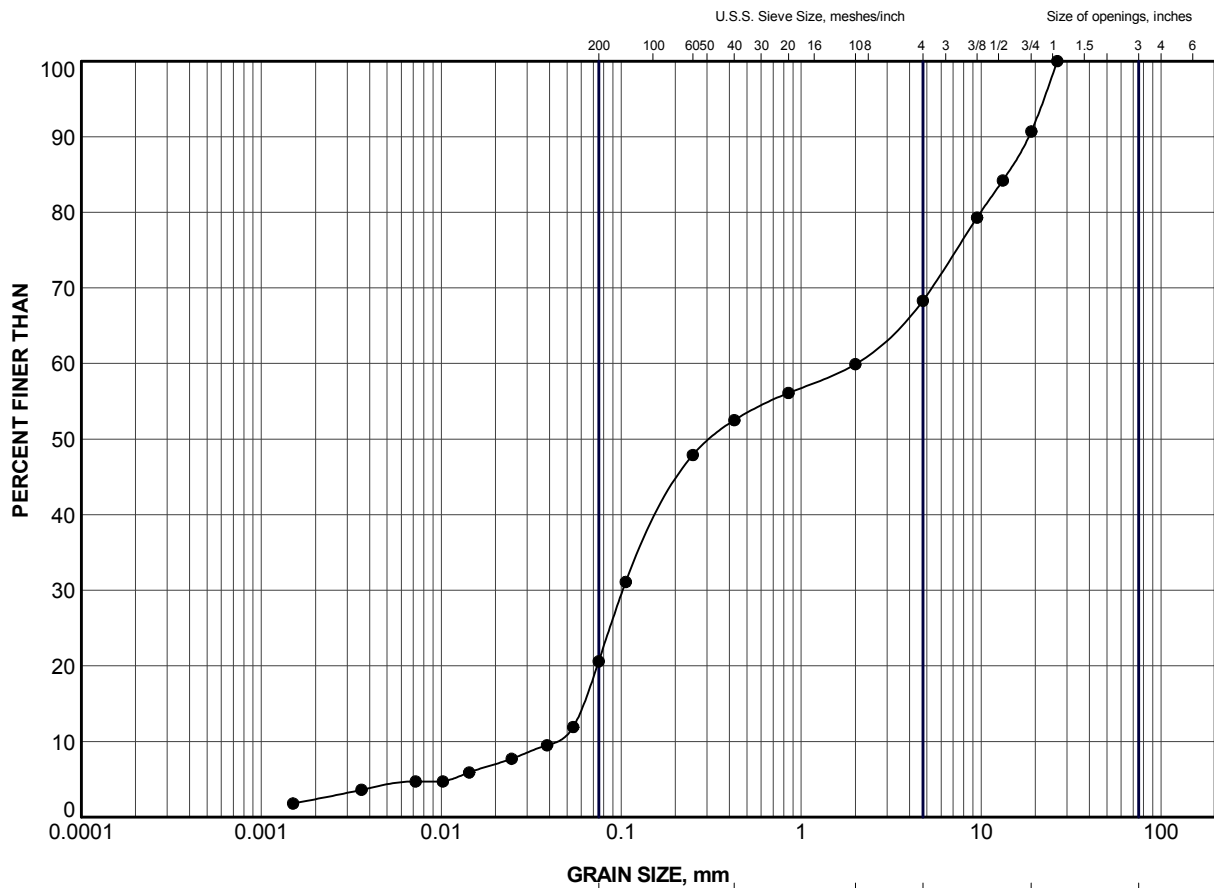
SAND and SILT



**Golder Associates**  
SUDBURY, ONTARIO

PROJECT No.	11-1191-0007	FILE#	N#910007 CULVERTS.GPJ
DRAWN	TB	Oct 2014	SCALE N/A REV.
CHECK	SEMP	Oct 2014	
APPR		Oct 2014	


**FIGURE B5**



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

#### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	H2-29	16	221.4

PROJECT					HIGHWAY 17 CULVERT STA 13+210				
TITLE					<b>GRAIN SIZE DISTRIBUTION</b> SAND and GRAVEL				
PROJECT No.		11-1191-0007		FILE#		N0910007 CULVERTS.GPJ			
DRAWN	TB	Oct 2014		SCALE	N/A		REV.		
CHECK	SEMP	Oct 2014		<b>FIGURE B6</b>					
APPR		Oct 2014							
 <b>Golder Associates</b> SUDBURY, ONTARIO									

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.

Africa	+ 27 11 254 4800
Asia	+ 86 21 6258 5522
Australasia	+ 61 3 8862 3500
Europe	+ 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 55 21 3095 9500

[solutions@golder.com](mailto:solutions@golder.com)  
[www.golder.com](http://www.golder.com)

**Golder Associates Ltd.**  
**1010 Lorne Street**  
**Sudbury, Ontario, P3C 4R9**  
**Canada**  
**T: +1 (705) 524 6861**

