



November 17, 2011

FOUNDATION INVESTIGATION REPORT

**HIGHWAY 11 SBL CULVERT REPLACEMENT AT STATION 19+545
TOWNSHIP OF SOUTH HIMSWORTH, ONTARIO
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5416-06-00**

Submitted to:
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GEOCRES NO. 31L-153

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Distribution:

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REPORT





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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by URS Canada Inc. (URS) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the proposed rehabilitation of the Highway 11 Southbound Lanes (SBL), including the culvert replacement at Station 19+545. This project is part of the detail design for the rehabilitation of Highway 11 Northbound Lanes (NBL) and SBL from 5.0 km south of Highway 534 northerly 3.5 km. The general location of this section of the Highway 11 alignment is shown on the Key Plan on Drawing 1 following the text of this report.

This report addresses the investigation carried out for the replacement of the culvert on Highway 11 SBL at Station 19+545 only. Separate reports will be submitted detailing the foundation investigations for other culverts for this project. The General Arrangement (GA) drawing for the proposed culvert alignment was provided to Golder by URS on June 4, 2010. Cross-sections showing invert information were provided on August 25, 2010.

Based on the information from URS, the culvert at Station 19+545 will be concrete and will have an opening of 1.2 m. The existing culvert is about 41 m long. The inverts at the west and east ends of the culvert will be Elevation 260.0 m and 260.6 m, respectively. The embankment in the culvert area is about 6 m high and we understand that neither a grade raise nor embankment widening are required at this culvert location.

The purpose of this investigation is to establish the subsurface conditions at the location of the proposed culvert replacement by borehole drilling, in situ testing and laboratory testing on selected samples.

The culvert alignment was located in the field by Golder relative to stakes installed by Callon Dietz Inc. (Callon Dietz), a professional surveying company retained by URS, and referencing plan drawings provided by URS. The investigated area is shown in plan on Drawing 1 following the text of this report.

2.0 SITE DESCRIPTION

The replacement culvert will be located on the same alignment as the existing culvert that is in the Township of South Huron near Powassan, Ontario, on Highway 11 approximately 500 m north of Proudfoot Road.

The existing culvert at Station 19+545 is an 800 millimetre diameter corrugated steel pipe (CSP) culvert. The Preliminary Design Report (PDR) dated December 2008 indicates that the condition of the culvert is below minimum tolerable and the culvert has no bottom now. Water flow through the culvert was not observed during our investigation.

In general, the topography in the area of the overall project limits consists of rolling terrain separated by creeks and swamps. The ground surface elevation on the west side of the Highway 11 embankment is at about Elevation 260 m and the ground surface of the shoulder of the embankment is at Elevation 266 m.

3.0 INVESTIGATION PROCEDURES

The fieldwork for the investigation associated with this culvert replacement at Station 19+545 was carried out on November 10, 11, 24 and 25, 2010, during which time a total of four (4) Boreholes (BH09-17 to BH09-20) and



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four (4) Dynamic Cone Penetration Tests (DCPTs) were advanced at the culvert location. The field investigation was carried out using a track mounted D-50 supplied and operated by Walker Drilling Ltd. of Utopia, Ontario for boreholes advanced near the toes of the embankment and using a truck mounted CME 55 supplied and operated by Landcore Drilling of Sudbury, Ontario for the boreholes advanced at the top of the embankment. The location of the boreholes is shown on Drawing 1 following the text of this report.

The boreholes were advanced through the overburden using 108 mm inside diameter hollow-stem augers. Soil samples were obtained continuously or at intervals of depth of about 0.75 m and 1.5 m, using a 50 mm outer diameter (O.D.) split-spoon sampler, performed in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586-08a). The DCPTs were advanced within 1.5 m of each borehole to determine the depth to refusal and to provide additional information on the density of the soil strata. All boreholes were backfilled with bentonite upon completion, in accordance with Ontario Regulation 903 (as amended by Ontario Regulation 372).

The boreholes were advanced to depths ranging between 10.2 m and 17.4 m below existing ground surface. Boreholes BH09-17 and BH09-20 were terminated on auger refusal and the associated DCPTs at these locations were terminated on refusal to further cone penetration. These depths to refusal do not confirm bedrock surface elevations, but may be inferred to indicate potential proximity to the bedrock surface. Boreholes BH09-18 and BH09-19 and associated DCPT were terminated within the sand to gravelly sand deposit.

The groundwater conditions and water levels in the open boreholes were observed during the drilling operations and are described on the Record of Borehole sheets in Appendix A. It should be noted that 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 on completion of drilling. Furthermore, groundwater elevations will vary depending on seasonal fluctuations, precipitation and local soil permeability.

The fieldwork was supervised throughout by a member of our 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 and grain size distribution) was carried out on selected soil samples. The results of the laboratory testing are included in Appendix B.

Survey stakes were installed near the SBL embankment east toe by Callon Dietz prior to drilling. The as-drilled borehole locations, in stations and offsets, were measured in reference to the stakes and were subsequently converted into MTM NAD 83 coordinates in AutoCAD. Borehole elevations were surveyed by a member of our technical staff in reference to the ground surface elevations at the stakes. The borehole locations shown on Drawing 1 are positioned relative to MTM NAD 83 northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum.

The as-drilled borehole locations, ground surface elevations at the drilled locations and borehole depths are summarized below.



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Borehole	Location (m)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing	Easting		
09-17	5 100 745.9	316 983.2	261.3	11.2
09-18	5 100 737.3	316 969.7	265.8	17.4
09-19	5 100 741.0	316 958.8	265.5	14.3
09-20	5 100 729.8	316 943.8	260.0	10.2

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

As delineated in The Physiography of Southern Ontario (Chapman and Putnam, 1984)¹, this section of Highway 11 lies within the physiographic region known as the Number 11 Strip, which extends along Highway 11 from Gravenhurst to North Bay. This part of the Number 11 Strip physiographic region is near the southwest shoreline of glacial Lake Algonquin. As a result, the streams entering Lake Algonquin deposited sand as delta features and silt and clay settled in deeper offshore water. Sand and gravel was also deposited as an esker which follows the strip from Bondfield to Gravenhurst.

The bedrock in the area consists typically of crystalline granite gneisses of the Powassan Domain of the Central Gneiss Belt, a subdivision of the Grenville Structural Province, as described in Geology of Ontario, OGS Special Volume 4².

4.2 Subsurface Conditions

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

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 (along the Highway 11 alignment) and therefore may differ from that shown on the drawing which represents magnetic north.

In general, the subsurface stratigraphy along the culvert alignment consists of embankment fill or organic materials underlain by silt to sandy silt and/or sand to gravelly sand at depth.

¹ Chapman, L.J. and Putnam, D.F., 1984. *The Physiography of Southern Ontario*, Ontario Geological Survey, Special Volume 2, Third Edition. Accompanied by Map P.2715, Scale 1:600,000.

² Geology of Ontario, 1991. Ontario Geological Society Special Volume 4, Part 2. Ministry of Northern Development and Mines, Ontario.



4.2.1 Fill

Boreholes BH09-18 and BH09-19 were advanced through the embankment and encountered asphalt 210 mm and 180 mm thick from ground surface, respectively. Below the asphalt in Boreholes BH09-18 and BH09-19, sand and gravel to silty sand and fill was encountered having a thickness of about 1.9 m and 3.9 m, respectively, and the surface of the upper fill was encountered at Elevation 265.6 m and 265.3 m, respectively. Sand and silt to silt fill was encountered below the sand and gravel to silty sand fill at Elevation 263.7 m and 261.4 m in Boreholes BH09-18 and BH09-19, respectively, and was about 3.5 m and 1.5 m thick, respectively.

The upper sand and gravel to silty sand fill is compact to dense with 'N'-values ranging from 11 blows to 41 blows per 0.3 m of penetration. The lower sand and silt to silt fill is loose to compact with 'N'-values of 4 blows to 26 blows per 0.3 m of penetration.

The grain size distributions of three samples of the upper sand and gravel to silty sand fill are presented on Figure B1 in Appendix B and three samples of the lower sand and silt to silt fill are shown on Figure B2.

The water content of selected sand and gravel to silty sand fill samples ranged from 4 percent to 13 percent and the water content of samples of the sand and silt to silt fill ranged from 11 percent to 26 percent.

4.2.2 Organic Soil

Organics were found at the surface of Borehole BH09-17 about 0.1 m thick (Elevation 261.3 m), about 0.8 m of organic silt was encountered beneath the fill in Borehole BH09-18 (Elevation 260.2 m) and about 0.7 m of organic silt was encountered at the surface of Borehole BH09-20 (Elevation 260.0 m).

The organic silt in Borehole BH09-18 was inferred to be loose based on the SPT sample obtained near Elevation 259.5 m. A sample retrieved from the standard penetration testing in the borehole had a water content of 40 percent and an organic content of 5.7 percent.

4.2.3 Silt to Sandy Silt

A deposit of silt was encountered below the organics in Borehole BH09-17, below the organic silt in Boreholes BH09-18 and BH09-20 and below the embankment fill in Borehole 09-19 and ranged in thickness from 7.7 m to 8.6 m. The silt contained seams and layers of clayey silt in Borehole BH09-17 and was found to be sandy in the lower samples of the deposit in Borehole BH09-19. The surface of the silt ranged between Elevation 259.3 and 261.2 m.

'N'-values of 2 blows to 22 blows per 0.3 m of penetration were obtained during the SPT testing, indicating a very loose to compact relative density.

The grain size distributions of eight samples of the silt to sandy silt are shown on Figure B3.

The clayey silt seams/layers are of low plasticity based on a single Atterberg Limits determination with a plastic limit of 19 percent, a liquid limit of 30 percent and a plasticity index of 11 percent. The results of the Atterberg Limit determination are shown on Figure B4.

The natural water content varied between 18 percent and 40 percent. The organic content of the silt near Elevation 259 m in Borehole BH09-18 is 2.2 percent.



4.2.4 Sand to Gravelly Sand

The silt to sandy silt in all four boreholes was underlain by sand to gravelly sand from Elevation 251.2 to 252.6 m. Each of the boreholes was terminated in the sand to gravelly sand deposit after exploring the deposit for 1.0 m to 2.8 m.

The sands are loose to dense based on measured SPT 'N'-values of 4 blows to 35 blows per 0.3 m of penetration.

The gradation of a sample of gravelly sand from BH09-18 is presented on Figure B5.

The natural water content of samples of sand to gravelly sand is 13 percent to 27 percent.

4.2.5 Refusal

In Borehole BH09-17, refusal to augering and DCPT cone penetration occurred at a depth of 11.2 m and 11.8 m, respectively, corresponding to Elevation 250.1 m and 249.5 m, respectively. In Borehole BH09-20, refusal to augering and DCPT cone penetration occurred at a depth of 10.2 m and 11.7 m, respectively, corresponding to Elevation 249.8 m and 248.3 m, respectively. These depths to refusal, while they do not confirm bedrock elevations, may be inferred to indicate potential proximity to the bedrock interface.

4.2.6 Groundwater Conditions

Water levels observed in the boreholes upon completion of drilling range from 2.9 m to 8.9 m below existing ground surface, ranging between Elevation 256.9 m and 257.8 m. These water levels may represent the water level in the underlying sand stratum. The water level in the silt to sandy silt stratum may be close to the surface of the stratum at about Elevation 259.0 m. Groundwater/surface water levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

5.0 CLOSURE

The field personnel supervising the drilling program were Mr. Ed Savard and Mr. Mathew Riopelle. The report was written by Ms. Dirka Prout, P.Eng., and reviewed by Mr. André Bom, P.Eng. Mr. Fintan Heffernan, one of Golder's MTO Designated Contacts, carried out a quality control review and reviewed the technical aspects of the report on behalf of Mr. Jorge M. A. Costa, P.Eng., the Designated MTO Contact for this project.



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Report Signature Page

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DUP/AB/FJH/lb/cl

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- Canadian Highway Bridge Design Code (CHBDC) and Commentary on CAN/CSA-S6-06. 2006. CSA Special Publication, S6.1-06. Canadian Standard Association.
- Chapman, L.J., and Putnam, D.F., 1984. The Physiography of Southern Ontario. Ontario Geological Survey, Special Volume 2, 3rd Edition. Ontario Ministry of Natural Resources.
- Geology of Ontario, 1991. Ontario Geological Society, Special Volume 4, Part 2. Eds. P.C. Thurston, H.R. Williams, R.H. Sutcliffe and G.M. Stott. Ministry of Northern Development and Mines, Ontario.

STANDARDS:

ASTM International:

- | | |
|----------------|---------------------------------------------------------------------------------------------|
| ASTM D1586-08a | Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils |
|----------------|---------------------------------------------------------------------------------------------|

Contract Design Estimating and Documentation (CDED):

- | | |
|--------------------------|---------------------------------------------------------------------------------------------------------------------------------|
| Special Provision 110S13 | Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material. May 2010. Amendment to OPSS 1010. |
|--------------------------|---------------------------------------------------------------------------------------------------------------------------------|

Ontario Occupational Health and Safety Act:

- | | |
|---------------------------|-------------------------------------|
| Ontario Regulation 213/91 | Construction Projects |
| Ontario Regulation 443/09 | Amendment to Ontario Regulation 213 |

Ontario Provincial Standard Drawing:

- | | |
|--------------|----------------------------------------------------------------------------------|
| OPSD 203.010 | Embankments Over Swamp – New Construction. |
| OPSD 802.031 | Rigid Pipe Bedding, Cover and Backfill Type 3 Soil - Earth Excavation. |
| OPSD 803.010 | Backfill and Cover for Concrete Culverts With Spans less than or equal to 3.0 m. |
| OPSD 810.010 | Rip-Rap Treatment for Sewer and Culvert Outlets. |

Ontario Provincial Standard Specification:

- | | |
|----------|-----------------------------------------------------------------------------------------------------|
| OPSS 209 | Construction Specification for Embankments Over Swamps and Compressible Soils. |
| OPSS 421 | Construction Specification For Pipe Culvert Installation In Open Cut. |
| OPSS 422 | Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut. |
| OPSS 501 | Construction Specification for Compacting. |
| OPSS 539 | Construction Specification for Temporary Protection Systems. |



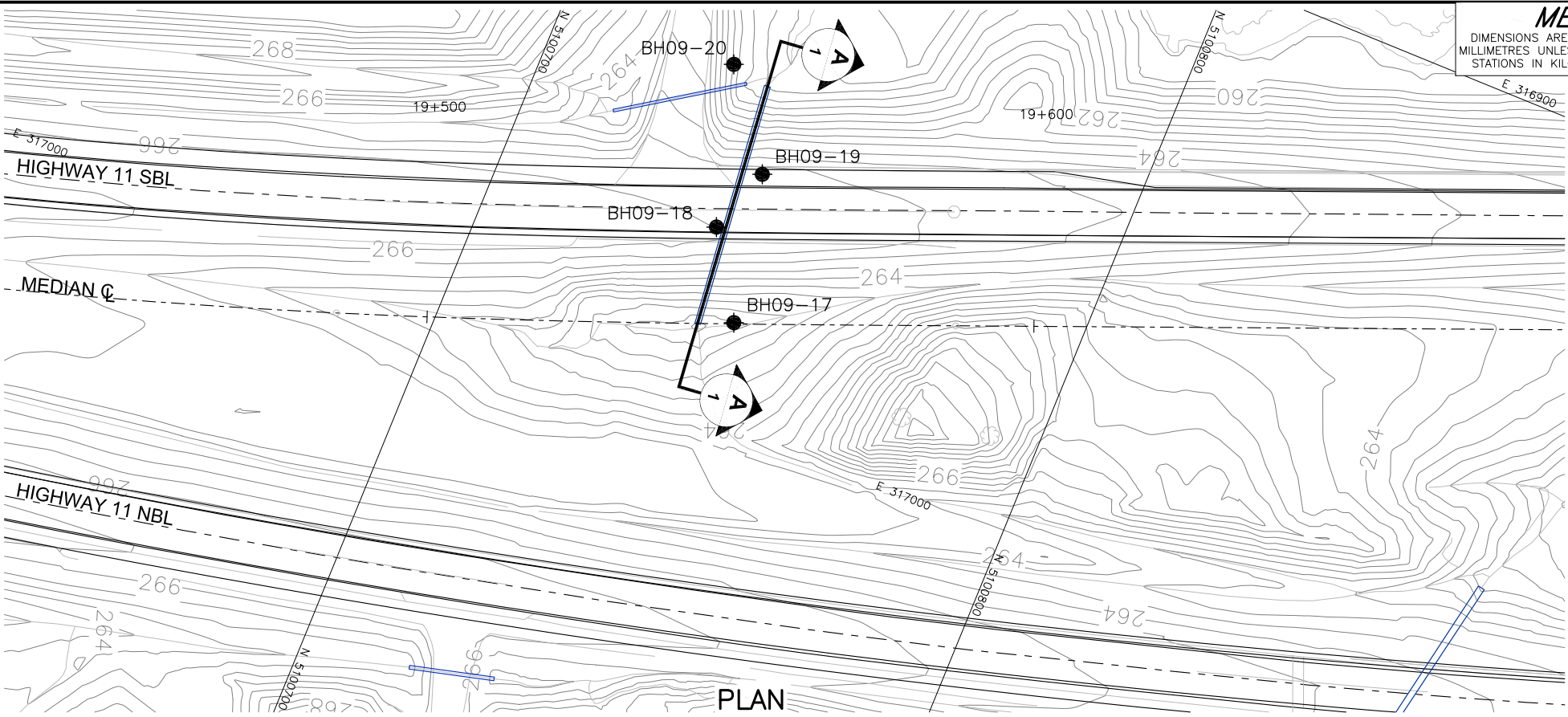
FOUNDATION REPORT - HIGHWAY 11 SBL STA 19+545 CULVERT REPLACEMENT

OPSS 1002 Material Specification for Aggregates – Concrete.

OPSS 1205 Material Specification for Clay Seal.

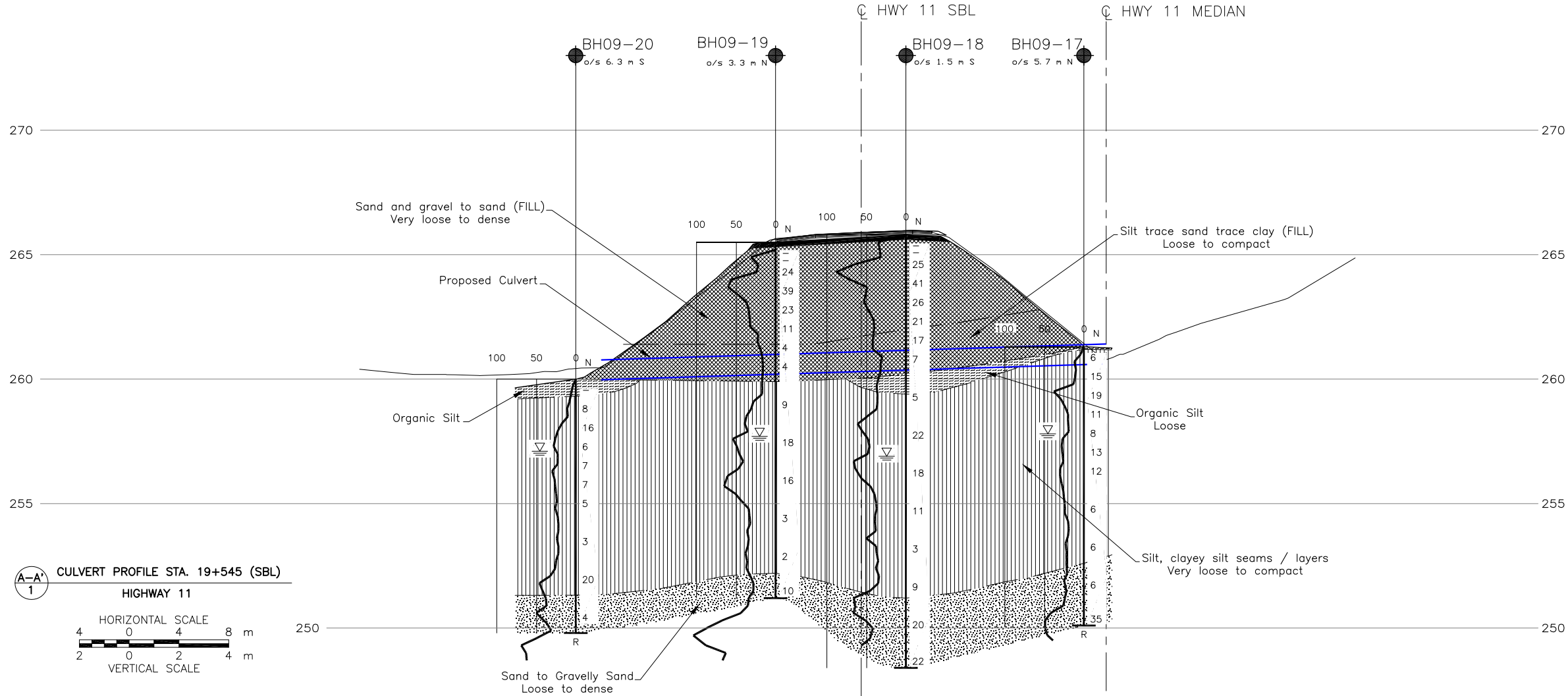
Ontario Water Resources Act:

Ontario Regulation 372/97 Amendment to Ontario Regulation 903



PLAN

SCALE 10 0 10 20 m



CULVERT PROFILE STA. 19+545 (SBL)

HORIZONTAL SCALE 4 0 4 8 m
VERTICAL SCALE 2 0 2 4 m

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

CONT No.
WP No. 5416-06-00

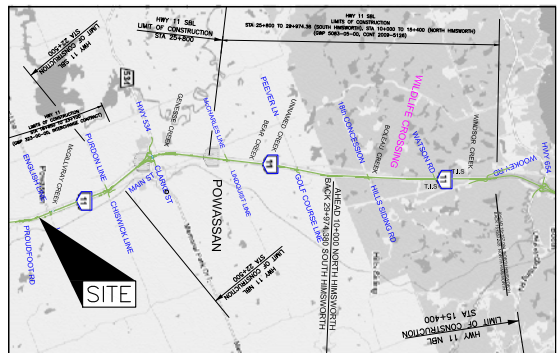
HIGHWAY 11
CULVERT AT STA 19+545 SBL
BOREHOLE LOCATIONS AND
SOIL STRATA



SHEET



Golder Associates Ltd.
SUDBURY, ONTARIO, CANADA



KEY PLAN

SCALE 2.5 0 2.5 km

LEGEND

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

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
BH09-17	261.3	5100745.9	316983.2
BH09-18	265.8	5100737.3	316969.7
BH09-19	265.5	5100741.0	316958.8
BH09-20	260.0	5100729.8	316943.8

NOTES

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

The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

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

REFERENCE

Base plans provided in digital format by URS, drawing file nos. BasePlan HWY 11.dwg dated June 4, 2010, received June 4, 2010. Keyplan provided in digital format by URS, drawing file Keyplan.dwg received June 3, 2011.

NO.	DATE	BY	REVISION
Geocres No.			
HWY. 11	PROJECT NO. 09-1191-0042		DIST.
SUBM'D. LG	CHKD. AB	DATE: NOV 2011	SITE:
DRAWN: JJL	CHKD.	APPD. FJH	DWG. 1



APPENDIX A

Record of Boreholes



LIST OF SYMBOLS

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

1. 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
V	volume
W	weight

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. stress: $\Delta\sigma$
ϵ	linear strain
ϵ_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

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

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

(a) Index Properties (continued)

w	water content
w_l	liquid limit
w_p	plastic limit
I_p	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_a	coefficient of secondary consolidation
m_v	coefficient of volume change
c_v	coefficient of consolidation
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation pressure
OCR	over-consolidation ratio $= \sigma'_p / \sigma'_{vo}$

(d) Shear Strength

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

Notes: 1 $\tau = c' + \sigma' \tan \phi'$
2 Shear strength = (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
SS	Split-spoon
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
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) 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

Percent 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 (cohesionless) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand

PROJECT 09-1191-0042			RECORD OF BOREHOLE No BH09-17			1 OF 1 METRIC											
W.P. 5416-06-00			LOCATION N 5100745.9; E 316983.2			ORIGINATED BY MR											
DIST HWY 11			BOREHOLE TYPE 108 mm I.D. Continuous Flight, Hollow Stem Augers			COMPILED BY JLL											
DATUM Geodetic			DATE November 25, 2010			CHECKED BY AB											
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					W _p W W _L WATER CONTENT (%)			γ	GR SA SI CL
261.3	GROUND SURFACE							20 40 60 80 100									
0.0	ORGANICS Black to brown Moist		1	SS	6		261										
0.1	SILT, trace to some clay, trace to some sand, clayey silt seams / layers Loose to compact Brown to grey Moist to wet		2	SS	15		260										
			3	SS	19		259										
			4	SS	11		258										0 2 73 25
			5	SS	8		257										
			6	SS	13		256										
			7	SS	12		255										0 7 72 21
			8	SS	6		254										
			9	SS	6		253										
252.6	SAND to Gravelly SAND, some silt Loose to dense Brown Wet		10	SS	6		252										
8.7			11	SS	35		251										
250.1	END OF BOREHOLE AUGER REFUSAL																
11.2	Note: 1. Water level at a depth of 3.5 m below ground surface (Elev. 257.8 m) upon completion of drilling. 2. Advanced DCPT 1.0 m south of Borehole BH09-17. Refusal at a depth of 11.8 m (Elev. 249.5 m).																

SUD-MTO 001 09-1191-0042-4000.GPJ GAL-MISS.GDT 16/11/11 DATA INPUT:

[illegible]

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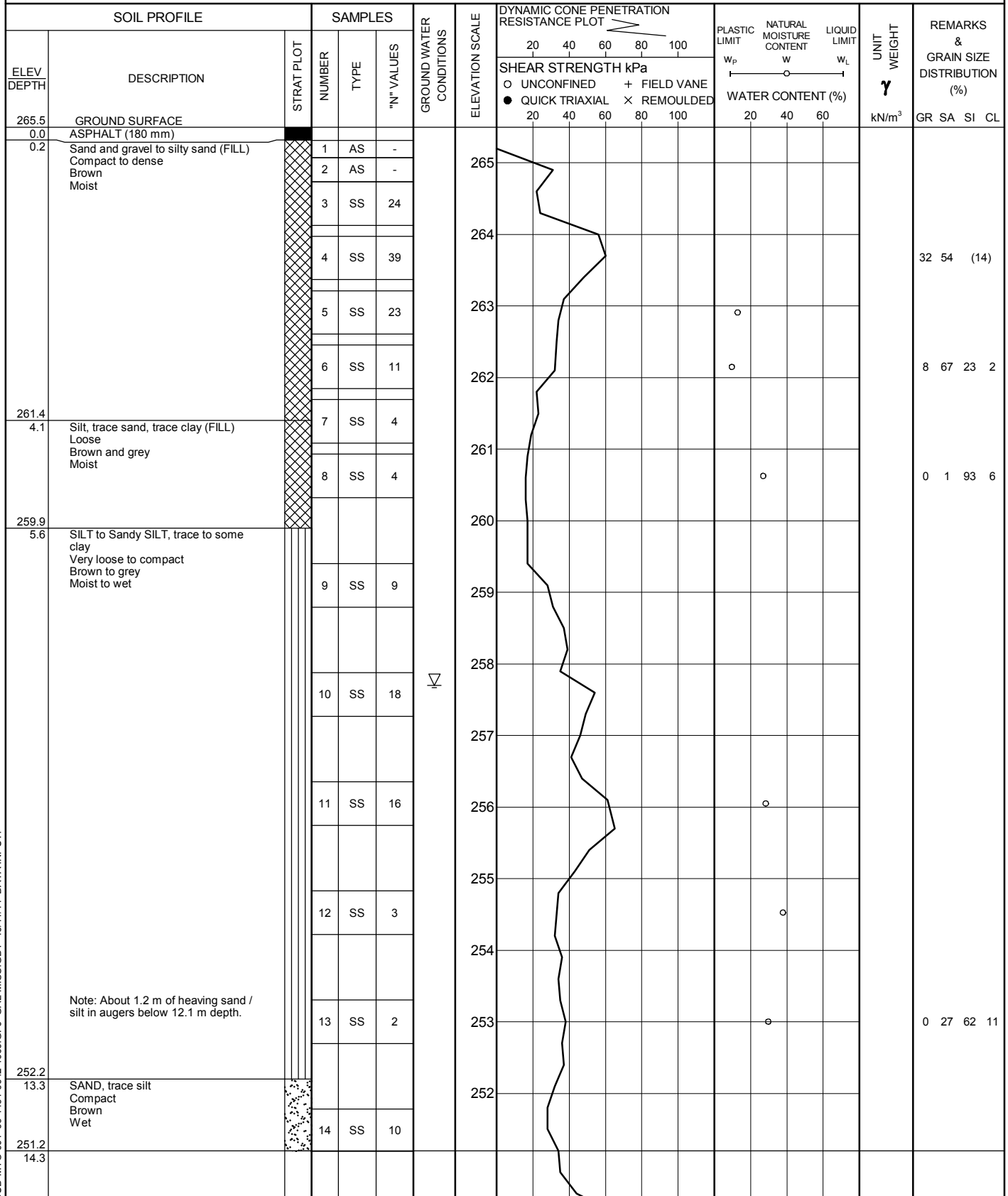
+³, ×³: Numbers refer to Sensitivity ○^{3%} STRAIN AT FAILURE

PROJECT <u>09-1191-0042</u>		RECORD OF BOREHOLE No BH09-18				2 OF 2 METRIC	
W.P. <u>5416-06-00</u>		LOCATION <u>N 5100737.3; E 316969.7</u>				ORIGINATED BY <u>MR</u>	
DIST <u> </u> HWY <u>11</u>		BOREHOLE TYPE <u>108 mm I.D. Continuous Flight, Hollow Stem Augers</u>				COMPILED BY <u>JJL</u>	
DATUM <u>Geodetic</u>		DATE <u>November 11, 2010</u>				CHECKED BY <u>AB</u>	

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					W _p	W		
							20	40	60	80	100					
	--- CONTINUED FROM PREVIOUS PAGE ---															
	SAND to Gravelly SAND, some silt, trace clay Compact Brown Wet	●	15	SS	20											
248.4			16	SS	22											
17.4	END OF BOREHOLE															
	Note: 1. Water level at a depth of 8.9 m below ground surface (Elev. 256.9 m) upon completion of drilling. 2. Advanced DCPT 1.5 m south of Borehole BH09-18. End of DCPT at a depth of 16.5 m (Elev. 249.3 m).															

SUD-MTO 001 09-1191-0042-4000.GPJ GAL-MISS.GDT 16/11/11 DATA INPUT:

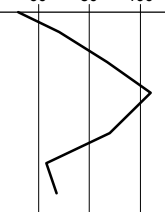
PROJECT <u>09-1191-0042</u>		RECORD OF BOREHOLE No BH09-19		1 OF 2 METRIC	
W.P. <u>5416-06-00</u>		LOCATION <u>N 5100741.0; E 316958.8</u>		ORIGINATED BY <u>MR</u>	
DIST <u> </u> HWY <u>11</u>		BOREHOLE TYPE <u>108 mm I.D. Continuous Flight, Hollow Stem Augers</u>		COMPILED BY <u>JJL</u>	
DATUM <u>Geodetic</u>		DATE <u>November 10, 2010</u>		CHECKED BY <u>AB</u>	



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

SUD-MTO 001 09-1191-0042-4000.GPJ GAL-MISS.GDT 16/11/11 DATA INPUT:

PROJECT <u>09-1191-0042</u>		RECORD OF BOREHOLE No BH09-19				2 OF 2 METRIC							
W.P. <u>5416-06-00</u>		LOCATION <u>N 5100741.0; E 316958.8</u>				ORIGINATED BY <u>MR</u>							
DIST <u> </u> HWY <u>11</u>		BOREHOLE TYPE <u>108 mm I.D. Continuous Flight, Hollow Stem Augers</u>				COMPILED BY <u>JJL</u>							
DATUM <u>Geodetic</u>		DATE <u>November 10, 2010</u>				CHECKED BY <u>AB</u>							
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ 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 ---						<div style="display: flex; justify-content: space-between;"> 20 40 60 80 100 20 40 60 80 100 </div> <div style="display: flex; justify-content: space-between;"> ○ UNCONFINED + FIELD VANE </div> <div style="display: flex; justify-content: space-between;"> ● QUICK TRIAXIAL × REMOULDED </div>						
	END OF BOREHOLE Note: 1. Water level at a depth of 7.8 m below ground surface (Elev. 257.7 m) upon completion of drilling. 2. Advanced DCPT 1.5 m north of Borehole BH09-19. End of DCPT at a depth of 16.8 m (Elev. 248.7 m).												

SUD-MTO 001 09-1191-0042-4000.GPJ GAL-MISS.GDT 16/11/11 DATA INPUT:

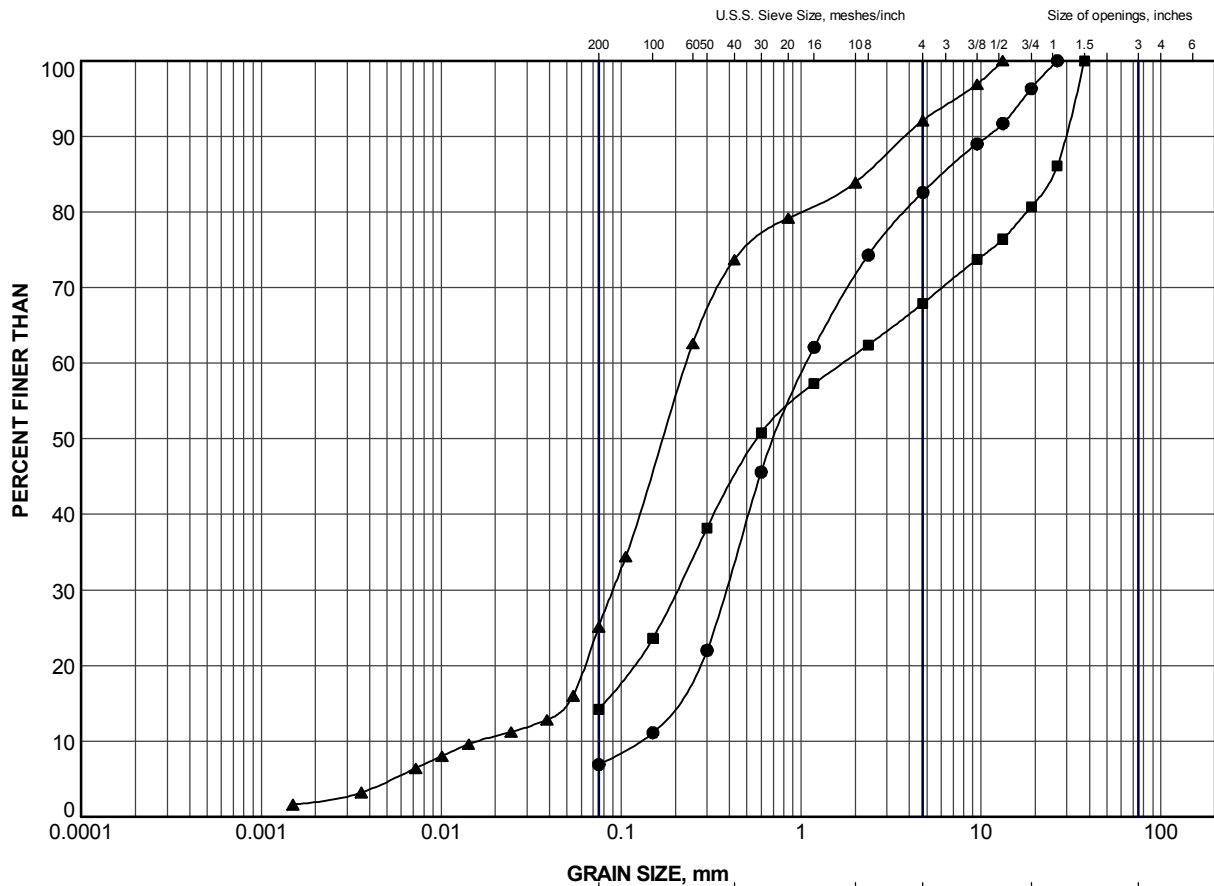
PROJECT 09-1191-0042			RECORD OF BOREHOLE No BH09-20			1 OF 1 METRIC														
W.P. 5416-06-00			LOCATION N 5100729.8; E 316943.8			ORIGINATED BY MR														
DIST HWY 11			BOREHOLE TYPE 108 mm I.D. Continuous Flight, Hollow Stem Augers			COMPILED BY JJJ														
DATUM Geodetic			DATE November 24, 2010			CHECKED BY AB														
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS			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		ELEVATION SCALE	SHEAR STRENGTH kPa					W _p W W _L			γ	GR SA SI CL			
260.0	GROUND SURFACE							20 40 60 80 100					20 40 60							
0.0	ORGANIC SILT Greenish grey Moist		1	AS	-			○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					WATER CONTENT (%)							
259.3								20 40 60 80 100					20 40 60							
0.7	SILT, trace to some sand, trace to some clay Very loose to compact Brown to grey Moist to wet		2	SS	8		259										0 2 78 20			
			3	SS	16		258													
			4	SS	6		257										0 12 74 14			
			5	SS	7		256													
			6	SS	7		255										0 9 74 17			
			7	SS	5		254													
			8	SS	3		253													
			9	SS	20		252													
251.3							251													
8.7	SAND, some gravel, trace silt Loose Brown Wet Note: About 0.3 m of heaving sand in augers below 9.1 m depth.		10	SS	4		250													
249.8																				
10.2	END OF BOREHOLE AUGER REFUSAL Note: 1. Water level at a depth of 2.9 m below ground surface (Elev. 257.1 m) upon completion of drilling. 2. Advanced DCPT 1.3 m east of Borehole BH09-20. Refusal at a depth of 11.7 m (Elev. 248.3 m).																			

SUD-MTO 001 09-1191-0042-4000.GPJ GAL-MISS.GDT 16/11/11 DATA INPUT:



APPENDIX B


Laboratory Test Results

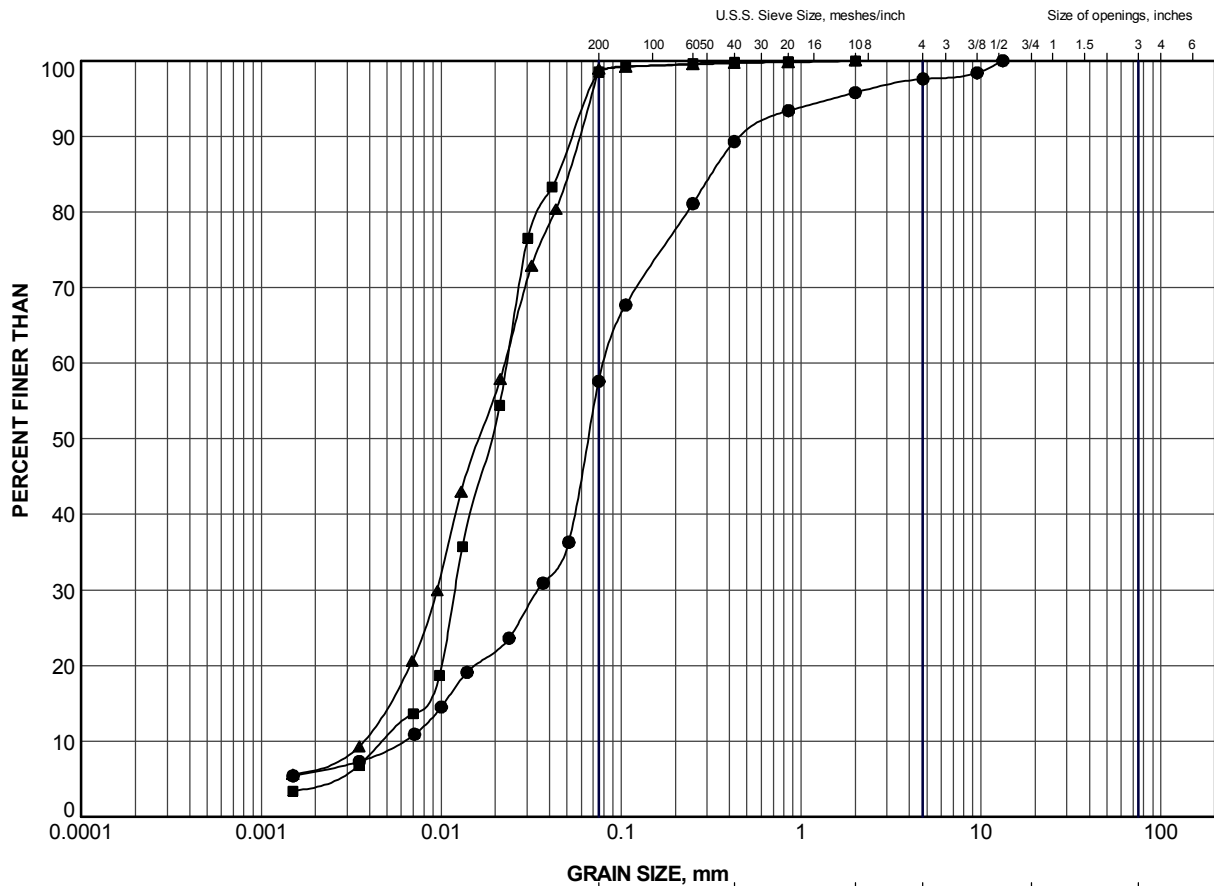


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH09-18	3	264.7
■	BH09-19	4	263.7
▲	BH09-19	6	262.1


PROJECT				
HIGHWAY 11 SBL CULVERT 19+545				
TITLE				
GRAIN SIZE DISTRIBUTION				
SAND AND GRAVEL TO SILTY SAND (FILL)				
PROJECT No.		09-1191-0042		FILE No. 09-1191-0042-4000.GPJ
DRAWN	JJL	Nov 2011	SCALE	N/A
CHECK	AB	Nov 2011	REV.	
APPR	FJH	Nov 2011		
 Golder Associates SUDBURY, ONTARIO			FIGURE B1	

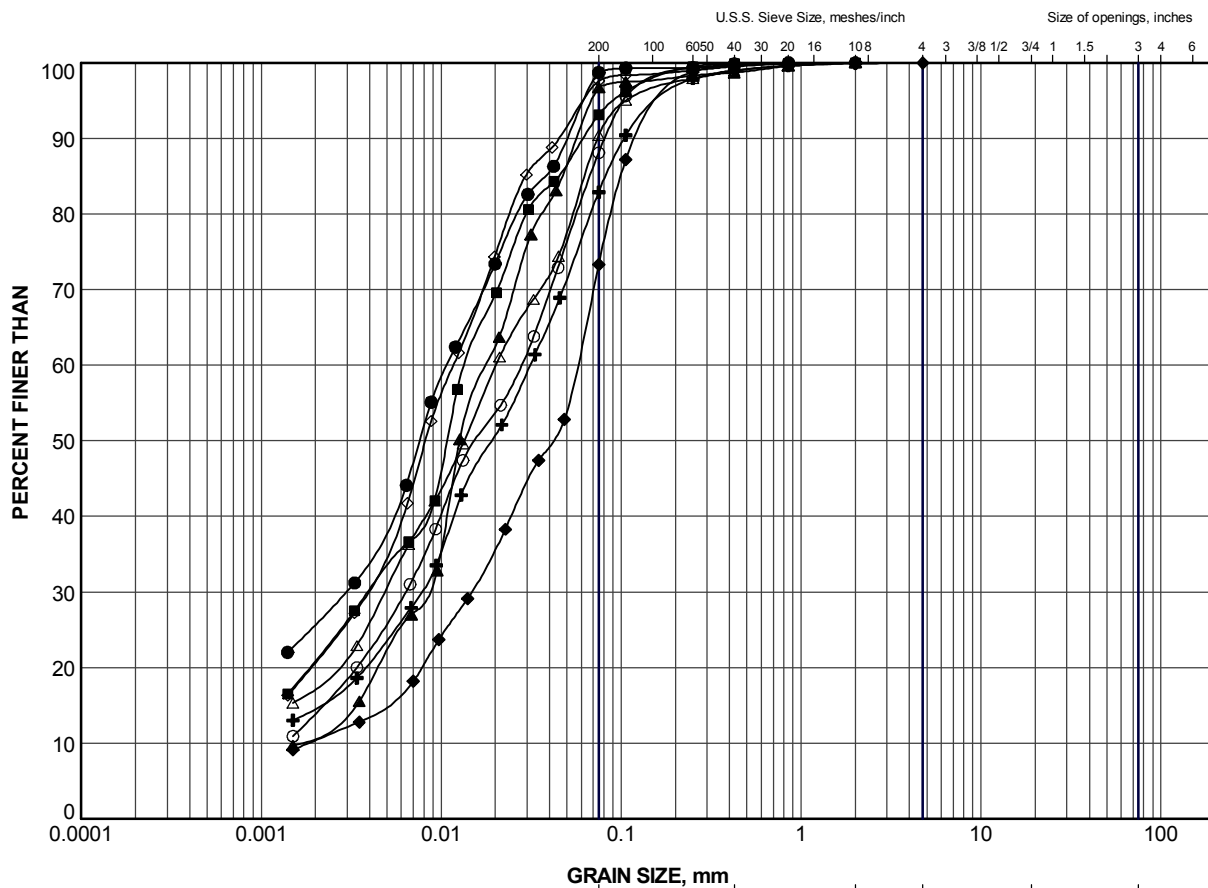


CLAY AND SILT	GRAVEL SIZE, mm						Cobble Size
	fine	medium	coarse	fine	coarse		
	SAND SIZE			GRAVEL SIZE			

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH09-18	5	263.2
■	BH09-18	7	261.7
▲	BH09-19	8	260.6

PROJECT				
HIGHWAY 11 SBL CULVERT 19+545				
TITLE				
GRAIN SIZE DISTRIBUTION				
SAND AND SILT TO SILT (FILL)				
PROJECT No.		09-1191-0042		FILE No. 09-1191-0042-4000.GPJ
DRAWN	JJL	Nov 2011	SCALE	N/A
CHECK	AB	Nov 2011	REV.	
APPR	FJH	Nov 2011		
 Golder Associates SUDBURY, ONTARIO			FIGURE B2	



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH09-17	4	258.7
■	BH09-17	8	254.9
▲	BH09-18	9b	259.2
+	BH09-18	11	256.4
◆	BH09-19	13	253.0
◇	BH09-20	2	258.9
○	BH09-20	4	257.4
△	BH09-20	7	255.1

PROJECT

HIGHWAY 11 SBL CULVERT 19+545

TITLE

GRAIN SIZE DISTRIBUTION

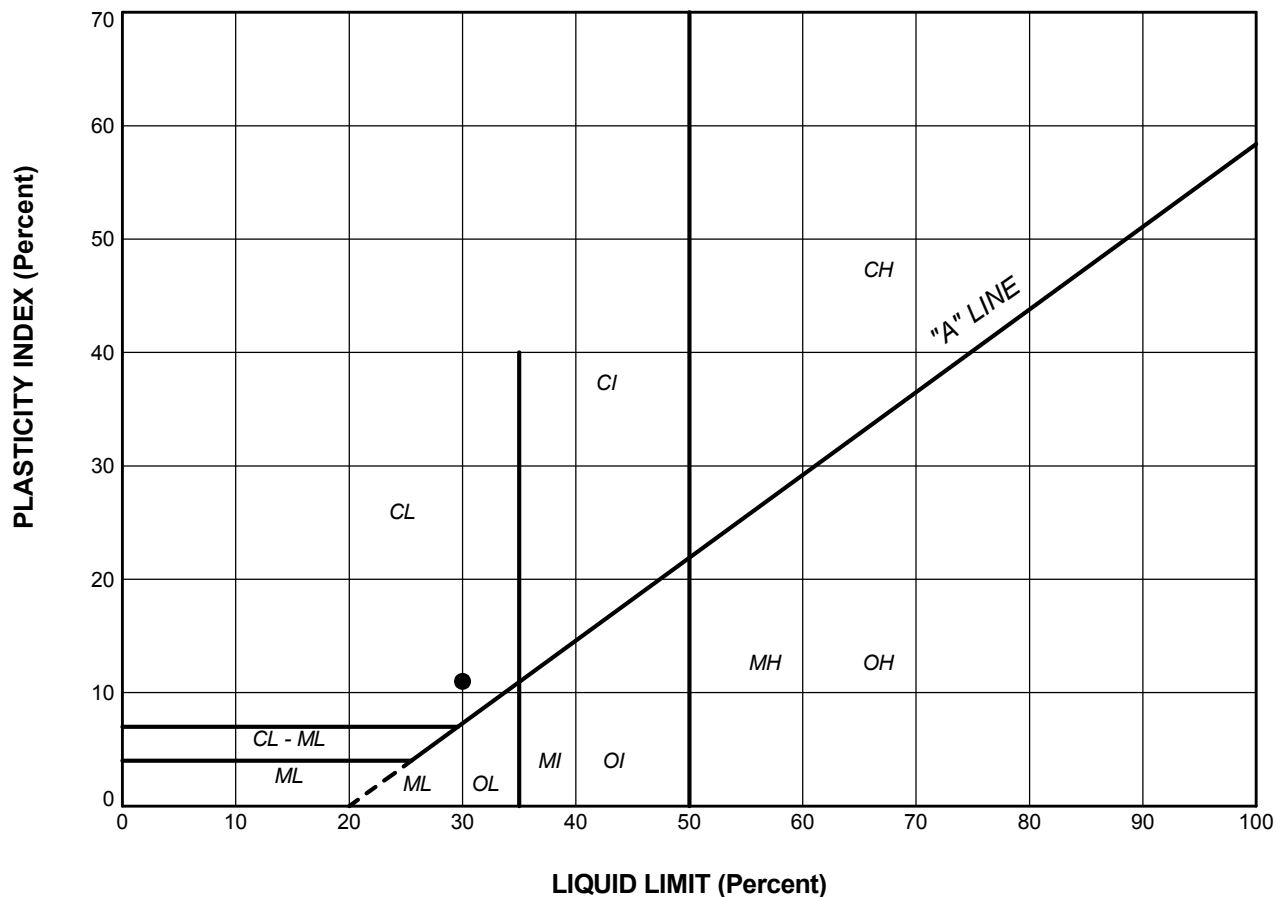
SILT TO SANDY SILT



Golder Associates
SUDBURY, ONTARIO

PROJECT No. 09-1191-0042		FILE No. 09-1191-0042-4000.GPJ	
DRAWN	JJL	Nov 2011	SCALE N/A
CHECK	AB	Nov 2011	REV.
APPR	FJH	Nov 2011	

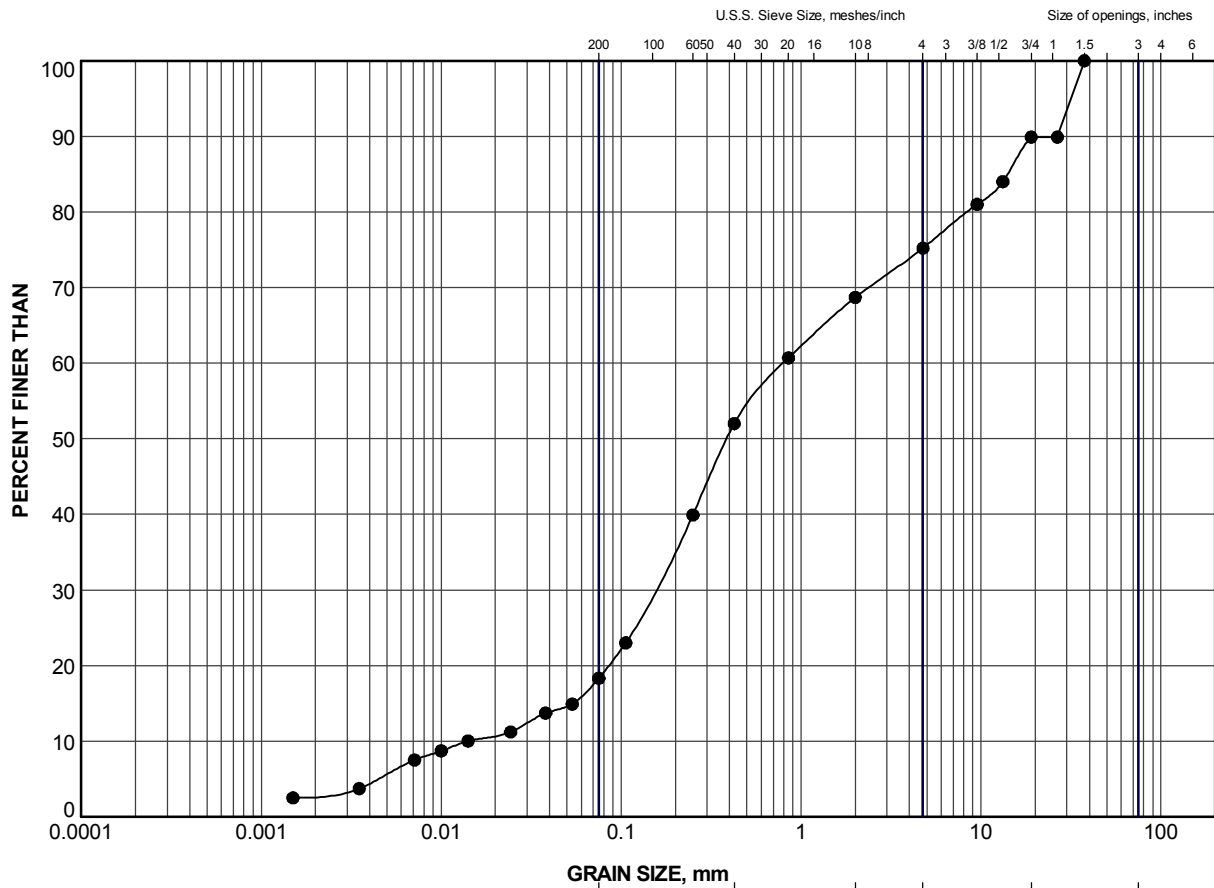
FIGURE B3



LEGEND					
SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	BH09-17	5	30.0	19.0	11.0

PROJECT					
HIGHWAY 11 SBL CULVERT 19+545					
TITLE					
PLASTICITY CHART CLAYEY SILT SEAMS / LAYERS					
PROJECT No. 09-1191-0042			FILE No. 09-1191-0042-4000.GPJ		
DRAWN	JJL	Nov 2011	SCALE	N/A	REV.
CHECK	AB	Nov 2011	FIGURE B4		
APPR	FJH	Nov 2011			






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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH09-18	15	250.3

PROJECT					
HIGHWAY 11 SBL CULVERT 19+545					
TITLE					
GRAIN SIZE DISTRIBUTION GRAVELLY SAND					
PROJECT No.		09-1191-0042		FILE No. 09-1191-0042-4000.GPJ	
DRAWN	JJL	Nov 2011	SCALE	N/A	REV.
CHECK	AB	Nov 2011			
APPR	FJH	Nov 2011			
 Golder Associates SUDBURY, ONTARIO			FIGURE B5		

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

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