REPORT

November 17, 2011

FOUNDATION INVESTIGATION REPORT

HIGHWAY 11 SBL CULVERT REPLACEMENT AT STATION 21+319
TOWNSHIP OF SOUTH HIMSWORTH, ONTARIO
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5416-06-00

Submitted to:
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GEOCRES NO. 31L-155

Report Number: 09-1191-0042-R08

Distribution:

1 e-copy: Ministry of Transportation, Ontario, North Bay, Ontario (Northeastern Region)
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1 e-copy: URS Canada Inc., Markham, Ontario
1 Copy: Golder Associates Ltd., Sudbury, Ontario

Golder Associates

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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 21+319. This project is part of the detail design for the rehabilitation of Highway 11 Northbound Lanes (NBL) and Southbound Lanes (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 21+319 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 21+319 will be concrete and will have an opening of 1.2 m. The existing culvert is about 36 m long. The inverts at the west and east ends of the culvert will be Elevation 269.2 m and 270.5 m, respectively. The height of the embankment in the culvert area is about 5 m (median) to 6 m (west side) 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 Himsworth near Powassan, Ontario, on Highway 11 approximately 700 m south of Purdon Line and Main Street.

The existing culvert at Station 21+319 is a 900 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 as it is rotted out. 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 about Elevation 269 m and the roadway surface at the top of the embankment is at about Elevation 275 m.

3.0 INVESTIGATION PROCEDURES

The fieldwork for the investigation associated with this culvert replacement at Station 21+319 was carried out on November 8, 9, 15 and 19, 2010, during which time a total of four (4) Boreholes (BH09-25 to BH09-28) and 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). Field vane shear tests were conducted in cohesive soils for determination of undrained shear strengths (ASTM D2573-08). The DCPTs were advanced within 2.5 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 5.3 m and 11.3 m below existing ground surface. In Borehole BH09-28, a total of 3.2 m of bedrock was cored. Boreholes BH09-25 and BH09-27 were advanced to auger refusal and all four DCPTs were terminated on refusal to cone penetration. These depths to refusal do not confirm bedrock surface elevations, but may be inferred to indicate potential proximity to the bedrock surface. Borehole BH09-26 was terminated within a silty sand to 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.

Borehole	Location (m)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing	Easting		
09-25	5 102 387.3	316 336.0	270.9	5.3
09-26	5 102 379.1	316 325.5	275.5	11.3
09-27	5 102 381.3	316 314.6	275.4	10.0
09-28	5 102 371.0	316 296.3	268.9	8.5

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 4[2].

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.

[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.

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 clayey silt, clayey silt to silty clay, silty sand to sand and sand and gravel (where encountered). As discussed in Section 3, bedrock was cored at one borehole location.

4.2.1 Fill

Boreholes BH09-26 and BH09-27 were drilled through the embankment and encountered about 130 mm and 150 mm of asphalt at ground surface, respectively. Sand and gravel to sand was found beneath the asphalt in Boreholes BH09-26 and BH09-27 having a thickness of 1.7 and 2.9 m, respectively, and the surface of the layer was at Elevation 275.3 and 275.4 m, respectively. Silty sand to sandy silt fill was encountered below the upper fill at Elevation 272.5 m and 273.6 m in Boreholes BH09-26 and BH08-27, respectively, and was 2.6 m and 4.0 m thick, respectively.

The upper predominantly sand and gravel to sand fill is compact with 'N'-values ranging from 12 blows to 24 blows per 0.3 m of penetration. The lower silty sand to sandy silt fill is very loose to compact with 'N'-values of 0 (weight of hammer) blows at depth to 16 blows per 0.3 m of penetration near the surface of this fill.

The grain size distributions of two samples of the upper fill are presented on Figure B1 in Appendix B and the gradation of two samples of the lower fill is shown on Figure B2.

The water content in the fill ranged from 10 percent to 28 percent.

4.2.2 Organics

Organic silt was encountered at the surface of Boreholes BH09-25 and BH09-28, with a thickness of approximately 0.7 m.

The organic silt in Boreholes BH09-28 was inferred to be very loose based on a SPT result of 1 blow per 0.3 m of penetration in Borehole BH09-28.

Water contents of two samples of this material are 42 percent and 47 percent and two organic content tests yielded 5 percent and 7 percent.

4.2.3 Silt to Clayey Silt

A deposit of silt to clayey silt was encountered below the organic silt in Borehole BH09-25 and below the embankment fill in Borehole BH09-26 and the deposit was between about 1.0 m and 2.6 metres thick. The surface of the silt to clayey silt ranged between Elevation 269.9 m and 270.2 m. A lower deposit of silt to clayey silt was encountered below the clayey silt to silty clay (discussed below) in Boreholes BH09-26 and BH09-27. The surface of the lower layer was at about Elevation 268.3 m and 268.2 m in Boreholes BH09-26 and BH09-27, respectively, and about 1.3 m and 0.9 m thick, respectively.

SPT 'N'-values of 4 blows to 12 blows per 0.3 m of penetration were obtained in the silt to clayey silt indicating a firm to very stiff consistency. An in situ vane test gave a shear strength value of in excess of 100 kPa.

The silt to clayey silt is of low plasticity based on four Atterberg Limits determinations with plastic limits of 17 and 18 percent, liquid limits of 21 to 23 percent and a plasticity index of 4 to 6 percent. The results of the Atterberg Limit determination are shown on Figure B3.

Grain size distributions of three samples of silt to clayey silt are shown on Figure B4.

The natural water content of the silt to clayey silt layer varied between 32 percent and 45 percent, which is well above the liquid limit values.

4.2.4 Clayey Silt to Silty Clay

About 0.8 m and 1.3 m thick clayey silt to silty clay layers were encountered in Boreholes BH09-26 and BH09-27, respectively, and the surface of the layers were encountered at about Elevation 269.0 m and 269.6 m, respectively.

One SPT N value of 6 blows per 0.3 m of penetration was obtained during the SPT testing in the clayey silt to clayey silt layer. In situ field shear vane testing was conducted within the deposit in Boreholes BH09-26 and the shear strength was approximately 87 kPa indicating a stiff consistency.

Two Atterberg Limits tests on samples of the layer yielded plastic limits of 18 percent and 20 percent, liquid limits of 35 percent and 39 percent and plasticity indices of 17 percent and 19 percent. The results of the Atterberg Limit determination are shown on Figure B5.

The natural water content of two samples of this layer is 39 percent and 43 percent which is near the liquid limit value.

4.2.5 Silty Sand to Sand

The silt and silty clay in all four boreholes was underlain by silty sand to sand trace to some gravel with the surface ranging from Elevation 266.8 to 267.6 m. The silty sand to sand was about 1.3 m to 3.2 m thick in Boreholes BH09-25, BH09-27 and BH09-28. Borehole BH09-26 was terminated after exploring the deposit for about 3.1 m. The sands are compact to very dense based on measured SPT 'N'-values of 10 blows to 64 blows per 0.3 m of penetration. The gradation of three samples of the silty sand to sand encountered is presented on Figure B6. The natural water content of samples of silty sand to sand is 9 percent to 10 percent.

4.2.6 Sand and Gravel

The silty sand encountered in BH09-25 was underlain by a sand and gravel layer of 0.7 m thickness. The surface elevation of the sand and gravel layer is at Elevation 266.3 m.

The grain size distribution of the sand and gravel layer is presented on Figure B7 in Appendix B.

4.2.7 Bedrock/ Refusal

In Borehole BH09-28, bedrock was encountered at a depth of 5.3 m (Elevation 263.6 m) and cored for 3.2 m. Based on the cored bedrock samples, the bedrock generally consists of gneiss, and may be described as fresh, medium grained and grey. The Rock Quality Designation (RQD) measured on the two core runs is 88 percent and 100 percent, generally indicating a rock mass of excellent quality. The Total Core Recovery (TCR) of the samples recovered is 100 percent.

In Borehole BH09-25, refusal to auger and DCPT cone penetration occurred at a depth of 5.3 m and 5.1 m, respectively, corresponding to Elevation 265.6 m and 265.8 m, respectively. In Borehole BH09-26, refusal to auger and DCPT cone penetration occurred at a depth of 11.3 m and 10.2 m, respectively, corresponding to Elevation 264.2 m and 265.3 m, respectively. In Borehole BH09-27, refusal to auger and DCPT cone penetration occurred at a depth of 10.0 m and 9.3 m, respectively, corresponding to Elevation 265.4 m and 266.1 m, respectively. Where bedrock was not cored, the depths to refusal, while they do not confirm bedrock elevations, may be inferred to indicate potential proximity to the bedrock interface.

4.2.8 Groundwater Conditions

Boreholes BH09-25 and BH09-28 were noted to be dry upon completion of drilling. Water levels observed in Boreholes BH09-26 and BH09-27 upon completion of drilling were 6.0 m and 6.8 m below existing ground surface corresponding to Elevation 268.7 m and 269.4 m, respectively. 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. This report was prepared by Mr. Matthew Thibeault in conjunction with 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.

Report Signature Page

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MT/AB/FJH/lb/cl

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REFERENCES

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
ASTM D2573	Standard Test Method for Field Vane Shear Test in Cohesive Soil

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.
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

MINISTRY OF TRANSPORTATION, ONTARIO

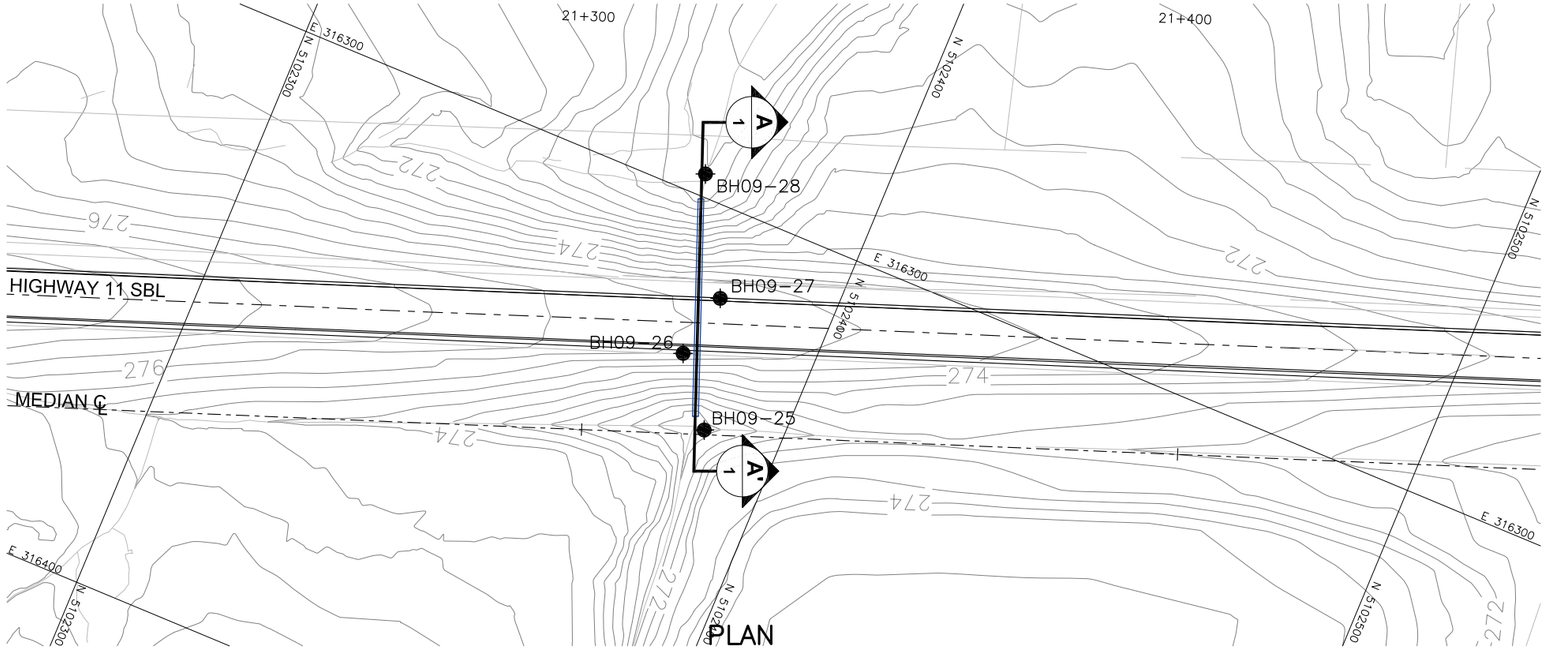
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 5416-06-00

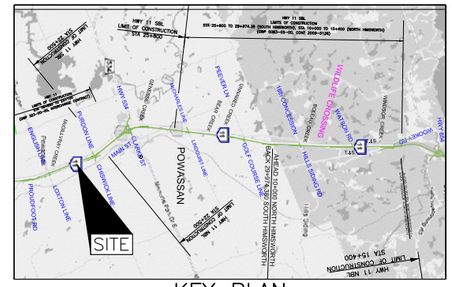
SHEET

HIGHWAY 11
CULVERT AT STA 21+319 SBL
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates Ltd.
SUDBURY, ONTARIO, CANADA



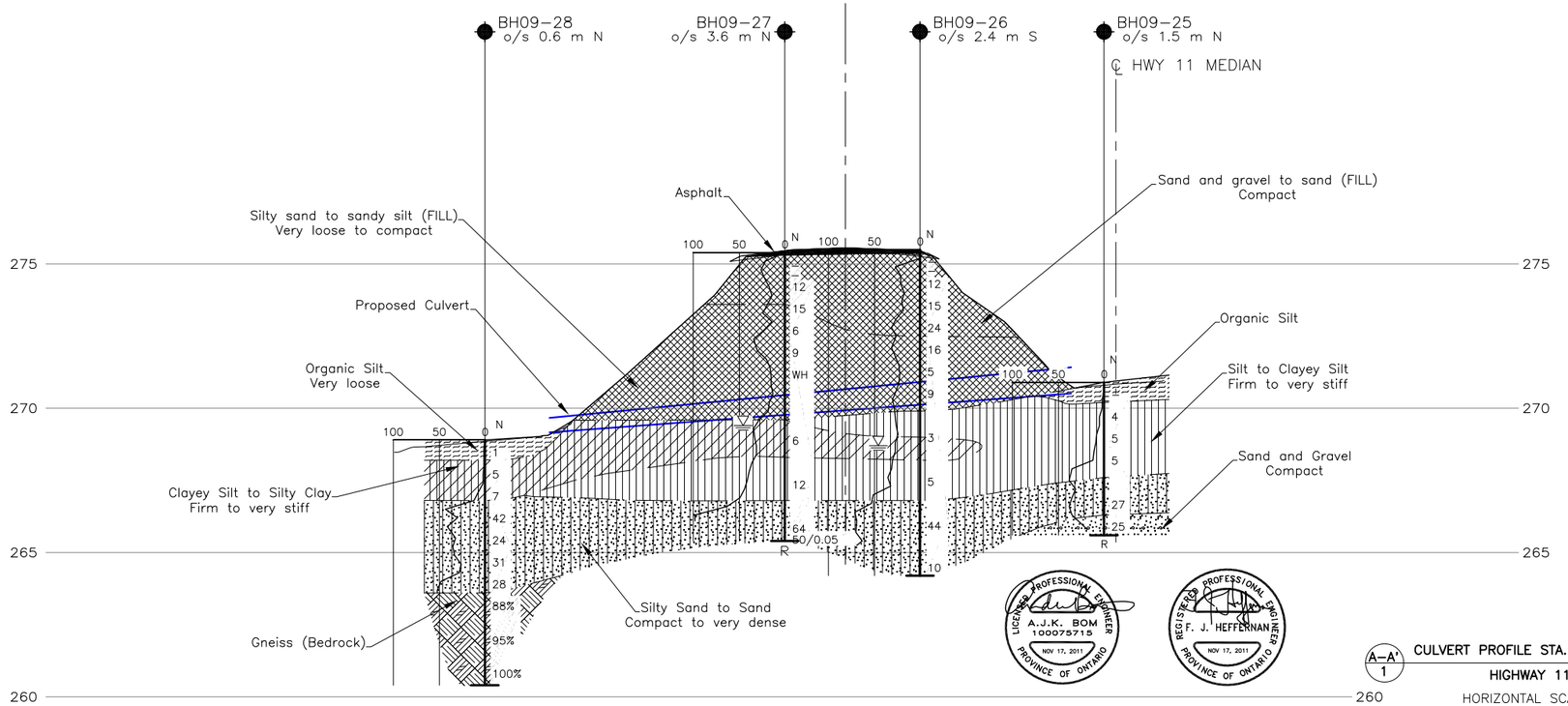
PLAN
SCALE
10 0 10 20 m



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
100%	Rock Quality Designation (RQD)
R	Refusal



A-A'
1
CULVERT PROFILE STA. 21+319 (SBL)
HIGHWAY 11
HORIZONTAL SCALE
4 0 4 8 m
2 0 2 4 m
VERTICAL SCALE

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
BH09-25	270.9	5102387.3	316336.0
BH09-26	275.5	5102379.1	316325.5
BH09-27	275.4	5102381.3	316314.6
BH09-28	268.9	5102371.0	316296.3

NOTES

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

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

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

REFERENCE

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

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NO.	DATE	BY	REVISION

Geocres No. 31L-155

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

PLOT DATE: November 16, 2011
FILENAME: \\vad1-s-DQC01\Golder\CAD\Projects\2009\09-1191-0042 Hwy 11 Culverts\09191042 Culvert 21319 SBL.dwg

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
in 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
v	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 = σ'_p / σ'_{vo}

(d) Shear Strength

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

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, 60º 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^2 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 / Relative Density	N 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	c_u, s_u psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

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

V. MINOR SOIL CONSTITUENTS

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

Golder Associates

RECORD OF BOREHOLE No BH09-25

1 OF 1 **METRIC**

PROJECT 09-1191-0042 | W.P. 5416-06-00 | LOCATION N 5102387.3; E 316336.0 | ORIGINATED BY MR

DIST _____ HWY 11 | BOREHOLE TYPE 108 mm I.D. Continous Flight, Hollow Stem Augers | COMPILED BY JJL

DATUM Geodetic | DATE November 19, 2010 | CHECKED BY AB

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa: ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
270.9	GROUND SURFACE										
0.0 / 270.2	ORGANIC SILT, trace to some sand, trace gravel Brown to black Moist to wet		1	AS	-					OC = 5.0%	
0.7	SILT to CLAYEY SILT, trace sand, trace organics in upper samples Firm to very stiff Grey Moist to wet		2	SS	4		270				
			3	SS	5		269				0 2 55 43
			4	SS	5		268	>100			
267.6											
3.3 / 266.3	Silty SAND, some gravel, trace clay Compact Grey Moist		5	SS	27		267				
4.6 / 265.6	SAND and GRAVEL, some silt Compact Grey Moist		6	SS	25		266				42 40 (18)
5.3	END OF BOREHOLE AUGER REFUSAL										

Note:

1. Attempted vane at 3.3 m depth, could not turn vane.

2. Borehole dry upon completion of drilling.

3. Advanced DCPT 1.0 m south of Borehole BH09-25. Refusal at a depth of 5.1 m (Elev. 265.8 m).

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

Golder Associates

RECORD OF BOREHOLE No BH09-26

1 OF 1 **METRIC**

PROJECT 09-1191-0042 | W.P. 5416-06-00 | DIST ____ HWY 11 | DATUM Geodetic

LOCATION N 5102379.1; E 316325.5 | BOREHOLE TYPE 108 mm I.D. Continous Flight, Hollow Stem Augers | DATE November 9, 2010

ORIGINATED BY MR | COMPILED BY JJL | CHECKED BY AB

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
275.5	GROUND SURFACE						275				
0.0	ASPHALT (130 mm)										
0.1	Sand and gravel to sand, some silt (FILL) Compact Brown Moist		1	AS	-						
			2	AS	-						
			3	SS	12		274				
			4	SS	15						
			5	SS	24		273				25 50 18 7
272.5											
3.0	Silty sand to sandy silt, trace to some gravel (FILL) Loose to compact Brown to grey Moist		6	SS	16						10 50 27 13
			7	SS	5		272				
			8	SS	9		271				
269.9							270				
5.6	SILT, some sand, trace clay, trace organics Brown to grey Moist		9a	SS	3						
269.0			9b				269				
6.5	CLAYEY SILT to SILTY CLAY Stiff Grey Wet					▽		+ 12			
268.2							268				
7.3	SILT to CLAYEY SILT Firm Grey Wet		10	SS	5						
267.3	Augers grinding below 8.2 m depth.						267				
8.2	Silty SAND to SAND, trace gravel Compact to dense Grey Wet										
			11	SS	44		266				
							265				
			12	SS	10						4 84 (12)
264.2											
11.3	END OF BOREHOLE										

Note:

1. Water level at a depth of 6.8 m below ground surface (Elev. 268.7 m) upon completion of drilling.

2. Advanced DCPT 2.5 m south of Borehole BH09-26. Refusal at a depth of 10.2 m (Elev. 265.3 m).

+ 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:

Golder Associates

RECORD OF BOREHOLE No BH09-27

1 OF 1 **METRIC**

PROJECT 09-1191-0042 | W.P. 5416-06-00 | LOCATION N 5102381.3; E 316314.6 | ORIGINATED BY MR

DIST _____ HWY 11 | BOREHOLE TYPE 108 mm I.D. Continous Flight, Hollow Stem Augers | COMPILED BY JJL

DATUM Geodetic | DATE November 8 and 9, 2010 | CHECKED BY AB

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
275.4	GROUND SURFACE										
0.0	ASPHALT (150 mm)										
0.1	Sand and gravel to sand, trace silt (FILL) Compact Brown Moist		1	AS	-						
			2	AS	-						
			3	SS	12						3 93 (4)
273.6											
1.8	Silty sand to sandy silt, trace clay, some gravel (FILL) Very loose to loose Brown to grey Moist		4	SS	15						
			5	SS	6						
			6	SS	9						
			7	SS	WH						12 57 (31)
			8	SS	1						
269.6											
5.8	SILTY CLAY, trace sand Stiff to very stiff Brown Moist to wet		9	SS	6	▽					
268.3								>100			
7.1	SILT to CLAYEY SILT Stiff Brown to grey Moist to wet		10	SS	12						0 7 73 20
267.2	Slower augering and grinding below 8.2 m depth.										
8.2	Silty SAND, trace to some clay, trace to some gravel Very dense Brown to grey Moist to wet		11	SS	64						
265.4			12	SS	50/0.05						16 56 (28)
10.0	END OF BOREHOLE SPOON AND AUGER REFUSAL										

Note:

1. Water level at a depth of 6.0 m below ground surface (Elev. 269.4 m) upon completion of drilling.

2. Advanced DCPT 1.5 m north of Borehole BH09-27. Refusal at a depth of 9.3 m (Elev. 266.1 m).

$+^3$, $\times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

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

Golder Associates

RECORD OF BOREHOLE No BH09-28

1 OF 1 **METRIC**

PROJECT 09-1191-0042 | W.P. 5416-06-00 | DIST ____ HWY 11 | DATUM Geodetic

LOCATION N 5102371.0; E 316296.3 | BOREHOLE TYPE 108 mm I.D. Continous Flight, Hollow Stem Augers | DATE November 15, 2010

ORIGINATED BY MR | COMPILED BY JJL | CHECKED BY AB

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ (kN/m³)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
268.9	GROUND SURFACE							
0.0	ORGANIC SILT Very loose Brown Moist to wet		1	SS	1			OC = 7.1%
268.2								
0.7	SILT to CLAYEY SILT, some sand Firm to stiff Brown to grey Moist to wet		2	SS	5			
			3	SS	7			0 12 74 14
266.8								
2.1	Silty SAND, some gravel Compact to dense Brown Moist		4	SS	42			22 51 (27)
			5	SS	24			
	Augers grinding at 3.8 m depth.		6	SS	31			
			7	SS	28			18 56 (26)
263.6								
5.3	GNEISS (BEDROCK) Bedrock cored from 5.3 m depth to 8.5 m depth. For coring details see Record of Drillhole BH09-28.		1	RC	REC 100%			RQD = 88%
			2	RC	REC 100%			RQD = 95%
			3	RC	REC 100%			RQD = 100%
260.4								
8.5	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling. 2. Advanced DCPT 1.0 m south of Borehole BH09-28. Refusal at a depth of 5.3 m (Elev. 263.6 m).							

ELEVATION SCALE: 268, 267, 266, 265, 264, 263, 262, 261

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED; 20 40 60 80 100

PLASTIC LIMIT w_P | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w_L

WATER CONTENT (%): 20 40 60

$+^3$, $\times^3$: 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: 09-1191-0042

RECORD OF DRILLHOLE: BH09-28

SHEET 1 OF 1

LOCATION: N 5102371.0 ;E 316296.3

DRILLING DATE: November 15, 2010

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: D-50

DRILLING CONTRACTOR: Walker Drilling

JN - Joint; FLT - Fault; SHR- Shear; VN - Vein; CJ - Conjugate; BD- Bedding; FO- Foliation; CO- Contact; OR- Orthogonal; CL - Cleavage; PL - Planar; CU - Curved; UN - Undulating; ST - Stepped; IR - Irregular; PO- Polished; K - Slickensided; SM- Smooth; Ro - Rough; MB- Mechanical Break; BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. / DEPTH (m)	RUN No.	COLOUR / % RETURN / FLUSH	RECOVERY: TOTAL CORE %	RECOVERY: SOLID CORE %	R.Q.D. %	FRACT. INDEX METRES	DISCONTINUITY DATA: B Angle	DISCONTINUITY DATA: DIP w.r.t. CORE AXIS	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	HYDRAULIC CONDUCTIVITY k, cm/s	Diametral Point Load Index (MPa)	RMC -Q' AVG.	NOTES WATER LEVELS INSTRUMENTATION
		Refer to Previous Page		263.6																
6	D-50 NQ Coring	GNEISS Fresh Grey Medium grained		5.3	1	GREY 100%							JIR JIR JIR							
7					2	GREY 100%							JIR JIR JIR JIR							
8					3	GREY 100%														
				260.4																
		END OF DRILLHOLE		8.5																
9																				
10																				
11																				
12																				
13																				
14																				
15																				

DEPTH SCALE

1 : 50

Golder Associates

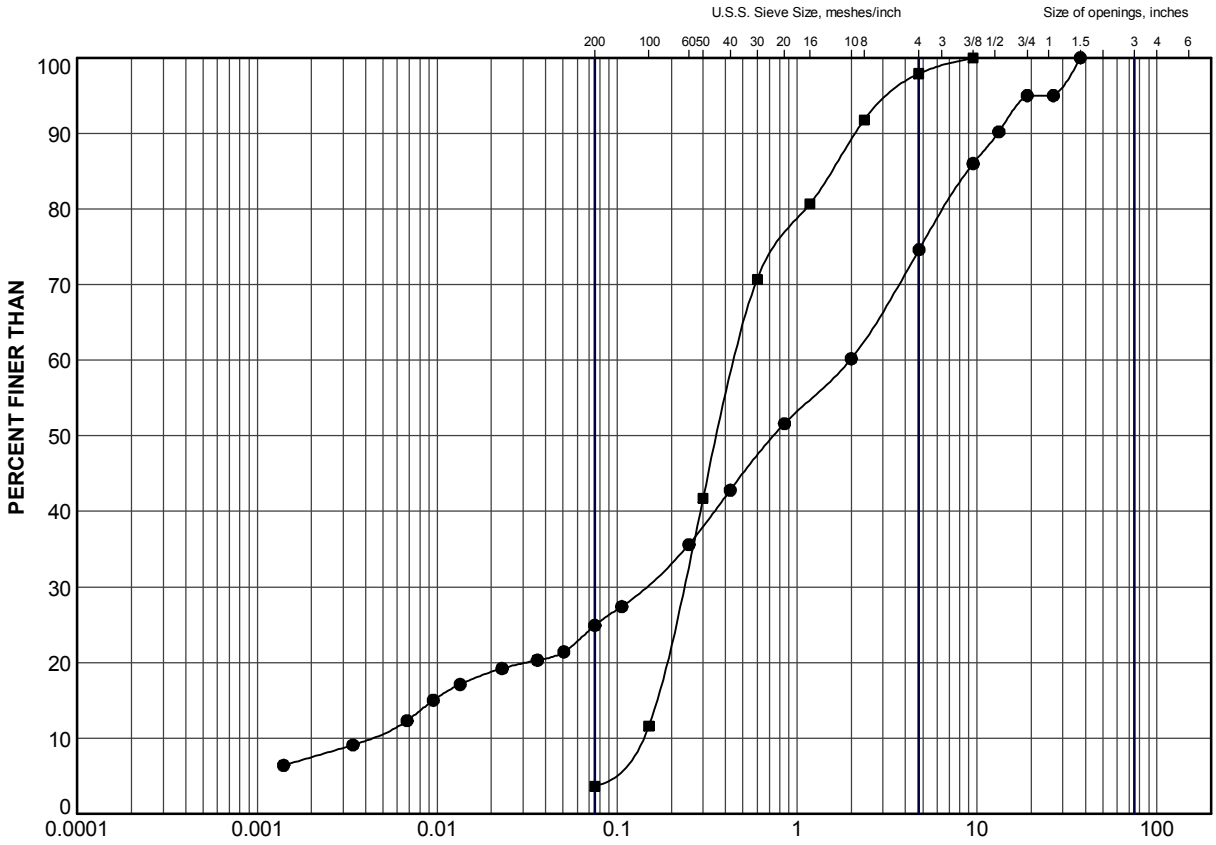
LOGGED: MR

CHECKED: AB

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

APPENDIX B

Laboratory Test Results



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH09-26	5	272.9
■	BH09-27	3	274.3

PROJECT

HIGHWAY 11 SBL CULVERT 21+319

TITLE

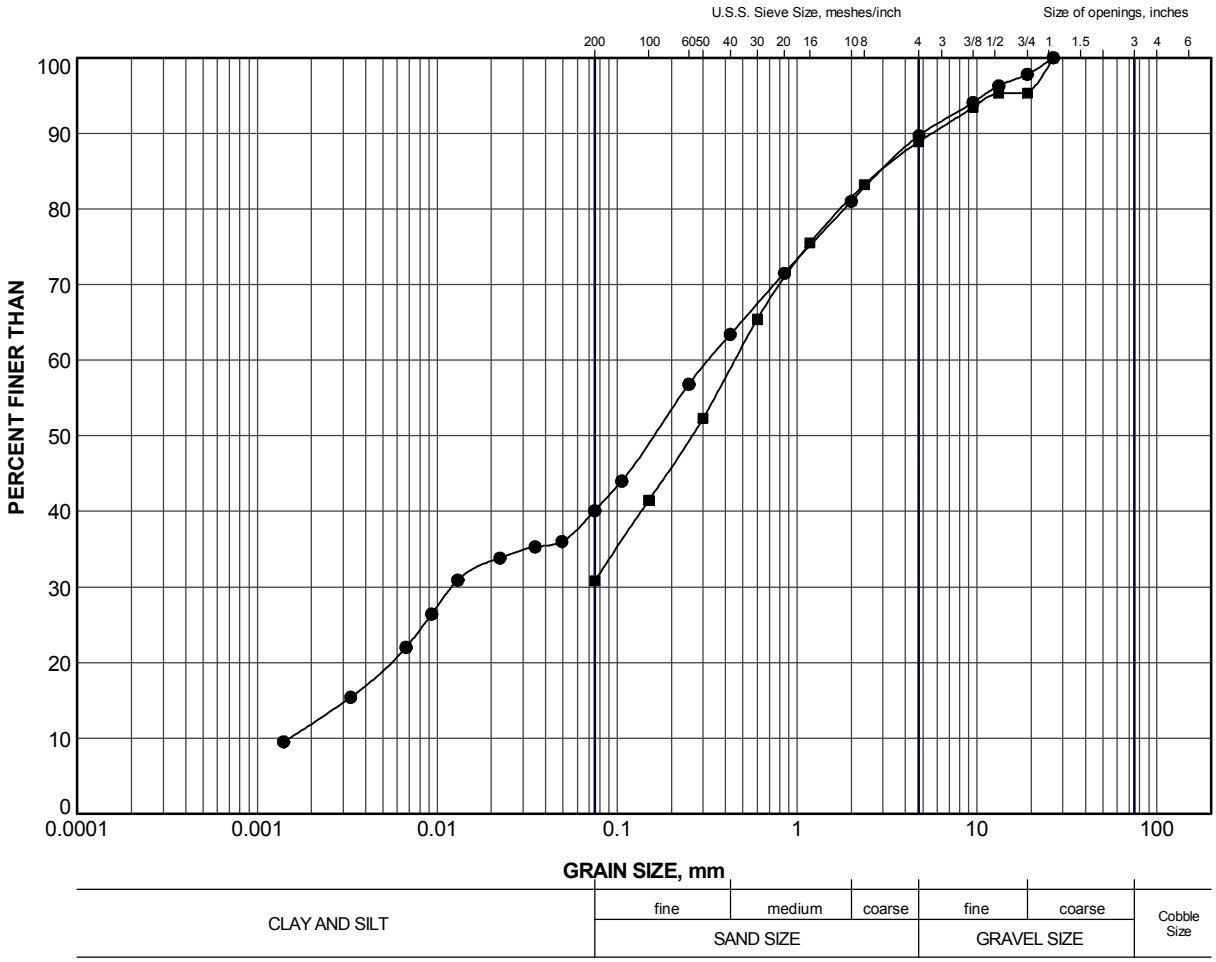
GRAIN SIZE DISTRIBUTION

GRAVELLY SAND TO SAND (FILL)

Golder Associates
SUDBURY, ONTARIO

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	**FIGURE B1**	

LDN_MTO_NEW GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH09-26	6	272.1
■	BH09-27	7	271.3

PROJECT

HIGHWAY 11 SBL CULVERT 21+319

TITLE

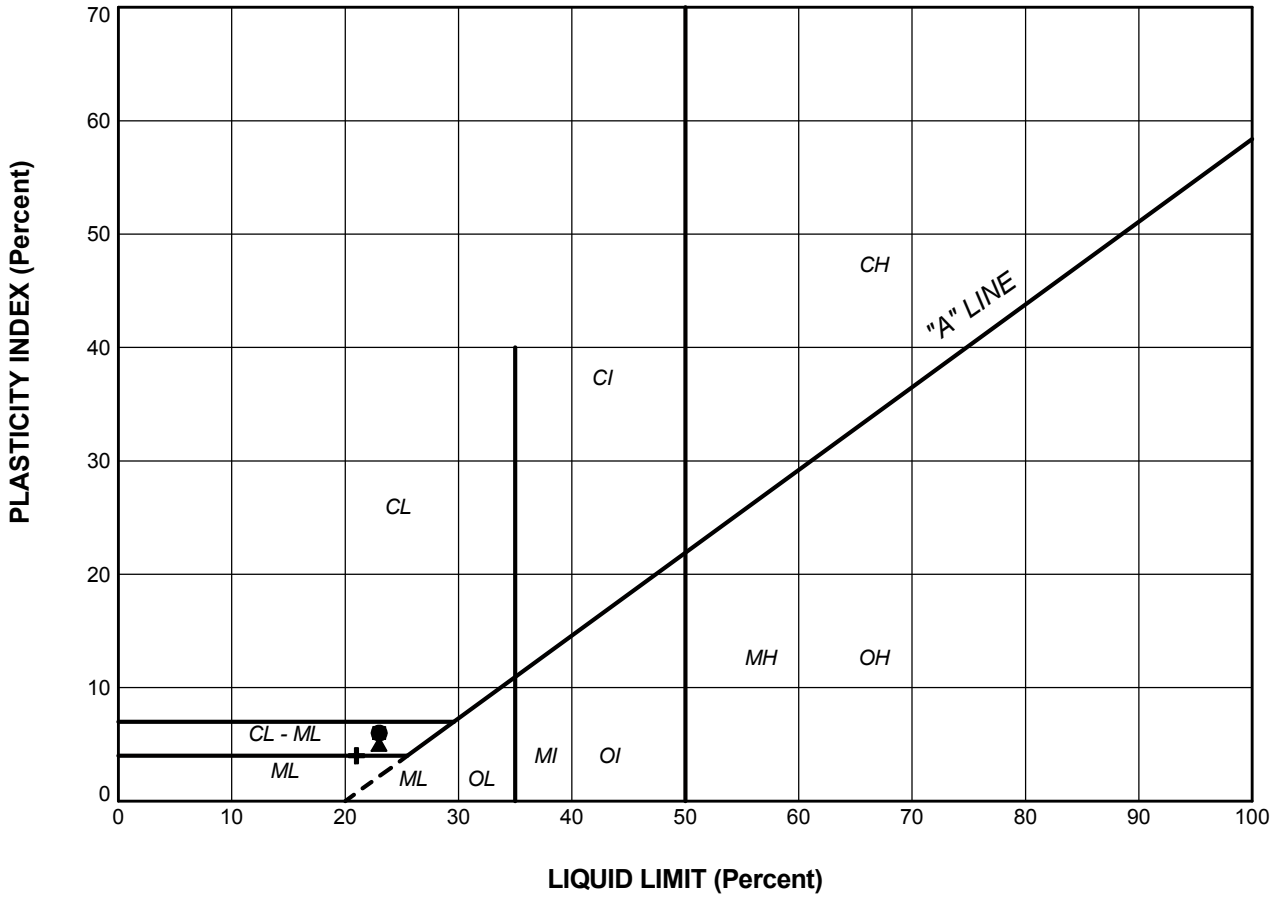
GRAIN SIZE DISTRIBUTION

SILTY SAND (FILL)

Golder Associates
SUDBURY, ONTARIO

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	**FIGURE B2**	

LDN_MTO_NEW GLDR_LDN.GDT



SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	BH09-25	2	23.0	17.0	6.0
■	BH09-25	4	23.0	17.0	6.0
▲	BH09-26	10	23.0	18.0	5.0
✚	BH09-28	3	21.0	17.0	4.0

PROJECT

HIGHWAY 11 SBL CULVERT 21+319

TITLE

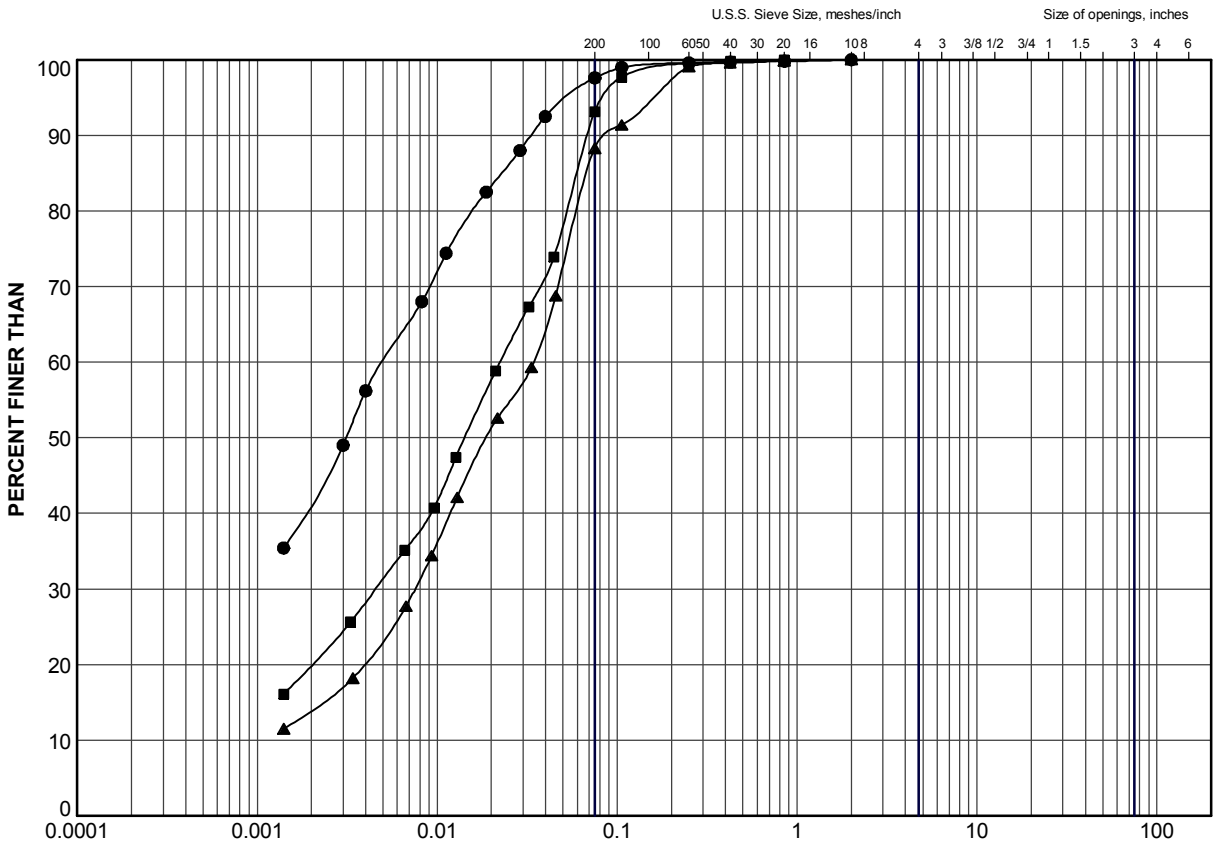
PLASTICITY CHART

SILT TO CLAYEY 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**

MTO_PI GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH09-25	3	269.1
■	BH09-27	10	267.5
▲	BH09-28	3	267.1

PROJECT

HIGHWAY 11 SBL CULVERT 21+319

TITLE

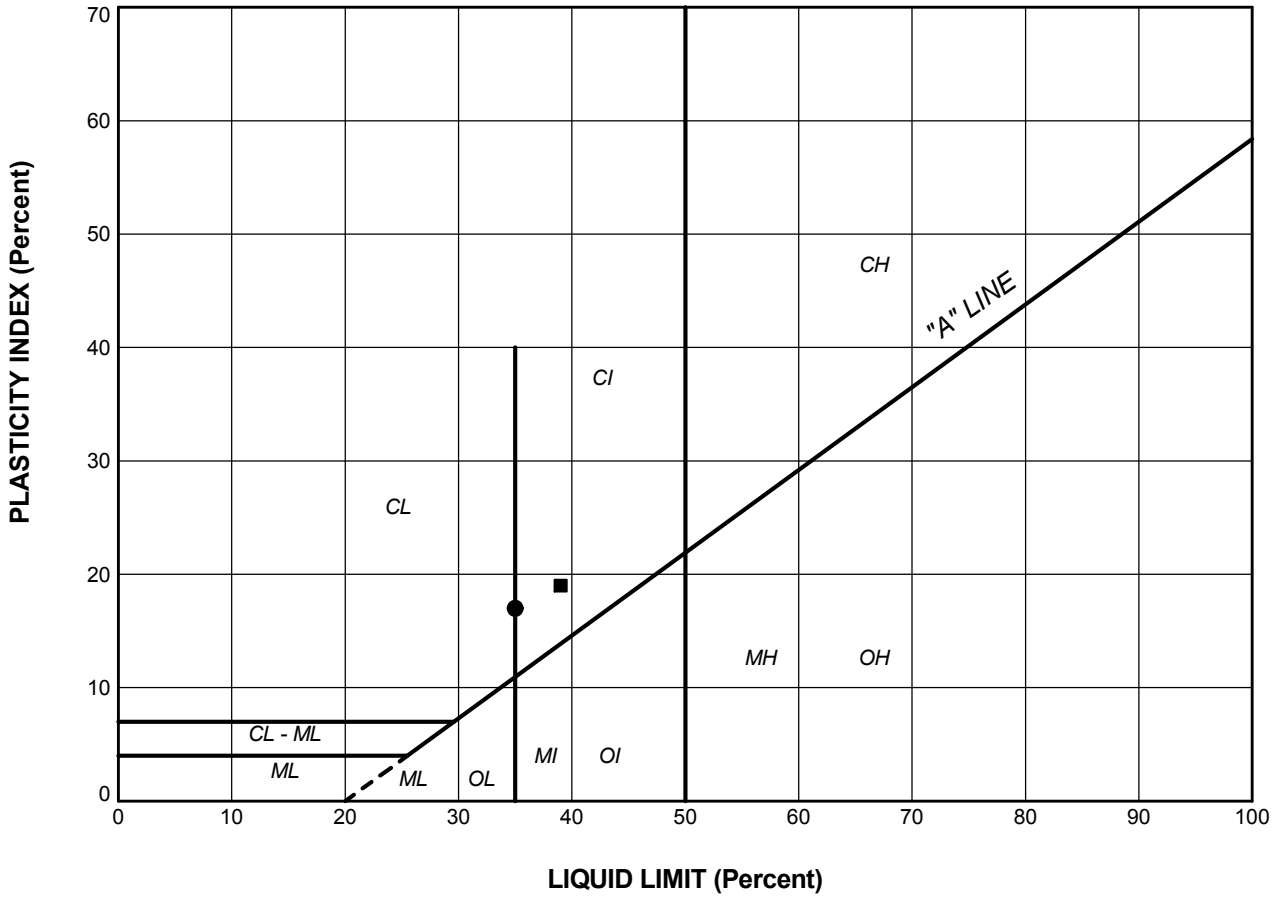
GRAIN SIZE DISTRIBUTION

SILT TO CLAEY SILT

Golder Associates
SUDBURY, ONTARIO

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	**FIGURE B4**	

LDN_MTO_NEW GLDR_LDN.GDT



SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	BH09-26	9b	35.0	18.0	17.0
■	BH09-27	9	39.0	20.0	19.0

PROJECT

HIGHWAY 11 SBL CULVERT 21+319

TITLE

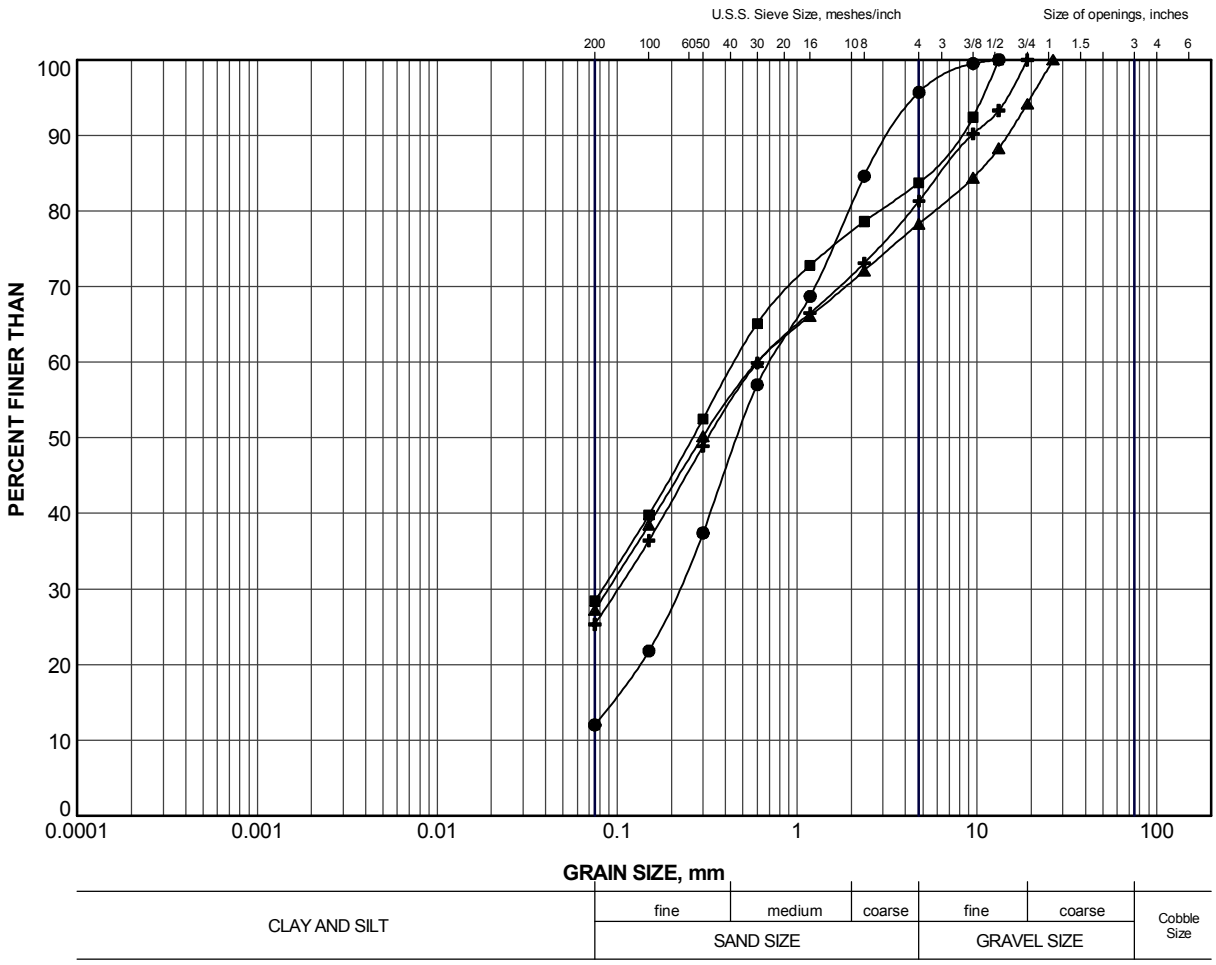
PLASTICITY CHART

CLAYEY SILT TO SILTY CLAY

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**	**B5**

MTO_PI GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH09-26	12	264.5
■	BH09-27	12	265.5
▲	BH09-28	4	266.3
✚	BH09-28	7	264.0

PROJECT

HIGHWAY 11 SBL CULVERT 21+319

TITLE

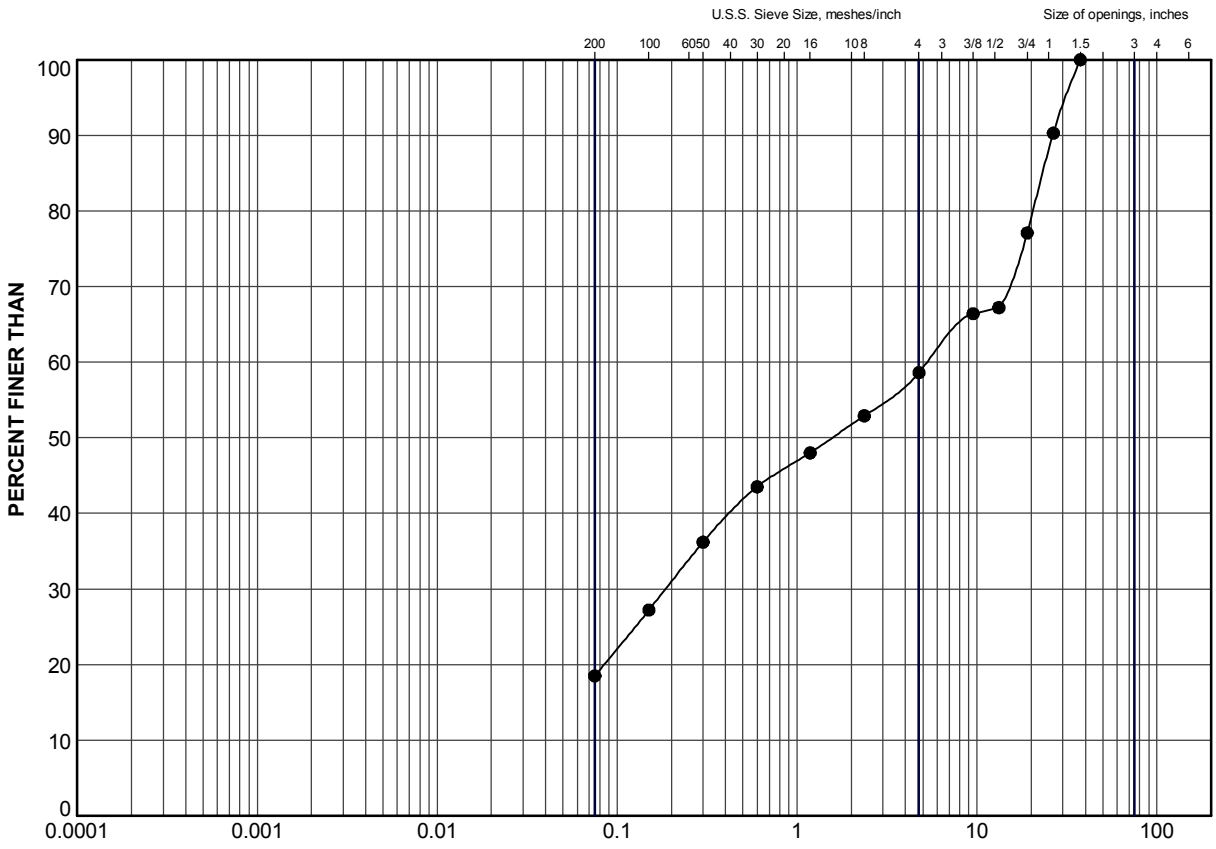
GRAIN SIZE DISTRIBUTION

SILTY SAND TO SAND

Golder Associates
SUDBURY, ONTARIO

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	**FIGURE B6**	

LDN_MTO_NEW GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH09-25	6	266.0

PROJECT

HIGHWAY 11 SBL CULVERT 21+319

TITLE

GRAIN SIZE DISTRIBUTION

SAND AND GRAVEL

Golder Associates
SUDBURY, ONTARIO

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	**FIGURE B7**	

LDN_MTO_NEW GLDR_LDN.GDT

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