REPORT

November 17, 2011

FOUNDATION INVESTIGATION REPORT

HIGHWAY 11 SBL CULVERT REPLACEMENT AT STATION 20+543
TOWNSHIP OF SOUTH HIMSWORTH, ONTARIO
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5416-06-00

Submitted to:
URS Canada Inc.
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GEOCRES NO. 31L-154

Report Number: 09-1191-0042-R07

Distribution:

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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 20+543. 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 at Highway 11 SBL at Station 20+543. The scope of work includes an assessment of stability and settlement of the embankment for the culvert replacement and providing recommendations on a preferred mitigation option that may be required as a means to minimize total and differential settlements (if applicable), geotechnical resistances (as applicable), and estimates of horizontal and vertical strains and maximum joint opening allowances along the culvert. The work also includes addressing foundation aspects for the final design and construction of head walls and wing walls associated with the culvert (where applicable), construction concerns and potential geotechnical problems associated with the culvert, including localized sub-excavation of soft / organic materials, placement of new fill and requirements for erosion protection and bedding materials.

We understand from URS that the culvert to be constructed under the SBL embankment at Station 20+543 will be a concrete pipe 1.2 m in diameter. The existing culvert is about 32 m long. The inverts at the west and east ends of the culvert will be Elevation 272.4 m and 275.7 m, respectively. The height of the embankment in the culvert area is about 2 m (median) to 5 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 500 m north of English and Loxton Lines.

The existing culvert at Station 20+543 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 and that the ends of the culvert are 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 272 m and on the east side is about Elevation 276 m. The ground surface at the top of the embankment is at about Elevation 278 m.

3.0 INVESTIGATION PROCEDURES

The fieldwork for the investigation associated with this culvert replacement at Station 20+543 was carried out on November 16 and 18, 2010 during which time a total of four (4) Boreholes (BH09-21 to BH09-24) 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 1.6 metres 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 13.6 m and 18.9 m below existing ground surface. Boreholes BH09-21, BH09-22 and BH09-24 were advanced to auger refusal and the DCPTs advanced adjacent to Borehole BH09-21 and BH09-24 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 BH09-23 and associated DCPT and the DCPT adjacent to Borehole BH09-22 were terminated within the sand and silt 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		
09-21	5 101 661.3	316 613.0	276.2	16.5
09-22	5 101 654.5	316 604.1	278.1	18.1
09-23	5 101 655.3	316 592.6	278.0	18.9
09-24	5 101 647.5	316 579.8	272.4	13.6

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.

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.

[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.

In general, the subsurface stratigraphy along the culvert alignment consists of embankment fill underlain by clayey silt to silty clay and clayey silt encountered from ground surface at the toes of the existing embankment. Underlying the clayey silt to silty clay, sand and silt to sand was encountered underlain by sand and gravel at one borehole location.

4.2.1 Fill

Boreholes BH09-22 and BH09-23 were advanced through the embankment. In Borehole BH09-22, about 135 mm of asphalt was encountered from ground surface. Below the asphalt in Borehole BH09-22 and from ground surface in Borehole BH09-23, about 1.0 m and 1.1 m of sand and gravel to sand fill was encountered, respectively. Silty sand to sandy silt fill was encountered below the sand and gravel to sand fill and was 2.3 m and 2.7 m thick and encountered at Elevation 277.0 m and 276.9 m in Boreholes BH09-22 and BH09-23, respectively.

The embankment fill was considered to be loose to compact with 'N'-values between 4 blows and 21 blows per 0.3 m of penetration.

The gradation of two samples of the silty sand to sandy silt fill is shown on Figure B1.

A water content of 11 percent was measured in a single sample of the lower fill from Borehole BH09-23.

4.2.2 Clayey Silt to Silty Clay

A deposit of clayey silt to silty clay was encountered at the surface of Boreholes BH09-21 and BH09-24 and beneath the fill in Boreholes BH09-22 and BH09-23 below Elevation 276.2 m to 272.4 m. The uppermost samples contained trace organics. The deposit is between about 1.5 m and 3.7 m thick.

SPT 'N'-values of 4 blows to 11 blows per 0.3 m of penetration were obtained indicating a firm to very stiff consistency. In situ field shear vane testing was conducted within the deposit in Boreholes BH09-21 and BH09-23 and the shear strength was approximately 100 to greater than 120 kilopascals, indicating a very stiff consistency.

A total of six (6) Atterberg Limits tests were carried out on the clayey silt to silty clay deposit and are shown on Figure B2. Plastic limits range from 17 percent to 21 percent; liquid limits range from 24 percent to 39 percent and plasticity indices range from 6 percent to 18 percent, indicating a low to medium plasticity clay.

The grain size distributions of two samples of clayey silt are shown on Figure B3.

The natural water content varied between 22 percent and 40 percent. The clayey silt sample near Elevation 275.0 m in Borehole BH09-22 has an organic content of 2.7 percent.

4.2.3 Sand and Silt to Sand

The cohesive layers in each of the boreholes were underlain by sand and silt to sand from Elevation 270.9 m to 272.5 m. Boreholes BH09-21, BH09-23 and BH09-24 were terminated in the sand and silt layer after exploring some 12.1 m to 12.8 m.

The sand and silt to sand deposit was found to be typically loose to dense but generally compact based on measured SPT 'N'-values of 7 blows to 33 blows per 0.3 m of penetration. One 'N'-value near the bottom of the deposit in Borehole BH09-23 was 90 blows per 0.3 m of penetration indicating a very dense relative density.

The gradations of twelve samples of sand and silt to sand are presented on Figure B4.

The natural water content of samples of the deposit varied between 4 percent and 19 percent.

4.2.4 Sand and Gravel

The sand and silt to sand in Borehole BH09-22 was underlain by sand and gravel. This borehole was terminated in the sand and gravel after exploring some 1.8 m below Elevation 261.8 m. The sand and gravel was very dense with an 'N'-value of 101 blows per 0.3 metres of penetration.

4.2.5 Refusal

In Borehole BH09-21, refusal to augering and DCPT cone penetration occurred at a depth of 16.5 m and 17.2 m, respectively, corresponding to Elevation 259.7 m and 259.0 m, respectively. In Borehole BH09-22, refusal to auger penetration occurred at a depth of 18.1 m corresponding to Elevation 260.0 m. In Borehole BH09-24, refusal to augering and DCPT cone penetration occurred at a depth of 13.6 m corresponding to Elevation 258.8 m. 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

Borehole BH09-24 was dry during and upon completion of drilling. Water levels observed in the three remaining boreholes upon completion of drilling range from 13.4 m to 17.6 m below existing ground surface or between Elevation 260.4 m and 262.8 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. This report was prepared by Ms. Dirka U. Prout, P.Eng., 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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DUP/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:

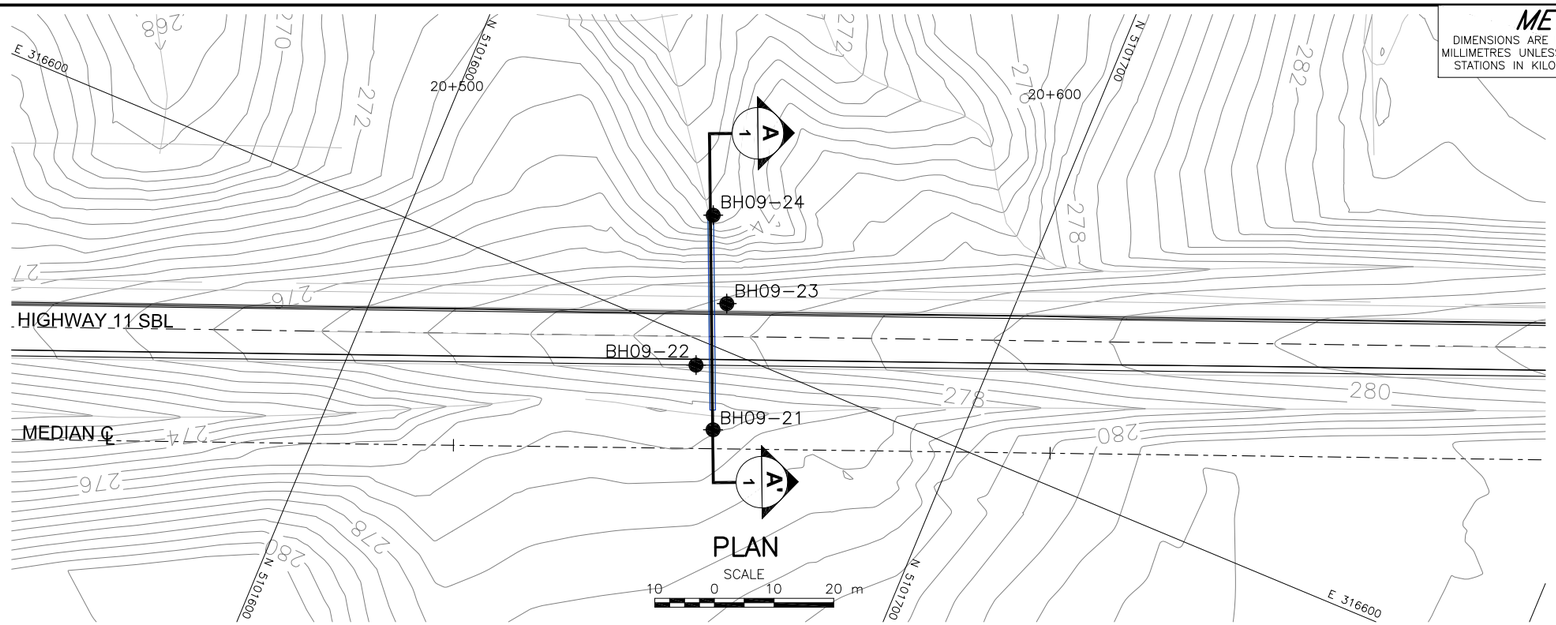
OPSS 209	Construction Specification for Embankments Over Swamps and Compressible Soils.
OPSS 421	Construction Specification For Pipe Culvert Installation In Open Cut.
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut.

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



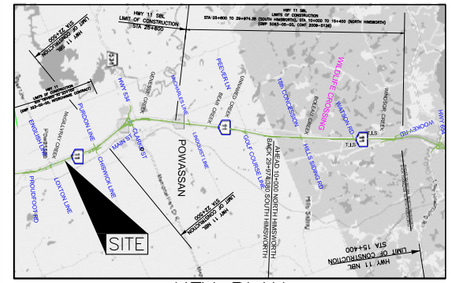
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 5416-06-00

SHEET

HIGHWAY 11
CULVERT AT STA 20+543 SBL
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates Ltd.
SUDBURY, ONTARIO, CANADA



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
BH09-21	276.2	5101661.3	316613.0
BH09-22	278.1	5101654.5	316604.1
BH09-23	278.0	5101655.3	316592.6
BH09-24	272.4	5101647.5	316579.8

NOTES

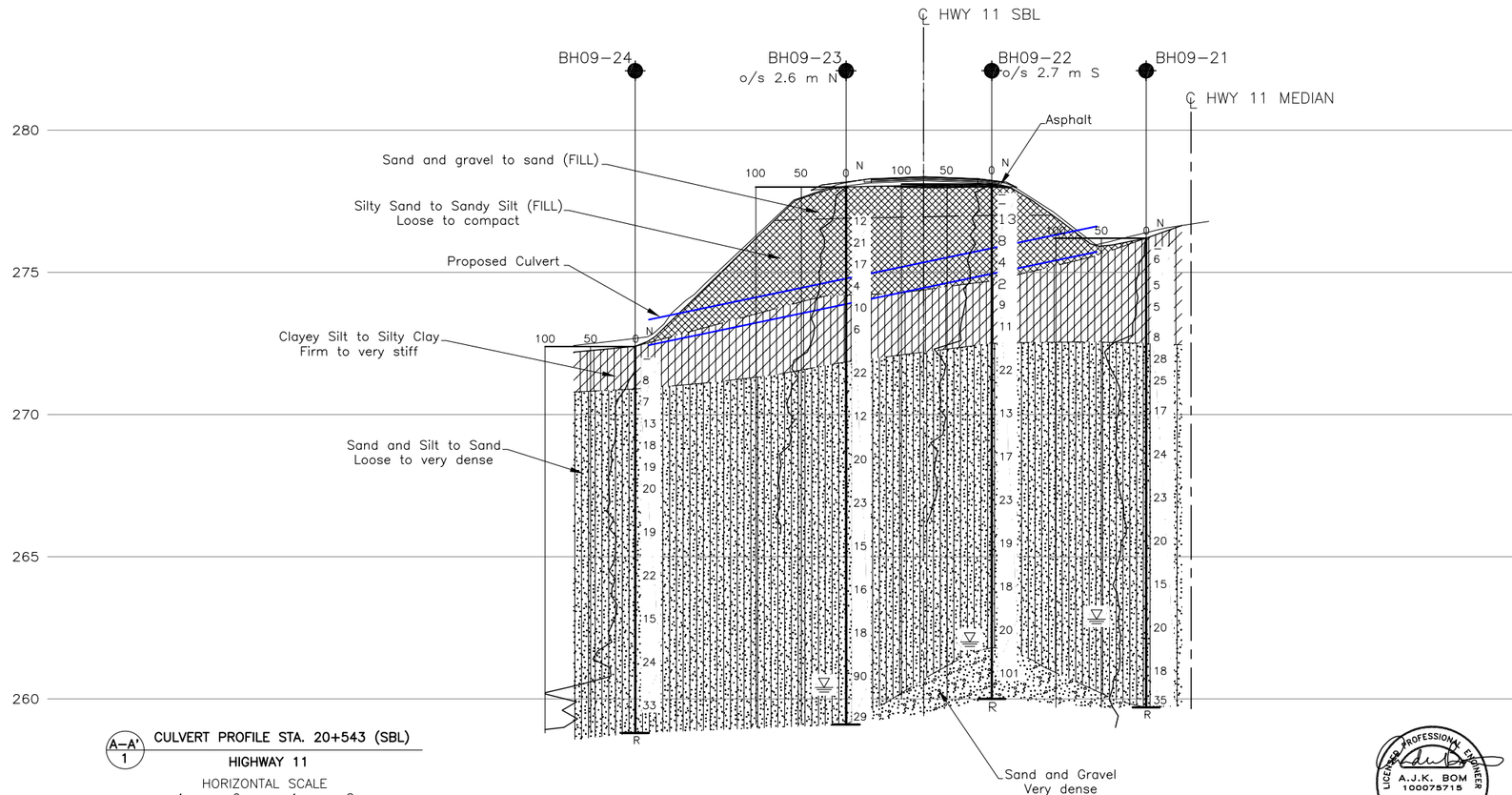
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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, Keyplan recieved June 3, 2011.



A-A' 1 CULVERT PROFILE STA. 20+543 (SBL)
HIGHWAY 11
HORIZONTAL SCALE
4 0 4 8 m
2 0 2 4 m
VERTICAL SCALE

LICENCED PROFESSIONAL ENGINEER A.J.K. BOM 100075715 NOV 17, 2011 PROVINCE OF ONTARIO

REGISTERED PROFESSIONAL ENGINEER F. J. HEFFERNAN NOV 17, 2011 PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

Geocres No. 31L-154

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: \\vaul1-s-cadgis1\Golder\CAD\Projects\2009\09-1191-0042 Hwy 11 Culverts\09119100042 Culvert 20543 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

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RECORD OF BOREHOLE No BH09-21

1 OF 2 **METRIC**

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

LOCATION N 5101661.3; E 316613.0 | BOREHOLE TYPE 108 mm I.D. Continous Flight, Hollow Stem Augers | DATE November 18, 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
276.2	GROUND SURFACE										
0.0	CLAYEY SILT, trace to some sand, trace organics in upper samples Firm to very stiff Brown to grey Moist to wet		1	AS	-		276				
			2	SS	6				○		0 23 54 23
			3	SS	5		275		⊢○		
			4	SS	5		274				
			5	SS	8		273	+ 7	⊢○		
272.5											
3.7	SAND and SILT to SAND, trace clay Compact Brown Moist to wet		6	SS	28		272				
			7	SS	25		271		○		0 47 50 3
			8	SS	17		270				
			9	SS	24		269		○		
			10	SS	23		268				0 84 (16)
			11	SS	20		267		○		
			12	SS	15		266				
			13	SS	20	▽	265				0 63 36 1
							264				
							263				
							262				

Continued Next Page

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

Golder Associates

RECORD OF BOREHOLE No BH09-21

2 OF 2 **METRIC**

PROJECT 09-1191-0042 | W.P. 5416-06-00 | LOCATION N 5101661.3; E 316613.0 | ORIGINATED BY MR
DIST ____ HWY 11 | BOREHOLE TYPE 108 mm I.D. Continous Flight, Hollow Stem Augers | COMPILED BY JJL
DATUM Geodetic | DATE November 18, 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
	--- CONTINUED FROM PREVIOUS PAGE ---										
	SAND and SILT to SAND, trace clay Compact Brown Moist to wet		14	SS	18		261		○		
259.7			15	SS	35		260				
16.5	END OF BOREHOLE SPOON AND AUGER REFUSAL Note: 1. Water level at a depth of 13.4 m below ground surface (Elev. 262.8 m) upon completion of drilling. 2. Advanced DCPT 1.5 m south and 1.0 m east of Borehole BH09-21. Refusal at a depth of 17.2 m (Elev. 259.0 m).										

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

Golder Associates

RECORD OF BOREHOLE No BH09-22

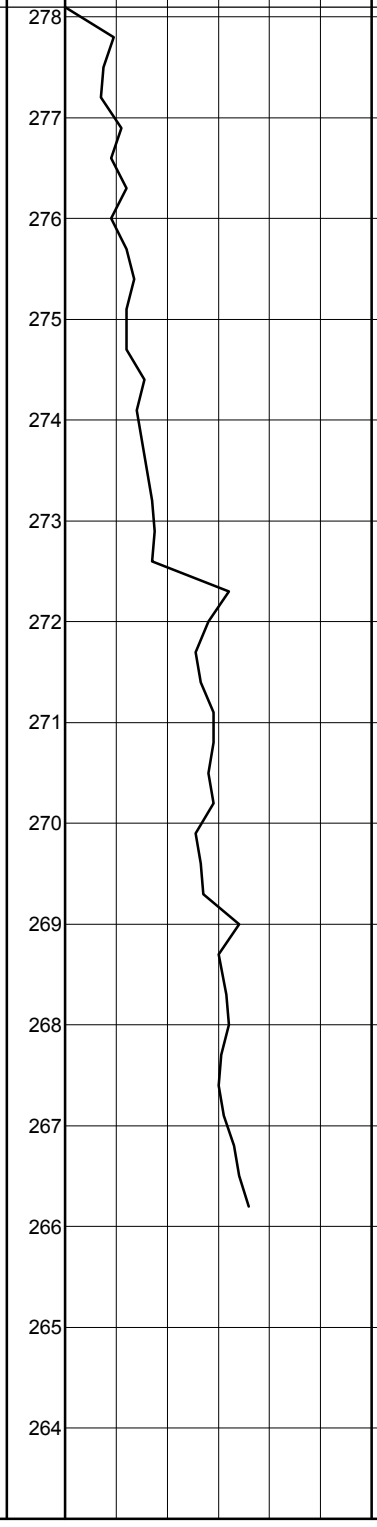
1 OF 2 **METRIC**

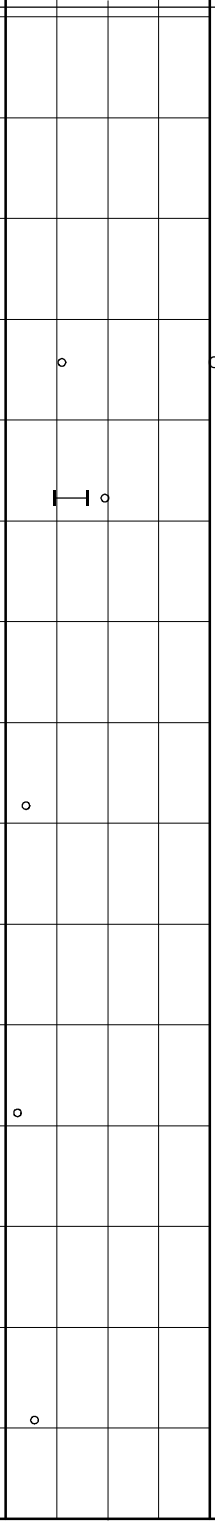
PROJECT 09-1191-0042 | W.P. 5416-06-00 | DIST ____ HWY 11 | DATUM Geodetic

LOCATION N 5101654.5; E 316604.1 | BOREHOLE TYPE 108 mm I.D. Continous Flight, Hollow Stem Augers | DATE November 18, 2010

ORIGINATED BY EHS | COMPILED BY JJL | CHECKED BY AB

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS
278.1	GROUND SURFACE					
0.0	ASPHALT (135 mm)					
0.1	Sand and gravel to sand (FILL) Compact Brown Moist		1	AS	-	
			2	AS	-	
277.0			3a	SS	13	
1.1	Silty sand to sandy silt, some clay (FILL) Loose Brown and grey Moist		3b			
			4	SS	8	
			5	SS	4	
274.7			6a	SS	2	
3.4	CLAYEY SILT, trace sand, trace organics Stiff Brown and grey Moist to wet		6b			
			7	SS	9	
			8	SS	11	
272.5						
5.6	SAND and SILT to SAND, trace gravel, trace clay Compact Brown Moist to wet		9	SS	22	
			10	SS	13	
			11	SS	17	
			12	SS	23	
			13	SS	19	
			14	SS	18	





UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	0 29 54 17
OC = 2.7%	0 19 60 21
	1 58 41 0
	0 86 12 2

Continued Next Page

$+^3, \times^3$: Numbers refer to Sensitivity

$\circ^{3\%}$ STRAIN AT FAILURE

Golder Associates

RECORD OF BOREHOLE No BH09-22

2 OF 2 **METRIC**

PROJECT 09-1191-0042 | W.P. 5416-06-00 | LOCATION N 5101654.5; E 316604.1 | ORIGINATED BY EHS

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

DATUM Geodetic | DATE November 18, 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 + FIELD VANE ● QUICK TRIAXIAL × 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
	--- CONTINUED FROM PREVIOUS PAGE ---										
	SAND and SILT to SAND, trace gravel, trace clay Compact Brown Moist to wet		15	SS	20	▽	263				
261.8							262				
16.3	SAND and GRAVEL, trace to some silt Very Dense Brown Wet		16	SS	101		261				
260.0							260				
18.1	END OF BOREHOLE AUGER REFUSAL Note: 1. Water level at a depth of 16.1 m below ground surface (Elev. 262.0 m) upon completion of drilling. 2. Advanced DCPT 1.5 m south of Borehole BH09-22. End of DCPT at a depth of 11.9 m (Elev. 266.2 m).										

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

Golder Associates

RECORD OF BOREHOLE No BH09-23

1 OF 2 **METRIC**

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

LOCATION N 5101655.3; E 316592.6 | BOREHOLE TYPE 108 mm I.D. Continous Flight, Hollow Stem Augers | DATE November 16, 2010

ORIGINATED BY EHS | COMPILED BY JJL | CHECKED BY AB

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
278.0	GROUND SURFACE					
0.0	Sand and gravel to sand (FILL) Compact Brown Moist	1	AS	-		
		2	AS	-		
276.9		3	SS	12		
1.1	Silty sand to sand and silt, trace to some clay (FILL) Loose to compact Brown to grey Moist	4	SS	21		
		5	SS	17		
		6	SS	4		2 30 47 21
274.2						
3.8	SILTY CLAY Stiff to very stiff Brown Moist to wet	7	SS	10		
		8	SS	6		
271.8						
6.2	SAND and SILT to SAND, trace gravel, trace to some clay Compact to very dense Brown Moist to wet	9a 9b	SS	22		3 29 55 13
		10	SS	12		
		11	SS	20		0 88 12 0
		12	SS	23		
		13	SS	15		
		14	SS	16		

GROUND WATER CONDITIONS

ELEVATION SCALE: 277, 276, 275, 274, 273, 272, 271, 270, 269, 268, 267, 266, 265, 264

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED

20 40 60 80 100

>120

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

WATER CONTENT (%): 20 40 60

+³, ×³: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

Continued Next Page

Golder Associates

RECORD OF BOREHOLE No BH09-23

2 OF 2 **METRIC**

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

LOCATION N 5101655.3; E 316592.6 | BOREHOLE TYPE 108 mm I.D. Continous Flight, Hollow Stem Augers | DATE November 16, 2010

ORIGINATED BY EHS | COMPILED BY JJL | 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
	--- CONTINUED FROM PREVIOUS PAGE ---										
	SAND and SILT to SAND, trace gravel, trace to some clay Compact to very dense Brown Moist to wet		15	SS	18	▽	262		○		0 65 33 2
			16	SS	90		261				
259.1			17	SS	29		260				14 53 (33)
18.9	END OF BOREHOLE Note: 1. Water level at a depth of 17.6 m below ground surface (Elev. 260.4 m) upon completion of drilling. 2. Advanced DCPT 1.5 m north of Borehole BH09-23. Refusal at a depth of 12.2 m (Elev. 265.8 m).										

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

Golder Associates

RECORD OF BOREHOLE No BH09-24

1 OF 2 **METRIC**

PROJECT 09-1191-0042 | W.P. 5416-06-00 | LOCATION N 5101647.5; E 316579.8 | ORIGINATED BY MR

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

DATUM Geodetic | DATE November 16, 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) (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
272.4	GROUND SURFACE										
0.0	CLAYEY SILT, trace organics Stiff Brown to grey Moist to wet		1	AS	-		272				
			2	SS	8						
270.9							271				
1.5	SAND and SILT to SAND, trace to some gravel Loose to very dense Brown Moist to wet		3	SS	7						
			4	SS	13		270				
			5	SS	18		269				1 84 (15)
			6	SS	19						
			7	SS	20		268				
			8	SS	19		267				0 70 (30)
			9	SS	22		266				
			10	SS	15		265				
			11	SS	24		264				15 81 (4)
			12	SS	33		263				
258.8							262				
13.6							261				
							260				
							259	136			

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

Continued Next Page

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

Golder Associates

RECORD OF BOREHOLE No BH09-24

2 OF 2 **METRIC**

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

LOCATION N 5101647.5; E 316579.8 | BOREHOLE TYPE 108 mm I.D. Continous Flight, Hollow Stem Augers | DATE November 16, 2010

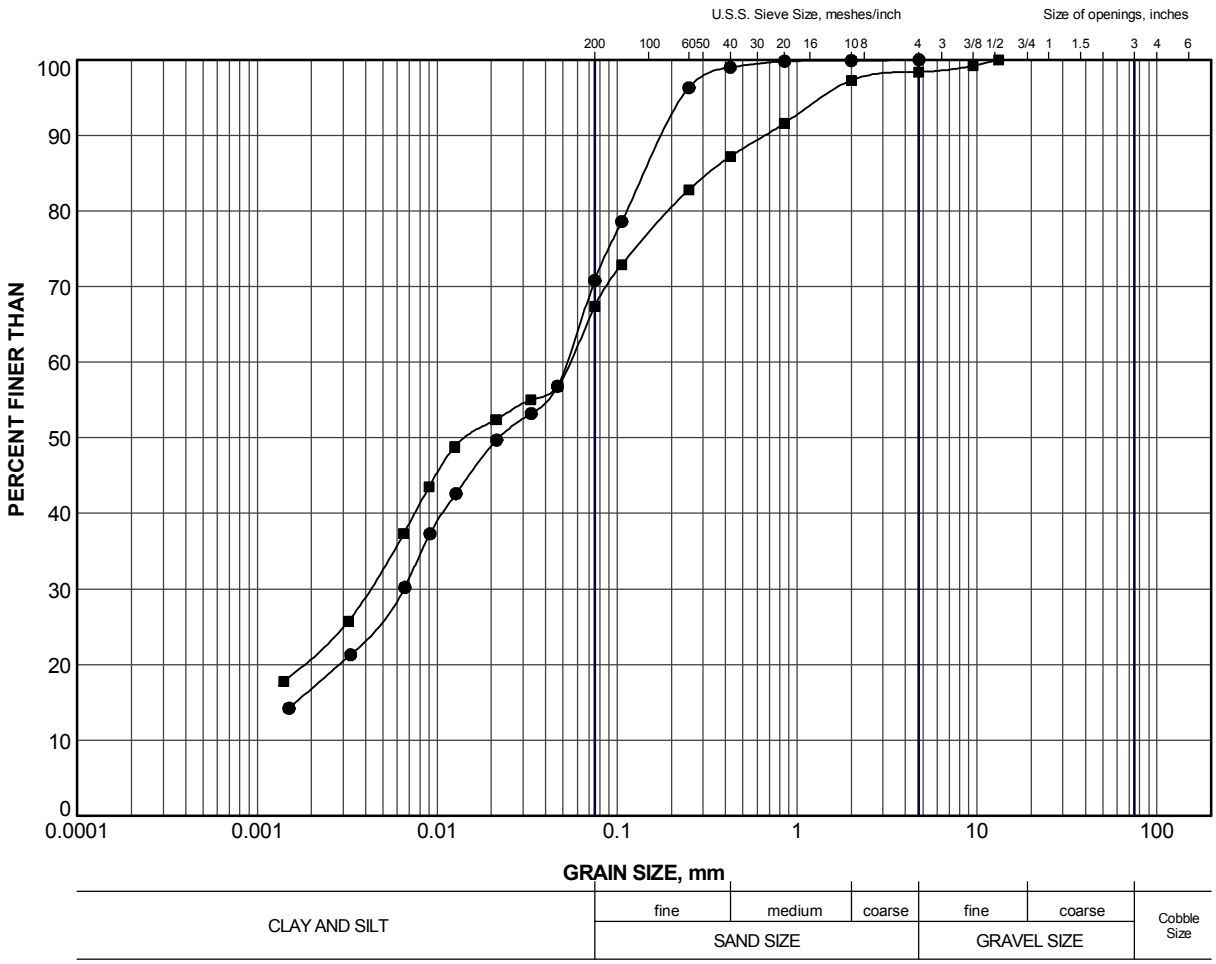
ORIGINATED BY MR | COMPILED BY JJL | CHECKED BY AB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	PLASTIC LIMIT / NATURAL MOISTURE CONTENT / LIQUID LIMIT / WATER CONTENT (%)	UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100; ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED	w_P w w_L; 20 40 60	γ kN/m³	GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
	END OF BOREHOLE AUGER REFUSAL Note: 1. Borehole dry upon completion of drilling. 2. Advanced DCPT 1.6 m east of Borehole BH09-24. Refusal at a depth of 13.6 m (Elev. 258.8 m).										

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

APPENDIX B

Laboratory Test Results



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH09-22	5	275.5
■	BH09-23	6	274.6

PROJECT

HIGHWAY 11 SBL CULVERT 20+543

TITLE

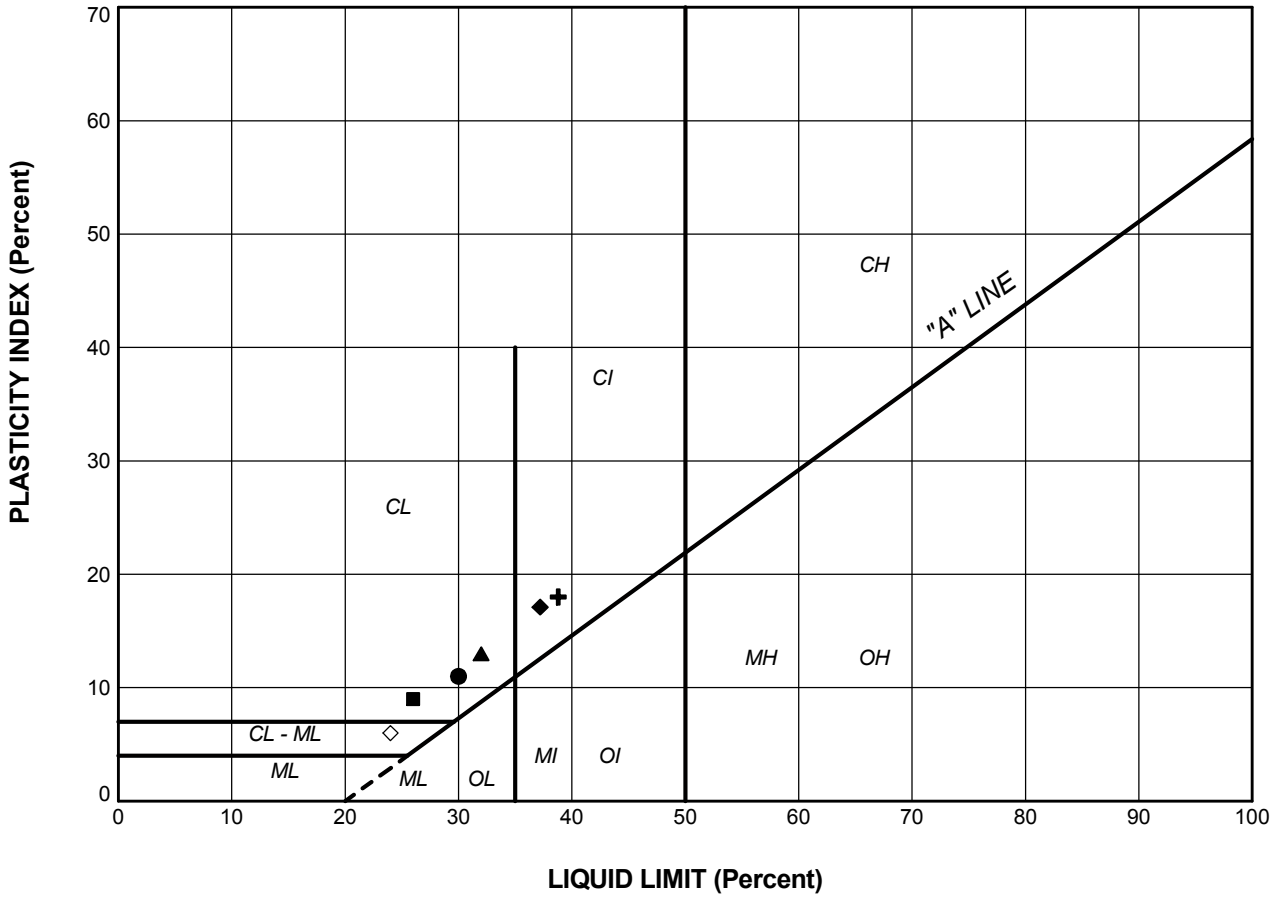
GRAIN SIZE DISTRIBUTION

SILTY SAND TO SANDY SILT (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



SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	BH09-21	3	30.0	19.0	11.0
■	BH09-21	5	26.0	17.0	9.0
▲	BH09-22	8	32.0	19.0	13.0
✚	BH09-23	7	38.8	20.8	18.0
◆	BH09-23	8	37.2	20.1	17.1
◇	BH09-24	1	24.0	18.0	6.0

PROJECT

HIGHWAY 11 SBL CULVERT 20+543

TITLE

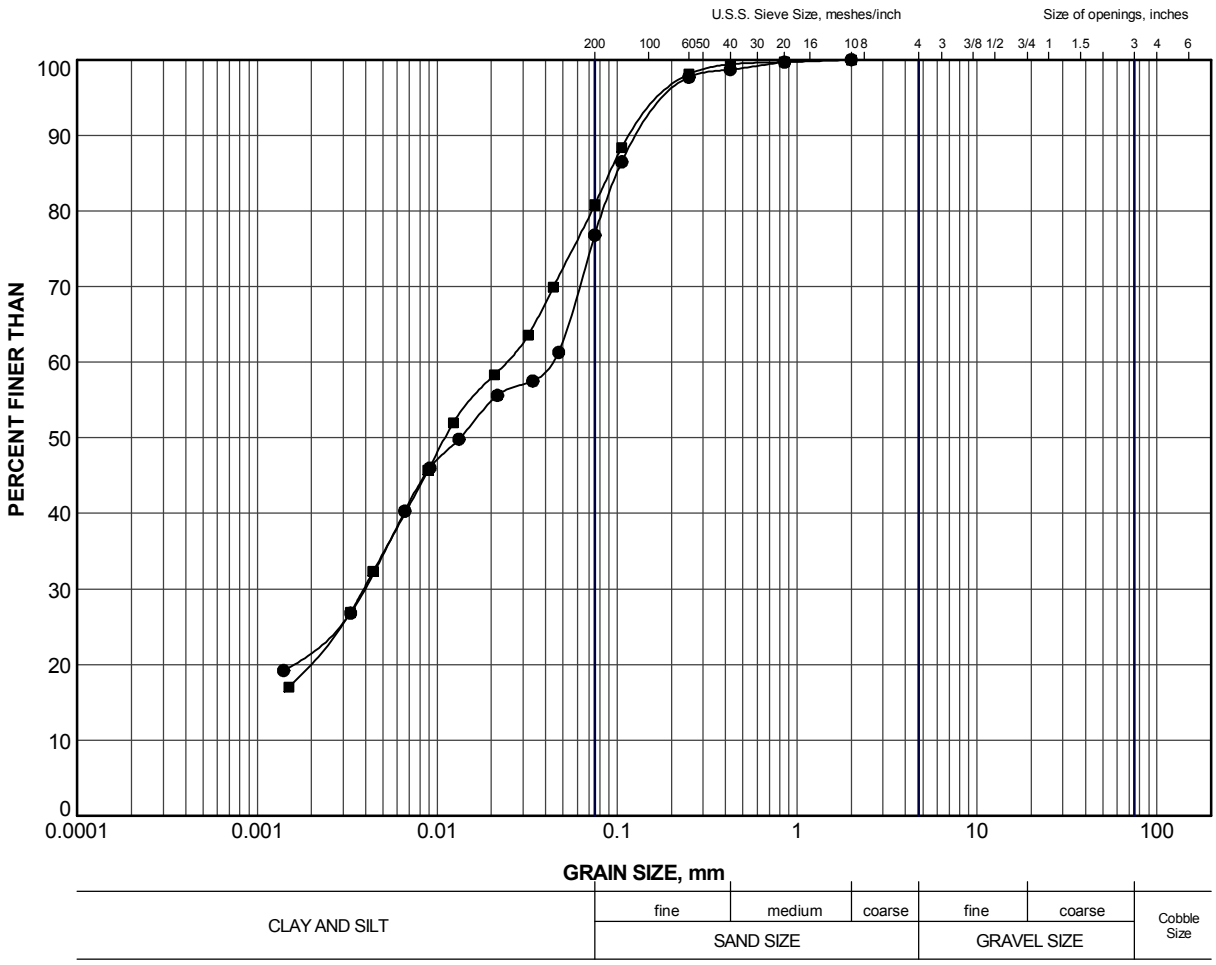
PLASTICITY CHART

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**	**B2**

MTO_PI GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH09-21	2	275.4
■	BH09-22	6b	274.7

PROJECT

HIGHWAY 11 SBL CULVERT 20+543

TITLE

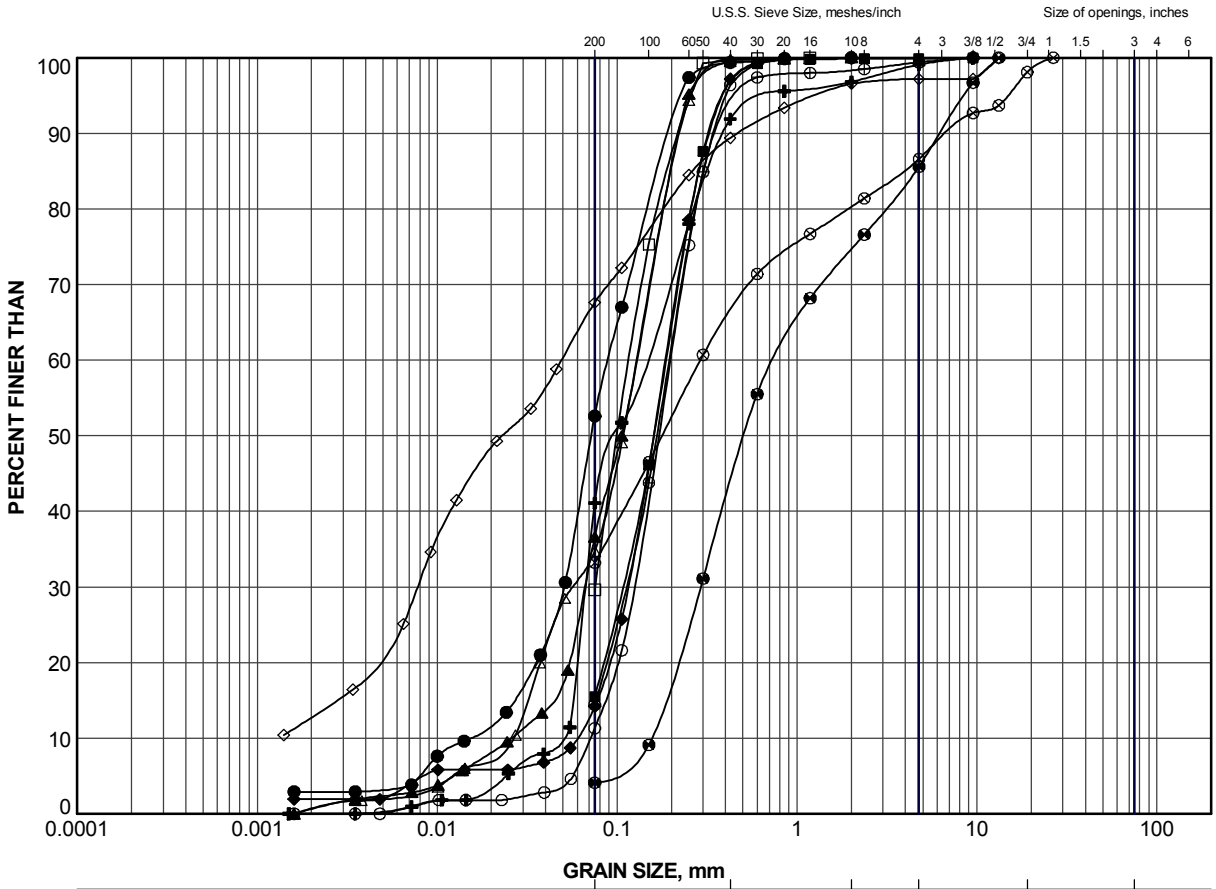
GRAIN SIZE DISTRIBUTION

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	REV.
CHECK	AB	Nov 2011		
APPR	FJH	Nov 2011	**FIGURE B3**	

LDN_MTO_NEW GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH09-21	7	271.3
■	BH09-21	10	267.2
▲	BH09-21	12	264.2
✚	BH09-22	10	270.2
◆	BH09-22	13	265.6
◇	BH09-23	9b	271.5
○	BH09-23	11	268.6
△	BH09-23	15	262.5
⊗	BH09-23	17	259.4
⊕	BH09-24	5	269.0
□	BH09-24	8	266.0
⓫	BH09-24	11	261.4

PROJECT

HIGHWAY 11 SBL CULVERT 20+543

TITLE

GRAIN SIZE DISTRIBUTION

SAND AND SILT 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 B4**	

LDN_MTO_GSD-15 GLDR_LDN.GDT

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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