REPORT

May 6, 2015

FOUNDATION INVESTIGATION REPORT

CULVERT AT STATION 12+620, TOWNSHIP OF DENISON HIGHWAY 17 FOUR-LANING EXTENSION FROM 20.5 KM WEST OF HIGHWAY 144, EASTERLY FOR 6.5 KM MINISTRY OF TRANSPORTATION, ONTARIO GWP 156-98-00

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GEOCRES NO.: 41I-329

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Golder Associates

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PART A

FOUNDATION INVESTIGATION REPORT

CULVERT AT STATION 12+620, TOWNSHIP OF DENISON

HIGHWAY 17 FOUR LANING EXTENSION FROM 20.5 KM WEST OF HIGHWAY 144, EASTERLY 6.5 KM

MINISTRY OF TRANSPORTATION, ONTARIO

GWP 156-98-00

May 6, 2015
Report No. 11-1191-0007-05

Golder Associates

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by D.M. Wills Associates Ltd. (DMW) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the proposed culvert which will cross the future Highway 17 alignment at STA 12+620 in the Township of Denison. The proposed work is part of the four lane extension of the existing Highway 17 at the West Junction of Sudbury Municipal Road 55, from 20.5 km West of Highway 144, easterly for 6.5 km and includes a new interchange. The general location of the proposed culvert is shown on the Site Location Plan on Drawing 1.

The Terms of Reference and the Scope of Work for the foundation investigation are outlined in MTO's Request for Proposal (RFP), dated March 2011. Golder's proposal for the associated foundation engineering services is contained in Section 6.8 of DMW's Technical Proposal for this assignment. The work has been carried out in accordance with Golder's Supplementary Specialty Plan for foundation engineering services for this project, dated November 11, 2011. The base Plan showing the proposed horizontal alignment and a drawing showing the proposed vertical alignment for the Highway 17 four-lane extension were provided to Golder by DMW in January 2012 and the General Arrangement (GA) for the culvert was provided to Golder by DMW on November 8, 2013.

This report addresses the investigation carried out for the proposed culverts at Station 12+620 only. Separate reports address the foundation investigations for the remaining culverts, High Fill embankments over swamps, and bridge structures.

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

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

2.0 SITE DESCRIPTION

The overall project consists of the detail design for the four-lane extension of Highway 17 from the present four lane terminus at the west junction of Sudbury Municipal Road 55, approximately 20.5 km west of Highway 144, easterly for 6.5 km, including a new interchange. The proposed highway alignment is south of and approximately follows the existing east-west alignment of Highway 17 within the project limits. Two culverts are to be constructed under the new four lane extension at STA12+620 within the Township of Denison. The

proposed culverts will be approximately 29.5 m long and 32.7 m long under the westbound lanes (WBL) and eastbound lanes (EBL), respectively.

In general, the topography is comprised of low-lying swamps with areas of standing water and various vegetation types and organic soils, with sparse to densely forested areas. The land use in the general area includes rural residential developments. The ground surface within the limits of the culvert alignments varies between about Elevation 257.7 m and Elevation 257.2 m. A detailed description of the subsurface conditions along the culvert alignments is presented in Section 4.0.

3.0 INVESTIGATION PROCEDURES

The investigation for the WBL and EBL culverts at STA 12+620 was carried out between February 25 and March 5, 2014, during which time a total of five (5) boreholes were advanced along to proposed culvert alignments. The locations of the boreholes are shown on Drawing 2 and are provided on the Record of Borehole sheets in Appendix A.

The field investigation was carried out using track-mounted CME-850 drill rig supplied and operated by Landcore Drilling (Landcore) of Sudbury, Ontario. The boreholes were advanced using 108 mm inner diameter hollow-stem augers. In general, soil samples were obtained at intervals of depth of about 0.75 m and 1.5 m, using a 50 mm outer diameter (O.D.) split-spoon sampler driven by an automatic hammer, in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586, Standard Test Method for Standard Penetration Test and Split-Barrel Sampling of Soils). Field vane shear tests were conducted in cohesive soils for assessment of undrained shear strengths (ASTM D2573, Standard Test Method for Field Vane Shear Test) using MTO Standard 'N' size. All boreholes were backfilled upon completion in accordance with Ontario Regulation 903 Wells (as amended).

The culvert boreholes were advanced to depths ranging between 15.3 m and 15.8 m below existing ground surface.

The groundwater conditions and water levels in the open boreholes were observed during the drilling operations and are described on the Record of Borehole sheets provided in Appendix A. Groundwater elevations as encountered in the boreholes may not be representative of static groundwater levels since the groundwater levels in the boreholes may not have stabilized upon completion of drilling. Furthermore, groundwater elevations will vary depending on seasonal fluctuations, precipitation and local soil permeability.

The field work was observed by members of our engineering and technical staff, who located the boreholes, arranged for the clearance of underground services, observed the drilling, sampling and in situ testing operations, logged the boreholes and examined and cared for the soil samples. The samples were identified in the field, placed in appropriate containers, labelled and transported to our Sudbury geotechnical laboratory where the samples underwent further visual examination and laboratory testing. All of the laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate. Classification testing (water content, Atterberg limits and grain size distribution) was carried out on selected representative samples. The results of the laboratory testing on samples from the culvert boreholes are included in Appendix B.

The proposed centreline of the new Highway 17 alignment and temporary benchmarks along the centrelines of the culverts were staked and surveyed in the field by exp. prior to drilling. The as-drilled borehole locations and ground surface elevations were referenced to the temporary benchmarks located along the centrelines of the

culverts. The locations and elevations of the temporary benchmarks were then provided to Golder by exp. The borehole locations given in the Record of Borehole sheets and shown on Drawing 2 are positioned relative to MTM NAD 83 northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum. The borehole locations, ground surface elevations and drilled depths are as follows:

Borehole	Location (MTM NAD 83)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing	Easting		
C2-1	5 136 822.9	276 753.9	257.2	15.8
C2-2	5 136 809.2	276 759.2	257.2	15.8
C2-3	5 136 791.7	276 765.9	257.2	15.8
C2-4	5 136 774.2	276 772.7	257.3	15.8
C2-5	5 136 757.5	276 779.1	257.7	15.3

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

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

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

4.2 General Overview of Local Subsurface Conditions

The detailed subsurface soil and groundwater conditions as encountered in the borings advanced during this investigation together with the results of the laboratory tests carried out on selected soil samples are presented on the attached Record of Borehole sheets and the laboratory test figures provided in Appendices A and B, respectively. The results of the in situ field tests (i.e. SPT 'N'-values and undrained shear strengths from the field vanes) as presented on the Record of Borehole sheets and in Section 4.0 are uncorrected. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling, observations of drilling progress and the results of SPTs and in situ testing. These boundaries, therefore,

[1] Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Digital Map Reference Number 41ISW.

[2] Ministry of Natural Resources (1991). Bedrock Geology of Ontario – West Central Sheet, Ontario Geological Survey - Map 2542

[3] Ontario Department of Mines (1969). Sudbury Mining Area, Sudbury District, Map 2170.

represent transitions between soil types rather than exact planes of geological change. Further, subsurface conditions will vary between and beyond the borehole locations.

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

The stratigraphy encountered at the site generally consists of topsoil/organics or peat at the ground surface underlain by a clayey silt to silty clay deposit further underlain by a deposit of silt to silt and sand.

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

4.2.1 Silty Organics/Topsoil/Peat

An approximately 0.6 m to 0.8 m thick deposit of black, fibrous peat was encountered at the ground surface in Boreholes C2-2 to C2-4. In Borehole C2-5, a 0.3 m thick layer of topsoil was encountered at the ground surface. In Borehole C2-1, a 0.8 m thick layer of silty organics was encountered at the ground surface. The surface of the silty organics/peat/topsoil deposit varies between Elevation 257.7 m and 257.2 m.

The SPT ‘N’-values measured within the peat deposit were typically 1 blow per 0.3 m of penetration, suggesting a very soft consistency. One SPT ‘N’-value measured within the peat deposit was 10 blows per 0.3 m of penetration and is inferred to indicate frozen ground conditions.

The natural water content measured on one sample of the peat is about 209 per cent.

4.2.2 Clayey Silt to Silty Clay

In all of the boreholes, a cohesive deposit was encountered beneath the silty organics/peat/topsoil deposit. In general, the cohesive deposit consisted of an upper clayey silt zone, transitioning into varved silty clay. At depth, within the deposit in the majority of the boreholes, the deposit was observed to be varved consisting of irregular layers of clayey silt to silty clay and silty clay to clay. The top of the clayey silt to silty clay deposit was encountered between Elevations 257.4 m and 256.4 m and the thickness of the overall deposit ranged between 6.0 m and 6.9 m.

The SPT ‘N’-values measured within the clayey silt to silty clay deposit typically ranged from 0 blows (weight of hammer) to 3 blows per 0.3 m of penetration. One SPT ‘N’-value measured in Borehole C2-5 within the clayey silt to clay deposit was 30 blows per 0.3 m of penetration, possibly due to the presence of gravel or a cobble within the cohesive deposit. In situ field vane tests carried out within the deposit measured undrained shear strengths ranging from about 19 kPa to 57 kPa. The field vane tests results indicate that the clayey silt to silty clay deposit generally has a soft to stiff consistency.

The grain size distributions for five samples of the clayey silt to silty clay deposit are presented on Figure B1 in Appendix B.

Atterberg limits tests were carried out on nine samples of the clayey silt to silty clay deposit and indicate liquid limits ranging from about 30 per cent to 49 per cent, plastic limits ranging from about 19 per cent to 25 per cent

and plasticity indices ranging from about 11 per cent to 24 per cent. The results of the Atterberg limits tests are shown on the plasticity chart on Figures B2 in Appendix B and indicate that the material is classified as clayey silt of low plasticity to silty clay of intermediate plasticity.

The natural water content measured on nine samples of this deposit range between about 31 per cent and 59 per cent.

4.2.3 Silt to Silt and Sand

Grey silt to silt and sand, trace to some clay was encountered beneath the clayey silt to silty clay deposit in all of the boreholes. The surface of this silt to silt and sand was encountered between Elevations 250.7 m to 249.8 m and all boreholes were terminated within this deposit after exploring for between 8.1 m and 9.2 m.

The SPT 'N'-values measured within this deposit range between 0 blows (weight of hammer) and 19 blows per 0.3 m of penetration, indicating a very loose to compact relative density. Split spoon refusal was encountered in Borehole C2-5 and recorded an SPT 'N'-value of 50 blows per 0.1 m prior to bouncing, likely indicative of cobbles/boulders or close proximity to the bedrock surface.

The grain size distributions of seven samples of this deposit are presented on Figures B3 in Appendix B. The results of Atterberg limits testing on two samples of the silt to silt and sand deposit indicated that the material is classified as non-plastic.

The natural water content measured on seven samples of this deposit range between about 22 per cent and 30 per cent.

4.2.4 Groundwater Conditions

In general, the samples taken in the boreholes were wet. The groundwater levels observed upon completion of drilling ranges from about Elevation 257.0 m to 253.9 m, measured between 0.2 m and 3.8 m below ground surface. It should be noted that the groundwater levels in the area fluctuate seasonally as well as during precipitation events and snowmelt.

5.0 CLOSURE

The field personnel supervising the drilling program were Messrs. Ed Savard and Matthew Thibeault, under the direction of Mr. Evan Childerhose, P.Eng. This report was prepared by Messrs. Adam Core and Matthew Thibeault and the technical aspects were reviewed by Ms. Sarah E. M. Poot, P.Eng., a senior geotechnical engineer and Associate of Golder. Mr. Jorge M. A. Costa, P.Eng., Golder's Designated MTO Contact for this project and Principal of Golder, conducted an independent quality control review of the report.

Report Signature Page

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N:\Active\2011\1190 Sudbury\1191\Temp folder 11-1191-0007\Report\Culverts\R05 - Culvert STA 12+620 Twp Denison (C2)\Final\11-1191-0007-05 RPT 15May01 FIDR Culvert 12+620 Denison.docx

MINISTRY OF TRANSPORTATION, ONTARIO

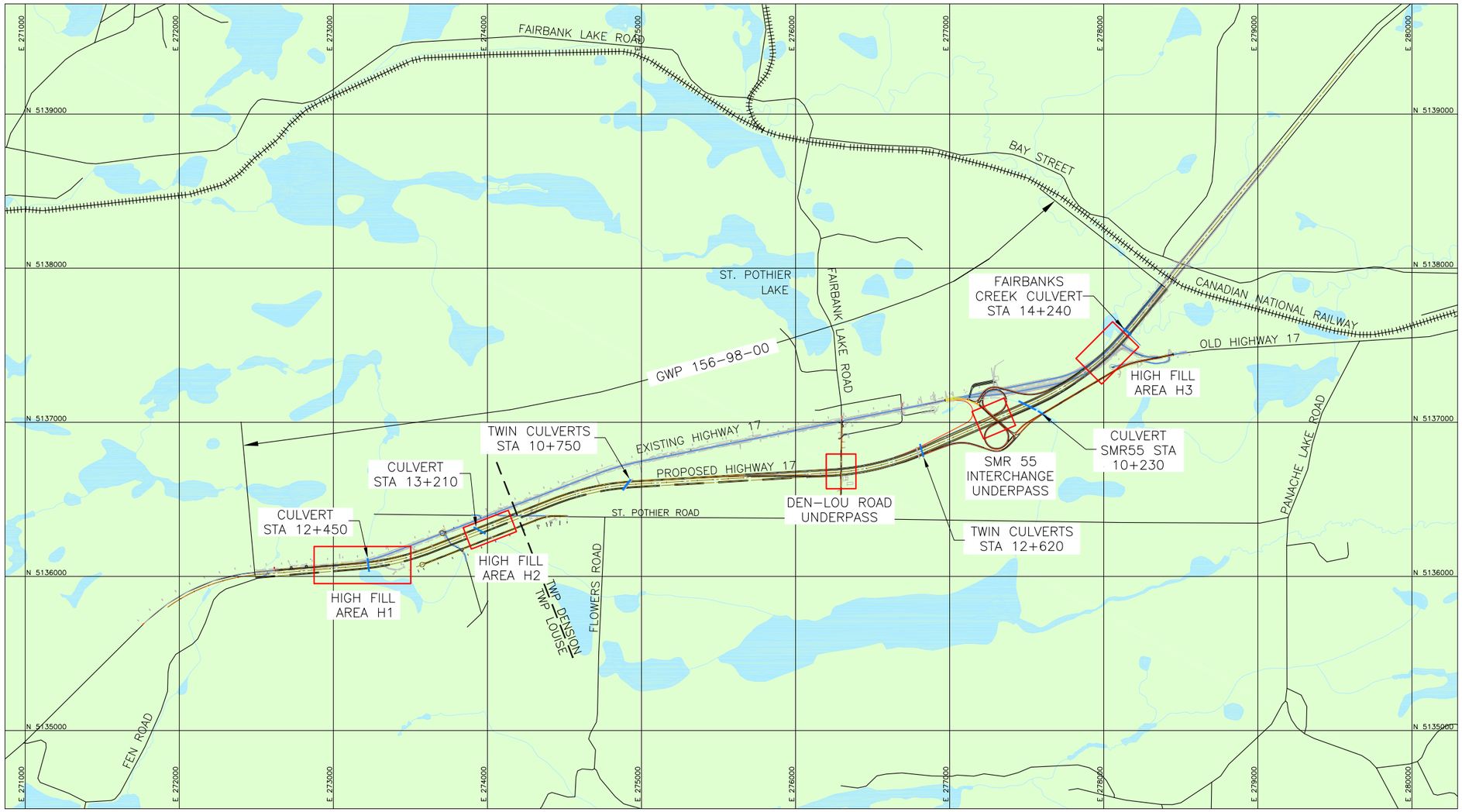
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
GWP No. 156-98-00

SHEET

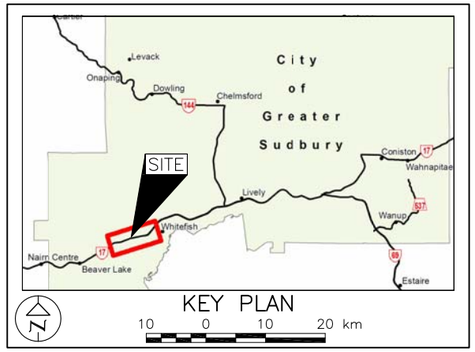
HIGHWAY 17
SITE LOCATION PLAN

Golder Associates Ltd.
SUDBURY, ONTARIO, CANADA



PLAN

SCALE
300 0 300 600 m



REFERENCE

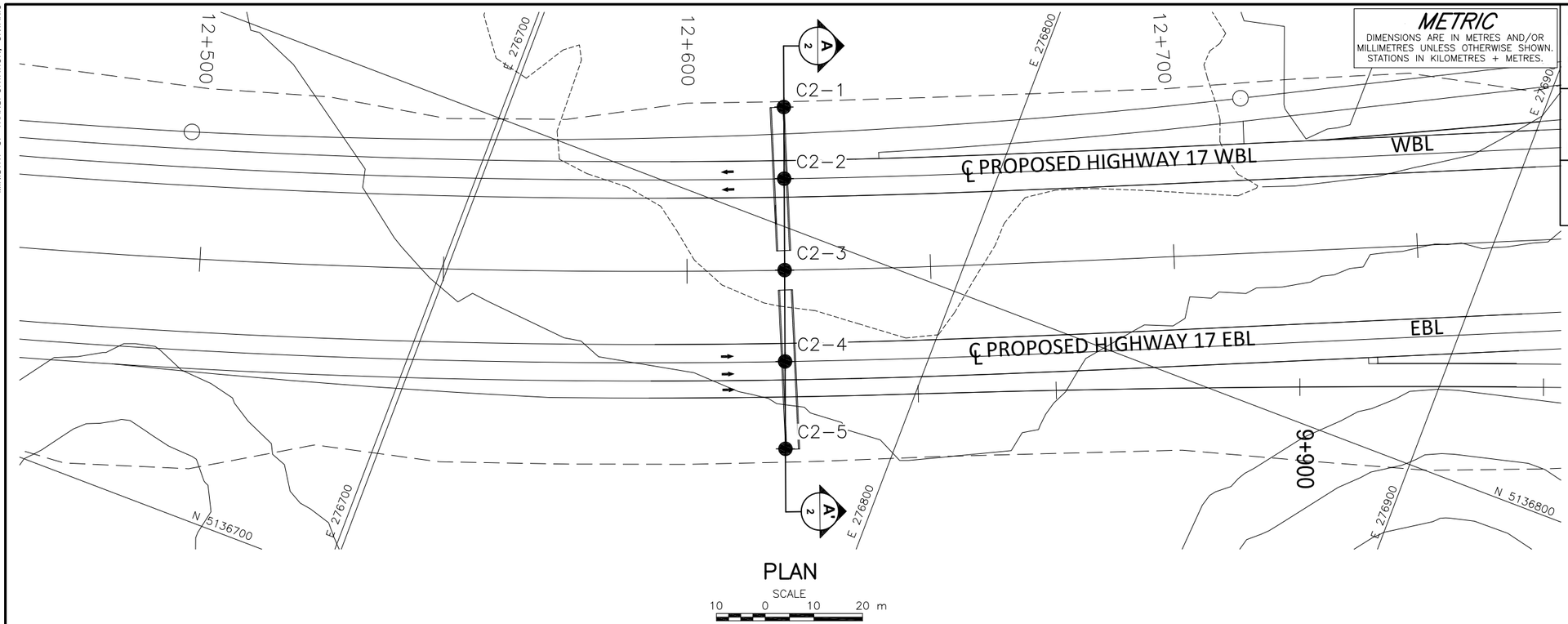
Base plans provided by Golder GIS and highway alignment provided in digital format by DM Wills, drawing file EBL & WBL PROFILES.dwg received Feb 28, 2013.

NO.	DATE	BY	REVISION

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

PLOT DATE: April 16, 2015
FILENAME: \\golder.gds\gal\Sudbury\CAD-GIS\CAD\Projects\2011\11-1191-0007 HWY 17 4 Laning\Culverts\11119100007 Ind.Culv.dwg

MINISTRY OF TRANSPORTATION, ONTARIO



PLAN

SCALE

10 0 10 20 m

METRIC

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

CONT No.

GWP No. 156–98–00

SHEET

HIGHWAY 17 4 LANING

CULVERT – STA 12+620

BOREHOLE LOCATIONS AND SOIL STRATA

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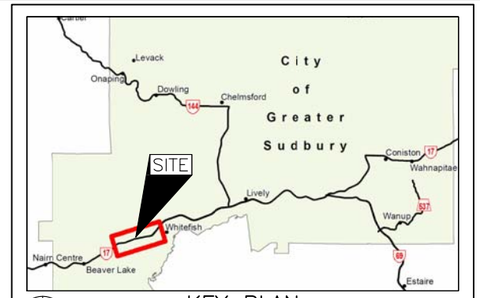
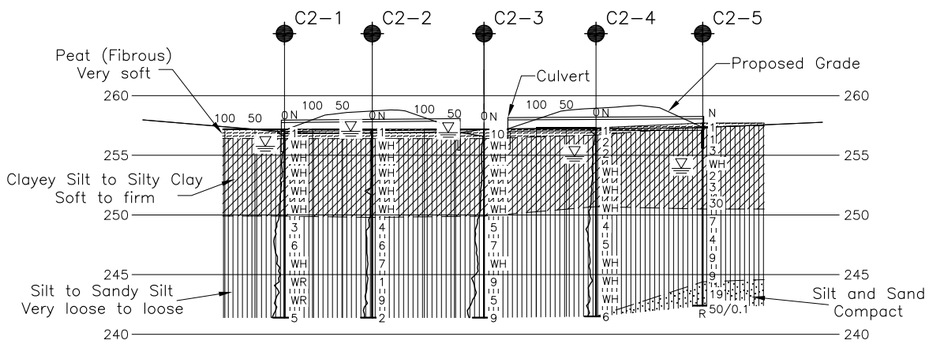


KEY PLAN

10 0 10 20 km

LEGEND

- Borehole – Current Investigation
- 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



A–A'
2

CULVERT AT STA 12+620
HIGHWAY 17

HORIZONTAL SCALE
10 0 10 20 m
5 0 5 10 m
VERTICAL SCALE

BOREHOLE CO–ORDINATES

No.	ELEVATION	NORTHING	EASTING
C2–1	257.2	5136822.9	276753.9
C2–2	257.2	5136809.2	276759.2
C2–3	257.2	5136791.7	276765.9
C2–4	257.3	5136774.2	276772.7
C2–5	257.7	5136757.5	276779.1

NOTES

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

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

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

REFERENCE

Base plans provided in digital format by DM Wills, drawing files 581_base.dwg, GWP156–98–00_B & C Plans.dwg and 581_contours.dwg received Jan 17, 12+620 –Geotech – 46–576 Structural Culvert.dwg provided in digital format by DM Wills received on April 15, 2014.

LICENCE PROFESSIONAL ENGINEER S.E.M. POOT 90471921 APR 15, 2015 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER J.M.A.COSTA APR 15, 2015 PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

Geocres No. 41I–329

HWY. 17	PROJECT NO. 11–1191–0007		DIST.
SUBM'D. AC	CHKD.	DATE: APR 2015	SITE: 46–576
DRAWN: TB	CHKD. SEMP	APPD. JMAC	DWG. 2

PLOT DATE: April 15, 2015
FILENAME: \\golder.gds\gal\Sudbury\CAD–GIS\CAD\Projects\2011\11–1191–0007 HWY 17 4 Laning\Culverts\11191I0007_Culverts.dwg

APPENDIX A

Record of Boreholes

LIST OF SYMBOLS

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

I. GENERAL

π	3.1416
ln x,	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
FoS	factor of safety

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
υ	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 or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index = $(w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_C	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_α	secondary compression index
m_v	coefficient of volume change
c_v	coefficient of consolidation (vertical direction)
c_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

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

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
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split-spoon
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

Dynamic Cone Penetration Resistance; N_d:

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 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) Non-Cohesive (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

Per cent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (non-cohesive (cohesionless)) or With (cohesive)	Sand and Gravel / Silty Clay with sand / Clayey Silt with sand

Golder Associates

RECORD OF BOREHOLE No C2-1

1 OF 2 **METRIC**

PROJECT 11-1191-0007
G.W.P. 156-98-00
LOCATION N 5136822.9; E 276753.9
ORIGINATED BY EHS
DIST HWY 17
BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers
COMPILED BY AC
DATUM GEODETIC
DATE February 25, 2014
CHECKED BY SEMP

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
257.2	GROUND SURFACE							
0.0	Silty ORGANICS, trace sand, trace rootlets Very Loose Brown Frozen to 0.2 m, then wet		1	SS	1			
256.4								
0.8	CLAYEY SILT to SILTY CLAY, trace rootlets in Sample 2 Soft to firm Brown to grey Wet		2	SS	WH	▽		
			3	SS	WH			
			4	SS	WH			
	Varved below 4.6 m depth.		5	SS	WH			
			6	SS	WH			
249.9								
7.3	SILT to Sandy SILT, trace to some clay Very loose to loose Grey Wet		7	SS	3		NP	0 2 85 13
			8	SS	6			
			9	SS	WH			

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

ELEVATION SCALE
257 256 255 254 253 252 251 250 249 248 247 246

10 25 10 10

Continued Next Page

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

Golder Associates

PROJECT 11-1191-0007

RECORD OF BOREHOLE No C2-1

2 OF 2 **METRIC**

G.W.P. 156-98-00 LOCATION N 5136822.9; E 276753.9 ORIGINATED BY EHS

DIST HWY 17 BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers COMPILED BY AC

DATUM GEODETIC DATE February 25, 2014 CHECKED BY SEMP

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
	SILT to Sandy SILT, trace to some clay Very loose to loose Grey Wet		10	SS	WH		245		○		0 22 75 3
			11	SS	WH		244				
			12	SS	5		243				
241.4							242				
15.8	END OF BOREHOLE Note: 1. Water level at a depth of 1.4 m below ground surface (Elev. 255.8 m) upon completion of drilling. 2. Advanced DCPT 1.5 m south, 0.5 m east of borehole.										

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

WATER CONTENT (%): 20 40 60

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

Golder Associates

RECORD OF BOREHOLE No C2-2

1 OF 2 **METRIC**

PROJECT 11-1191-0007 | G.W.P. 156-98-00 | LOCATION N 5136809.2; E 276759.2 | ORIGINATED BY MT/EHS

DIST | HWY 17 | BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers | COMPILED BY AC

DATUM GEODETIC | DATE February 26 and 27, 2014 | CHECKED BY SEMP

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS
257.2	GROUND SURFACE					
0.0	PEAT (Fibrous) Very Soft Black Wet		1	SS	1	▽
256.4						
0.8	CLAYEY SILT to SILTY CLAY Soft to firm Grey Wet		2	SS	WH	
			3	SS	WH	
			4	TO	WH	
			5	SS	WH	
	Varved below 6.1 m depth.		6	SS	WH	
249.8						
7.4	SILT, trace to some clay, trace to some sand Very loose to loose Grey Wet		7	SS	4	
			8	SS	6	
			9	SS	7	

DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100)

SHEAR STRENGTH kPa (20 40 60 80 100)
○ 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
0	0	50	50
0	3	91	6

Continued Next Page

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

Golder Associates

PROJECT 11-1191-0007

RECORD OF BOREHOLE No C2-2

 METRIC

G.W.P. 156-98-00 LOCATION N 5136809.2; E 276759.2 ORIGINATED BY MT/EHS

DIST HWY 17 BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers COMPILED BY AC

DATUM GEODETIC DATE February 26 and 27, 2014 CHECKED BY SEMP

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 ---										
	SILT, trace to some clay, trace to some sand Very loose to loose Grey Wet		10	SS	1		245				
							244				
			11	SS	9		243				
							242				
241.4			12	SS	2						
15.8	END OF BOREHOLE Note: 1. Water level 0.2 m below ground surface (Elev. 257.0 m) upon completion of drilling. 2. Advanced DCPT 1.5 m south, 1.0 m east of borehole.										

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

Golder Associates

RECORD OF BOREHOLE No C2-3

1 OF 2 **METRIC**

PROJECT 11-1191-0007
G.W.P. 156-98-00
DIST _____ HWY 17
DATUM GEODETIC
LOCATION N 5136791.7; E 276765.9
BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers
DATE March 3, 2014
ORIGINATED BY EHS
COMPILED BY AC
CHECKED BY SEMP

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
257.2	GROUND SURFACE										
0.0	PEAT (Fibrous) Very Soft Black Frozen to 0.3 m, then wet		1	SS	10	▽	257		209.3		
256.4											
0.8	CLAYEY SILT to SILTY CLAY, trace rootlets Firm Grey Wet		2	SS	WH		256				
			3	SS	WH		255	23			
			4	SS	WH		254				0 0 39 61
			5	SS	WH		253	23			
			6	SS	WH		252	7			
249.9							251				
7.3	SILT, trace to some clay, trace to some sand Very loose to loose Grey Wet		7	SS	5		250	6		NP	0 2 85 13
			8	SS	7		249				
			9	SS	WH		248				
							247				
							246				

Continued Next Page

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

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RECORD OF BOREHOLE No C2-3

2 OF 2 **METRIC**

PROJECT 11-1191-0007 | G.W.P. 156-98-00 | LOCATION N 5136791.7; E 276765.9 | ORIGINATED BY EHS

DIST _____ HWY 17 | BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers | COMPILED BY AC

DATUM GEODETIC | DATE March 3, 2014 | CHECKED BY SEMP

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × REMOULDED)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---							20 40 60 80 100	20 40 60		
	SILT, trace to some clay, trace to some sand Very loose to loose Grey Wet		10	SS	9		245				
							244				
			11	SS	5		243		○		0 18 79 3
							242				
241.4			12	SS	9						
15.8	END OF BOREHOLE Note: 1. Water level 0.3 m below ground surface (Elev. 256.9 m) upon completion of drilling. 2. Advanced DCPT 1.5 m south, 1.0 m east of borehole.										

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

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RECORD OF BOREHOLE No C2-4

1 OF 2 **METRIC**

PROJECT 11-1191-0007 | G.W.P. 156-98-00 | LOCATION N 5136774.2; E 276772.7 | ORIGINATED BY EHS

DIST _____ HWY 17 | BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers | COMPILED BY AC

DATUM GEODETIC | DATE March 4, 2014 | CHECKED BY SEMP

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	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
257.3	GROUND SURFACE										
0.0	PEAT (Fibrous) Very Soft Black Frozen to 0.15 m, then wet		1	SS	1		257				
256.7											
0.6	CLAYEY SILT to SILTY CLAY, trace rootlets in sample 2 Soft to firm Grey Wet		2	SS	2		256				0 0 58 42
			3	SS	2						
	Varved below 2.0 m depth.					▽	255	25			
			4	SS	WH		254				
								10			
			5	SS	WH		253				
							252	9			
250.7			6	SS	WH		251				
6.6	SILT, trace to some clay, trace to some sand Very loose to loose Grey Wet						250				
			7	SS	4		249				
			8	SS	5		248				0 2 94 4
							247				
			9	SS	WH		246				

Continued Next Page

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

Golder Associates

RECORD OF BOREHOLE No C2-4

2 OF 2 **METRIC**

PROJECT 11-1191-0007 | G.W.P. 156-98-00 | LOCATION N 5136774.2; E 276772.7 | ORIGINATED BY EHS

DIST _____ HWY 17 | BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers | COMPILED BY AC

DATUM GEODETIC | DATE March 4, 2014 | CHECKED BY SEMP

SOIL PROFILE			SAMPLES			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
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	--- CONTINUED FROM PREVIOUS PAGE ---										
	SILT, trace to some clay, trace to some sand Very loose to loose Grey Wet		10	SS	WH		245				
							244				
			11	SS	WH		243				
							242				
241.5			12	SS	6						
15.8	END OF BOREHOLE Note: 1. Water level 2.4 m below ground surface (Elev. 254.9 m) upon completion of drilling. 2. Advanced DCPT 1.5 m east of borehole.										

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

Golder Associates

RECORD OF BOREHOLE No C2-5

1 OF 2 **METRIC**

PROJECT 11-1191-0007
G.W.P. 156-98-00
LOCATION N 5136757.5; E 276779.1
ORIGINATED BY EHS
DIST _____ HWY 17
BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers
COMPILED BY AC
DATUM GEODETIC
DATE March 5, 2014
CHECKED BY SEMP

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
257.7	GROUND SURFACE										
0.0	TOPSOIL										
257.4	Black										
0.3	Frozen		1	SS	1		257				
	CLAYEY SILT to SILTY CLAY, trace rootlets in samples 1 and 2 Soft to firm Grey Wet		2	SS	1						
			3	SS	3		256				0 6 61 33
	Varved below 2.6 m depth.		4	SS	WH		255				
			5	SS	2	▽	254				
			6	SS	3		253	3			0 1 54 45
	Possible cobble encountered at 6.1 m depth.		7	SS	30		252				
250.5							251				
7.2	SILT, trace to some clay, trace to some sand Very loose to loose Grey Wet		8	SS	7		250				
			9	SS	4		249				
			10	SS	9		248				
							247				
							246				

Continued Next Page

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

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RECORD OF BOREHOLE No C2-5

2 OF 2 **METRIC**

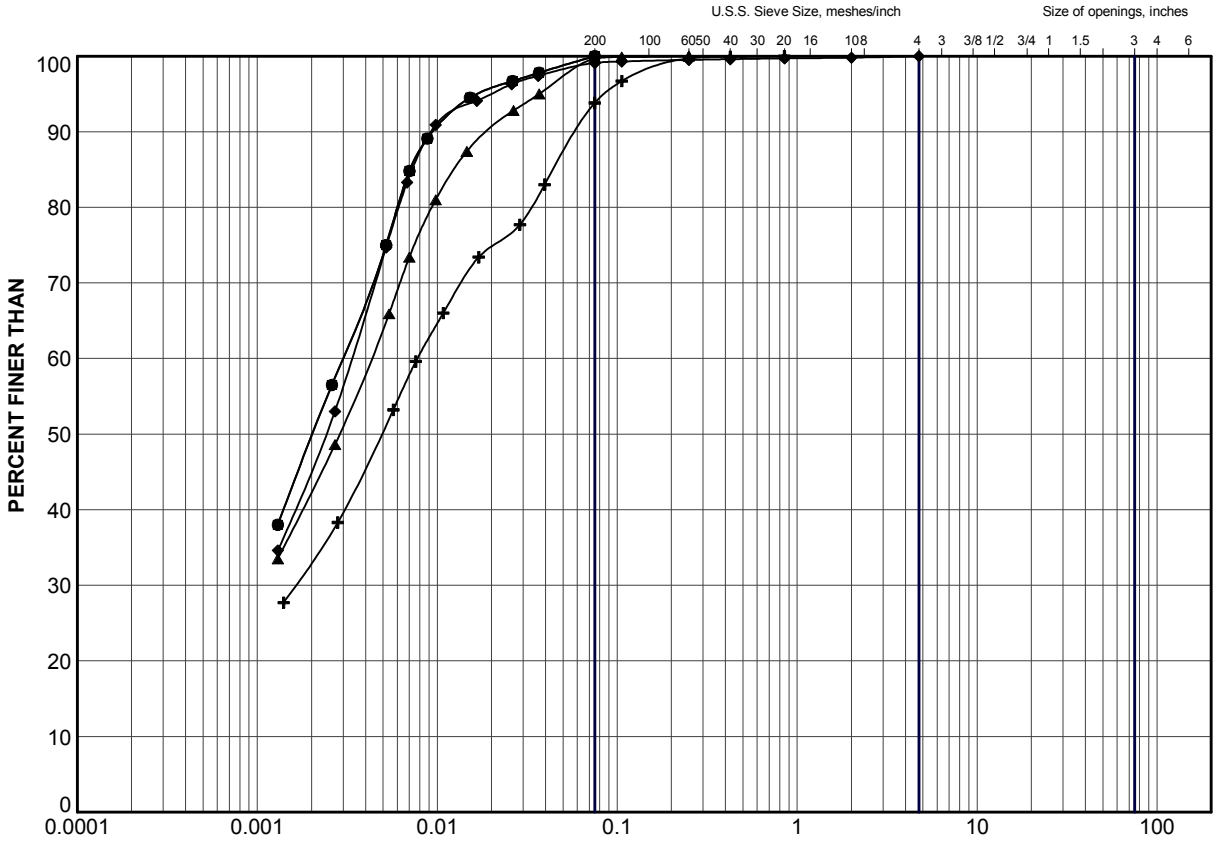
PROJECT 11-1191-0007 | G.W.P. 156-98-00 | LOCATION N 5136757.5; E 276779.1 | ORIGINATED BY EHS
DIST _____ HWY 17 | BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers | COMPILED BY AC
DATUM GEODETIC | DATE March 5, 2014 | CHECKED BY SEMP

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 ---										
	SILT, trace to some clay, trace to some sand Very loose to loose Grey Wet		11	SS	9		245				
244.4											
13.3	SILT and SAND, trace gravel, trace clay Compact Grey Wet		12	SS	19		244		○		2 40 55 3
							243				
242.4			13	SS	50/0.1						
15.3	END OF BOREHOLE SPOON REFUSAL (HAMMER BOUNCING) Note: 1. Water level 3.8 m below ground surface (Elev. 253.9 m) upon completion of drilling.										

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

APPENDIX B

Laboratory Test Results



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C2-2	3	255.4
■	C2-3	4	253.9
▲	C2-4	2	256.2
+	C2-5	3	255.9
◆	C2-5	6	252.8

PROJECT

HIGHWAY 17
CULVERT STA 12+620

TITLE

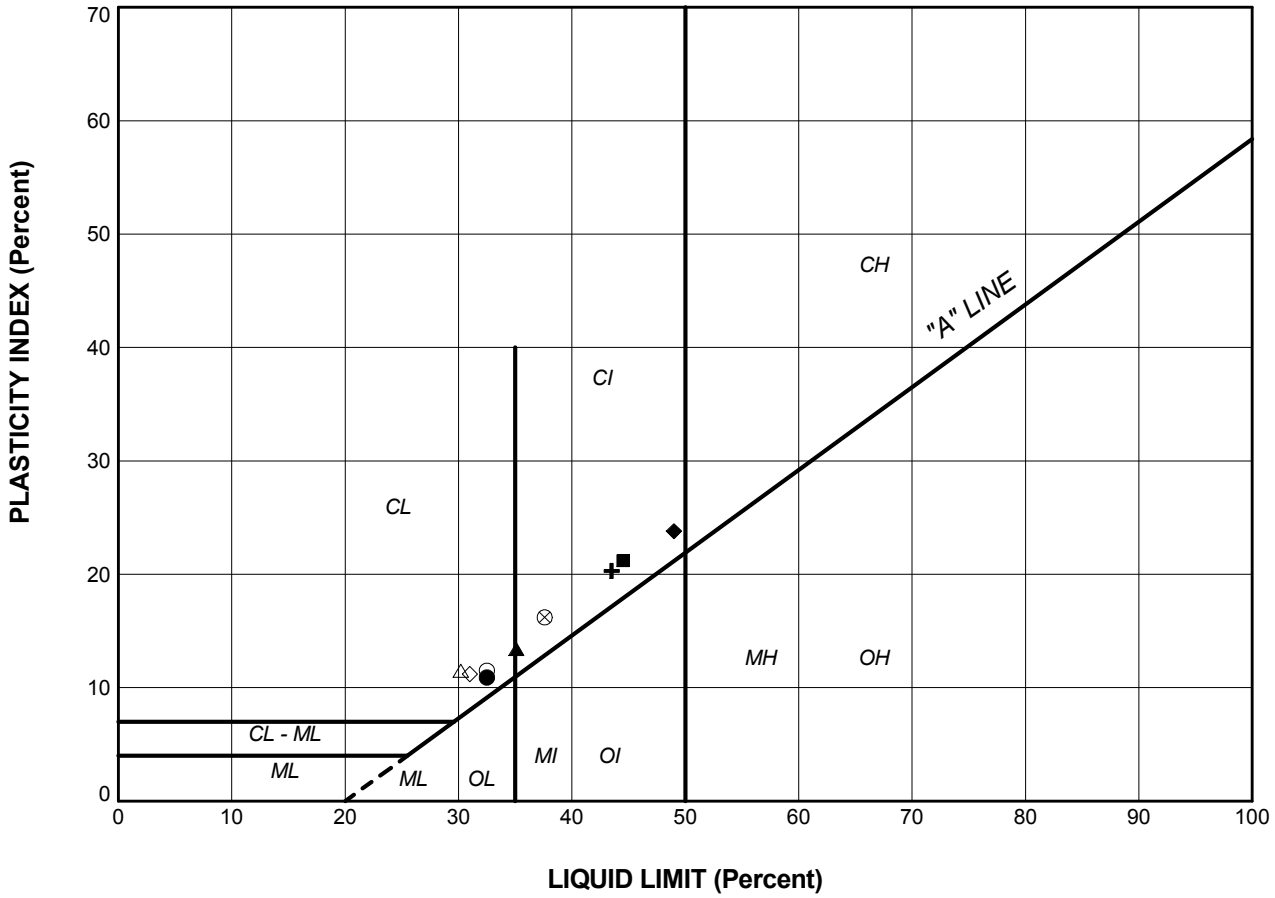
GRAIN SIZE DISTRIBUTION

CLAYEY SILT to SILTY CLAY

Golder Associates
SUDBURY, ONTARIO

PROJECT No.	11-1191-0007		FILE No. 1119110007 CULVERTS.GPJ	
DRAWN	TB	Oct 2014	SCALE N/A	REV.
CHECK	SEMP	Oct 2014		
APPR		Oct 2014	**FIGURE B1**	

SUD-MTO GSD (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
●	C2-1	2	32.5	21.6	10.9
■	C2-1	5	44.5	23.3	21.2
▲	C2-2	3	35.1	21.7	13.4
+	C2-2	5	43.5	23.2	20.3
◆	C2-3	4	49.0	25.2	23.8
◇	C2-4	2	31.0	19.8	11.2
○	C2-4	6	32.5	21.0	11.5
△	C2-5	3	30.2	18.7	11.5
⊗	C2-5	6	37.6	21.4	16.2

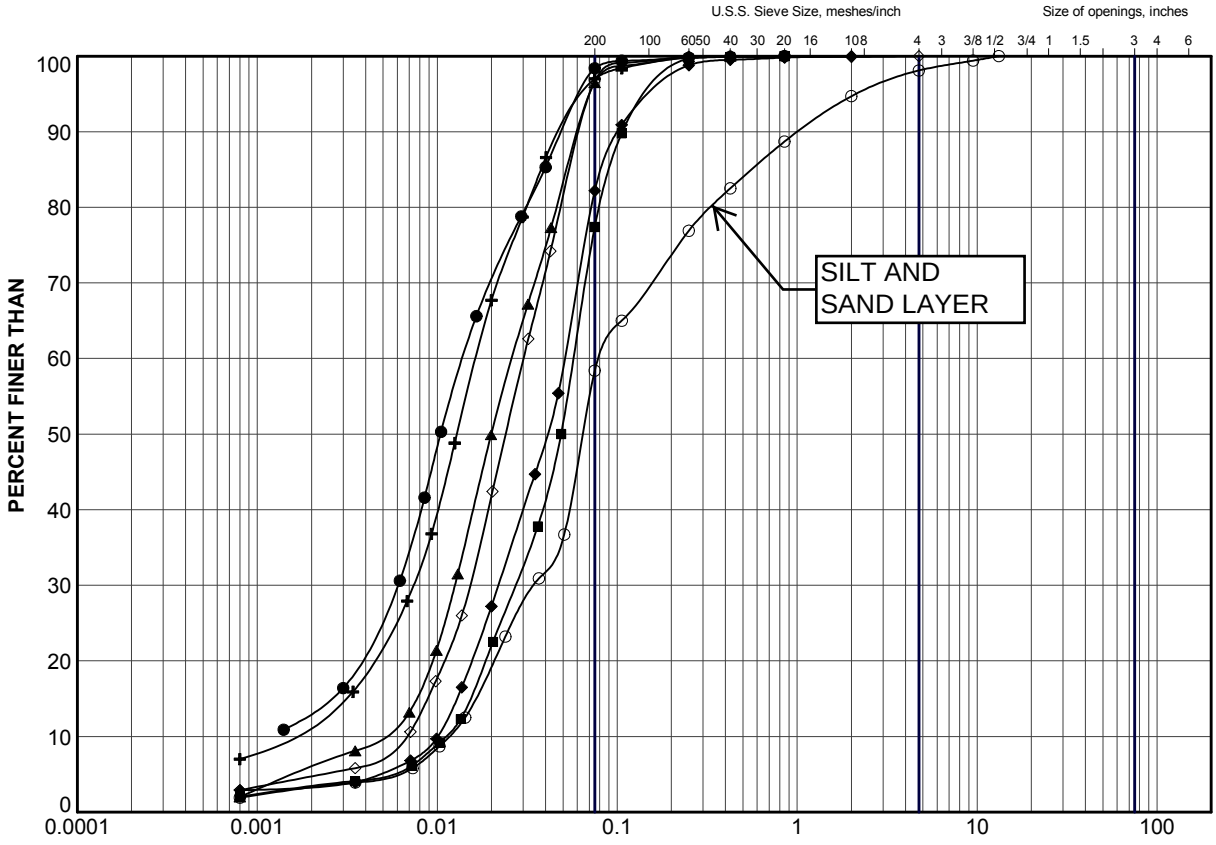
PROJECT
HIGHWAY 17
CULVERT STA 12+620

TITLE
PLASTICITY CHART
CLAYEY SILT to SILTY CLAY

Golder Associates
SUDBURY, ONTARIO

PROJECT No.	11-1191-0007		FILE No.	111910007 CULVERTS.GPJ
DRAWN	TB	Oct 2014	SCALE N/A	REV.
CHECK	SEMP	Oct 2014		
APPR		Oct 2014	**FIGURE B2**	

SUD-MTO PL (NEW) GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C2-1	7	249.3
■	C2-1	10	244.7
▲	C2-2	8	247.8
+	C2-3	7	249.3
◆	C2-3	11	243.2
◇	C2-4	8	247.9
○	C2-5	12	243.7

PROJECT

HIGHWAY 17
CULVERT STA 12+620

TITLE

GRAIN SIZE DISTRIBUTION

SILT to SILT and SAND

Golder Associates
SUDBURY, ONTARIO

PROJECT No.	11-1191-0007		FILE No. 11119100007 CULVERTS.GPJ	
DRAWN	TB	Oct 2014	SCALE N/A	REV.
CHECK	SEMP	Oct 2014		
APPR		Oct 2014	**FIGURE B3**	

SUD-MTO GSD (NEW) 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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