REPORT

April 06, 2018

PRELIMINARY FOUNDATION INVESTIGATION REPORT

CHIN RIVER BRIDGE REPLACEMENT - SITE NO. 39E-197
LAT. 49.251387; LONG. -80.646589
HIGHWAY 652, COCHRANE DISTRICT
TOWNSHIP OF HEIGHINGTON
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5416-15-00; WP 5416-15-01

Submitted to:
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GEOCRES NO.: 42H-74

Report Number: 1651997-WO5-001

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Golder Associates

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PART A

PRELIMINARY FOUNDATION INVESTIGATION REPORT
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MINISTRY OF TRANSPORTATION, ONTARIO
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Golder Associates

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by AECOM Canada Ltd. (AECOM) on behalf of the Ministry of Transportation, Ontario (MTO), to provide preliminary foundation engineering services for the replacement of the Chin River Bridge (Site No. 39E-197). The Chin River Bridge is located in the Cochrane District in the Township of Heighington, Ontario at about Sta. 10+340 (approximately 24 km north of Translimit Road). The general location of this section of Highway 652 is shown on the Key Plan on Drawing 1.

2.0 SITE DESCRIPTION AND BACKGROUND INFORMATION

It should be noted that the orientation (i.e., north, south, east, west) stated in the text of the report is referenced to project north and therefore may differ from magnetic north shown on the drawing. For the purpose of this report, Highway 652 is oriented in a north-south direction.

In general, the topography in the area of the Chin River Bridge consists of undulating to rolling terrain with densely forested areas immediately beyond the Highway 652 right-of-way and in the vicinity of the river. The existing Chin River Bridge consists of an approximately 48.8 m long by 4.6 m wide, three-span, single-lane Temporary Modular Bridge (TMB). Based on the previous General Arrangement (GA) drawing (GEOCRES 42H-23), the existing bridge is supported by driven steel friction piles (HP310x79) at both the abutments and piers. Based on the survey drawing provided by AECOM, the bridge deck is at Elevation 284.3 m at both the north and south abutments. The existing front slopes are about 6.5 m to 7.5 m high and the approach embankments side slopes are about 3 m to 4 m high. The existing embankment front slopes and side slopes are inclined at a profile of about 2 Horizontal to 1 Vertical (2H:1V). The ground surface conditions at the bridge abutments are shown on Photographs 1 to 3. Based on the 2016 Ontario Structure Inspection Manual (OSIM) report, our July 2017 site review, and the available site photographs, the existing embankments appear to be performing satisfactorily. However, as noted in the OSIM report, there is some slight erosion of the exposed granular front slope at the north abutment.

3.0 INVESTIGATION PROCEDURE

The field work for this subsurface investigation was carried out on July 19, 20 and 28, 2017, during which time a total of four boreholes (CR-1 to CR-4) were advanced at the approximate locations shown on Drawing 1. Boreholes CR-1 and CR-3 were advanced through the existing highway embankment at the existing north and south abutments, respectively. Boreholes CR-2 and CR-4 were advanced at the east toe of the north and south embankment slopes, respectively. Boreholes CR-1 to CR-4 were advanced using a track-mounted CME 55LC drill rig equipped with 108 mm inside diameter hollow-stem augers. The drill rig was supplied and operated by George Downing Estate Drilling Ltd. of Grenville-sur-la-Rouge Quebec.

Soil samples were obtained at depth intervals of 0.75 m and 1.5 m, using 50 mm outer diameter split-spoon samplers driven by an automatic hammer, carried out in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586). The groundwater level in the open boreholes was observed during the drilling operations as described on the Record of Borehole sheets in Appendix A. The boreholes advanced at the existing bridge abutments were backfilled with a full column of bentonite grout. The boreholes advanced at the toe of the embankment slope were backfilled with bentonite pellets and soil cuttings upon completion in accordance with Ontario Regulation 903 Wells (as amended).

The field work was supervised on a full-time basis by members of Golder's technical staff who: located the boreholes in the field; arranged for the clearance of underground services; supervised the drilling and sampling operations; logged the boreholes; and examined and cared for the soil samples. The soil samples were identified in the field, placed in labelled containers and transported to Golder's geotechnical laboratory in Sudbury for further examination and laboratory testing. Index and classification testing consisting of water content determinations, grain size distributions and Atterberg limits were carried out on selected soil samples. The geotechnical laboratory testing was performed in accordance with MTO LS standards.

Soil samples were obtained on July 28, 2017, from Boreholes CR-1 and CR-3 at the north and south abutments, respectively, using appropriate sampling protocols and submitted to a specialist analytical laboratory under chain of custody procedures for testing for a suite of parameters including pH, resistivity, conductivity, sulphates and chlorides. The results of the analytical testing are presented in Table B1 in Appendix B. It should be noted that the samples were submitted beyond the standard hold times and as such some parameters may not be reliable.

The as-drilled borehole locations were measured and surveyed by members of our technical staff. The borehole locations were referenced to the highway centerline and existing bridge and converted to northing/easting coordinates on the plan drawing. The ground surface elevations were referenced to local benchmarks in the vicinity of the bridge and the benchmark elevations were obtained from the General Arrangement (GA) drawing provided by AECOM (drawing 60547656-P1.dwg). The MTM NAD83 Zone 12 northing and easting coordinates and geographical coordinates, ground surface elevations referenced to Geodetic datum, and borehole depths at each borehole location are presented on the Record of Borehole Sheets in Appendix A and summarized below.

Borehole Number	MTM NAD83 Northing (Latitude)	MTM NAD83 Easting (Longitude)	Ground Surface Elevation	Borehole Depth
CR-1	5457122.5 m (49.2515939)	330572.2 m (-80.6459628)	284.3 m	9.8 m
CR-2	5457115.4 m (49.2515295)	330585.4 m (-80.645782)	280.0 m	20.4 m
CR-3	5457073.3 m (49.2511523)	330552.5 m (-80.6462366)	284.3 m	9.8 m
CR-4	5457069.0 m (49.2511131)	330566.5 m (-80.6460446)	280.2 m	21.9 m

4.0 SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain (NOEGTS)[1] Mapping, the Chin River Bridge site is located within a glaciolacustrine plain deposit consisting primarily of clay and silt soils bordered by organic terrain deposits of peat/muck and ground moraine deposits of clayey till.

[1] Digital Northern Ontario Engineering Geology Terrain Study (NOEGTS). Ontario Geological Survey, Miscellaneous Release – Date 160, Map 42HSE.

Based on geological mapping by the Ontario Ministry of Northern Development and Mines (MNDM)[2], the site is underlain by massive to foliated granodiorite to granite bedrock.

4.2 Subsoil Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of in situ and laboratory testing are provided on the Record of Borehole sheets contained in Appendix A. The results of the geotechnical laboratory testing are contained in Appendix B. The results of the in-situ tests (i.e., SPT 'N'-values) as presented on the Record of Borehole sheets and described in Section 4 are uncorrected. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profile on Drawing 1 and in the sections on Drawing 2 are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

At the time of the previous 1981 foundation investigation (GEOCRES 42H-43), prior to construction of the existing embankments and bridge, the subsurface soil conditions at the site generally consisted of peat overlying thin deposits of firm to stiff silty clay underlain by an extensive deposit of compact to very dense silty sand. The subsoil conditions encountered during the current borehole investigation consist of granular embankment fill and clayey silt to silty clay fill overlying deposits of firm clayey silt and loose to very dense sand and silt to silty sand (till) containing cobbles and boulders, which is generally consistent with the previous findings. A more detailed description of the soil deposits and groundwater conditions encountered in the boreholes as part of the current investigation is provided below.

Deposit/Layer Description	Boreholes	Deposit Thickness (m)	Deposit Surface Elevation (m)	SPT N Values (blows/0.3 m) Relative Density	Laboratory Testing
Asphalt	CR-1 & CR-3	0.050	284.3	n/a	n/a
(FILL) Gravelly Sand to Sand, trace to some silt, trace clay, brown; moist to wet	CR-1 to CR-4	3.5 – 8.6	284.2 – 278.6	N = 0 (WH) to 25 **Very Loose to Compact**	w = 4% – 6% 5 – M/MH (Fig. B1)
(FILL) Clayey Silt to Silty Clay some sand, some organics, trace wood, dark brown; wet	CR-2 & CR-4	1.4 & 1.5	280.0	N = 9 **Stiff**	W = 29% 1 – AL (Fig. B2) w_l = 36% w_p = 16% I_p = 20%
Clayey Silt, trace gravel, trace sand; brown; wet	CR-1 & CR-2	>1.6 and 0.4 (not fully penetrated in Borehole CR-1)	276.1 & 275.1	N = 5 **Firm**	w = 20% & 28% 2 – AL (Fig. B3) w_l = 24% & 28% w_p = 14% I_p = 9% & 13%

[2] Ministry of Northern Development of Mines. Bedrock Geology of Ontario – East Central Sheet, Ontario Geological Survey – Map 2543

Deposit/Layer Description	Boreholes	Deposit Thickness (m)	Deposit Surface Elevation (m)	SPT N Values (blows/0.3 m) / Relative Density	Laboratory Testing
Sand and Silt to Silty Sand (TILL), trace to some gravel, trace to some clay; grey; wet (presence of cobbles and boulders within TILL inferred from auger grinding)	CR-2 to CR-4	>1.3 – >16.6 (Boreholes terminated in this deposit)	275.6 – 274.7	N = 6 to 129 **Loose to Very Dense**	w = 8% – 10% 7 – MH (Fig. C4) 7 – AL (NP)

Where:
N = SPT 'N'-value; number of blows for 0.3 m of penetration (uncorrected)
w = Natural Moisture Content (%)
M = Sieve analysis for particle size
MH = Combined Sieve and Hydrometer analysis
AL = Atterberg Limits Test
w_p = Plastic Limit (%)
w_l = Liquid Limit (%)
I_p = Plasticity Index (%)
NP = Non-Plastic test result

Clayey Silt to Silty Clay Fill

The surficial clayey silt fill in Borehole CR-4 was placed by Golder during the field investigation to provide a level drilling platform and as such has not been included as part of the subsoil conditions summary provided above. A 0.2 m thick layer of silty clay fill was encountered in Borehole CR-4 at 276.4 m within the existing sand fill layer.

Topsoil

A 0.1 m thick layer of silty topsoil was encountered at ground surface in Borehole CR-4 prior to constructing the clayey silt fill drilling platform.

4.3 Groundwater Conditions

The unstabilized groundwater levels measured in the open boreholes upon completion of drilling are summarized below. The river water level was measured by others at Elevation 276.8 m in August 2017. Groundwater and river water levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

Borehole	Ground Surface Elevation (m)	Depth to Groundwater (mbgs)	Groundwater Elevation (m)
CR-1	284.3	Dry (samples wet below 3.8 m)	Possible perched water at about 280.5
CR-2	280.0	2.0	278.0
CR-3	284.3	Dry (samples wet below 7.6 m)	Possible perched water at about 276.7
CR-4	280.2	2.2	278.0

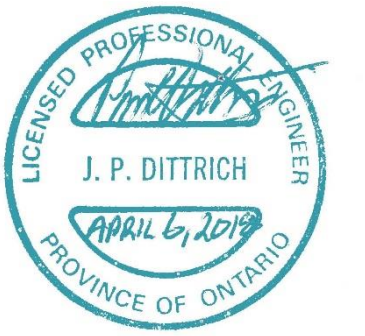
5.0 CLOSURE

This Foundation Investigation Report was prepared by Mr. Adam Core, P.Eng., and the technical aspects were reviewed by Mr. David Muldowney, P.Eng. Mr. Paul Dittrich, Ph.D., P.Eng., a Principal and Designated MTO Foundations Contact for Golder, conducted an independent quality control review of this report.

Report Signature Page

GOLDER ASSOCIATES LTD.

Adam Core, P.Eng.
Geotechnical Engineer



David Muldowney, P.Eng.
Senior Geotechnical Engineer

Paul Dittrich, Ph.D., P.Eng.
Principal, MTO Foundations Designated Contact, Principal

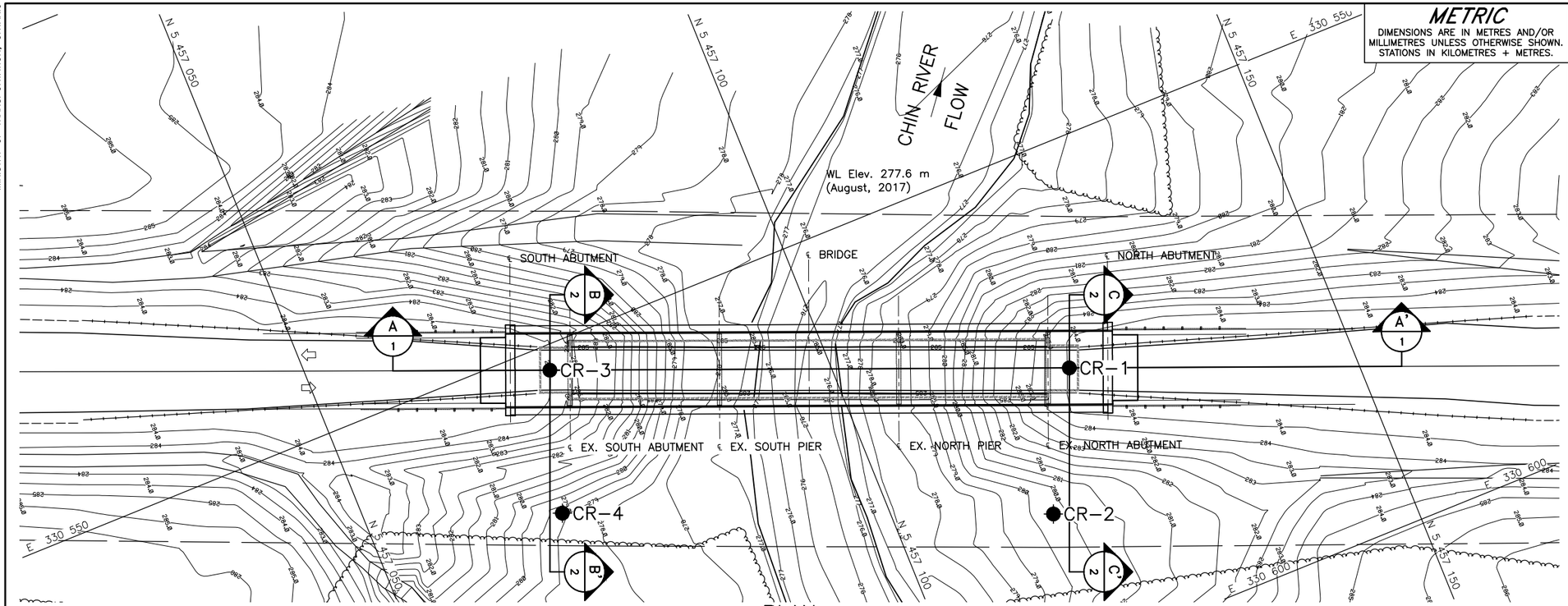
AC/DAM/JPD/kp/nh

Photograph 1: Chin River Bridge
North Approach Facing South

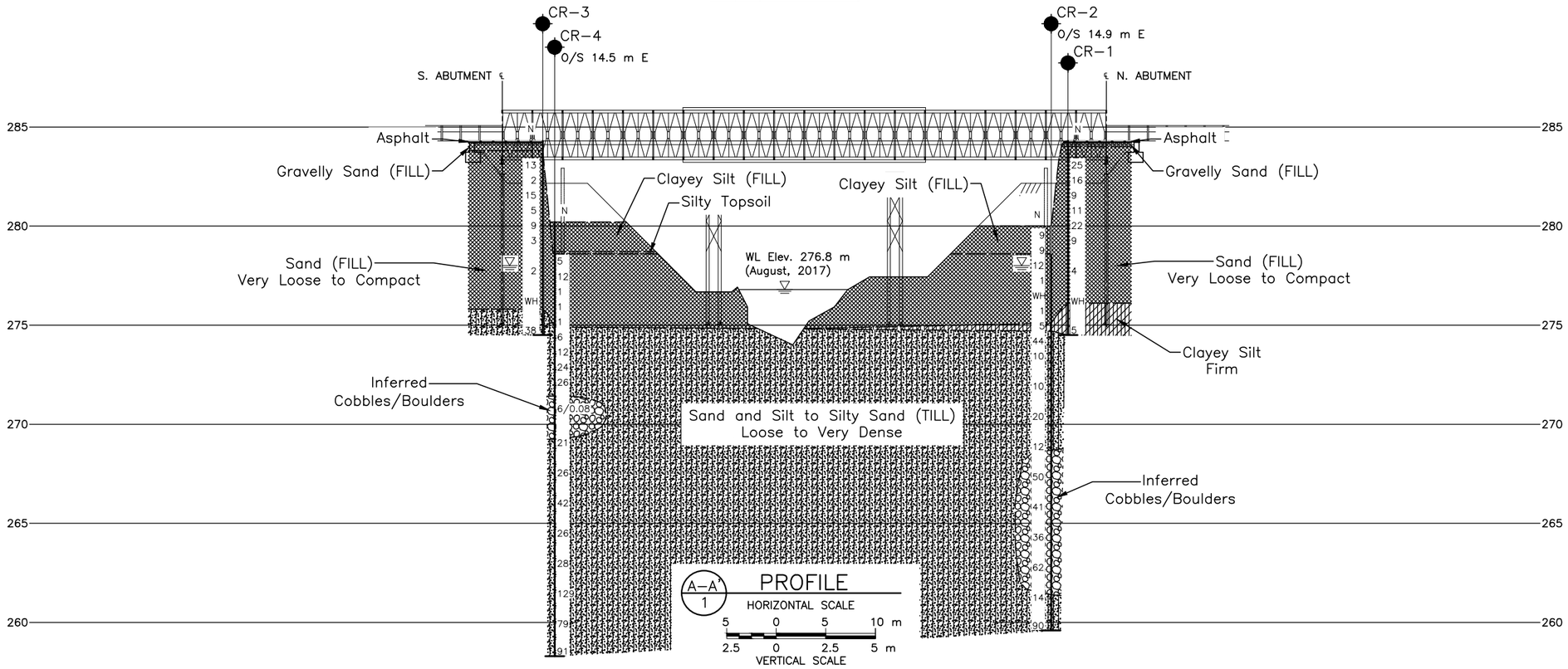
Photograph 2: Chin River Bridge
South Approach facing South

Photograph 3: Chin River Bridge
North Approach Facing South

MINISTRY OF TRANSPORTATION, ONTARIO



PLAN
SCALE
5 0 5 10 m



A-A'
1
PROFILE
HORIZONTAL SCALE
5 0 5 10 m
2.5 0 2.5 5 m
VERTICAL SCALE

METRIC

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

CONT No.
WP No. 5416-15-01

SHEET
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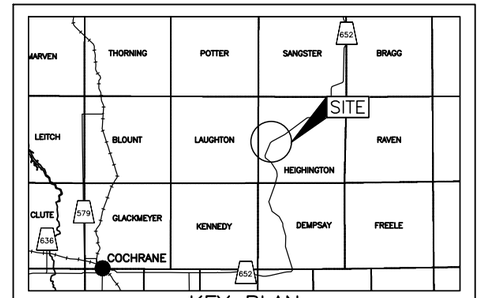
HIGHWAY 652
CHIN RIVER BRIDGE
LAT. 49.251387; LONG. -80.646589
BOREHOLE LOCATIONS AND SOIL STRATA

GOLDER



KEY PLAN
SCALE
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

BOREHOLE CO-ORDINATES (NAD83 MTM ZONE12)

No.	ELEVATION	NORTHING	EASTING
CR-1	284.3	5457122.5	330572.2
CR-2	280.0	5457115.4	330585.4
CR-3	284.3	5457073.3	330552.5
CR-4	280.2	5457069.0	330566.5

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.

REFERENCE

Base plans provided in digital format by AECOM, drawing file nos. Chin.dwg, received SEPT 26, 2017. General Arrangement provided by AECOM, drawing file nos. 60547656-P1.dwg, received October 6, 2017.

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LICENSED PROFESSIONAL ENGINEER
J. P. DITTRICH
PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION
.	.	.	.

Geocres No. 42H-74

HWY. 652	PROJECT NO. 1651997		DIST. .
SUBM'D. AC	CHKD. .	DATE: 4/6/2018	SITE: 39E-197
DRAWN: JJL/TB	CHKD. DAM	APPD. JPD	DWG. 1

PLOT DATE: April 6, 2018
FILENAME: S:\Clients\MTO\1651997 AECOM_5015-E-0045_NE Rev\Final\09_PROJ\1651997_Chin_River\40_PROD\0001\1651997-0001-BS-0001.dwg

MINISTRY OF TRANSPORTATION, ONTARIO

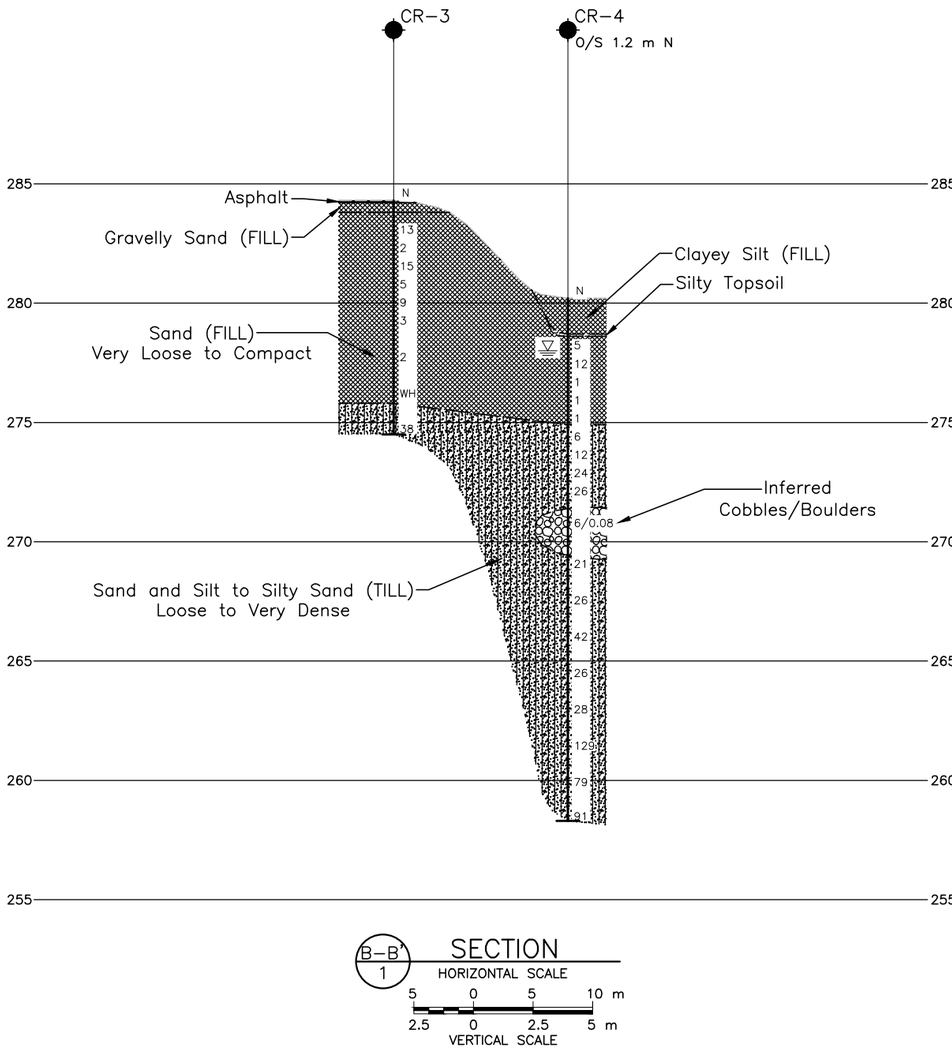
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 5416-15-01

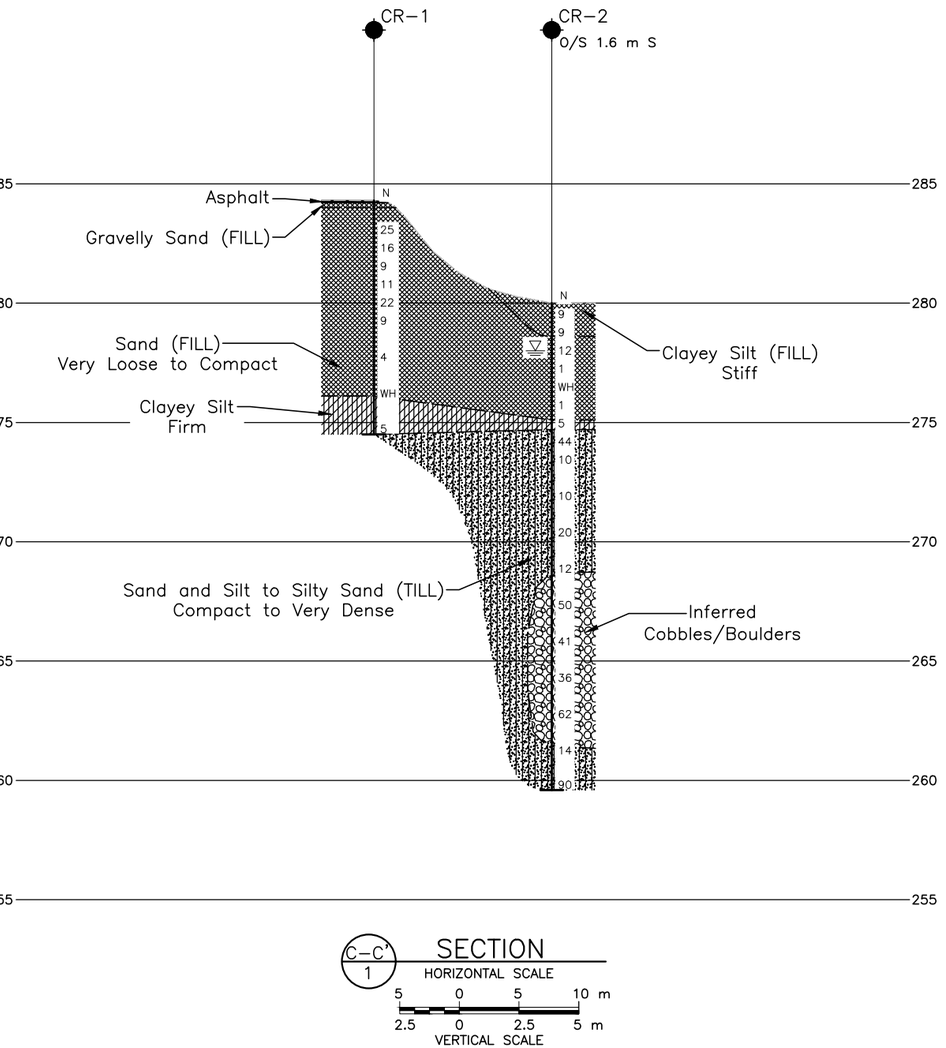
HIGHWAY 652
CHIN RIVER BRIDGE
LAT. 49.251387; LONG. -80.646589
SOIL STRATA

SHEET
.

GOLDER



B-B' 1 SECTION
HORIZONTAL SCALE
5 0 5 10 m
2.5 0 2.5 5 m
VERTICAL SCALE



C-C' 1 SECTION
HORIZONTAL SCALE
5 0 5 10 m
2.5 0 2.5 5 m
VERTICAL SCALE

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

BOREHOLE CO-ORDINATES (NAD83 MTM ZONE12)

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LICENSED PROFESSIONAL ENGINEER
J. P. DITTRICH
PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION
.	.	.	.

Geocres No. 42H-74

HWY. 652		PROJECT NO. 1651997	DIST. .
SUBM'D. AC	CHKD. .	DATE: 4/6/2018	SITE: 39E-197
DRAWN: JJL/TB	CHKD. DAM	APPD. JPD	DWG. 2

PLOT DATE: April 5, 2018
FILENAME: S:\Clients\MTO\1651997 AECOM_2013-E-0045_NE Redzone\09_PROJ\1651997_Chin_River\40_PROD\0001\1651997-0001-BS-0001.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 δ
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

Compactness Condition	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

RECORD OF BOREHOLE No CR-1

1 OF 1 **METRIC**

PROJECT 16519971651997-WO5
W.P. 5416-15-01
DIST _____ HWY 652
DATUM GEODETIC

LOCATION N 5457122.5; E 330572.2 NAD83 MTM ZONE 12 (LAT. 49.251594; LONG. -80.645963)
BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers
DATE July 28, 2017

ORIGINATED BY MR
COMPILED BY AC
CHECKED BY DAM

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
284.3	GROUND SURFACE										
0.0	ASPHALT (50 mm)										
	Gravelly sand (FILL)										
0.3	Brown Moist										
	Sand, trace to some gravel, trace silt, trace clay (FILL) Very loose to compact Brown Moist to wet		1	SS	25		284				
			2	SS	16		283				
			3	SS	9		282		○		1 93 2 4
			4	SS	11		281				
	Samples wet below 3.8 m depth.		5	SS	22		280				
			6	SS	9		279				
			7	SS	4		278		○		13 83 (4)
			8	SS	WH		277				
276.1											
8.2	CLAYEY SILT, trace sand, trace gravel Firm Grey Wet		9	SS	5		276 275		⊢○⊣		
274.5											
9.8	END OF BOREHOLE										
	Note: 1. Borehole dry upon completion of drilling inside augers.										

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

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

GOLDER

RECORD OF BOREHOLE No CR-2

1 OF 2 **METRIC**

PROJECT 16519971651997-WO5
W.P. 5416-15-01
DIST HWY 652
DATUM GEODETIC

LOCATION N 5457115.4; E 330585.4 NAD83 MTM ZONE 12 (LAT. 49.251529; LONG. -80.645782)
BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers
DATE July 19, 2017

ORIGINATED BY MR
COMPILED BY AC
CHECKED BY DAM

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
280.0	GROUND SURFACE										
0.0	Clayey silt, some organics, trace wood (FILL) Stiff Dark brown Wet		1	SS	9						
			2	SS	9		279				
278.6											
1.4	Sand, trace to some gravel, trace to some silt (FILL) Very loose to compact Brown Moist to wet		3	SS	12	▽	278		○		9 82 (9)
			4	SS	1						
			5	SS	WH		277				
			6	SS	1		276				
275.1			7A	SS	5						
4.9	CLAYEY SILT Firm Grey Wet		7B				275				
274.7											
5.3	SAND and SILT to Silty SAND, trace to some gravel, trace to some clay (TILL) Compact to very dense Grey Wet		8	SS	44		274				
			9	SS	10		273				
			10	SS	10		272				
			11	SS	20		271		○		NP 8 46 40 6
			12	SS	12		270				
							269				
	Augers grinding on inferred cobbles/boulders between 11.4 m and 18.3 m depth.										

Continued Next Page

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

GOLDER

RECORD OF BOREHOLE No CR-2

2 OF 2 **METRIC**

PROJECT 16519971651997-WO5
W.P. 5416-15-01
DIST HWY 652
DATUM GEODETIC

LOCATION N 5457115.4; E 330585.4 NAD83 MTM ZONE 12 (LAT. 49.251529; LONG. -80.645782)
BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers
DATE July 19, 2017

ORIGINATED BY MR
COMPILED BY AC
CHECKED BY DAM

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 Silty SAND, trace to some gravel, trace to some clay (TILL) Compact to very dense Grey Wet		13	SS	50		267				
			14	SS	41		266		○	NP	19 49 24 8
	Augers grinding on inferred cobbles/boulders between 11.4 m and 18.3 m depth.		15	SS	36		265				
			16	SS	62		264				
			17	SS	14		263			NP	10 54 27 9
			18	SS	90		262				
259.6							261				
20.4	END OF BOREHOLE Note: 1. Water level at a depth of 2.0 m below ground surface (Elev. 278.0 m) upon completion of drilling.						260				

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

SUD-MTO 001 MTM ZN INC LAT/LONG S:\CLIENTS\MTO\1651997 AECOM_5015-E-0045_NE RETAINER\02_DATA\GINT\1651997.GPJ GAL-MISS.GDT 4/6/18 TB

GOLDER

RECORD OF BOREHOLE No CR-3

1 OF 1 **METRIC**

PROJECT 16519971651997-WO5

W.P. 5416-15-01 LOCATION N 5457073.3; E 330552.5 NAD83 MTM ZONE 12 (LAT. 49.251152; LONG. -80.646237) ORIGINATED BY MR

DIST HWY 652 BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers COMPILED BY AC

DATUM GEODETIC DATE July 28, 2017 CHECKED BY DAM

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
284.3	GROUND SURFACE										
0.0	ASPHALT (50 mm)										
0.1	Gravelly sand (FILL) Brown Moist						284				
283.8 / 0.5	Sand, trace to some silt, trace gravel, trace clay (FILL) Very loose to compact Brown Moist		1	SS	13		283				
			2	SS	2						
			3	SS	15		282				
			4	SS	5		281		○		2 86 11 1
			5	SS	9		280				
			6	SS	3						
			7	SS	2		279				
	Samples wet below 7.6 m depth.		8	SS	WH		278				
275.6							277				
8.7	Gravelly Silty SAND, trace to some clay (TILL) Dense Grey Wet						276				
274.5			9	SS	38		275		○	NP	21 48 26 5
9.8	END OF BOREHOLE										

Note:

1. Borehole dry upon completion of drilling inside augers.

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

SUD-MTO 001 MTM ZN INC LAT/LONG S:\CLIENTS\MTO\1651997 AECOM_5015-E-0045_NE RETAINER\02_DATA\GINT\1651997.GPJ GAL-MISS.GDT 3/29/18 TB

GOLDER

RECORD OF BOREHOLE No CR-4

1 OF 2 **METRIC**

PROJECT 16519971651997-WO5
W.P. 5416-15-01
DIST HWY 652
DATUM GEODETIC

LOCATION N 5457069.0; E 330566.5 NAD83 MTM ZONE 12 (LAT. 49.251113; LONG. -80.646045)
BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers
DATE July 20, 2017

ORIGINATED BY MR
COMPILED BY AC
CHECKED BY DAM

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
280.2	GROUND SURFACE						280				
0.0	Clayey silt, some sand, some organics (FILL) Brown to black Moist										
278.7							279				
1.6	Silty TOPSOIL Black Wet		1	SS	5						
	Sand, trace to some silt (FILL) Very loose to compact Brown Wet		2	SS	12	▽	278		○		0 94 (6)
			3	SS	1		277				
	A 0.2 m thick silty clay (fill) layer encountered at 3.8 m depth.		4A 4B	SS	WH				⊢○⊣		
274.9			5	SS	1		276				
5.3	SAND and SILT to Silty SAND, trace to some gravel, trace to some clay (TILL) Loose to very dense Grey Wet		6	SS	6		275				
			7	SS	12		274		○		NP 2 58 33 7
			8	SS	24		273				
			9	SS	26		272				
			10	SS	6/0.08		271				
	Split-spoon refusal (hammer bouncing) at 9.4 m depth. Augers grinding on inferred cobbles/boulders between 9.4 m and 10.7 m depth.						270				
			11	SS	21		269		○		NP 9 53 29 9

Continued Next Page

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

GOLDER

PROJECT 16519971651997-WO5

RECORD OF BOREHOLE No CR-4

2 OF 2 **METRIC**

W.P. 5416-15-01 LOCATION N 5457069.0; E 330566.5 NAD83 MTM ZONE 12 (LAT. 49.251113; LONG. -80.646045) ORIGINATED BY MR

DIST HWY 652 BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers COMPILED BY AC

DATUM GEODETIC DATE July 20, 2017 CHECKED BY DAM

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 Silty SAND, trace to some gravel, trace to some clay (TILL) Loose to very dense Grey Wet		12	SS	26		268				
							267				
			13	SS	42		266				
			14	SS	26		265				
			15	SS	28		264				
			16	SS	129		263		ϕ	NP	12 58 22 8
			17	SS	79		262				
			18	SS	91		261				
258.3							260				
21.9	END OF BOREHOLE Note: 1. The surficial clayey silt fill to 1.5 m depth was placed by Golder to provide a level drilling platform. 2. Water level at a depth of 2.2 m below ground surface (Elev. 278.0 m) upon completion of drilling.						259				

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

APPENDIX B

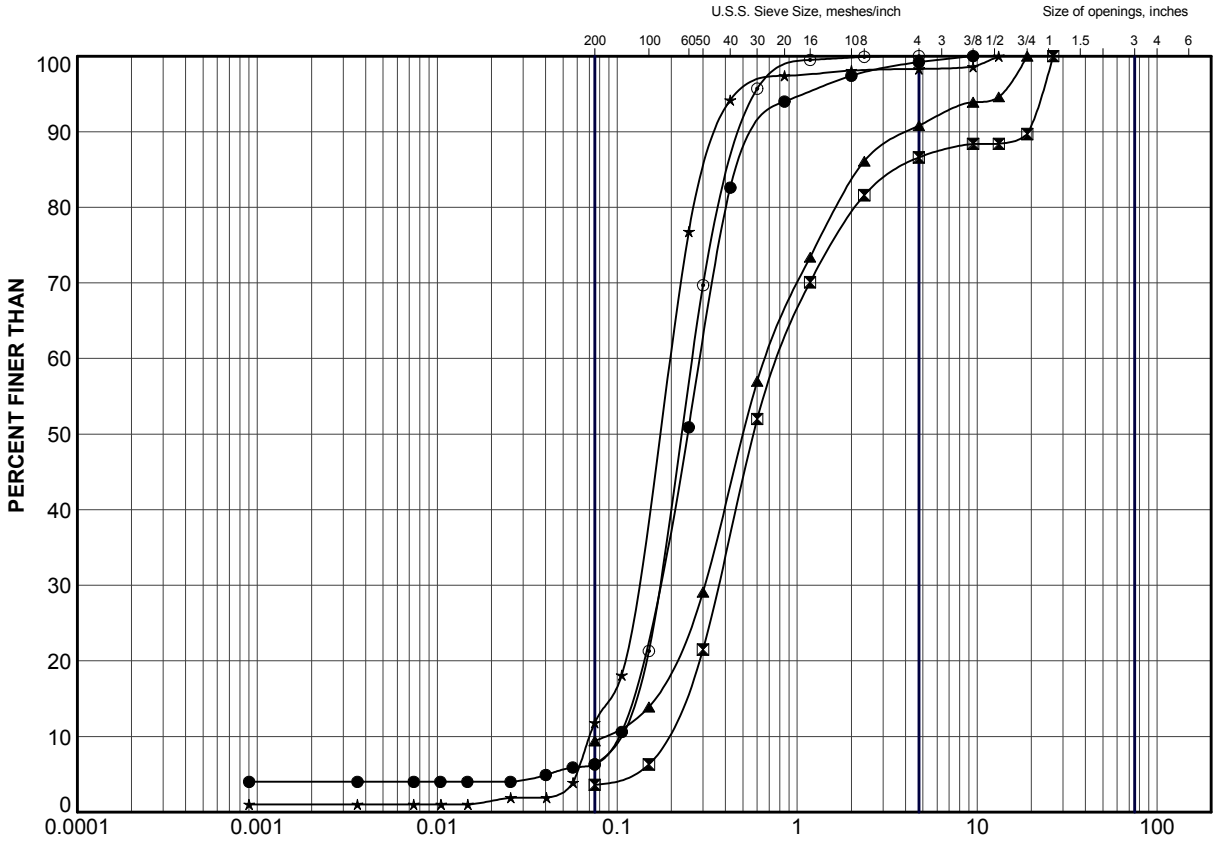
Laboratory Test Results

Table B1: Summary of Analytical Testing of Chin River Soil Samples

Location	Parameter	Units	Result
North Abutment (CR-1 SA4)	Chloride (CL)	ug/g	Not Detected (ND) (i.e., less than 20 ug/g)
	Sulphate (SO4)	ug/g	ND
	Conductivity (EC)	umho/cm	105
	Resistivity	ohm-cm	9,600
	pH	n/a	7.98
South Abutment (CR-3 SA5)	Chloride (CL)	ug/g	ND
	Sulphate (SO4)	ug/g	ND
	Conductivity (EC)	umho/cm	98
	Resistivity	ohm-cm	10,000
	pH	n/a	8.11

Notes: 1. Samples obtained on July 26, 2017 and submitted November 22, 2017
2. Analytical testing carried out by Maxxam.

Prepared by: AC
Checked by: DAM
Reviewed by: JPD



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	CR-1	3	281.7
⊠	CR-1	7	277.9
▲	CR-2	3	278.2
★	CR-3	4	280.9
⊙	CR-4	2	277.6

PROJECT

HIGHWAY 652
CHIN RIVER BRIDGE

TITLE

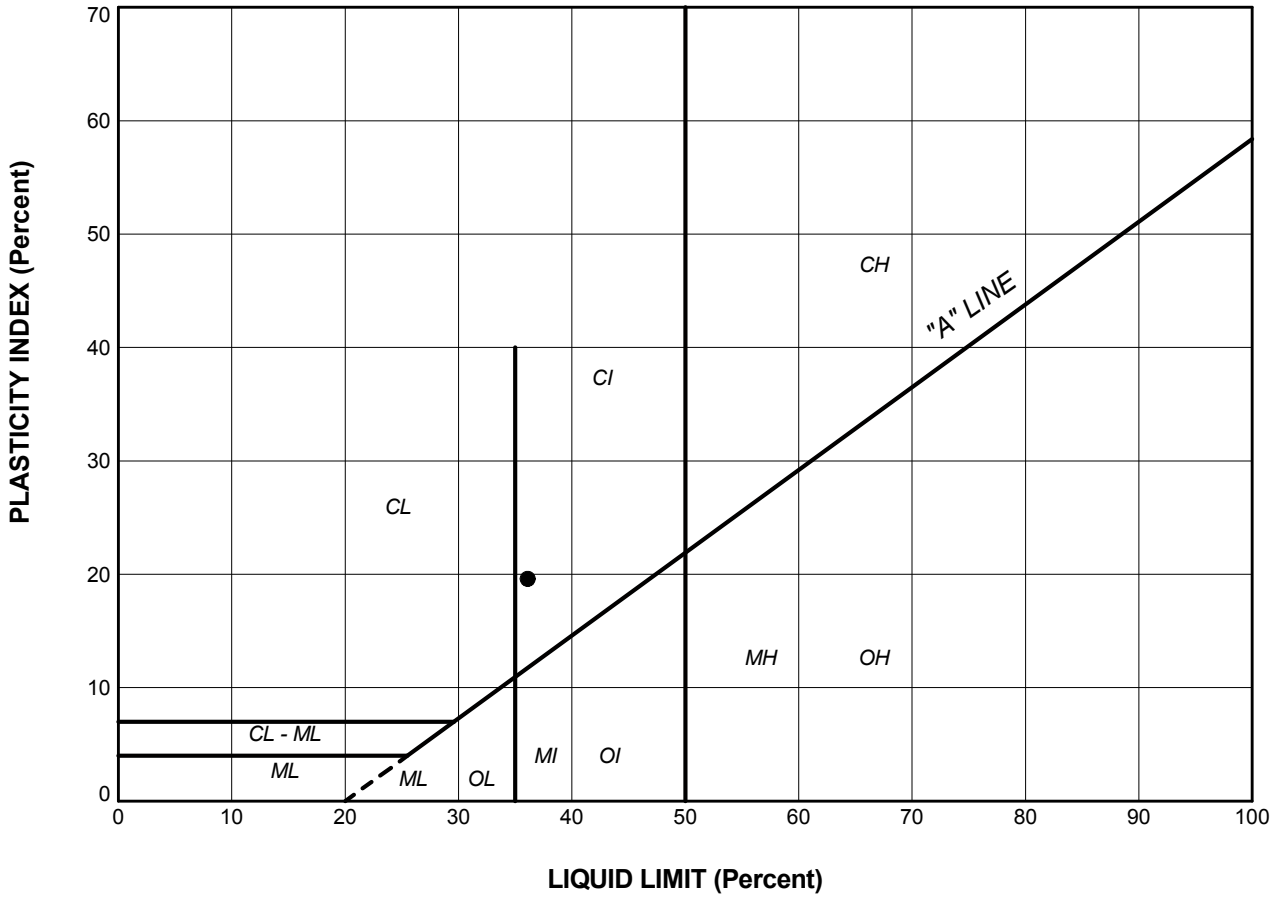
GRAIN SIZE DISTRIBUTION

SAND (FILL)

Golder Associates
SUDBURY, ONTARIO

PROJECT No.			FILE No.	1651997.GPJ
DRAWN	JJL	Dec 2017	SCALE N/A	REV.
CHECK	DAM	Dec 2017		
APPR	JPD	Dec 2017	**FIGURE B1**	

SUD-MTO GSD (2016) 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
●	CR-4	4A	36.1	16.5	19.6

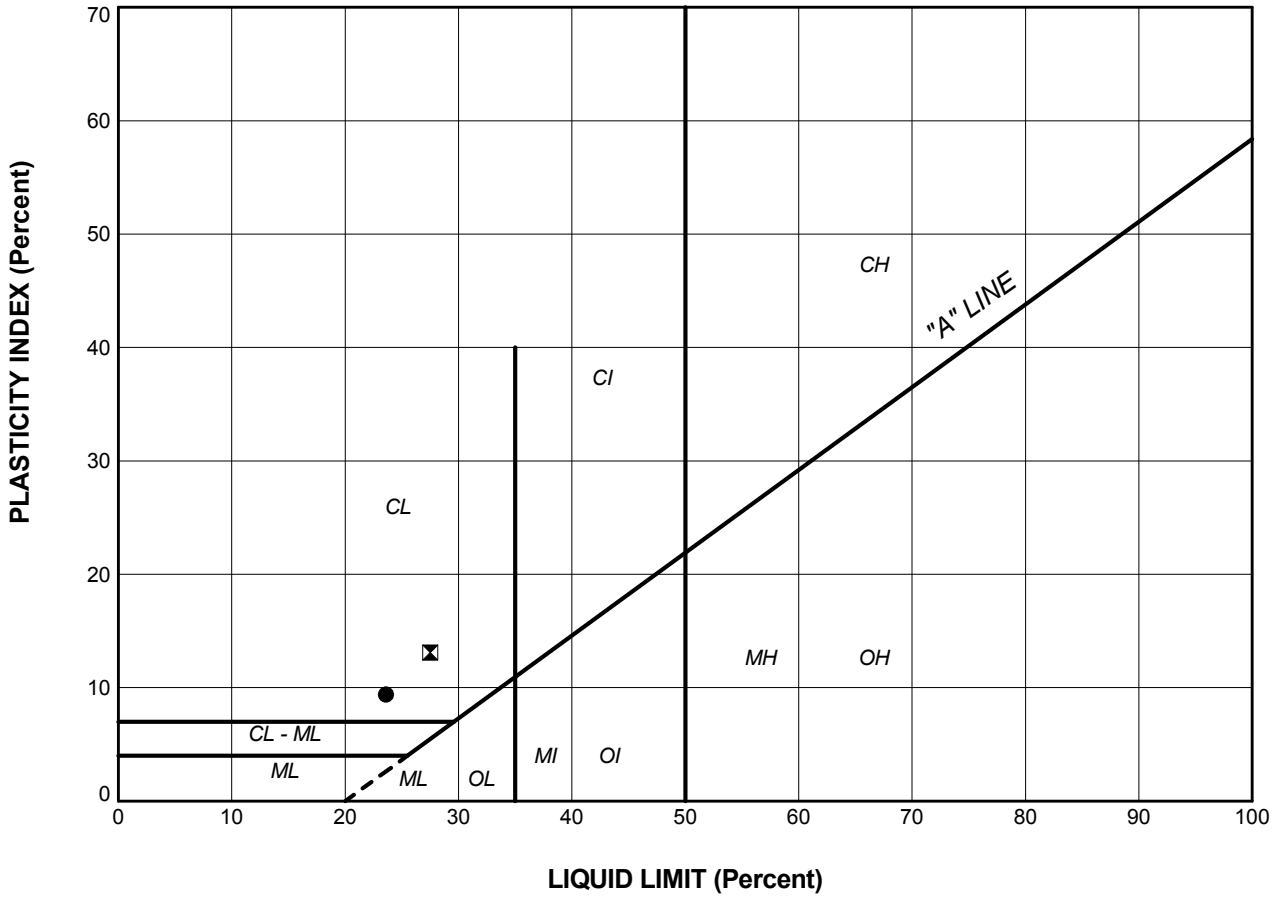
PROJECT
HIGHWAY 652
CHIN RIVER BRIDGE

TITLE
PLASTICITY CHART
SILTY CLAY (FILL)

Golder Associates
SUDBURY, ONTARIO

PROJECT No.			FILE No.	1651997.GPJ	
DRAWN	JJL	Dec 2017	SCALE	N/A	REV.
CHECK	DAM	Dec 2017			
APPR	JPD	Dec 2017	**FIGURE**	**B2**	

SUD-MTO PL (2016) GLDR_LDN.GDT



LIQUID LIMIT (Percent)

SOIL TYPE	**PLASTICITY**
C = Clay	L = Low
M = Silt	I = Intermediate
O = Organic	H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	CR-1	9	23.6	14.2	9.4
⊠	CR-2	7B	27.5	14.4	13.1

PROJECT

HIGHWAY 652
CHIN RIVER BRIDGE

TITLE

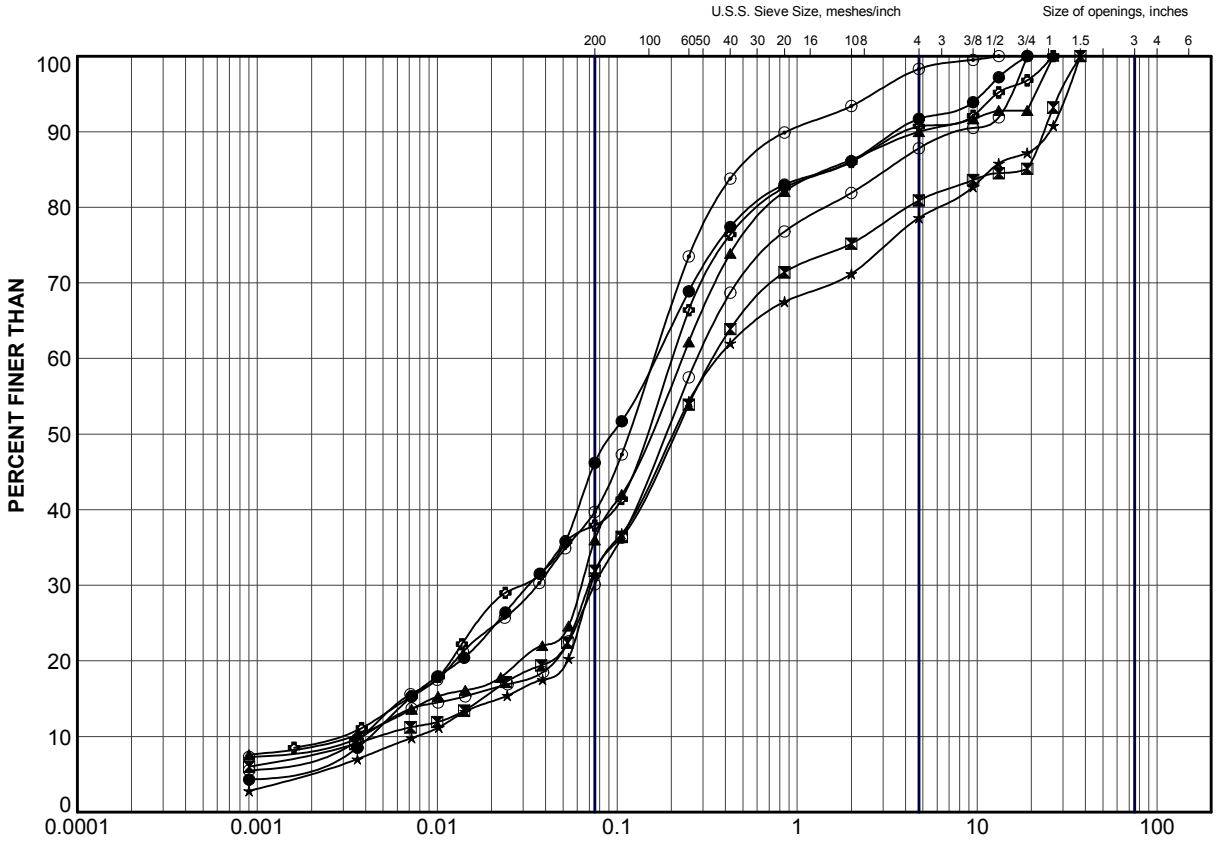
PLASTICITY CHART

CLAYEY SILT

Golder Associates
SUDBURY, ONTARIO

PROJECT No.			FILE No.	1651997.GPJ
DRAWN	JJL	Dec 2017	SCALE N/A	REV.
CHECK	DAM	Dec 2017		
APPR	JPD	Dec 2017	**FIGURE B3**	

SUD-MTO PL (2016) GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	CR-2	11	270.6
⊠	CR-2	14	266.0
▲	CR-2	17	261.4
★	CR-3	9	274.8
⊙	CR-4	7	273.8
✿	CR-4	11	269.2
○	CR-4	16	261.6

PROJECT

HIGHWAY 652
CHIN RIVER BRIDGE

TITLE

GRAIN SIZE DISTRIBUTION

SAND and SILT to SILTY SAND (TILL)

Golder Associates
SUDBURY, ONTARIO

PROJECT No.			FILE No.	1651997.GPJ
DRAWN	JJL	Dec 2017	SCALE N/A	REV.
CHECK	DAM	Dec 2017		
APPR	JPD	Dec 2017	**FIGURE B4**	

SUD-MTO GSD (2016) GLDR_LDN.GDT

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

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