



March 15, 2016

FOUNDATION INVESTIGATION REPORT

HIGHWAY 542 BLUE JAY CREEK CULVERT, SITE 49-36/C
TOWNSHIP OF TEHKUMMAH, MANITOULIN ISLAND, ONTARIO
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5090-13-00, WP 5064-07-01

Submitted to:

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REPORT





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PART A

FOUNDATION INVESTIGATION REPORT
HIGHWAY 542 BLUE JAY CREEK CULVERT, SITE 49-36/C
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by McIntosh Perry Consulting Engineers Ltd. (McIntosh Perry) on behalf of the Ministry of Transportation, Ontario, (MTO) to provide foundation engineering services for the replacement of the Highway 542 Blue Jay Creek culvert at Station 11+014 (Site # 49-36/C), in the Township of Tehkummah on Manitoulin Island, Ontario. The Key Plan showing the general location of this section of Highway 542 and the location of the investigated area are shown on Drawing 1. The orientation (i.e., north, south, east and west) stated in the text of the report is referenced up-chainage along the existing Highway 542 alignment. For purposes of this report, Highway 542 is oriented north-south.

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

2.0 SITE DESCRIPTION

The Blue Jay Creek culvert is located in the Township of Tehkummah on Highway 542, approximately 1.3 km north of Highway 6. The land use in the area is generally rural with a few residences and commercial buildings in the vicinity of the site.

In general, the topography in the area of the overall project limits is generally flat with gently rolling hills separated by the Blue Jay Creek, which meanders along and below Highway 542 in this area. The creek banks are vegetated with grass and small trees. The creek flows from east to west and is approximately 5 m wide at the culvert location.

The existing highway grade at the culvert is at about Elevations 208.25 m with the Blue Jay Creek located about 6.4 m below the existing highway grade. The existing culvert, which was constructed in 1985, is a 5.3 m span by 3.0 m rise by 35.5 m long (on the skew including beveled ends) Structural Plate Corrugated Steel Pipe Arch (SPCSPA) under approximately 4.0 m of fill. The existing inlet and outlet inverts are at Elevation 201.83 m, respectively. A 2010 structural inspection indicated significant deterioration of the culvert barrel with bolt line cracking and breakdown of the structural steel coating. Photographs taken at the site are included following the text of this report.

3.0 INVESTIGATION PROCEDURES

The fieldwork for the investigation was carried out on September 17, 18 and 24, and November 6 and 7, 2012, during which time a total of three boreholes (BJE-1 to BJE-3) were advanced at the culvert location. The locations of the boreholes are shown on Drawing 1.

Boreholes BJE-1 and BJE-2 were advanced using a track-mounted CME-850 drill rig supplied and operated by Landcore Drilling Inc. of Sudbury, Ontario and Borehole BJE-3 was advanced using a D-25 portable drill rig supplied and operated by Walker Drilling Ltd. of Barrie, Ontario.

Boreholes BJE-1 and BJE-2 were advanced through the overburden using 108 mm inside diameter hollow-stem augers, as well as NW casing and NQ size core barrel. Borehole BJE-3 was advanced using NW casing and NQ size core barrel. Soil samples were obtained at intervals of depth of about 0.75 m to 1.5 m, using a 50 mm



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outer diameter split-spoon sampler, operated by an automatic hammer on the drill rig, in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586-08a). The groundwater levels in the open boreholes were observed during the drilling operations as described on the Record of Borehole sheets in Appendix A. The boreholes were backfilled with bentonite upon completion in accordance with Ontario Regulation 903 (as amended by Ontario Regulation 372).

The boreholes were advanced to depths ranging between 5.5 m and 12.6 m below existing ground surface. In Borehole BJE-1, a total of 3.2 m of bedrock was cored. In Borehole BJE-2, bedrock coring was terminated after penetrating 0.9 m into the bedrock once flush water was observed to be flowing into the creek from the borehole location, likely from the bedrock joints. In Borehole BJE-3, bedrock coring was terminated after penetrating a depth of 0.5 m due to observations of flush water entering the creek at Borehole BJE-2 and due to the sensitivity of the creek in this area. A Dynamic Cone Penetration Test (DCPT) was advanced adjacent to Boreholes BJE-1 and BJE-2 to refusal at depths of 9.4 m and 4.5 m, respectively, below the existing ground surface.

The fieldwork was supervised throughout by members of our technical staff who: located the boreholes; arranged for the clearance of underground services; supervised the drilling and sampling operations; logged the boreholes and examined and cared for the soil and bedrock 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 contents and grain size distribution) was carried out on selected soil samples. The results of the laboratory testing are included on the Record of Borehole Sheets in Appendix A and in Appendix B.

A sample of the creek water was obtained during the field investigation using appropriate sampling protocols and submitted to a specialist analytical laboratory under chain of custody procedures for testing for a suite of parameters. The results of the analytical testing are summarized in Table B1 in Appendix B.

The as-drilled borehole locations and ground surface elevations were measured and surveyed by members of our technical staff, referenced to stations on the highway. The MTM NAD 83 northing and easting 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 are summarized below.

Borehole	Location (m)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing	Easting		
BJE-1	5058322.6	344883.4	208.5	12.6
BJE-2	5058311.4	344861.2	203.9	5.5
BJE-3	5058344.5	344884.3	204.6	5.5



4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on the Physiography of Southern Ontario (Ministry of Northern Development and Mines)¹, the site is located within clay plains, which are interrupted by drumlin formations of till and/or rock.

Based on geological mapping in the area (Ministry of Northern Development and Mines)², the bedrock in the area consists typically of sandstone, shale, dolostone, and siltstone from the Amabel Formation from the Silurian Period of the Paleozoic Era.

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 and Drillhole sheets in Appendix A. The results of the laboratory testing are provided in Appendix B. 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, 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 soil stratigraphy based on the results of the boreholes is shown in profile on Drawing 1.

In general, the subsurface conditions encountered at the site generally consist of embankment fill at the midpoint of the culvert and east culvert end and a surficial layer of peat near the west culvert end overlying a loose to very dense gravelly sandy silt to silty sand underlain by a compact layer of gravelly sand overlying bedrock. A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Surface Treatment

A 50 mm thick layer of surface treatment was encountered at ground surface (Elevation 208.5 m) in Borehole BJE-1, which was advanced through the existing roadway.

4.2.2 Fill

Underlying the surface treatment in Borehole BJE-1, embankment fill material consisting of an upper and lower layer of brown, moist gravelly silty sand was encountered with a middle layer of brown, moist silt and sand fill. The granular fill thickness is about 5.5 m. The augers were noted to be grinding on cobbles within the fill at a depth of 5.5 m below the existing ground surface.

In Borehole BJE-3, a 0.1 m thick layer of topsoil fill was encountered from ground surface at Elevation 204.6 m.

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 Ministry of Northern Development and Mines, 1991. *Bedrock Geology of Ontario*, Southern Sheet, Map 2544.



The Standard Penetration Test (SPT) 'N'-value measured in the granular fill ranged from 8 blows to 64 blows per 0.3 m of penetration, suggesting a loose to very dense relative density.

Grain size distribution testing was carried out on two samples of the gravelly silty sand fill and the results are shown on Figure B1 in Appendix B and the results of grain size distribution testing on one sample of the silt and sand fill are shown on Figure B2.

The moisture content measured on two samples of the gravelly silty sand fill are 2 per cent and 9 per cent and the sample of silt and sand fill is 18 per cent.

4.2.3 Peat

An approximately 0.5 m thick layer of amorphous peat was encountered from ground surface in Boreholes BJE-2 (Elevation 203.9 m).

The SPT 'N'-value within the peat is 4 blows per 0.3 m penetration, suggesting a soft to firm consistency.

4.2.4 Gravelly Sandy Silt to Silty Sand

In Borehole BJE-1, a 2.9 m thick deposit of grey, wet gravelly silt and sand, trace to some clay was encountered underlying the fill material at a depth of 5.6 m below ground surface at Elevation 202.9 m. One split-spoon drive at a depth of about 6.4 m did not penetrate the full sampling interval indicative of likely presence of cobbles and the augers were noted to be grinding likely on cobbles at a depth of 6.6 m below the existing ground surface.

In Borehole BJE-2, a 4.1 m thick deposit of grey, wet silty sand to gravelly sandy silt, trace to some clay was encountered underlying the peat at a depth of 0.5 m below ground surface at Elevation 203.4 m. The augers were noted to be grinding likely on cobbles at depths of 0.9 m, 2.0 m and 2.9 m. The bottom of the deposit is defined by bedrock coring.

In Borehole BJE-3, a 1.6 m thick deposit of brown to grey, wet silty sand to sand and silt, some gravel, some clay was encountered underlying the fill material at a depth of 2.1 m below ground surface at Elevation 202.5 m.

The SPT 'N'-value within the gravelly sandy silt to silty sand deposit is 3 blows per 0.3 m of penetration to 50 blows per 0.1 m penetration, indicating a very loose to very dense relative density, though generally loose to compact.

Grain size distribution testing was carried out on five samples of this deposit and the results are shown on Figure B3 in Appendix B.

Atterberg limits testing was carried out on four samples of the gravelly sandy silt to silty sand and measured liquid limits ranging from 15 per cent to 20 per cent, plastic limits ranging from 11 per cent to 15 per cent and plasticity indices ranging from 4 per cent to 6 per cent, respectively. These results, which are plotted on a plasticity chart on Figure B4 in Appendix B, indicate that the stratum is classified as a silt with slight plasticity.

The natural water content measured on five samples of this deposit ranged from about 7 per cent to 16 per cent.



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4.2.5 Gravelly Sand

A 0.9 m and 1.3 m thick deposit of grey, wet gravelly sand, trace to some silt was encountered underlying the gravelly sand and silt to silty sand in Boreholes BJE-1 and BJE-3 at a depth of 8.5 m and 3.7 m below ground surface, corresponding to Elevation 200.0 m and 200.9 m, respectively. The bottom of the deposit is defined by bedrock coring in both boreholes.

One SPT 'N'-values within the gravelly sand deposit is 16 blows per 0.3 m penetration, indicating a compact relative density.

4.2.6 Bedrock

Bedrock was cored in all three boreholes and the bedrock surface depths and elevations are presented below.

Borehole No.	Depth to Bedrock/Refusal Surface (m)	Bedrock/Refusal Surface Elevation (m)	Bedrock Core Length (m)
BJE-1	9.4	199.1	3.2
BJE-2	4.6	199.3	0.9*
BJE-3	5.0	199.6	0.5*

Note: * Borehole terminated before reaching 3 m of bedrock core as discussed in Section 3.

The retrieved bedrock core is described as a fine grained, slightly weathered, grey to brown, dolomitic limestone, as presented in the Record of Drillhole sheets in Appendix A. Photographs of the retrieved bedrock core samples are shown on Figure B5 in Appendix B.

The Total Core Recovery (TCR) during bedrock coring ranges from 92 per cent to 100 per cent. The Rock Quality Designation (RQD) measured on the core samples ranges from 40 per cent to 100 per cent, indicating a rock mass of poor to excellent quality as per Table 3.10 of the Canadian Foundation Engineering Manual (CFEM, 2006).

4.2.7 Groundwater Conditions

Unstabilized groundwater levels measured in the open boreholes upon completion of drilling are summarized in the table below.

Borehole No.	Depth to Groundwater Level (m)	Groundwater Elevation (m)
BJE-1	5.6	202.9
BJE-2	0.7	203.2
BJE-3	0.9	203.7



Groundwater levels encountered in the boreholes shortly after drilling may not be representative of static groundwater levels since the groundwater levels in the boreholes may not have stabilized on completion of drilling. The water in the creek at the time of the investigation in September 2012 was at about Elevation 202.2 m, just above the culvert invert. Groundwater levels in the area are subject to seasonal fluctuations and to fluctuations after precipitation events and snowmelt.

5.0 CLOSURE

The field personnel supervising the drilling program was Mr. Ed Savard. This report was prepared by Ms. Michelle He and Mr. Dave Muldowney, P.Eng., and the technical aspects were reviewed by Mr. André Bom, P.Eng. Mr. Fintan Heffernan, P.Eng., Golder's Designated MTO Contact for this project, carried out a quality control review and reviewed the technical aspects of the report.



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Report Signature Page

GOLDER ASSOCIATES LTD.



André Bom, P.Eng., PMP
Associate/Geotechnical Engineer



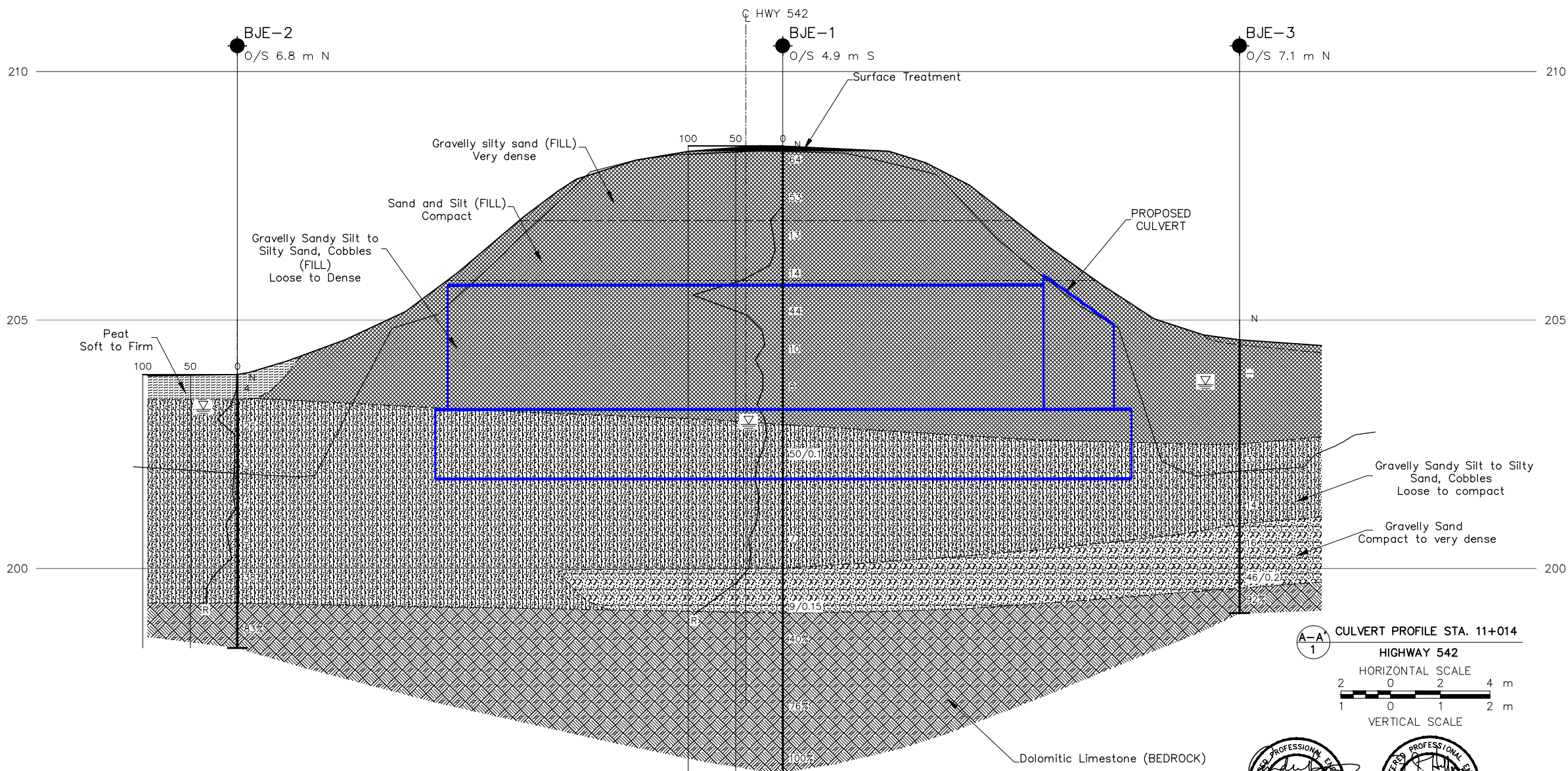
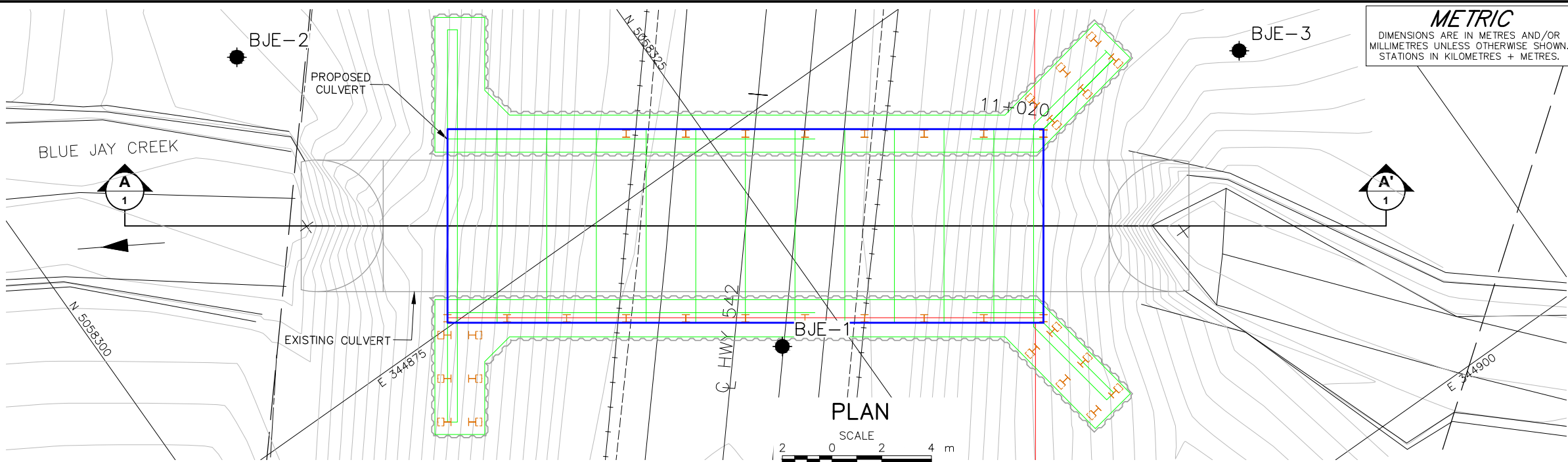
Fintan J. Heffernan, P.Eng.
Designated MTO Contact

DAM/AB/FJH/kp

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MINISTRY OF TRANSPORTATION, ONTARIO



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

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GWP No. 5090-13-00

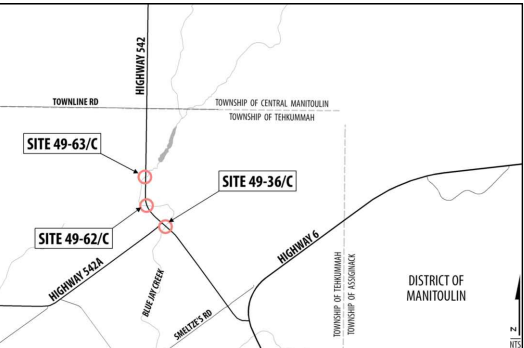
HIGHWAY 542
BLUE JAY CREEK CULVERT STA. 11+014
BOREHOLE LOCATIONS AND
SOIL STRATA



SHEET



Golder Associates Ltd.
SUDBURY, ONTARIO, CANADA



KEY PLAN
N.T.S.



LEGEND

- Borehole
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated
(Std. Pen. Test, 475 j/blow)
- R Refusal
- 100% Rock Quality Designation (RQD)
- ▽ WL upon completion of drilling

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
BJE-1	208.5	5058322.6	344883.4
BJE-2	203.9	5058311.4	344861.2
BJE-3	204.6	5058344.5	344884.3

NOTES

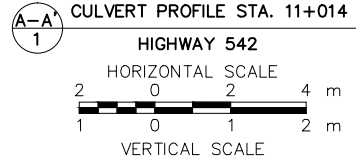
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

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

REFERENCE

Base plans provided in digital format by McIntosh Perry, drawing file nos. 11-684-Bluejay (all 3) - XREF.dwg, received OCT 19, 2012.
Cross-sections drawing file nos. Blue Jay and Jocko Cross-Sections.dwg, received NOV 22, 2012, Keyplan received August 24, 2012 file nos. KM11684-49-63,49-62 and 49-36 Location Map - June 26,2012.jpg.
Proposed culvert plan and profile drawing file no. GA- FOR GOLDER.DWG, received MAR 11, 2016.



NO.	DATE	BY	REVISION
1			
Geocres No. 41H-125			
HWY. 542		PROJECT NO. 12-1191-0014	
SUBM'D. DAM		DATE: MAR 2016	
DRAWN: J.J.L.		SITE: 49-36/C	
		DWG. 1	



SITE PHOTOGRAPHS (Site 49-36)

Photograph 1: Looking east at culvert inlet (November 2012)



Photograph 2: Looking east at culvert outlet (November 2012)





APPENDIX A

Record of Boreholes and Drillholes



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
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

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

(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

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

Notes: 1
2

$$\tau = c' + \sigma' \tan \phi'$$

$$\text{shear strength} = (\text{compressive strength})/2$$



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, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

Density Index	N
Relative Density	Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils Consistency

	c_u, s_u	
	kPa	psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

IV. SOIL TESTS

w	water content
w _p	plastic limit
w _l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D _R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO ₄	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

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

V. MINOR SOIL CONSTITUENTS

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



LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

WEATHERINGS STATE

Fresh: no visible sign of weathering

Faintly weathered: weathering limited to the surface of major discontinuities.

Slightly weathered: penetrative weathering developed on open discontinuity surfaces but only slight weathering of rock material.

Moderately weathered: weathering extends throughout the rock mass but the rock material is not friable.

Highly weathered: weathering extends throughout rock mass and the rock material is partly friable.

Completely weathered: rock is wholly decomposed and in a friable condition but the rock and structure are preserved.

BEDDING THICKNESS

Description	Bedding Plane Spacing
Very thickly bedded	Greater than 2 m
Thickly bedded	0.6 m to 2 m
Medium bedded	0.2 m to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 mm to 60 mm
Laminated	6 mm to 20 mm
Thinly laminated	Less than 6 mm

JOINT OR FOLIATION SPACING

Description	Spacing
Very wide	Greater than 3 m
Wide	1 m to 3 m
Moderately close	0.3 m to 1 m
Close	50 mm to 300 mm
Very close	Less than 50 mm

GRAIN SIZE

Term	Size*
Very Coarse Grained	Greater than 60 mm
Coarse Grained	2 mm to 60 mm
Medium Grained	60 microns to 2 mm
Fine Grained	2 microns to 60 microns
Very Fine Grained	Less than 2 microns

Note: * Grains greater than 60 microns diameter are visible to the naked eye.

CORE CONDITION

Total Core Recovery (TCR)

The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

Solid Core Recovery (SCR)

The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

Rock Quality Designation (RQD)

The percentage of solid drill core, greater than 100 mm length, recovered at full diameter, measured relative to the length of the total core run. RQD varied from 0% for completely broken core to 100% for core in solid sticks.

DISCONTINUITY DATA

Fracture Index

A count of the number of discontinuities (physical separations) in the rock core, including both naturally occurring fractures and mechanically induced breaks caused by drilling.

Dip with Respect to Core Axis

The angle of the discontinuity relative to the axis (length) of the core. In a vertical borehole a discontinuity with a 90° angle is horizontal.

Description and Notes

An abbreviation description of the discontinuities, whether naturally occurring separations such as fractures, bedding planes and foliation planes or mechanically induced features caused by drilling such as ground or shattered core and mechanically separated bedding or foliation surfaces. Additional information concerning the nature of fracture surfaces and infillings are also noted.

Abbreviations

JN Joint	PL Planar
FLT Fault	CU Curved
SH Shear	UN Undulating
VN Vein	IR Irregular
FR Fracture	K Slickensided
SY Stylolite	PO Polished
BD Bedding	SM Smooth
FO Foliation	SR Slightly Rough
CO Contact	RO Rough
AXJ Axial Joint	VR Very Rough
KV Karstic Void	
MB Mechanical Break	

PROJECT 12-1191-0014			RECORD OF BOREHOLE No BJE-1			1 OF 2 METRIC						
G.W.P. 5465-09-00			LOCATION N 5058322.6; E 344883.4			ORIGINATED BY EHS						
DIST _____ HWY 542			BOREHOLE TYPE 108 mm I.D. Continuous Hollow Stem Augers, NW Casing, NQ Coring			COMPILED BY MH						
DATUM GEODETIC			DATE September 17 and 18, 2012			CHECKED BY AB						
SOIL PROFILE		SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER			TYPE	"N" VALUES					
208.5	GROUND SURFACE											
0.0	Surface Treatment (50 mm)		1	SS	64							
	Gravelly silty sand (FILL) Very dense Brown Moist		2	SS	53							27 48 (25)
207.0												
1.5	Silt and sand, some clay, trace gravel (FILL) Compact Brown Moist		3	SS	13							
			4	SS	14							
205.8												
2.7	Gravelly silty sand (FILL) Loose to dense Brown Moist		5	SS	44							
			6	SS	10							
			7	SS	8							
202.9	Augers grinding on cobbles at 5.5 m depth.											
5.6	Gravelly SILT and SAND, trace to some clay Loose to very dense Grey Wet		8	SS	50/0.1							
	Spoon refusal (hammer bouncing) at 6.4 m depth.											
	Augers grinding on cobbles at 6.6 m depth.											
			9	SS	7							23 35 31 11
200.0												
8.5	Gravelly SAND, some silt Grey Wet											
199.1			10	SS	9/0.15							
9.4	DOLOMITIC LIMESTONE (BEDROCK) Bedrock cored from 9.4 m depth to 12.6 m depth. For coring details see Record of Drillhole BJE-1.		1	RC	REC 100%							RQD = 40%
			2	RC	REC 92%							RQD = 76%
			3	RC	REC 100%							RQD = 100%
195.9												
12.6	END OF BOREHOLE Note: 1. Water level at a depth of 5.6 m below ground surface (Elev. 202.9 m) upon completion of drilling. 2. Advanced DCPT 1.0 m south of Borehole BJE-1. Augered to 1.5 m depth prior to start of DCPT. DCPT refusal (hammer bouncing) at 9.4 m depth (Elev. 199.1 m).											

SHEET 2 OF 2

DATUM: GEODETIC

DRILLING CONTRACTOR: Landcore Drilling

CHECKED: AB

SUD-RCK 1211910014.GPJ GAL-MISS.GDT 11/03/13 DATA INPUT:

PROJECT		12-1191-0014		RECORD OF BOREHOLE No BJE-2		1 OF 2 METRIC					
G.W.P.		5465-09-00		LOCATION		N 5058311.4; E 344861.2					
DIST		HWY 542		BOREHOLE TYPE		108 mm I.D. Continuous Hollow Stem Augers, NW Casing, NQ Coring					
DATUM		GEODETIC		DATE		September 24, 2012					
ORIGINATED BY		EHS		COMPILED BY		MH					
CHECKED BY		AB									
SOIL PROFILE		SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER			TYPE	"N" VALUES	SHEAR STRENGTH kPa			
203.9	GROUND SURFACE										
0.0	PEAT (Amorphous)		1	SS	4						
203.4	Soft to firm										
0.5	Brown Moist		2	SS	26						17 56 21 6
	Silty SAND to Gravelly Sandy SILT, trace to some clay										
	Loose to dense										
	Grey Wet		3	SS	3						
	Augers grinding on cobbles at 0.9 m and between 2.0 m and 2.9 m depth.		4	SS	4						9 43 36 12
			5	SS	5						
			6	SS	38						22 20 48 10
199.3	DOLOMITIC LIMESTONE (BEDROCK)		1	RC	REC 100%						RQD = 83%
4.6	Bedrock cored from 4.6 m depth to 5.5 m depth.										
198.4	For coring details see Record of Drillhole BJE-2.										
5.5	END OF BOREHOLE										
	Note:										
	1. Water level at a depth of 0.7 m below ground surface (Elev. 203.2 m) upon completion of drilling.										
	2. Drillhole terminated 0.9 m into bedrock as flush water was observed to be flowing into Blue Jay Creek likely through the bedrock joints.										
	3. Advanced DCPT 1.0 m south of Borehole BJE-2. Advanced DCPT from 0.0 to 0.9 m depth then augered between 0.9 m and 1.5 m depth to advance DCPT. DCPT refusal (hammer bouncing) at 4.5 m depth (Elev. 199.4 m).										

PROJECT: 12-1191-0014

RECORD OF DRILLHOLE: **BJE-2**

SHEET 2 OF 2

LOCATION: N 5058311.4 ; E 344861.2


DRILLING DATE: September 24, 2012

DATUM: GEODETIC

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 850

DRILLING CONTRACTOR: Landcore Drilling

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	JN - Joint FLT - Fault SHR- Shear VN - Vein CJ - Conjugate BD- Bedding FO- Foliation CO- Contact OR- Orthogonal CL - Cleavage PL - Planar CU- Curved UN- Undulating ST - Stepped IR - Irregular PO- Polished K - Slickensided SM- Smooth Ro - Rough MB- Mechanical Break BR - Broken Rock NOTE: For additional abbreviations refer to list of abbreviations & symbols.																NOTES WATER LEVELS INSTRUMENTATION
							FLUSH	RECOVERY		R.Q.D. %	FRACT. INDEX METRES	DISCONTINUITY DATA						HYDRAULIC CONDUCTIVITY		Diametral Point Load Index (MPa)	RMC -Q' AVG.		
								TOTAL CORE %	SOLID CORE %			B Angle	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION		Jr	Ja	Jn	k, cm/s				
														10	10							10	
5	September 24, 2012 NQ Coring NW	~SEE PREVIOUS PAGE~ DOLOMITIC LIMESTONE Fine grained Slightly weathered Grey to brown		199.3 4.6 <																			

DEPTH SCALE



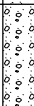

1 : 50



LOGGED: EHS

CHECKED: AB

SUD-RCK 1211910014.GPJ GAL-MISS.GDT 11/03/13 DATA INPUT:

PROJECT 12-1191-0014				RECORD OF BOREHOLE No BJE-3				1 OF 2 METRIC									
G.W.P. 5465-09-00				LOCATION N 5058344.5; E 344884.3				ORIGINATED BY AC									
DIST _____ HWY 542				BOREHOLE TYPE 108 mm I.D. Continuous Hollow Stem Augers, NW Casing, NQ Coring				COMPILED BY MH									
DATUM GEODETIC				DATE November 6 and 7, 2012				CHECKED BY AB									
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
204.6	GROUND SURFACE							20	40	60	80	100					
0.9	Topsoil (FILL) Gravelly silty sand, trace clay, trace organics, cobbles and boulders (FILL) Compact Brown Moist to wet Boulders up to 0.5 m in diameter.		1	TP	-												33 42 21 4
202.5																	
2.1	Silty SAND to SAND and SILT, some gravel, some clay Very loose to compact Brown to grey Wet		2	SS	3												
			3	SS	14												15 33 40 12
200.9																	
3.7	Gravelly SAND, trace to some silt Compact Grey Wet		4	SS	16												
			5	SS	46/0.2												
199.6																	
5.0	DOLOMITIC LIMESTONE (BEDROCK)		1	RC	REC 92%												RQD = 92%
199.1																	
5.5	Bedrock cored from 5.0 m depth to 5.5 m depth. For coring details see Record of Drillhole BJE-3. END OF BOREHOLE Note: 1. Auger refusal encountered at 0.5 m depth at original borehole. Sample 1 obtained from test pit advanced at original borehole location. Moved 2.0 m east to advance new borehole using NW casing to a depth of 2.1 m (Elev. 202.5 m) without sampling. 2. Water level at a depth of 0.9 m below ground surface (Elev. 203.7 m) upon completion of drilling. 3. Drillhole terminated 0.5 m into bedrock as flush water was observed to be flowing into Blue Jay Creek likely though the bedrock joints.																

SUD-MTO 001 1211910014.GPJ GAL-MISS.GDT 09/04/13 DATA INPUT:

PROJECT: 12-1191-0014

RECORD OF DRILLHOLE: BJE-3

SHEET 2 OF 2

LOCATION: N 5058344.5 ; E 344884.3

DRILLING DATE: November 6 and 7, 2012

DATUM: GEODETIC

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: D-25

DRILLING CONTRACTOR: Walker Drilling

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH	COLOUR % RETURN	JN - Joint FLT - Fault SHR - Shear VN - Vein CJ - Conjugate	BD - Bedding FO - Foliation CO - Contact OR - Orthogonal CL - Cleavage	PL - Planar CU - Curved UN - Undulating ST - Stepped IR - Irregular	PO - Polished K - Slickensided SM - Smooth Ro - Rough MB - Mechanical Break	BR - Broken Rock NOTE: For additional abbreviations refer to list of abbreviations & symbols.	NOTES WATER LEVELS INSTRUMENTATION
		~SEE PREVIOUS PAGE~		199.6									
5	NQ Coring	DOLOMITIC LIMESTONE Fine grained Slightly weathered Grey		5.0	1	GREY	100%						
		END OF DRILLHOLE		199.1									
				5.5									
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													

DEPTH SCALE

1 : 50



LOGGED: AC

CHECKED: AB

SUD-RCK 1211910014.GPJ GAL-MISS.GDT 11/03/13 DATA INPUT:



APPENDIX B

Laboratory Test Results

Table B1 - Summary of Analytical Testing of Creek Water

Parameter	Units	Method Detection Limit	Result
Resistivity	ohm-cm	n/a	3100
Conductivity	µmho/cm	1	320
pH	n/a	n/a	8.09
Sulphate	mg/L	1	14
Chloride	mg/L	1	3

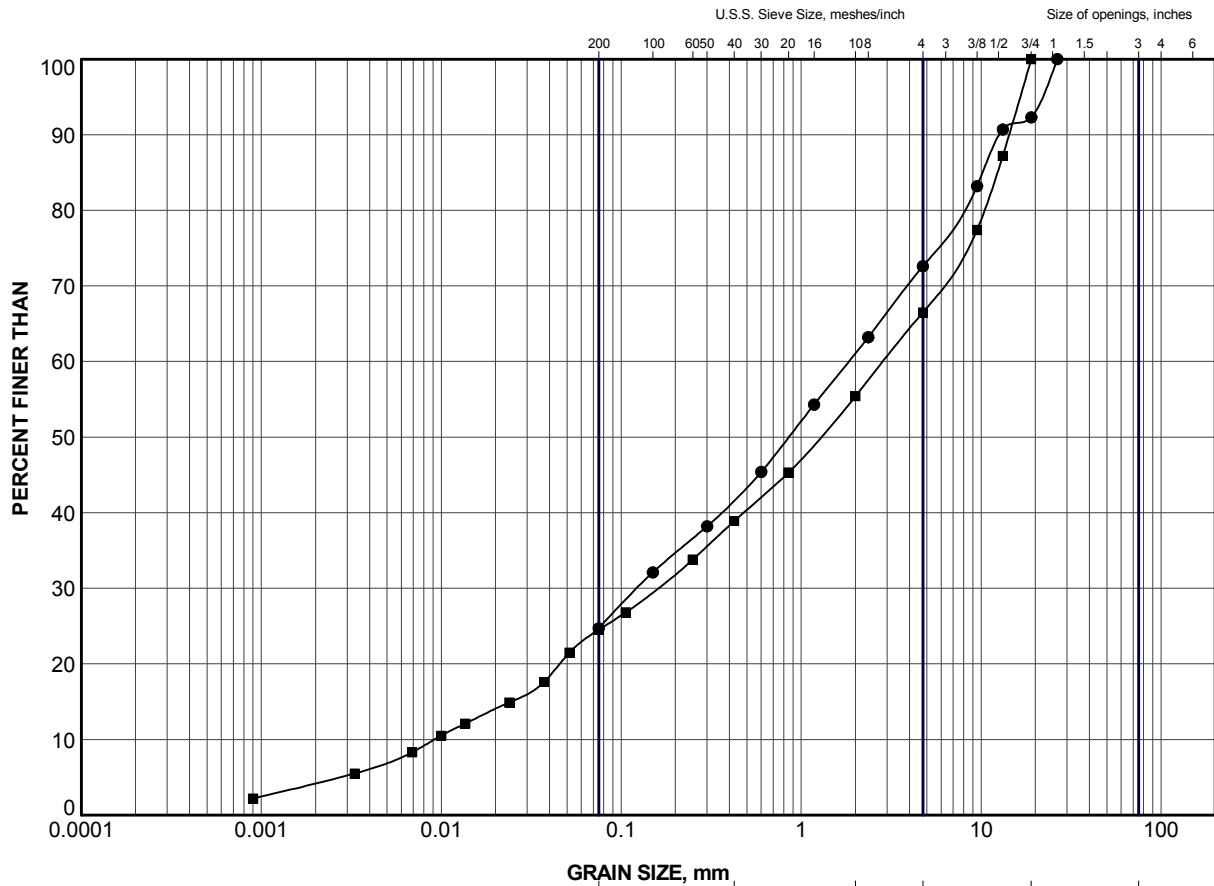
Notes:

1. Sample obtained November 5, 2012.

2. Analytical testing carried out by Maxxam Analytics Inc.

Prepared by: DAM

Reviewed by: AB



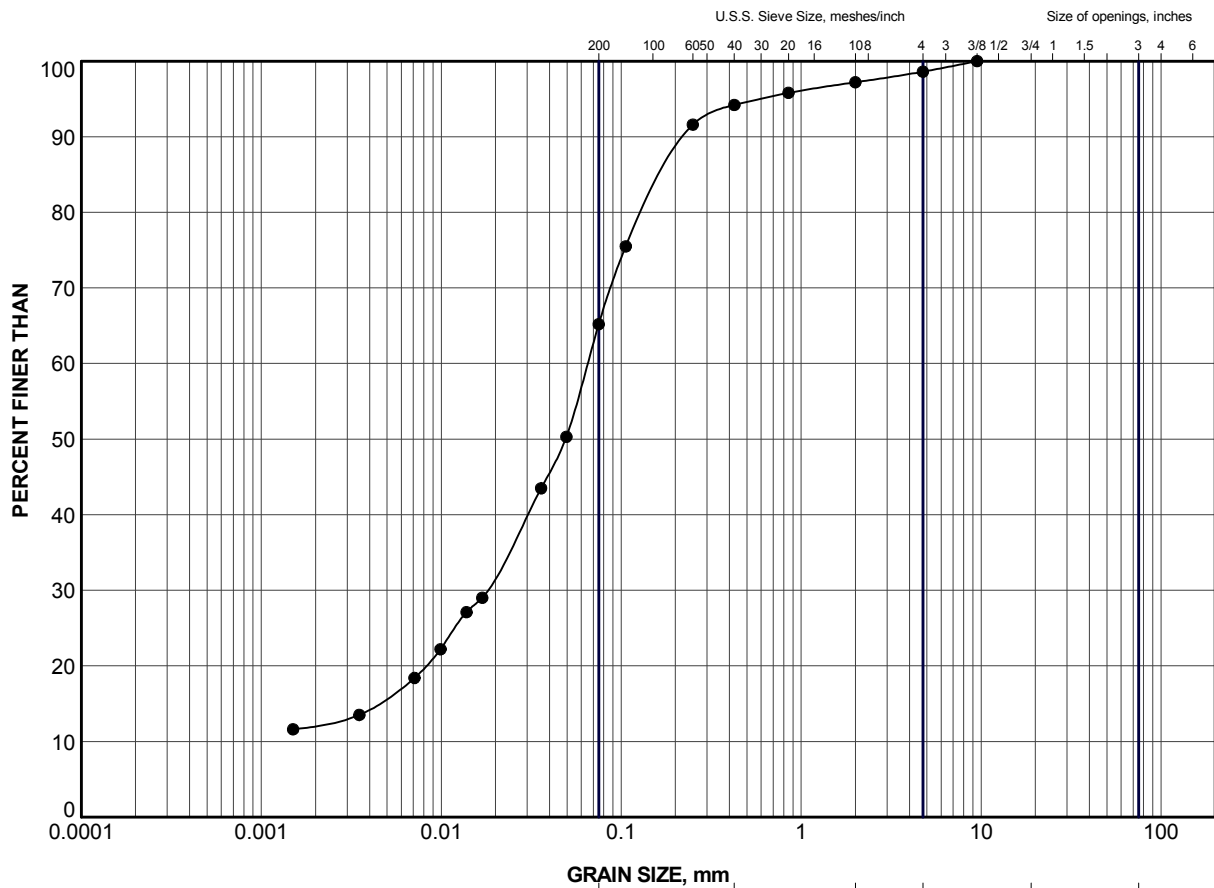
CLAY AND SILT	GRAVEL SIZE, mm					Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BJE-1	2	207.4
■	BJE-3	1	203.9

PROJECT					
HIGHWAY 542 BLUE JAY CREEK CULVERT					
TITLE					
GRAIN SIZE DISTRIBUTION GRAVELLY SILTY SAND (FILL)					
PROJECT No.		12-1191-0014		FILE No. 1211910014.GPJ	
DRAWN	JJL	Sep 2013	SCALE	N/A	REV.
CHECK	AB	Sep 2013	FIGURE C1		
APPR	FJH	Sep 2013			




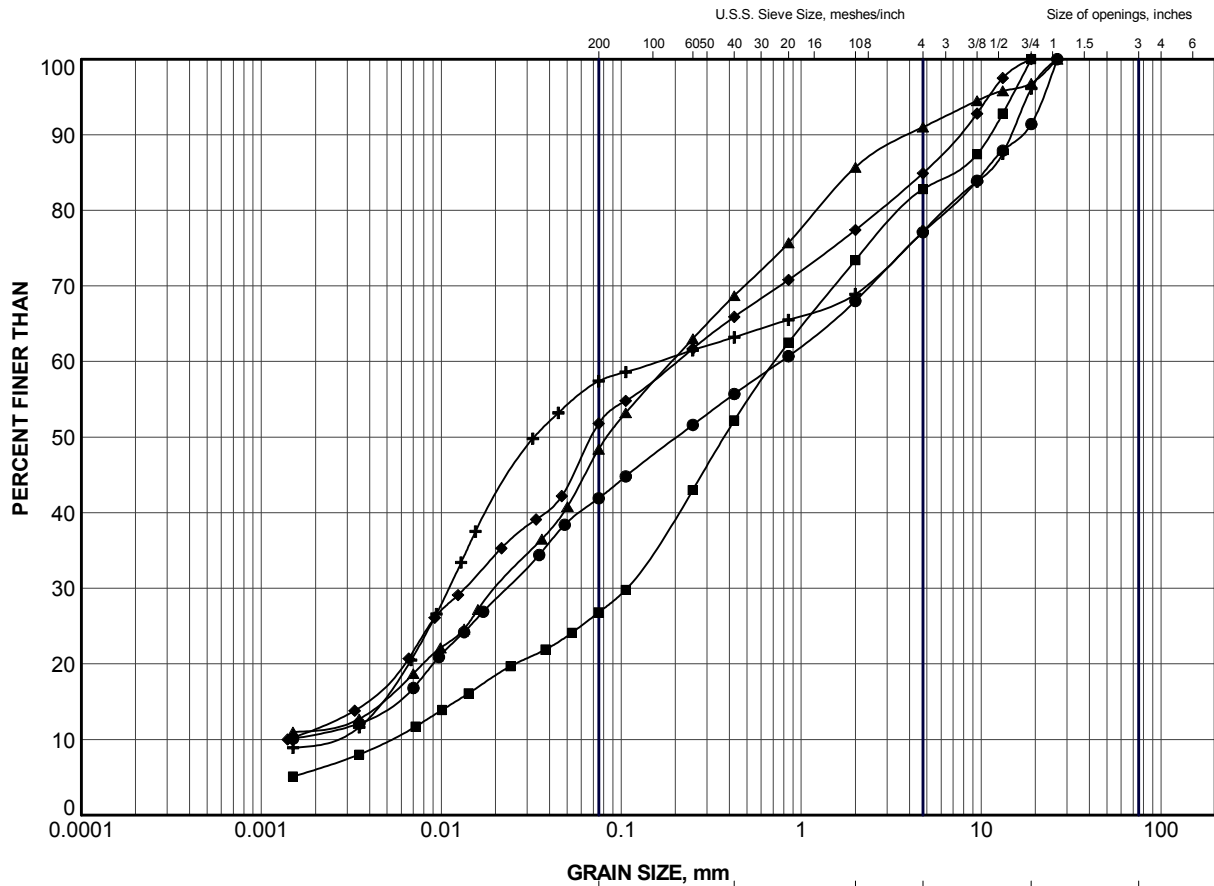


GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BJE-1	4a	206.0

PROJECT					HIGHWAY 542 BLUE JAY CREEK CULVERT				
TITLE					GRAIN SIZE DISTRIBUTION SAND AND SILT (FILL)				
PROJECT No.		12-1191-0014		FILE No.		1211910014.GPJ			
DRAWN	JJL	Sep 2013	SCALE	N/A	REV.				
CHECK	AB	Sep 2013							
APPR	FJH	Sep 2013							
 Golder Associates SUDBURY, ONTARIO			FIGURE C2						



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BJE-1	9	200.6
■	BJE-2	2	202.8
▲	BJE-2	4	201.3
+	BJE-2	6	199.8
◆	BJE-3	3	201.2

PROJECT

HIGHWAY 542
BLUE JAY CREEK CULVERT

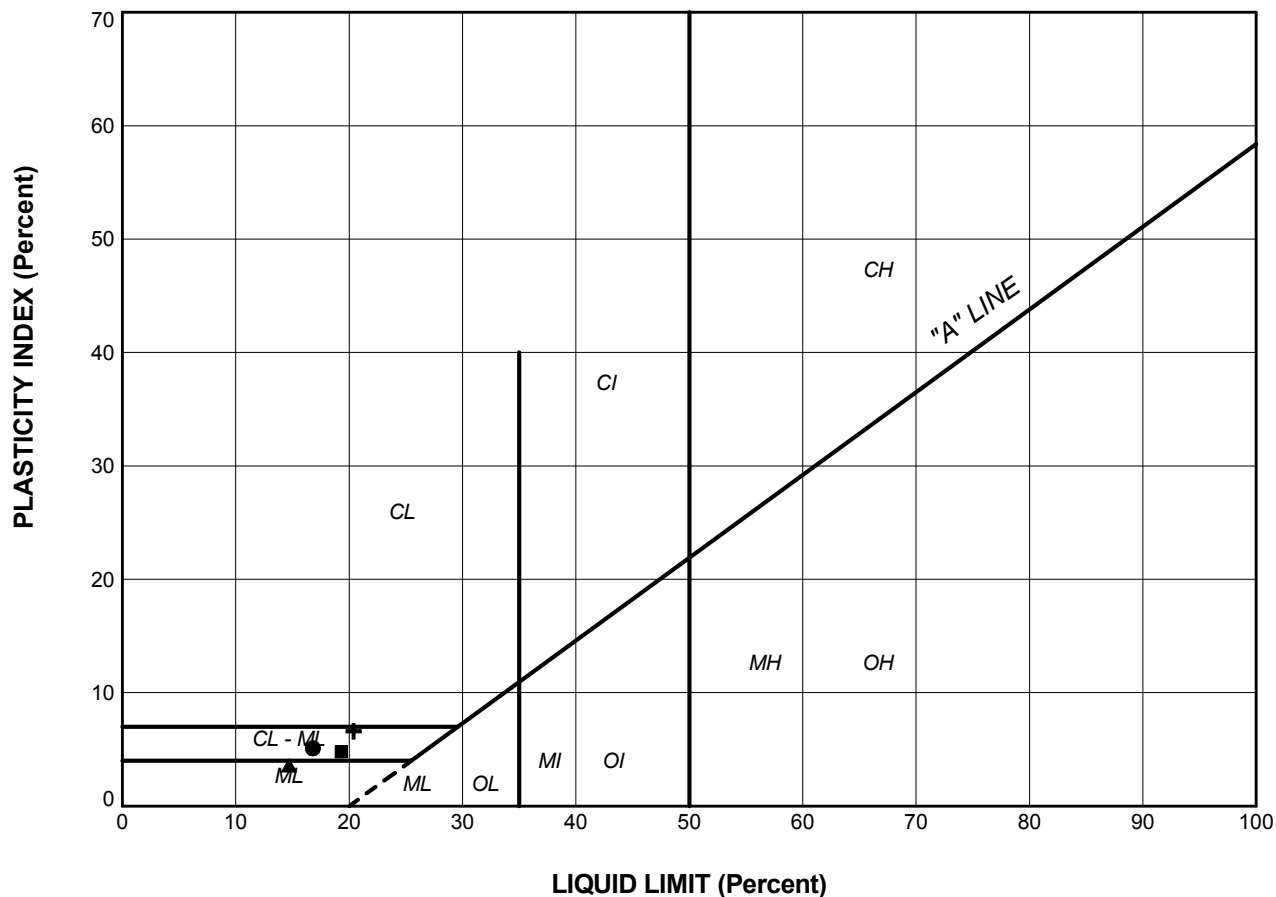
TITLE

GRAIN SIZE DISTRIBUTION
GRAVELLY SANDY SILT TO SILTY SAND



PROJECT No. 12-1191-0014		FILE No. 1211910014.GPJ	
DRAWN	JJL	Sep 2013	SCALE N/A
CHECK	AB	Sep 2013	REV.
APPR	FJH	Sep 2013	

FIGURE C3



LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	BJE-1	9	16.8	11.7	5.1
■	BJE-2	4	19.3	14.5	4.8
▲	BJE-2	6	14.7	11.1	3.6
+	BJE-3	3	20.4	13.8	6.6

PROJECT					
HIGHWAY 542 BLUE JAY CREEK CULVERT					
TITLE					
PLASTICITY CHART GRAVELLY SANDY SILT TO SILTY SAND					
PROJECT No.		12-1191-0014		FILE No.	
DRAWN		JJL		Mar 2013	
CHECK		AB		Mar 2013	
APPR				Mar 2013	
SCALE		N/A		REV.	
FIGURE B4					



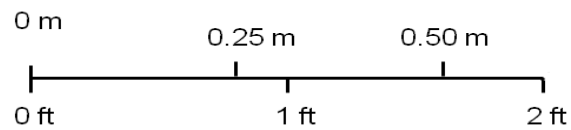
Elevation 199.1 m to 195.9 m




Elevation 199.3 m to 198.4 m



Elevation 199.6 m to 199.1 m



PROJECT			HWY 542								
			Blue Jay Creek Culvert Site # 49-36/C								
TITLE											
BEDROCK CORE											
 Golder Associates											
						PROJECT No. 12-1191-0014			FILE No. ----		
						DESIGN	MH	Aug 2013	SCALE AS SHOWN REV.		
						CADD	--		FIGURE B5		
						CHECK	AB	Aug 2013			
REVIEW											

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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