



November 15, 2013

FOUNDATION INVESTIGATION REPORT

**CULVERT AT STATION 14+860 (BC5)
REALIGNMENT OF HIGHWAY 66 AT VIRGINIATOWN FROM 10.6 KM EAST OF
HIGHWAY 624 EASTERLY 3.4 KM
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5091-07-00**

Submitted to:
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REPORT

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Table of Contents

PART A – FOUNDATION INVESTIGATION REPORT

1.0 INTRODUCTION.....	1
2.0 SITE DESCRIPTION.....	1
3.0 INVESTIGATION PROCEDURES	1
3.1 Foundation Investigation.....	1
4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS	3
4.1 Regional Geology	3
4.2 General Overview of Local Subsurface Conditions	3
4.2.1 Topsoil	4
4.2.2 Clayey Silt to Gravelly Silty Clay	4
4.2.3 Silt to Silt and Sand.....	4
4.2.4 Sand and Gravel.....	5
4.2.5 Bedrock.....	5
4.3 Groundwater Conditions	6
5.0 CLOSURE	6

REFERENCES

DRAWINGS

Drawing 1 Borehole Locations and Soil Strata

LIST OF APPENDICES

Appendix A Record of Boreholes and Drillholes

List of Symbols and Abbreviations
Lithological and Geotechnical Rock Description Terminology
Record of Boreholes BC5-1 to BC5-3
Record of Drillholes BC5-1 to BC5-3

Appendix B Laboratory Test Results

Figure B1 Grain Size Distribution – Clayey Silt to Gravelly Silty Clay
Figure B2 Plasticity Chart – Clayey Silt to Gravelly Silty Clay
Figure B3 Grain Size Distribution – Silt to Silt and Sand
Figure B4 Grain Size Distribution – Sand and Gravel
Figure B5 Bedrock Core Photographs



PART A

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by McCormick Rankin Corporation (MRC), a member of MMM Group Limited (MMM) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the proposed Culvert BC5, crossing the proposed Highway 66 realignment at Station 14+860. The proposed work is part of the overall Highway 66 realignment from 10.6 km east of Highway 624 easterly 3.4 km. The foundation engineering components within the overall project limits include the engineering of high fill embankments and embankments over swamps; a deep cut section; as well as a number of culverts. The proposed Culvert BC5 is located about 12.9 km east of Highway 624 within the High Fill area H3. The general location of the proposed Culvert BC5 is shown on the Key Plan on Drawing 1.

This report addresses the investigation carried out for the proposed Culvert BC5 only. Separate reports address the foundation investigations for the remaining culverts, swamp crossing/high fill areas and deep cut section.

The purpose of this investigation is to establish the subsurface conditions along the proposed culvert alignment by methods of borehole drilling, rock coring, in situ testing and laboratory testing on selected samples. The centreline of the proposed Highway 66 realignment was staked in the field by MRC and the foundation investigation was carried out at Culvert BC5, as defined in the Terms of Reference. The investigation area is shown in plan on Drawing 1.

2.0 SITE DESCRIPTION

The new Highway 66 alignment is oriented generally in an east-west direction within the Township of McGarry. The proposed culvert will be approximately 32 m long extending across the proposed realigned Highway 66 at about STA 14+860. The land in the vicinity of Culvert BC5 is used for recreation.

In general, the topography in the vicinity of Culvert BC5 consists of rolling terrain, with visible bedrock outcrops. The proposed culvert location is in a lower portion of this rolling terrain in an area with moderate tree cover, with the terrain sloping downward to the culvert from the east and the west, and overall sloping downward towards the north. The ground surface within the limits of the culvert alignment varies between about Elevation 307 m and Elevation 309 m. A detailed description of the subsurface conditions along the culvert alignment is presented in Section 4.0.

3.0 INVESTIGATION PROCEDURES

3.1 Foundation Investigation

The investigation for Culvert BC5 crossing the realigned Highway 66 was carried out between August 16 and 18, 2011, during which time a total of three boreholes were advanced along the proposed culvert alignment. The locations of the boreholes are shown on Drawing 1 and are provided on the Record of Borehole sheets in Appendix A.

The field investigation was carried out using a track-mounted D50 Gas drill rig supplied and operated by Walker Drilling Ltd. (Walker) of Barrie, Ontario. The boreholes were advanced through the overburden using 108 mm inner diameter (I.D.) hollow-stem augers, and/or 'NW' casing with wash boring techniques. In general, soil samples were obtained at intervals of depth of about 0.75 m and 1.5 m, using a 50 mm O.D. split-spoon sampler driven by automatic or cathead hammers, and carried out in accordance with Standard Penetration Test (SPT)



procedures (ASTM D1586, Standard Test Method for Standard Penetration Test). Samples of the bedrock were obtained using an 'NQ' size rock core barrel. Two boreholes were backfilled with bentonite upon completion in accordance with Ontario Regulation 903 Wells (as amended).

The culvert boreholes were advanced to depths ranging between 3.9 m and 13.1 m below existing ground surface, including bedrock coring for lengths between 3.0 m and 3.5 m.

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. A piezometer was installed in Borehole BC5-2 to permit monitoring of the groundwater level at this location. The piezometer consists of a 34 mm diameter PVC pipe with a 1.5 m long slotted screen sealed within the bedrock. The borehole annulus surrounding the piezometer screen was backfilled with sand and the remainder of the borehole was backfilled with bentonite. The piezometer was decommissioned with bentonite in accordance with the regulations.

The fieldwork was observed by a member 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 and rock core samples. The samples were identified in the field, placed in appropriate containers, labelled and transported to our Sudbury and Mississauga geotechnical laboratories 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 soil samples. Uniaxial compression strength (UCS) tests were carried out on selected specimens of the rock core. The results of the laboratory testing on samples of the soil/bedrock from the culvert boreholes are included in Appendix B.

Classification of the rock mass quality of the bedrock with respect to the Rock Quality Designation (RQD) and UCS are described based on Table 3.10 and Table 3.5, respectively, of the Canadian Foundation Engineering Manual (CFEM, 2006)¹. The degree of weathering of the bedrock samples (i.e. fresh to completely weathered) and the strength classification of the intact rock mass based on field identification (i.e. strong to very strong) are described in accordance with Table B.3 and Table B.6, respectively, of the International Society for Rock Mechanics (ISRM²) standard classification system.

The proposed centreline of the new highway alignment was staked in the field by MRC prior to drilling. The as-drilled borehole locations, in stations and offsets, were measured in reference to the centreline alignment and were subsequently converted into MTM NAD 83 coordinates in AutoCAD. Borehole elevations were surveyed by a member of our technical staff in reference to the ground surface elevations at temporary benchmarks, which were installed by MRC prior to the commencement of fieldwork. The borehole locations given in the Record of Borehole sheets and shown on Drawing 1 are positioned relative to MTM NAD 83 northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum. The borehole locations, ground surface elevations and drilled depths are as follows:

¹Canadian Geotechnical Society, 2006. Canadian Foundation Engineering Manual, 4th Edition.

² International Society for Rock Mechanics Commission on Test Methods, 1985. Int. J. Rock Mech.Min. Sci. & Geomech. Abstr. Vol 22, No. 2, pp. 51-60.



Borehole	Location (MTM NAD 83)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing	Easting		
BC5-1	5334864.8	410413.5	307.7	6.3
BC5-2	5334886.8	410403.9	306.6	3.9
BC5-3	5334848.4	410420.7	309.0	13.1

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

In the Quaternary Period, the Virginiatown area was encompassed by glacial Lakes of Barlow and Ojibway. In areas of more turbulent waters in these lakes, coarse grained sediments of sand and gravel were deposited. In the calmer portions of the glacial lakes fine grained sediments consisting primarily of varved clay, were deposited. After Lakes Barlow and Ojibway receded, organic materials were deposited. In the Kirkland Lake area the organic deposits are usually found as fens, bogs and swamps containing varying thicknesses of organics and are often encountered in glaciolacustrine plains (overlying the sand and gravel or clay), along creeks and streams and in bedrock basins (Baker, 1985) ³.

Based on NOEGTS⁴ Mapping, the subsoils in the vicinity of the Highway 66 realignment generally consist of till deposited as a ground moraine. A primarily clay/clayey glaciolacustrine deposit is located further than 1 km north of the realignment. The soils along the Highway 66 realignment consist of variable deposits of organic materials, lacustrine sand, silt and clay and till.

Published literature indicates that the site is located in the Abitibi Subprovince of the Superior Province (OGS, 1991)⁵. The Abitibi Subprovince contains rocks of up to 2.75 Ga in age, is about 800 km by 300 km in area and lies within the southern portion of the Superior Province. Bedrock in this subprovince consists primarily of zones of mafic to intermediate metavolcanic rocks and metasedimentary rocks.

4.2 General Overview of Local Subsurface Conditions

The detailed subsurface soil and groundwater conditions as encountered in the boreholes advanced during this investigation, together with the results of the laboratory tests carried out on selected soil and bedrock samples, are presented on the attached Record of Borehole sheets and the soil laboratory test sheets provided in Appendices A and B. The results of the in situ field tests (i.e. SPT 'N'-values) as presented on the Record of Borehole sheets and in Section 4 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 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 result of the boreholes is shown in profile on Drawing 1. The orientation (i.e. north, south, east, west) stated in the text of the report is typically referenced to project north

³ C.L. Baker, 1985. Quaternary Geology of the Kirkland Lake Area, Districts of Cochrane and Timiskaming; Ontario Geological Survey.

⁴ Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Map Reference Number 32DSW.

⁵ Ontario Geological Survey, 1991. Geology of Ontario, Special Volume 4, Part 1. Eds P.C. Thurston, H.R. Williams, R.H. Sutcliffe and G.M. Stott, Ministry of Northern Development and Mines, Ontario.



and/or up-chainage (along the proposed Highway 66 alignment). For purposes of this report, Highway 66 is oriented east-west.

In general, the subsurface conditions encountered at the site consist of topsoil at the ground surface, underlain at the north and south ends of the culvert by deposits of gravelly silty clay and clayey silt, respectively. The cohesive deposits are underlain by bedrock at the north end of the culvert and by deposits of silt to silt and sand, underlain by a deposit of sand and gravel, underlain by bedrock.

Detailed descriptions of the subsurface conditions along the investigated culvert alignment 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 Topsoil

A 150 mm to 380 mm thick layer of topsoil was encountered from ground surface in the boreholes, ranging from Elevations 309.0 m to 306.6 m.

4.2.2 Clayey Silt to Gravelly Silty Clay

A deposit of cohesive soil comprised of brown gravelly silty clay or clayey silt, trace to some sand, trace organics was encountered below the topsoil in Boreholes BC5-2 and BC5-3, respectively. The surface of this deposit was encountered at Elevations 306.4 m and 308.6 m, and the thickness of the deposit is between 0.3 m and 1.1 m at the respective boreholes. The bottom of the deposit is defined by bedrock in Borehole BC5-2.

The SPT 'N'-values recorded within this deposit are 9 blows and 11 blows per 0.3 m of penetration indicating a stiff consistency. One SPT did not penetrate the full sample thickness, inferred to be indicative of the presence of gravel in Borehole BC5-2.

The natural water content measured on two samples of this deposit are about 29 per cent and 36 per cent.

The results of grain size distribution tests completed on two samples of this deposit are shown on Figure B1 in Appendix B.

Atterberg limits tests were carried out on two samples of this deposit and measured liquid limits of about 31 per cent and 47 per cent, corresponding plastic limits of about 20 per cent and 22 per cent and plasticity indices of about 11 per cent and 25 per cent. The results of the Atterberg limits tests are shown on the plasticity chart on Figure B2 in Appendix B and indicate the material is classified as a clayey silt of low plasticity to silty clay of intermediate plasticity.

4.2.3 Silt to Silt and Sand

A 1.8 m and 3.2 m thick deposit of brown to grey, wet silt to silt and sand, trace to some clay, trace gravel was encountered underlying the topsoil in Borehole BC5-1 and underlying the clayey silt deposit in Borehole BC5-3, respectively. The surface of the silt deposit was encountered at Elevations 307.3 m and 307.5 m in the respective boreholes.



The SPT 'N'-values recorded within the silt to silt and sand deposit range from 8 blows to 16 blows per 0.3 m of penetration with one SPT of 70 blows per 0.13 m of penetration indicating a loose to very dense relative density. The SPT test did not penetrate the full sample thickness in Borehole BC5-1, is inferred indicative of the presence of gravel.

The natural water content measured on four selected samples of the deposit is between 16 per cent and 28 per cent.

The result of a grain size distribution test completed on one sample of the silt deposit is shown on Figure B3 in Appendix B. Atterberg limits tests on two samples of the silt to silt and sand deposit indicates that this material is non-plastic.

4.2.4 Sand and Gravel

A 1.1 m and 4.9 m thick deposit of brown to grey, wet sand and gravel, some silt, trace clay was encountered underlying the silt to silt to sand deposit in Boreholes BC5-1 and BC5-3, respectively. The surface of this deposit was encountered at Elevations 305.5 m and 304.3 m. The bottom of the deposit is defined by bedrock.

The SPT 'N'-values recorded within the sand and gravel deposit typically range from 21 blows to 36 blows per 0.3 m of penetration indicating a compact to dense relative density. Three SPTs did not penetrate the full sample depth indicating a very dense relative density.

The natural water content measured on three samples of this deposit ranges from about 8 per cent to 12 per cent.

A grain size distribution test completed on one sample of the sand and gravel deposit is shown on Figure B4 in Appendix B.

4.2.5 Bedrock

Bedrock was encountered in all of the boreholes. The depth to the surface of the bedrock in these boreholes ranges from 0.5 m to 9.6 m below the ground surface corresponding to between Elevation 306.1 m and Elevation 299.4 m.

Bedrock was cored in all the boreholes for lengths between 3.0 m and 3.5 m. The retrieved bedrock core is described as very fine grained to very coarse grained, fresh to completely weathered, dark grey to grey, metasediment or metasiltstone with occasional vertical joints, as presented in the Record of Drillhole sheets in Appendix A. Photographs of the retrieved bedrock core samples are shown on Figure B5.

The Total Core Recovery (TCR) measured on the core samples ranges from 89 per cent to 100 per cent and the Solid Core Recovery (SCR) of the rock core samples range from 0 per cent to 80 per cent. The Rock Quality Designation (RQD) measured on the core samples ranges from 68 per cent to 100 per cent, indicating a rock mass of fair to excellent quality.

Laboratory Uniaxial Compression Strength (UCS) tests were carried out on two selected bedrock core samples from Borehole BC5-1 and BC5-3. The UCS values are presented on the Record of Drillhole sheets in Appendix A and are summarized below, and indicate that the bedrock is very strong.



Borehole	Elevation (m)	UCS (MPa)
BC5-1	301.9	143
BC5-3	297.3	166

4.3 Groundwater Conditions

Groundwater levels were measured in the open boreholes during and upon completion of drilling and a piezometer was installed in Borehole BC5-2, sealed within the bedrock to monitor the groundwater levels. The groundwater levels measured in the open boreholes and piezometer are presented below.

Borehole	Installation	Time and/or Date	Depth to Groundwater (Below ground surface) (m)	Groundwater Elevation (m)
BC5-1	Open Borehole	August 18, 2011	1.8	305.9
BC5-2	Open Borehole	August 16, 2011	2.7	303.9
	Piezometer	November 15, 2012	-0.5 (i.e. above ground surface)	307.1
	Piezometer	May 15, 2013	-0.6 (i.e. above ground surface)	307.2
BC5-3	Open Borehole	August 18, 2011	2.5	306.5

Groundwater elevations as encountered in the open boreholes may not be representative of static groundwater levels since the groundwater levels in the boreholes may not have stabilized on completion of drilling. Furthermore, groundwater elevations will vary depending on seasonal fluctuations, precipitation and local soil permeability.

5.0 CLOSURE

The drilling program was supervised by Mr. Ed Savard. This report was prepared by Ms. Michelle He and Mr. Matt Thibeault, EIT and reviewed by Ms. Sarah Coyne, P.Eng., a senior geotechnical engineer and Associate with Golder. Mr. Jorge M. A. Costa, P.Eng., Golder's Designated MTO Contact for this project and Principal with Golder, conducted an independent quality control review of the report.



Report Signature Page

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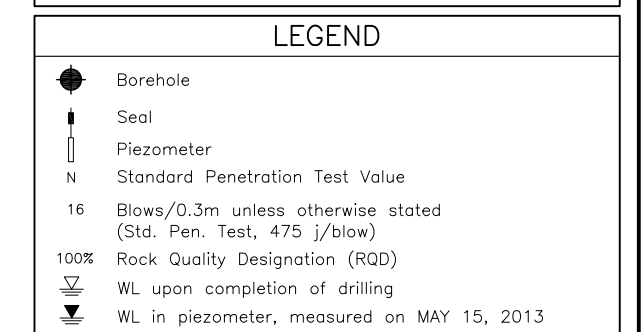
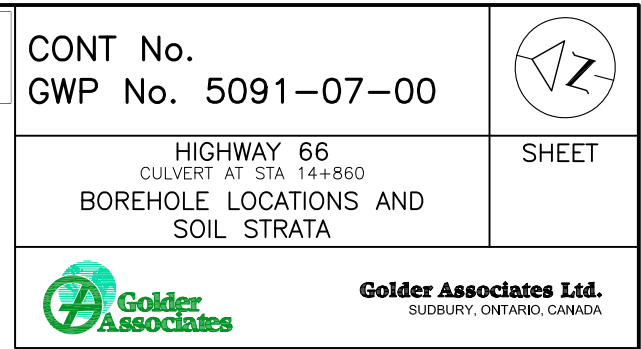
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NOTES

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.

Base plans provided in digital format by MMM, drawing file nos. H3211009D16 ROLL PLAN-ULTIMATE and PDR.dwg, received DEC 3, 2012. Keyplan drawing file nos. H3211009G02 received JAN 24, 2013.

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APPENDIX A

Highway 66 Realignment, Virginiatown — Culvert at STA 14+860 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
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		10-1191-0044				RECORD OF BOREHOLE No BC5-1				1 OF 2 METRIC							
G.W.P.		5091-07-00		LOCATION		N 5334864.8; E 410413.5				ORIGINATED BY EHS							
DIST		HWY 66		BOREHOLE TYPE		108 mm I.D. Continuous Flight Hollow Stem Augers, NW Casing, Wash Boring				COMPILED BY MT							
DATUM		GEODETIC		DATE		August 16, 2011				CHECKED BY SEMC							
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
307.7	GROUND SURFACE																
0.0	TOPSOIL		1	SS	8												
307.3																	
0.4	SILT and SAND, trace clay, trace gravel Very dense Brown to grey Wet		2	SS	15												
			3	SS	7/0.13												
305.5																	
2.2	SAND and GRAVEL Very dense Brown to grey Wet		4	SS	50/0.08												
304.4			5	SS	50/0.05												
3.3	METASEDIMENT (SILTSTONE) (BEDROCK) Bedrock cored from depths of 3.3 m to 6.3 m For bedrock coring details, refer to Record of Drillhole C5-1		1	RC	REC 100%												
			2	RC	REC 100%												
			3	RC	REC 100%												
301.4																	
6.3	END OF BOREHOLE Note: 1. Water level at a depth of 1.8 m below ground surface (Elev. 305.9 m) on August 18, 2011. 2. Spoon bouncing at Samples 3, 4 and 5																

SHEET 2 OF 2

DATUM: GEODETIC

DRILLING CONTRACTOR: Walker Drilling Ltd.

CHECKED: SEMC

SUD-RCK 10-1191-0044SUD.GPJ GAL-MISS.GDT 16/08/13 DATA INPUT:

PROJECT 10-1191-0044				RECORD OF BOREHOLE No BC5-2				1 OF 2 METRIC									
G.W.P. 5091-07-00				LOCATION N 5334886.8; E 410403.9				ORIGINATED BY EHS									
DIST _____ HWY 66				BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers, NW Casing, Wash Boring				COMPILED BY MT									
DATUM GEODETIC				DATE August 16, 2011				CHECKED BY SEMC									
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 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
306.6	GROUND SURFACE																
0.0	TOPSOIL		1a	SS	6/0.25												
306.1	Gravelly SILTY CLAY, trace to some sand, trace rootlets		1b														26 7 43 24
0.5	Firm Brown Wet METASEDIMENT (BEDROCK)		1	RC	REC 100%												RQD = 100%
	Bedrock cored from depths of 0.5 m to 3.9 m																
	For bedrock coring details, refer to Record of Drillhole C5-2		2	RC	REC 89%												RQD = 89%
			3	RC	REC 97%												RQD = 93%
302.7	END OF BOREHOLE																
3.9	Note: 1. Water level at a depth of 2.7 m below ground surface (Elev. 303.9 m) upon completion of drilling. 2. Water level at a depth of 1.0 m below ground surface (Elev. 305.6 m) upon completion of piezometer installation. 3. Water level in piezometer at 0.5 m above ground surface (Elev. 307.1 m) on November 15, 2012 and at 0.6 m above ground surface (Elev. 307.2 m) on May 15, 2013.																

SUD_MTO 003 10-1191-0044SUD.GPJ GAL-MISS.GDT 16/08/13 DATA INPUT:

PROJECT: 10-1191-0044

RECORD OF DRILLHOLE: BC5-2

SHEET 2 OF 2

LOCATION: N 5334886.8 ; E 410403.9

DRILLING DATE: August 16, 2011

DATUM: GEODETIC

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: D50

DRILLING CONTRACTOR: Walker Drilling Ltd.

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	NOTES WATER LEVELS INSTRUMENTATION
		REFER TO PREVIOUS PAGE		306.1									
1	NW	METASEDEMENT Very fine grained Fresh Dark grey		0.5	1	GREY	100%						
2	August 16, 2011 NQ Coring				2	GREY	100%						
3					3	GREY	100%						
4		END OF DRILLHOLE		302.7									
5				3.9									
6													
7													
8													
9													
10													

DEPTH SCALE

1 : 50



LOGGED: EHS

CHECKED: SEMC

SUD-RCK 10-1191-0044SUD.GPJ GAL-MISS.GDT 16/08/13 DATA INPUT:

PROJECT 10-1191-0044		RECORD OF BOREHOLE No BC5-3				1 OF 2 METRIC										
G.W.P. 5091-07-00		LOCATION N 5334848.4; E 410420.7				ORIGINATED BY EHS										
DIST _____ HWY 66		BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers, NW Casing, Wash Boring				COMPILED BY MT										
DATUM GEODETIC		DATE August 18, 2011				CHECKED BY SEMC										
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								
309.0	GROUND SURFACE															
0.0	TOPSOIL		1	SS	11											
308.6																
0.4	CLAYEY SILT, trace sand, trace organics, clay seams Stiff Brown Moist		2	SS	9											
307.5																
1.5	SILT, trace to some clay Loose to compact Brown to grey Wet		3	SS	16											
			4	SS	11											
			5	SS	12											
			6	SS	9											
304.3																
4.7	SAND and GRAVEL, some silt, trace clay Compact to very dense Grey to brown Wet		7	SS	30											
			8	SS	36											
			9	SS	21											
299.4			10	SS	93/0.23											
9.6	METASEDIMENT (BEDROCK) Bedrock cored from depths of 9.6 m to 13.1 m For bedrock coring details, refer to Record of Drillhole C5-3		1	RC	REC 100%											
			2	RC	REC 100%											
			3	RC	REC 93%											
295.9																
13.1	END OF BOREHOLE Note: 1. Water level inside casing at a depth of 2.5 m below ground surface (Elev. 306.5 m) upon completion of drilling.															

SUD_MTO 003 10-1191-0044SUD.GPJ GAL-MISS.GDT 16/08/13 DATA INPUT:

PROJECT: 10-1191-0044

RECORD OF DRILLHOLE: BC5-3

SHEET 2 OF 2

LOCATION: N 5334848.4 ;E 410420.7

DRILLING DATE: August 18, 2011

DATUM: GEODETIC

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: D50

DRILLING CONTRACTOR: Walker Drilling Ltd.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH	RECOVERY	R.Q.D. %	FRACT. INDEX METRES	B Angle	DIP w.r.t. CORE AXIS	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	HYDRAULIC CONDUCTIVITY k, cm/s	Diametral Point Load Index (MPa)	RMC -Q AVG.	NOTES WATER LEVELS INSTRUMENTATION
		REFER TO PREVIOUS PAGE		299.4															
10	NW	METASEDIMENT Very strong Very fine to very coarse grained Fresh to completely weathered Grey		9.6	1	GREY 100%						JN,IR,Ro JN,IR,Ro JN,IR,Ro JN,IR,Ro							
11	August 18, 2011 NQ Coring				2	GREY 100%						JN,FO,K JN,FO,Ro							
12		Completely weathered zone between 12.5 m and 12.6 m depth.			3	GREY 100%						JN,PL,Ro JN,IR,Ro JN,IR,Ro						166 MPa	
13		END OF DRILLHOLE		295.9 13.1															
14																			
15																			
16																			
17																			
18																			
19																			

DEPTH SCALE

1 : 50



LOGGED: EHS

CHECKED: SEMC

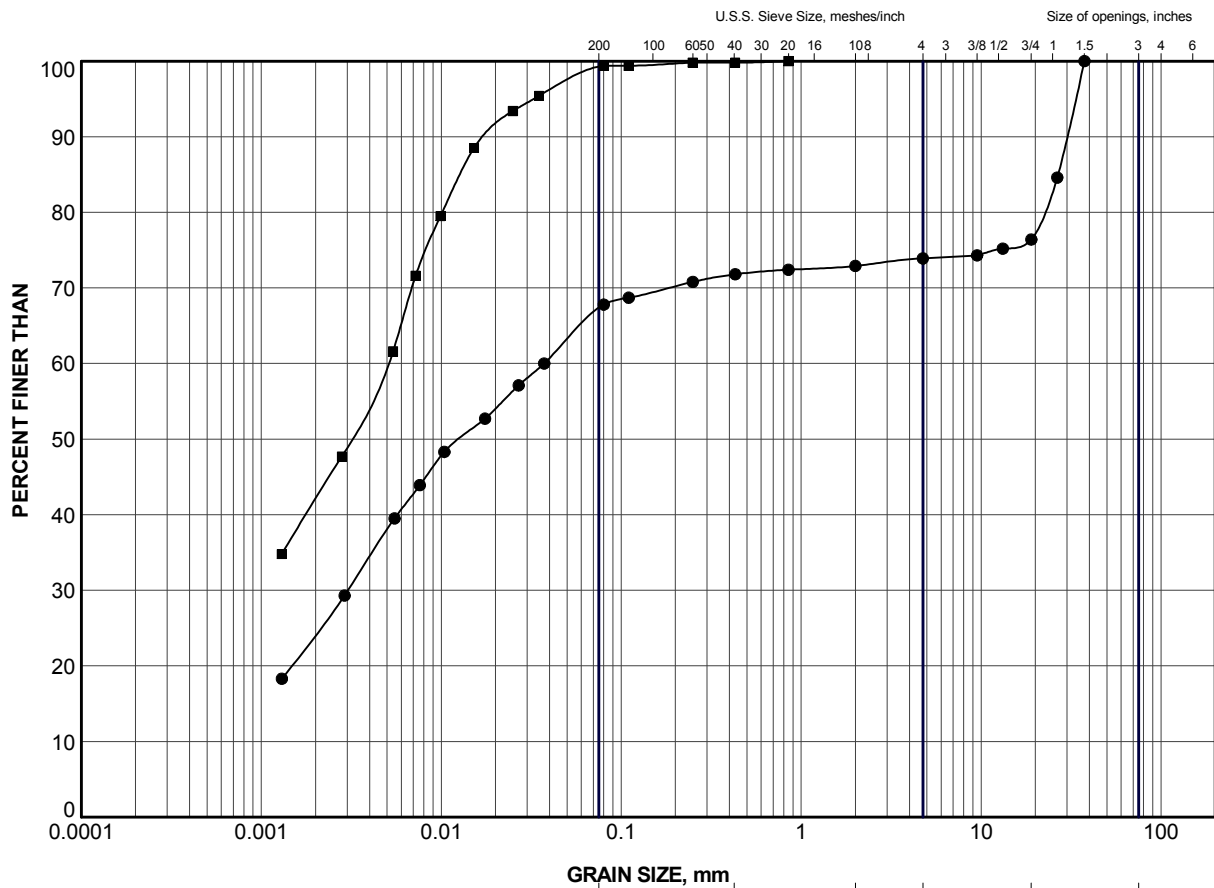
SUD-RCK 10-1191-0044SUD.GPJ GAL-MISS.GDT 16/08/13 DATA INPUT:



APPENDIX B

Highway 66 Realignment, Virginiatown — Culvert at STA 14+860

Laboratory Tests Results



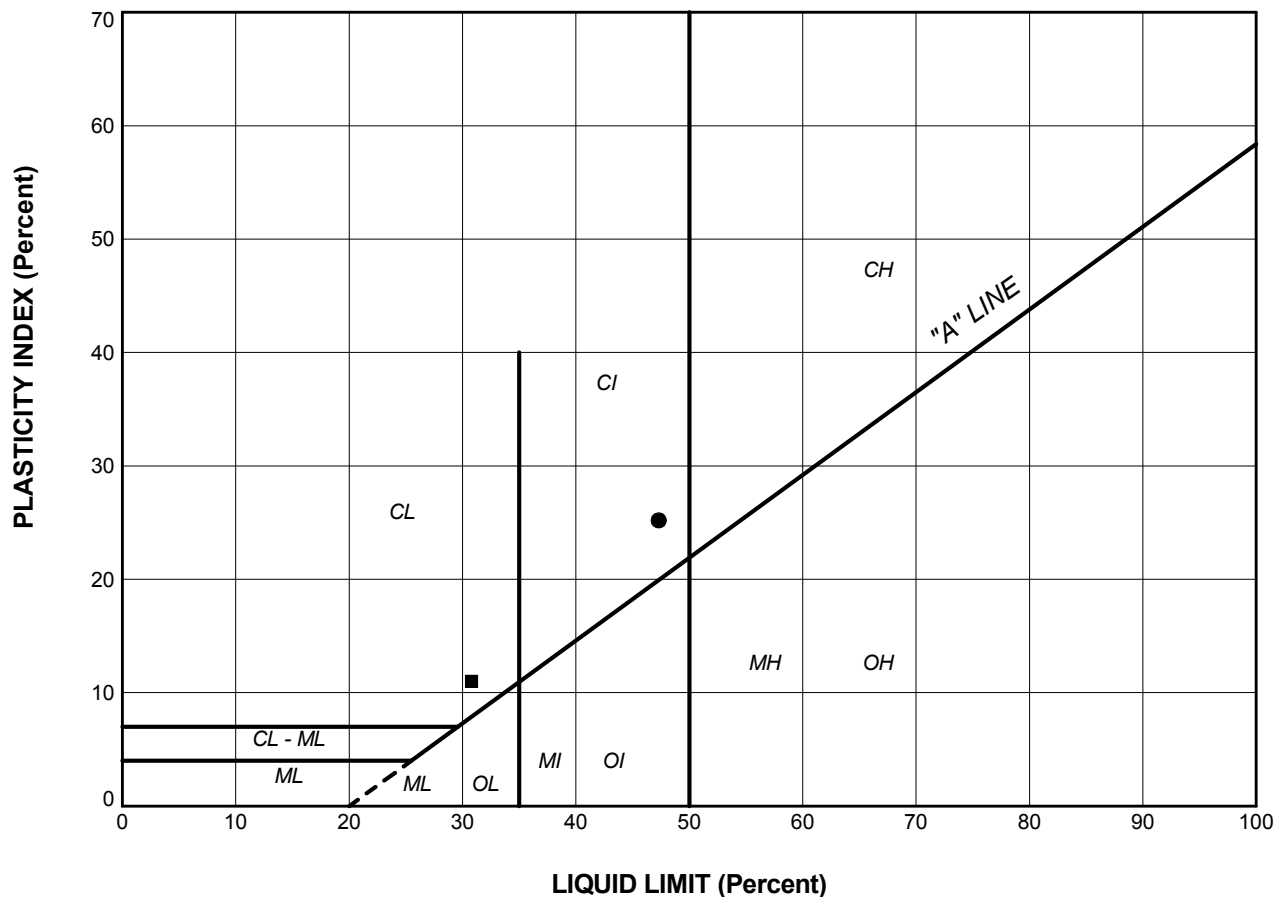
GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BC5-2	1b	306.3
■	BC5-3	2	307.9


PROJECT					
HIGHWAY 66 - CULVERT BC5 STA 14+860					
TITLE					
GRAIN SIZE DISTRIBUTION CLAYEY SILT to GRAVELLY SILTY CLAY					
PROJECT No.		10-1191-0044		FILE No. 10-1191-0044C.GPJ	
DRAWN	JJL	Aug 2013	SCALE	N/A	REV.
CHECK	SEMC	Aug 2013			
APPR		Aug 2013			
			FIGURE B1		

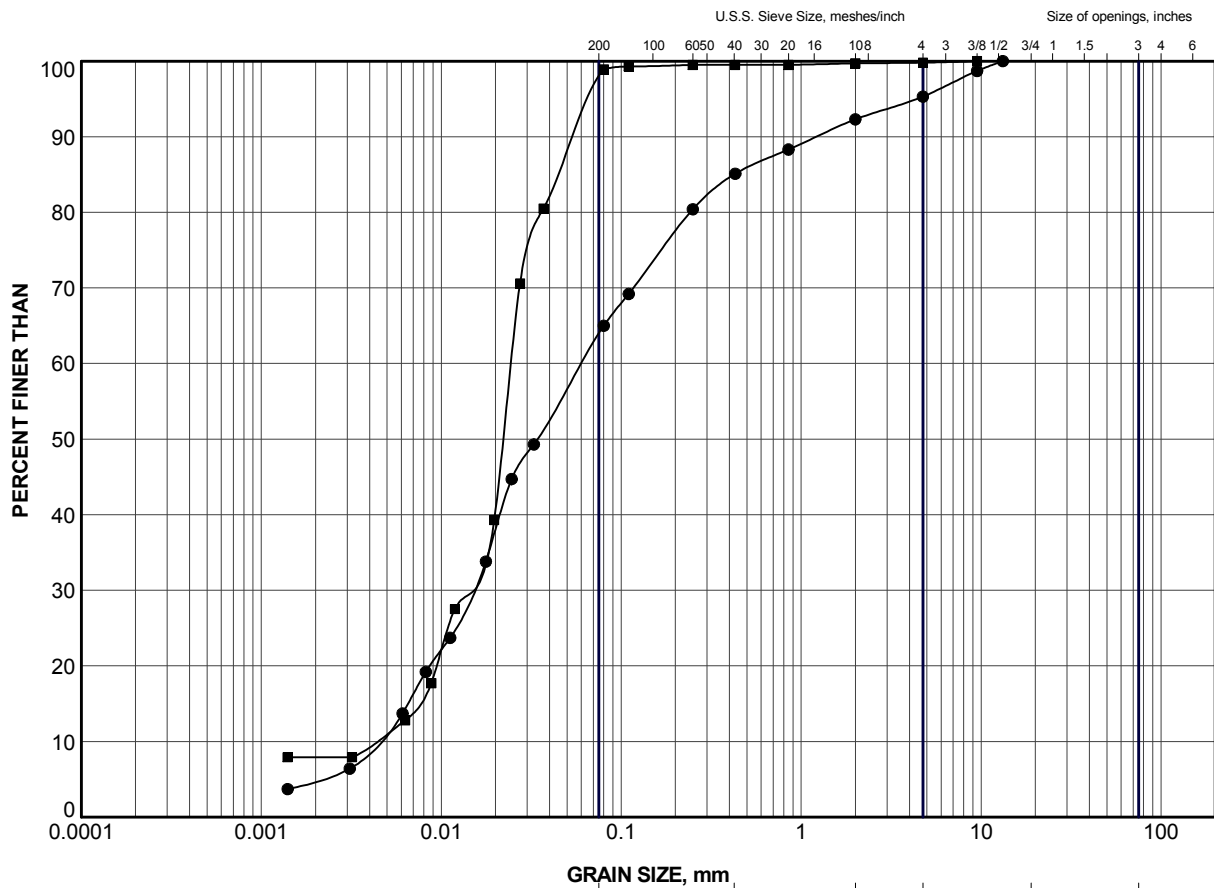




LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	BC5-2	1b	47.3	22.1	25.2
■	BC5-3	2	30.8	19.8	11.0


PROJECT					
HIGHWAY 66 - CULVERT BC5 STA 14+860					
TITLE					
PLASTICITY CHART CLAYEY SILT to GRAVELLY SILTY CLAY					
PROJECT No.		10-1191-0044		FILE No.	
DRAWN		J.J.L.		Aug 2013	
CHECK		SEMC		Aug 2013	
APPR				Aug 2013	
 Golder Associates SUDBURY, ONTARIO				SCALE N/A REV.	
				FIGURE B2	

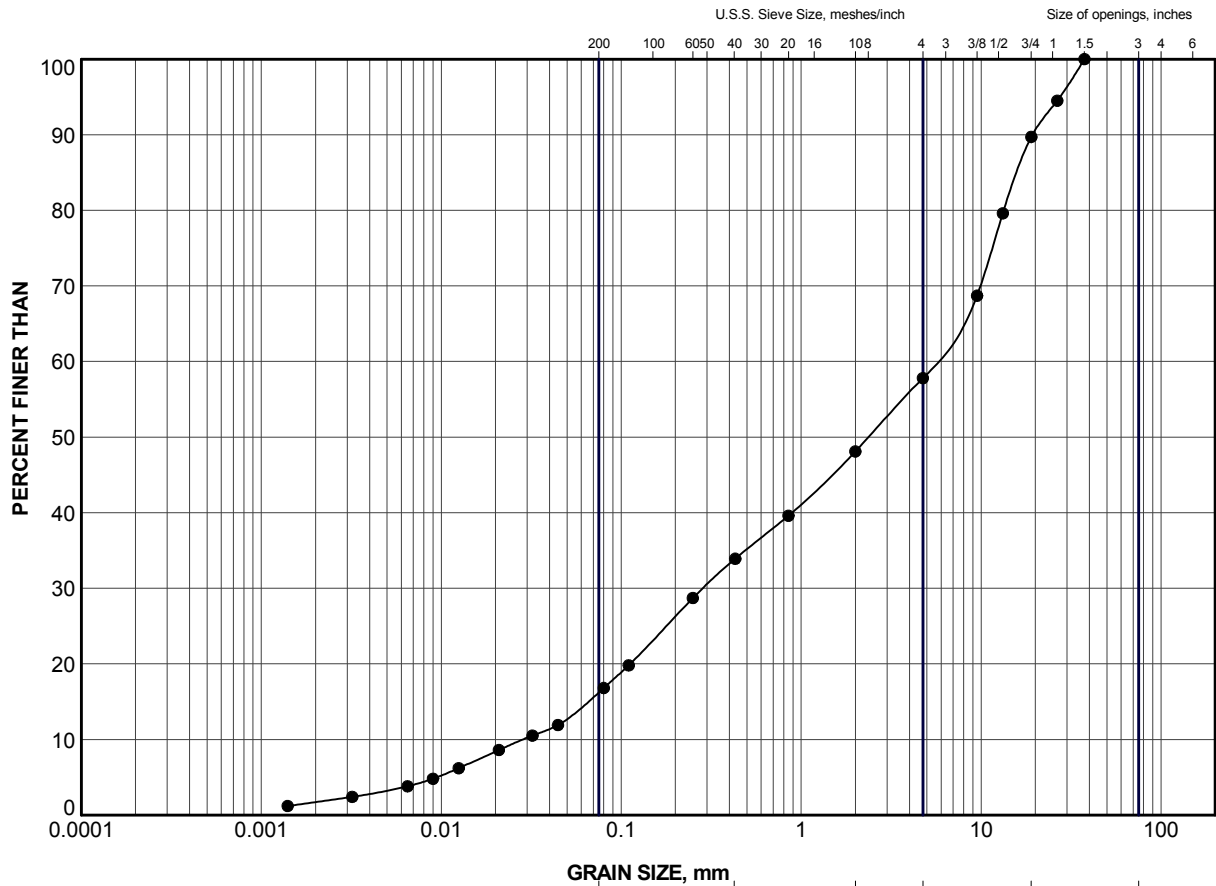


GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND


SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BC5-1	3	306.1
■	BC5-3	5	305.6

PROJECT					
HIGHWAY 66 - CULVERT BC5 STA 14+860					
TITLE					
GRAIN SIZE DISTRIBUTION SILT to SILT and SAND					
PROJECT No.		10-1191-0044		FILE No. 10-1191-0044C.GPJ	
DRAWN	JJL	Aug 2013	SCALE	N/A	REV.
CHECK	SEMC	Aug 2013			
APPR		Aug 2013			
 Golder Associates SUDBURY, ONTARIO			FIGURE B3		

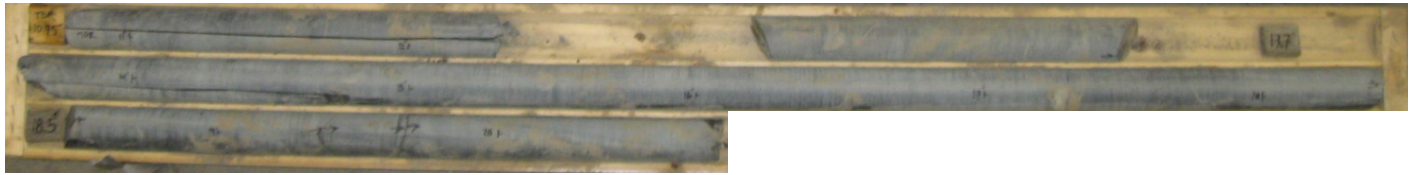


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

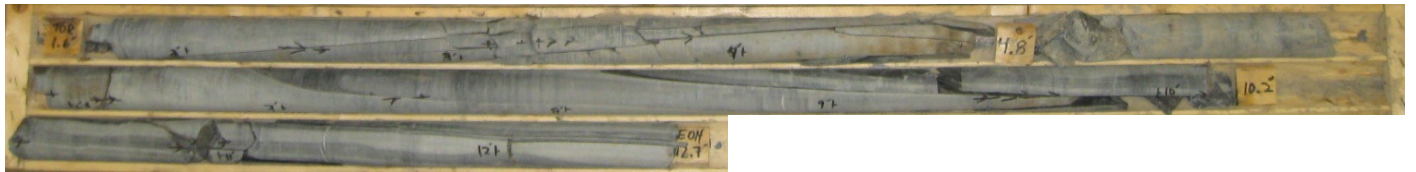
LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BC5-3	8	302.6

PROJECT					
HIGHWAY 66 - CULVERT BC5 STA 14+860					
TITLE					
GRAIN SIZE DISTRIBUTION SAND AND GRAVEL					
		PROJECT No.		10-1191-0044	
		FILE No.		10-1191-0044C.GPJ	
		DRAWN	JJL	Aug 2013	SCALE N/A
		CHECK	SEMC	Aug 2013	REV.
		APPR		Aug 2013	
					FIGURE B4

SUD-MTO GSD GLDR_LDN.GDT



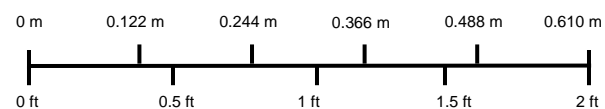
Borehole BC5-1
Elevation 304.4 m to 301.4 m




Borehole BC5-2
Elevation 306.1 m to 302.7 m



Borehole BC5-3
Elevation 299.4 m to 295.9 m



PROJECT		HIGHWAY 66 – Culvert BC5 STA 14+860			
TITLE		BEDROCK CORE PHOTOGRAPHS			
	PROJECT No. 10-1191-0044			FILE No. ----	
	DESIGN	MT	APR 2013	SCALE	AS SHOWN
	CADD	--			REV.
	CHECK	SEMC	APR 2013	FIGURE B5	
	REVIEW	JMAC	APR 2013		

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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