



FINAL REPORT

**Foundation Investigation
Borthwick Creek Culvert Rehabilitation
Site No. 3-730/C, Highway 417
Ottawa, Ontario**

G.W.P. No. 4099-11-00

W.P. 4326-13-01

Submitted to:

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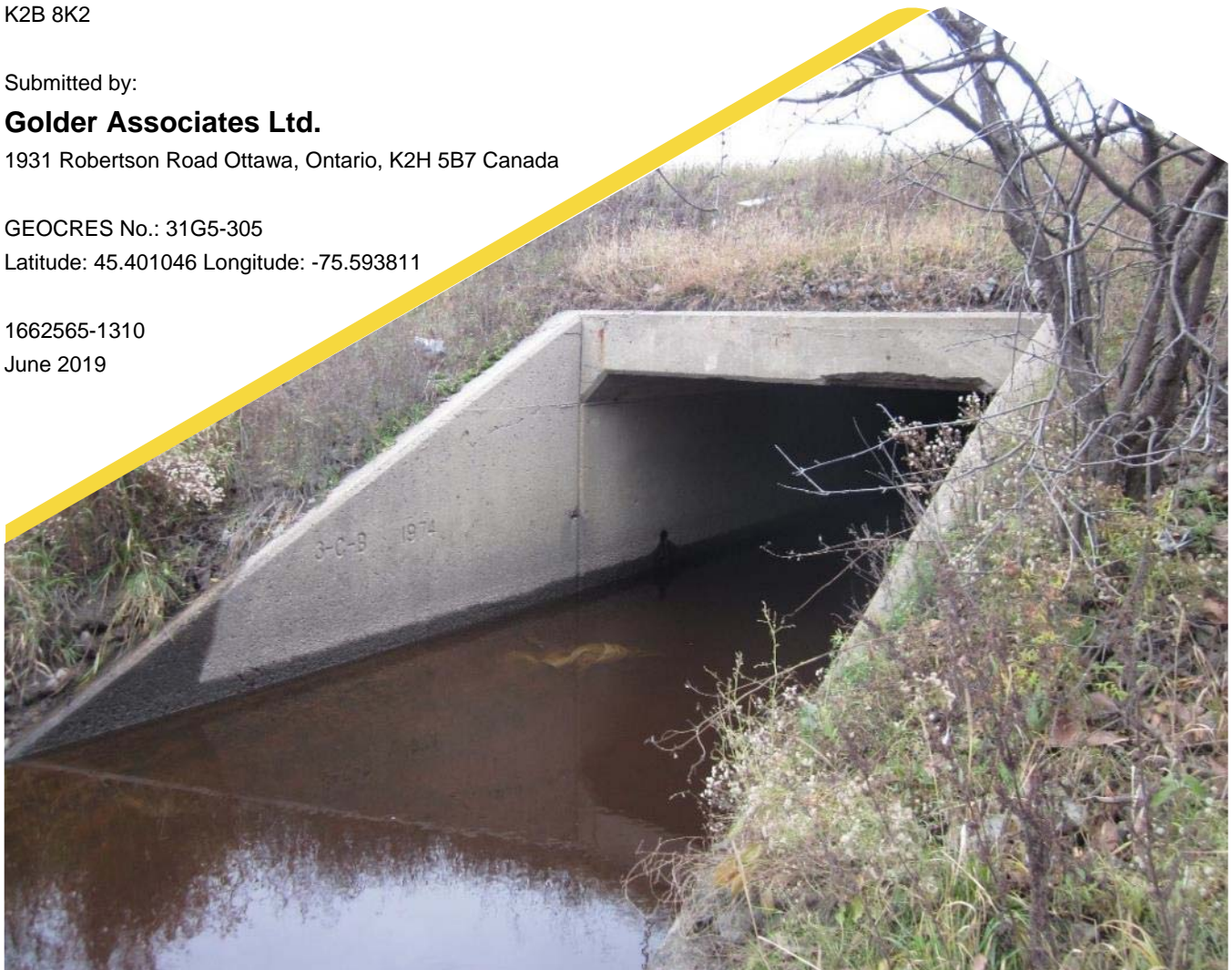
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Table of Contents

PART A – FOUNDATION INVESTIGATION

1.0 INTRODUCTION	1
2.0 SITE DESCRIPTION AND GEOLOGY	1
2.1 General.....	1
2.2 Regional Geology.....	2
3.0 INVESTIGATION PROCEDURES	2
3.1 Current Investigation (2018).....	2
3.2 Previous Investigation (1973).....	3
4.0 DESCRIPTION OF SUBSURFACE CONDITIONS	4
4.1 General.....	4
4.2 Site Stratigraphy Overview.....	4
4.3 Surficial Materials.....	4
4.4 Fill.....	5
4.5 Silty Clay	5
4.6 Glacial Till.....	5
4.7 Bedrock	6
4.8 Groundwater Conditions	7
4.9 Steel Corrosion and Sulphate Attack, Chemical Analysis	7
5.0 CLOSURE	8

TABLES

Table 1: Borehole Summary 2018 Investigation	3
Table 2: Summary of Bedrock Surface Depths and Elevation	6
Table 3: Summary of Groundwater Conditions	7
Table 4: Steel Corrosion and Sulphate Attack, Chemical Analysis.....	7

DRAWINGS

Drawing 1 - Borthwick Creek Culvert Rehabilitation, Borehole Locations and Soil Strata

APPENDICES**APPENDIX A****Record of Boreholes and Drillholes - Current Investigation**

Lists of Abbreviations and Symbols

Lithological and Geotechnical Rock Description Terminology

Records of Boreholes 18-3101 to 18-3105

Bedrock Core Photographs, Figures A1 to A9

APPENDIX B**Laboratory Test Results, Current Investigation**

Figure B1 – Plasticity Chart – Clay

Figure B2 – Grain Size Distribution Test Results – Clay

Figure B3 – Grain Size Distribution Test Results – Silty Gravel and Sand (Till)

Figure B4 – Grain Size Distribution Test Results – Gravelly Silty Clay some Sand (Till)

Figure B5 – Plasticity Chart – Glacial Till

Figure B6 – Summary of Laboratory Compressive Strength Unconfined Compression Tests

APPENDIX C**Borehole Record and Laboratory Test Results
(Previous Investigation, GEOCREs No. 31G05-091)**

Records of Previous Boreholes BH 3 to BH 5

Laboratory Test Results

Bore Hole Location and Soil Strata Drawing

APPENDIX D**Basic Chemical Analysis – Eurofins Report Number 1816326****APPENDIX E****Site Photographs**

PART A

Foundation Investigation
Borthwick Creek Culvert Rehabilitation
Site No. 3-730/C, Highway 417
Ottawa, Ontario
G.W.P. No. 4099-11-00
W.P. 4326-13-01

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by WSP Canada Group Limited (WSP) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out foundation investigations associated with numerous bridge and structural culvert rehabilitations and/or replacements on Highway 417 between the Aviation Parkway and Ramsayville Road as well as the widening of Highway 417 from Ottawa Regional Road 174 (OR 174) to Hunt Club Road in Ottawa, Ontario (Assignment number 4016-E-0008).

This report presents the results of the foundation investigation carried out for the proposed rehabilitation and possible temporary water diversion systems associated with the Borthwick Creek culvert (Site No. 3-730/C) located beneath the eastbound and westbound lanes of Highway 417 in Ottawa, Ontario, (G.W.P. 4099-11-00 and W.P. 4326-13-01).

The terms of reference and scope of work for the foundation investigation are outlined in the MTO's Request for Proposal (RFP), dated May 2016, and subsequent addenda. Golder's scope of work for foundation engineering services associated with this culvert site is contained in Table 17.8.3 of WSP's Technical Proposal for this assignment. The work has been carried out in accordance with Golder's Quality Control Plan for foundation engineering services for this project dated May 13, 2017.

2.0 SITE DESCRIPTION AND GEOLOGY

2.1 General

Culvert 3-730/C is located at approximate Station 16+950 on Highway 417, approximately 350 m northwest of the Highway 417 / Walkley Road Interchange in Ottawa, Ontario. The location of the culvert is shown on the Key Plan on Drawing 1. Site photographs showing the general conditions at the site are present in Appendix E.

Highway 417 at this location has two through lanes in each direction consisting of a rural cross section with partially paved shoulders and ditches. The eastbound off-ramp and the westbound on-ramp for the Walkley Road Interchange also extend over the existing culvert. The travelled lanes including the on and off ramps are generally separated by vegetated median ditches.

Archival construction drawings indicate that the existing 116 m long, closed bottom, concrete culvert has an internal span of 3.0 m and height of 2.4 m. Based on the noted invert elevations of the culvert of between Elevations 60.5 and 60.7 m, the existing culvert is likely founded in the silty clay strata. The flow in the culvert is from east to west.

The existing pavement grade at the culvert location is at approximate Elevation 65.5 m in the eastbound and westbound lanes of Highway 417. Upwards of 2.0 m of fill has been placed over top of the existing culvert beneath the travel lanes of the highway; however only up to 1.0 m of fill was noted at the culvert inlet and outlet. Limited cover should also be anticipated within the median ditchlines. The existing embankment slopes at the culvert location are grass and brush covered and appear to be performing well with no signs of slope instability/distress observed during Golder's field investigation program.

2.2 Regional Geology

As delineated in *The Physiography of Southern Ontario*¹, this section of Highway 417 lies within the minor physiographic regions known as the Ottawa Valley Clay Plain, which lies within the major physiographic region of the Ottawa-St. Lawrence Lowland.

The Ottawa Valley Clay Plain region is characterized by relatively thick deposits of sensitive marine clay, silt and silty clay that were deposited within the Champlain Sea basin. These deposits, known as the Champlain Sea clay or Leda clay, overlie relatively thin, commonly reworked glacial till and glaciofluvial deposits, that in turn overlie bedrock².

This region is underlain by a series of sedimentary rocks, consisting of sandstones, dolostones, limestones and shales that are, in turn, underlain at depth by igneous and metamorphic bedrock of the Precambrian Shield. Regional bedrock mapping indicates that the bedrock at this site is primarily shale of the Carlsbad Formation.³ The shales were described as thinly bedded and fine grained.

The site falls within the Western Québec (WQ) seismic zone according to the Geological Survey of Canada. The WQ zone constitutes a large area which encompasses the urban areas of Montreal, Ottawa-Hull and Cornwall. Within the WQ zone recent seismic activity has been concentrated in two subzones; one along the Ottawa River and another more active subzone along the Montreal-Maniwaki axis. The two major earthquakes in the WQ zone includes the 1935 Témiscaming event which had a magnitude (i.e., a measure of the intensity of the earthquake) of 6.2, and the 1944 Cornwall-Massena event which had a magnitude of 5.6.

3.0 INVESTIGATION PROCEDURES

3.1 Current Investigation (2018)

The subsurface investigation for the culvert rehabilitation was carried out between August 9 and 20, 2018, and included advancing a total of five boreholes designated 18-3101 to 18-3105, inclusive. The NAD83 CSRS CBNv6-2010.0 MTM Zone 9 locations and ground surface elevations of the boreholes are shown on Drawing 1.

The embankment and median boreholes 18-3102 through 18-3104 were advanced using 108 mm inside diameter (200 mm outside diameter) continuous flight hollow stem augers on a track mounted drill rig, supplied and operated by George Downing Estate Drilling Ltd. These boreholes were drilled to depths ranging from about 11.3 to 12.4 m below the existing ground surface. The remaining inlet and outlet boreholes were advanced using a portable rotary drill equipment operated by Ohlmann Geotechnical Services Inc. and drilled to depths of 9.5 and 10.5 m below the existing ground surface.

Soil samples from the embankment and median boreholes were obtained at vertical intervals of about 0.76 m, using a 50 mm outside diameter split spoon samplers in general accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586). The inlet and outlet boreholes were sampled in continuous increments of about 0.6 m with a 50 mm outer diameter split-spoon sampler also in accordance with ASTM D1586. In-situ vane testing was carried out within the cohesive deposits, where possible, specifically in Boreholes 18-3102 and 18-3105.

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. Ontario Ministry of Natural Resources.

² Belanger, J.R. "Urban Geology of Canada's National Capital Area", in *Urban Geology of Canadian Cities*, Geological Association of Canada Special Paper 42, Ed. P.F. Karrow and O.L. White, 1998.

³ Williams, D.A. Rae, A.M., and Wolf, R.R. 1984: Paleozoic Geology of the Ottawa Area, Southern Ontario, Ontario Geological Survey, Map P.2716. Geological Series-Preliminary Map, scale 1:50,000. Geology 1982.

Upon reaching refusal to casing advancement, the boreholes were advanced into the bedrock surface to depths of 3.2 to 3.5 m using rotary diamond drilling techniques while retrieving NQ sized core. A water truck was on site to supply the drill rigs with water for advancing the casing in the overburden and for the coring the bedrock. Traffic control required to allow the water truck and support vehicles to park adjacent to the site was supplied by Beacon Lite Ltd. of Ottawa, Ontario.

A monitoring well was installed in Borehole 18-3103 to monitor the groundwater level at the site. The monitoring wells consisted of 30 mm inside diameter PVC tubing with a 1.5 m long screen. The final groundwater levels were measured in the well on October 12, 2018 and then the well was decommissioned in accordance with O.Reg 903.

The remainder of the boreholes were backfilled with bentonite mixed with soil cuttings. The site conditions were restored following completion of the field work.

The field work was supervised on a full-time basis by members of Golder's staff who located the boreholes in the field, directed the drilling, sampling and in-situ testing operations, logged the boreholes, and examined and cared for the soil samples. The soil samples were identified in the field, placed in appropriate containers, and transported to Golder's laboratory in Ottawa for further examination and testing. Index and classification tests consisting of water content determinations, Atterberg Limits testing, and grain size distribution analyses were carried out on selected soil samples. In addition, an unconfined compressive strength test was also carried out on a single bedrock core sample. The laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate.

One soil sample from Borehole 18-3102 was submitted to Eurofins Environment Testing for chemical analysis related to potential corrosion of exposed buried steel and potential sulphate attack on buried concrete elements (corrosion and sulphate attack).

The borehole locations and elevations were surveyed by Golder using a Trimble R8 GPS unit referenced to the NAD83 CSRS CBNv6-2010.0 MTM Zone 9 geodetic datum. The borehole locations, including northing and easting coordinates, ground surface elevations, and drilled depths are summarized in Table 1.

Table 1: Borehole Summary 2018 Investigation

Borehole	Location	NAD83 CSRS CBNv6-2010.0 MTM Zone 9		Ground Surface Elevation (m)	Borehole Depth (m)
		Northing (m)	Easting (m)		
18-3101	East End of Culvert (inlet)	5029446.7	375790.2	64.1	10.5
18-3102	WBL Embankment	5029437.9	375759.6	65.6	12.3
18-3103	Highway Vegetated Median	5029433.7	375731.2	64.1	11.3
18-3104	EBL Embankment	5029426.8	375708.3	65.2	12.4
18-3105	West End of Culvert (outlet)	5029422.9	375681.0	63.1	9.5

3.2 Previous Investigation (1973)

A previous investigation was carried out in 1973 by the Ministry of Transportation and Communications, Ontario for the design of the existing culvert. The results of that investigation are contained in the report titled "Foundation Investigation Report for Proposed Culverts at the Crossing of the Borthwick Creek Diversion and the Walkley Rd. Extension Hwy. #417, District No. 9 (Ottawa), W.O. 71-11146 – W.P. 10-69-21/22" dated March 9, 1973 (GEOCREs No. 31G05-091).

As part of the current assignment, previously collected subsurface information pertinent to the site was reviewed and compiled.

A total of five boreholes were advanced at the site as part of the 1973 investigation, with three boreholes (Borehole 3 to 5) located along the then-proposed culvert alignment. The Record of Borehole sheets and laboratory testing results from the previous investigation are provided for reference in Appendix C.

The approximate borehole locations and ground surface elevations are included on the Record of Borehole and are also shown on Drawing 1. The locations and ground surface elevations of the previous test hole locations should be considered approximate since the locations were referenced to an imperial borehole location plan and elevation datum rather than metric MTM coordinates.

4.0 DESCRIPTION OF SUBSURFACE CONDITIONS

4.1 General

The subsurface soil, bedrock and groundwater conditions encountered in the boreholes and the results of in-situ and laboratory testing from the current investigation are given on the Record of Borehole sheets presented in Appendix A. Photographs of the bedrock cored during the current investigation are provided in Figures A1 to A9 also provided in Appendix A. The results of geotechnical laboratory testing from the current investigation are presented on Figures B1 to B6 in Appendix B. The results of basic chemical analysis carried out on a single soil sample from Borehole 18-3102 are included in Appendix D. The borehole locations and the interpreted stratigraphic profile along the proposed alignment of the trenchless diversion pipe installation (north of the existing culvert) are shown on Drawing 1.

The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic section 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.

4.2 Site Stratigraphy Overview

In general, the subsurface conditions at the borehole locations consist of a thin layer of surficial topsoil materials (median, inlet/outlet boreholes) extending down to depths of 0.1 and 0.2 (Elevations 63.0 m to 64.0 m) or asphalt (roadway shoulder boreholes) extending down to a depth of 0.1 m (Elevations 65.0 m and 65.5 m). Below the surficial topsoil materials, the pavement structure and embankment fill materials, where encountered, extend down to depths of 1.4 to 2.4 m (Elevations 62.7 m to 64.0 m) overlying a clay / silty clay deposit extending down to depths of 4.4 to 6.7 m (Elevations 58.5 m to 59.5 m). The fill materials and clay / silty clay overlie a glacial till that extends down to depths of between 6.3 to 8.9 m (Elevations 56.0 to 56.8 m). The overburden materials are underlain by a shale bedrock. The depth to the bedrock surface was proved by coring in all boreholes at depths ranging between 6.3 and 8.9 m (Elevations 56.0 to 56.8 m). The boreholes from the current investigation were terminated in bedrock.

The groundwater level was measured at a depth of 1.3 m (Elevations 62.8 m) in Borehole 18-3103.

4.3 Surficial Materials

Boreholes 18-3102 and 18-31-04 were advanced through the Highway 417 pavement shoulder structure. The thickness of the asphalt at the borehole locations was 100 mm.

A layer of topsoil was encountered at the ground surface in Boreholes 18-3101, 18-3103 and 18-3105. The thickness of this layer ranged from 100 to 200 mm at the borehole locations.

4.4 Fill

Gravel and Sand

A fill layer consisting predominantly of gravel and sand with varying amounts of silt was encountered below the asphalt in the embankment boreholes 18-3102 and 18-3104. The top of this layer was encountered at Elevation 65.5 and 65.1 m. The thickness of the layer was 2.2 and 2.3 m. The SPT N values ranged from 3 to 31, indicating a very loose to dense condition, but typically compact. Cobbles were noted in this layer.

Silty Clay

A silty clay fill layer with varying amounts of sand and gravel was encountered beneath the topsoil layer in the median Borehole 18-3103. The top of this layer was encountered at Elevation 63.9 m. The thickness of the layer was 1.2 m. The SPT N values ranged from 7 to 15, indicating a stiff to very stiff consistency.

The moisture content for one soil sample was 23 percent.

4.5 Silty Clay

A grey-brown weathered clay crust deposit was encountered beneath the fill materials in the embankment boreholes and below the topsoil in Boreholes 18-3101, 18-1303 and 18-3105. The top of this layer ranges from Elevation 62.7 to 64.0 m. The thickness of this layer ranged from 1.7 to 2.0 m. The SPT N values ranged from 2 to 26, indicating a firm to very stiff consistency but typically very stiff.

The moisture content of the samples tested ranged from 29 to 51 percent. The results of grain size analysis testing conducted on samples of this material are illustrated on Figure B2 in Appendix B. The results of three Atterberg Limits tests completed on this material indicated liquid limits ranging from 56 to 57, plastic limits ranging from 19 to 21, and plasticity indices ranging from 34 to 37. Atterberg Limits analysis results are illustrated on Figure B1 in Appendix B and indicate a clay with high plasticity (CH).

A grey silty clay deposit was encountered beneath the clay crust in all boreholes. The top of this layer ranges from Elevation 60.8 to 62.0 m. The thickness of this layer ranged from 1.8 to 2.5 m. The SPT N values ranged from 1 to 13 for the silty clay. In-situ shear vane test results indicated undrained shear strengths of the silty clay ranges from 50 to 75 kPa, indicating a stiff consistency. Based on the ratio of the measured in-situ natural shear strength to the remolded shear strength ranging from 5.3 to 8.0 the silty clay is classified as sensitive.

The moisture content of the samples tested ranged from 28 to 44 percent. The results of six Atterberg Limits tests completed on this material indicated liquid limits ranging from 29 to 38, plastic limits ranging from 17 to 18, and plasticity indices ranging from 12 to 20. Atterberg Limits analysis results are illustrated on Figure B1 in Appendix B and indicate a silty clay with a low to intermediate plasticity to clayey silt (CL to CI).

4.6 Glacial Till

Silty Gravel and Sand

A non-cohesive glacial till deposit consisting of a heterogeneous mixture of sand, gravel and silt was encountered beneath the silty clay layer in Boreholes 18-3101, 18-3103 and 18-3104. The top of this layer ranges from Elevation 58.5 to 59.5 m. The thickness of this layer ranged from 1.8 to 2.8 m. The SPT N values ranged from 24 to greater than 100 indicating a compact to very dense condition, but typically dense. Cobbles and boulders were noted in this layer.

The moisture content of the samples tested ranged from 1 to 16 percent. The results of grain size analysis testing conducted on samples of this material are illustrated on Figure B3 in Appendix B.

Gravelly Silty Clay

A cohesive glacial till deposit consisting of a heterogeneous mixture of clay and silt with varying amounts of sand and gravel was encountered beneath the silty clay layer in Boreholes 18-3102 and 18-3105. The top of this layer ranges from Elevation 58.7 to 59.5 m. The thickness of this layer ranged from 1.9 to 2.8 m. The SPT N values ranged from 2 to 57, indicating firm to hard consistency, but typically stiff to very stiff. Cobbles and boulders were noted in this layer which may account for the higher SPT N values recorded.

The moisture content of the samples tested ranged from 8 to 12 percent. The results of grain size analysis testing conducted on samples of this material are illustrated on Figure B4 in Appendix B. The results of two Atterberg Limits tests completed on this material indicated liquid limits ranging from 18 to 20, plastic limits ranging from 12 to 15, and plasticity indices ranging from 5 to 6. Atterberg Limits analysis results are illustrated on Figure B5 in Appendix B and indicate a silty clay to clayey silt (CL-ML).

4.7 Bedrock

The overburden materials were underlain by a grey shale. Bedrock geology mapping indicates the shale bedrock is of the Carlsbad Formation. The boreholes were advanced into bedrock by coring with NQ-size coring equipment. Photographs of the bedrock core are provided in Appendix A.

Table 2 summarizes the depth to, and the elevation of the bedrock surface as encountered at the borehole locations from the current investigation.

Table 2: Summary of Bedrock Surface Depths and Elevation

Borehole Number	Existing Ground Surface Elevation (m)	Depth to Bedrock Surface (m)	Bedrock Surface Elevation (m)	Cored Length (m)
18-3101	64.1	7.3	56.8	3.2
18-3102	65.6	8.9	56.7	3.4
18-3103	64.1	8.1	56.0	3.2
18-3104	65.2	8.9	56.3	3.5
18-3105	63.1	6.3	56.8	3.2

The bedrock encountered in these boreholes consist of slightly weathered to fresh, thinly to thickly bedded, grey, fine grained, porous shale with limestone partings. The Rock Quality Designation (RQD) values measured on recovered bedrock core samples ranged from about 34 to 100 percent but was more typically from 70 to 100 percent indicating a fair to excellent quality.

Unconfined compressive strength testing was carried out on a single specimen of bedrock core; (see results on Figure B5 in Appendix B). Based on the measured compressive strength of 35 MPa, the shale bedrock is classified as medium strong.

4.8 Groundwater Conditions

A groundwater monitoring well was installed in Borehole 18-3103 to monitor the groundwater level at the site. Table 3 summarizes the depths and elevations of the groundwater level measured in the monitoring well on October 12, 2018, some two months after installation.

Table 3: Summary of Groundwater Conditions

Borehole	Ground Surface Elevation (m)	Screened Interval Material	Water Level	
			Depth (m)	Elevation (m)
18-3103	64.1	Bedrock	1.3	62.8

It is expected that the groundwater level will be subject to fluctuations both seasonally and as a result of precipitation events.

4.9 Steel Corrosion and Sulphate Attack, Chemical Analysis

One soil sample from Borehole 18-3102 was submitted to Eurofins Environment Testing for chemical analysis related to potential corrosion of exposed buried steel and potential sulphate attack on buried concrete elements (corrosion and sulphate attack). The test results are provided in Appendix D and are summarized in Table 4.

Table 4: Steel Corrosion and Sulphate Attack, Chemical Analysis

Borehole	Sample Depth (m)	Sample Type	Chloride (%)	pH	Electrical Conductivity (mS/cm)	Resistivity (ohm-cm)	Sulphate Soil (%)
18-3102	3.1 – 3.7	Clay	0.107	8.11	2.02	495	0.02

5.0 CLOSURE

This Foundation Investigation Report was prepared by Mr. Kenton Power, P.Eng. and was reviewed by Mr. Michael Snow, P.Eng., a Principal and senior geotechnical engineer with Golder. Mr. Fin Heffernan, P.Eng., Golder's Designated MTO Foundations Contact for this project, conducted an independent quality review of the report.

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Designated MTO Foundations Contact



KCP/MSS/FJH/mvrd

[https://golderassociates.sharepoint.com/sites/11263g/shared documents/01_foundations/6 - reports/1310 borthwick/final/1662565-1310-r-rev0-borthwick creek culvert-06-2019_fir.docx](https://golderassociates.sharepoint.com/sites/11263g/shared%20documents/01_foundations/6%20-%20reports/1310_borthwick/final/1662565-1310-r-rev0-borthwick%20creek%20culvert-06-2019_fir.docx)

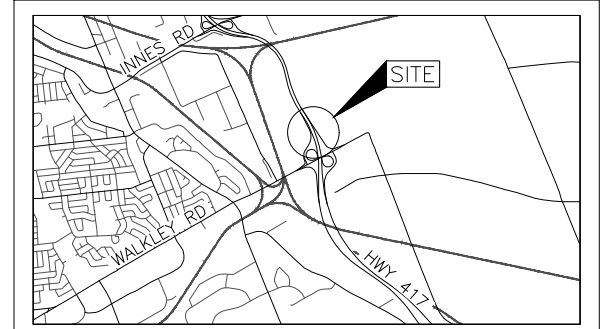
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METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

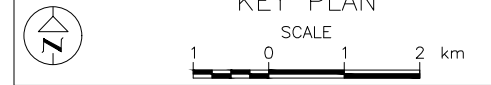
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BORTHWICK CREEK CULVERT REHABILITATION
HIGHWAY 417
BOREHOLE LOCATIONS AND SOIL STRATA
LAT. 45.4010468 LONG. -75.593811



SHEET

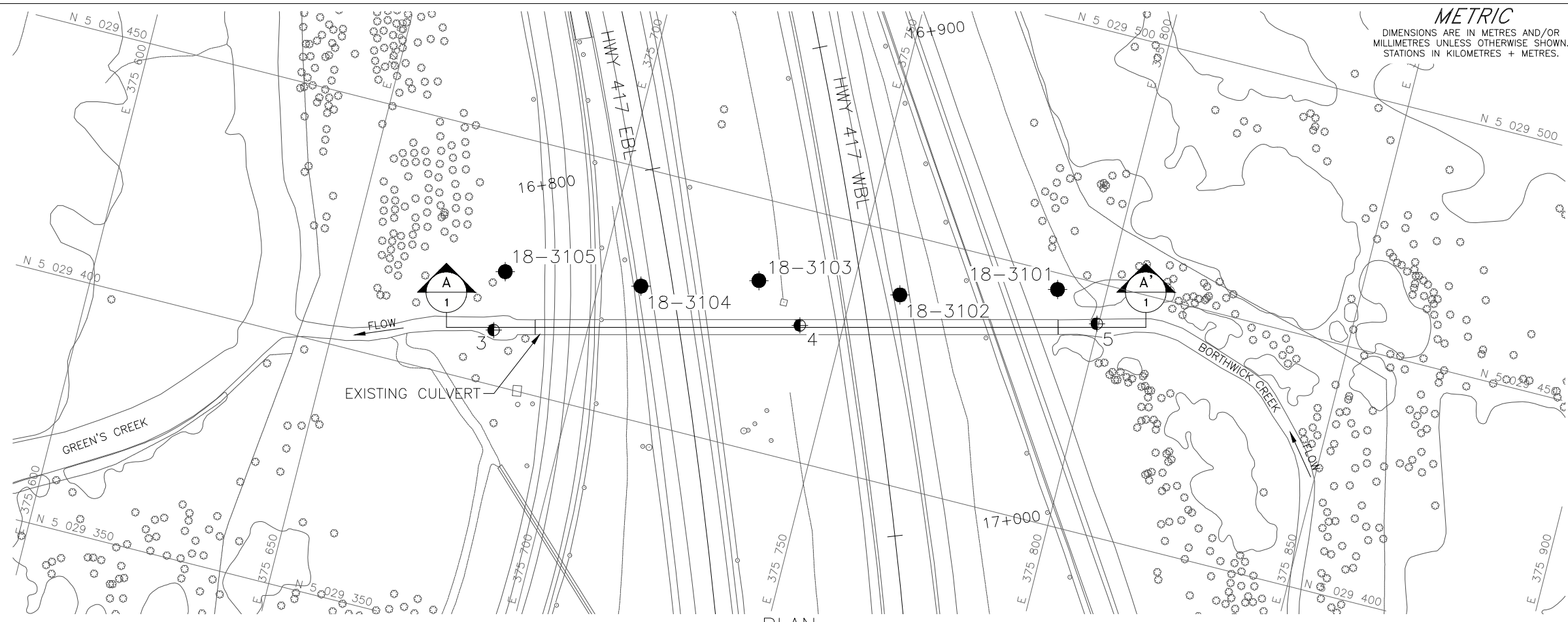


KEY PLAN

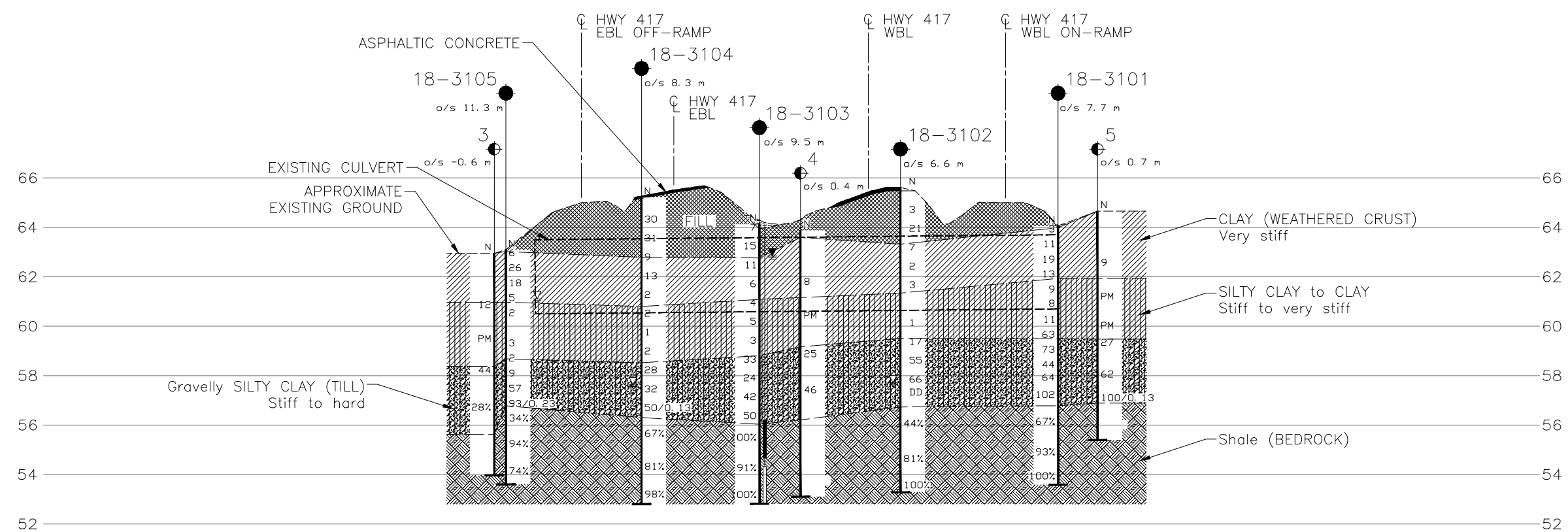


LEGEND

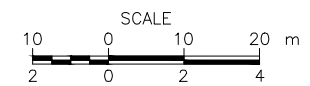
- Borehole - Current Investigation
- Borehole - Previous Investigation (Geocres No. 31605-091)
- ⊥ Seal
- ⊥ Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% Rock Quality Designation (RQD)
- ⊥ WL in piezometer, measured on Oct. 12, 2018
- ⊥ WL upon completion of drilling



PLAN



PROFILE A-A'



BOREHOLE CO-ORDINATES (MTM ZONE 9)			
No.	ELEVATION	NORTHING	EASTING
18-3101	64.1	5029446.7	375790.2
18-3102	65.6	5029437.9	375759.6
18-3103	64.1	5029433.7	375731.2
18-3104	65.2	5029426.8	375708.3
18-3105	63.1	5029422.9	375681.0
3	63.0	5029410.8	375681.6
4	63.9	5029426.9	375741.5
5	64.7	5029442.0	375799.7

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 WSP, drawing file nos. XA1-NAD 83.dwg and XB1-NAD 83 (CSRS).dwg, received APR. 19, 2017.

NO.	DATE	BY	REVISION

Geocres No. 3165-305		PROJECT NO. 1662565-1310		DIST. EASTERN	
HWY. 417	CHKD. KP	DATE: 6/17/2019	SITE: 3-730/C		
SUBM'D. KP	CHKD. KP	APPD. FJH	DWG. 1		

PLOT DATE: 15 2019
 FILENAME: N:\Active\Projects\1662565_1310\1662565_1310\1662565-1310-001.dwg



APPENDIX A

Record of Boreholes and Drillholes - Current Investigation

Lists of Abbreviations and Symbols

Lithological and Geotechnical Rock Description Terminology

Records of Boreholes 18-3101 to 18-3105

Bedrock Core Photographs, Figures A1 to A9

LIST OF SYMBOLS

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

I.	GENERAL	(a)	Index Properties (continued)
π	3.1416	w	water content
$\ln x$,	natural logarithm of x	w_l or LL	liquid limit
\log_{10}	x or log x, logarithm of x to base 10	w_p or PL	plastic limit
g	acceleration due to gravity	I_p or PI	plasticity index = $(w_l - w_p)$
t	time	w_s	shrinkage limit
FoS	factor of safety	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)
II.	STRESS AND STRAIN	(b)	Hydraulic Properties
γ	shear strain	h	hydraulic head or potential
Δ	change in, e.g. in stress: $\Delta \sigma$	q	rate of flow
ε	linear strain	v	velocity of flow
ε_v	volumetric strain	i	hydraulic gradient
η	coefficient of viscosity	k	hydraulic conductivity (coefficient of permeability)
ν	Poisson's ratio	j	seepage force per unit volume
	total stress	(c)	Consolidation (one-dimensional)
σ'	effective stress ($\sigma' = \sigma - u$)	C	compression index (normally consolidated range)
σ'_{vo}	initial effective overburden stress	C_r	recompression index (over-consolidated range)
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, minor)	C_s	swelling index
σ_{oct}	mean stress or octahedral stress = $(\sigma_1 + \sigma_2 + \sigma_3)/3$	C_α	secondary compression index
τ	shear stress	m_v	coefficient of volume change
u	porewater pressure	c_v	coefficient of consolidation (vertical direction)
E	modulus of deformation	C_h	coefficient of consolidation (horizontal direction)
G	shear modulus of deformation	T_v	time factor (vertical direction)
K	bulk modulus of compressibility	U	degree of consolidation
III.	SOIL PROPERTIES	σ'_p	pre-consolidation stress
(a)	Index Properties	OCR	over-consolidation ratio = σ'_p / σ'_{vo}
$\rho(\gamma)$	bulk density (bulk unit weight)*	(d)	Shear Strength
$\rho_d(\gamma_d)$	dry density (dry unit weight)	τ_p, τ_r	peak and residual shear strength
$\rho_w(\gamma_w)$	density (unit weight) of water	ϕ'	effective angle of internal friction
$\rho_s(\gamma_s)$	density (unit weight) of solid particles	δ	angle of interface friction
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)	μ	coefficient of friction = $\tan \delta$
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)	c'	effective cohesion
e	void ratio	C_u, S_u	undrained shear strength ($\phi = 0$ analysis)
n	porosity	p	mean total stress $(\sigma_1 + \sigma_3)/2$
S	degree of saturation	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	$\tau = c' + \sigma' \tan \phi'$
		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, 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.

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

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

Compactness	N
Condition	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.

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

<u>Description</u>	<u>Bedding Plane Spacing</u>
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

<u>Description</u>	<u>Spacing</u>
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

<u>Term</u>	<u>Size*</u>
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 <u>1662565-1310</u>	RECORD OF BOREHOLE No 18-3101	SHEET 1 OF 3	METRIC
G.W.P. <u>4099-11-00</u>	LOCATION <u>N 5029446.7; E 375790.2 NAD 83 MTM ZONE 9 (LAT. 45.401368; LONG. -75.593202)</u>	ORIGINATED BY <u>DJG</u>	
DIST <u>Eastern</u> HWY <u>417</u>	BOREHOLE TYPE <u>Portable Drill, BW Casing/NQ3 Core</u>	COMPILED BY <u>ZS</u>	
DATUM <u>Geodetic</u>	DATE <u>August 9, 2018</u>	CHECKED BY <u>KP</u>	

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	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
			NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
							20	40	60	80	100						
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					WATER CONTENT (%)					
							20	40	60	80	100	25	50	75			
64.1	GROUND SURFACE																
0.0	(ML) Clayey silt (TOPSOIL) Brown Moist		1	SS	3												
	(CH) CLAY (WEATHERED CRUST) Firm to very stiff Grey-brown Moist		2	SS	11												
			3	SS	19												
62.0			4	SS	13												
2.1	(CI/CL) SILTY CLAY Very stiff Grey brown to grey Moist		5	SS	9												
			6	SS	8												
			7	SS	11												
59.5			8	SS	63												
4.6	(GM/SM) SILTY GRAVEL and SAND, contains clay/silt seams (TILL) Very dense Grey Wet		9	SS	73												
59.2			10	SS	44												
4.9	(SM) SILTY SAND, contains silt seams (TILL) Very dense Grey-brown Wet		11	SS	64											36 33 25 6	
58.6			12	SS	102												
5.5	(GM/SM) SILTY GRAVEL and SAND, contains cobbles and boulders (TILL) Dense to very dense Grey-brown Wet																
56.8	Shale (BEDROCK)		1	RC	REC 100%											RQD = 67%	
7.3	Bedrock cored from depths 7.3 m to 10.5 m For bedrock coring details refer to Record of Drillhole 18-3101		2	RC	REC 100%											RQD = 93%	
			3	RC	REC 100%											RQD = 100%	

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

PROJECT <u>1662565-1310</u>	RECORD OF BOREHOLE No 18-3101	SHEET 2 OF 3	METRIC
G.W.P. <u>4099-11-00</u>	LOCATION <u>N 5029446.7; E 375790.2 NAD 83 MTM ZONE 9 (LAT. 45.401368; LONG. -75.593202)</u>	ORIGINATED BY <u>DJG</u>	
DIST <u>Eastern</u> HWY <u>417</u>	BOREHOLE TYPE <u>Portable Drill, BW Casing/NQ3 Core</u>	COMPILED BY <u>ZS</u>	
DATUM <u>Geodetic</u>	DATE <u>August 9, 2018</u>	CHECKED BY <u>KP</u>	

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	20	40	60	80	100	W _p	W			W _L
53.6	--- CONTINUED FROM PREVIOUS PAGE ---	[Hatched Box]	3	RC	REC 100%	54											
10.5	END OF BOREHOLE																

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PROJECT <u>1662565-1310</u>	RECORD OF BOREHOLE No 18-3102	SHEET 1 OF 3	METRIC
G.W.P. <u>4099-11-00</u>	LOCATION <u>N 5029437.9; E 375759.6 NAD 83 MTM ZONE 9 (LAT. 45.401291; LONG. -75.593595)</u>	ORIGINATED BY <u>KM</u>	
DIST <u>Eastern</u> HWY <u>417</u>	BOREHOLE TYPE <u>Power Auger, 200 mm Diam. (Hollow Stem)/NW Casing/NQ3 Core</u>	COMPILED BY <u>ZS</u>	
DATUM <u>Geodetic</u>	DATE <u>August 15-16, 2018</u>	CHECKED BY <u>KP</u>	

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	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 (%)
			NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
65.6	GROUND SURFACE																
0.0	ASPHALTIC CONCRETE																
0.1	(SP/GP) Sand and gravel (FILL) Brown Moist																
65.1																	
0.5	(SP) Gravelly sand, contains cobbles (FILL) Brown Moist						65										
64.5			1	SS	3												
1.1	(SP) Sand, trace gravel (FILL) Compact Brown Moist						64										
63.3			2	SS	21												
2.3	(CH) CLAY (WEATHERED CRUST) Very stiff to stiff Grey-brown Moist						63										
61.3			3	SS	7												
4.3	(CH) CLAY (WEATHERED CRUST) Very stiff to stiff Grey-brown Moist						62										
61.3			4	SS	2												
4.3	(CL/CI) SILTY CLAY, contains silt seams/layers Stiff Grey Moist						61										
59.5			5	SS	3												
6.1	(CL-ML) Gravelly SILTY CLAY, some sand, contains cobbles and boulders (TILL) Very stiff to hard Grey Moist						60										
59.5			6	SS	1												
6.1			7	SS	17		59										19 18 52 11
56.7			8	SS	55												
8.9			9	SS	66		58										
8.9	Shale (BEDROCK)						57										
8.9	Bedrock cored from depths 8.9 m to 12.3 m For bedrock coring details refer to Record of Drillhole 18-3102		1	RC	REC 92%		56										

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

PROJECT 1662565-1310 **RECORD OF BOREHOLE No 18-3103** **SHEET 1 OF 3** **METRIC**
G.W.P. 4099-11-00 **LOCATION** N 5029433.7; E 375731.2 NAD 83 MTM ZONE 9 (LAT. 45.401256; LONG. -75.593958) **ORIGINATED BY** KM
DIST Eastern **HWY** 417 **BOREHOLE TYPE** Power Auger, 200 mm Diam. (Hollow Stem)/NW Casing/NQ3 Core **COMPILED BY** ZS
DATUM Geodetic **DATE** August 19-20, 2018 **CHECKED BY** KP

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	W _p W W _L	25 50 75	GR SA SI CL		
64.1	GROUND SURFACE												
0.0 63.9 0.2	(ML) Sandy silt (TOPSOIL) Dark brown Moist	1	SS	7									
	(CI) Silty clay, some sand, trace gravel, contains sand seams (FILL) Stiff to very stiff Brown Moist	2	SS	15									
62.7 1.4	(CH) CLAY (WEATHERED CRUST) Stiff to very stiff Grey-brown Moist	3	SS	11									
		4	SS	6								0 1 35 64	
61.0 3.1	(CL) SILTY CLAY, contains silt layers Stiff Grey Moist	5	SS	4									
		6	SS	5									
		7	SS	3									
58.8 5.3	(GM/SM) SILTY GRAVEL and SAND, trace clay, contains cobbles, boulders and shale fragments (TILL) Compact to very dense Grey Wet	8	SS	33								38 36 20 6	
		9	SS	24									
		10	SS	42									
		11	SS	50									
56.0 8.1	Shale (BEDROCK) Bedrock cored from depths 8.1 m to 11.3 m For bedrock coring details refer to Record of Drillhole 18-3103	1	RC	REC 100%								RQD = 100%	
		2	RC	REC 100%								RQD = 91%	

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

PROJECT <u>1662565-1310</u>	RECORD OF BOREHOLE No 18-3103	SHEET 2 OF 3	METRIC
G.W.P. <u>4099-11-00</u>	LOCATION <u>N 5029433.7; E 375731.2 NAD 83 MTM ZONE 9 (LAT. 45.401256; LONG. -75.593958)</u>	ORIGINATED BY <u>KM</u>	
DIST <u>Eastern</u> HWY <u>417</u>	BOREHOLE TYPE <u>Power Auger, 200 mm Diam. (Hollow Stem)/NW Casing/NQ3 Core</u>	COMPILED BY <u>ZS</u>	
DATUM <u>Geodetic</u>	DATE <u>August 19-20, 2018</u>	CHECKED BY <u>KP</u>	

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	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
			NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
52.8	Shale (BEDROCK)	[Hatched Pattern]	2	RC	REC 100%	[Pattern]	54									RQD = 91%	
53		[Hatched Pattern]	3	RC	REC 100%	[Pattern]	53									RQD = 100%	
11.3	END OF BOREHOLE NOTES: 1. Water level in well screen at a depth of 1.3 m below ground surface (Elev. 62.8 m), measured on October 12, 2018.																

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PROJECT <u>1662565-1310</u>	RECORD OF BOREHOLE No 18-3104	SHEET 1 OF 3	METRIC
G.W.P. <u>4099-11-00</u>	LOCATION <u>N 5029426.8; E 375708.3 NAD 83 MTM ZONE 9 (LAT. 45.401196; LONG. -75.594251)</u>	ORIGINATED BY <u>KM</u>	
DIST <u>Eastern</u> HWY <u>417</u>	BOREHOLE TYPE <u>Power Auger, 200 mm Diam. (Hollow Stem)/NW Casing/NQ3 Core</u>	COMPILED BY <u>ZS</u>	
DATUM <u>Geodetic</u>	DATE <u>August 16-17, 2018</u>	CHECKED BY <u>KP</u>	

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								WATER CONTENT (%)								
						20	40	60	80	100	20	40	60	80	100	25	50	75		GR	SA	SI	CL	
65.2	GROUND SURFACE																							
0.0	ASPHALTIC CONCRETE																							
0.1	(SP/GP) SAND and GRAVEL (FILL)																							
64.7	Brown Moist																							
0.5	(SM/GM) Gravelly silty sand, contains cobbles (FILL)																							
	Compact Brown Moist		1	SS	30																			
63.5	(SP) Sand, trace gravel (FILL)																							
	Compact Brown Moist		2	SS	31																			
62.8	(CH) CLAY (WEATHERED CRUST)																							
	Firm to very stiff Grey-brown Moist		3	SS	9																			
			4	SS	13																			
			5	SS	2																			
60.8	(CI/CL) SILTY CLAY																							
	Stiff Grey Moist		6	SS	2																			
			7	SS	1																			
			8	SS	2																			
58.5	(GM/SM) SILTY GRAVEL and SAND, contains cobbles and boulders (TILL)																							
	Compact to very dense Grey Moist to wet		9	SS	28																			
			10	SS	32																			
			11	SS	50/0.13																			
56.3	- Contains cobbles and boulders from 8.8 m to 8.9 m depth.																							
8.9	Shale (BEDROCK)																							
	Bedrock cored from depths 8.9 m to 12.4 m		1	RC	REC 93%																			
	For bedrock coring details refer to Record of Drillhole 18-3104																							

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

PROJECT <u>1662565-1310</u>	RECORD OF BOREHOLE No 18-3104	SHEET 2 OF 3	METRIC
G.W.P. <u>4099-11-00</u>	LOCATION <u>N 5029426.8; E 375708.3 NAD 83 MTM ZONE 9 (LAT. 45.401196; LONG. -75.594251)</u>	ORIGINATED BY <u>KM</u>	
DIST <u>Eastern</u> HWY <u>417</u>	BOREHOLE TYPE <u>Power Auger, 200 mm Diam. (Hollow Stem)/NW Casing/NQ3 Core</u>	COMPILED BY <u>ZS</u>	
DATUM <u>Geodetic</u>	DATE <u>August 16-17, 2018</u>	CHECKED BY <u>KP</u>	

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	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
			NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
	--- CONTINUED FROM PREVIOUS PAGE --- Shale (BEDROCK)		1	RC			55									RQD = 67%	
			2	RC	REC 95%		54									RQD = 81%	
			3	RC	REC 100%		53									RQD = 98%	
52.8 12.4	END OF BOREHOLE NOTES: 1. Water level in open borehole at 7.6 m depth (Elev. 57.6 m), measured during drilling (before coring).																

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

PROJECT <u>1662565-1310</u>	RECORD OF BOREHOLE No 18-3105	SHEET 1 OF 2	METRIC
G.W.P. <u>4099-11-00</u>	LOCATION <u>N 5029422.9; E 375681.0 NAD 83 MTM ZONE 9 (LAT. 45.401164; LONG. -75.594601)</u>	ORIGINATED BY <u>DJG</u>	
DIST <u>Eastern</u> HWY <u>417</u>	BOREHOLE TYPE <u>Portable Rotary Drill, BW Casing/NQ3 Core</u>	COMPILED BY <u>ZS</u>	
DATUM <u>Geodetic</u>	DATE <u>August 13, 2018</u>	CHECKED BY <u>KP</u>	

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	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
			NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								20	40	60	80	100					
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					WATER CONTENT (%)				
								20	40	60	80	100	25	50	75		
63.1	GROUND SURFACE																
0.0	(ML) Clayey silt (TOPSOIL) Dark brown Moist		1	SS	6												
	(CH) CLAY, contains trace organic matter (rootlets) (WEATHERED CRUST) Very stiff Grey-brown Moist		2	SS	26								○				
			3	SS	18												
61.0			4	SS	5	▽							┌───┐	○			
2.1	(CL) SILTY CLAY, contains silt layers Stiff to firm Grey Moist to wet		5	SS	2									○			
			6	SS	3			×		+							
			7	SS	2												
58.7	(CL-ML) Gravelly SILTY CLAY, some sand and clay, contains cobbles and boulders (TILL) Firm to hard Grey-brown Wet		8	SS	9												27 32 29 12
4.4			9	SS	57									○			24 23 42 11
56.8	Shale (BEDROCK)		10	SS	93/0.23												
6.3	Bedrock cored from depths 6.3 m to 9.5 m For bedrock coring details refer to Record of Drillhole 18-3105		1	RC	REC 100%												RQD = 34%
			2	RC	REC 100%												RQD = 94%
			3	RC	REC 82%												RQD = 74%
53.6	END OF BOREHOLE																
9.5																	

GTA-MTO 001 N:\ACTIVE\SPATIAL_IMMTO\HWY417REHAB&WIDENING\02_DATA\GINT\1662565.GPJ GAL-GTA.GDT 5/31/19 ZS

Continued Next Page

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

PROJECT <u>1662565-1310</u>	RECORD OF BOREHOLE No 18-3105	SHEET 2 OF 2	METRIC
G.W.P. <u>4099-11-00</u>	LOCATION <u>N 5029422.9; E 375681.0 NAD 83 MTM ZONE 9 (LAT. 45.401164; LONG. -75.594601)</u>	ORIGINATED BY <u>DJG</u>	
DIST <u>Eastern</u> HWY <u>417</u>	BOREHOLE TYPE <u>Portable Rotary Drill, BW Casing/NQ3 Core</u>	COMPILED BY <u>ZS</u>	
DATUM <u>Geodetic</u>	DATE <u>August 13, 2018</u>	CHECKED BY <u>KP</u>	

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	20			40	60	80	100	SHEAR STRENGTH kPa					
	--- CONTINUED FROM PREVIOUS PAGE ---																
	NOTES: 1. Water level in open borehole at 2.0 m depth (Elev. 61.1 m), measured during drilling.																

GTA-MTO 001 N:\ACTIVE\SPATIAL_IMMTO\HWY417REHAB&WIDENING\02_DATA\GINT\1662565.GPJ GAL-GTA.GDT 5/31/19 ZS

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

BH 18-3101 DRY
7.28 m to 10.48 m

7.28 m
BEDROCK
SURFACE



10.48 m END OF
BOREHOLE



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Borthwick Creek Culvert Rehabilitation
Ottawa, Ontario

Project No:	1662565-1310
Drawn:	RK
Date:	27/11/2018
Checked:	
Review:	

FIGURE A1

BH 18-3101 WET
7.28 m to 10.48 m



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Review:	

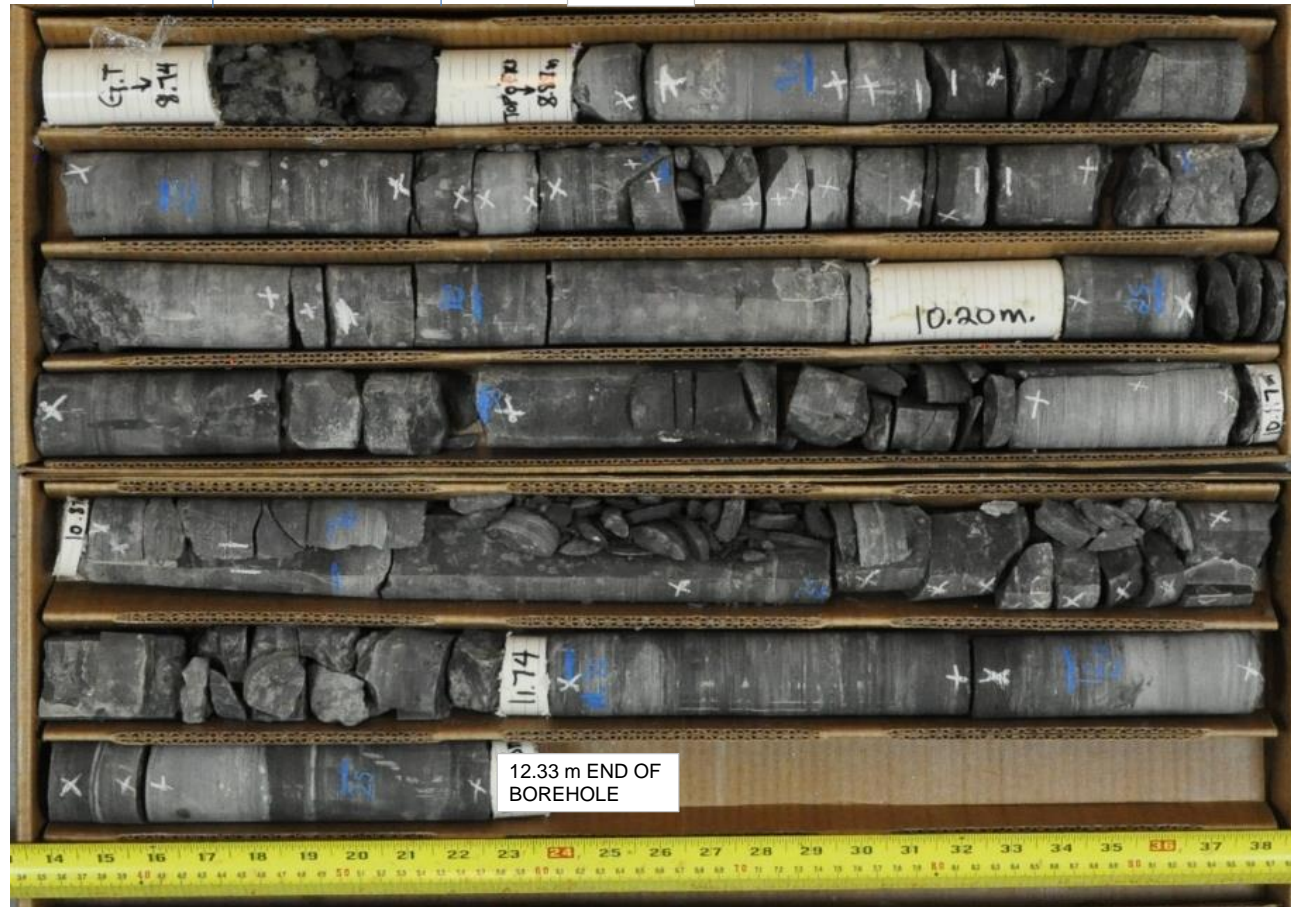
FIGURE A2

BH 18-3102 DRY

8.74 m to 12.33 m

8.74 to 8.88 m GLACIAL TILL

8.88 m
BEDROCK
SURFACE



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Borthwick Creek Culvert Rehabilitation
Ottawa, Ontario

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Date:	27/11/2018
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Review:	

FIGURE A3

BH 18-3103 DRY
8.10 m to 11.32 m

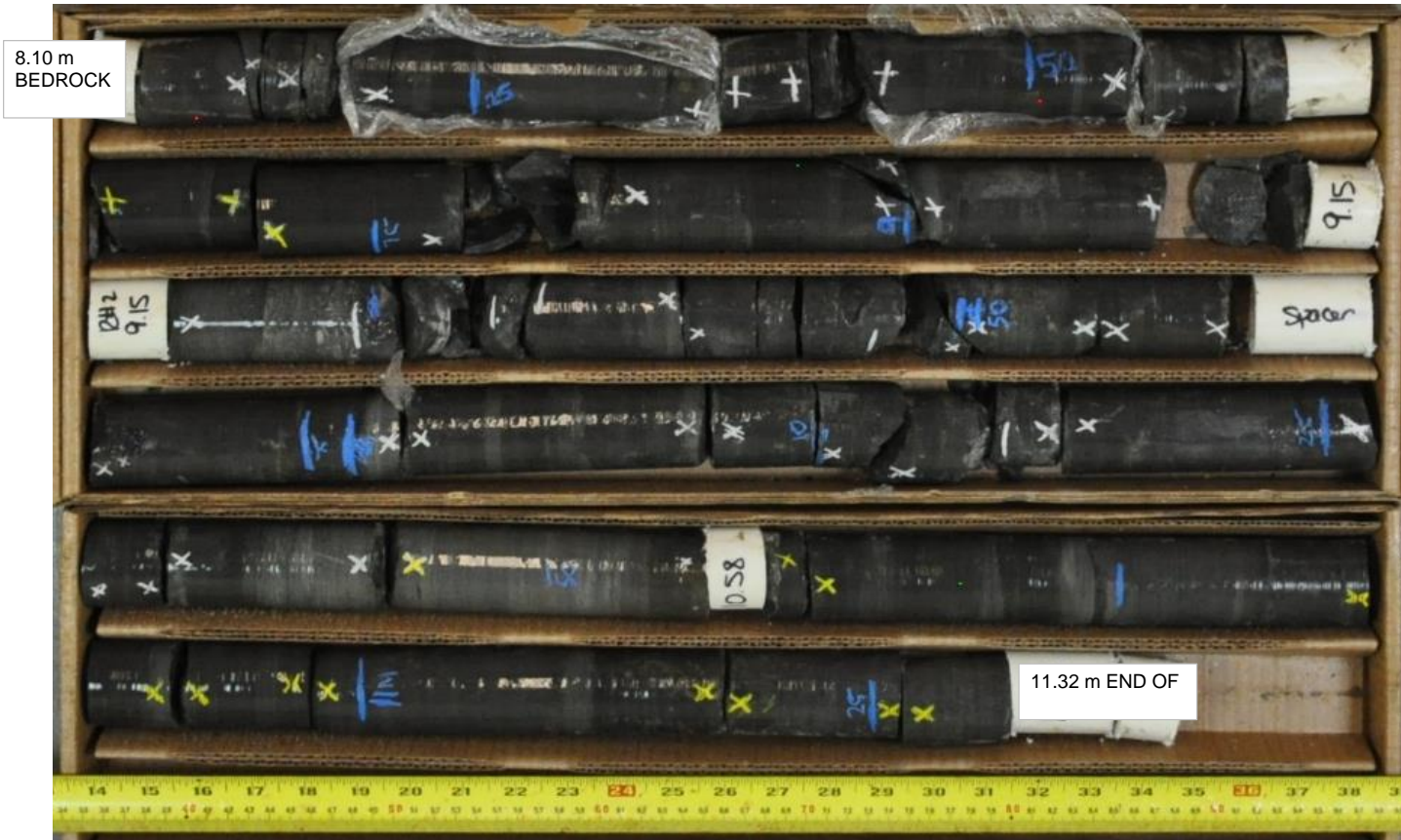


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Ottawa, Ontario

Project No:	1662565-1310
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FIGURE A4

BH 18-3103 WET
8.10 m to 11.32 m



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Ottawa, Ontario

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Date:	27/11/2018
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Review:	

FIGURE A5

BH 18-3104 DRY
8.92 m to 12.42 m

8.84 to 8.92 m
BOULDERS

8.92 m
BEDROCK
SURFACE



Foundation Investigation and Design
Borthwick Creek Culvert Rehabilitation
Ottawa, Ontario

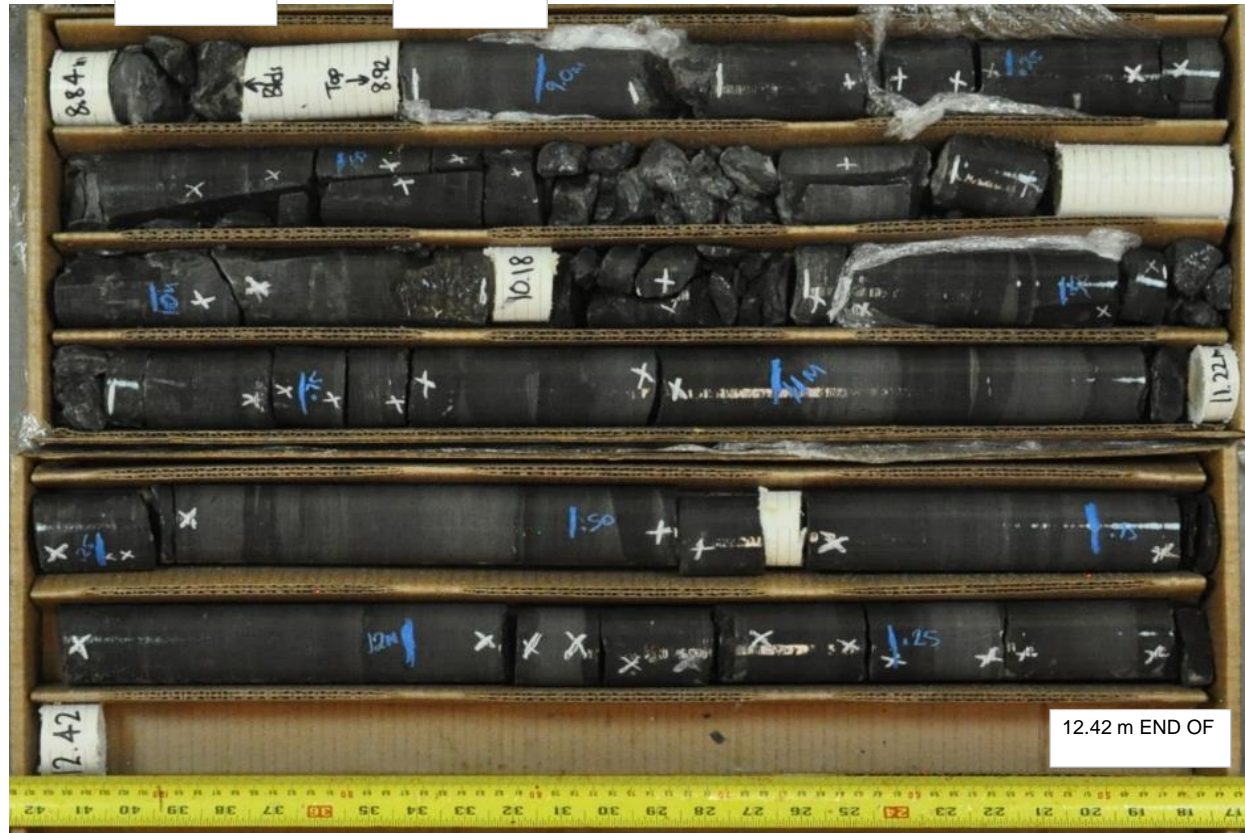
Project No:	1662565-1310
Drawn:	RK
Date:	27/11/2018
Checked:	
Review:	

FIGURE A6

BH 18-3104 WET
8.92 m to 12.42 m

8.84 to 8.92 m
BOULDERS

8.92 m
BEDROCK



12.42 m END OF



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Drawn:	RK
Date:	27/11/2018
Checked:	
Review:	

FIGURE A7

BH 18-3105 DRY
6.32 m to 9.50 m

6.32 m
BEDROCK



9.50 m END
OF
BOREHOLE



Foundation Investigation and Design
Borthwick Creek Culvert Rehabilitation
Ottawa, Ontario

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Drawn:	RK
Date:	27/11/2018
Checked:	
Review:	

FIGURE A8

BH 18-3105 WET
6.32 m to 9.50 m

6.32 m
BEDROCK



9.50 m END
OF
BOREHOLE



Foundation Investigation and Design
Borthwick Creek Culvert Rehabilitation
Ottawa, Ontario

Project No:	1662565-1310
Drawn:	RK
Date:	27/11/2018
Checked:	
Review:	

FIGURE A9

APPENDIX B

Laboratory Test Results - Current Investigation

Figure B1 – Plasticity Chart – Clay

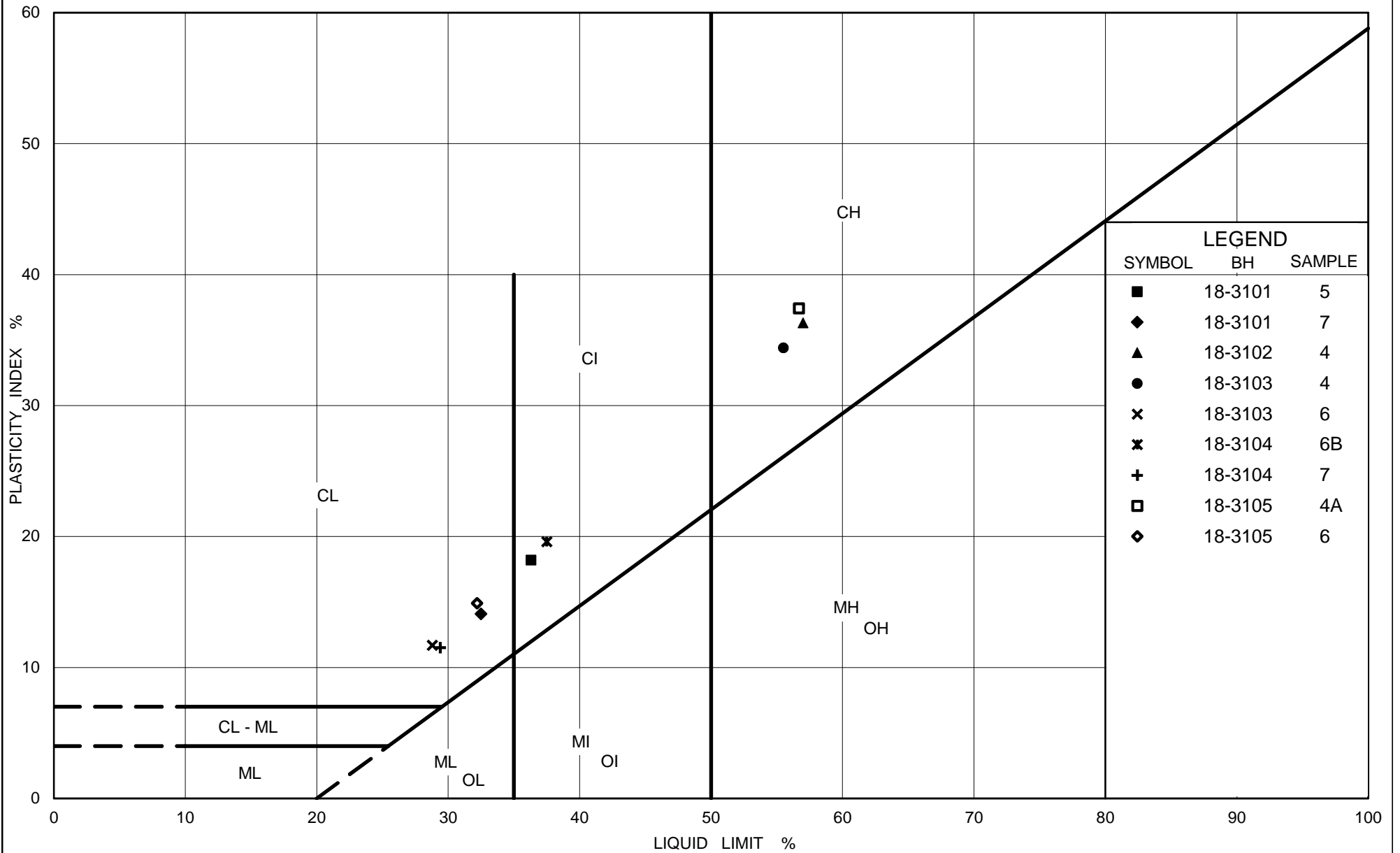
Figure B2 – Grain Size Distribution Test Results – Clay

Figure B3 – Grain Size Distribution Test Results – Silty Gravel and Sand (Till)

Figure B4 – Grain Size Distribution Test Results – Gravelly Silty Clay some Sand (Till)

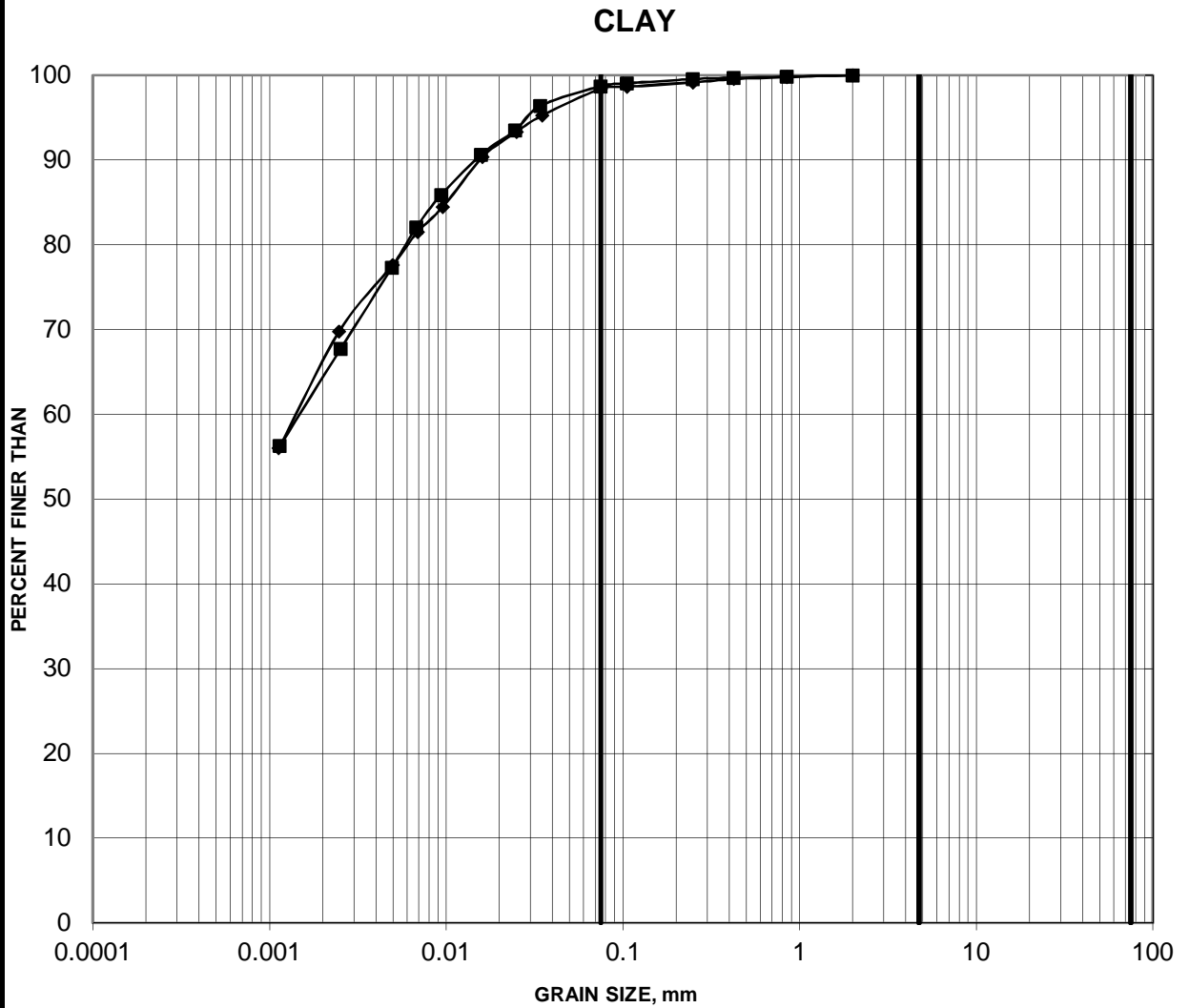
Figure B5 – Plasticity Chart – Glacial Till

Figure B6 – Summary of Laboratory Compressive Strength Unconfined Compression Tests



GRAIN SIZE DISTRIBUTION

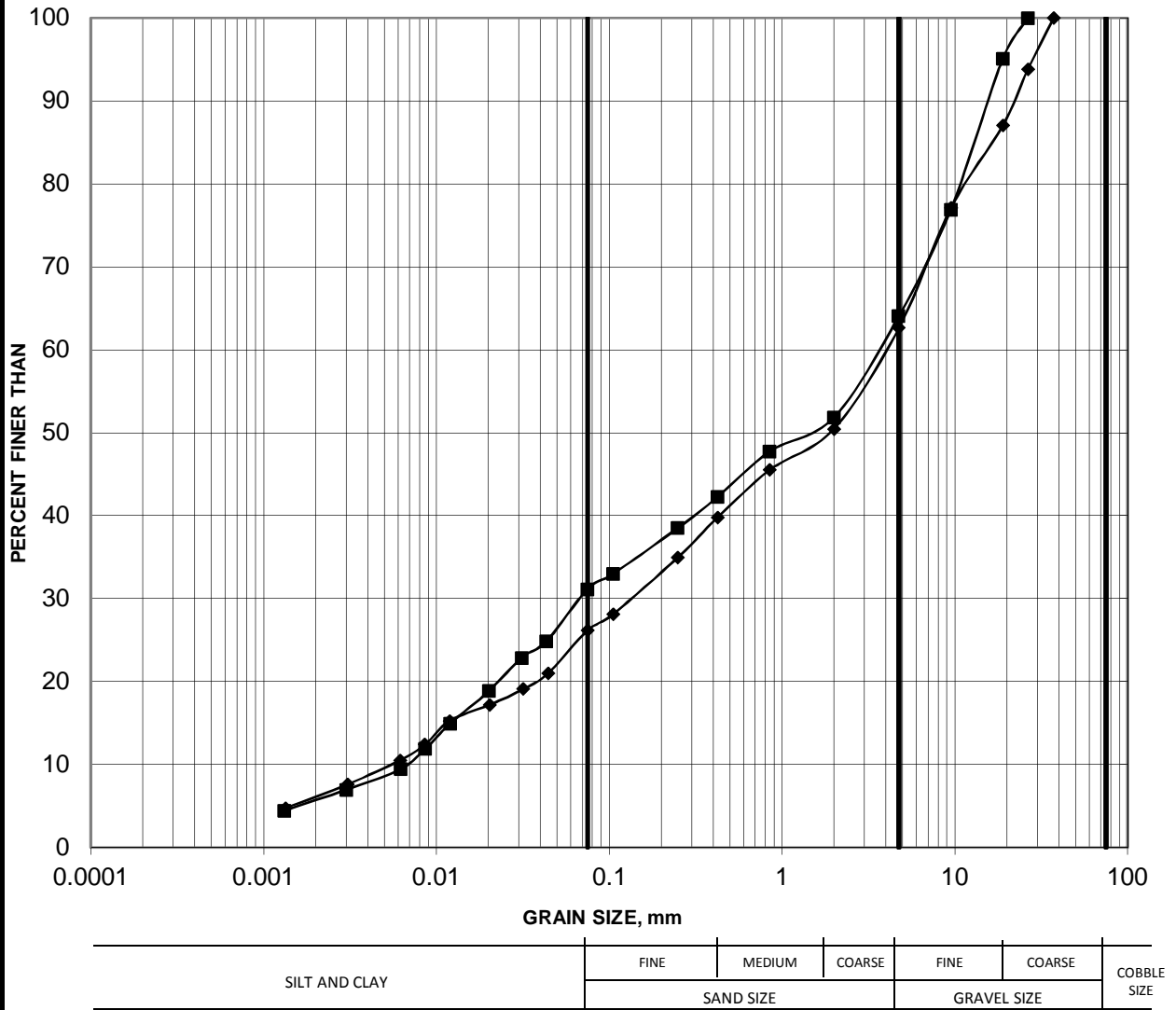
FIGURE B2



SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

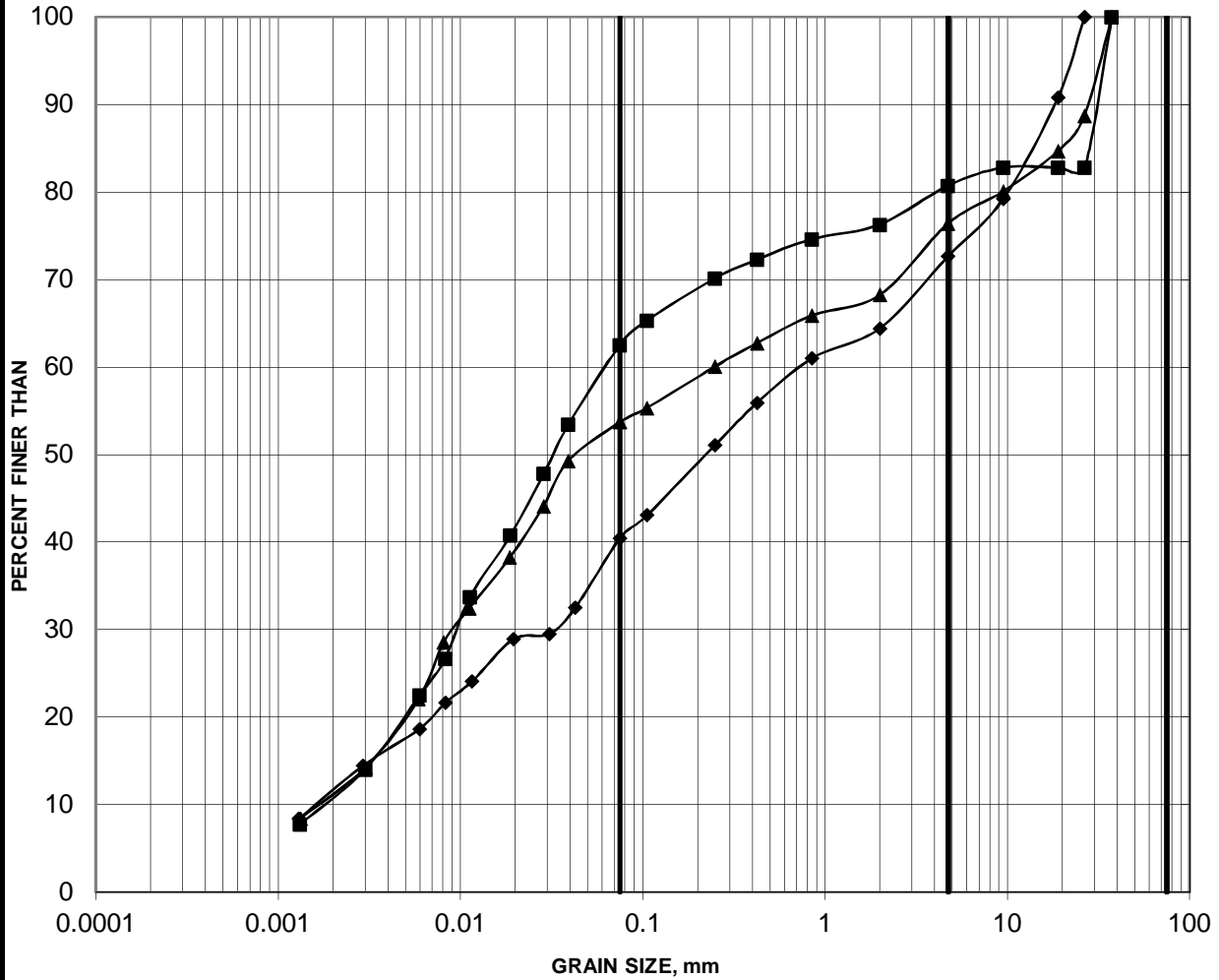
Borehole	Sample	Depth (m)
—■— 18-3103	4	2.29-2.90
—◆— 18-3104	5	3.81-4.42

SILTY GRAVEL AND SAND (TILL)



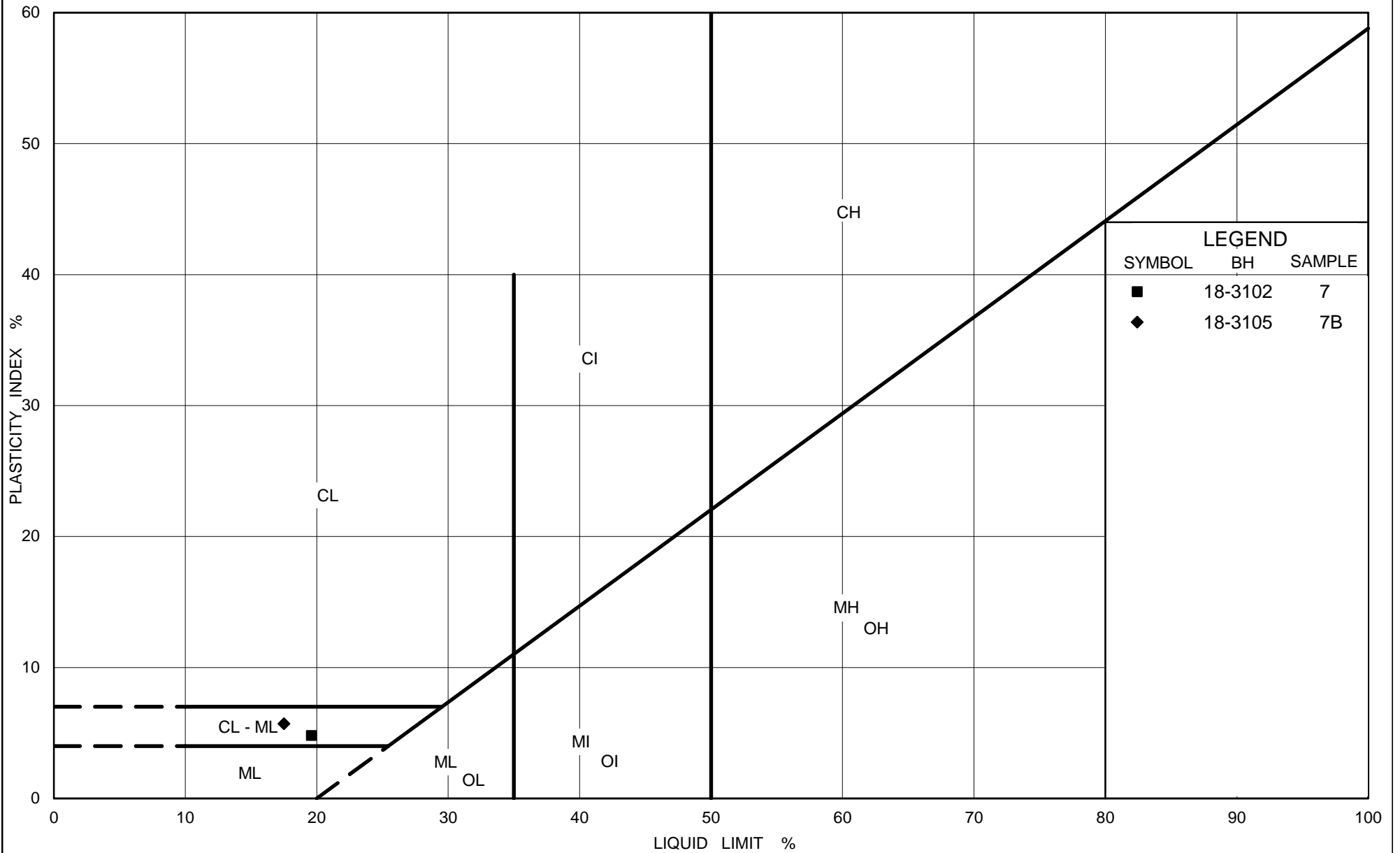
Borehole	Sample	Depth (m)
—■— 18-3101	11	6.10-6.71
—◆— 18-3103	8	5.33-5.94

GRAVELLY SILTY CLAY SOME SAND (TILL)



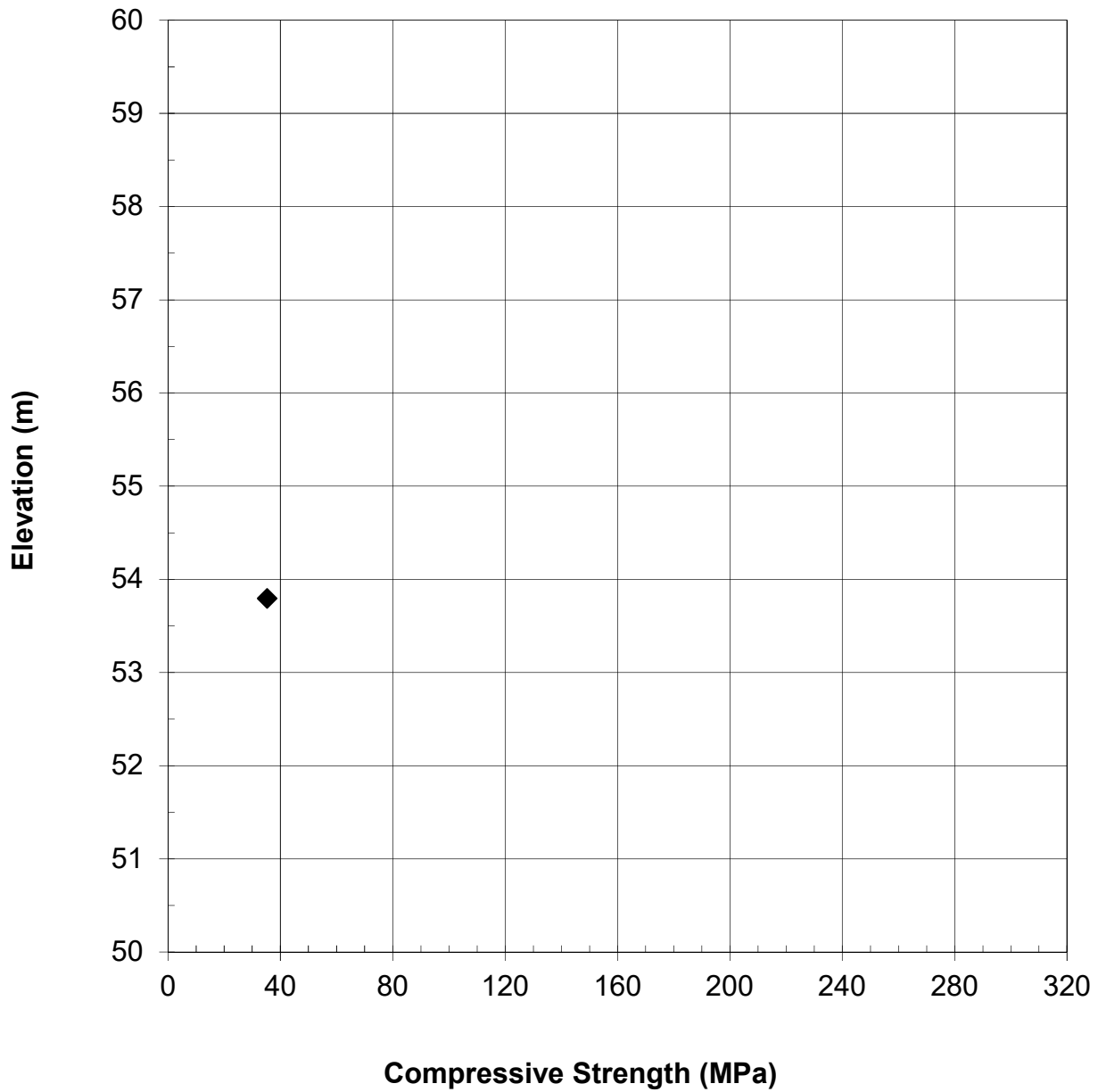
SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

Borehole	Sample	Depth (m)
18-3102	7	6.10-6.71
18-3105	7B	4.39-4.88
18-3105	9	5.49-6.10



**SUMMARY OF LABORATORY COMPRESSIVE STRENGTH
UNCONFINED COMPRESSION TESTS**

FIGURE B6



◆ 18-3102

APPENDIX C

**Borehole Record and Laboratory Test Results
(Previous Investigation, GEOCREs No. 31G05-091)**

Records of Previous Boreholes BH 3 to BH 5

Laboratory Test Results

Bore Hole Location and Soil Strata Drawing

DESIGN SERVICES BRANCH

FOUNDATIONS OFFICE

RECORD OF BOREHOLE NO 1

JOB 72-11146

LOCATION Co-Ords. 499,529 N, 233,953 E.

ORIGINATED BY D.B.

W.P. 10-69

BORING DATE January 18, 19, 1973

COMPILED BY D.B.

DATUM Geodetic

BOREHOLE TYPE Washboring - NX BX Casing-BX Rock Core

CHECKED BY

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT			LIQUID LIMIT — W _L PLASTIC LIMIT — W _P WATER CONTENT — W			BULK DENSITY γ	REMARKS	
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT		SHEAR STRENGTH P.S.F. ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE			W _P	W	W _L			P.C.F.
206.4	Ground Level														
205.4	Sandy Top Soil													EL. 207.4 ▽ Head	
1.0	Sand, Trace to Some Gravel		1	CS	-	200								0 98 (2) In open BH Jan. 1973	
	Grey to Brown		2	SS	5										
	Loose to Compact		3	SS	5										17 77 (6)
			4	SS	9										
189.8			5	SS	30	190								34 50 (16)	
16.6	Het. Mixture of Silt, Sand & Gravel Trace of Clay, (Till) Dense														
	Bouldery Zone Boulders up to 5 inches in size		6	BX-Rec RC	31%										
182.2	Very Dense		7	BX-Rec RC	53%									Elev. 182.2	
24.2	Bedrock Interbedded shale and shaley to silty limestone Grey Sound		8	BX-Rec RC	100%									Artesian Head Encountered Elev. 182.2	
			9	BX-Rec RC	98%	180									
			10	BX-Rec RC	100%										
171.7															
34.7	End of Borehole					170									

OFFICE REPORT SOIL EXPLORATION

DESIGN SERVICES BRANCH

FOUNDATIONS OFFICE

RECORD OF BOREHOLE NO 2

JOB 72-11146

LOCATION Co-ords. 499,443 N., 234,049 E.

ORIGINATED BY D.B.

W.P. 10-69

BORING DATE January 23, 1973

COMPILED BY D.B.

DATUM Geodetic

BOREHOLE TYPE Washboring-NX BX Casing-BX Rock Core

CHECKED BY 10

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT				LIQUID LIMIT W_L PLASTIC LIMIT W_P WATER CONTENT W			BULK DENSITY γ	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT		SHEAR STRENGTH P.S.F.				WATER CONTENT %				
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE				15	30	45	P.C.F.	GR. SA. SI. CL.
206.9	Ground Level														
205.9	Clayey Topsoil														206.1
1.0	Sand Trace to some Gravel Grey to Brown		1	CS	-										In open B.H.
	Loose to Compact		2	SS	5	200									0 99 (1)
			3	SS	15										
			4	SS	27	190									9 87 (4)
187.9	Het. Mixture of Sand & Gravel, trace of silt & clay (Glacial Till)		5	SS	36										
19.0	Dense to V. Dense		6	RC	37% Rec										
182.9	Bouldery Zone														
24.0	Bedrock		7	RC	97% REC	180									
	Interbedded shale and shaley to silty limestone. Grey														
177.6	Sound														
29.3	End of Borehole					170									

OFFICE REPORT SOIL EXPLORATION

DESIGN SERVICES BRANCH

FOUNDATIONS OFFICE

RECORD OF BOREHOLE NO 3

JOB 72-11146 LOCATION Co-Ords. 499.960 N, 232.463 E. ORIGINATED BY D.B.
 W.P. 10-69 BORING DATE January 29, 30, 1973 COMPILED BY B.T.D.
 DATUM Geodetic BOREHOLE TYPE Washboring NX. BX Casing- BX Rock Core CHECKED BY SD

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT					LIQUID LIMIT W_L PLASTIC LIMIT W_P WATER CONTENT W			BULK DENSITY γ	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT		SHEAR STRENGTH P.S.F.					WATER CONTENT %				
206.4	Ground Level					400	800	1200	1600	2000	15	30	45	P.C.F.	GR.SA.SI.CL.	
0.0	Varved Material Dark Grey Varves Silty Clay Grey Varves Clayey Silt to Silt Individual Varves Range from 1/2" to 1" Very Stiff to Firm		1	SS	12	200										
			2	TW	PM											
191.4																
15.0	Het. Mixture of Silt & Sand, Some Clay & Gravel Glacial Till Very Dense		3	SS	44	190										
	Bouldery Zone Boulders up to 5" in size		4	BX-RC	28% Rec.											
182.4																
24.0	Bedrock interbedded shale and shaley limestone Sound		5	BX-RC	97% Rec.	180										
176.9																
29.5	End of Borehole					170										

OFFICE REPORT SOIL EXPLORATION

DESIGN SERVICES BRANCH

FOUNDATIONS OFFICE

RECORD OF BOREHOLE NO 4

JOB 72-11146

LOCATION Co-ords. 500.012 N. 232.660 E.

ORIGINATED BY D.B.

W.P. 10-69

BORING DATE January 25, 26 1973

COMPILED BY D.B.

DATUM Geodetic

BOREHOLE TYPE Washboring - NX BX Casing - BX Rock Core

CHECKED BY

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT					LIQUID LIMIT — W _L PLASTIC LIMIT — W _p WATER CONTENT — W			BULK DENSITY γ	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT		SHEAR STRENGTH P.S.F.					WATER CONTENT %				
						400	800	1200	1600	2000	15	30	45	P.C.F.	GR.SA.SI.CL.	
209.5	Ground Level															
208.5	Clayey Topsoil														Elev. 208.8 In open BH Jan. 26 1973	
1.0	Varved Material		1	CS	-											
	Dark Grey Varves															
	Silty Clay		2	SS	8											
	Grey Varves															
	Clayey Silt to Silt															
	Individual varves range from 1/2" to 1"		3	TW	PM										clay e ₀ =0.65 c _c =0.06	
	Very Stiff to Firm															
194.0	Silt with Gravel		4	SS	25											
	Compact															
191.2	Het. Mixture of Silt & Sand with Some Clay and Gravel, Glacial Till.		5	SS	46											
184.3	Dense to V. Dense		6	BX RC	18% Rec.											
25.2	Bedrock Interbedded shale and Shaley limestone		7	BX RC	99% Rec.											
	Sound		8	BX RC	100% Rec.											
174.1																
35.4	End of Borehole															

OFFICE REPORT SOIL EXPLORATION

DESIGN SERVICES BRANCH

FOUNDATIONS OFFICE

RECORD OF BOREHOLE NO 5

JOB 72-11146

LOCATION Co-ords. 500,060 N., 232,852 E.

ORIGINATED BY D.B.

W.P.10-69

BORING DATE January 25, 1973

COMPILED BY D.B.

DATUM Geodetic

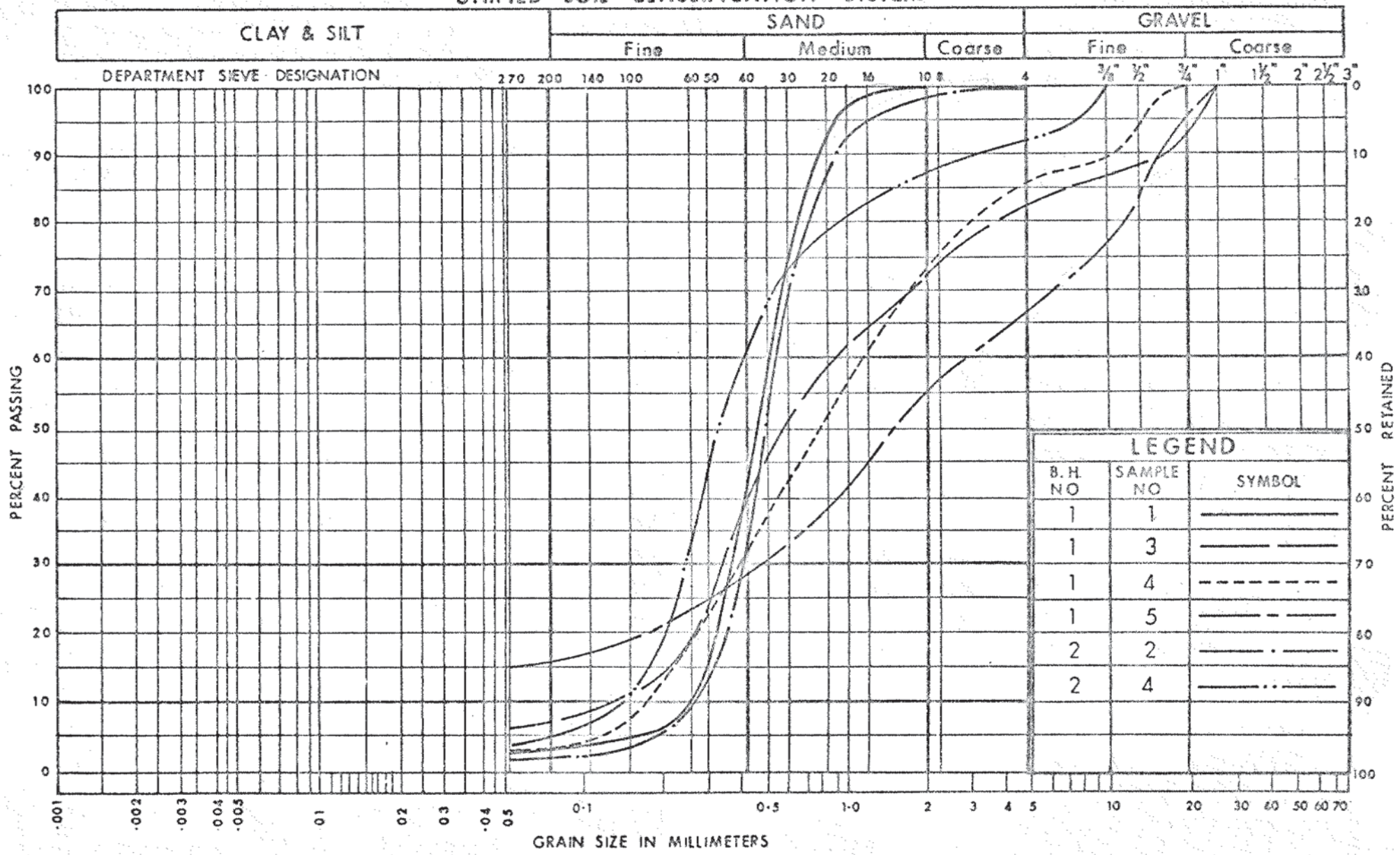
BOREHOLE TYPE Diamond

CHECKED BY

SOIL PROFILE		SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT					LIQUID LIMIT w_L PLASTIC LIMIT w_p WATER CONTENT w			BULK DENSITY γ	REMARKS	
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE		BLOWS/FOOT	SHEAR STRENGTH P.S.F.					WATER CONTENT %				
						○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE 400 800 1200 1600 2000					15 30 45					
212.0	Ground Level															
0.0	Varved Material															
	Dark Grey Varves		1	CS	-	210										
	Silty Clay															
	Grey Varves		2	SS	9											
	Clayey Silt to Silt															
	Individual varves range from 1/2" to 1"															
	Very Stiff to Stiff				200											
			3	TW	PM											
			4	TW	PM											
195.0			5	SS	27											
17.0	Het. Mixture of Silt and Sand with some clay and Gravel															
	Glacial Till		6	SS	62											
	Compact to V. Dense				190											
186.5			7	SS	100											
25.5	Bedrock				180											
	Interbedded shale and shaley limestone		8	RC	100% Rec.											
181.6																
30.4	End of Borehole															

OFFICE REPORT SOIL EXPLORATION

UNIFIED SOIL CLASSIFICATION SYSTEM

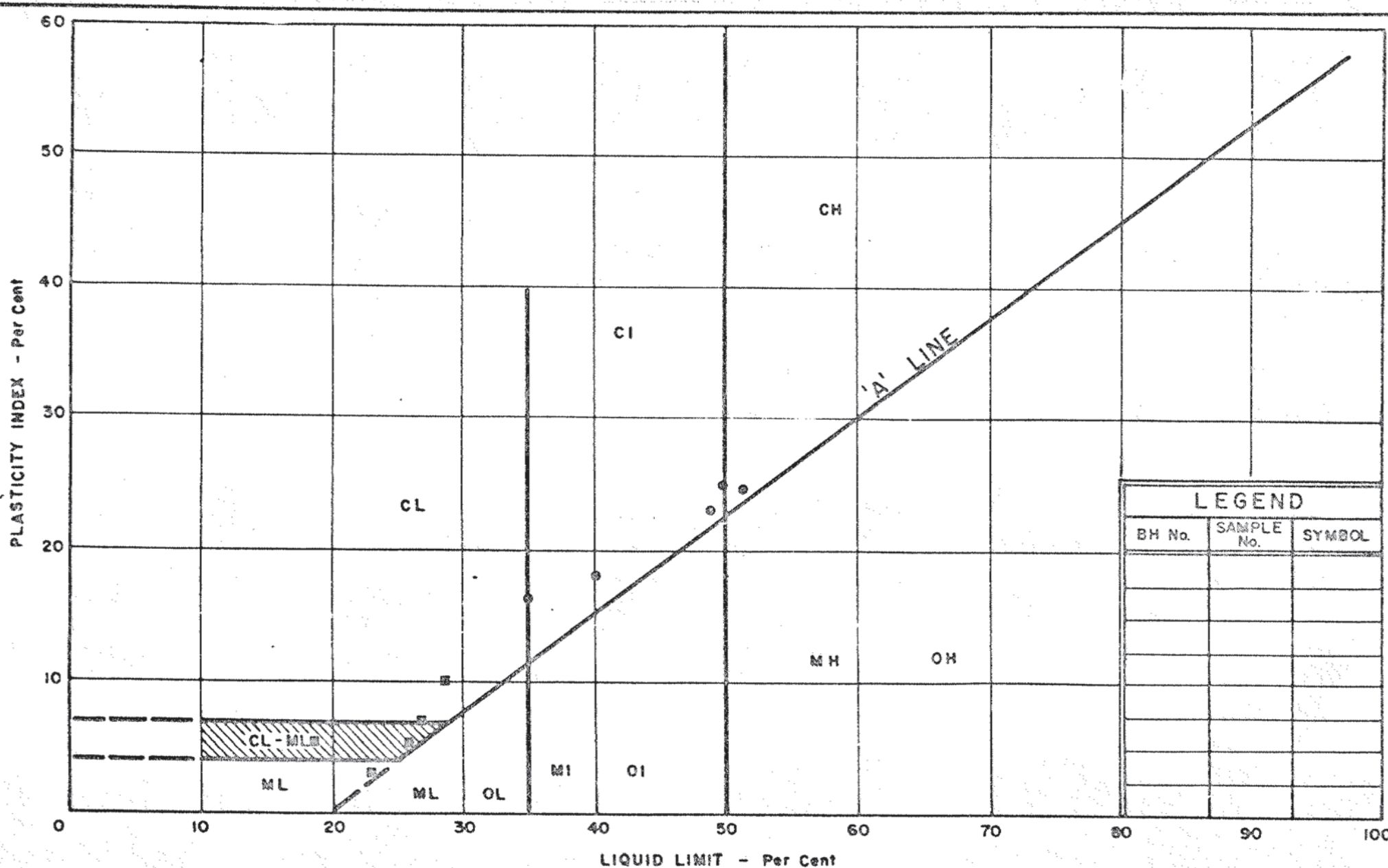


DEPARTMENT
OF
TRANSPORTATION AND COMMUNICATIONS

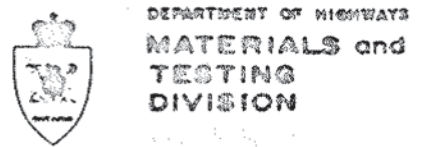
DESIGN SERVICES
BRANCH

GRAIN SIZE DISTRIBUTION
SAND
TRACE TO SOME GRAVEL

W.P. No. 10 - 69
JOB No. 72 - 11146
FIG. 1



LEGEND		
BH No.	SAMPLE No.	SYMBOL



DEPARTMENT OF HIGHWAYS
MATERIALS and TESTING
 DIVISION

PLASTICITY CHART

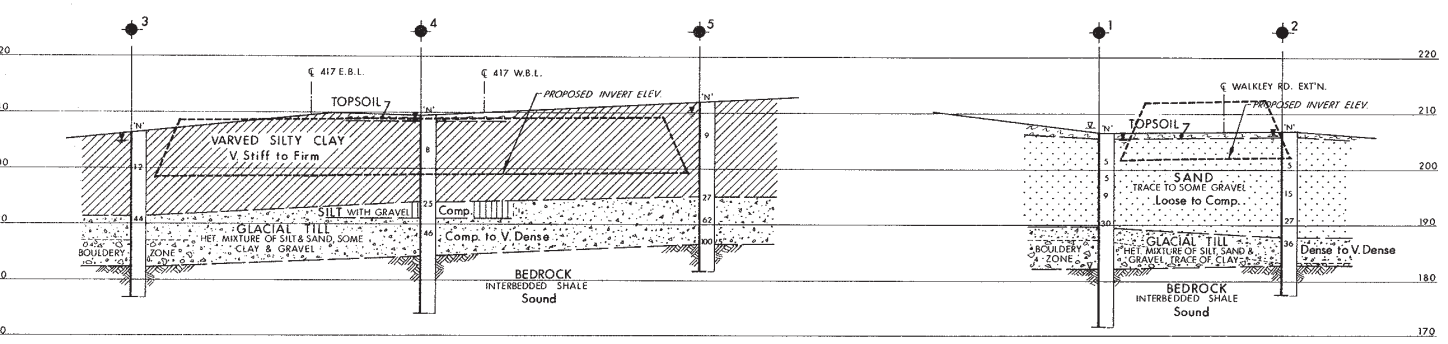
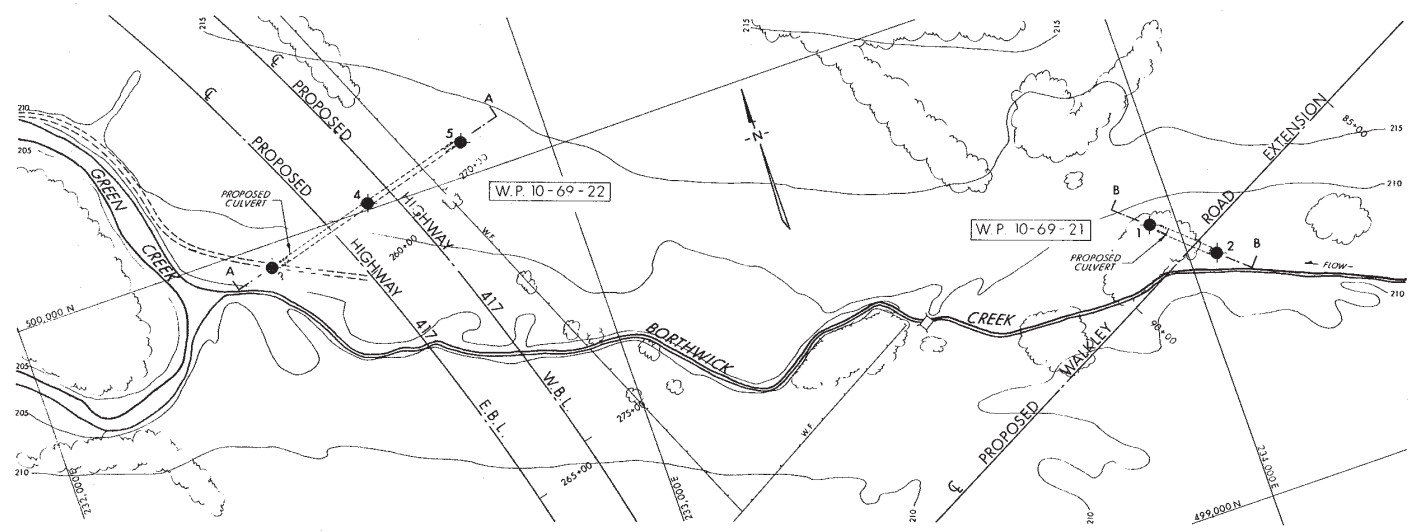
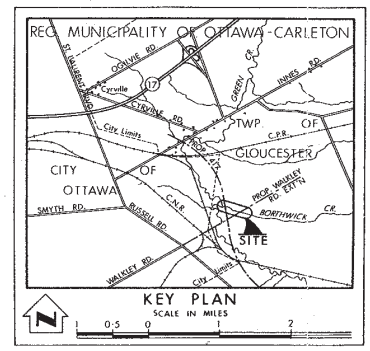
VARVED SILTY CLAY STRATUM

- SILTY CLAY VARVES
- CLAYEY SILT TO SILT VARVES

WP No. 10-69

JOB No. 72-11146

FIG. 2



LEGEND

- Bore Hole
- ⊕ Cone Penetration Test
- ⊕ Bore Hole & Cone Test
- ⊕ Water Levels established at time of field investigation, JAN. 1973
- ⊕ Head
- ⊕ Encountered ARTESIAN WATER

NO.	ELEVATION	CO-ORDINATES	
		NORTH	EAST
1	206.4	499,529	233,953
2	206.9	499,443	234,049
3	206.4	499,960	232,463
4	209.5	500,012	232,660
5	212.0	500,060	232,852

NOTE
 The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.

REVISIONS	DATE	BY	DESCRIPTION

MINISTRY OF TRANSPORTATION AND COMMUNICATIONS—ONTARIO
 DESIGN SERVICES BRANCH—FOUNDATIONS OFFICE

BORTHWICK CREEK CULVERTS

HIGHWAY NO. 417 & WALKLEY RD. EXT'N. DIST. NO. 9
 REG. MUNICIPALITY OF OTTAWA-CARLETON
 TWP. GLOUCESTER LOT CON.

BORE HOLE LOCATIONS & SOIL STRATA

SUBWD. D.B. CHECKED	W.P. NO. 10-69-21	DRAWING NO.
DATE 23 FEB. 1973	W.O. NO. 72-11146	72-11146A
APPROVED	SITE NO. 3-C-A	BRIDGE DRAWING NO.
	CONT. NO. 73-6D	3-C-A-2

NOTE: The complete soil investigation report for this structure may be examined at the Bridge Office and Foundations Office, Downsview, and at the OTTAWA District Office.

APPENDIX D

Basic Chemical Analysis – Eurofins Report Number 1816326

Certificate of Analysis

Client: Golder Associates Ltd (Ottawa)
 1931 Robertson Road,
 Ottawa, Ontario
 K2E 7Y1
 Attention: Ms. Gabrielle Marcotte
 PO#:
 Invoice to: Golder Associates Ltd

Report Number: 1816326
 Date Submitted: 2018-09-10
 Date Reported: 2018-09-13
 Project: 1662565/1310
 COC #: 835566

Lab I.D. 1386358
 Sample Matrix Soil
 Sample Type
 Sampling Date 2018-08-15
 Sample I.D. 18-3102 SA4 /0-12

Group	Analyte	MRL	Units	Guideline	
Anions	Cl	0.002	%		0.107
	SO4	0.01	%		0.02
General Chemistry	Electrical Conductivity	0.05	mS/cm		2.02
	pH	2.00			8.11
	Resistivity	1	ohm-cm		495

Guideline = * = **Guideline Exceedence**

Results relate only to the parameters tested on the samples submitted.
 Methods references and/or additional QA/QC information available on request.

MRL = Method Reporting Limit, AO = Aesthetic Objective, OG = Operational Guideline, MAC = Maximum Acceptable Concentration, IMAC = Interim Maximum Acceptable Concentration, STD = Standard, PWQO = Provincial Water Quality Guideline, IPWQO = Interim Provincial Water Quality Objective, TDR = Typical Desired Range

APPENDIX E

Site Photographs



Photograph 1: Looking west towards culvert inlet



Photograph 2: Looking east towards culvert outlet



Photograph 3: Looking upstream from culvert inlet



Photograph 4: Looking downstream from culvert outlet



golder.com