REPORT

Foundation Investigation
CPR Overhead Bridge Rehabilitation
Site No. 3-302/1 (EBL) and Site 3-302/2 (WBL)
Highway 417
Ottawa Ontario

G.W.P. 4074-11-00
W.P. 267-00-01 and 267-00-02

Submitted to:

WSP Canada Group Limited
300-2611 Queensview Drive
Ottawa, Ontario
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Submitted by:

Golder Associates Ltd.
1931 Robertson Road, Ottawa, Ontario, K2H 5B7, Canada

Geocres Number: 31G5-302
Latitude: 45.411671 Latitude: -75.601219

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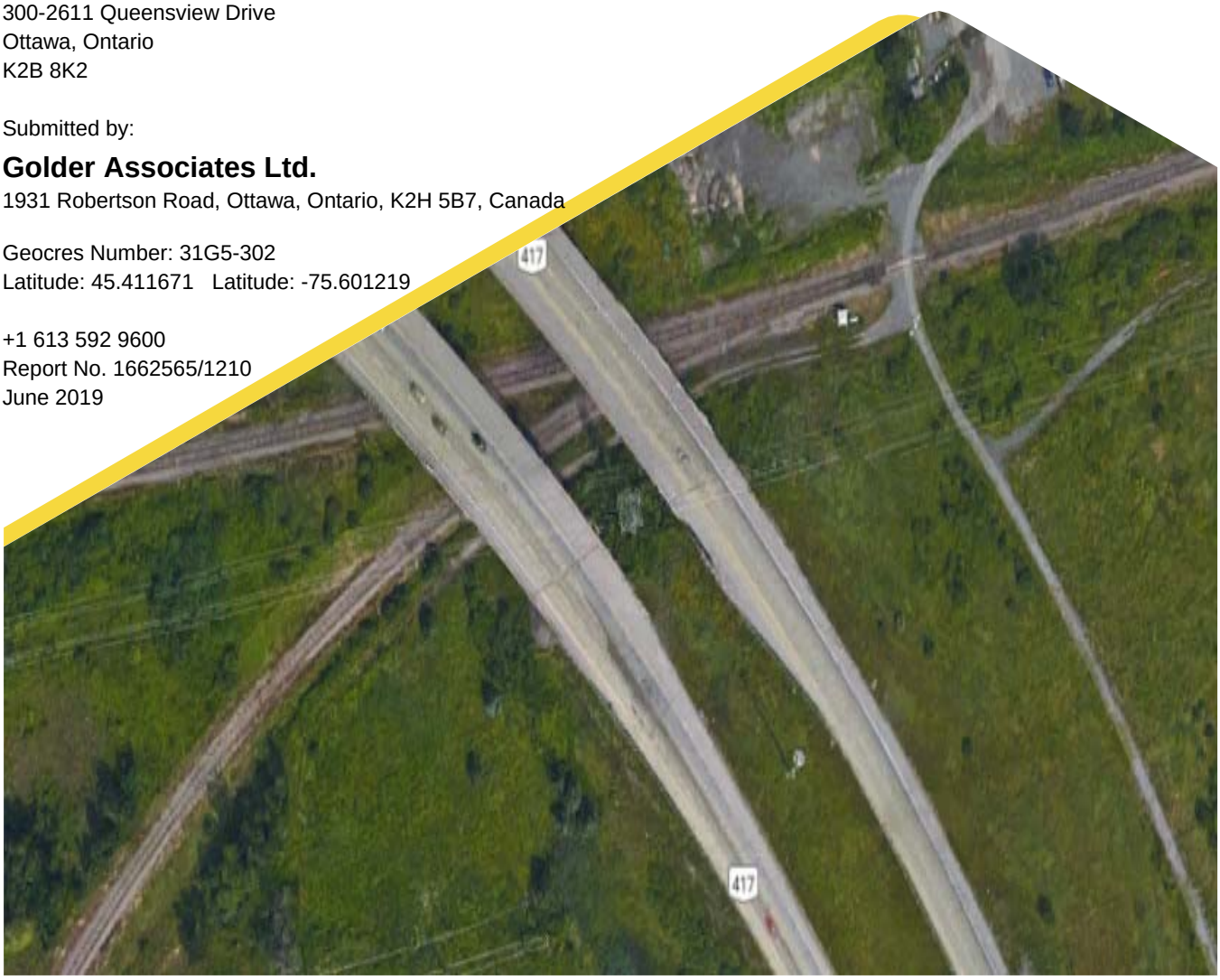
Report No. 1662565/1210
June 2019



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PART A – FOUNDATION INVESTIGATION

Highway 417 CPR Overhead Bridge Rehabilitation
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G.W.P. 4074-11-00
W.P. 267-00-01 and 267-00-02

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 bridges and structural culverts rehabilitation and/or replacements on Highway 417 between the Aviation Parkway and Ramsayville Road and also includes widening of Highway 417 from Ottawa Road 174 to Hunt Club Road in Ottawa, Ontario (Assignment number 4016-E-0008).

This report presents the results of the foundation investigation carried out to collect subsurface information required for the static and seismic assessment of the bridge foundations, and provision of temporary protection systems (TPS) as input to the rehabilitation of the Canadian Pacific Railway (CPR) Overhead bridge, Site No. 3-302/1 (Eastbound Lane) and Site No. 3-302/2 (Westbound Lane) located on Highway 417 in Ottawa, Ontario (G.W.P. 4074-11-00; W.P. 267-00-01 and 267-00-02, respectively). The rehabilitation of the existing structures is to be carried out in accordance with the current version of the Canadian Highway Bridge Design Code (CHBDC, S6-14).

The terms of reference and scope of work for the foundation investigation are outlined in the MTO's Request for Proposal, dated May 2016, and subsequent addenda. Golder's scope of work for foundation engineering services associated with the CPR Overhead bridge at Highway 417 is contained in Table 17.8.3 of WSP's Technical Proposal for this assignment dated June 28, 2016. The work has been carried out in accordance with Golder's Quality Control Plan for foundation engineering services for this project dated March 13, 2017.

2.0 SITE DESCRIPTION AND GEOLOGY

2.1 Site Description

The CPR Overhead structures are located within a mixed-use area of the City of Ottawa, and are located approximately 740 m southeast of Innes Road exit on Highway 417. At this location, Highway 417 is a divided highway with two through lanes in each direction with a widened shoulder on each inside lane. The eastbound structure also accommodates an acceleration lane from the Innes Road interchange.

The railway tracks at this site are owned by CPR and operated by VIA Rail and Canadian National Railway (CNR). The tracks start to form a Y configuration just east of the CPR Overhead structures, forming two distinct rail lines west of the structures connecting to the mainline CNR line to Ottawa immediately west of Highway 417. The track of the main CPR line, splitting off to the southwest just west of the CPR Overhead structures, has been abandoned and removed approximately 400 m east of the structures where it has then been converted to a recreational trail.

The existing eastbound CPR Overhead bridge structure (Site No. 3-302/1) was constructed in 1975. The bridge is a four span, 79.0 m long (20.4 m, 19.1 m, 19.1 m and 20.4 m), reinforced concrete slab on prestressed girders (AASHTO III) structure. The overall structure width is 20.4 m including barrier walls, with a roadway width of 19.5 m. The bridge carries two through lanes of eastbound traffic and one on-ramp. The bridge abutments sit on "perched" foundations supported on vertical battered steel piles end bearing on bedrock. The piles are battered in line with the Highway 417 Lanes. The west and centre piers (Pier 1 and Pier 2, respectively) consist of five circular columns and the east pier (Pier 3) consists of 4 circular columns. The piers are supported on concrete caissons socketed in the bedrock.

The existing westbound CPR Overhead bridge structure (Site No. 3-302/2) was constructed in 1975. The bridge is a three span, 64.0 m long (19.5 m, 24.1 m and 20.4 m) reinforced concrete slab on prestressed girders (AASHTO III) structure. The overall structure width is 17.4 m including barrier walls, with a roadway width of 16.5 m. The bridge carries two through lanes of westbound traffic. The bridge abutments sit on “perched” foundations supported on vertical and battered steel piles end bearing on bedrock. The west and east piers (Pier 1 and Pier 2, respectively) consist of four circular columns supported on concrete caissons socketed in the bedrock.

Based on visual observation at the time of planning and carrying out the site investigation, the existing foundations and embankment side slopes appear to be performing satisfactorily.

2.2 Regional Geology

As delineated in *The Physiography of Southern Ontario* (Chapman and Putnam,1984), this section of Highway 417 lies on the boundary of the minor physiographic regions known as the Ottawa Valley Clay Plain and the Russell and Prescott Sand 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 bedrock. The Russell and Prescott Sand Plains are generally characterized by a sand mantle about 3 to 5 m thick overlying an extensive deposit of sensitive marine clay deposited within the Champlain Sea basin, underlain by glacial till and shale bedrock. 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 bedrock of the Carlsbad Formation.

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 field work for the current subsurface investigation was carried out on June 8 and 9, 2018 and between June 20 to 27, 2018. During that time, four boreholes (numbered 18-2101 to 18-2104, inclusive) were advanced within the driving lanes of Highway 417 at the location of the existing abutments. The borehole location are shown on Drawings 1 and 2.

The boreholes were advanced using 108 inside diameter (200 mm outside diameter) continuous flight hollow stem augers on truck mounted drill rigs supplied and operated by George Downing Estate Drilling Ltd. of Grenville-sur-la-rouge, Québec. The boreholes were advanced to about 11.0 m to 25.4 m depth below the ground surface.

Samples of the overburden were obtained at 0.8 to 1.5 m intervals of depth using 50 mm outside diameter split-spoon samplers in general accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586).

Upon reaching refusal to casing advancement in Borehole 18-2104, the borehole was advanced into the bedrock surface to a depth of about 3.4 m using rotary diamond drilling techniques while retrieving HQ3 sized core. A water truck was on site to supply the drill rig with water for advancing the casing in the overburden and for coring the bedrock. Traffic control required to close the driving lanes of Highway 417 at the site was supplied by Beacon Lite Ltd. of Ottawa, Ontario.

One monitoring well was installed in Borehole 18-2102 to monitor the groundwater level at the site. The monitoring well consisted of 30 mm outside diameter PVC tubing with a 3.0 m long screen. The groundwater level was measured in the monitoring well on July 25, 2018.

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 a member 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 and bedrock samples. The soil and bedrock 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 Limit tests, and grain size distribution analyses were carried out on selected soil samples at the Golder Ottawa laboratory. One unconfined compressive strength test was carried out on a selected rock core specimen at Golder's laboratory. The laboratory tests were carried out to MTO and/or ASTM standards, as appropriate.

In addition to the borehole investigation, shear wave velocity profiling at the site was completed using the Multichannel Analysis of Surface Waves (MASW) technique. Two tests were conducted on July 18, 2018 by personnel from the Golder Associates' Mississauga office. A series of 24 low frequency (4.5 Hz) geophones were laid out at 3 m intervals. A 9.9 kg sledge hammer and 45 kg weight drop were used as the seismic source. The source locations were offset at distances of 5, 10, and 15 m off the end and collinear with the geophone array.

The borehole locations and elevations were surveyed by Golder using a Trimble R8 GPS unit. The borehole locations, including MTM NAD83 northing and easting coordinates, ground surface elevations referenced to geodetic datum, and drilled depth are summarized in the following table and are shown on Drawing 1 and 2.

Table 1: Summary of Borehole Locations

Borehole Number	Borehole Location	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)	Borehole Total Depth (m)
18-2101	Hwy 417 EBL west abutment	5030617.4	375081.8	75.0	17.4
18-2102	Hwy 417 WBL west abutment	5030619.8	375121.6	74.2	17.4
18-2103	Hwy 417 EBL east abutment	5030551.6	375173.1	75.6	11.0
18-2104	Hwy 417 WBL east abutment	5030560.7	375196.9	74.7	25.4

3.2 Previous Investigation (1972)

A previous investigation was carried out on November 1972 by the MTO (then the Department of Transportation and Communications) for the design of the existing overpass structures. The results of that investigation are contained in the report titled "*Foundation Investigation Report for Proposed New Structures at the Crossing of Hwy. #417 and C.P.R., Regional Municipality of Ottawa-Carleton, District #9 - Ottawa, W.O. 71-11126 - W.P. 13-68-06, 13-68-07*", dated February 17, 1972 (GEOCRES No. 31G5-80).

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

A total of twelve boreholes, ten with an adjacent Dynamic Cone Penetration Test (DCPT) were put down at the site as part of the original investigation along the then-proposed bridge alignments. The approximate borehole and ground surface elevations are shown on the Record of Borehole sheets included in Appendix C and are also shown on Drawings 1 and 2. The locations and ground surface elevations of the previous boreholes and DCPTs should be considered approximate since the locations were referenced to an imperial borehole location plan rather than metric MTM coordinates. The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of in situ and laboratory testing are given on the borehole records from the 1972 investigation.

4.0 DESCRIPTION OF SUBSURFACE CONDITIONS

4.1 Site Stratigraphy

The subsurface soil 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. The results of geotechnical laboratory testing from the current investigation are presented on Figures B1 to B5 in Appendix B. Photos of the bedrock core from the current investigation are provided in Figure A1 in Appendix A. The Record of Borehole sheets as well as laboratory testing from the previous investigation at the site (GEOCRES No. 31G5-80) are provided for reference in Appendix C. The results of basic chemical analysis completed on select soil samples are provided in Appendix D. The borehole locations and the interpreted stratigraphic profile projected along the CPR Overhead structures are shown on Drawings 1 and 2.
The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profile are inferred from observations of drilling progress and noncontinuous 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.

The MASW test results and report are presented in Appendix E and include the calculated shear wave velocity profile measured from the field testing and a graphical representation of the shear wave velocity profile with depth.

Photographs of the site are shown in Appendix G.

In general, the subsurface conditions at the borehole locations consist of pavement structure and embankment fill extending down to depths of about 7.6 m to 11.3 m (Elevations 63.5 m to 68.0 m) over a discontinuous deposit of silty clay extending down to a depth of about 12.2 m (Elevation 62.8 m). The fill and clayey silt are underlain by a deposit of sand to silty sand extending down to depths of about 17.4 m to 18.3 m (Elevations 56.4 m to 57.6 m). The embankment fill and sandy deposit are overlying a discontinuous deposit of glacial till extending down to depths of about 11.0 m to 22.0 m (Elevations 52.7 m to 64.6 m) and the shale bedrock. Shale bedrock was indicated to be present at depths of about 22.0 m (Elevation 52.7 m). The groundwater level was encountered at a depth of about 14.0 m (Elevation 60.2 m).

A detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2 Pavement Structure and Fill

Boreholes 18-2101 and 18-2103 were advanced through the pavement structure of the EBL left shoulder of Highway 417 and Boreholes 18-2102 and 18-2104 were advanced through the pavement structure of the WBL left shoulder of Highway 417. The pavement structure at these locations consists of about 200 mm of asphaltic concrete over 0.5 to 1.3 m of gravelly sand base layer.

SPT 'N' values ranging from 39 to 82 blows per 0.3 m of penetration were measured in the gravelly sand base layer, indicating a compact to very dense state of packing.

The pavement structure is underlain by embankment fill in Boreholes 18-2101 to 18-2104. The embankment fill extends to depths ranging from about 9.1 to 11.3 m below the existing ground surface (Elevations ranging from about 63.5 to 68.0 m) and consists of sand and gravel, sandy gravel to sand with varying amount of silt and clay to silty clay. The fill also contains cobbles, boulders, and shale fragments.

SPT 'N' values ranging from 6 to greater than 50 blows per 0.3 m of penetration were measured in the embankment fill, indicating a loose to very dense state of packing.

The results of grain size distribution testing were carried out on ten samples of the embankment fill are provided on Figure B1.

The results of Atterberg Limits testing on two samples of silty clay fill gave a plasticity index of about 9 and 12 percent and a liquid limit of about 25 and 28 percent, which indicates a silty clay of low plasticity. The measured water content of 20 samples of the embankment fill range from about 3 to 22 percent. The results of the Atterberg limit testing are provided on Figure B2.

4.3 Silty Clay

A deposit of silty clay exists below the embankment fill in Borehole 18-2101. The silty clay extends to a depth of about 12.2 m below the existing ground surface (Elevation 62.8 m).

One SPT 'N' value of 11 blows per 0.3 m of penetration was measured in the silty clay, indicating a stiff consistency.

The results of Atterberg Limit testing carried out on one sample of the silty clay gave a plasticity index value of about 11 percent and a liquid limit value of about 26 percent indicating a silty clay of low plasticity. The measured water content of one sample of the silty clay is 21 percent. The results of the Atterberg limit testing are provided on Figure B3.

4.4 Silty Sand to Sand

A deposit of silty sand to sand with varying amounts of gravel and clay was encountered below the embankment fill and silty clay, where encountered, in Boreholes 18-2101, 18-2102, and 18-2104 and at the ground surface in Boreholes 1 to 12. Where penetrated, the silty sand to sand extends to a depth of about 18.3 m below the existing Highway 417 grade at Borehole 18-2104, and up to about 11.0 m below the existing natural ground surface at the time of the 1971 borehole investigation (Elevations ranging from about 54.0 to 56.4 m).

SPT ‘N’ values measured in the silty sand to sand deposit range from 18 to 48 blows per 0.3 m of penetration, indicating a compact to dense state of packing.

The measured water contents of the silty sand to sand range from about 7 to 20 percent.

The results of grain size distribution testing carried out on seven samples of the silty sand to sand deposit are provided on Figure B4.

4.5 Silty sand (Till)

A deposit of glacial till was encountered below the silty sand to sand in Borehole 18-2104. The till generally consists of a heterogeneous mixture of gravel, cobbles and boulders in a soil matrix of silty sand. Though not encountered at all borehole locations, the till is expected to contain cobbles and boulders. The till extends to a depth of about 22.0 m below the existing ground surface (Elevation 52.7 m) in Borehole 18-2104.

SPT ‘N’ values ranging from 30 to greater than 50 blows per 0.3 m of penetration were measured in the till deposit, indicating a dense to very dense state of packing.

The measured water contents of five samples of till range from about 9 to 15 percent.

The results of grain size distribution testing carried out on two samples of till are provided on Figure B5.

4.6 Auger Refusal and Bedrock

The bedrock was encountered below the overburden in Borehole 18-2104 from the current investigation and Boreholes 2, 7, 8, and 11 from the previous investigation.

The surface of the bedrock was encountered at a depth of about 22.0 m below the existing ground surface (Elevations 52.7 m) and was cored for a length of about 3.4 m while retrieving HQ3 sized bedrock core.

The following table summarizes the sound bedrock surface depths and elevations as encountered at the borehole location from the current and the previous investigations.

Table 2: Summary of Bedrock Depth and Elevation

Borehole Number	Existing Ground Surface Elevation (m)	Depth to Bedrock Surface (m)	Bedrock Surface Elevation (m)
18-2104	74.7	22	52.7
2	64.1	11.0	53.1
3	64.3	11.9(1)	52.5(1)
5	64.0	10.4	53.7
7	64.4	10.1	54.3
8	64.0	10.1	54.0
9	63.8	9.7(1)	54.0(1)
10	64.3	9.8(1)	54.5(1)
11	64.1	9.8	54.3

Note (1): Depth and elevation to bedrock inferred from refusal to auger advancement.

The bedrock encountered at the site consists of fresh, thinly bedded, dark grey to black, fine grained shale. The Rock Quality Designation (RQD) values of the cored bedrock are about 39 to 100 percent, indicating a poor to excellent quality rock.

Photos of the bedrock core obtained from Borehole 18-2104 during the current investigation are provided in Appendix A on Figure A1.

Results of unconfined compressive strength testing carried out on one bedrock core sample are presented in Figure B6. The result is 71.5 MPa indicating a strong bedrock.

4.7 Groundwater Conditions

A monitoring well was installed in Borehole 18-2102 to monitor the groundwater level at the site. The water level measured in the monitoring well in Borehole 18-2102 on July 25, 2018 is summarized in the table below.

Table 3: Summary of Groundwater Conditions

Borehole Number	Existing Ground Surface Elevation (m)	Water Level Depth (m)	Screened Interval	Water Level Elevation (m)	Date
18-2102	74.2	14.0	Sand	60.2	July 25, 2018

It should be noted that groundwater levels in the area are subject to fluctuations both seasonally and with precipitation events.

5.0 CLOSURE

This report was prepared by Mr. Fady Ghobrial, Geotechnical Specialist. It was reviewed by Mr. Michael Snow, P.Eng., a Senior Geotechnical Engineer. Mr. Fintan Heffernan, P.Eng. a Senior Consultant with Golder and the Designated MTO Foundations Contact for this project, conducted an independent quality control review of this report.

Golder Associates Ltd.

Fady Ghobrial
Geotechnical Specialist

Michael Snow, P.Eng.
Principal, Senior Geotechnical Engineer

Fintan Heffernan, P.Eng.
Designated MTO Foundations Contact

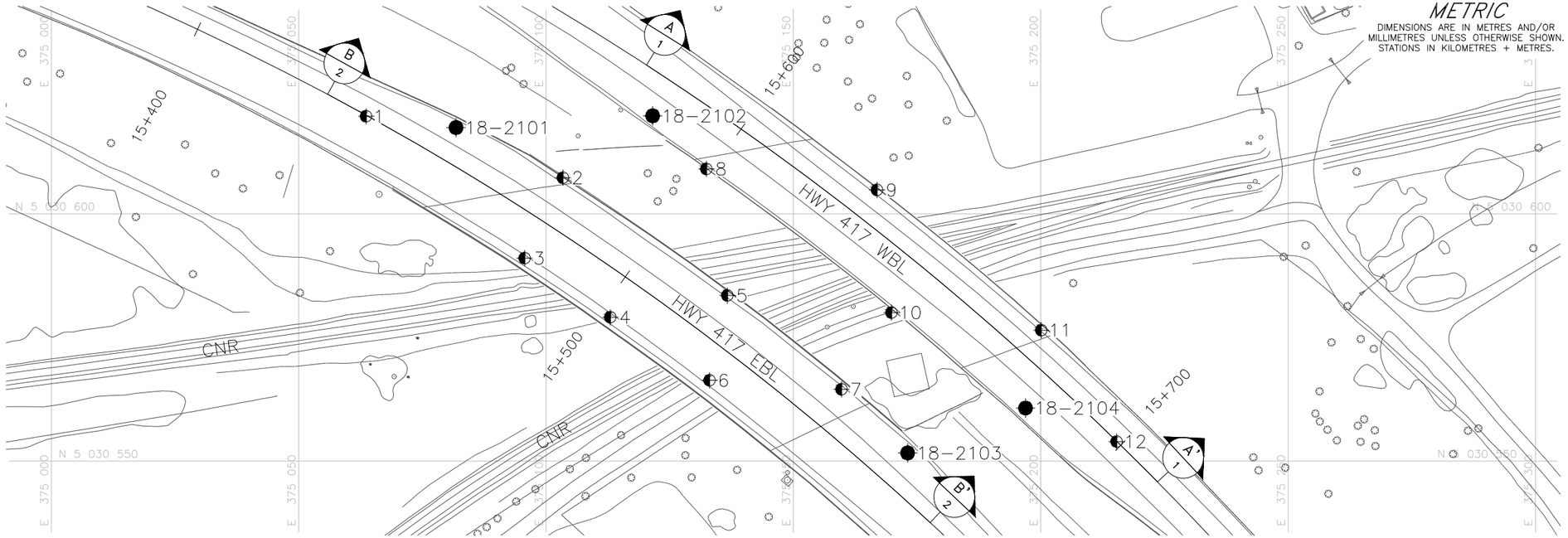
MSS/FJH/mvrd
https://golderassociates.sharepoint.com/sites/11263g/shared documents/01_foundations/6 - reports/1210 cpr/final/1662565-1210-002-r-rev0-cpr overhead-06_2019 fir.docx

REFERENCES

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

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.

MINISTRY OF TRANSPORTATION, ONTARIO



PLAN

SCALE

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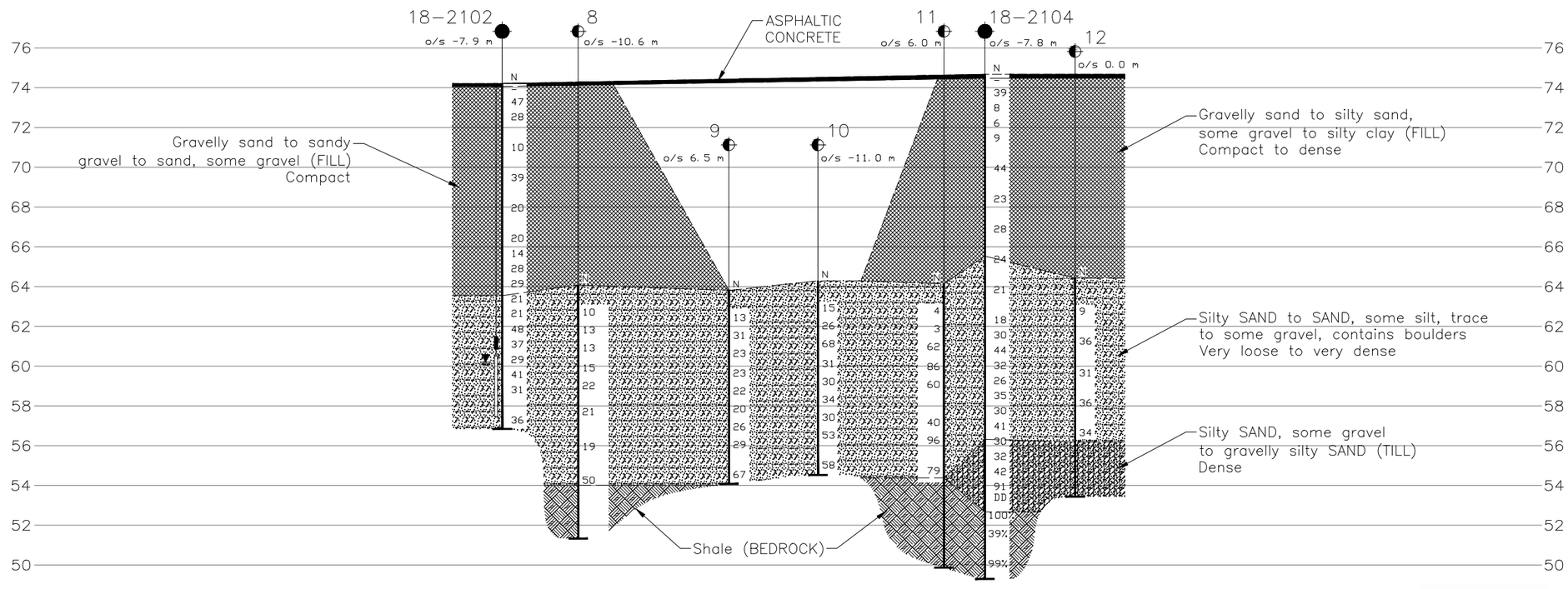

PROFILE A–A'

SCALE

10 0 10 20 m

2.5 0 2.5 5

NOTES

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

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

METRIC

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

WP No. 4074-11-00

CPR OVERHEAD WIDENING

HIGHWAY 417
BOREHOLE LOCATIONS AND SOIL STRATA
LAT. 45.411684 LONG. -75.601224

SHEET

GOLDER

KEY PLAN

SCALE

1 0 1 2 km

LEGEND

- Borehole – Current Investigation
- Borehole – Previous Investigation (Geocres No. 31G05-080)
- 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 July 2018

BOREHOLE CO-ORDINATES (MTM ZONE 9)

No.	ELEVATION	NORTHING	EASTING
1	64.0	5030619.7	375063.6
2	64.1	5030607.3	375103.4
3	64.4	5030591.0	375095.7
4	64.4	5030579.1	375113.0
5	64.1	5030583.5	375136.7
6	64.5	5030566.3	375133.1
7	64.4	5030564.5	375159.7
8	64.1	5030609.0	375132.4
9	63.8	5030604.8	375166.9
10	64.3	5030580.0	375169.8
11	64.1	5030576.5	375200.1
12	64.4	5030553.9	375215.3
18-2101	75.0	5030617.4	375081.8
18-2102	74.2	5030619.8	375121.6
18-2103	75.6	5030551.6	375173.1
18-2104	74.7	5030560.7	375196.9

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.

LICENSED PROFESSIONAL ENGINEER M.S. SNOW June 23, 2019 PROVINCE OF ONTARIO

REGISTERED PROFESSIONAL ENGINEER F. J. HEFFERNAN June 27, 19 PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

Geocres No. 31G5-302

HWY. 417	PROJECT NO. 1662565		DIST. EASTERN
SUBM'D. FG	CHKD. FG	DATE: 11/12/2018	SITE: 3-302 A & B
DRAWN: JM	CHKD. SAT	APPD. FJH	DWG. 1

PLOT DATE: July 4, 2019
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MINISTRY OF TRANSPORTATION, ONTARIO

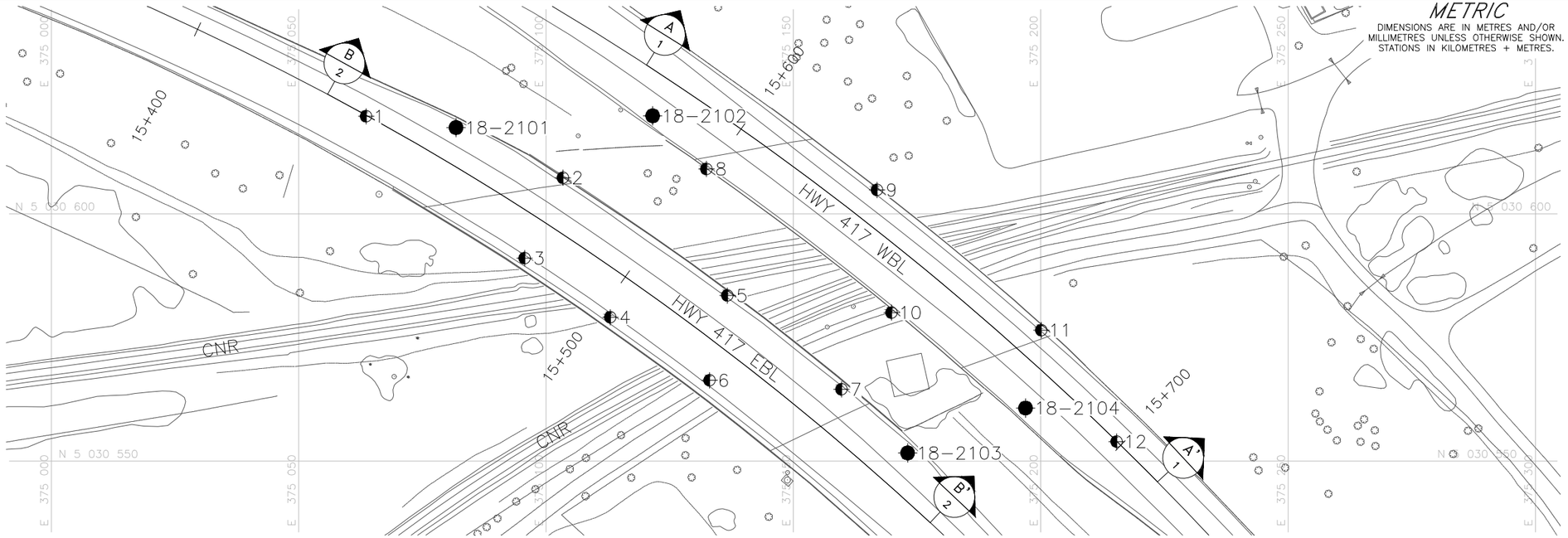
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

WP No. 4074-11-00

CPR OVERHEAD WIDENING
HIGHWAY 417
BOREHOLE LOCATIONS AND SOIL STRATA
LAT. 45.411684 LONG. -75.601224

SHEET

GOLDER



PLAN
SCALE
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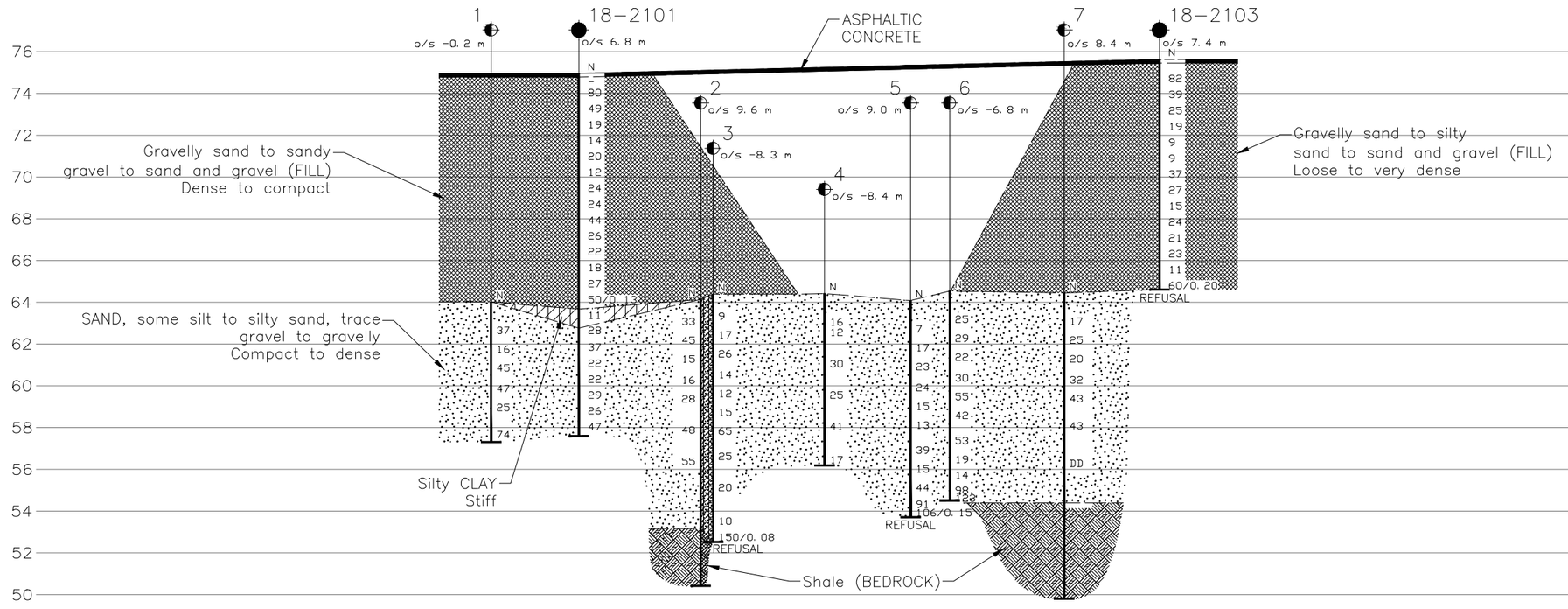

PROFILE B-B'
SCALE
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2.5 0 2.5 5

LEGEND

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- Borehole – Previous Investigation (Geocres No. 31G05-080)
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- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
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LICENSED PROFESSIONAL ENGINEER 100 M.S. SNOW PROVINCE OF ONTARIO June 23, 2019

REGISTERED PROFESSIONAL ENGINEER F. J. HEFFERNAN PROVINCE OF ONTARIO July 23, 19

NO.	DATE	BY	REVISION

Geocres No. 31G5-302

HWY. 417	PROJECT NO. 1662565		DIST. EASTERN
SUBM'D. FG	CHKD. FG	DATE: 11/12/2018	SITE: 3-302 A & B
DRAWN: JM	CHKD. SAT	APPD. FJH	DWG. 2

PLOT DATE: July 4, 2019
FILENAME: N:\Active\Spatial_MV\01\Hwy417Rehab&Widening\99_PROJ\1662565_MTO_Hwy417Replacements\A0_PROD\0013_CPR_Overhead\1662565-0013-BS-0001.dwg

APPENDIX A

Borehole and Drillhole Records, Current Investigation

Lists of Abbreviations and Symbols

Lithological and Geotechnical Rock Description Terminology

Records of Boreholes 18-2101 to 18-2104

Figure A1 – Rock Core Photographs

LIST OF SYMBOLS

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

I. GENERAL

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

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

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

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

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index = $(w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_C	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

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

Notes: 1 $\tau = c' + \sigma' \tan \phi'$

2 shear strength = (compressive strength)/2

LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

I. SAMPLE TYPE

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

II. PENETRATION RESISTANCE

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

Dynamic Cone Penetration Resistance; N_d:
The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60º cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure
PM: Sampler advanced by manual pressure
WH: Sampler advanced by static weight of hammer
WR: Sampler advanced by weight of sampler and rod

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

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

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

(b) Cohesive Soils

Consistency	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	100 to 200	1,000 to 2,000
Very stiff	over 200	over 4,000
Hard		

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 10	Trace	Trace sand
10 to 20	Some	Some sand
20 to 35	(ey) or (y)	Sandy
over 35	And	Sand and Gravel

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, as measured along the centerline axis of the core, relative to the length of the total core run. RQD varies from 0% for completely broken core to 100% for core in solid segments.

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 90º 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
FLT Fault
SH Shear
VN Vein
FR Fracture
SY Stylolite
BD Bedding
FO Foliation
CO Contact
AXJ Axial Joint
KV Karstic Void
MB Mechanical Break

PL Planar
CU Curved
UN Undulating
IR Irregular
K Slickensided
PO Polished
SM Smooth
SR Slightly Rough
RO Rough
VR Very Rough

GOLDER

RECORD OF BOREHOLE No 18-2101

SHEET 1 OF 2

METRIC

PROJECT 1662565-1210

G.W.P. 4074-11-00

LOCATION N 5030617.4; E 375081.8 NAD 83 MTM ZONE 9 (LAT. 45.403120; LONG. -75.711130)

ORIGINATED BY DG

DIST Eastern HWY 417

BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem)

COMPILED BY ZS

DATUM Geodetic

DATE June 20-21, 2018

CHECKED BY MJK

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (25 50 75)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
75.0	GROUND SURFACE										
0.0 / 74.8	ASPHALTIC CONCRETE										
0.2 / 74.3	(SP) Gravelly sand, angular (FILL) Moist		1	GRAB	-						
0.7	(SP/GP) Sand and gravel, some silt, trace to some clay, contains shale fragments (FILL) Very dense to compact Grey Moist		2	SS	80		74				
			3	SS	49		73				
			4	SS	19				○		40 38 16 6
			5	SS	14		72				
			6	SS	20		71		○		
70.5											
4.5	(GP-SP/GP) Sandy gravel to sand and gravel, some silt to silty, trace to some clay, contains shale fragments (FILL) Compact to dense Brown Moist		7	SS	12		70				
			8	SS	24		69		○		
			9	SS	24						
			10	SS	44		68		○		50 30 16 4
			11	SS	26		67				
			12	SS	22		66		○		
			13	SS	18						

Continued Next Page

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

$○^{3\%}$ STRAIN AT FAILURE

GOLDER

PROJECT 1662565-1210

RECORD OF BOREHOLE No 18-2101

SHEET 2 OF 2

METRIC

G.W.P. 4074-11-00 LOCATION N 5030617.4; E 375081.8 NAD 83 MTM ZONE 9 (LAT. 45.403120; LONG. -75.711130) ORIGINATED BY DG

DIST Eastern HWY 417 BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem) COMPILED BY ZS

DATUM Geodetic DATE June 20-21, 2018 CHECKED BY MJK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (25 50 75)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
	(GP-SP/GP) Sandy gravel to sand and gravel, some silt to silty, trace to some clay, contains shale fragments (FILL) Compact to dense Brown Moist		14	SS	27				○		37 35 21 7
			15	SS	50/0.13						
63.7							64				
11.3	(CL) Silty CLAY, trace sand Stiff Grey Wet		16	SS	11				⊖		
62.8							63				
12.2	(SM) Silty SAND, trace gravel Compact Grey-brown Wet		17	SS	28				○		
62.2											
12.8	(SP/SM) SAND, trace to some silt, trace gravel, trace clay Compact to dense Wet		18	SS	37		62				
			19	SS	22		61		○		7 85 7 1
			20	SS	22		60				
			21	SS	29				○		0 85 14 1
			22	SS	26		59				
			23	SS	47		58		○		
57.6											
17.4	END OF BOREHOLE										

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

GOLDER

RECORD OF BOREHOLE No 18-2102

SHEET 1 OF 2

METRIC

PROJECT 1662565-1210

G.W.P. 4074-11-00

LOCATION N 5030619.8; E 375121.6 NAD 83 MTM ZONE 9 (LAT. 45.402700; LONG. -75.710870)

ORIGINATED BY DG

DIST Eastern HWY 417

BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem)

COMPILED BY ZS

DATUM Geodetic

DATE June 24-25, 2018

CHECKED BY MJK

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (25 50 75)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
74.2	GROUND SURFACE										
0.0	ASPHALTIC CONCRETE										
0.2	(SP) Gravelly sand (FILL) Dense Grey Moist		1	GRAB	-		74				
			2	SS	47		73				
72.7											
1.5	(GP) Sandy gravel (FILL) Compact Grey Moist		3	SS	28		72				
71.2											
3.1	(SP/SM) Sand, some gravel to gravelly, some silt to silty, some clay (FILL) Compact to dense Brown Moist		4	SS	10		71		○		
			5	SS	39		70				
			6	SS	20		69				
			7	SS	20		68		○		17 40 30 14
			8	SS	14		67				
			9	SS	28		66		○		23 41 19 17
							65				

Continued Next Page

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

$○^{3\%}$ STRAIN AT FAILURE

GOLDER

PROJECT 1662565-1210

RECORD OF BOREHOLE No 18-2102

SHEET 2 OF 2

METRIC

G.W.P. 4074-11-00 LOCATION N 5030619.8; E 375121.6 NAD 83 MTM ZONE 9 (LAT. 45.402700; LONG. -75.710870) ORIGINATED BY DG

DIST Eastern HWY 417 BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem) COMPILED BY ZS

DATUM Geodetic DATE June 24-25, 2018 CHECKED BY MJK

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 25 50 75	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
			10	SS	29		64		○		
63.5											
10.7	(SP/SM) SAND, some silt, trace to some gravel, trace to some clay Compact to dense Brown Moist		11	SS	21		63				
			12	SS	21				○		6 70 17 7
			13	SS	48		62			CHEM	
61.4											
12.8	(SP) SAND, some gravel, trace silt and clay, contains cobbles and boulders Compact to dense Grey-brown Wet		14	SS	37		61		○		
			15	SS	29	▼	60				
			16	SS	41				○		
			17	SS	31		59				
							58				
			18	SS	36		57		○		20 73 6 1
56.8											
17.4	END OF BOREHOLE NOTES: 1. Water level in well screen at a depth of 14.0 m below ground surface (Elev. 60.2 m), measured on July 25, 2018.										

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

GOLDER

RECORD OF BOREHOLE No 18-2103

SHEET 1 OF 2

METRIC

PROJECT 1662565-1210

G.W.P. 4074-11-00 LOCATION N 5030551.6; E 375173.1 NAD 83 MTM ZONE 9 (LAT. 45.403160; LONG. -75.710970) ORIGINATED BY DG

DIST Eastern HWY 417 BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem) COMPILED BY ZS

DATUM Geodetic DATE June 8-9, 2018 CHECKED BY MJK

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 25 50 75	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
75.6	GROUND SURFACE										
0.0 / 75.4	ASPHALTIC CONCRETE										
0.2 / 74.1	(SP) Gravelly sand (FILL) Very dense Grey Moist		1	SS	82		75				
1.5 / 72.6	(SP-GP) Sand and gravel, some silt, trace clay (FILL) Compact Grey Moist		2	SS	39		74				
			3	SS	25		73		○		47 35 15 3
3.1 / 70.3	(SM) Silty sand, trace gravel, contains cobbles and boulders (FILL) Compact to loose Grey-brown Moist		4	SS	19		72				
			5	SS	9				○		
			6	SS	9		71				
5.3 / 69.5	(SP-GP) Sand and gravel, some silt, trace clay, contains cobbles and boulders (FILL) Dense Grey-brown Moist		7	SS	37		70		○		37 41 18 4
6.1 / 68.7	(SM) Silty sand, trace gravel (FILL) Compact Grey-brown moist		8	SS	27		69		○		
6.9 / 68.0	(CL) Silty clay (FILL) Grey Moist		9	SS	15				○⊢		
7.6	(SM) Gravelly silty SAND, trace to some clay (FILL) Compact to very dense Grey-brown Moist		10	SS	24		68		○		29 36 27 8
			11	SS	21		67				
			12	SS	23		66		○		24 49 21 6

Continued Next Page

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

GOLDER

RECORD OF BOREHOLE No 18-2103

SHEET 2 OF 2

METRIC

PROJECT 1662565-1210

G.W.P. 4074-11-00

LOCATION N 5030551.6; E 375173.1 NAD 83 MTM ZONE 9 (LAT. 45.403160; LONG. -75.710970)

ORIGINATED BY DG

DIST Eastern HWY 417

BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem)

COMPILED BY ZS

DATUM Geodetic

DATE June 8-9, 2018

CHECKED BY MJK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (25 50 75)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED		kN/m³	GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
	(SM) Gravelly silty SAND, trace to some clay (FILL) Compact to very dense Grey-brown Moist		13	SS	11		65				
64.6			14	SS	60/0.20				○		
11.0	END OF BOREHOLE AUGER REFUSAL										

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

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

GTA-MTO 001 N:\ACTIVE\SPATIAL_IMMTO\HWY417REHAB&WIDENING\02_DATA\GINT\1662565.GPJ GAL-GTA.GDT 19-6-17 ZS

GOLDER

PROJECT 1662565-1210

RECORD OF BOREHOLE No 18-2104

SHEET 1 OF 3

METRIC

G.W.P. 4074-11-00 LOCATION N 5030560.7; E 375196.9 NAD 83 MTM ZONE 9 (LAT. 45.402720; LONG. -75.710700) ORIGINATED BY DG

DIST Eastern HWY 417 BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem)/Wash Boring, HW Casing/ Rotary Drill, HQ Core COMPILED BY ZS

DATUM Geodetic DATE June 25-27, 2018 CHECKED BY MJK

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (25 50 75)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
74.7	GROUND SURFACE										
0.0 / 74.5	ASPHALTIC CONCRETE										
0.2	(SP) Gravelly sand (FILL) Dense Brown Moist		1	GRAB	-						
			2	SS	39		74				
73.3											
1.4	(SM) Silty sand, some gravel and clay (FILL) Loose Brown Moist		3	SS	8		73		○		
			4	SS	6		72				
			5	SS	9		71		○		17 42 27 14
70.1											
4.6	(SM) Silty sand, contains shale fragments (FILL) Dense Grey Moist		6	SS	44		70		○		
68.6							69				
6.1	(CL/SM) Silty clay and silty sand, layered (FILL) Compact Brown Moist		7	SS	23		68		○		
67.1											
7.6	(SM) Silty sand, contains shale fragments (FILL) Compact Grey-brown Moist		8	SS	28		67		○		
65.6							66				
9.1	(SM) Silty SAND, trace clay Compact Brown Moist		9	SS	24		65		○		

Continued Next Page

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

GOLDER

PROJECT 1662565-1210

RECORD OF BOREHOLE No 18-2104 SHEET 2 OF 3 METRIC

G.W.P. 4074-11-00 LOCATION N 5030560.7; E 375196.9 NAD 83 MTM ZONE 9 (LAT. 45.402720; LONG. -75.710700) ORIGINATED BY DG

DIST Eastern HWY 417 BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem)/Wash Boring, HW Casing/ Rotary Drill, HQ Core COMPILED BY ZS

DATUM Geodetic DATE June 25-27, 2018 CHECKED BY MJK

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 25 50 75	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
	(SM) Silty SAND, trace clay Compact Brown Moist										
			10	SS	21		64				
							63				
61.9			11	SS	18		62		○		0 52 46 2
12.8	(SM) Silty SAND, trace clay Dense Grey-brown Wet		12	SS	30		61				
			13	SS	44				○		0 56 43 1
59.5			14	SS	32		60				
15.2	(SP) SAND, some gravel, trace to some silt Dense to compact Grey-brown Wet		15	SS	26		59		○		17 76 7 0
			16	SS	35		58				
			17	SS	30				○		
			18	SS	41		57				
56.4											
18.3	(SM) Silty SAND, some gravel, trace to some clay (TILL) Dense Grey Wet		19	SS	30		56		○		15 49 28 8
			20	SS	32						
							55				

Continued Next Page

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

GOLDER

RECORD OF BOREHOLE No 18-2104

SHEET 3 OF 3 **METRIC**

PROJECT 1662565-1210
G.W.P. 4074-11-00
DIST Eastern HWY 417
DATUM Geodetic

LOCATION N 5030560.7; E 375196.9 NAD 83 MTM ZONE 9 (LAT. 45.402720; LONG. -75.710700) ORIGINATED BY DG
BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem)/Wash Boring, HW Casing/ Rotary Drill, HQ Core COMPILED BY ZS
DATE June 25-27, 2018 CHECKED BY MJK

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (25 50 75)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
54.3			21	SS	42						
20.4	(SP/SM) Gravelly SAND, some silt, trace to some clay (TILL) Very dense Grey-brown Wet		22	SS	91		54		○		22 56 16 6
52.7			23	RC	DD		53				
22.0	Shale (BEDROCK) Bedrock cored from depths of 22.0 m to 25.4 m For bedrock coring details refer to Record of Drillhole 18-2104		1	RC	REC 100%						RQD = 100%
			2	RC	REC 97%		52				RQD = 39%
							51				
49.3			3	RC	REC 100%		50				RQD = 99%
25.4	END OF BOREHOLE										

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

PROJECT: 1662565-1210

RECORD OF DRILLHOLE: 18-2104

SHEET 1 OF 1

LOCATION: N 5030560.7 ;E 375196.9

DRILLING DATE: June 25-27, 2018

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 75

DRILLING CONTRACTOR: Downing Drilling

NOTE:
For abbreviations, symbols and descriptions refer to
LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. / DEPTH (m)	RUN No.	FLUSH RETURN	RECOVERY: TOTAL CORE % (80 60 40 20)	RECOVERY: SOLID CORE % (80 60 40 20)	R.Q.D. % (80 60 40 20)	FRACT. INDEX PER (5 10 15 20)	DISCONTINUITY DATA: DIP w.r.t. CORE AXIS (0 30 60 90)	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	Jr	Ja	HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-6} 10^{-5} 10^{-4} 10^{-3})	WEATHERING INDEX (W1 W2 W3 W4 W5 W6)	FEATURES
		BEDROCK SURFACE		52.67													
23	Rotary Drill HQ3 Crore	Shale (BEDROCK) Fresh Thinly to medium bedded Grey-black Fine grained Slightly porous Weak		22.01	1	100											
24					2	100											
25				49.31	3	100											
		END OF DRILLHOLE		25.37													
26																	
27																	
28																	
29																	
30																	
31																	
32																	

DEPTH SCALE
1 : 50

GOLDER

LOGGED: DG
CHECKED: MJK

GTA-RCK 031 N:\ACTIVE\SPATIAL_IMMTO\HWY417REHAB&WIDENING\02_DATA\GINT\1662565.GPJ GAL-MISS.GDT 19-6-17 ZS

BH 18-2204

Cored Length of 21.10 to 25.37 metres

Core Box 1 and 2 of 2

21.10 m Top of Core

22.01 m Top of Bedrock

25.37 m EOH

Note: Material in core box from 21.10 m to 22.01 m is a gravel in Glacial Till

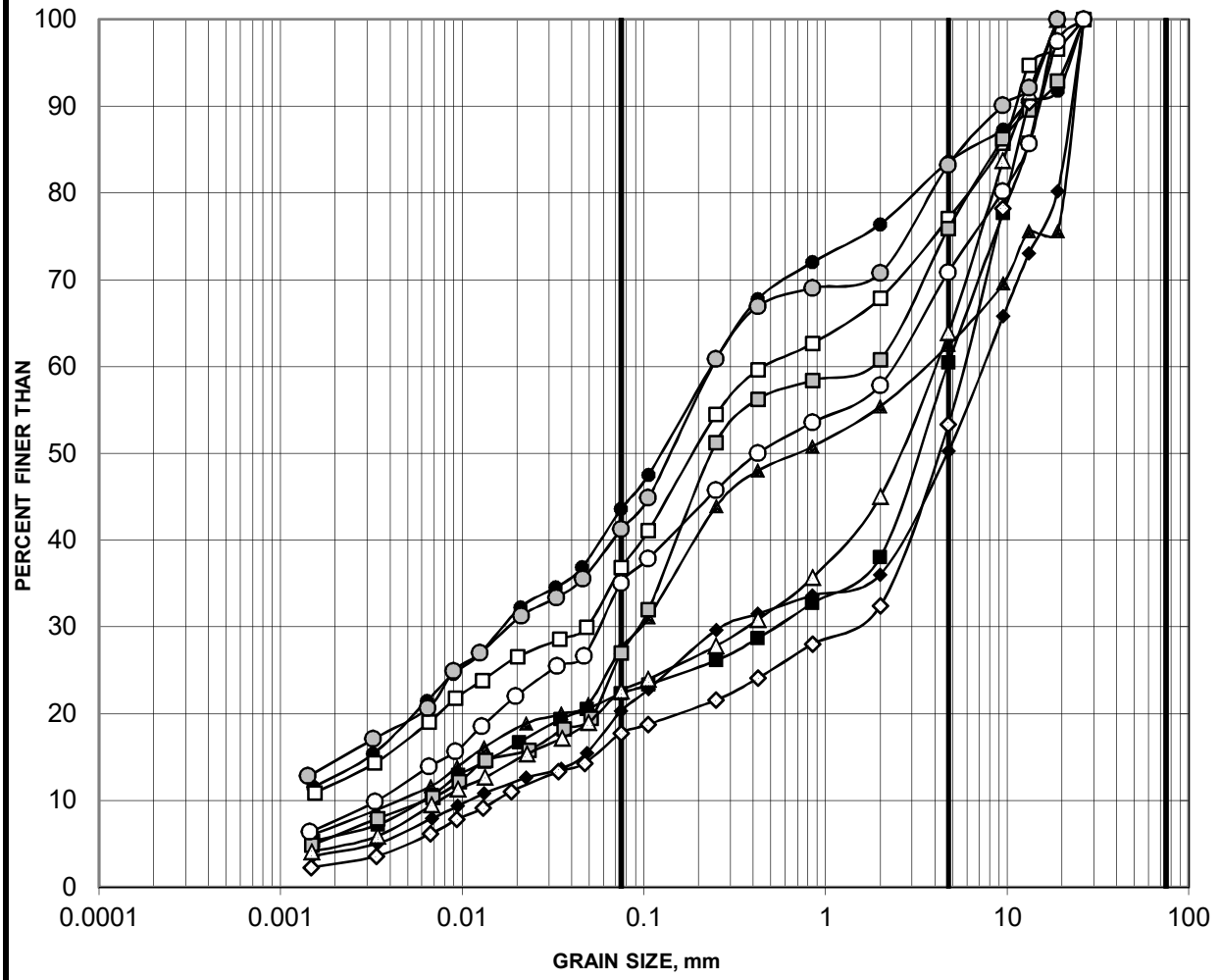
GOLDER	**Foundation Investigation** **CPR Overhead** **Ottawa, Ontario**	Project No. 1662565 / 1210 Drawn: WAM Date: 12/14/2018 Checked: Review:	**Figure A1**

APPENDIX B

Laboratory Test Results, Current Investigation

GRAIN SIZE DISTRIBUTION	FIGURE B1

SAND AND GRAVEL (FILL)



Borehole	Sample	Depth (m)
18-2101	4	2.29-2.90
18-2101	10	6.86-7.47
18-2101	14	9.91-10.52
18-2102	6	6.10-6.71
18-2102	8	8.38-8.99
18-2103	3	2.29-2.90
18-2103	7	5.33-5.94
18-2103	10	7.62-8.23
18-2103	12	9.14-9.75
18-2104	5	3.05-3.66

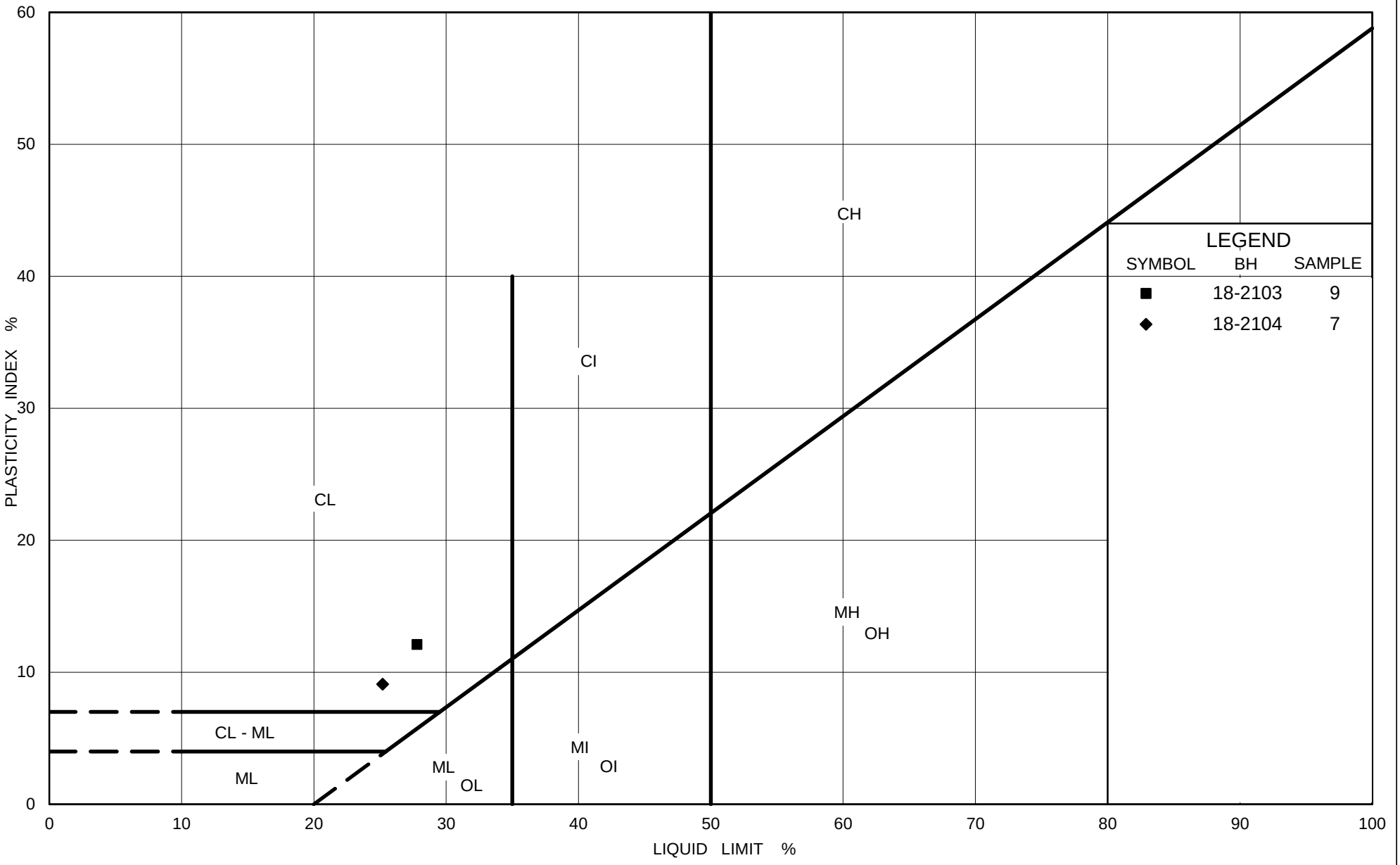
Project: 1662565/1210

Golder Associates

Created by: CW

Checked by: GM

Oct 75, FF-S-21



Ministry of Transportation

Ontario

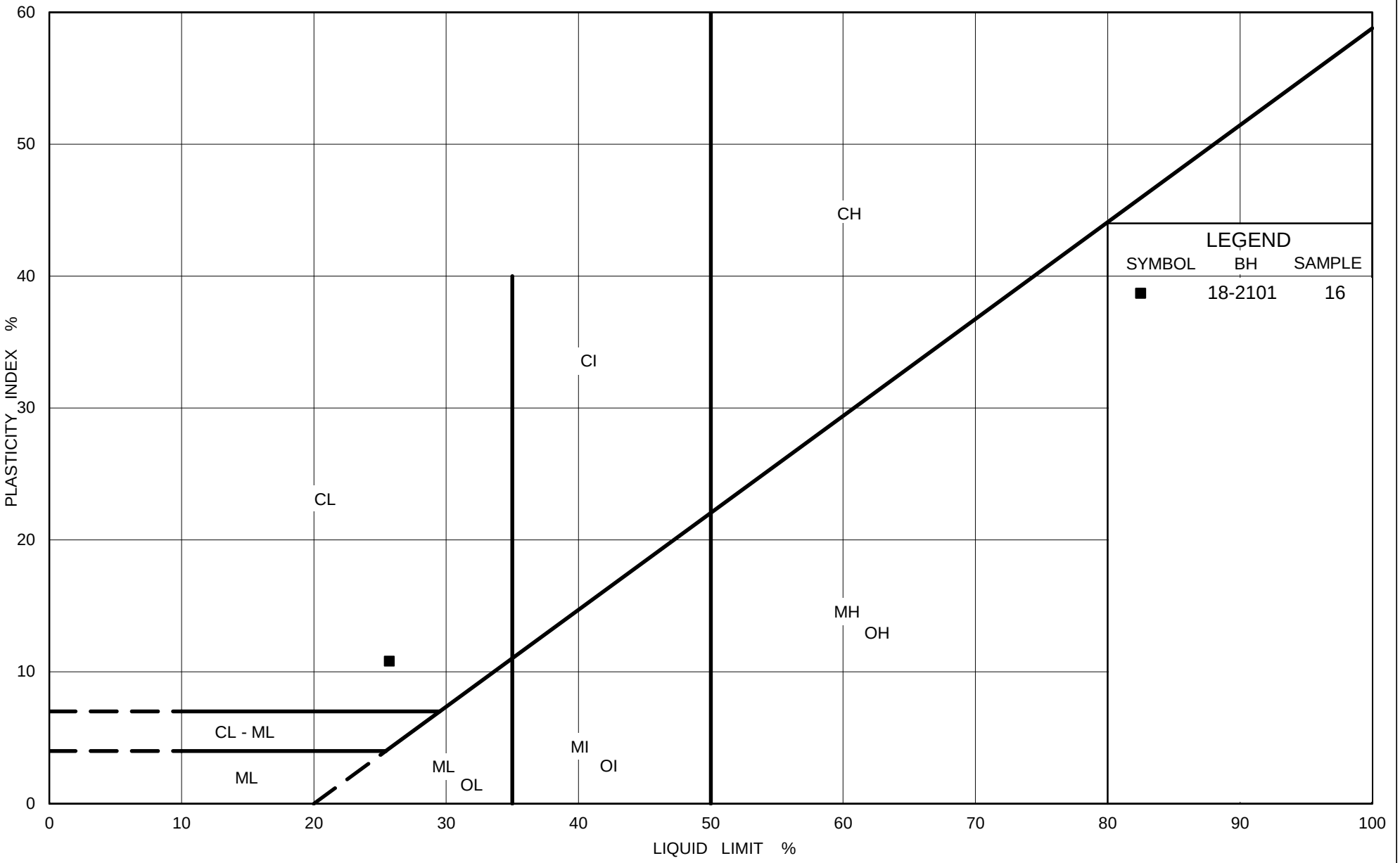
PLASTICITY CHART
SILTY CLAY (FILL)

FIG No. B2

Project No. 1662565/1210

Compiled By : MI Checked By : CW

Oct 75, FF-S-21



Ministry of Transportation

Ontario

PLASTICITY CHART
SILTY CLAY

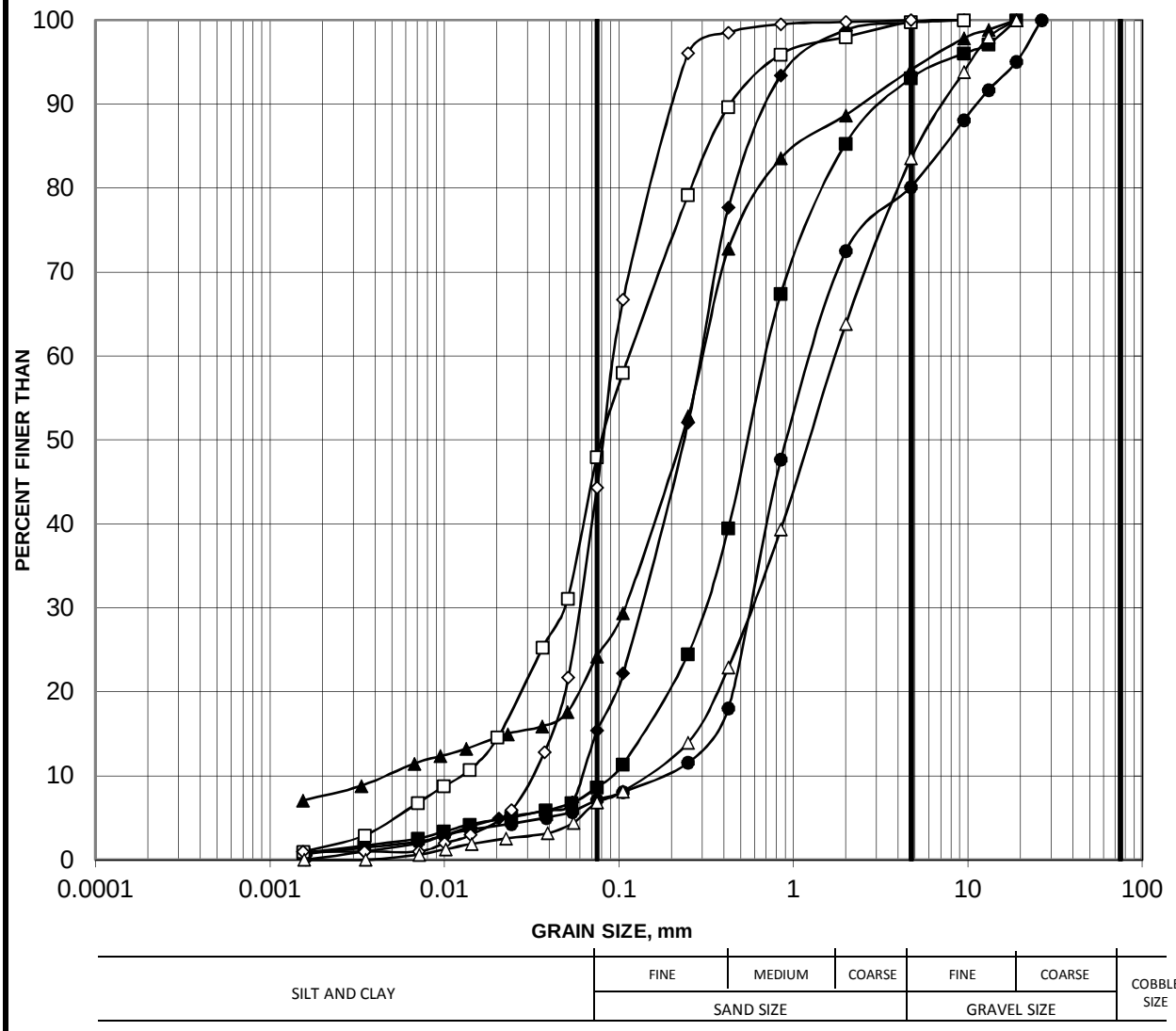
FIG No. B3

Project No. 1662565/1210

Compiled By : MI Checked By : CW

GRAIN SIZE DISTRIBUTION	FIGURE B4

SILTY SAND TO SAND



Borehole	Sample	Depth (m)
18-2101	19	13.72-14.33
18-2101	21	15.24-15.85
18-2102	12	11.43-12.04
18-2102	18	16.76-17.37
18-2104	11	12.19-12.80
18-2104	13	13.72-14.33
18-2104	15	15.24-15.85

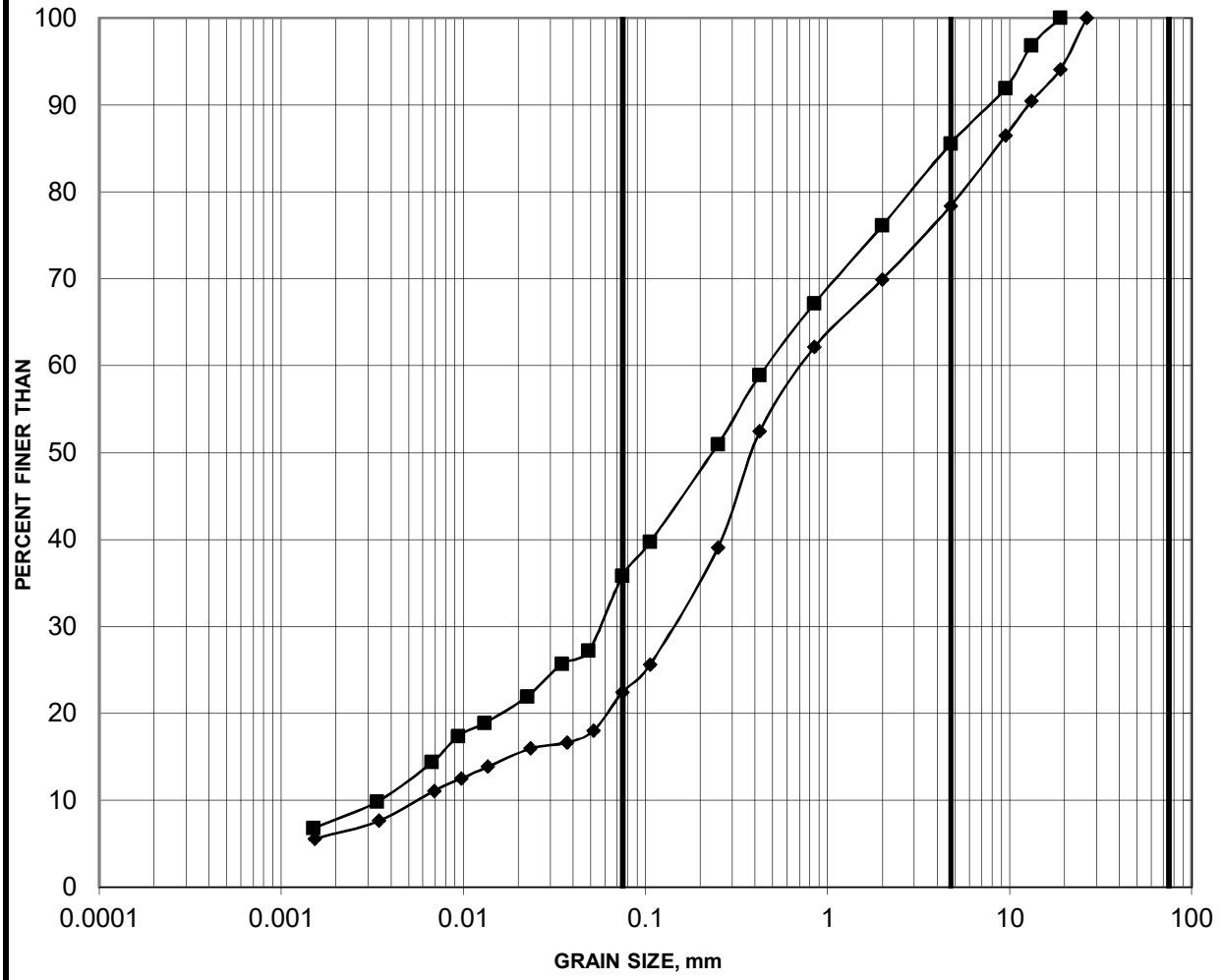
Project: 1662565/1210

Golder Associates

Created by: MI
Checked by: CW

GRAIN SIZE DISTRIBUTION	FIGURE B5

GRAVELLY SILTY SAND (TILL)



Borehole	Sample	Depth (m)
18-2104	19	18-29-18.90
18-2104	22	20.57-21.18

Project: 1662565/1210

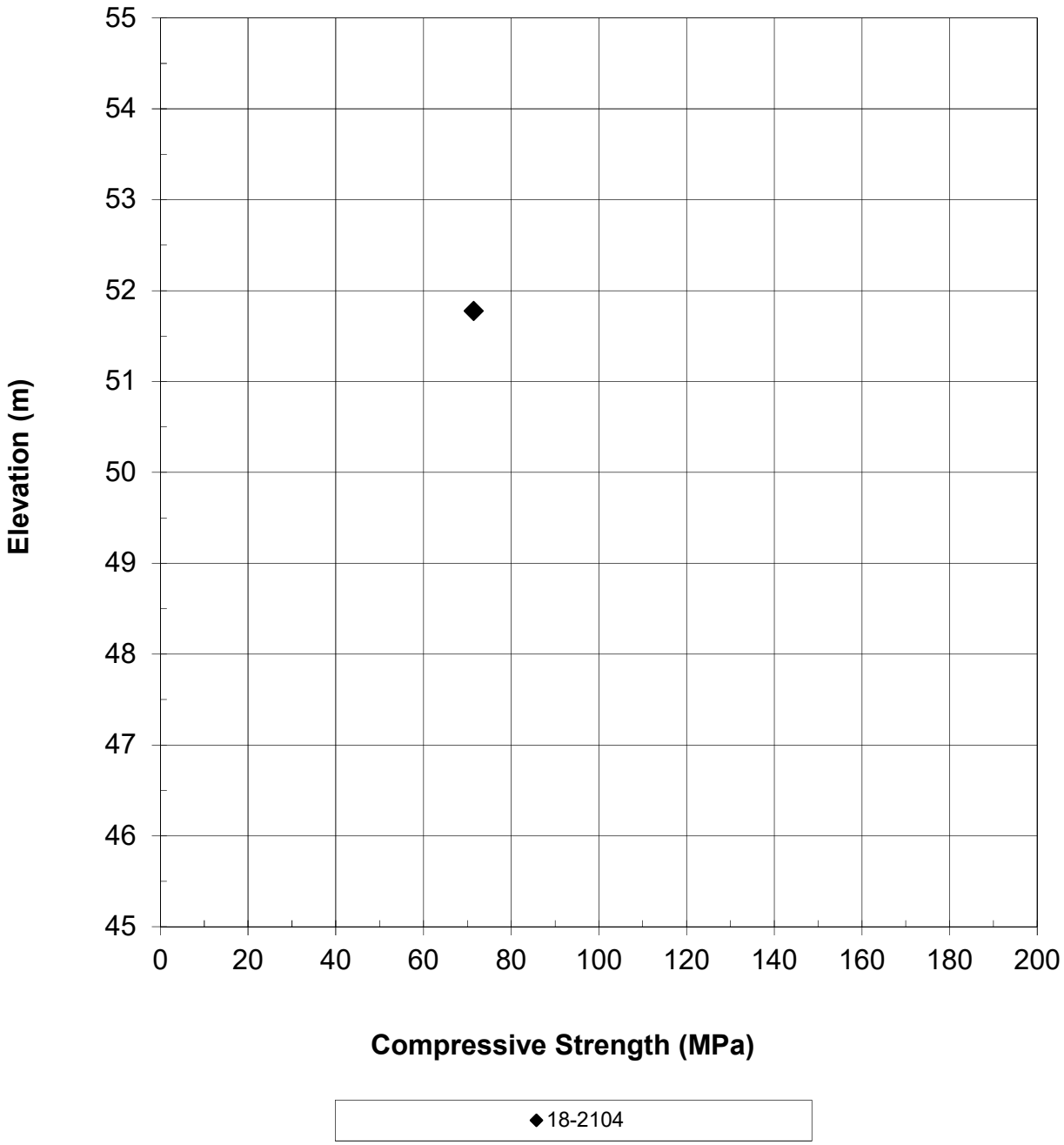
Golder Associates

Created by: CW

Checked by: GM

SUMMARY OF LABORATORY COMPRESSIVE STRENGTH
UNCONFINED COMPRESSION TESTS

FIGURE B6



Project: 1662565 /1210

GOLDER

Created by: CW
Checked by: CM

APPENDIX C

Borehole Records and Laboratory Test Results (Previous Investigation, GEOCRES No. 31G5-80)

Records of Previous Boreholes 1 to 12

Laboratory Test Results

FORM CD-M[illegible]- 126 (REV. 1969) OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 1

FOUNDATION SECTION

JOB 71-11126 LOCATION Co-ords. 16,503,918 N; 1,230,442 E. ORIGINATED BY SAA

W.P. 13-68-06 BORING DATE Nov. 2, 1971 COMPILED BY SAA

DATUM Geodetic BOREHOLE TYPE Washbore NX Casing CHECKED BY [illegible]

ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/FOOT	ELEV. SCALE
208.9	Ground Level					
0.0	Silty sand with some gravel. Compact to Very Dense Brown Grey		1	SS	37	200
			2	SS	16	
			3	SS	45	
			4	SS	47	
			5	SS	25	
187.9			6	SS	74	190
22.0	End of Borehole					180

DYNAMIC PENETRATION RESISTANCE
BLOWS / FOOT 20 40 60 80 100

SHEAR STRENGTH P.S.F.
o UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB. VANE

LIQUID LIMIT —— w_L
PLASTIC LIMIT —— w_P
WATER CONTENT —— w

w_P w w_L

WATER CONTENT % 10 20 30

BULK DENSITY γ P.C.F.	REMARKS GR. SA. SI. CL.
	▼ 208.2
	25 69 (6)
	7 91 (2)
	0 96 (4)

FORM OD-MTC - 126 (REV. 1969) OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 2

FOUNDATION SECTION

JOB 71-11126 LOCATION Co-ords. 16,503,878 N; 1,230,571 E. ORIGINATED BY WH

W.P. 13-68-06 BORING DATE November 15, 1971 COMPILED BY SAA

DATUM Geodetic BOREHOLE TYPE Washboring - NX & BX Casing CHECKED BY

SOIL PROFILE ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS/FOOT	ELEV. SCALE
210.3	Ground Level					
0.0	Silty sand with some gravel, trace of clayey silt. Brown Grey Compact to Dense Boulders up to 8" in thickness		1	SS	33	200
			2	SS	45	
			3	SS	15	
			4	SS	16	
			5	SS	28	
			6	SS	48	190
			7	SS	55	
			8	BX	27%	180
174.3						
36.0 170.9	Shale Bedrock Fractured. Grey		9	BX	22%	170
39.4 165.3	Shale Bedrock Sound Grey		10	BX	100%	
45.0	End of Borehole					

DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT — 20 40 60 80 100

SHEAR STRENGTH P.S.F.
o UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB. VANE

LIQUID LIMIT —— w_L
PLASTIC LIMIT —— w_P
WATER CONTENT —— w

WATER CONTENT % 10 20 30

BULK DENSITY γ P.C.F.

REMARKS GR. SA. SI. CL

▼ 207.2

18 43 30

21 75 (4

FORM OD-[illegible] - 126 (REV. 1969) OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 3

FOUNDATION SECTIO

JOB 71-11126 LOCATION Co-ords. 16,503,826 N; 1,230,546 E. ORIGINATED BY WH

W.P. 13-68-06 BORING DATE November 15, 1971 COMPILED BY SAA

DATUM Geodetic BOREHOLE TYPE Washboring - BX & NX Casing CHECKED BY

SOIL PROFILE ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS/FOOT	ELEV. SCALE
211.1	Ground Level					
0.0	Silty sand with some gravel, occ. seams of clayey silt up to 1" thick. Compact to Very Dense Brown - Grey		1	SS	9	210
			2	SS	17	
			3	SS	26	
			4	SS	14	200
			5	SS	12	
			6	SS	15	
			7	SS	65	190
			8	SS	25	
			9	SS	20	180
			10	SS	10	
172.2			11	SS	150/3"	
38.9	End of Borehole Probable Bedrock					170

DYNAMIC PENETRATION RESISTANCE
BLOWS / FOOT 20 40 60 80 100
SHEAR STRENGTH P.S.F.
○ UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB. VANE

125/9"

LIQUID LIMIT —— w_L
PLASTIC LIMIT —— w_P
WATER CONTENT —— w
w_P w w_L
WATER CONTENT % 10 20 30

BULK DENSITY γ P.C.F.

REMARKS GR.SA.SI.C

▼207.0

3 92 (5

20-75 (5

15 73 (12)

43 47 (1

FORM OD-M 126 (REV. 1969) OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 4

FOUNDATION SECTION

JOB 71-11126 LOCATION Co-ords. 16,503,788 N; 1,230,600 E. ORIGINATED BY WH
W.P. 13-68-06 BORING DATE November 19, 1971 COMPILED BY SAA
DATUM Geodetic BOREHOLE TYPE CHECKED BY

ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/FOOT	ELEV. SCALE
211.2	Ground Level					
0.0	Grey silty sand with some gravel.		1	SS	16	210
			2	SS	12	
	Compact to Dense		3	SS	30	200
	Brown - Grey		4	SS	25	
			5	SS	41	190
184.2			6	SS	17	
27.0	End of Borehole					180

DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT

SHEAR STRENGTH P.S.F.
o UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB. VANE

LIQUID LIMIT —— w_L
PLASTIC LIMIT —— w_P
WATER CONTENT —— w

w_P w w_L

WATER CONTENT %
10 20 30

BULK DENSITY γ P.C.F.

REMARKS

GR. SA. SI. CL.

208.2

1 95 (4)

38 56 (6)

Piez. Tip El. 189.1

FORM OD-M[illegible] - 126 (REV. 1969) OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 5

FOUNDATION SECTION

JOB 71-11126 LOCATION Co-ords. 16,503,798 N; 1,230,680 E. ORIGINATED BY WH
W.P. 13-68-06 BORING DATE November 18, 1971 COMPILED BY SAA
DATUM Geodetic BOREHOLE TYPE Washboring - NX CHECKED BY

SOIL PROFILE ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS/FOOT	ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS/FOOT (20 40 60 80 100) SHEAR STRENGTH P.S.F. (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB. VANE)	LIQUID LIMIT w_L PLASTIC LIMIT w_P WATER CONTENT w (WATER CONTENT % 10 20 30)	BULK DENSITY γ P.C.F.	REMARKS GR.SA.SI.CL
210.1	Ground Level									
0.0	Silty sand with some gravel - occ. seams of clayey silt. Compact to Dense Brown - Grey		1	SS	7					▽ 207.
			2	SS	17			○		29 57 12
			3	SS	23	200				
			4	SS	24			○		
			5	SS	15					
			6	SS	13					14 84 (2)
			7	SS	39	190				
			8	SS	15					
			9	SS	44					15 50 26
			10	SS	91	180				
176.1			11	SS	100/6"		130/8"			5 44 (11)
34.0	End of Borehole Probable Bedrock					170				

FORM OD-M[illegible] 126 (REV. 1969) OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 6

FOUNDATION SECTION

JOB 71-11126 LOCATION Co-ords. 16,503,742 N; 1,230,670 E. ORIGINATED BY VK

W.P. 13-68-06 BORING DATE November 17, 1971 COMPILED BY SAA

DATUM Geodetic BOREHOLE TYPE Washbore with NX Casing CHECKED BY

ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/FOOT	REMARKS
211.6	Ground Level					GR. SA. SI. CL.
0.0	Silty sand with trace of gravel, occ. clayey silt seams. Compact to Very Dense Brown-Grey		1	SS	25	▼207.6
			2	SS	29	12 73 (15)
			3	SS	22	
			4	SS	30	
			5	SS	55	
			6	SS	42	11 83 (6)
			7	SS	53	
			8	SS	19	2 93 (5)
			9	SS	11	7 59 25 9
			10	SS	98	
178.7			11	SS	123	
32.9	End of Borehole					

ELEV. SCALE: 210, 200, 190, 180, 170

DYNAMIC PENETRATION RESISTANCE
BLOWS / FOOT 20 40 60 80 100

SHEAR STRENGTH P.S.F.
o UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB. VANE

LIQUID LIMIT —— w_L
PLASTIC LIMIT —— w_P
WATER CONTENT —— w
w_P w w_L
WATER CONTENT % 10 20 30

BULK DENSITY γ P.C.F.

FORM OD-M 126 (REV. 1969) OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 7

FOUNDATION SECTION

JOB 71-11126 LOCATION Co-ords. 16,503,738 N; 1,230,755 E. ORIGINATED BY VK
W.P. 13-68-06 BORING DATE November 15, 1971 COMPILED BY SAA
DATUM Geodetic BOREHOLE TYPE Washbore - NX Casing CHECKED BY

ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT	ELEV. SCALE
211.3	Ground Level					
0.0	Silty sand with some gravel, occasional seams of clayey silt. Compact to Dense Brown - Grey		1	SS	17	210
			2	SS	25	
			3	SS	20	
			4	SS	32	200
			5	SS	43	
			6	SS	43	190
	Boulders up to 8" in thickness.		7	BX	6½" boulder	
178.3			8	BX	7%	180
33.0	Shale Bedrock Fractured Grey		9	BX	32%	
170.3			10	BX	20%	
41.0	Shale Bedrock Sound Grey		11	BX	61%	170
163.3			12	BX	100%	

DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT
20 40 60 80 100
SHEAR STRENGTH P.S.F.
o UNCONFINED + FIELD VANE
ø QUICK TRIAXIAL x LAB. VANE

LIQUID LIMIT —— w_L
PLASTIC LIMIT —— w_P
WATER CONTENT —— w
w_P w w_L
WATER CONTENT %
10 20 30

CH

BULK DENSITY γ P.C.F.

REMARKS GR. SA. SI. CL.

▽ 207.1

18 76 (6)

7 65 22 6

FORM OD-MT 126 (REV. 1969) OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 8

FOUNDATION SECTION

JOB 71-11126 LOCATION Co-ords. 16,503,885 N; 1,230,570 E. ORIGINATED BY AO
W.P. 13-68-06 BORING DATE November 24, 1971 COMPILED BY SAA
DATUM Geodetic BOREHOLE TYPE Washboring, BX and NX Casing CHECKED BY

ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS / FOOT
210.1	Ground Level				
0.0	Silty sand with some gravel, occ. seams of clayey silt. Compact Brown to grey		1	SS	10
			2	SS	13
			3	SS	13
			4	SS	15
			5	SS	22
			6	SS	21
			7	SS	19
177.1			8	SS	50
33.0	Shale Bedrock Weathered - Grey		9	RC	19%
172.6			10	RC	27%
37.5	Shale Bedrock		11	RC	83%
168.3	Sound Grey		12	RC	100%
41.8	End of Borehole				

ELEV. SCALE: 200, 190, 180, 170

DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT: 20 40 60 80 100

SHEAR STRENGTH P.S.F.
o UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB. VANE

LIQUID LIMIT —— w_L
PLASTIC LIMIT —— w_P
WATER CONTENT —— w

w_P w w_L

WATER CONTENT %: 10 20 30

BULK DENSITY γ P.C.F.

REMARKS

GR SA SI CL

▽205.6

0 11 87 2

6 93 (1)

Piez. Tip El.184.6

51 32 16 1

FORM OD-M[illegible] 126 (REV. 1969) OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 9

FOUNDATION SECTION

JOB 71-11126 LOCATION CoOords. 16,503,872 N; 1,230,780 E. ORIGINATED BY SAA
W.P. 13-68-06 BORING DATE November 23, 1971 COMPILED BY SAA
DATUM Geodetic BOREHOLE TYPE Washboring-BX & NX Casing CHECKED BY

ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/FOOT	ELEV. SCALE
209.2	Ground Level					
0.0	Silty sand with some gravel, occ. seams of clayey silt. Compact to Dense Brown - Grey		1	SS	13	
			2	SS	31	
			3	SS	23	200
			4	SS	23	
			5	SS	22	
			6	SS	20	190
			7	SS	26	
			8	SS	29	
						180
177.3			9	SS	67	
31.9	End of Borehole Probable Bedrock					170

DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT 20 40 60 80 100
SHEAR STRENGTH P.S.F.
o UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB. VANE

LIQUID LIMIT —— w_L
PLASTIC LIMIT —— w_P
WATER CONTENT —— w
w_P w w_L
WATER CONTENT % 10 20 30

BULK DENSITY γ P.C.F.

REMARKS

GR. SA. SI. CL.

▽ 206.2

15 82 (3)

32 61 (7)

FORM OD-M[illegible] 126 (REV. 1969) OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 10

FOUNDATION SECTION

JOB 71-11126 LOCATION Co-ords. 16,503,790 N; 1,230,788 E. ORIGINATED BY WH
W.P. 13-68-06 BORING DATE November 19, 1971 COMPILED BY SAA
DATUM Geodetic BOREHOLE TYPE CHECKED BY

ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/FOOT	ELEV. SCALE
210.8	Ground Level					210
0.0	Silty sand with some gravel Compact to Very Dense Grey Brown		1	SS	15	
			2	SS	26	
			3	SS	68	200
			4	SS	31	
			5	SS	30	
			6	SS	34	
			7	SS	30	190
			8	SS	53	
178.8			9	SS	58	180
32.0	End of Borehole Probable Bedrock					170

DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT
20 40 60 80 100
SHEAR STRENGTH P.S.F.
o UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB. VANE

LIQUID LIMIT —— w_L
PLASTIC LIMIT —— w_P
WATER CONTENT —— w
w_P w w_L
WATER CONTENT %
10 20 30

BULK DENSITY γ P.C.F.

REMARKS GR. SA. SI. CL.

206.8
9 62 (29)
29 60 (11)
26 62 (12)

FORM OD-M[illegible] 126 (REV. 1969) OFFICE REPOR[illegible]ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 11

FOUNDATION SECTION

JOB 71-11126 LOCATION Co-ords. 16,503,778 N; 1,230,886 E. ORIGINATED BY SAA
W.P. 13-68-06 BORING DATE November 23, 1971 COMPILED BY SAA
DATUM Geodetic BOREHOLE TYPE CHECKED BY

ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS/FOOT
210.3	Ground Level				
0.0	Silty sand with some gravel, occ. seams of clayey silt. Very Loose-Very Dense Brown Grey		1	SS	4
			2	SS	3
			3	SS	62
			4	SS	86
			5	SS	60
			6	SS	40
			7	SS	96
178.3			8	SS	79
32.0	Fractured weathered shale. Grey		9	RC	59%
			10	SS	60/2"
			11	RC	37%
169.3					
41.0	Shale Bedrock Sound Grey		12	RC	100%
163.5					

ELEV. SCALE: 210, 200, 190, 180, 170

DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT — 20 40 60 80 100

SHEAR STRENGTH P.S.F.
o UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB. VANE

LIQUID LIMIT —— w_L
PLASTIC LIMIT —— w_P
WATER CONTENT —— w
w_P w w_L
WATER CONTENT % 10 20 30

BULK DENSITY γ P.C.F.

REMARKS

GR. SA. SI. CL.

205.

5 53 (42)

0 97 (3)

Piez. Tip El. 181.0

FORM OD-M[illegible]- 126 (REV. 1969) OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 12

FOUNDATION SECTION AO

JOB 71-11126 LOCATION Co-ords. 16,503 705 N; 1,230,936 E. ORIGINATED BY

W.P. 13-68-06 BORING DATE November 25, 1971 COMPILED BY SAA

DATUM Geodetic BOREHOLE TYPE Washboring-NX BX Casing CHECKED BY

ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/FOOT	ELEV. SCALE
211.2	Ground Level					
0.0	Silty sand with some gravel, occ. seams of clayey silt. Loose to Dense Brown to Grey		1	SS	9	210
			2	SS	36	200
			3	SS	31	
			4	SS	36	190
184.2			5	SS	34	
27.0	End of Borehole					180
175.2						
36.0	End of Cone Test					170

DYNAMIC PENETRATION RESISTANCE BLOWS/FOOT 20 40 60 80 100

SHEAR STRENGTH P.S.F.
o UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB. VANE

LIQUID LIMIT —— w_L
PLASTIC LIMIT —— w_P
WATER CONTENT —— w

w_P w w_L

WATER CONTENT % 10 20 30

BULK DENSITY γ P.C.F.

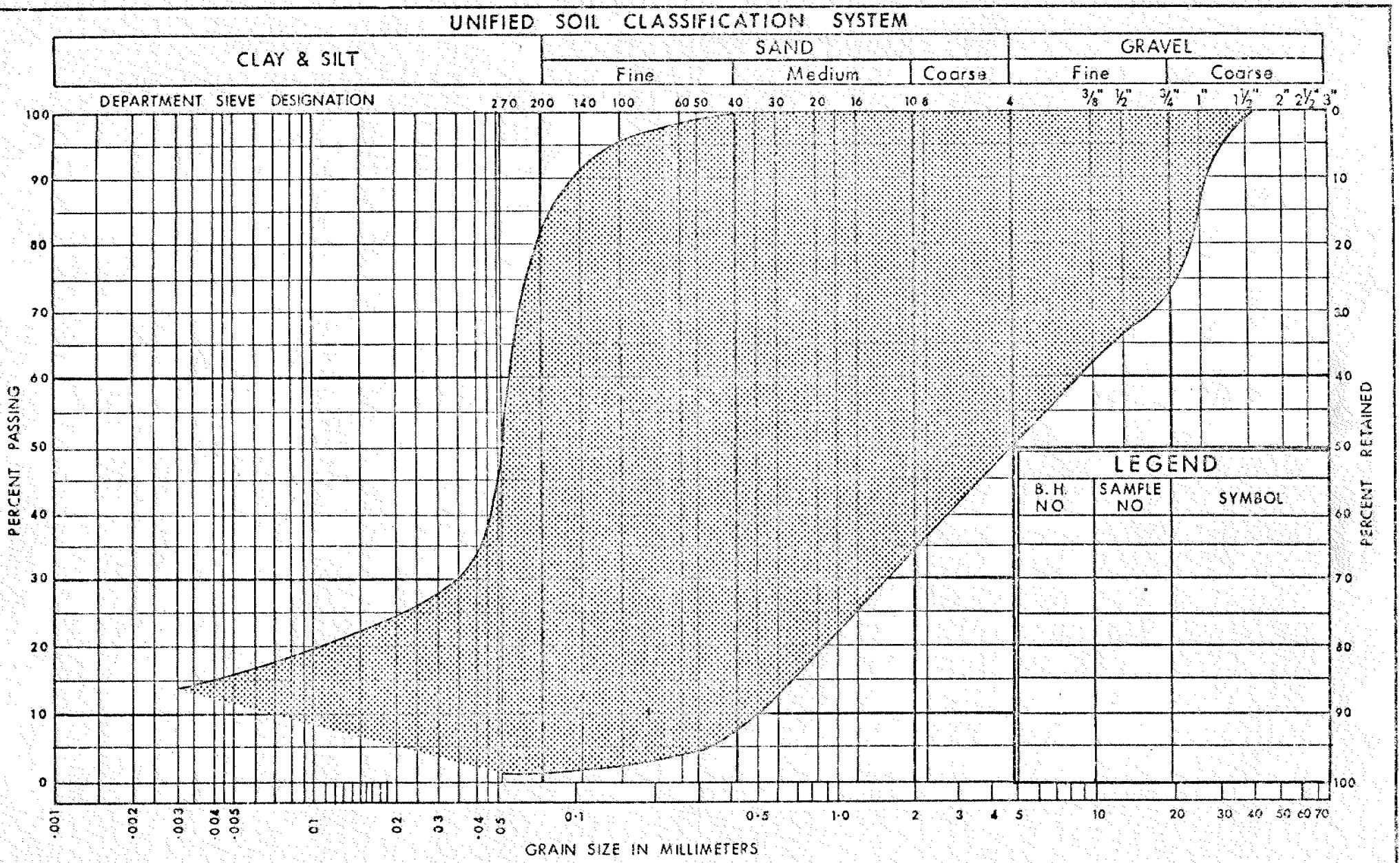
REMARKS GR. SA. SI. CL.

Nov. 25/72
▼ 206.2
4 83 (13)

30 60 (10)

1 94 (5)

FORM OD-MT-1
REV. AUG. 1971



DEPARTMENT OF TRANSPORTATION AND COMMUNICATIONS
ONTARIO
DESIGN SERVICES BRANCH

GRAIN SIZE DISTRIBUTION

SILTY SAND WITH SOME GRAVEL

W.P. No. 13-68-06
JOB No. 71-11126
FIG No. 1

APPENDIX D

Basic Chemical Analysis – Eurofins Report No. 1814200

Certificate of Analysis

eurofins | Environment Testing

Client: Golder Associates Ltd. (Ottawa)
1931 Robertson Road
Ottawa, ON
K2H 5B7
Attention: Mr. Alex Meacoe
PO#:
Invoice to: Golder Associates Ltd. (Ottawa)

Report Number: 1814200
Date Submitted: 2018-08-09
Date Reported: 2018-08-16
Project: 1662565/1210
COC #: 834571

				Lab I.D.	1379728
				Sample Matrix	Soil
				Sample Type	
				Sampling Date	2018-08-09
				Sample I.D.	18-2102Sa13/40-42'
Group	**Analyte**	**MRL**	**Units**	**Guideline**	
Anions	Cl	0.002	%		0.015
	SO4	0.01	%		0.03
General Chemistry	Electrical Conductivity	0.05	mS/cm		0.55
	pH	2.00			8.42
	Resistivity	1	ohm-cm		1820

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

Results of MASW Testing

TECHNICAL MEMORANDUM

DATE June 27, 2019 **Project No.** 1662565/1210

TO Susan Trickey, Golder Associates Ltd.

FROM Peter Giamou, Christopher Phillips **EMAIL** pgiamou@golder.com, cphillips@golder.com

CHBDC SEISMIC SITE CLASS TESTING RESULTS

CPR AND HIGHWAY 417, OTTAWA, ONTARIO

This technical memorandum presents the results of two Multichannel Analysis of Surface Waves (MASW) tests performed for the purpose of the Canadian Highway Bridge Design Code (CHBDC 2014) Seismic Site Classification (Figure 1). The tests are located on each side of the interchange between Canadian Pacific Railway (CPR) and Highway 417 in Ottawa. The geophysical testing was performed by Golder Associates Ltd. (Golder) personnel on July 18, 2018.

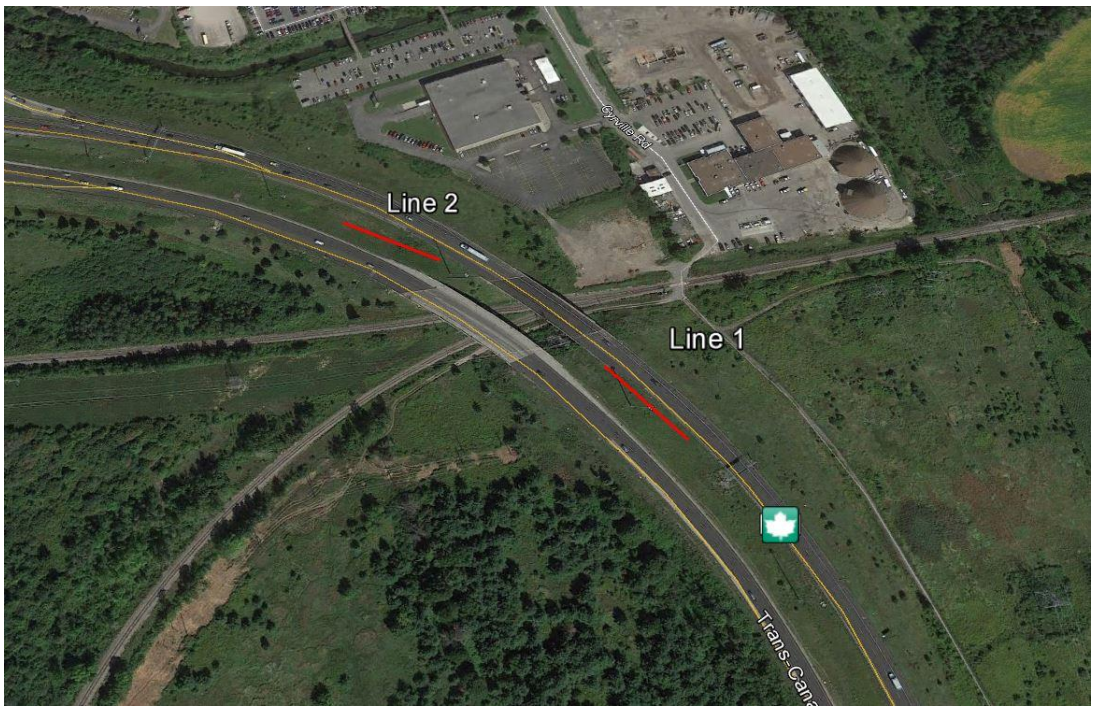


Figure 1: MASW Location Site Map. MASW Lines in red – Line 1 and Line 2.

Golder Associates Ltd.
6925 Century Avenue, Suite #100 Mississauga, Ontario, L5N 7K2 Canada T: +1 905 567 4444 +1 905 567 6561

Methodology

The MASW method measures variations in surface-wave velocity with increasing distance and wavelength and can be used to infer the rock/soil types, stratigraphy and soil conditions.

A typical MASW survey requires a seismic source, to generate surface waves, and a minimum of two geophone receivers, to measure the ground response at some distance from the source. Surface waves are a special type of seismic wave whose propagation is confined to the near surface medium.

The depth of penetration of a surface wave into a medium is directly proportional to its wavelength. In a non-homogeneous medium, surface waves are dispersive, i.e., each wavelength has a characteristic velocity owing to the subsurface heterogeneities within the depth interval that particular wavelength of surface wave propagates through. The relationship between surface-wave velocity and wavelength is used to obtain the shear-wave velocity and attenuation profile of the medium with increasing depth.

The seismic source used can be either active or passive, depending on the application and location of the survey. Examples of active sources include explosives, weight-drops, sledge hammer and vibrating pads. Examples of passive sources are road traffic, micro-tremors, and water-wave action (in near-shore environments).

The geophone receivers measure the wave-train associated with the surface wave travelling from a seismic source at different distances from the source.

The participation of surface waves with different wavelengths can be determined from the wave-train by transforming the wave-train results into the frequency domain. The surface-wave velocity profile with respect to wavelength (called the ‘dispersion curve’) is determined by the delay in wave propagation measured between the geophone receivers. The dispersion curve is then matched to a theoretical dispersion curve using an iterative forward-modelling procedure. The result is a shear-wave velocity profile of the tested medium with depth, which can be used to estimate the dynamic shear-modulus of the medium as a function of depth.

Field Work

The MASW field work was conducted on July 18, 2018, by personnel from the Golder Mississauga office. For each MASW line, a series of 24 low frequency (4.5 Hz) geophones were laid out at 3 m intervals. Both active and passive readings were recorded along the MASW lines. For the active investigation, a seismic drop of 45 kg and a 9.9 kg sledge hammer were used as seismic sources. Active seismic records were collected with seismic sources located 5, 10, and 15 m from and collinear to the geophone array. A seismic refraction survey was also conducted along both lines to be able to determine the depth to bedrock as well as to estimate the shear wave velocity of the overburden. An example of active seismic records collected at each line are shown in Figures 2 and 3, below.

Table 1: Location of MASW Lines

Location	MTM NAD83 Zone 9 Northing (m)	MTM NAD83 Zone 9 Easting (m)
Line 1 – Start	5,030,492.3	375,256.1
Line 1 – End	5,030,539.4	375,206.2
Line 2 – Start	5,030,620.4	375,097.7
Line 2 – End	5,030,649.3	375,036.1

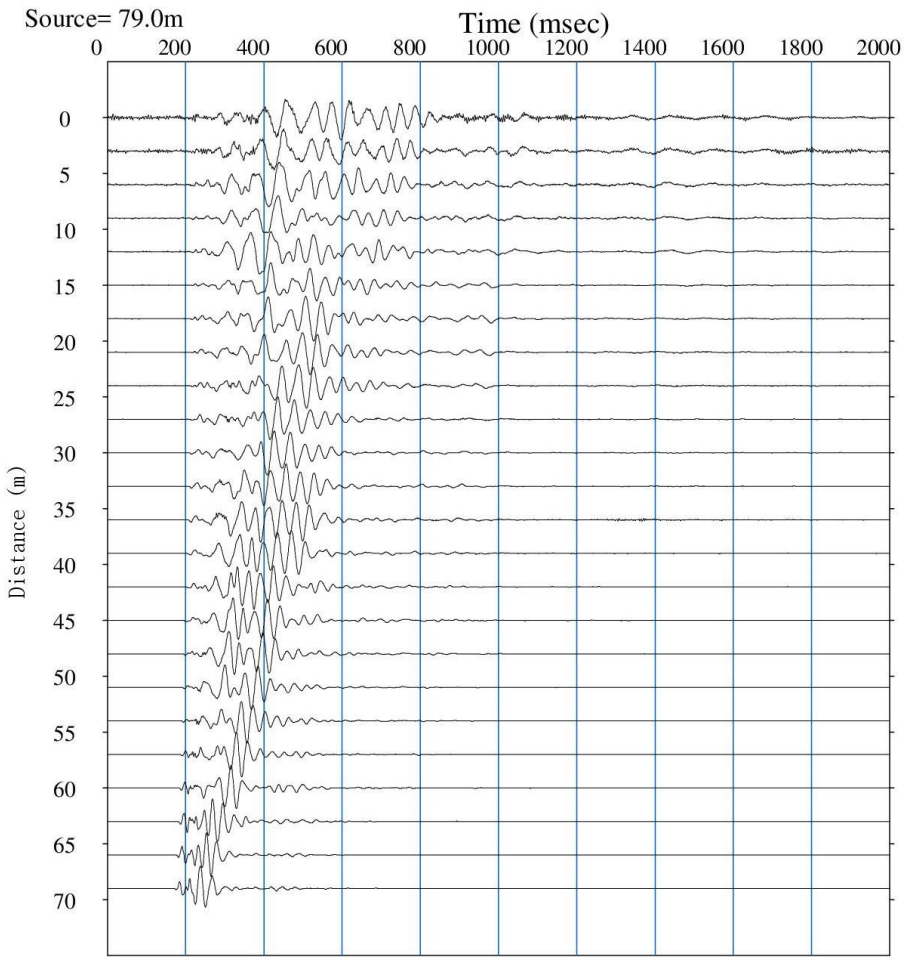


Figure 2: Typical seismic record collected at the site of MASW Line 1.

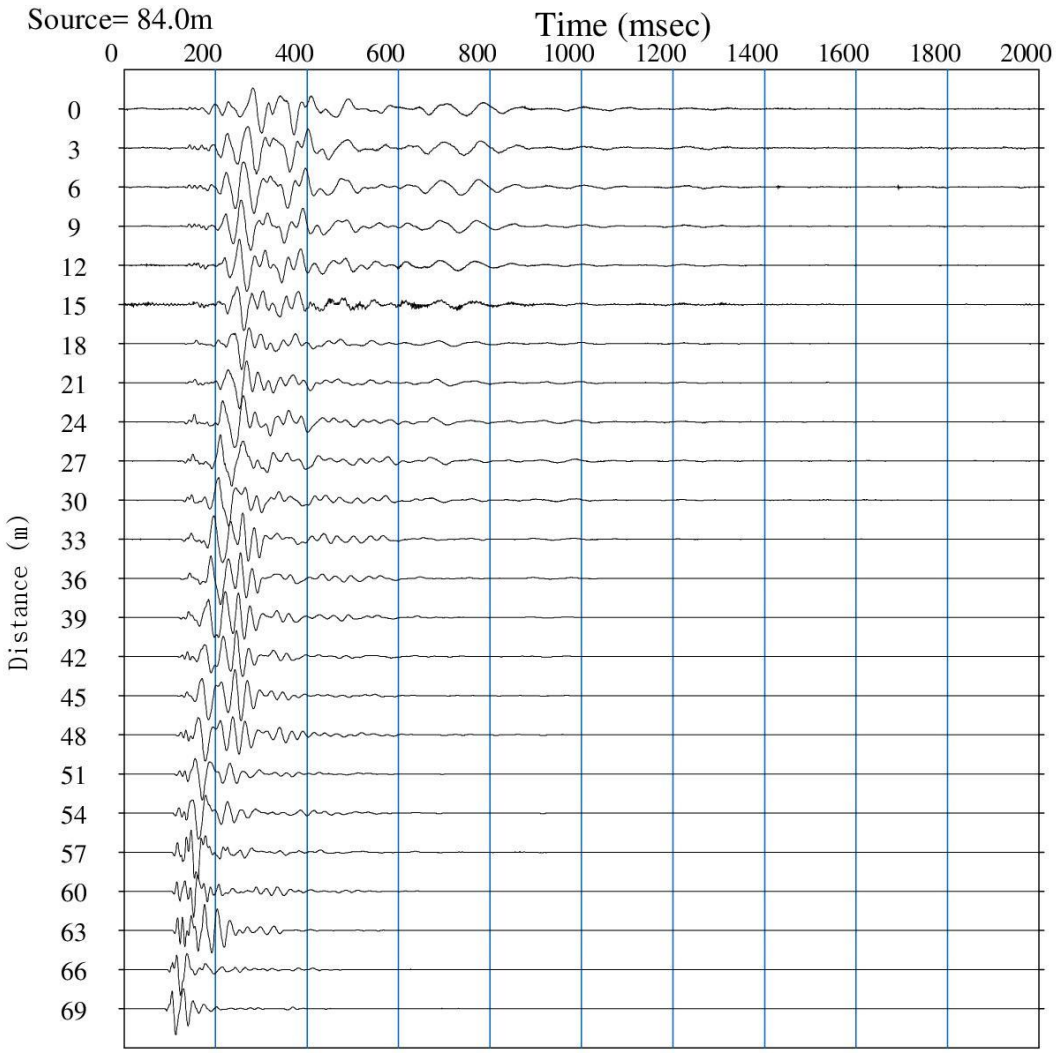


Figure 3: Typical seismic record collected at the site of MASW Line 2.

Data Processing

Processing of the MASW test results consisted of the following main steps:

1) Transformation of the time domain data into the frequency domain using a Fast-Fourier Transform (FFT) for each source location;

2) Calculation of the phase for each frequency component;

3) Linear regression to calculate phase velocity for each frequency component;

4) Filtering of the calculated phase velocities based on the Pearson correlation coefficient (r2) between the data and the linear regression best fit line used to calculate phase velocity;

5) Generation of the dispersion curve by combining calculated phase velocities for each shot location of a single MASW test; and,

6) Generation of the stiffness profile, through forward iterative modelling and matching of model data to the field collected dispersion curve.

Processing of the MASW data was completed using the SeisImager/SW software package (Geometrics Inc.). The calculated phase velocities for a seismic shot point were combined and the dispersion curve generated by choosing the minimum phase velocity calculated for each frequency component as shown on Figure 4 for Line 1 and Figure 5 for Line 2. Shear wave velocity profiles were generated through inverse modelling to best fit the calculated dispersion curves. The active survey of Line 1 provided a dispersion curve with a suitable frequency range (6-25 Hz). The active survey of Line 2 provided a dispersion curve with a suitable frequency range (9-38 Hz).

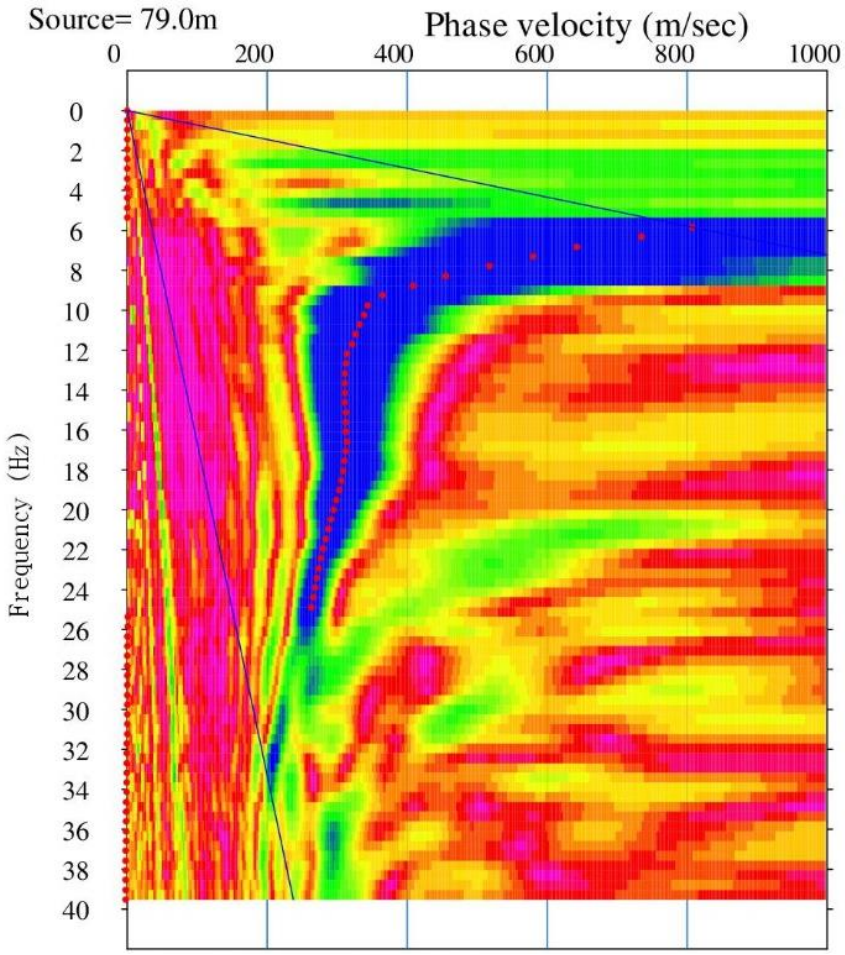


Figure 4: Active MASW Dispersion Curve Picks (red dots) along MASW Line 1

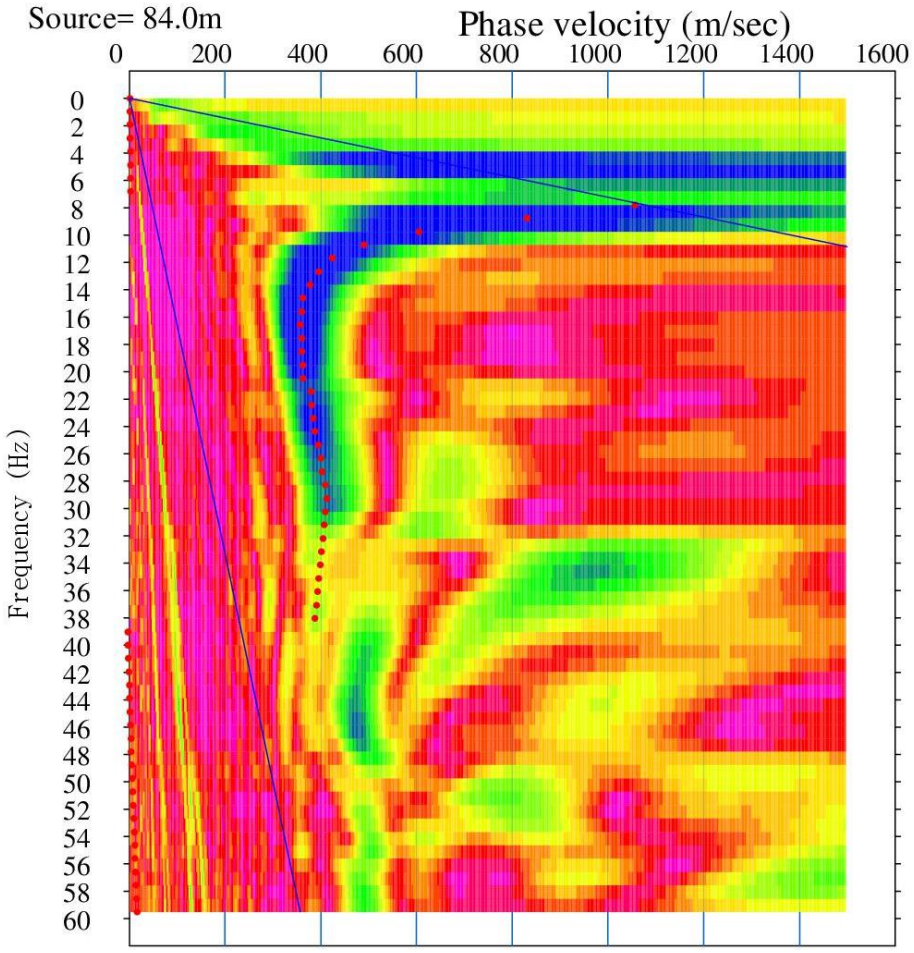


Figure 5: Active MASW Dispersion Curve Picks (red dots) along MASW Line 2

Results

The MASW test results are presented in Figures 6 and 7, which present the calculated shear wave velocity profile derived from the field testing along MASW Lines 1 and 2, respectively. The results along MASW Line 1 have been calculated using a weight-drop located 10 m from the last geophone. The results along MASW Line 2 have also been calculated using a weight-drop located 5 m from the last geophone. The field collected dispersion curves are compared with the model generated dispersion curves on Figures 8 and 9 for MASW Lines 1 and 2, respectively. There is a satisfactory correlation between the field collected and model calculated dispersion curves, with a root mean squared error of less than 3% along both lines.

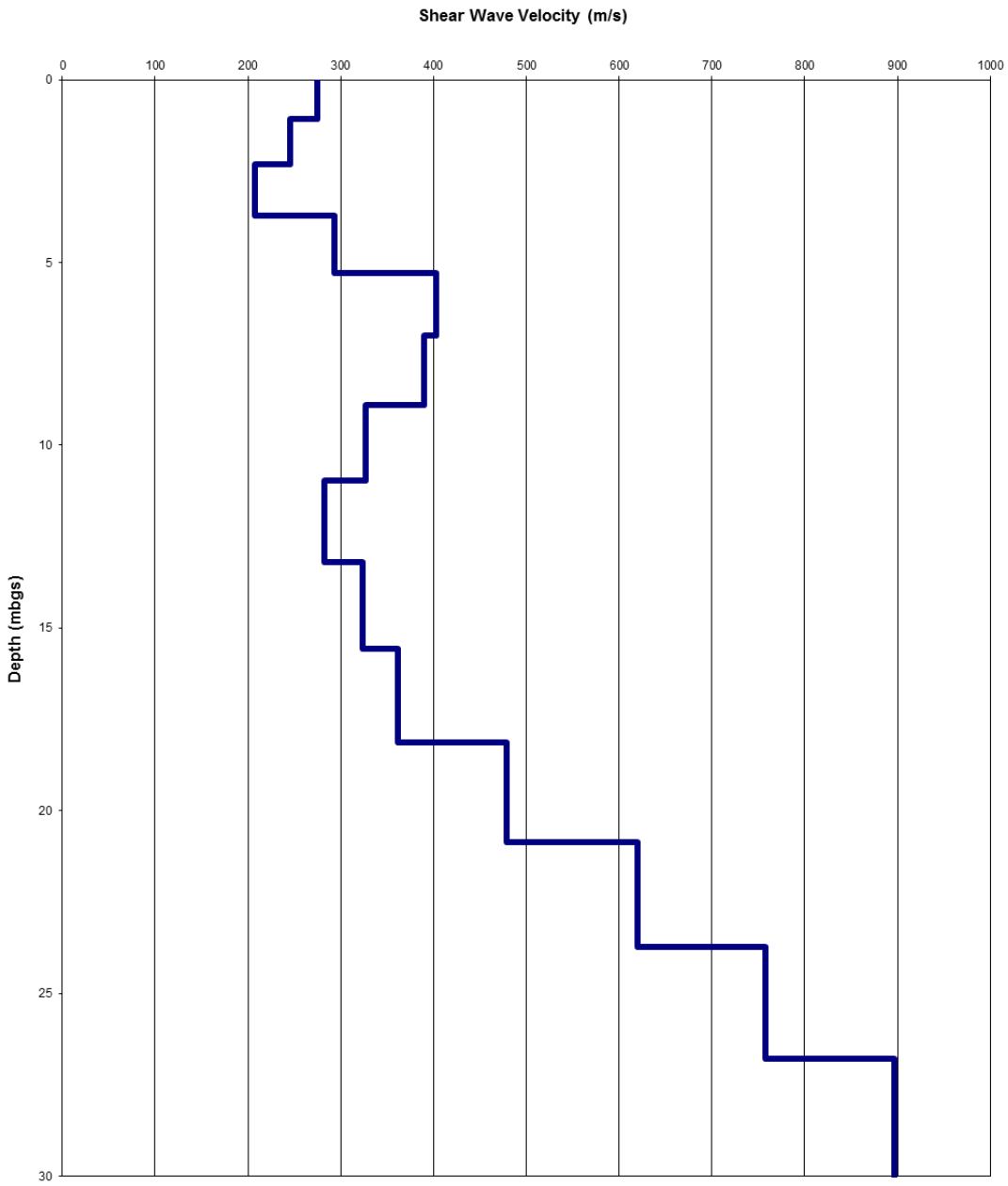


Figure 6: MASW Modelled Shear-Wave Velocity Depth profile along MASW Line 1

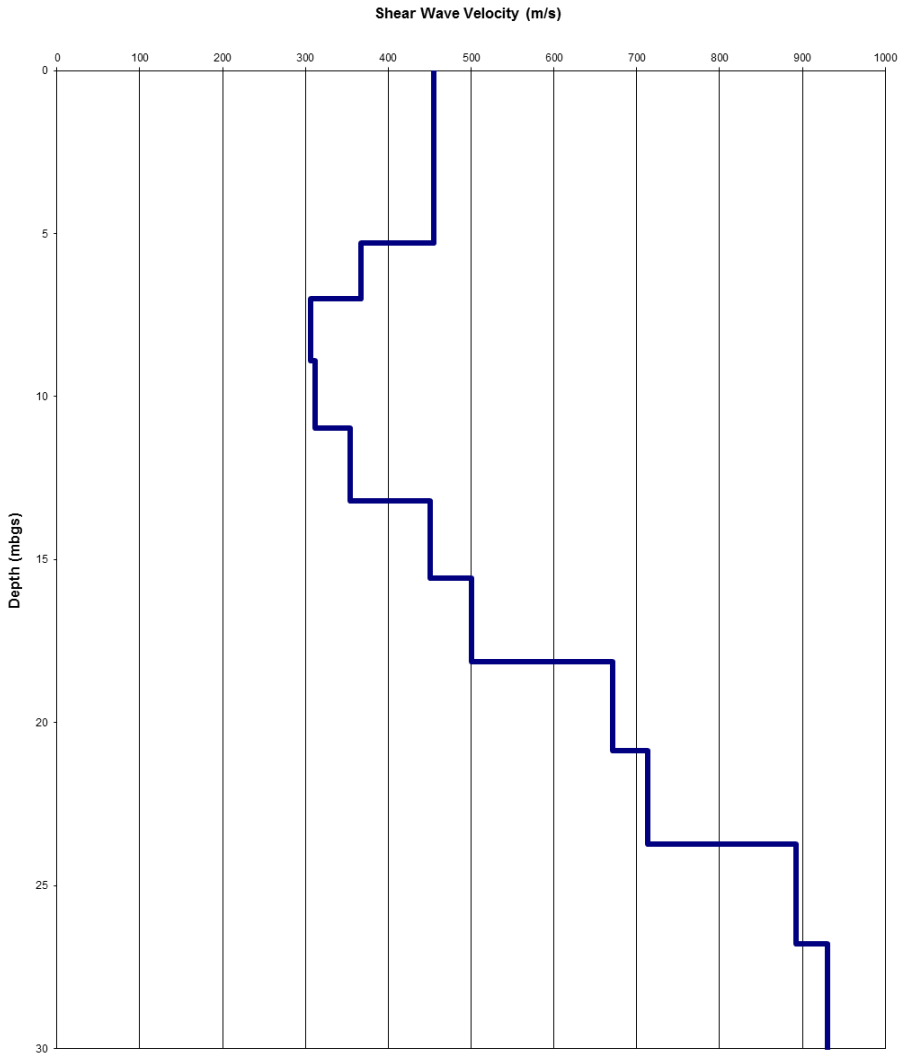


Figure 7: MASW Modelled Shear-Wave Velocity Depth profile along MASW Line 2

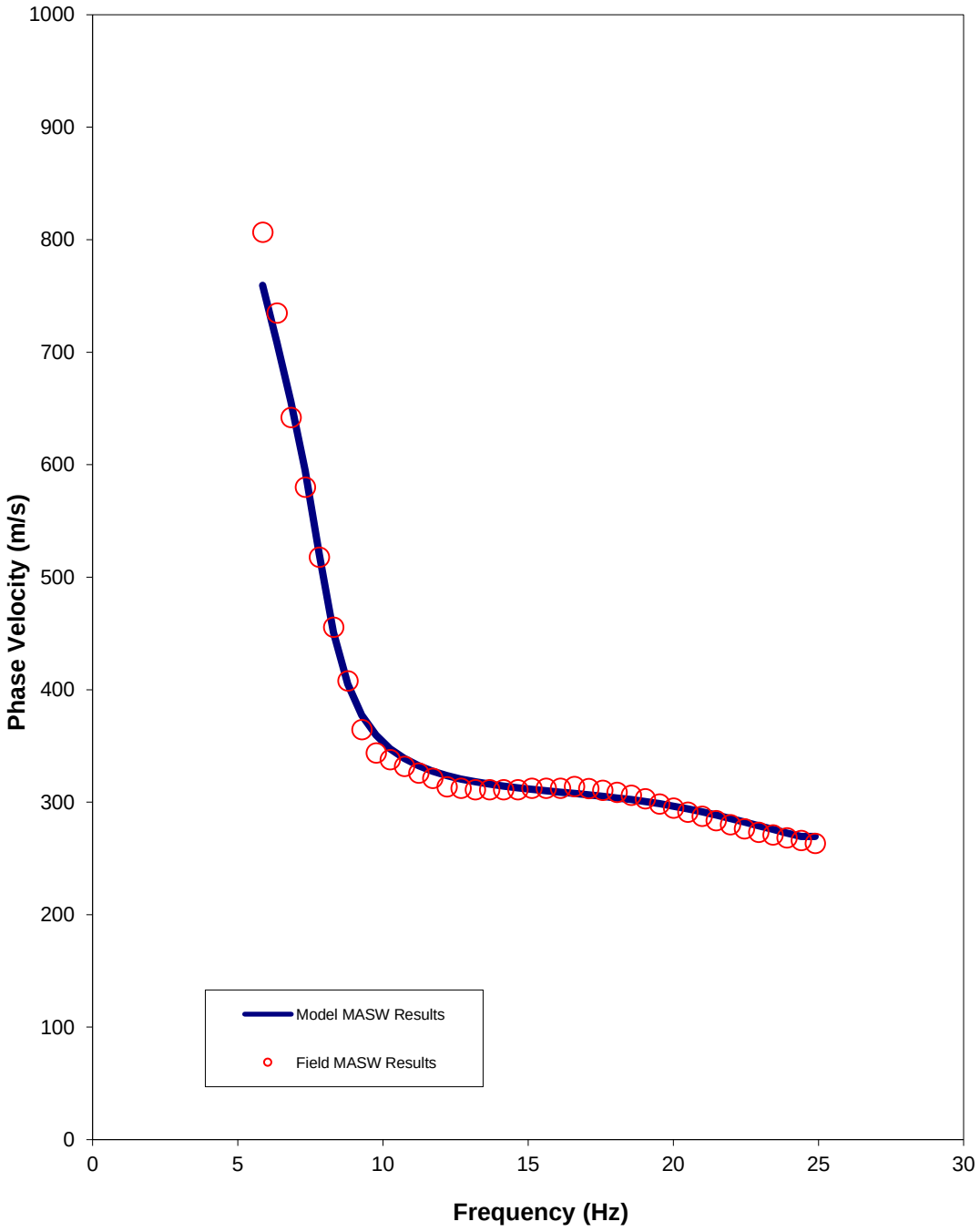


Figure 8: Comparison of Field (red dots) vs. Modelled Data (blue line) along MASW Line 1

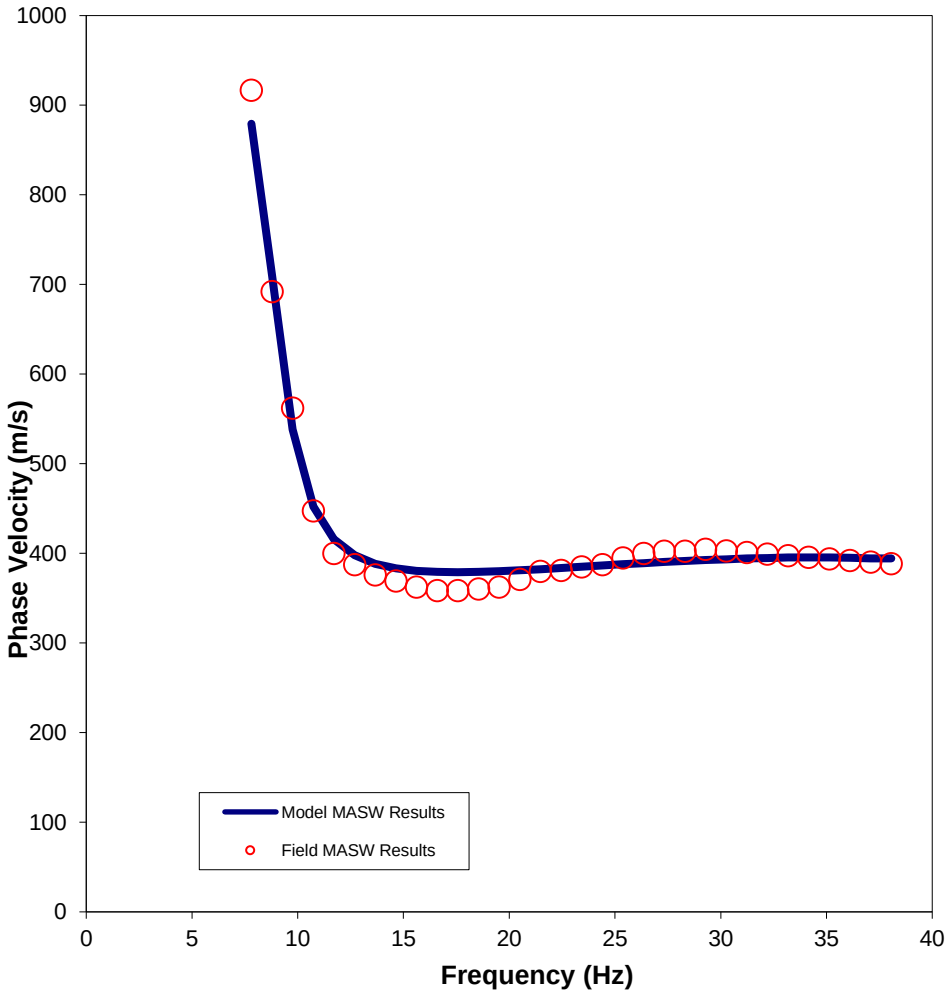


Figure 9: Comparison of Field (red dots) vs. Modelled Data (blue line) along MASW Line 2

To calculate the average shear-wave velocity as required by the CHBDC 2014, the results were modelled to 30 metres below ground surface. The average shear-wave velocity along MASW Line 1 in the south was found to be 391 m/s (Table 1). The average shear-wave velocity along MASW Line 2 in the north was found to be 494 m/s (Table 2).

Table 2: Shear-Wave Velocity Profile along MASW Line 1

Model Layer (mbgs)		Layer Thickness (m)	Shear Wave Velocity (m/s)	Shear Wave Travel Time Through Layer (s)
Top	Bottom			
0.00	1.07	1.07	275	0.003893
1.07	2.31	1.24	245	0.005043
2.31	3.71	1.40	208	0.006747
3.71	5.27	1.57	293	0.005343
5.27	7.01	1.73	403	0.004297
7.01	8.90	1.90	390	0.004866
8.90	10.96	2.06	326	0.006311
10.96	13.19	2.23	282	0.007882
13.19	15.58	2.39	324	0.007378
15.58	18.13	2.55	361	0.007071
18.13	20.85	2.72	479	0.005682
20.85	23.74	2.88	619	0.004657
23.74	26.79	3.05	758	0.004023
26.79	30.00	3.21	897	0.003585
Vs Average to 30 mbgs (m/s)				**391**

Table 3: Shear-Wave Velocity Profile along MASW Line 2

Model Layer (mbgs)		Layer Thickness (m)	Shear Wave Velocity (m/s)	Shear Wave Travel Time Through Layer (s)
Top	Bottom			
0.00	1.07	1.07	455	0.002353
1.07	2.31	1.24	455	0.002714
2.31	3.71	1.40	455	0.003076

Model Layer (mbgs)		Layer Thickness (m)	Shear Wave Velocity (m/s)	Shear Wave Travel Time Through Layer (s)
Top	Bottom			
3.71	5.27	1.57	455	0.003438
5.27	7.01	1.73	368	0.004709
7.01	8.90	1.90	306	0.006193
8.90	10.96	2.06	311	0.006618
10.96	13.19	2.23	354	0.006281
13.19	15.58	2.39	450	0.005308
15.58	18.13	2.55	500	0.005106
18.13	20.85	2.72	671	0.004054
20.85	23.74	2.88	713	0.004044
23.74	26.79	3.05	892	0.003418
26.79	30.00	3.21	931	0.003453
Vs Average to 30 mbgs (m/s)				**494**

The CHBDC 2014 requires special site specific evaluation if certain soil types are encountered on the site, so the site classification stated here should be reviewed, and modified if necessary, according to borehole stratigraphy, standard penetration resistance results, and undrained shear strength measurements, if available for this site.

Limitations

This technical memorandum is based on data and information collected by Golder Associates Ltd. and is based solely on the conditions of the properties at the time of the work, supplemented by historical information and data obtained by Golder Associates Ltd. as described in this memo.

Golder Associates Ltd. has relied in good faith on all information provided and does not accept responsibility for any deficiency, misstatements, or inaccuracies contained in the reports as a result of omissions, misinterpretation, or fraudulent acts of the persons contacted or errors or omissions in the reviewed documentation.

The services performed, as described in this memo, were conducted in a manner consistent with that level of care and skill normally exercised by other members of the engineering and science professions currently practicing under similar conditions, subject to the time limits and financial and physical constraints applicable to the services.

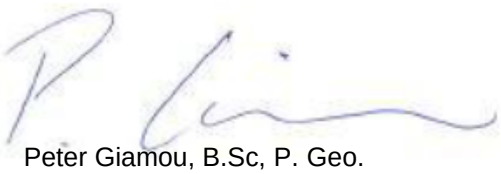
Any use which a third party makes of this memo, or any reliance on, or decisions to be made based on it, are the responsibilities of such third parties. Golder Associates Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this memo.

The findings and conclusions of this memo are valid only as of the date of this memo. If new information is discovered in future work, including excavations, borings, or other studies, Golder Associates Ltd. should be requested to re-evaluate the conclusions of this memo, and to provide amendments as required.

Closure

We trust that this technical memorandum meets your needs at the present time. If you have any questions or require clarification, please contact the undersigned at your convenience.

GOLDER ASSOCIATES LTD.



Peter Giamou, B.Sc, P. Geo.
Geophysicist

Christopher Phillips, M.Sc., P. Geo.
Senior Geophysicist, Principal

SS/CRP/PG/jl

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APPENDIX F

Site Photographs

Photograph 1: East of Site 3-302/1 (EBL), looking southeast (November 2018).

Photograph 2: South of west abutment of Site 3-302/1 (EBL), looking north (November 2018).

CLIENT
WSP CANADA GROUP LIMITED

CONSULTANT
GOLDER

YYYY-MM-DD	2019/03/07
PREPARED	WAM
DESIGN	--
REVIEW	MJK
APPROVED	--

PROJECT
CPR OVERHEAD BRIDGE REHABILITATION
SITE NO. 3-302/1 (EBL) AND 3-302/2 (WBL)
HIGHWAY 417, OTTAWA, ONTARIO

TITLE
SELECTED SITE PHOTOGRAPHS

PROJECT No.	Phase	Rev.	Figure
1662565	**1210**	**1**	**F1**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI A

Photograph 3: East of east abutment and piers of Site 3-302/2 (WBL), looking west (November 2018).

Photograph 4: West abutment and piers of Site 3-302/2 (WBL), looking northwest (November 2018).

CLIENT
WSP CANADA GROUP LIMITED

CONSULTANT
GOLDER

YYYY-MM-DD	2019/03/07
PREPARED	WAM
DESIGN	--
REVIEW	MJK
APPROVED	--

PROJECT
CPR OVERHEAD BRIDGE REHABILITATION
SITE NO. 3-302/1 (EBL) AND 3-302/2 (WBL)
HIGHWAY 417, OTTAWA, ONTARIO

TITLE
SELECTED SITE PHOTOGRAPHS

PROJECT No.	Phase	Rev.	Figure
1662565	**1210**	**1**	**F2**

golder.com