



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT
STRUCTURAL CULVERT No. 07X-0142/C0
HIGHWAY 15 RIDEAU CANAL BACKWATER CULVERT
CITY OF KINGSTON, ON
G.W.P. 4185-13-00
AGREEMENT NUMBER: 4016-E-0014**

GEOCRES NUMBER: 31C-284

**SUBMITTED TO
MCINTOSH PERRY CONSULTING ENGINEERS**

**LOCATION:
LATITUDE: 44.394420°
LONGITUDE: -76.318340°**

**AUGUST 2019
20482**

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual data obtained from a foundation investigation conducted by Thurber Engineering Ltd. (Thurber) for the Rideau Canal Backwater Culvert located on Highway 15, within the City of Kingston. Thurber carried out the investigation as a subconsultant to McIntosh Perry Consulting Engineers (MPCE) as part of Agreement No. 4016-E-0014.

A base plan was provided by MPCE for the preparation of this report.

No previous foundation investigation information for the subject culvert was available.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on this data, provide a borehole location plan, record of boreholes, a stratigraphic profile, laboratory test results and a written description of the subsurface conditions.

2 SITE DESCRIPTION

Culvert 07X-0142/C0 is located at approximate Station 31+863 on Highway 15, approximately 1.9 km north of the intersection with Sand Hill Road, within the City of Kingston, Ontario. The location of the culvert is shown on the inset Key Plan on Drawings No. 1 and 2 in Appendix A.

It is noted that for project orientation purposes, Highway 15 within the project limits, will be assumed to run north-south. Flow through the culvert is from east to west.

The existing 16.8 m long structure is composed of a 12.2 m long open bottom concrete culvert (inlet end) and a 4.6 m long concrete closed box culvert (outlet end). Both sections have an internal span of 5.5 m, and height of 1.8 m. A gabion headwall is present at the culvert inlet. The 2014 OSIM report identified issues including 100 mm to 200 mm of settlement at the east/inlet end and 35 mm to 85 mm of settlement at the mid-length construction joint.

At the culvert site, Highway 15 is undivided with one through lane in each direction. Based on the drawings provided, the roadway cross-section at the culvert location consists of two 3.75 m wide lanes with a 3.0 m wide southbound shoulder and a 1.75 m wide northbound shoulder. There are steel beam guide rails present along both sides of the highway. A private entrance is present on the west side of the highway, approximately 50 m north of the existing culvert.

The existing embankment slopes are inclined at approximately 2H:1V (Horizontal:Vertical) and are grass and brush covered on the west side and gravel covered with some brush on the east side. It is understood that the top of pavement at the centreline of Highway 15 above the culvert

alignment is at elevation 94.585 m. The maximum fill height above the culvert is approximately 1.2 m. Erosion was noted in the embankment at each end of the gabion.

The site is located within a physiographic region known as the Leeds Knobs and Flats which is characterized by knobs of granite and other Precambrian rocks with clay flats left by a late stage of Lake Iroquois or other subsequent lakes.

Wetland and waterbodies are present both upstream and downstream of the structure. Beyond the wet areas are elevated wooded areas. There is bedrock outcropping along the west side of the highway, approximately 50 m south of the existing culvert. The storm water drainage in the area is to existing culverts, ditches and water ways.

Site photographs showing the general conditions at the site, along the highway embankment and at the inlet and outlet are presented in Appendix E. The roadway surface was in generally fair to good condition with occasional transverse and centreline cracking but no major distortions were noted at the culvert location. Photograph 2 indicates that the top of the existing culvert at the inlet is significantly lower at the north (right) side than the south (left) side which indicates that differential settlement has occurred. The gabion headwall above the culvert inlet has tilted with the culvert. No signs of embankment instability were noted.

3 SITE INVESTIGATION

The field investigation was carried out in phases based on design development and the results of the preceding investigation phases. The first phase of the investigation was carried out between September 12 and October 3, 2017. The investigation included advancing six boreholes (Boreholes 17-1 through 17-6). The second phase of the field investigation was carried out between May 22 and August 24, 2018 and included advancing four boreholes (Boreholes 101 through 104) and a seismic cone penetration test (SCPT 107). The final phase of the investigation was carried out between April 22 and April 23, 2019 and included advancing two boreholes (Boreholes 19-01 and 19-02).

The approximate MTM Zone 9 locations and ground surface elevations of the test holes are shown on Drawings No. 1 through 2, provided in Appendix A and are summarized in Table 3-1.

Table 3-1: Borehole Summary

Borehole	Location	Northing (m)	Easting (m)	Ground Surface Elevation (m)	Termination Depth Below Ground Surface (m)
17-1	Outlet	4 917 188.7	319 267.2	91.8	11.4*
17-2		4 917 179.6	319 262.6	91.8	11.8**
17-3	Highway 15 Southbound	4 917 173.2	319 269.1	94.5	15.8*
17-4	Highway 15 Northbound	4 917 181.8	319 282.5	94.5	22.3**
17-5	Inlet Side	4 917 178.7	319 287.8	92.3	15.8*
17-6		4 917 167.0	319 281.2	92.0	25.5**
101	Highway 15	4 917 160.3	319 270.8	94.5	11.1
					10.8
					15.8

Borehole	Location	Northing (m)	Easting (m)	Ground Surface Elevation (m)	Termination Depth Below Ground Surface (m)
	Northbound				
102	Inlet Side	4 917 163.6	319 280.1	92.1	11.8
103	Outlet Side	4 917 172.6	319 257.4	92.3	10.1
104	Highway 15 Southbound	4 917 171.0	319 267.2	94.5	15.8* 16.9**
SCPT107	Highway 15 Northbound	4 917 167.5	319 273.1	94.5	20.6
19-01	Highway 15 Northbound	4 917 170.8	319 275.7	94.5	26.9
19-02	Highway 15 Southbound	4 917 183.1	319 275.3	94.5	25.3

NOTES: * – Termination of Sampled Borehole
** – DCPT refusal

As a component of our standard procedures and due diligence, Thurber contacted Ontario One Call to provide utility locates/clearances for the borehole locations.

The boreholes through the roadway embankment were advanced with a CME750 truck mounted drill rig. The inlet and outlet boreholes were advanced with portable drilling equipment from a raft using a full weight hammer for SPT testing during the 2017 investigation; a half weight hammer was used during the 2018 investigation at Boreholes 102 and 103. The SPT N values presented for Boreholes 102 and 103 in this report have been corrected to provide an estimate of the SPT N value from a full-weight hammer.

The SCPT test hole (SCPT 107) was advanced to refusal with a 30 Ton CPT truck mounted rig. The pavement structure at the SCPT test hole was pre-augered to a depth of approximately 1.5 m before advancing the cone.

The subsurface stratigraphy encountered in the boreholes was recorded in the field by Thurber personnel. Split spoon samples were collected at regular depth intervals in all boreholes during the completion of Standard Penetration Tests (SPT), following the methods described in ASTM Standard D1586-11. Thin-walled tube samples (Shelby tube samples) were collected in the cohesive deposits in Boreholes 17-3 and 104. In-situ shear vane testing was carried out within cohesive strata. The upper 9.1 m overburden in Boreholes 19-01 and 19-02 was not sampled. All soil samples recovered from the boreholes were placed in moisture-proof containers and the samples were transported to Thurber's Ottawa geotechnical laboratory for further examination and testing. Bedrock was cored with NQ size coring equipment, following ASTM Standard D6032-08, in Boreholes 103, 19-01 and 19-02. Bedrock core samples were stored in core boxes for transport.

The boreholes were backfilled with a low-permeability combination of auger cuttings and bentonite pellets in accordance with Ontario MOE Regulation 903, as amended. Boreholes advanced within paved areas were capped with 150 mm of cold patch asphalt.

The as-drilled locations of the boreholes and ground surface elevations at the borehole locations were surveyed by Thurber. The vertical datum used was the temporary benchmark (TBM) located on the southwest corner of the culvert outlet. Data provided by MPCE indicated that the TBM has a geodetic elevation of 93.262 m. The location of the TBM is indicated on Drawings No. 1 and 2 in Appendix A.

4 LABORATORY TESTING

Geotechnical laboratory testing consisted of natural moisture content determination and visual identification of all soil samples in accordance with the current MTO standards. Grain size distribution analyses, and Atterberg Limits testing was carried out on selected samples to MTO and ASTM standards. Organic content testing was carried out on selected samples. All rock core was logged and core recoveries and RQD values were measured.

The geotechnical laboratory test results are presented on the Record of Borehole sheets in Appendix B and are illustrated on the figures in Appendix C.

Chemical analysis for determination of pH, resistivity, soluble sulphate and chloride concentrations was carried out on three soil samples. The chemical analysis results are provided in Appendix C.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

5.1 Overview / General

Reference is made to the Record of Borehole sheets in Appendix B for details of the soil stratigraphy encountered in the boreholes. The results of the SCPT are provided in Appendix D. Stratigraphic profiles are presented on Drawings No. 1 and 2, provided in Appendix A for illustrative purposes. An overall description of the stratigraphy is given in the following paragraphs; however, the factual data presented in the Record of Boreholes governs any interpretation of the site conditions.

In general, the stratigraphy is characterized by organic layers (peat, marl, organic silt or silty sand with organic matter), overlying silty sand to silt, overlying a cohesive deposit (clay to silty clay), overlying bedrock. Within the footprint of the highway embankment, these materials are overlain by the pavement structure and embankment fill. More detailed descriptions of the individual strata are presented below.

5.2 Asphalt

Six boreholes were advanced through the Highway 15 lane or shoulder pavement structure. The thickness of the asphalt ranged from 115 mm to 200 mm.

5.3 Fill

A fill layer consisting predominantly of sand and varying amounts of gravel and silt was encountered in Boreholes 17-3, 17-4, 17-5, 17-6, 101 and 104. The top of this layer ranges from elevation 92.0 m to 94.4 m. The thickness of the layer ranged from 1.2 m to 2.8 m. The SPT N values ranged from 21 to greater than 100 in the four roadway boreholes, indicating compact to very dense relative density, and from 1 to 4 in Boreholes 17-5 and 17-6, indicating a very loose relative density. Occasional cobbles and boulders were noted in this layer in the roadway

boreholes and coring techniques were required to penetrate this layer at some locations. Wood fragments and some organics were observed in Borehole 17-5.

The moisture content of the samples tested ranged from 2% to 22%. The results of three grain size analysis tests indicated a gravel content ranging from 3% to 54%, a sand content ranging from 38% to 89%, and a fines content (combined silt and clay size particles) of 7% to 8%. Grain size analysis results are illustrated on Figure 1 in Appendix C.

5.4 Silty Clay with Sand

A 0.8 m thick layer of silty clay with sand was observed beneath a 75 mm rootmat layer in Borehole 103. The underside elevation of this silty clay was observed to be 91.9 m. The SPT N value was 11 indicating a stiff consistency. The moisture content was measured to be 27%.

5.5 Organic Layers

5.5.1 Peat

An amorphous peat layer was encountered beneath the fill layers in Boreholes 17-5, 17-6 and 102. The top of this layer was encountered between elevation 90.8 m and 91.5 m and the thickness of the peat ranged from 0.6 m to 2.3 m. The SPT N values were 2 and less; indicating a very loose condition. The moisture content of the samples tested ranged from 99% to 624%.

5.5.2 Marl (OH)

A layer of marl was encountered beneath the peat layer in Borehole 102 and beneath the sandy silt with organics in Borehole 103. The top of this layer was encountered at elevation 90.9 m and 91.1 m and the layer had a thickness of 200 mm and 400 mm. The SPT N value was 1; indicating a very loose condition.

The moisture content of the samples tested were 118% and 158%. The results of organic content testing on a sample of the marl indicated an organic content of 11%. The results of a grain size analysis test indicated a gravel content of 0%, a sand content of 41%, a silt content of 47% and a clay content of 12%. Grain size analysis results are illustrated on Figure 2 in Appendix C.

The results of Atterberg Limits testing completed on a sample of the marl material indicated a liquid limit of 75, a plastic limit of 64, and a plasticity index of 11. Atterberg Limits analysis results are illustrated on Figure 3 in Appendix C and indicate an OH material.

5.5.3 Sandy Organic Silt (OH) to Silty Sand with Organics (SM)

A sand and silt with organics was encountered at the ground surface of Boreholes 17-1, 17-2 and 102, beneath the fill layers in Boreholes 17-3 and 17-4, beneath the surficial silty clay in Borehole 103 and beneath the peat and marl layers in Boreholes 17-5, 102 and 103. The top of this layer ranges from elevation 88.7 m to 92.1 m. The thickness of the layer ranged from 300 mm to 2.2 m. The SPT N values ranged from weight of rods to 9; indicating a very loose to loose condition.

The moisture content of the samples tested ranged from 25% to 277%. The organic content in the layer was determined to be 34% in one sample. The results of grain size analysis tests indicated a gravel content of 0% to 1%, a sand content ranging from 22% to 87%, a silt content

ranging from 12% to 70% and a clay content ranging from 0% to 17%. Grain size analysis results are illustrated on Figure 4 in Appendix C. Note that the results may have been affected by the presence of organics.

The results of Atterberg Limits testing completed on four samples of the sandy silt material indicated non-plastic material for two samples; two other samples exhibited some plasticity with a liquid limit of 26 and 37, a plastic limit of 23 and 28, and a plasticity index of 3 and 9. The material can be characterized as non-plastic silt to a silt with intermediate plasticity. The results of testing on a sample of sandy organic silt indicated a liquid limit of 194, plastic limit of 165 and a plasticity index of 29; this sample can be classified as a high plastic organic silt (OH). Atterberg Limits analysis results are illustrated on Figure 5 in Appendix C.

5.6 Silty Sand (SM) to Sandy Silt (ML) to Silt (ML)

Layers of silty sand, sandy silt and silt were observed beneath the fill in Borehole 101 and 104, beneath the sandy organic silt layer in Boreholes 17-4, 102, and 103, and beneath the peat in Borehole 17-6. The top of this layer ranges from elevation 89.3 m to 91.6 m. The thickness of the layer ranged from 700 mm and 6.1 m. SPT N values ranged from weight of hammer to 36 indicating a very loose to dense condition.

Moisture contents ranged from 12% to 54%. The results of grain size analysis testing on six samples indicated a gravel content ranging from 0% to 12%, sand content ranging from 15% to 86%, a silt content ranging from 14% to 74% and a clay content ranging from 11% to 17%. Grain size analysis results are illustrated on Figure 6 in Appendix C.

The results of Atterberg Limit testing on five samples indicated this material to be non-plastic (SM or ML).

5.7 Silty Clay (CL-ML) with Sand to Silty Clay (CL-ML)

A silty clay with sand deposit was encountered beneath the sandy silt with organics layer in Boreholes 17-1, 17-3, and 17-5 and below the sandy silt layer in Borehole 17-6. The top of this layer ranges from elevation 86.4 m to 91.5 m. The thickness of the layer ranged from 1.3 m to 2.7 m. Based on the SPT N values, the consistency of this layer is typically estimated to be stiff to very stiff, with the exception of Borehole 17-5 where the consistency is estimated to be firm to stiff.

The moisture content of the samples tested ranged from 21% to 27%. The results of grain size analysis tests on four samples indicated a gravel content of 0%, sand content ranging from 9% to 23%, a silt content ranging from 57% to 65% and a clay content ranging from 20% to 27%. Grain size analysis results are illustrated on Figure 7 in Appendix C.

The results of Atterberg Limits testing completed on this material indicated a liquid limit ranging from 19 to 22, a plastic limit of 14 and 15, and a plasticity index ranging from 5 to 7. Atterberg Limits analysis results are illustrated on Figure 8 in Appendix C. The test results indicate a silty clay (CL-ML).

5.8 Clay (CL to CH)

A grey clay deposit was encountered in all boreholes. The top of this layer ranges from elevation 83.2 m to 90.8 m. Sampling of the overburden in Boreholes 19-01 and 19-02 was initiated in this grey clay at a depth of 9.1 m (elev. 85.4 m). Borehole sampling was terminated within the clay layer in all boreholes except Boreholes 103, 19-01 and 19-02 at elevations ranging from 78.7 m to 81.2 m. The clay layer was fully penetrated in Boreholes 103, 19-01 and 19-02 and ranged in thickness from 5.0 m to greater than 13.2 m. The material at the base of this unit was observed to be siltier in Borehole 19-02. An interlayer of silt was encountered within the clay layer in Boreholes 101 through 103. The interlayer was encountered at elevations ranging from 83.9 m to 87.9 m and had a thickness ranging from 300 mm to 1.5 m.

In-situ shear vane test results indicated undrained shear strengths of the clay ranging from 32 kPa to greater than 100 kPa; indicating a firm to very stiff consistency but typically stiff. The sensitivity of the clay ranged from 1 to 10 with an average of 5.7, indicating low to extra sensitive clay, but typically sensitive. The measured SPT N value of the silt interlayer was 4 indicating a loose condition.

The moisture content of the samples tested ranged from 21% to 61% for the clay layer and 20% to 22% for the silt interlayer. The results of grain size analysis tests carried out on 25 samples of this material indicated a gravel content of 0% to 1%, sand content ranging from 0% to 16%, a silt content ranging from 36% to 69% and a clay content ranging from 21% to 63%. The results of grain size analysis tests carried out on two samples of the interlayer indicated a gravel content of 0%, sand content of 14%, a silt content of 70% and 71% and a clay content of 15% and 16%. Grain size analysis results are illustrated on Figures 9 through 13 and Figure 19 in Appendix C, for the clay and silt interlayer respectively.

The results of Atterberg Limits testing completed on 25 samples of the clay material indicated a liquid limit ranging from 25 to 54, a plastic limit ranging from 13 to 24, and a plasticity index ranging from 11 to 31, corresponding to clay of low to high plasticity (CL to CH). The liquidity index ranged from 0.1 to 3.3 with a median value of 1.0. Atterberg Limits analysis results are illustrated on Figures 14 through 18 in Appendix C. One sample from directly above the bedrock in Borehole 19-02 was siltier (0% gravel, 10% sand, 69% silt and 10% clay) and had a liquid limit of 22, plastic limit of 16 and plasticity index of 6, indicating a silty clay (CL-ML). Lab test results for the CL-ML material are illustrated on Figures 21 and 22 in Appendix C.

Atterberg limit test results on a sample of the silt interlayer indicated a liquid limit of 20, plastic limit of 16 and plasticity index of 4, corresponding to silt (ML). These test results are presented on Figure 20 in Appendix C.

5.9 Cobbles and Boulders

Cobbles and boulders were encountered directly above the bedrock in Borehole 19-01. The top of the layer was encountered at elevation 72.2 m and the layer had a thickness of 0.9 m. The borehole was advanced through this layer by coring, however, no core sample was recovered.

5.10 Bedrock

The overburden materials were underlain by white to grey granite bedrock in Borehole 103 and green, grey and black gneiss bedrock in Boreholes 19-01 and 19-02. Boreholes 103, 19-01 and 19-02 were advanced into the bedrock by coring with NQ-size coring equipment. The depth below existing grade to the bedrock surface ranged significantly from 8.5 to 23.2 m (elev. 71.3 to 83.7 m).

The total core recovery (TCR) ranged from 85 to 100% with one single TCR value of 45% in Borehole 19-01, the solid core recovery (SCR) ranged from 0% to 95% and the RQD ranged from 0% to 79%. Vertical fractures were encountered in all cored boreholes, as shown on the Record of Borehole sheets in Appendix B. Based on the RQD value the bedrock is classified as very poor to good. Unconfined compressive strength testing carried out on four samples of gneiss bedrock indicating the bedrock to have strengths ranging from 19 to 96 MPa. Based on these results, the gneiss bedrock ranges from weak to strong.

Boreholes 17-1, 17-3, 17-4 and 104 were extended beyond sampling limits by DCPT.

DCPT refusal was encountered at elevation 69.0 m in the roadway Borehole 17-4, 80.0 m in Borehole 17-1 and 77.6 m in Borehole 104. The DCPT refusal may have occurred on bedrock or glacial till. DCPT testing was terminated at elevation 72.2 m in Borehole 17-3 prior to reaching refusal as the drill rods were deflected out of alignment due to an inferred boulder.

5.11 Groundwater Conditions

The water level in the Rideau Canal Backwater Culvert was measured during Thurber's field investigation at elevation 92.8 m on April 23, 2019, at both the inlet and outlet. The groundwater level in the area of the culvert is expected to reflect the surrounding river water level.

This observation is considered a short-term reading and seasonal fluctuations of the groundwater level and water level in the culvert are to be expected. In particular, the groundwater level may be at a higher elevation after the spring snowmelt or after periods of heavy rainfall.

5.12 Analytical Test Results

Three samples of the native soils encountered at the site were submitted to Paracel Laboratories in Ottawa, Ontario for analysis of pH, water soluble sulphate and chloride concentrations, and resistivity. The analysis results are summarized in the Table 5-1. A copy of the test results is provided in Appendix C.

Table 5-1: Results of Chemical Analysis

Borehole	Sample	Depth (m)	pH	Resistivity (Ohm-cm)	Chloride (µg/g)	Sulphate (µg/g)
17-3	SS6	4.1	7.65	1060	555	71
17-5	SS7	5.6	7.40	1760	29	435
101	SS6	4.1	7.95	2470	131	29

6 MISCELLANEOUS

Thurber staked and/or marked the borehole locations in the field and obtained utility clearances prior to drilling. Thurber surveyed the borehole locations and determined the ground surface elevations based on a temporary benchmark by McIntosh Perry Consulting Engineers. George Downing Estate Drilling Ltd. and Forage M3 Drilling Services Inc. both of Hawkesbury, Ontario supplied and operated the drilling equipment to carry out the drilling, sampling, and in-situ testing. The drilling, and sampling operations in the field were supervised on a full-time basis by Katya Edney, P.Eng., Deanna Pizycki, EIT, Sean O'Bryan, C.E.T., and Nick Weil of Thurber. Laboratory testing was carried out by Thurber in its MTO-approved laboratory in Ottawa. Organic content testing was carried out by Stantec Consulting Ltd. in its MTO-approved laboratory in Ottawa

Overall project management and direction of the field program was provided by Paul Carnaffan, P.Eng. Interpretation of the field data and preparation of this report was completed by Katya Edney, P.Eng. The report was reviewed by Paul Carnaffan, P.Eng. and Dr. Fred Griffiths, P.Eng., a Designated Principal Contact for MTO Foundations Projects.



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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This section of the report presents an interpretation of the factual data obtained from a foundation investigation conducted by Thurber and provides geotechnical assessment and recommendations to support the project team in designing the replacement of the Rideau Canal Backwater Culvert (Rideau Culvert) located on Highway 15, in the City of Kingston, Ontario.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. The construction or design build Contractor must make their own interpretation based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Contractors must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

The following sections provide geotechnical recommendations for the replacement of the existing Rideau Culvert. The discussions and recommendations presented in this report are based on the information provided by McIntosh Perry Consulting Engineers (MPCE) and on the factual data obtained during the course of the investigation.

7.1 Existing and Proposed Structure

The existing 16.8 m long structure is composed of a 12.2 m long open bottom concrete culvert (inlet/east end) and a 4.6 m long concrete closed box culvert (outlet/west end). Both culvert segments have a 5.5 m span and 1.8 m height. The 2010 underwater inspection report and 2014 OSIM report identified issues including 100 mm to 200 mm of settlement at the east/inlet end (open footed culvert) and 35 mm to 85 mm of settlement at the mid-length construction joint.

At the time of the foundation field investigation, it was evident that the north side of the culvert at the inlet had settled significantly more than the south side. (see Photograph 2 in Appendix E). It is noted that the observed settlement is at the same end of the culvert alignment where peat and organic silt were observed in the boreholes and the structure has an open bottom and is supported by spread footings. The gabion head walls at the inlet appear to have moved with the culvert. Erosion was noted in the embankment at each end of the gabion.

Based on information provided by MPCE, the existing culvert is to be replaced with a new culvert with a larger hydraulic opening: 6.0 m wide by 2.5 m high. To accommodate the increased rise, the asphalt will be placed on a waterproofing membrane placed directly on the top of the culvert. Cast-in-place approach slabs will be provided on each side. The new culvert is to include

wingwalls extending out from both sides at each end of the culvert. The profile of Highway 15 and the platform width will remain unchanged.

7.2 Design Code Considerations

The geotechnical assessment presented below has been prepared based on the available data regarding the proposed foundations and existing ground conditions and in accordance with the Canadian Highway Bridge Design Code version CSA S6-14 (CHBDC).

In accordance with CHBDC, the analysis and design of the structure takes into consideration the importance of the structure and the consequence associated with exceeding limit states. The importance category and consequence classification are defined by the Regulatory Authority, which in this case is the Ministry of Transportation, Ontario (MTO).

It is understood that the replacement of the Rideau Culvert is being designed to the Other Route importance category.

This project has been assigned Typical Consequence Classification, in accordance with Section 6.5.1 of the CHBDC. Accordingly, a consequence factor (Ψ) of 1.0, as per Table 6.1 of the CHBDC, has been used in assessing the factored geotechnical resistances.

7.3 Frost Penetration Depth

The estimated frost penetration depth at this site is 1.5 m as per OPSD 3090.101.

8 SEISMIC CONSIDERATIONS

8.1 Spectral and Peak Acceleration Hazard Values

The seismic hazard data for the CHBDC is based on the fifth-generation seismic model developed by the Geological Survey of Canada (GSC). Seismic hazard data for this site has been obtained from the GSC's seismic hazard calculator. The data includes peak ground acceleration (PGA), peak ground velocity (PGV), and the 5% damped spectral response acceleration values ($S_a(T)$) for the reference ground condition (Site Class C) for a range of periods (T) and for a range of return periods including the 475-year, 975-year and 2475-year events. The GSC seismic hazard calculation data sheet for this site is presented in Appendix G.

The site coefficients used to determine the design spectral acceleration and displacement values are a function of the Site Class and the peak ground acceleration (PGA). For this location, for a reference Site Class C with a 2% probability of exceedance in 50 years, the PGA is 0.108g. This value is to be scaled by the $F(PGA)$ factor based on the site-specific Site Class as per Section 4.4.3.3 and Table 4.8 of the CHBDC.

8.2 Seismic Liquefaction

8.2.1 Cohesionless Soils – Native Silty Sand to Sandy Silt

Liquefaction triggering analyses for the cohesionless soils at the site were carried out by comparing the estimated Cyclic Stress Ratio (CSR) and the Cyclic Resistance Ratio (CRR) of the soil. Initially the CSR and CRR were calculated based on the simplified method proposed by Idriss and Boulanger (2008⁽³⁾, 2014⁽⁴⁾) using SPT-N values obtained during the 2017 investigation.

These analyses indicated potentially liquefiable soils present in the cohesionless deposits above elevation 87.5 m.

The liquefaction triggering analysis was refined based on shear wave velocity data. SCPT 107 was pushed between the existing and alternative culvert alignments to obtain shear wave velocity measurements and continuous resistance profiles. The raw SCPT data from the ConeTec was processed using the commercially available software CPTe-IT and CLiq by Geologismiki. Program parameters used in CPTe-IT were first correlated to existing borehole data to develop the normalized soil behaviour type (SBT) profile used for the liquefaction triggering analysis; see Figure 1 in Appendix D.

The CRR was calculated in CLiq following the method proposed by Idriss and Boulanger (2008⁽³⁾, 2014⁽⁴⁾). The CSR was calculated using the computer program Deepsoil v6.1 developed by Dr. Youssef Hashash at the University of Illinois at Urbana-Champaign⁽⁵⁾. The depths of the soil columns used in the analysis were based on the depth to bedrock encountered in the investigation and shear wave velocity measurements from the SCPT testing. Select earthquake time histories were scaled to match a Site Class A uniform hazard spectrum for the project site for the 1:2475 year return period earthquake. Based on this more rigorous analysis the native silty sands to sandy silts are considered non-liquefiable based on the design earthquake.

8.2.2 Cohesive Soils – Native Clays

A clay deposit was encountered across the site below native sands and silts at the site. The susceptibility of the cohesive soils to experience cyclic mobility or cyclic softening was initially assessed using the Bray et al. (2004)⁽¹⁾ criteria using samples collected from the investigation and index property testing. Soils that were considered potentially susceptible were subsequently assessed based on the in-situ shear strength measurements using the simplified procedure outlined in Boulanger and Idris (2007)⁽²⁾. Based on the results of both analyses, the cohesive material at this site is classified as non-susceptible to cyclic mobility or cyclic softening.

8.3 CHBDC Seismic Site Classification

In accordance with the CHBDC, the selection of the seismic site classification is based on the soil conditions encountered in the upper 30 m of the stratigraphy. The shear wave velocity profile is provided in Appendix D. In accordance with Table 4.1 of the CHBDC, the site is classified as a Seismic Site Class D based on the seismic shear wave velocity profile measured at the site.

9 DESIGN DISCUSSION

9.1 Geotechnical Assessment

Based on the location and nature of the observed deformation at the inlet of the culvert, the structure type and the geotechnical conditions observed in the boreholes, it is concluded that the sandy silt with organics was left in place beneath the culvert. This layer extends to as deep as elevation 87.0 m in Borehole 17-5 near the northeast corner of the culvert. Settlement of the sandy silt with organics is the likely cause of the deformation observed in the culvert.

It is noted that two alignments were considered for the replacement culvert: the existing alignment and an alternative approximately 12.5 m to the south (centre to centre).

Based on the results of the field and laboratory investigation and the information provided by MPCE with regards to the proposed culvert requirements, the geotechnical foundation design considerations include the following:

- The stiff to firm clay and loose to compact sandy silt encountered at the proposed foundation elevation provide limited bearing resistance; a closed bottom culvert or deep foundations would be required.
- The peat and organic silt layers observed at the existing culvert alignment extend to as deep as 87.0 m, are highly compressible and are not suitable for the support of the culvert (closed box or open footing) or wingwalls. The peat and organic silt would need to be removed from beneath the proposed culvert and wingwalls unless deep foundations are used. These materials would also result in short term and long term settlement of the highway if the existing culvert was backfilled for abandonment and the replacement was on a new alignment.
- Along the alternative alignment, peat, marl and organic silt layers were encountered and extend to as deep as elevation 89.5 m. These organic deposits would need to be removed from beneath the proposed culvert and wingwalls unless deep foundations are used.
- Open water is present on both sides of the culvert and highway embankment. In addition, excavation for the culvert replacement will extend significantly below the level of the open water. Extensive cofferdam and dewatering requirements will be required. It would be advantageous to maintain flow in the existing culvert while constructing the replacement culvert on a new alignment, however, installation of a temporary diversion culvert is also possible. The open water also limits the available space for staging of the construction work.

9.2 Design Alternatives

The design alternatives must address the issues identified above in Section 9.1.

A range of design alternatives were evaluated. The following design alternatives were ruled out as not feasible or not permissible due to environmental constraints:

- Trenchless installation at this site has been ruled out as there is insufficient cover and open water on both sides where entry and exit pits would be located.
- The option of increasing the length of the culvert to eliminate the need for the wingwalls was ruled out due to environmental constraints.
- Lining of the existing culvert would not allow for the hydraulic opening to be increased. Furthermore, backfill of the space between the liner and original culvert would exacerbate the observed settlements.

The following design alternatives were evaluated for both replacement on the existing alignment and replacement on a new alignment to the south:

- A closed box culvert with cast-in-place wingwalls on native soil and/or a granular pad following sub-excavation for removal of weak/compressible soils.
- A closed box culvert on native soil and/or a granular pad following sub-excavation for removal of weak/compressible soils and sheet pile wingwalls.
- An open bottom culvert and cast-in-place wingwalls supported on steel piles driven to bedrock

As noted in Section 9.1, the east side of the highway embankment at the existing culvert alignment is underlain by compressible organic soils and peat was encountered in the borehole at the inlet. Backfilling the opening of the existing culvert would result in both short term and long term settlement of the underling soils. The estimated total settlement is in the range of 150 mm, with about 80% of that occurring within the initial 6 months. This assumes that only the organic silt is present beneath the highway embankment. The settlement would be greater if peat is present beneath the area to be backfilled. The magnitude of settlement can be somewhat reduced by using cellular concrete as lightweight fill, however, buoyancy must also be taken into account and cofferdams and dewatering would be required to place the cellular concrete. The need for a second set of cofferdams and dewatering systems in addition to on-going maintenance due to the long term settlement work against the option of construction on a new alignment.

A detailed evaluation of the culvert alignment alternatives including the advantages, disadvantages, risk/consequences and relative cost from a foundations perspective is provided in Appendix F.

9.3 Recommended Foundation Alternative

From a foundation engineering perspective, replacing the culvert on the existing alignment with an open-bottom culvert and cast-in-place wingwalls supported on piles is recommended. This option does not require sub-excavation of organic material which reduces the depth, complexity and cost of temporary protection and dewatering systems. In addition, this option eliminates the settlement issues with respect to decommissioning the existing culvert.

The May 2019 GA drawing prepared by MPCE indicates that the culvert will be approximately 14 m long and that the wingwalls will be approximately 6.2 m long.

10 FOUNDATION DESIGN RECOMMENDATIONS

The culvert and wingwalls may be supported on steel H-piles driven to bedrock.

Approximate key elevations are as follows:

- Proposed top of pavement at C/L 94.585 m
- Base of footing 89.985 m
- Water level on Sept. 28, 2017 92.75 m
- Bedrock surface 69.0 to 83.7 m

10.1 Axial Compression

The factored geotechnical resistance of steel piles driven to bedrock at this site are as follows and are based on an unconfined compressive strength of 50 MPa:

Table 10-1: Factored Geotechnical Resistances at ULS and SLS

Pile Section	Factored Geotechnical Resistance at ULS (kN)	Factored Geotechnical Resistance at SLS (kN)
HP 310x110	2200	N/A

The SLS condition will not govern for piles driven to bedrock. The factored structural resistance of the pile at ULS may be lower than the geotechnical resistance and may govern the design.

The factored geotechnical resistances include the following factors as per Table 6.2 of the CHBDC:

- $\phi_{gu} = 0.4$ (ULS; static analysis; typical degree of understanding)
- $\phi_{gs} = 0.8$ (SLS; static analysis; typical degree of understanding)

Given that there is no grade-raise (or-net load increase) proposed at this site, downdrag loads do not need to be considered. If a grade-raise is proposed, the downdrag loads would need to be assessed and accounted for.

The length of the piles is expected to range significantly across site. It is recommended to assume an approximate bedrock elevation of 72.7 and 69.0 m west and east of the Highway 15 centreline, respectively. Suggested wording for a Notice to Contractor to alert the Contractor to the expected variation in existing subsurface conditions is provided in Appendix H.

Frost protection for pile caps should consist of 1.5 m of soil cover, or equivalent.

10.2 Pile Installation

Driven piles must be installed in accordance with OPSS.PROV 903 and SSP 109F57. Due to the sloping bedrock conditions, it is recommended that the piles be fitted with Titus HD Rock Injector pile points, or approved equivalent.

The appropriate pile driving note is "Piles to be fitted with Titus HD Rock Injector points and driven into bedrock in accordance with OPSS.PROV 903."

10.3 Embankment Design and Reinstatement

All excavation for the culvert replacement is expected to take place within a sheet pile enclosure just large enough to encompass the proposed culvert and wingwalls. All backfill will consist of Granular A. The backfill will be contained between the wingwalls and culvert walls and therefore stability of the backfill is not a concern. Minimal settlement is expected since the finished grades will match the existing grades; some settlement of the new backfill should be expected, however, it is noted that the structure includes concrete approach slabs.

Based on the foundation boreholes, the exiting highway embankment fill within the frost depth are typically non-frost susceptible sand and gravel. Therefore a frost taper is likely not required, however, this should be reviewed by the pavement design engineer.

Outside of the wingwalls, the intent is to reinstate the original slopes at approximately 2H:1V and to cover the slopes with rip-rap. Some settlement of this material may occur where peat and organic soils have been left in place.

10.4 Structure Backfill and Lateral Earth Pressures

Backfill for the culvert must consist of free draining granular material conforming to OPSS.PROV 1010 Granular A material specifications.

Compaction of backfill materials should be carried out in accordance with OPSS.PROV 501.

The lateral earth pressure parameters provided in Table 10-2 and 10-3 below are based on the assumption that the backfill is fully drained so that there are no unbalanced hydrostatic pressures. If adequate drainage cannot be confirmed, the potential for buildup of hydrostatic pressures should be considered in the design.

Static Lateral Earth Pressure Coefficients

Lateral earth pressures acting on vertical structures should be computed in accordance with the CHBDC but generally are given by the expression:

$$P_h = K^*(\gamma h + q)$$

where:

P_h	=	horizontal pressure on the wall (kPa)
K	=	earth pressure coefficient
γ'	=	unit weight of retained soil (kN/m ³); use submerged unit weight for soils below the groundwater level
H	=	depth below top of fill where pressure is computed (m)
q	=	value of any surcharge (kPa)

The recommended lateral earth pressure parameters for use in the design of vertical walls with a horizontal backslope are provided in Table 10-2.

Table 10-2: Static Lateral Earth Pressure Coefficient

Parameter	OPSS Granular A & B Type II	Existing Fill, SSM & Native Silty Sand / Silt
Soil Unit Weight, kN/m ³ , γ	21.0	19.0
Angle of Internal Friction, ϕ	35°	30°
Coefficient of at Rest Earth Pressure, K_o (Restrained Wall)	0.43	0.50
Coefficient of Active Earth Pressure, K_a (Unrestrained Wall)	0.27	0.33

If lateral movement is not permissible and/or the wall is restrained from lateral yielding, it is recommended that at-rest horizontal lateral earth pressures be used for design. Active pressures should be used for the design of unrestrained walls. For static analysis of permanent structures, passive earth resistance should be ignored, and therefore has not been provided.

A lateral pressure due to backfill compaction should be added to the calculated lateral earth pressure in accordance with Section 6.12.3 of the CHBDC.

Combined Static and Seismic Lateral Earth Pressure Parameters

The following recommendations are per Section C4.6.5 of the Commentary of the CHBDC which states that seismically induced lateral soil pressures may be calculated using the Mononobe-Okabe Method with:

- $k_h = \frac{1}{2} F(PGA) \cdot PGA$ for structures that allow for 25 mm to 50 mm of movement, and
- $k_h = F(PGA) \cdot PGA$ for non-yielding walls

The recommended seismic lateral earth pressure parameters for use in the design of vertical walls that are provided in Table 10-3 assume the following:

- Seismic Site Class of D
- Site Coefficient F(PGA) of 1.29 as per Table 4.8 of the CHBDC,
- Site adjusted PGA with a 2% probability of exceedance in 50 years of 0.139g; as outlined in Section 8.0
- Horizontal backslope, vertical wall.

Table 10-3: Lateral Earth Pressure (Under Seismic Loads)

Parameter	OPSS Granular A & B Type II
Soil Unit Weight, kN/m ³ , γ	21.0
Angle of Internal Friction, ϕ	35°
Non-Yielding Wall	
Dynamic Active Earth Pressure Coefficient, K_{AE}	0.35
Yielding Wall	
Dynamic Active Earth Pressure Coefficient, K_{AE}	0.31

The total pressure due to combined static and seismic loads acting at a specific depth below the top of the wall may be determined using the following equation that includes consideration of material properties and the soil profile:

$$\sigma_h = K\gamma d + (K_{AE} - K_a) \gamma (H - d)$$

where:

- σ_h = lateral earth pressure at depth, d (kPa)
- d = depth below the top of the wall (m)
- K = static earth pressure coefficient
(K_o for non-yielding and K_a for yielding walls)
- γ = unit weight of retained soil (kN/m³); use submerged unit weight for soils below the groundwater level
- K_{AE} = combined static and seismic earth pressure coefficient
- H = total height of the wall (m)

10.5 Cement Type and Corrosion Potential

Three samples of the soils encountered were submitted to Paracel Laboratories in Ottawa, Ontario for analysis of pH, water soluble sulphate and chloride concentrations, and resistivity. The analysis results are summarized in Table 5-1 and copies of the test results are provided in Appendix C.

The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with the soil and groundwater at the site. The sulphate results in Table 5-1 were compared with Table 3 of Canadian Standards Association Standard A23.1-14 (CSA A23.1) and generally indicate a low degree of sulphate attack potential on concrete structures at this site.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The test results provided in Table 5-1 were compared with

Table 3.2 of the MTO Gravity Pipe Design Guideline and generally indicate a severe to moderately corrosive environment. The test results provided in Table 5-1 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects.

11 CONSTRUCTION CONSIDERATIONS

11.1 Excavations

It is anticipated that temporary excavations in the order of 4.6 m below the existing highway surface will be required for removal of the existing culvert and wingwalls and for construction of the new culvert foundations.

All excavations must be conducted in accordance with the requirements of the Occupational Health & Safety Act & Regulations (OHSA) for Construction Projects. The fills at the site should be classified as Type 3 above and Type 4 below the groundwater table in accordance with OHSA. The native clay materials should be classified as Type 3. Any alluvium or cohesionless silts and sands below the groundwater level would be classified as Type 4. As indicated in OHSA, if an excavation contains more than one type of soil, the soil type for the excavation shall be classified as the type with the highest number among the soil types present within the excavation. Unsupported excavations made in Type 4 soils must have side slopes no steeper than 3H:1V from the base of the excavation. Flatter slopes may be required where water seepage is present.

A dry excavation will be required for pile driving. Since the soils at the underside of the pile caps include weak soils that will be easily disturbed, it is recommended that the base of the excavation be protected with a concrete working slab.

The combination of dewatering methods and excavation support must ensure basal heave does not occur, see Section 11.3.

11.2 Temporary Protection Systems

The proposed methodology is to construct the culvert in stages. The protection system should be provided in accordance with OPSS.PROV 539 and SP 105S09 and designed for Performance Level 2.

The design of temporary protection systems is the responsibility of the Contractor. All shoring should be designed by a licensed professional engineer experienced in such designs. Lateral earth pressure coefficients for the use in the design are provided in Table 10.2. The clay deposit should be considered to have a total unit weight of 18.0 kN/m³ and undrained shear strength of 40 kPa. The designer of the protection systems must ensure the penetration depth is sufficient to provide base fixity, prevent basal instability, incorporate traffic loading and surcharge loading due to construction equipment and operations, and shall consider the slope of temporary embankments above the top of the protection system (if present).

For preliminary assessment purposes, the use of sheet piles is considered feasible. Internal bracing and/or dead-man anchors could be included to enhance lateral resistance.

Except where doing so would present a conflict with the construction staging or permanent structures, the protection systems may be left in place. Given the nature of the soils at this site the contract should prohibit the use of vibratory hammers for the installation and/or removal of the sheet piles.

11.3 Dewatering

Surface water diversion will be required as the depth of excavation will extend below the water level observed at the time of investigation. Water from surface flow and/or groundwater must be diverted away from excavation(s) at all times. Groundwater perched within the embankment and surface water will tend to seep into and accumulate in excavations. The Contractor must be prepared to control the groundwater and surface water at the site to permit construction in a dry and stable environment.

The design of dewatering systems is the responsibility of the Contractor. The Contract Documents must alert the Contractor to this responsibility and to design the system in accordance with SP FOUN0003 which amends OPSS 902. A preconstruction survey is recommended, thus Designer Fill-In ** in SP FOUN0003 should be "100 m".

The hydrogeologic conditions at the site are considered to be complex, thus it is recommended that FOUN0003 be modified to include an experience requirement for the dewatering designer.

The groundwater level will fluctuate. The minimum groundwater elevation for the site at the time of the proposed works should be taken as the level provided by the design storm for the diversion.

Construction of cofferdams will be required to divert flow away from the area of the existing culvert. It is recommended that the replacement work be enclosed within a water tight enclosure.

Excavation below the groundwater level to replace the existing culverts without prior dewatering from inside a fully enclosed sheetpile cofferdam is not recommended since the inflow of groundwater will cause base heave/boiling and sloughing of the foundation soil below the water level. Further assessment of dewatering requirements and the need for a PTTW should be carried out by specialists experienced in this field.

Suggested wording of dewatering for an NSSP is provided in Appendix H.

11.4 Erosion Protection

Slope protection and drainage measures will be required to ensure the long-term surficial stability of the embankment slopes. The contractor should provide silt fences and erosion control blankets, as required, throughout the duration of the construction to prevent silt/sediments from running off the site as per OPSS 805.

Erosion protection should be provided at the culvert inlet and outlet areas. Design of the erosion protection measures must consider hydrologic and hydraulic factors and should be carried out by specialists experienced in this field. The recommended erosion protection measures should be reviewed by the Foundations Engineer.

Typically, rock protection should be provided over all surfaces with which surface water is likely to be in contact. Treatment at the inlet and outlet should be in accordance with OPSD 810.010. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS.PROV 804.

12 CONSTRUCTION CONCERNS

The planned construction methodology includes an open cut excavation for the installation of a new culvert.

Potential construction concerns include, but are not necessarily limited to, the following:

- Construction will extend below the surface water level. An adequate and effective surface water management and dewatering plan must be implemented to construct the replacement culvert and wingwalls in the dry.
- The combination of dewatering methods and excavation support must ensure basal heave does not occur.
- A suitable internal bracing system or dead man anchors may need to be incorporated into the roadway protection and dewatering system design.
- Sloping bedrock is present at this site. Piles must be fitted with rock injector pile points and care must be taken when driving the piles. As described in OPSS.PROV 903, driving must be stopped as soon as contact with the bedrock surface is made; driving then resumes using 10% of the hammer energy and the energy is stepped up as the pile is seated into the bedrock.
- The subgrade at the base of the excavation will be easily disturbed and should be protected promptly after excavation, inspection and approval.

The successful performance of this structure will depend largely upon good workmanship and quality control during construction. Observation of the excavation and backfilling operations will be required as per MTO SP 109S12 during construction to confirm that the foundation recommendations are correctly implemented, and material specifications are met.

13 CLOSURE

Overall project management and direction of the field program was provided by Paul Carnaffan, P.Eng. Interpretation of the field data and preparation of this report was completed by Katya Edney, P.Eng. and Deanna Pizycki, E.I.T. The report was reviewed by Paul Carnaffan, P.Eng. and Dr. Fred Griffiths, P.Eng., a Designated Principal Contact for MTO Foundations Projects.



Katya Edney, P.Eng.
Geotechnical Engineer



Paul Carnaffan, P.Eng.
Principal, Senior Geotechnical Engineer

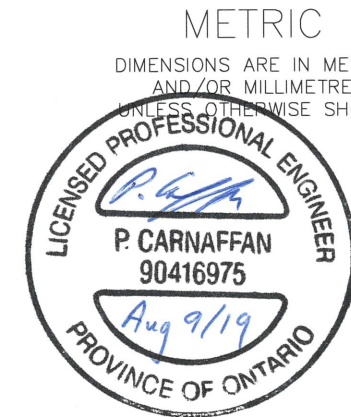
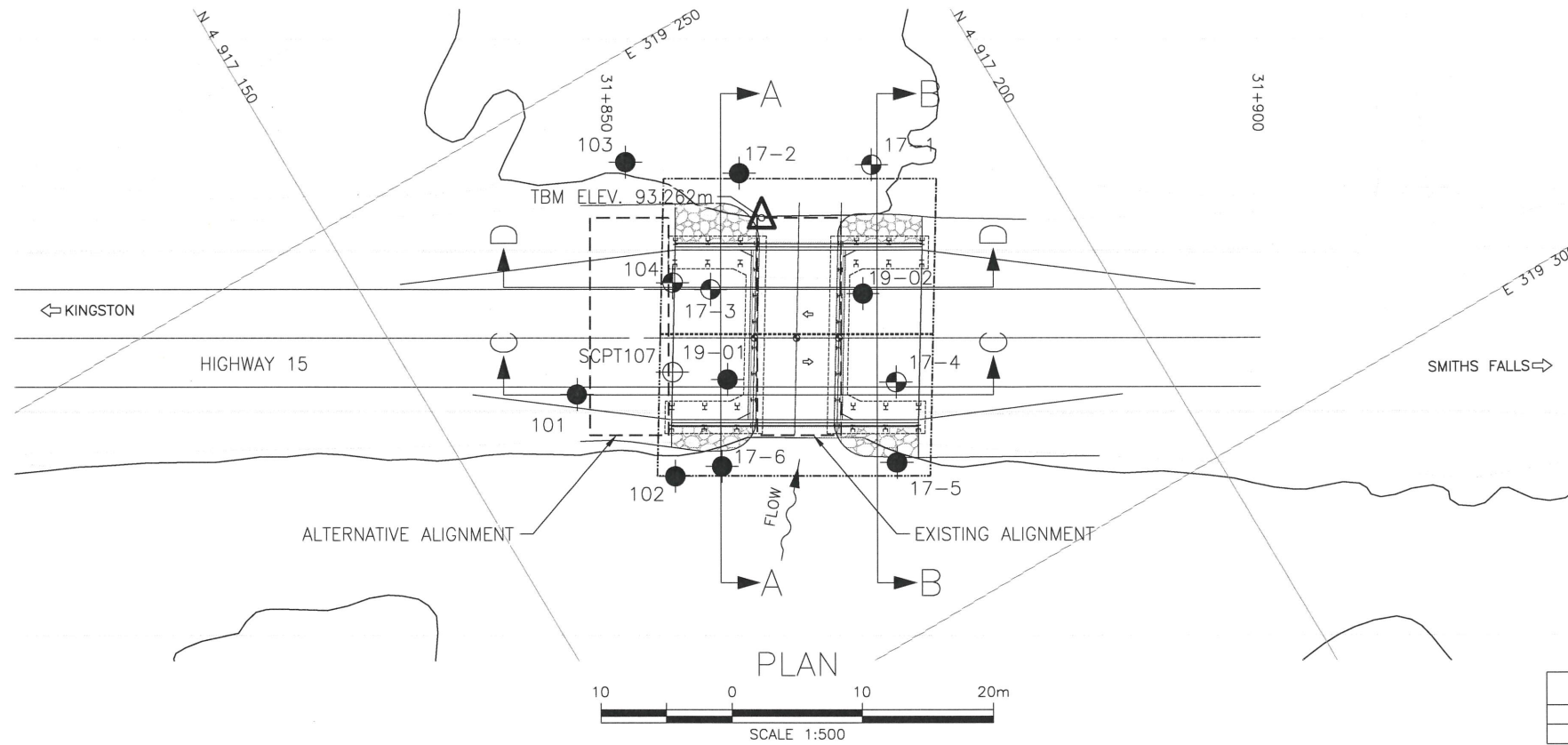


Fred J. Griffiths, Ph.D., P.Eng.
Review Principal, Designated MTO Contact

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- [2] Boulanger, R. W. and Idriss, I. M. (2007). Evaluation of cyclic softening in silts and clays, ASCE, Journal of Geotechnical and Geoenvironmental Engineering, 133(6), 641-652.
- [3] Idriss, I. M., and Boulanger, R. W. (2008). Soil liquefaction during earthquakes, Monograph MNO-12, Earthquake Engineering Research Institute, Oakland, CA, 261 pp.
- [4] Boulanger, R. W., and Idriss, I. M. (2014). CPT and SPT based liquefaction triggering procedures, Report No. UCD/CGM-14/01, Center for Geotechnical Modeling, Department of Civil and Environmental Engineering, University of California, Davis, CA, 134 pp.
- [5] Hashash Y.M.A., Musgrove M.I., Harmon J.A., Groholski D.R., Phillips C.A. and Park D. (2016). DEEPSOIL 6.1, User Manual

APPENDIX A
BOREHOLE LOCATIONS AND SOIL STRATA DRAWINGS

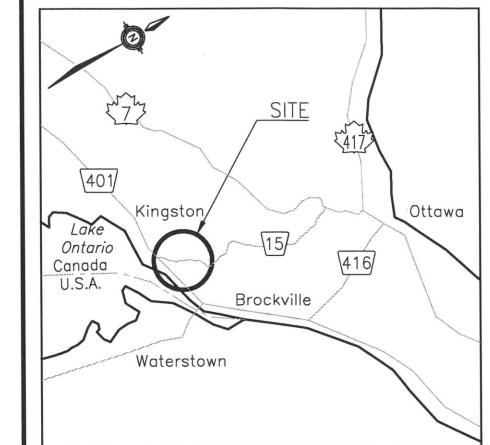


NO	ELEVATION	NORTHING	EASTING
19-01	94.5	4 917 170.8	319 275.7
19-02	94.5	4 917 183.1	319 275.3

CONT No 2019-4037
GWP No 4185-13-00

RIDEAU CANAL
BACKWATER CULVERT
REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

McINTOSH PERRY



KEYPLAN

LEGEND

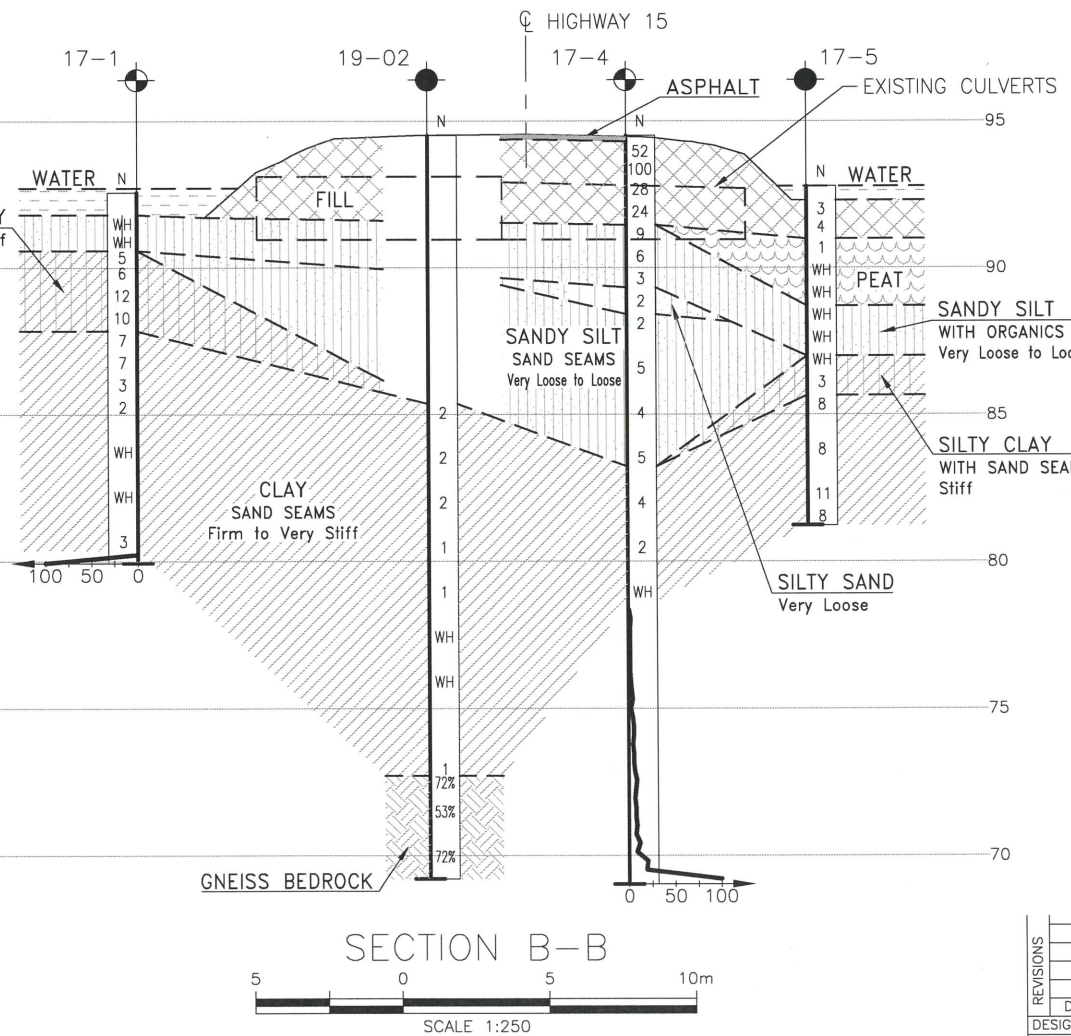
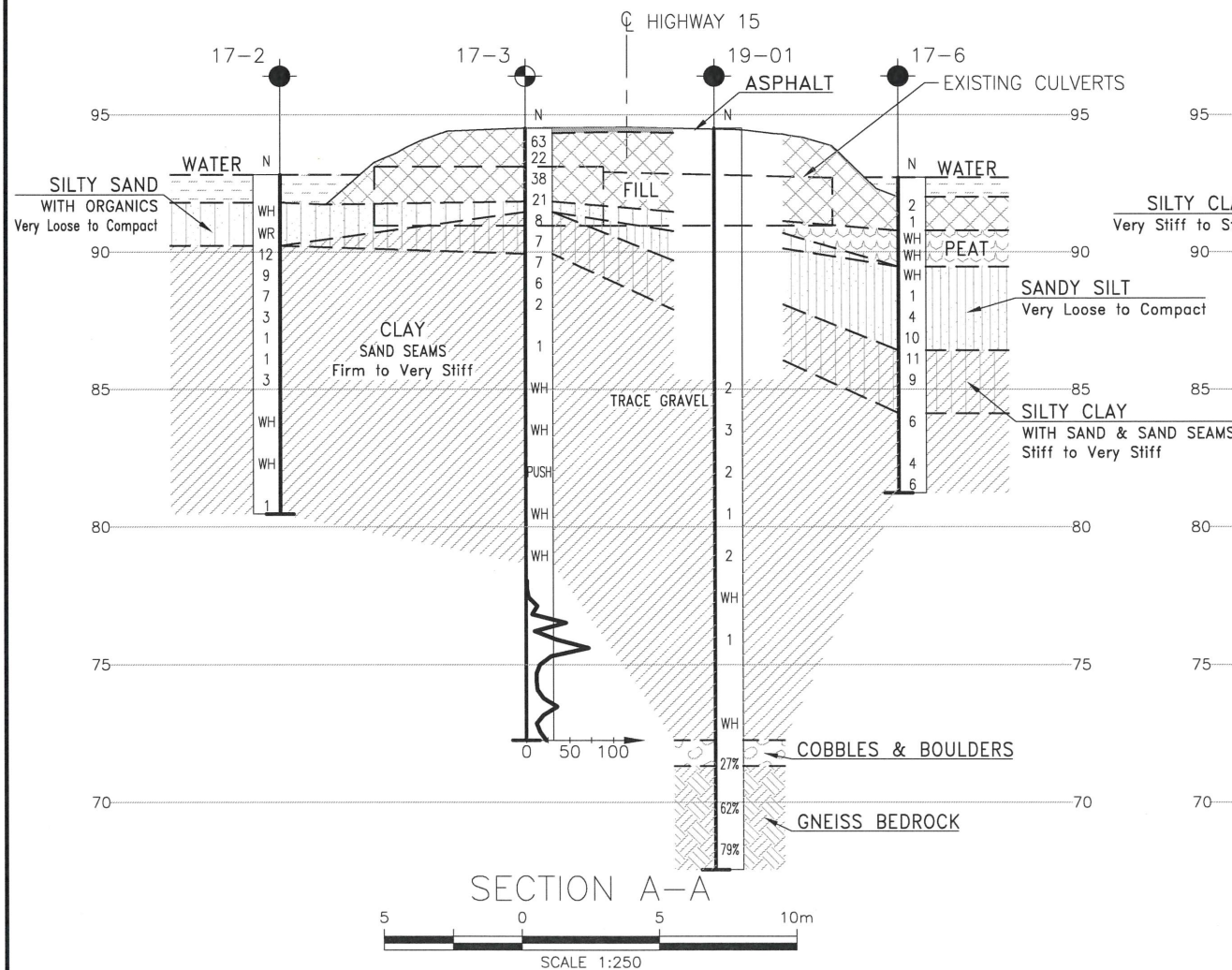
- Borehole
- Borehole and Cone
- SCPT Borehole
- Temporary Benchmark
- N
- Blows /0.3m (Std Pen Test, 475J/blow)
- Blows /0.3m (60° Cone, 475J/blow)
- Water Level
- Head Artesian Water
- Piezometer
- 90% Rock Quality Designation (RQD)
- Auger Refusal

NO	ELEVATION	NORTHING	EASTING
101	94.5	4 917 160.3	319 270.8
102	92.1	4 917 163.6	319 280.1
103	92.3	4 917 172.6	319 257.4
104	94.5	4 917 171.0	319 267.2
17-1	91.8	4 917 188.7	319 267.2
17-2	91.8	4 917 179.6	319 262.6
17-3	94.5	4 917 173.2	319 269.1
17-4	94.5	4 917 181.8	319 282.5
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SCPT107	94.5	4 917 167.5	319 273.1

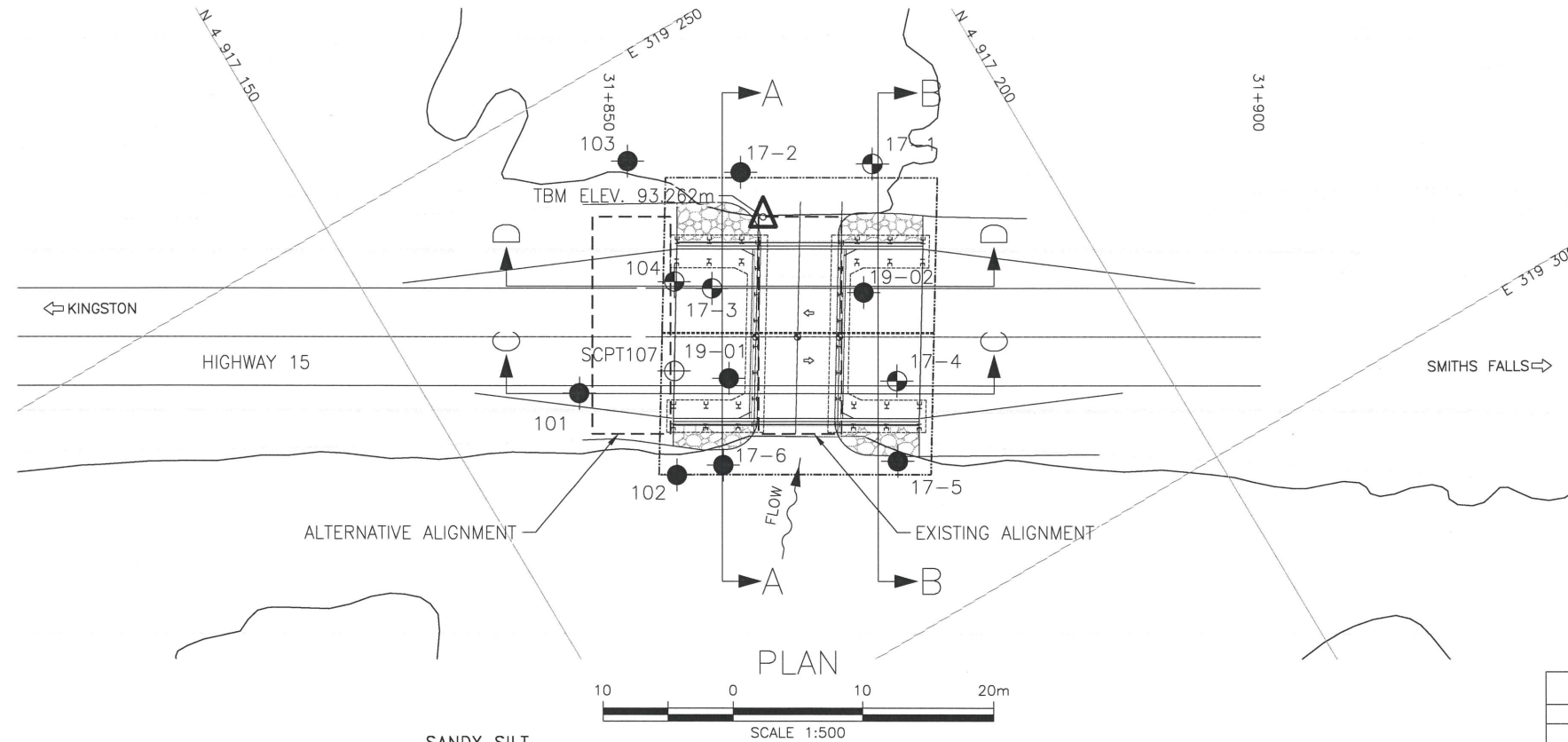
NOTES

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Borehole locations are shown in MTM Zone 9 coordinates.

GEOCRES No. 31C-284

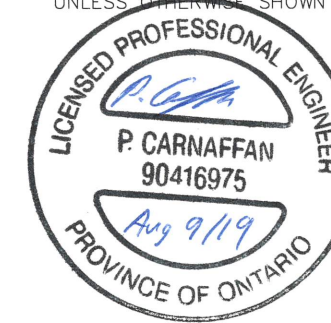


DATE	BY	DESCRIPTION
DESIGN	KP	CHK -
DRAWN	MFA	CHK PC
CODE	LOAD	DATE
SITE 07X-0142/CQ	STRUCT	DWG 1



NO	ELEVATION	NORTHING	EASTING
19-01	94.5	4 917 170.8	319 275.7
19-02	94.5	4 917 183.1	319 275.3

METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN



CONT No 2019-4037
GWP No 4185-13-00

RIDEAU CANAL
BACKWATER CULVERT
REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

McINTOSH PERRY



LEGEND

- Borehole
- ⊕ Borehole and Cone
- ⊕ SCPT Borehole
- △ Temporary Benchmark
- N Blows /0.3m (Std Pen Test, 475J/blow)
- CONE Blows /0.3m (60' Cone, 475J/blow)
- ▽ Water Level
- ↑ Head Artesian Water
- ⊕ Piezometer
- 90% Rock Quality Designation (RQD)
- A/R Auger Refusal

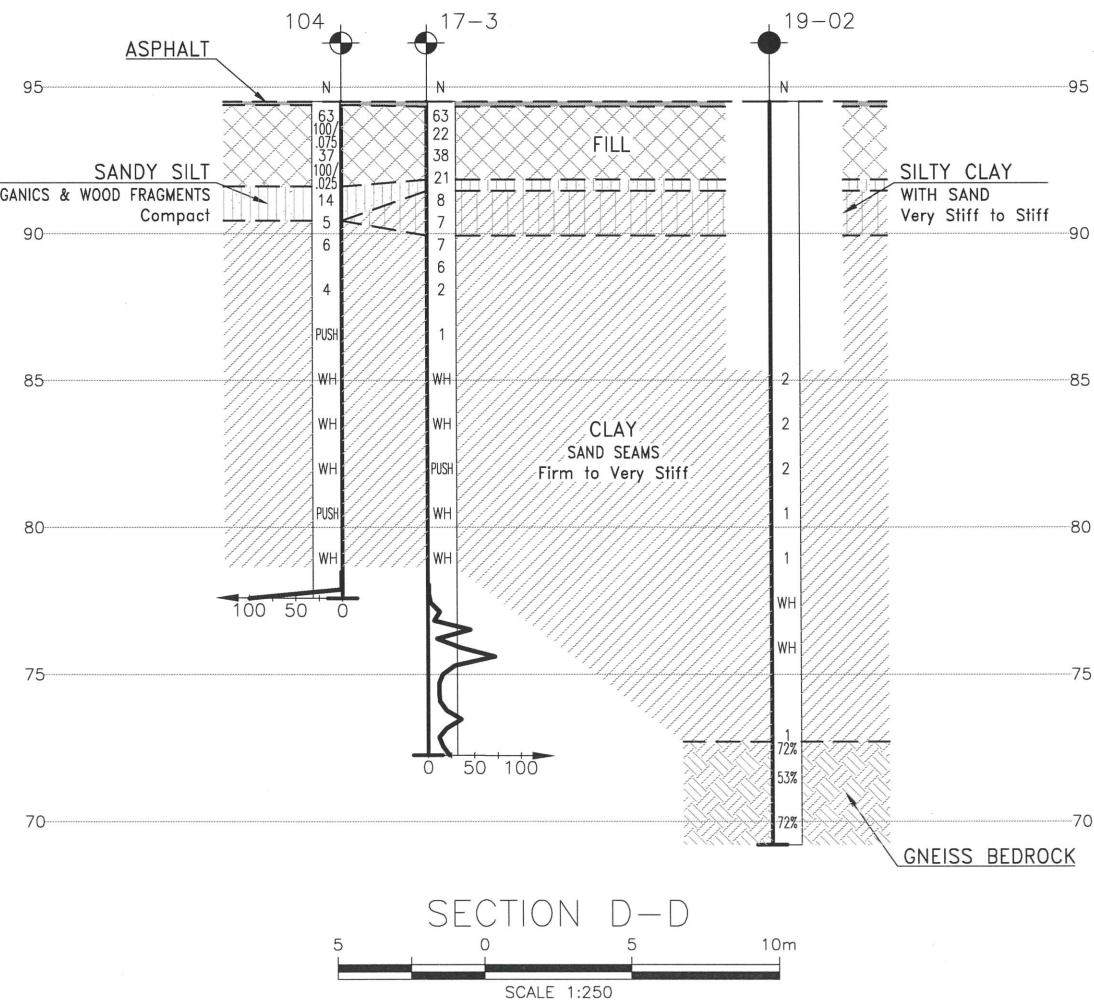
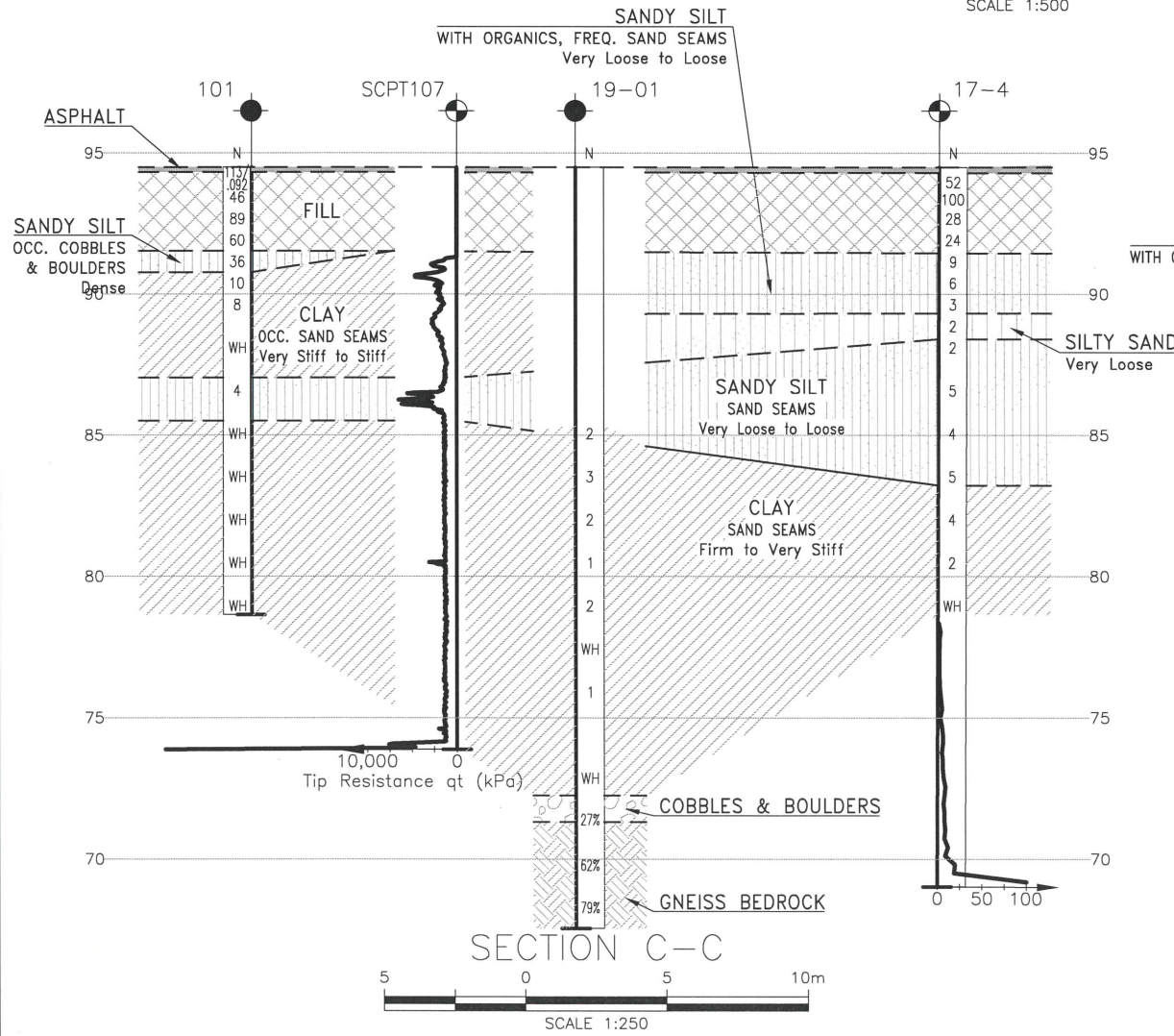
NO	ELEVATION	NORTHING	EASTING
101	94.5	4 917 160.3	319 270.8
102	92.1	4 917 163.6	319 280.1
103	92.3	4 917 172.6	319 257.4
104	94.5	4 917 171.0	319 267.2
17-1	91.8	4 917 188.7	319 267.2
17-2	91.8	4 917 179.6	319 262.6
17-3	94.5	4 917 173.2	319 269.1
17-4	94.5	4 917 181.8	319 282.5
17-5	92.3	4 917 178.7	319 287.8
17-6	92.0	4 917 167.0	319 281.2
SCPT107	94.5	4 917 167.5	319 273.1

NOTES

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Borehole locations are shown in MTM Zone 9 coordinates.

GEOCRES No. 31C-284

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	KP	CHK -	CODE
DRAWN	MFA	CHK PC	SITE 07X-0142/CO/STRUCT
			DATE AUG 2019
			DWG 2



APPENDIX B
RECORD OF BOREHOLE SHEETS



SYMBOLS, ABBREVIATIONS AND TERMS USED ON TEST HOLE RECORDS

TERMINOLOGY DESCRIBING COMMON SOIL GENESIS

Topsoil	mixture of soil and humus capable of supporting vegetative growth
Peat	mixture of fragments of decayed organic matter
Till	unstratified glacial deposit which may include particles ranging in sizes from clay to boulder
Fill	material below the surface identified as placed by humans (excluding buried services)

TERMINOLOGY DESCRIBING SOIL STRUCTURE:

Desiccated	having visible signs of weathering by oxidization of clay materials, shrinkage cracks, etc.
Fissured	having cracks, and hence a blocky structure
Varved	composed of alternating layers of silt and clay
Stratified	composed of alternating successions of different soil types, e.g. silt and sand
Layer	> 75 mm in thickness
Seam	2 mm to 75 mm in thickness
Parting	< 2 mm in thickness

RECOVERY:

For soil samples, the recovery is recorded as the length of the soil sample recovered.

N-VALUE:

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 63.5 kg hammer falling 0.76 m, required to drive a 50 mm O.D. split spoon sampler 0.3 m into undisturbed soil. For samples where insufficient penetration was achieved and N-value cannot be presented, the number of blows are reported over the sampler penetration in millimetres (e.g. 50/75).

DYNAMIC CONE PENETRATION TEST (DCPT):

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to an "A" size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone 0.3 m into the soil. The DCPT is used as a probe to assess soil variability.



STRATA PLOT:

Strata plots symbolize the soil and bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.



Boulders
Cobbles
Gravel Sand Silt Clay Organics Asphalt Concrete Fill Bedrock

TEXTURING CLASSIFICATION OF SOILS

Classification	Particle Size
Boulders	Greater than 200 mm
Cobbles	75 – 200 mm
Gravel	4.75 – 75 mm
Sand	0.075 – 4.75 mm
Silt	0.002 – 0.075 mm
Clay	Less than 0.002 mm

TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

Descriptive Term	Undrained Shear Strength (kPa)
Very Soft	12 or less
Soft	12 – 25
Firm	25 – 50
Stiff	50 – 100
Very Stiff	100 – 200
Hard	Greater than 200

NOTE: Clay sensitivity is defined as the ratio of the undisturbed strength over the remolded strength.

SAMPLE TYPES

SS	Split spoon samples
ST	Shelby tube or thin wall tube
DP	Direct push sample
PS	Piston sample
BS	Bulk sample
WS	Wash sample
HQ, NQ, BQ etc.	Rock core sample obtained with the use of standard size diamond coring equipment

TERMS DESCRIBING CONSISTENCY (COHESIONLESS SOILS ONLY)

Descriptive Term	SPT “N” Value
Very Loose	Less than 4
Loose	4 – 10
Compact	10 – 30
Dense	30 – 50
Very Dense	Greater than 50

MODIFIED UNIFIED SOIL CLASSIFICATION

Major Divisions		Group Symbol	Typical Description
COARSE GRAINED SOIL	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILT AND CLAY SOILS $W_L < 35\%$	ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
		OL	Organic silts and organic silty-clays of low plasticity.
	SILT AND CLAY SOILS $35\% < W_L < 50\%$	MI	Inorganic compressible fine sandy silt with clay of medium plasticity, clayey silts.
		CI	Inorganic clays of medium plasticity, silty clays.
		OI	Organic silty clays of medium plasticity.
	SILT AND CLAY SOILS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy of silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other organic soils.

Note - W_L = Liquid Limit



EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

Fresh (FR)	No visible signs of weathering.
Fresh Jointed (FJ)	Weathering limited to surface of major discontinuities.
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock materials.
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structures are preserved.

TERMS

Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.
Solid Core Recovery: (SCR)	Percent ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1 m in length or larger, as a percentage of total core length
Unconfined Compressive Strength: (UCS)	Axial stress required to break the specimen.
Fracture Index: (FI)	Frequency of natural fractures per 0.3 m of core run.

DISCONTINUITY SPACING

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

STRENGTH CLASSIFICATION




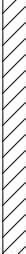
Rock Strength	Approximate Uniaxial Compressive Strength (MPa)
Extremely Strong	Greater than 250
Very Strong	100 – 250
Strong	50 – 100
Medium Strong	25 – 50
Weak	5 – 25
Very Weak	1 – 5
Extremely Weak	0.25 – 1

RECORD OF BOREHOLE No 101

1 OF 2

METRIC

GWP# 4185-13-00 LOCATION Lat: 44.3943051° Long: -76.3183547° MTM Zone 9: N 4 917 160.3 E 319 270.8 ORIGINATED BY DJP
 HWY 15 BOREHOLE TYPE HSA / NW Casing / NQ Coring COMPILED BY DJP
 DATUM Geodetic DATE 2018.05.22 - 2018.05.22 CHECKED BY PC

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 (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)
94.5								20	40	60	80	100					
0.0	180 mm ASPHALT																
0.2	Gravel with silt and sand Occasional cobbles		1	SS	113/ 92mm		94										54 38 8 (SI+CL)
93.8	Very dense Brown Moist FILL																
0.7	Sand with gravel Occasional cobbles and boulders Dense to very dense Brown Moist to wet FILL		2	SS	46												
							93										
			3	SS	89												
92.3																	
2.2	Sand with silt and gravel Occasional cobbles and boulders Very dense to dense Grey FILL		4	SS	60		92										
91.5	- Cored 300 mm boulder at 2.7 m																
3.0	SANDY SILT (ML) Occasional cobbles and boulders Dense Grey		5	SS	36		91										
90.8																	
3.7	CLAY (CL to CI) - occasional sand seams Very stiff to stiff Grey		6	SS	10		90										
				7	SS	8											0 2 56 42
	- Vane attempted: S _u > 106 kPa - Vane attempted: S _u > 106 kPa							89									
			8	SS	WH		88										
87.0																	

Continued Next Page

+³, ×³: Numbers refer to Sensitivity
 20
 15
 10
 (%) STRAIN AT FAILURE

DOUBLE LINE RIDEAU BH.GPJ 2012TEMPLATE(MTO).GDT 6/6/19

RECORD OF BOREHOLE No 101

2 OF 2

METRIC

GWP# 4185-13-00 LOCATION Lat: 44.3943051° Long: -76.3183547° MTM Zone 9: N 4 917 160.3 E 319 270.8 ORIGINATED BY DJP
 HWY 15 BOREHOLE TYPE HSA / NW Casing / NQ Coring COMPILED BY DJP
 DATUM Geodetic DATE 2018.05.22 - 2018.05.22 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			W P W W L				GR SA SI CL				
								20 40 60 80 100	○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE			WATER CONTENT (%)							
	Continued From Previous Page							20 40 60 80 100				20 40 60							
78.7 15.8	CLAY (Cl) - occasional sand seams Stiff to firm Grey - becomes firm below 14 m						84												
		11	SS	WH															
								83											
		12	SS	WH															
								81											
		13	SS	WH															
								80											
			14	SS	WH		79												
	End of Borehole																		

DOUBLE LINE RIDEAU BH.GPJ 2012TEMPLATE(MTO).GDT 6/6/19

+³, ×³: Numbers refer to Sensitivity
 20
 15
 10
 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 102

1 OF 2

METRIC

GWP# 4185-13-00 LOCATION Lat: 44.3943347° Long: -76.3182378° MTM Zone 9: N 4 917 163.6 E 319 280.1 ORIGINATED BY NW
HWY 15 BOREHOLE TYPE Portable Drill / 1/2 Weight Hammer / NW Casing COMPILED BY KCP
DATUM Geodetic DATE 2018.08.20 - 2018.08.21 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
93.1	Water						20 40 60 80 100	○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE			W P W W L		GR SA SI CL	
0.0	WATER						20 40 60 80 100							
92.1														
1.0	Sandy SILT (ML) with organics Very loose Brown		1	SS	2									
91.5														
1.5	PEAT mixed with some silt Very loose Brown		2	SS	2									
90.9														
90.8	MARL - occasional shells Very loose Brown - grey		3	SS	1									
90.3														
2.7	Sandy SILT (ML) with organics Very loose Grey		4	SS	1									
	Sandy SILT (ML) Loose to compact Grey		5	SS	3									
			6	SS	4									
			7	SS	13									
			8	SS	13									
			9	SS	8									
86.7														
6.4	CLAY (CL) - occasional sand seams Very stiff to stiff Grey		10	SS	14									
			11	SS	22									
			12	SS	12									
	- Vane attempted: S _u > 106 kPa													
83.9														
83.7	Silt (ML) Loose Grey		13	SS	8									
9.4	CLAY (CL) Very stiff to stiff													

DOUBLE LINE RIDEAU BH.GPJ 2012TEMPLATE(MTO).GDT 6/6/19

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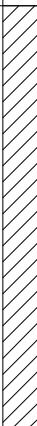

+³, ×³: Numbers refer to Sensitivity
20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 102

2 OF 2

METRIC

GWP# 4185-13-00 LOCATION Lat: 44.3943347° Long: -76.3182378° MTM Zone 9: N 4 917 163.6 E 319 280.1 ORIGINATED BY NW
 HWY 15 BOREHOLE TYPE Portable Drill / 1/2 Weight Hammer / NW Casing COMPILED BY KCP
 DATUM Geodetic DATE 2018.08.20 - 2018.08.21 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
	Continued From Previous Page							<div><div>20406080100</div><div>○ UNCONFINED + FIELD VANE</div><div>● QUICK TRIAXIAL × LAB VANE</div></div> <div><div>PLASTIC LIMIT</div><div>NATURAL MOISTURE CONTENT</div><div>LIQUID LIMIT</div><div>W P W W L</div><div>WATER CONTENT (%)</div><div>204060</div></div>						
80.3 12.8	Grey - Vane attempted: S _u > 106 kPa						83							
	14		SS	7		82								
						81								
	15		SS	8										0 6 55 39
	End of Borehole Note: A 50% (32 kg) drop hammer was used to advance the splitspoon sampler. The SPT N values presented above have been corrected to provide an estimate of the SPT N value that would have been obtained with a standard full weight hammer.													

+³, ×³: Numbers refer to Sensitivity
 20
 15
 10
 5
 0
 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 103

1 OF 2

METRIC

GWP# 4185-13-00 LOCATION Lat: 44.3944161° Long: -76.3185225° MTM Zone 9: N 4 917 172.6 E 319 257.4 ORIGINATED BY NW
HWY 15 BOREHOLE TYPE Portable Drill / 1/2 Weight Hammer / NW Casing / NTW Coring COMPILED BY KCP
DATUM Geodetic DATE 2018.08.22 - 2018.08.27 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W P W W L			
93.1	Water							20 40 60 80 100					GR SA SI CL
0.0	WATER						93						
92.3													
92.2	75 mm ROOTMAT		1	SS	11								
0.9	SILTY CLAY with sand						92						
91.9	Stiff Grey		2	SS	1								
1.2	Sandy SILT (ML) with organics Very loose Grey												
91.1			3	SS	1		91						
2.0	MARL - occasional shells Very loose												
90.7	Brown - grey		4	SS	1								
2.4	Sandy SILT (ML) with organics Very loose Grey		5	SS	2		90						
89.5			6	SS	9								
3.6	SILT (ML) Loose Brown to grey						89						
88.8			7	SS	19								
4.3	CLAY (CH) Very stiff Grey		8	SS	15		88						
87.9			9	SS	15								
5.2	SILT (ML) Compact Grey		10	SS	11		87						
87.5			11	SS	9								
5.6	CLAY (CH) Very stiff Grey						86						
	- Vane attempted: S _u > 106 kPa												
			12	SS	10		85						
	- Vane attempted: S _u > 106 kPa												
83.7							84						
9.3	GNEISS BEDROCK Slightly weathered Very close joint spacing Very poor quality		1	RUN									RUN #1 TCR=100% SCR=50% RQD=17%

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

DOUBLE LINE RIDEAU BH.GPJ 2012TEMPLATE(MTO).GDT 6/6/19

RECORD OF BOREHOLE No 103

2 OF 2

METRIC

GWP# 4185-13-00 LOCATION Lat: 44.3944161° Long: -76.3185225° MTM Zone 9: N 4 917 172.6 E 319 257.4 ORIGINATED BY NW
 HWY 15 BOREHOLE TYPE Portable Drill / 1/2 Weight Hammer / NW Casing / NTW Coring COMPILED BY KCP
 DATUM Geodetic DATE 2018.08.22 - 2018.08.27 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE							WATER CONTENT (%) PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W P W W L			
	Continued From Previous Page							20	40	60	80	100						
82.2	Grey Vertical fracture from 10 m to 10.5 m		2	RUN			83											RUN #2 TCR=100% SCR=92% RQD=0%
10.9	End of Borehole Note: A 50% (32 kg) drop hammer was used to advance the splitspoon sampler. The SPT N values presented above have been corrected to provide an estimate of the SPT N value that would have been obtained with a standard full weight hammer.		3	RUN														RUN #3 TCR=100% SCR=0% RQD=0%

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 104

1 OF 2

METRIC

GWP# 4185-13-00 LOCATION Lat: 44.3944015°, Long: -76.3183996° MTM Zone 9: N 4 917 171.0 E 319 267.2 ORIGINATED BY DJP
 HWY 15 BOREHOLE TYPE NW Casing / DCPT COMPILED BY DJP
 DATUM Geodetic DATE 2018.05.23 - 2018.05.23 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
94.5								20	40	60	80	100				
0.0	115 mm ASPHALT															
0.1	Sand with gravel Very dense Brown Moist		1	SS	63		94									
93.6	FILL		2	SS	100/											
0.9	Sand with gravel Frequent cobbles and boulders Dense to very dense Brown FILL - cored 190 mm cobble at 1.0 m - cored 120 mm cobble at 1.3 m - cored 360 mm boulder at 2.1 m				75mm		93									
			3	SS	37											
			4	SS	100/		92									
					25mm											
91.6																
2.9	SANDY SILT (ML), trace rootlets Compact Grey		5	SS	14		91									
90.4			6	SS	5		90									
4.1	CLAY (CL) - occasional sand seams Very stiff to stiff Grey - Vane attempted: Su > 106 kPa - Vane attempted: Su > 106 kPa		7	SS	6		89									
			8	SS	4		88									
							87									
			9	ST	PUSH											
							86									
			10	SS	WH		85									

Continued Next Page

+³, ×³: Numbers refer to Sensitivity
 20
 15
 10
 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 104

2 OF 2

METRIC

GWP# 4185-13-00 LOCATION Lat: 44.3944015°, Long: -76.3183996° MTM Zone 9: N 4 917 171.0 E 319 267.2 ORIGINATED BY DJP
 HWY 15 BOREHOLE TYPE NW Casing / DCPT COMPILED BY DJP
 DATUM Geodetic DATE 2018.05.23 - 2018.05.23 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	
	Continued From Previous Page							SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	WATER CONTENT (%) 20 40 60			GR SA SI CL
	CLAY (CL) - occasional sand seams Stiff to firm Grey		11	SS	WH		84	8.3 9.7				
							83	7.7 7.4				
			12	SS	WH		82					0 0 40 60
							81	7.7 8.0				
			13	ST	PUSH		80	5.5 4.4				
							79					
78.7			14	SS	WH		78					
15.8	End of Borehole DCPT from 15.8 m to 16.9 m											
77.6												
16.9	End of DCPT DCPT refusal at elev. 77.6 m											

DOUBLE LINE RIDEAU BH.GPJ 2012TEMPLATE(MTO).GDT 6/6/19

+³, ×³: Numbers refer to Sensitivity
 20
 15
 10
 (%) STRAIN AT FAILURE

METRIC

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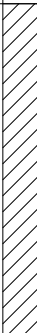
+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 17-1

2 OF 2

METRIC

GWP# 4185-13-00 LOCATION Lat: 44.3945608°, Long: -76.3183991° MTM Zone 9: N 4 917 188.7 E 319 267.2 ORIGINATED BY KE
 HWY 15 BOREHOLE TYPE Portable Drill / NW Casing COMPILED BY DJP
 DATUM Geodetic DATE 2017.09.28 - 2017.09.28 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)		
								20 40 60 80 100										
	Continued From Previous Page							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE										
	CLAY (CH) Firm Grey		12	SS	WH		82											
									1.1 +									
										2.3 +								
80.4			13	SS	3		81											
12.2	End of Borehole DCPT from 12.2 m to 12.6 m																	
80.0																		
12.6	End of DCPT						80											

+³, ×³: Numbers refer to Sensitivity
 20
15
10
5
0
(%) STRAIN AT FAILURE

METRIC

SOIL PROFILE			SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa		W P W L			
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	WATER CONTENT (%)					
92.8 0.0	Water						20 40 60 80 100	20 40 60					
	WATER												
91.8 1.0	Silty SAND (SM) with organics Very loose Black to brown		1	SS	WH						145		
			2	SS	WR						82	1 87 12 (SI+CL)	
90.2 2.6	CLAY (CI to CL) Very stiff to stiff Grey		3	SS	12							0 4 53 43	
			4	SS	9								
			5	SS	7								
	- frequent sand seams below 4.9 m		6	SS	3								
			7	SS	1							0 16 49 35	
			8	SS	1								
			9	SS	3								
			10	SS	WH							1 1 43 55	
							1.8 1.9 2.2 3.3						

+³, ×³: Numbers refer to Sensitivity

DOUBLE LINE RIDEAU BH.GPJ 2012TEMPLATE(MTO).GDT 6/6/19

RECORD OF BOREHOLE No 17-2

2 OF 2

METRIC

GWP# 4185-13-00 LOCATION Lat: 44.394479°, Long: -76.3184571° MTM Zone 9: N 4 917 179.6 E 319 262.6 ORIGINATED BY KE
 HWY 15 BOREHOLE TYPE Portable Drill / NW Casing COMPILED BY DJP
 DATUM Geodetic DATE 2017.09.27 - 2017.09.27 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE LIQUID CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				W P W W L				GR SA SI CL			
								20 40 60 80 100	WATER CONTENT (%)										
	Continued From Previous Page																		
	CLAY (Cl to CL) Stiff to firm Grey		11	SS	WH		82												
	- becomes firm below 11 m								2.4 +										
	- frequent sand seams below 11.7 m								6.9 +										
80.5			12	SS	1		81							11	o			1 4 63 32	
12.3	End of Borehole																		

DOUBLE LINE RIDEAU BH.GPJ 2012TEMPLATE(MTO).GDT 6/6/19

+³, ×³: Numbers refer to Sensitivity
 20
 15
 10
 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-3

1 OF 3

METRIC

GWP# 4185-13-00 LOCATION Lat: 44.3944213°, Long: -76.3183757° MTM Zone 9: N 4 917 173.2 E 319 269.1 ORIGINATED BY KE
 HWY 15 BOREHOLE TYPE HSA COMPILED BY KCP
 DATUM Geodetic DATE 2017.09.12 - 2017.09.13 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
								UNCONFINED + FIELD VANE							
								● QUICK TRIAXIAL × LAB VANE							
							WATER CONTENT (%)								
							PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT								
							W P W W L								
94.5							20	40	60	80	100				
0.0	180 mm ASPHALT														
0.2	Sand trace to some gravel trace silt Compact to very dense Brown FILL		1	SS	63										
			2	SS	22										
	- occasional cobbles from 1.5 m to 2.7 m		3	SS	38										3 89 8 (SI+CL)
91.8			4	SS	21										
2.7	Sandy SILT (ML) - with organics and wood fragments														
91.5	Compact														
3.0	Dark brown		5	SS	8										0 23 57 20
	Silty CLAY (CL-ML) with sand Very stiff to stiff Grey		6	SS	7										
89.9															
4.6	CLAY (CL to CI) - some sand seams Stiff Grey		7	SS	7										0 2 57 41
			8	SS	6										
			9	SS	2										
	- frequent sand seams below 7.6 m		10	SS	1										0 10 57 33
			11	SS	WH										

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
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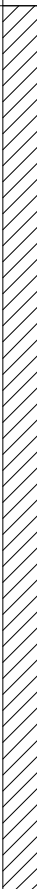
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-3

2 OF 3

METRIC

GWP# 4185-13-00 LOCATION Lat: 44.3944213° Long: -76.3183757° MTM Zone 9: N 4 917 173.2 E 319 269.1 ORIGINATED BY KE
 HWY 15 BOREHOLE TYPE HSA COMPILED BY KCP
 DATUM Geodetic DATE 2017.09.12 - 2017.09.13 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)	
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE							
	Continued From Previous Page							20 40 60 80 100		20 40 60						
78.7 15.8	CLAY (CL to Cl) -some sand seams Stiff to firm Grey - becomes firm below 12 m						84	8.8 6.2								
			12	SS	WH		83	7.8 5.3								
							82									
			13	ST	PUSH		81	6.0 4.5								
							80									
			14	SS	WH		79	6.9 4.0								
	End of Borehole DCPT from 15.8 m to 22.3 m						78									
							77									
							76									
							75									

Continued Next Page

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-3

3 OF 3

METRIC

GWP# 4185-13-00 LOCATION Lat: 44.3944213°, Long: -76.3183757° MTM Zone 9: N 4 917 173.2 E 319 269.1 ORIGINATED BY KE
 HWY 15 BOREHOLE TYPE HSA COMPILED BY KCP
 DATUM Geodetic DATE 2017.09.12 - 2017.09.13 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	WATER CONTENT (%)					
	Continued From Previous Page DCPT Continued						<div> <div>20 40 60 80 100</div> <div> <div>○ UNCONFINED</div> <div>● QUICK TRIAXIAL</div> </div> <div> <div>+ FIELD VANE</div> <div>× LAB VANE</div> </div> </div>	<div>20 40 60</div>						
72.2														
22.3	End of DCPT													

RECORD OF BOREHOLE No 17-4

1 OF 3

METRIC

GWP# 4185-13-00 LOCATION Lat: 44.3944984° Long: -76.3182072° MTM Zone 9: N 4 917 181.8 E 319 282.5 ORIGINATED BY KE
 HWY 15 BOREHOLE TYPE HSA COMPILED BY KCP
 DATUM Geodetic DATE 2017.09.13 - 2017.09.13 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								20 40 60 80 100								
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE								
WATER CONTENT (%)				20 40 60												
94.5																
0.0	200 mm ASPHALT															
0.2	Gravel with silt and sand Very dense Brown FILL		1	SS	52											
			2	SS	100											51 42 7 (SI+CL)
93.0																
1.5	Silty sand with gravel - occasional cobbles Compact Brown FILL		3	SS	28											
			4	SS	24											
91.5																
3.0	Sandy SILT (ML) with organics - frequent sand seams Loose Grey - organic seams from 3.6 m to 4.1 m		5	SS	9											0 27 61 12
			6	SS	6											
90.4																
4.1	Sandy Organic SILT (OH) Very loose to loose Grey - trace shells		7	SS	3											0 22 70 8 Organic Content = 34%
89.3																
5.2	Silty SAND (SM) Very loose Brown		8	SS	2											0 86 14 (SI+CL)
88.4																
6.1	Sandy SILT (ML) - frequent sand seams Very loose to loose Grey		9	SS	2											0 35 52 13 non-plastic
			10	SS	5											
			11	SS	4											

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-4

2 OF 3

METRIC

GWP# 4185-13-00 LOCATION Lat: 44.3944984° Long: -76.3182072° MTM Zone 9: N 4 917 181.8 E 319 282.5 ORIGINATED BY KE
HWY 15 BOREHOLE TYPE HSA COMPILED BY KCP
DATUM Geodetic DATE 2017.09.13 - 2017.09.13 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE								
	Continued From Previous Page						20 40 60 80 100					W _p W W _L				
83.2	Sandy SILT (ML) Loose		12	SS	5										0 15 74 11 non-plastic	
11.3	CLAY (CL to CI) - frequent sand seams Very stiff to stiff Grey - Vane attempted: S _u > 106 kPa		13	SS	4											
	- Vane attempted: S _u > 106 kPa		14	SS	2											
			15	SS	WH										0 1 51 48	
78.7	End of Borehole DCPT from 15.8 m to 25.5 m															
15.8																

Continued Next Page

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-4

3 OF 3

METRIC

GWP# 4185-13-00 LOCATION Lat: 44.3944984° Long: -76.3182072° MTM Zone 9: N 4 917 181.8 E 319 282.5 ORIGINATED BY KE
 HWY 15 BOREHOLE TYPE HSA COMPILED BY KCP
 DATUM Geodetic DATE 2017.09.13 - 2017.09.13 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	WATER CONTENT (%)					
	Continued From Previous Page DCPT Continued						20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	20 40 60						
69.0	End of DCPT DCPT Refusal at elev. 69.0 m													

DOUBLE LINE RIDEAU BH.GPJ 2012TEMPLATE(MTO).GDT 6/6/19

RECORD OF BOREHOLE No 17-5

1 OF 2

METRIC

GWP# 4185-13-00 LOCATION Lat: 44.3944704° Long: -76.3181408° MTM Zone 9: N 4 917 178.7 E 319 287.8 ORIGINATED BY KE
HWY 15 BOREHOLE TYPE Portable Drill / NW Casing COMPILED BY DJP
DATUM Geodetic DATE 2017.10.03 - 2017.10.03 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W P W W L			
92.8	Water												
0.0	WATER												
92.3													
0.5	Sand with gravel with wood fragments and some organics Very loose Grey FILL		1	SS	3		92						
			2	SS	4								
91.0							91						
1.8	PEAT - Amorphous Very soft Black		3	SS	1								
			4	SS	WH		90						
			5	SS	WH		89						
88.7													
4.1	Sandy SILT (ML) with organics Very loose Brown		6	SS	WH		88						
			7	SS	WH								
87.0													
5.8	SILTY CLAY (CL-ML) - with sand seams Stiff Grey		8	SS	WH		87						
			9	SS	3		86						
85.7													
7.1	CLAY (CL-CI) Stiff Grey		10	SS	8		85						
			11	SS	8		84						
							83						

Continued Next Page


+³, ×³: Numbers refer to
Sensitivity 20
15 10 5 0
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-5

2 OF 2

METRIC

GWP# 4185-13-00 LOCATION Lat: 44.3944704° Long: -76.3181408° MTM Zone 9: N 4 917 178.7 E 319 287.8 ORIGINATED BY KE
 HWY 15 BOREHOLE TYPE Portable Drill / NW Casing COMPILED BY DJP
 DATUM Geodetic DATE 2017.10.03 - 2017.10.03 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT							UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE												
	Continued From Previous Page							20	40	60	80	100								
81.2	CLAY (CL-CI) Stiff Grey		12	SS	11		82													
11.6			13	SS	8															
	End of Borehole																			
																		</		

RECORD OF BOREHOLE No 17-6

1 OF 2

METRIC

GWP# 4185-13-00 LOCATION Lat: 44.3943652°, Long: -76.3182239° MTM Zone 9: N 4 917 167.0 E 319 281.2 ORIGINATED BY KE
HWY 15 BOREHOLE TYPE Portable Drill / NW Casing COMPILED BY DJP
DATUM Geodetic DATE 2017.10.02 - 2017.10.02 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	
92.7	Water											
0.0	WATER											
92.0												
0.7	Sand with silt and gravel Grey FILL		1	SS	2		92					
			2	SS	1		91					
90.8												
1.9	PEAT Very soft - Amorphous - trace shells Black		3	SS	WH		90				624	
			4	SS	WH						226	
89.4												
3.3	Sandy SILT (ML) Very loose to compact Grey		5	SS	WH		89					0 31 54 15 Non-plastic
			6	SS	1		88					
			7	SS	4							
			8	SS	10		87					
86.4												
6.3	SILTY CLAY (CL-ML) with sand - with sand seams Very stiff Grey		9	SS	11		86					0 18 60 22
			10	SS	9		85					
84.1												
8.6	CLAY (CL to CI) Very stiff to stiff Grey		11	SS	6		84					0 4 61 35
							83					

DOUBLE LINE RIDEAU BH.GPJ 2012TEMPLATE(MTO).GDT 6/6/19

Continued Next Page


+³, ×³: Numbers refer to Sensitivity
20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-6

2 OF 2

METRIC

GWP# 4185-13-00 LOCATION Lat: 44.3943652°, Long: -76.3182239° MTM Zone 9: N 4 917 167.0 E 319 281.2 ORIGINATED BY KE
 HWY 15 BOREHOLE TYPE Portable Drill / NW Casing COMPILED BY DJP
 DATUM Geodetic DATE 2017.10.02 - 2017.10.02 CHECKED BY PC

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 (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)			GR	SA	SI	CL
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE																
	Continued From Previous Page							20	40	60	80	100												
81.2	CLAY (CL-CI) Very stiff Grey		12	SS	4		82																	
11.5			13	SS	6															0	1	38	61	
	End of Borehole																							

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

METRIC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W _P W W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100			
94.5							SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	WATER CONTENT (%) 20 40 60				

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 19-01

2 OF 3

METRIC

GWP# 4185-13-00 LOCATION MTM Zone 9: N 4 917 170.8 E 319 275.7 ORIGINATED BY SOB
 HWY 15 BOREHOLE TYPE HSA / NW Casing COMPILED BY AC
 DATUM Geodetic DATE 2019.04.23 - 2019.04.23 CHECKED BY PC

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			SHEAR STRENGTH kPa			W P W W L				
								○ UNCONFINED + FIELD VANE			WATER CONTENT (%)				
								● QUICK TRIAXIAL × LAB VANE							
	Continued From Previous Page						20 40 60 80 100	20 40 60 80 100	20 40 60						
83.8	CLAY (CL) stiff grey						84								
10.7	CLAY (CL/CI) stiff grey		2	SS	3		83	5.2 +							
								4.3 +							
		3	SS	2		82							0 1 39 60		
							7.3 +	5.3 +							
		4	SS	1		81									
						80	5.2 +	4.7 +							
		5	SS	2		79									
							5.1 +	3.5 +							
		6	SS	WH		78									
							4.3 +	3.9 +							
7	SS	1		76							0 1 51 48				
						4.6 +	4.4 +								
75															

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
5
0
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 19-01

3 OF 3

METRIC

GWP# 4185-13-00 LOCATION MTM Zone 9: N 4 917 170.8 E 319 275.7 ORIGINATED BY SOB
 HWY 15 BOREHOLE TYPE HSA / NW Casing COMPILED BY AC
 DATUM Geodetic DATE 2019.04.23 - 2019.04.23 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
								○ UNCONFINED + FIELD VANE					
								● QUICK TRIAXIAL × LAB VANE					
	Continued From Previous Page						20 40 60 80 100						
72.2	CLAY (CL/CI) stiff grey												
	- becomes firm and silty below 21.3 m		8	SS	WH								
22.3	Cobbles and Boulders												
71.3			1	RUN	-								
23.2	GNEISS BEDROCK slightly weathered medium to coarse grained weak to medium-strong green, grey, black												
	broken rock from elev. 69.9 to 69.8 m vertical fracture from elev. 69.8 to 69.7 m		2	RUN	-								
	vertical fracture from elev. 69.4 to 69.2 m												
			3	RUN	-								
67.6													
26.9	End of Borehole												

ONTMT4S RIDEAU BH.GPJ 2012TEMPLATE(MTO).GDT 6/6/19

METRIC

[illegible]

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+³, ×³: Numbers refer to Sensitivity

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

DOUBLE LINE RIDEAU BH.GPJ 2012TEMPLATE(MTO).GDT 6/6/19

METRIC

[illegible]

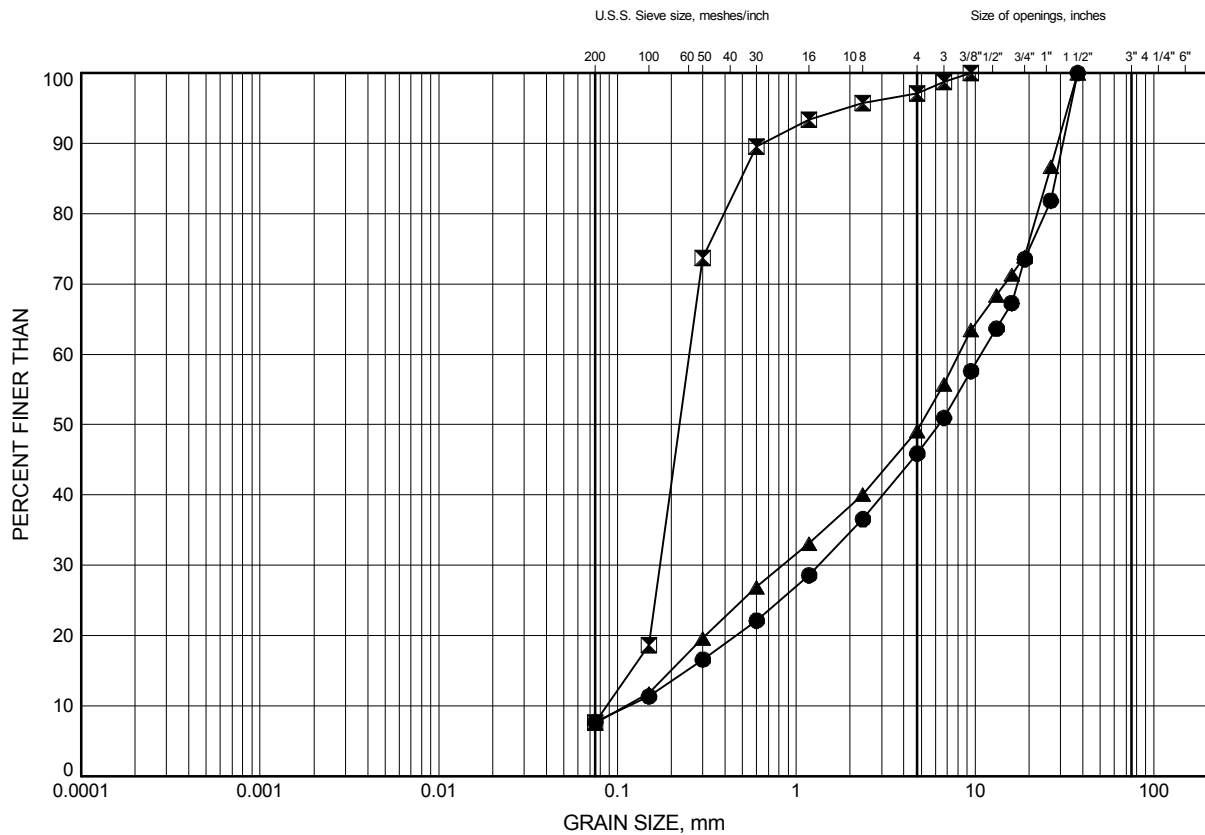
+³, ×³: Numbers refer to Sensitivity

APPENDIX C
LABORATORY TEST RESULTS
CORE PHOTOS

Site 7-148/C Rideau Canal Backwater Culvert
GRAIN SIZE DISTRIBUTION

FIGURE 1

FILL - Gravel with Silt and Sand to Sand Trace Gravel Trace Silt



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	101	0.4	94.1
⊠	17-3	1.2	93.3
▲	17-4	1.1	93.4

Date ..September 2018.....

GWP# ..4185-13-00.....

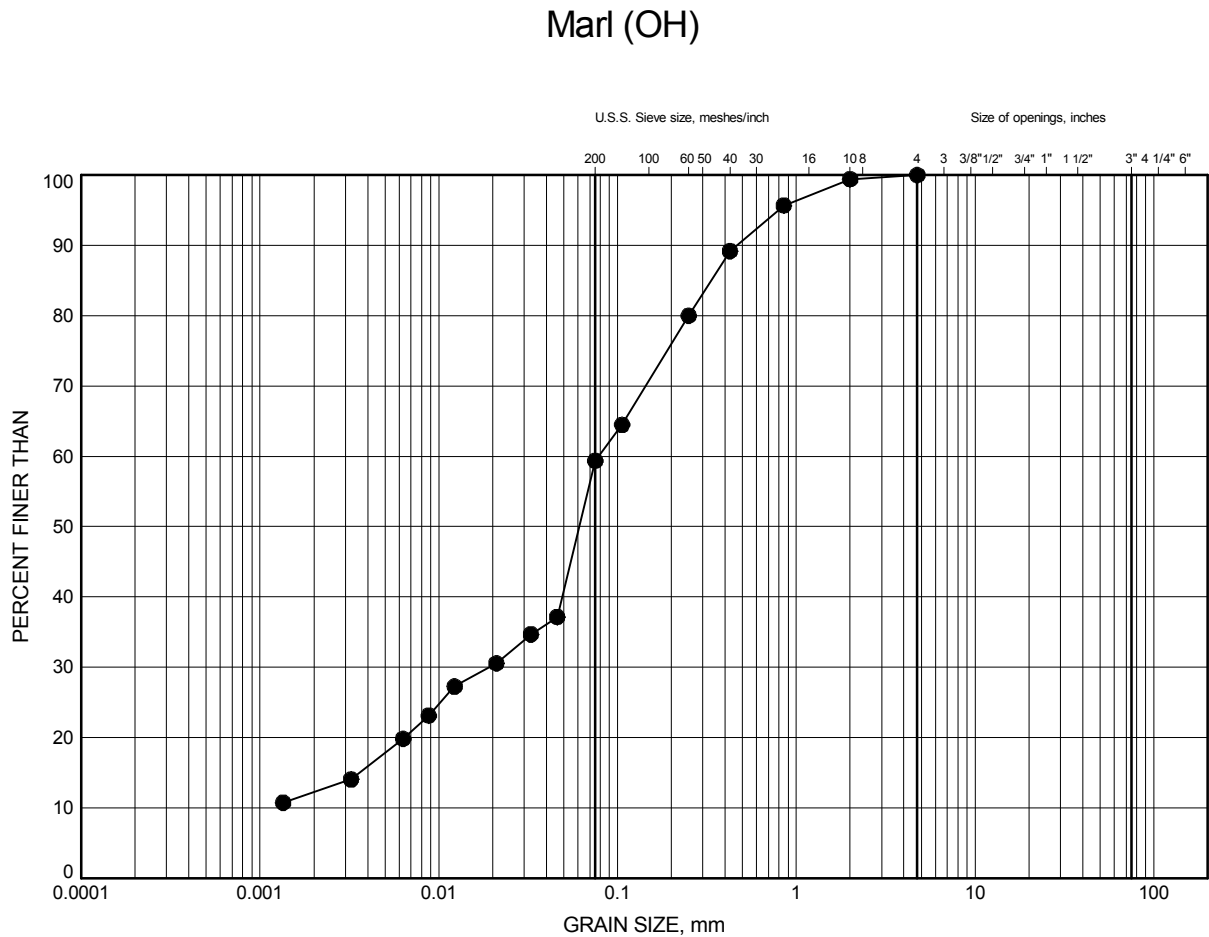


Prep'dKCP.....

Chkd.FG.....

Site 7-148/C Rideau Canal Backwater Culvert
GRAIN SIZE DISTRIBUTION

FIGURE 2



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	103	1.9	90.9

Date May 2019
GWP# 4185-13-00

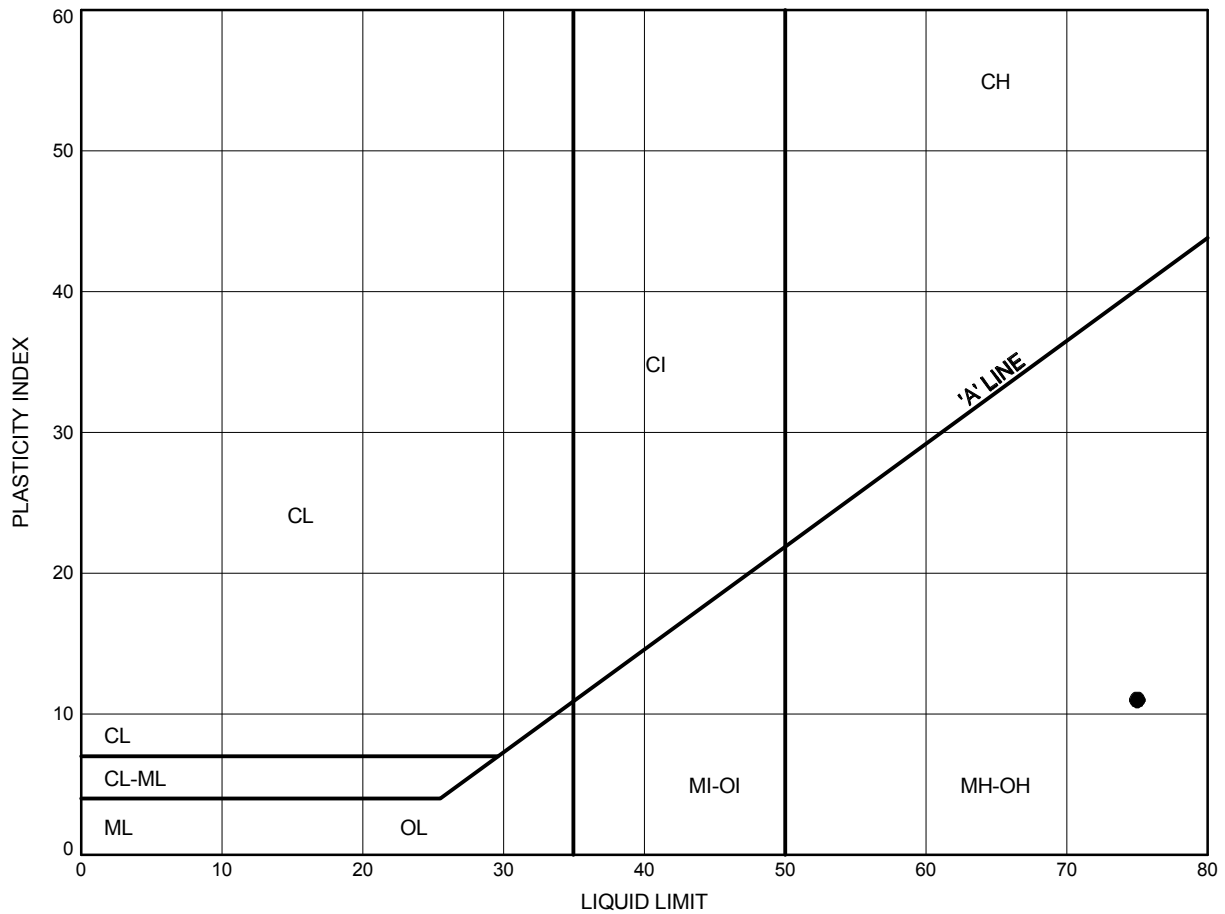


Prep'd KE
Chkd. PC

Site 7-148/C Rideau Canal Backwater Culvert
ATTERBERG LIMITS TEST RESULTS

FIGURE 3

Marl (MH-OH)



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	103	1.9	90.9

Date ..September 2018.....
 GWP# ..4185-13-00.....

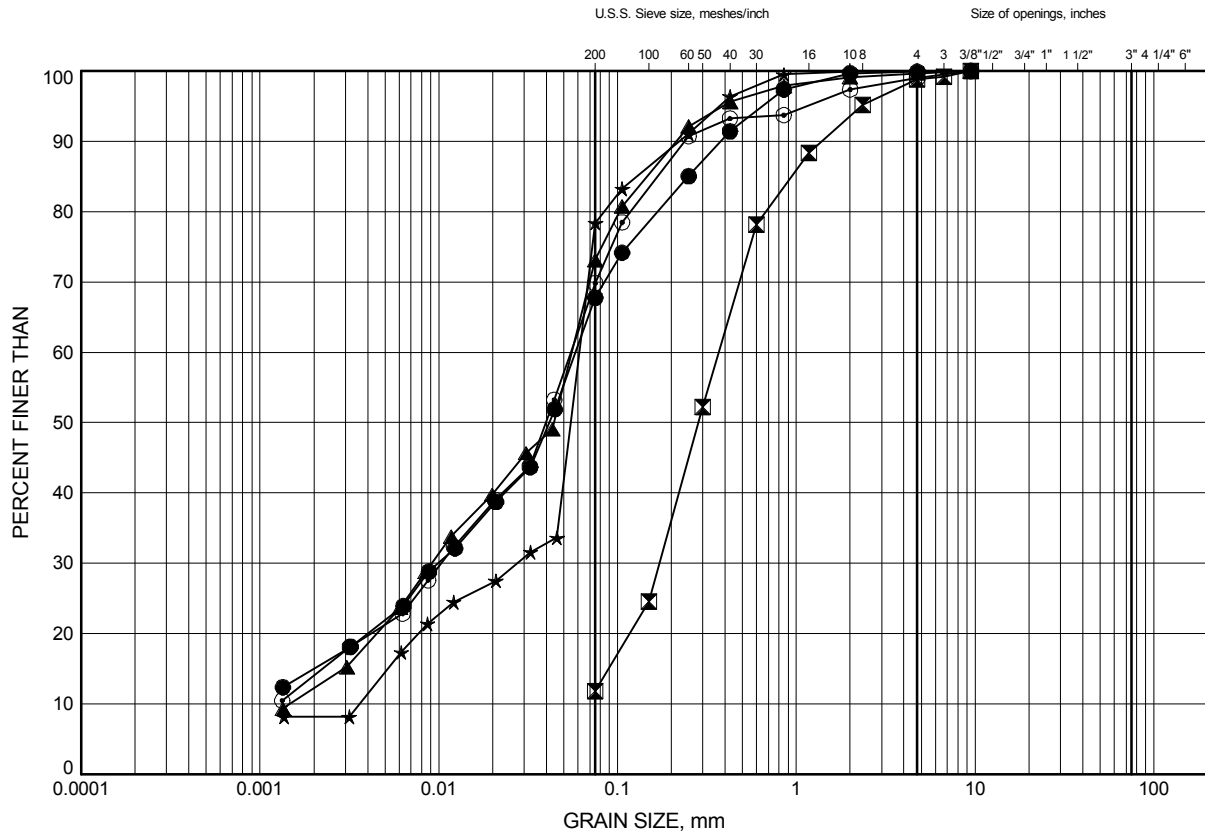


Prep'dKCP.....
 Chkd.FG.....

Site 7-148/C Rideau Canal Backwater Culvert
GRAIN SIZE DISTRIBUTION

FIGURE 4

Sandy Organic Silt (OH) to Silty Sand with Organics (SM)



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	103	2.7	90.4
⊠	17-2	2.1	90.7
▲	17-4	3.4	91.1
★	17-4	4.9	89.6
⊙	17-5	4.4	88.4

Date September 2018

GWP# 4185-13-00



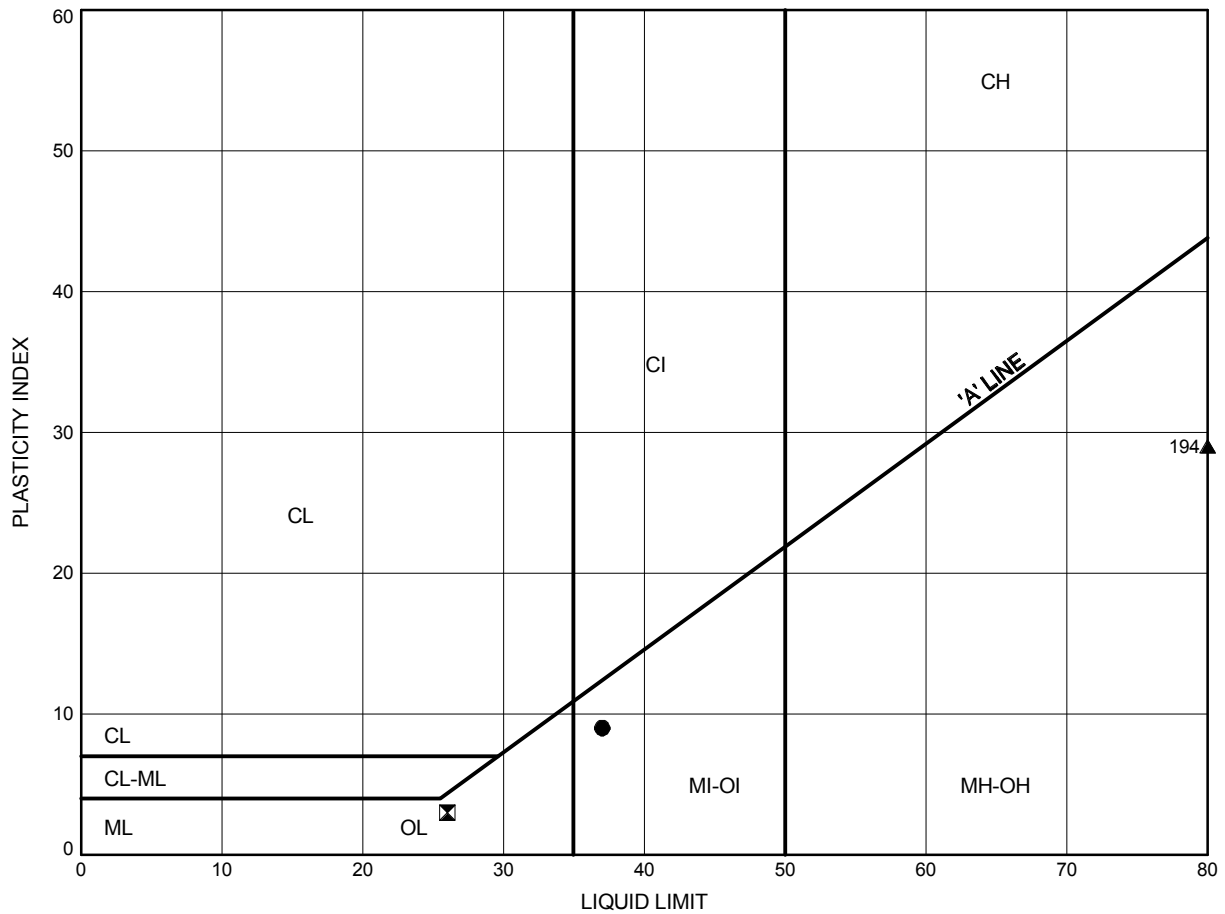
Prep'd KCP

Chkd. FG

Site 7-148/C Rideau Canal Backwater Culvert
ATTERBERG LIMITS TEST RESULTS

FIGURE 5

Sandy Organic Silt (OH) to Silty Sand with Organics (SM)



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	103	2.7	90.4
⊠	17-4	3.4	91.1
▲	17-4	4.9	89.6

Date September 2018
 GWP# 4185-13-00

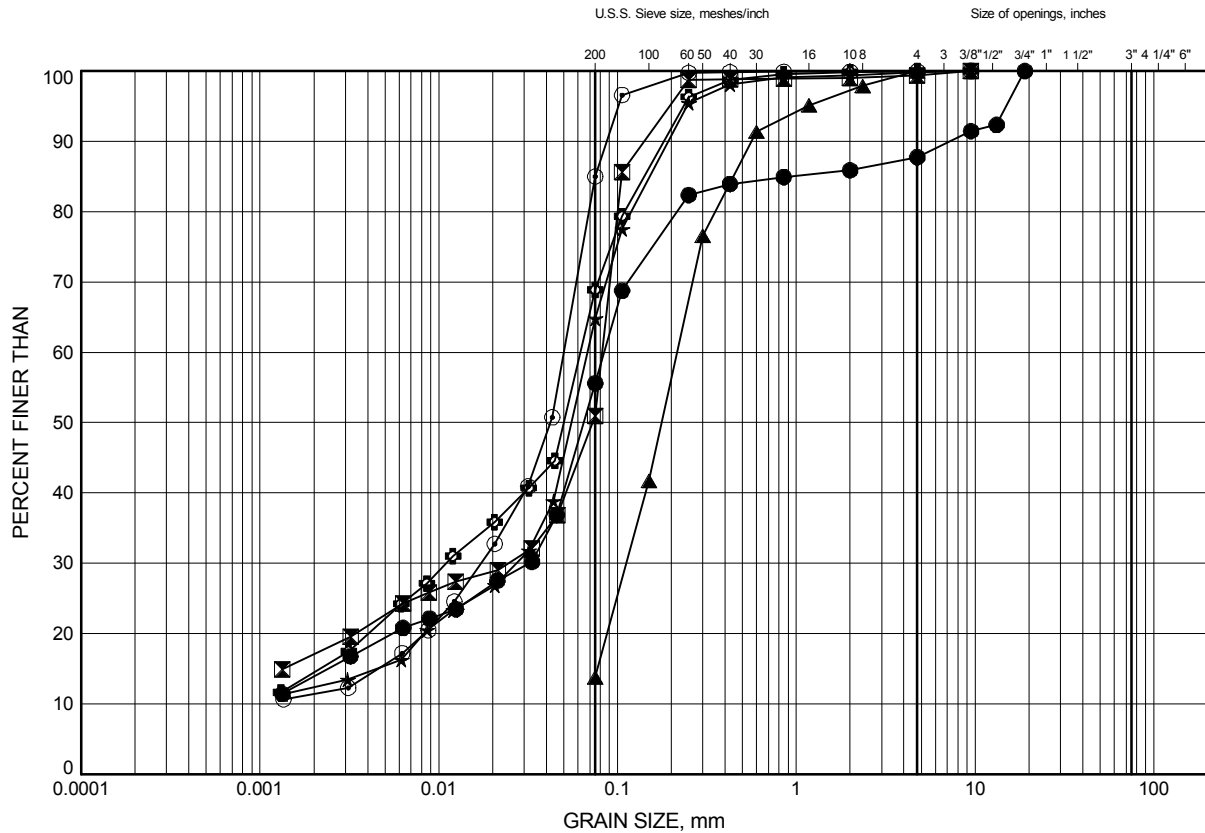


Prep'd KCP
 Chkd. FG

Site 7-148/C Rideau Canal Backwater Culvert
GRAIN SIZE DISTRIBUTION

FIGURE 6

Silty Sand (SM) to Sandy Silt (ML) to Silt (ML)



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	102	5.5	87.6
⊠	104	3.9	90.6
▲	17-4	5.7	88.8
★	17-4	6.4	88.1
⊙	17-4	11.0	83.5
⊕	17-6	3.6	89.1

Date September 2018

GWP# 4185-13-00



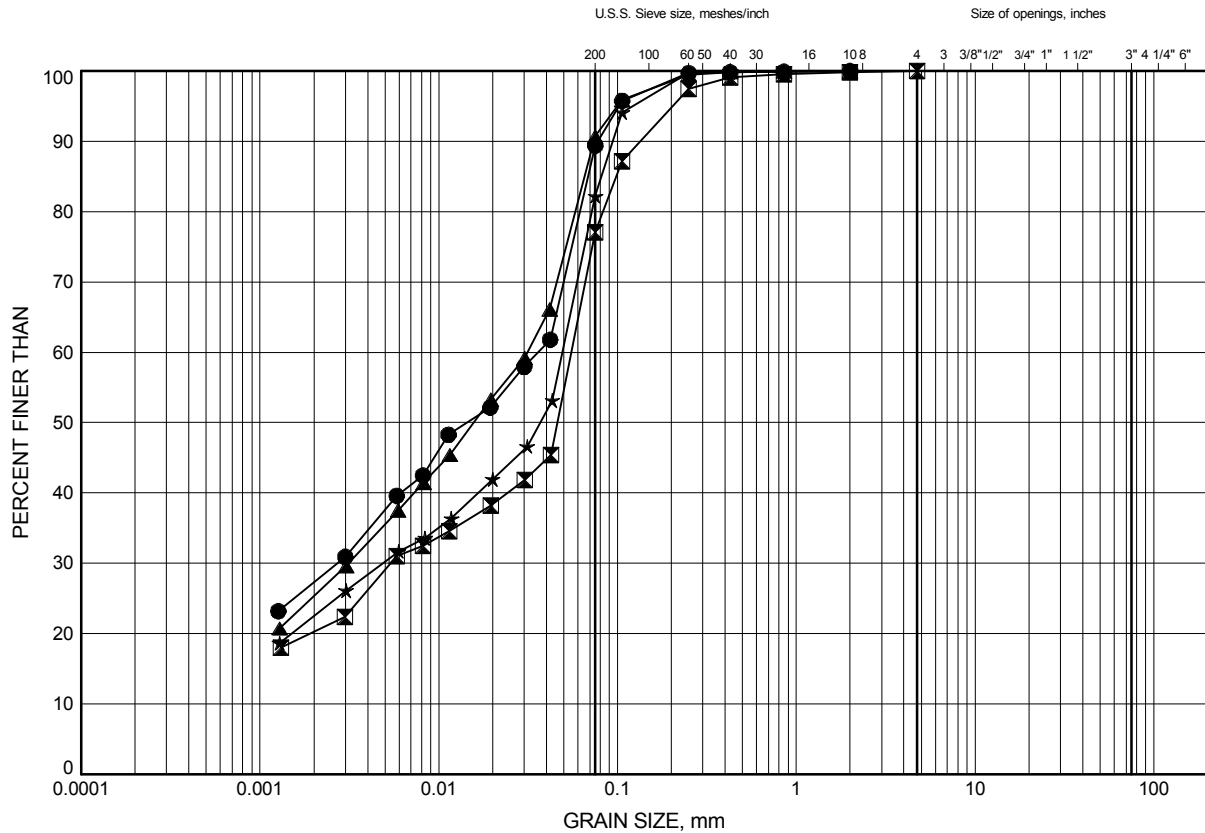
Prep'd KCP

Chkd. FG

Site 7-148/C Rideau Canal Backwater Culvert
GRAIN SIZE DISTRIBUTION

FIGURE 7

Silty Clay (CL-ML) with Sand to Silty Clay (CL-ML)



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-1	2.2	90.4
⊠	17-3	3.4	91.1
▲	17-5	6.7	86.1
★	17-6	6.6	86.1

Date September 2018

GWP# 4185-13-00



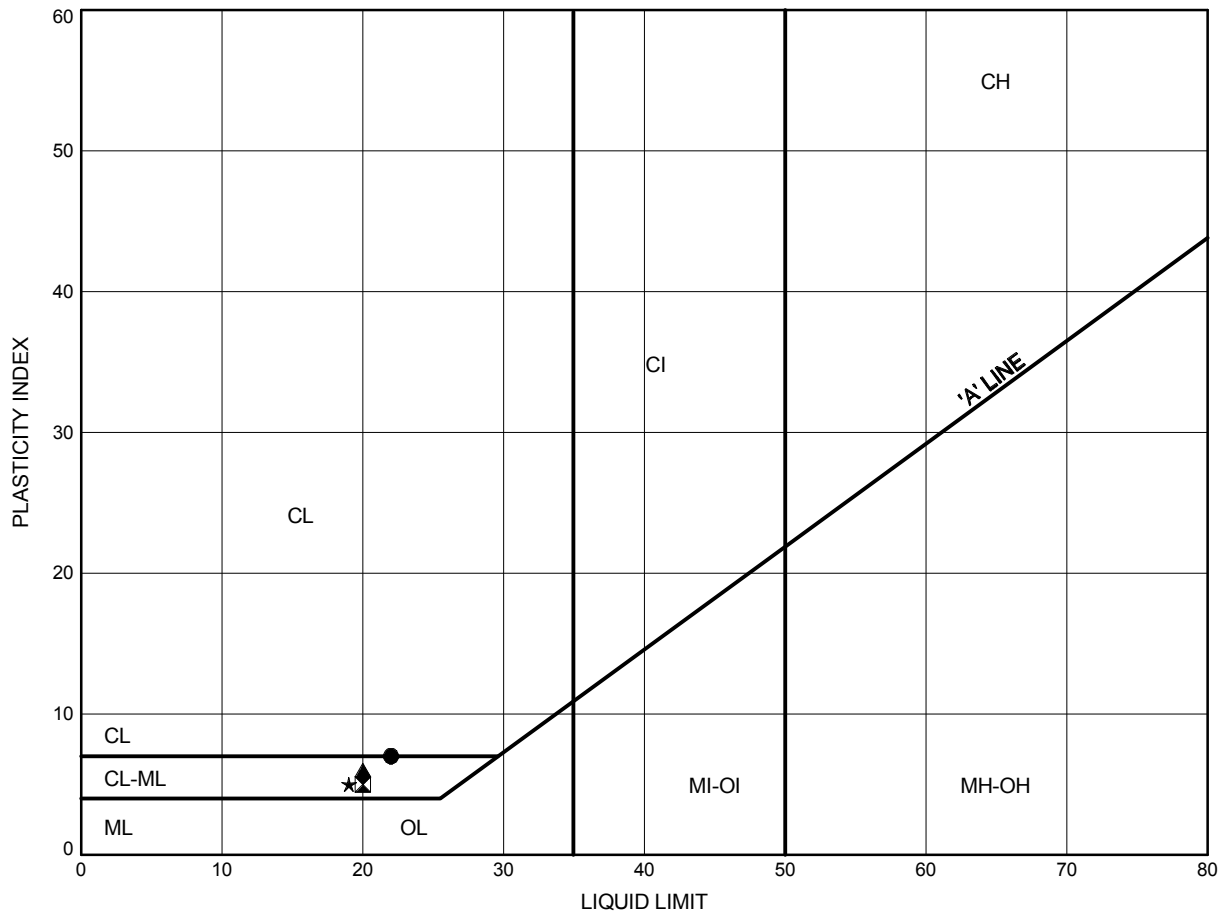
Prep'd KCP

Chkd. FG

Site 7-148/C Rideau Canal Backwater Culvert
ATTERBERG LIMITS TEST RESULTS

FIGURE 8

Silty Clay (CL-ML) with Sand to Silty Clay (CL-ML)



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-1	2.2	90.4
⊠	17-3	3.4	91.1
▲	17-5	6.7	86.1
★	17-6	6.6	86.1

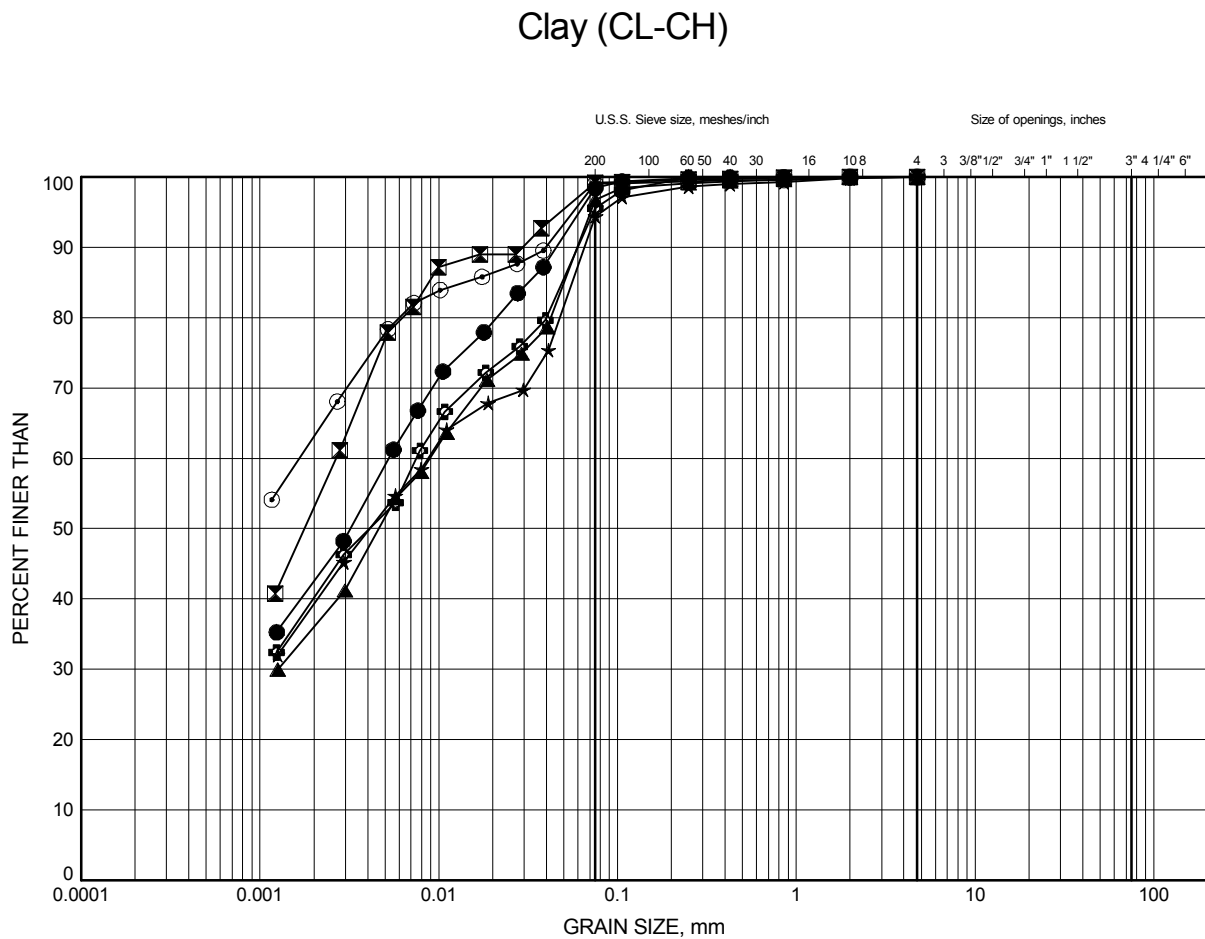
Date September 2018
 GWP# 4185-13-00



Prep'd KCP
 Chkd. FG

Site 7-148/C Rideau Canal Backwater Culvert
GRAIN SIZE DISTRIBUTION

FIGURE 9



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	101	4.9	89.6
⊠	101	14.0	80.5
▲	102	6.7	86.4
★	102	12.5	80.6
⊙	103	7.0	86.1
⊕	104	4.9	89.6

Date September 2018

GWP# 4185-13-00

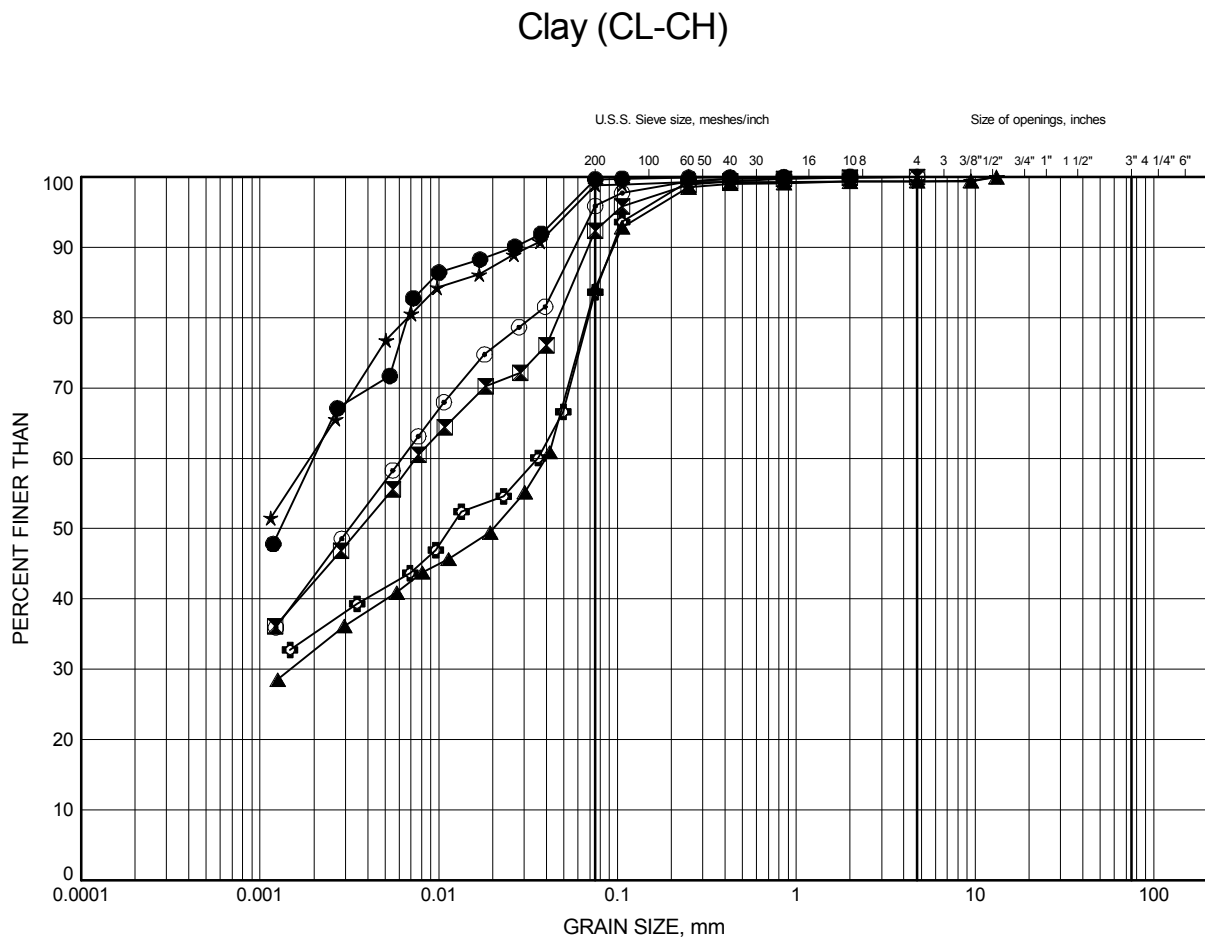


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Chkd. FG

Site 7-148/C Rideau Canal Backwater Culvert
GRAIN SIZE DISTRIBUTION

FIGURE 10



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	104	12.5	82.0
⊠	17-1	5.0	87.6
▲	17-1	6.6	86.0
★	17-1	8.8	83.8
⊙	17-2	2.9	89.9
⊕	17-2	5.9	86.9

Date September 2018

GWP# 4185-13-00

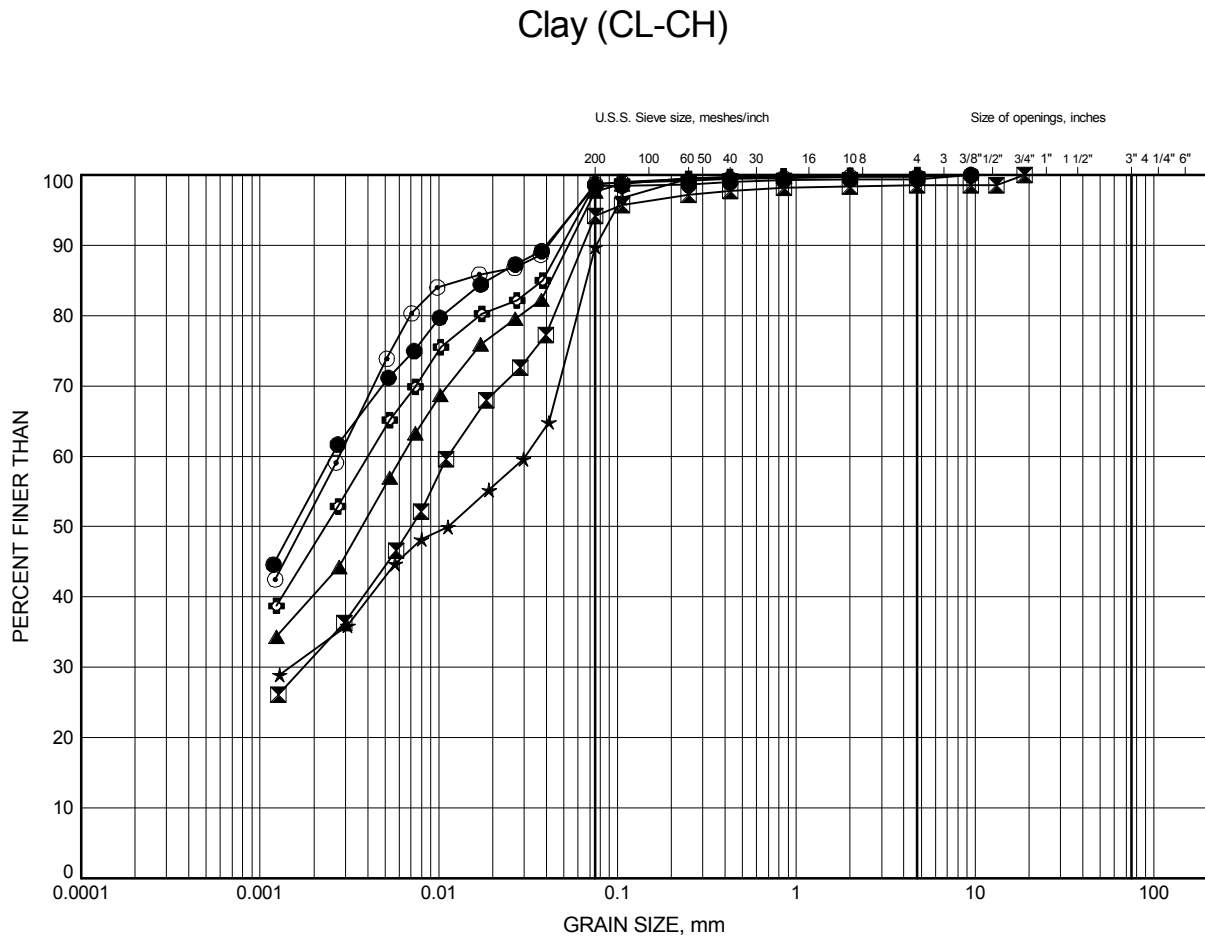


Prep'd KCP

Chkd. FG

Site 7-148/C Rideau Canal Backwater Culvert
GRAIN SIZE DISTRIBUTION

FIGURE 11



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-2	9.0	83.8
⊠	17-2	12.0	80.8
▲	17-3	4.9	89.6
★	17-3	7.9	86.6
⊙	17-3	14.0	80.5
⊕	17-4	15.5	79.0

Date September 2018

GWP# 4185-13-00

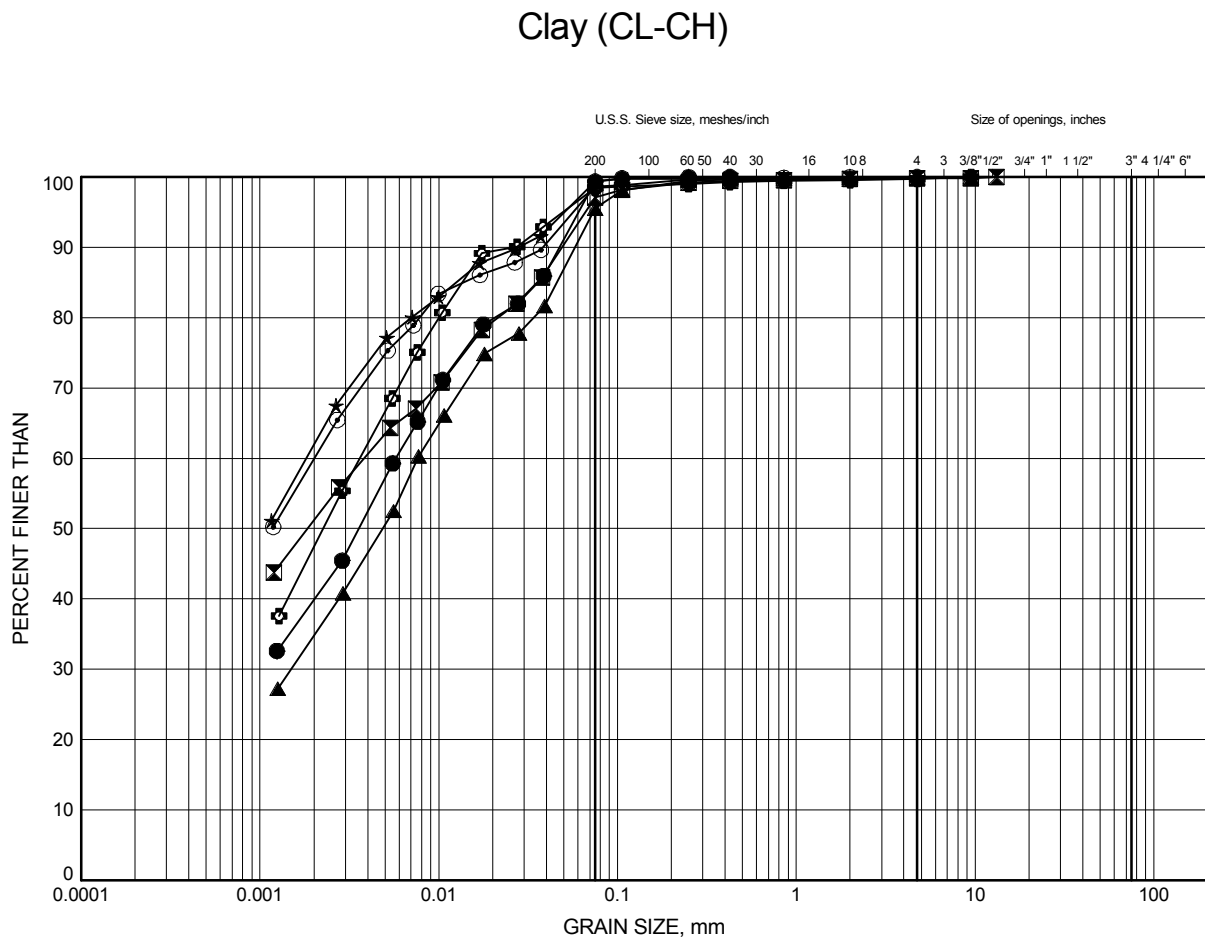


Prep'd KCP

Chkd. FG

Site 7-148/C Rideau Canal Backwater Culvert
GRAIN SIZE DISTRIBUTION

FIGURE 12



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-5	7.4	85.4
⊠	17-5	11.2	81.6
▲	17-6	8.9	83.8
★	17-6	11.2	81.5
⊙	19-01	12.5	82.0
⊕	19-01	18.6	75.9

Date May 2019

GWP# 4185-13-00

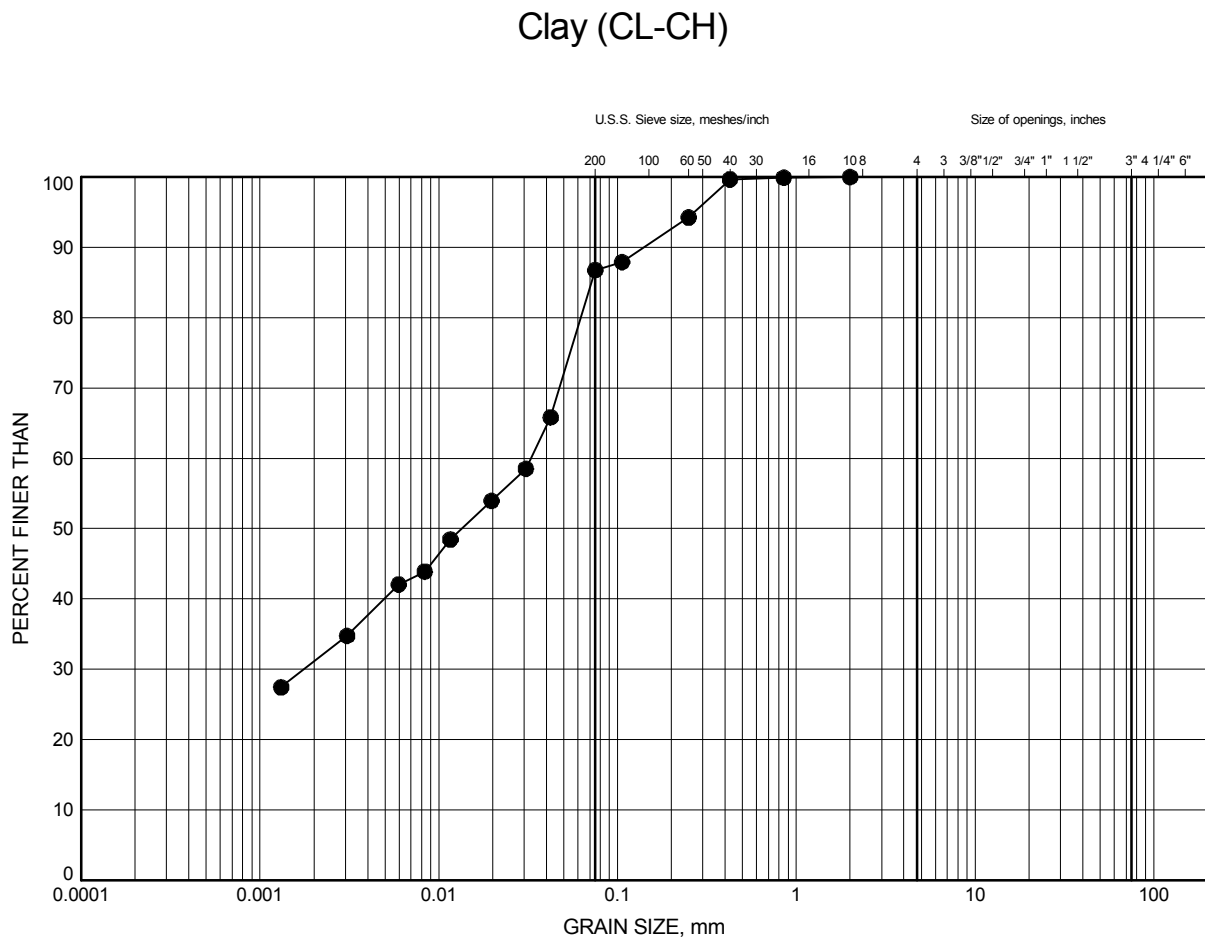


Prep'd KE

Chkd. PC

Site 7-148/C Rideau Canal Backwater Culvert
GRAIN SIZE DISTRIBUTION

FIGURE 13



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	19-02	9.4	85.1

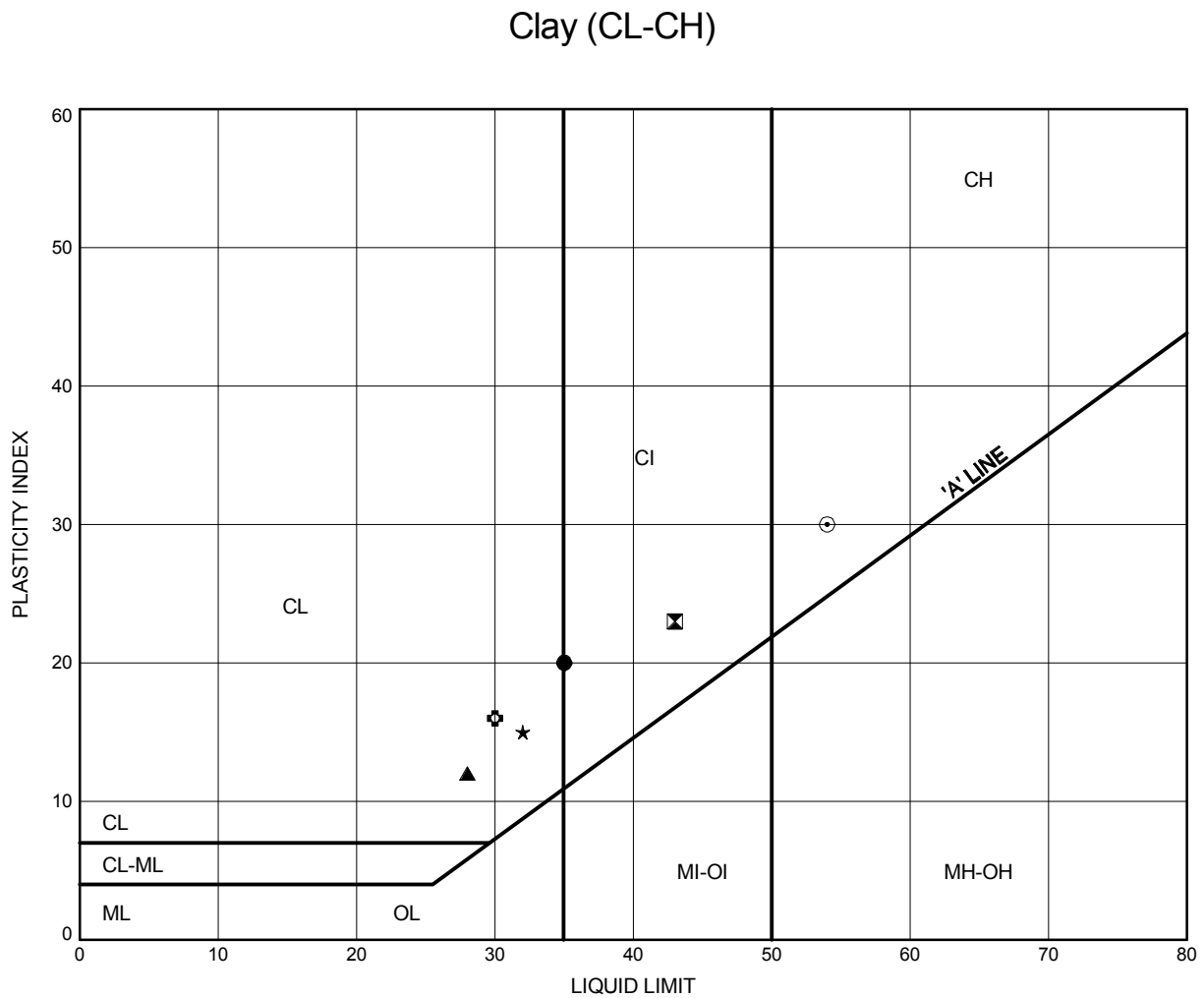
Date May 2019
GWP# 4185-13-00



Prep'd KE
Chkd. PC

Site 7-148/C Rideau Canal Backwater Culvert
ATTERBERG LIMITS TEST RESULTS

FIGURE 14



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	101	4.9	89.6
⊠	101	14.0	80.5
▲	102	6.7	86.4
★	102	12.5	80.6
⊙	103	7.0	86.1
⊕	104	4.9	89.6

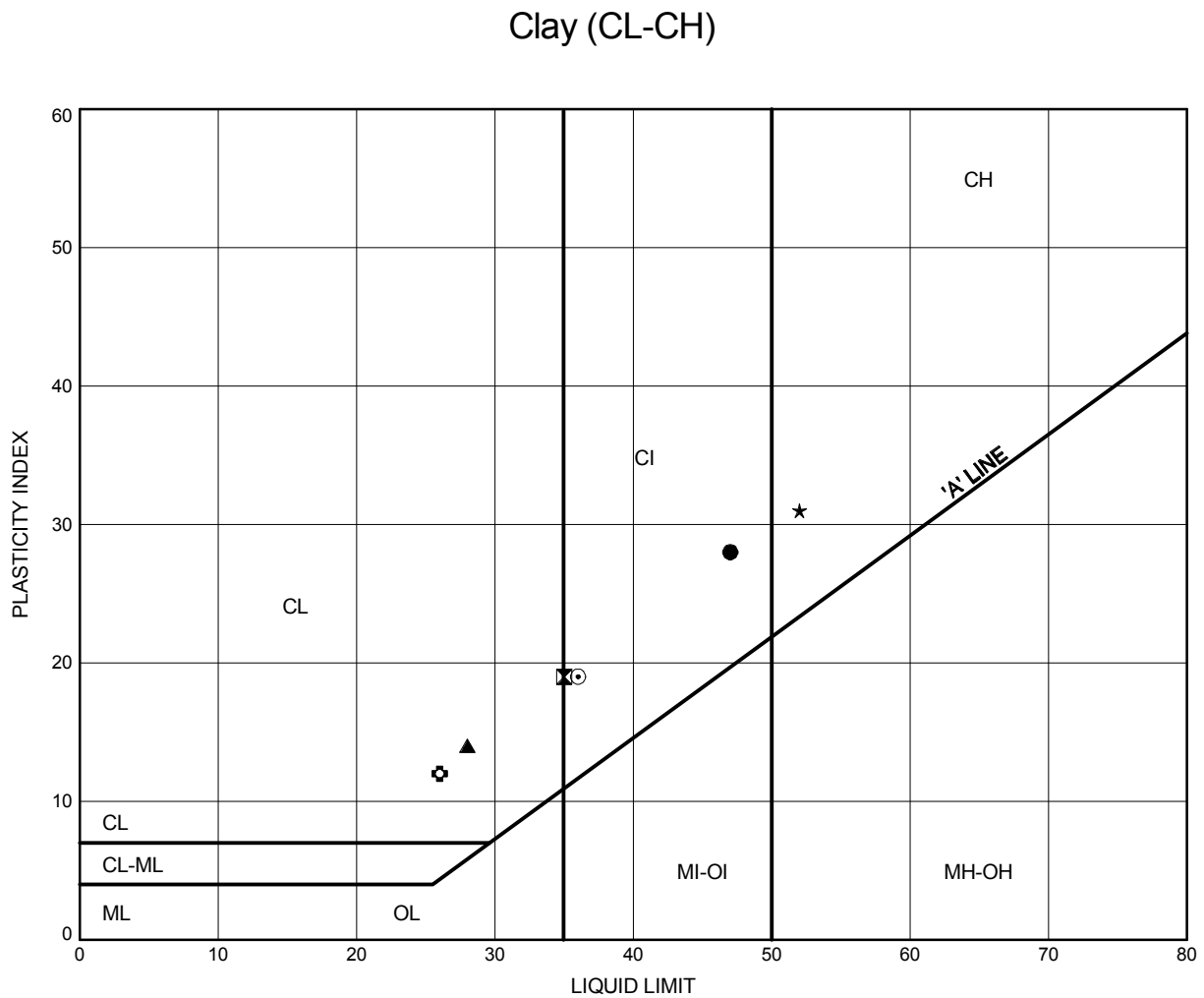
Date May 2019
 GWP# 4185-13-00



Prep'd KE
 Chkd. PC

Site 7-148/C Rideau Canal Backwater Culvert
ATTERBERG LIMITS TEST RESULTS

FIGURE 15



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	104	12.5	82.0
⊠	17-1	5.0	87.6
▲	17-1	6.6	86.0
★	17-1	8.8	83.8
⊙	17-2	2.9	89.9
⊕	17-2	5.9	86.9

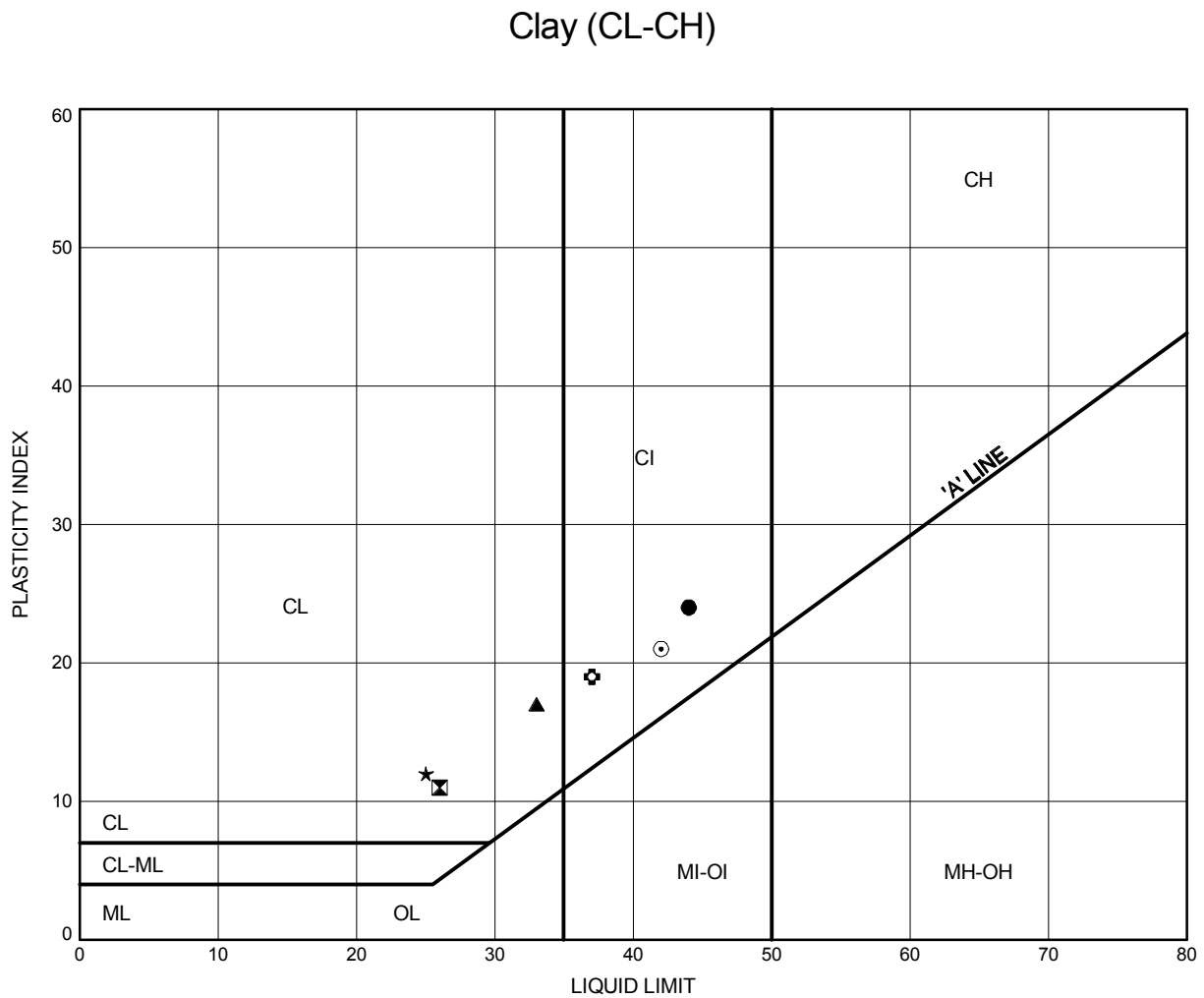
Date May 2019
 GWP# 4185-13-00



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Site 7-148/C Rideau Canal Backwater Culvert
ATTERBERG LIMITS TEST RESULTS

FIGURE 16



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-2	9.0	83.8
⊠	17-2	12.0	80.8
▲	17-3	4.9	89.6
★	17-3	7.9	86.6
⊙	17-3	14.0	80.5
⊕	17-4	15.5	79.0

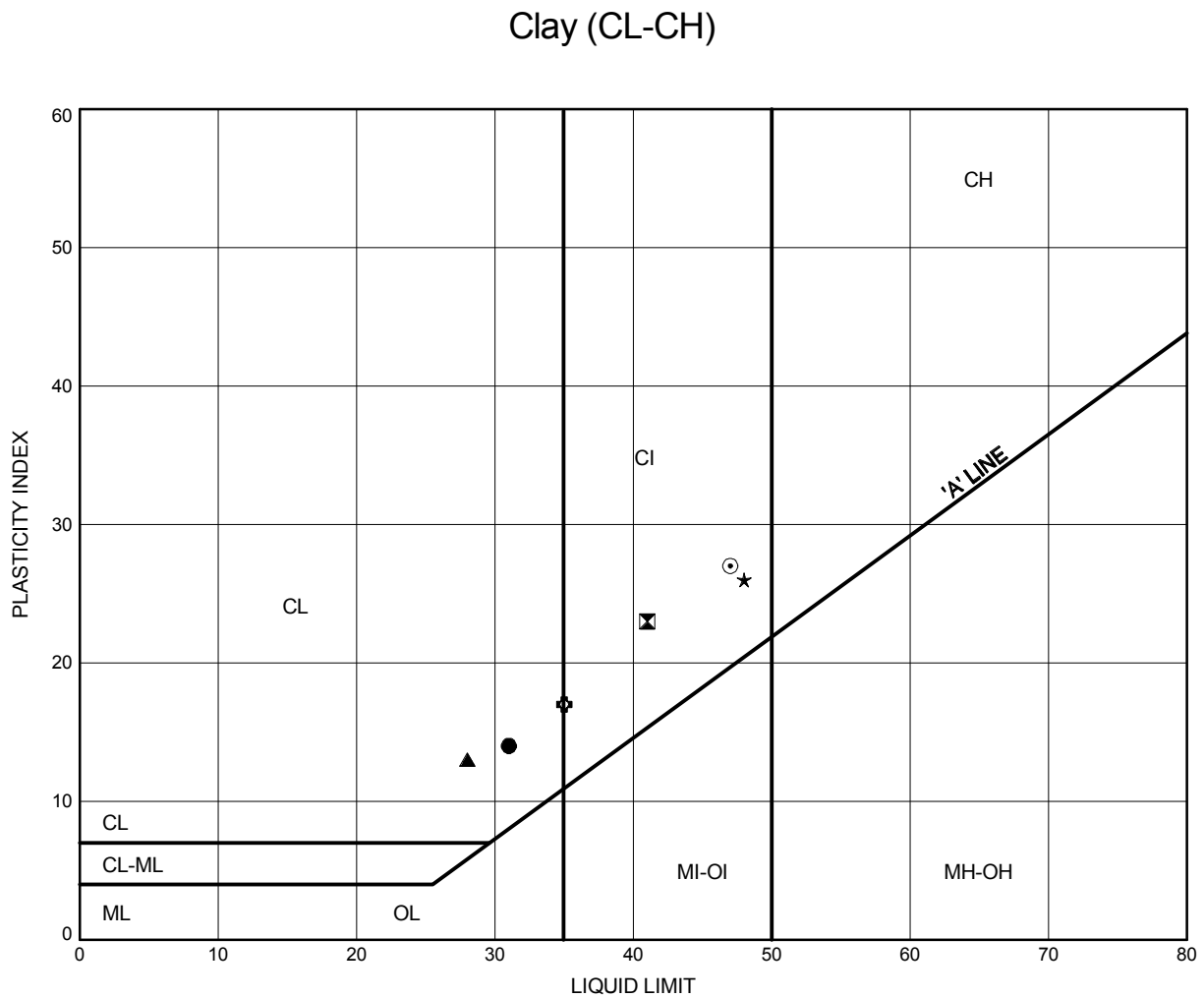
Date May 2019
 GWP# 4185-13-00



Prep'd KE
 Chkd. PC

Site 7-148/C Rideau Canal Backwater Culvert
ATTERBERG LIMITS TEST RESULTS

FIGURE 17



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-5	7.4	85.4
⊠	17-5	11.2	81.6
▲	17-6	8.9	83.8
★	17-6	11.2	81.5
⊙	19-01	12.5	82.0
⊕	19-01	18.6	75.9

Date May 2019
 GWP# 4185-13-00

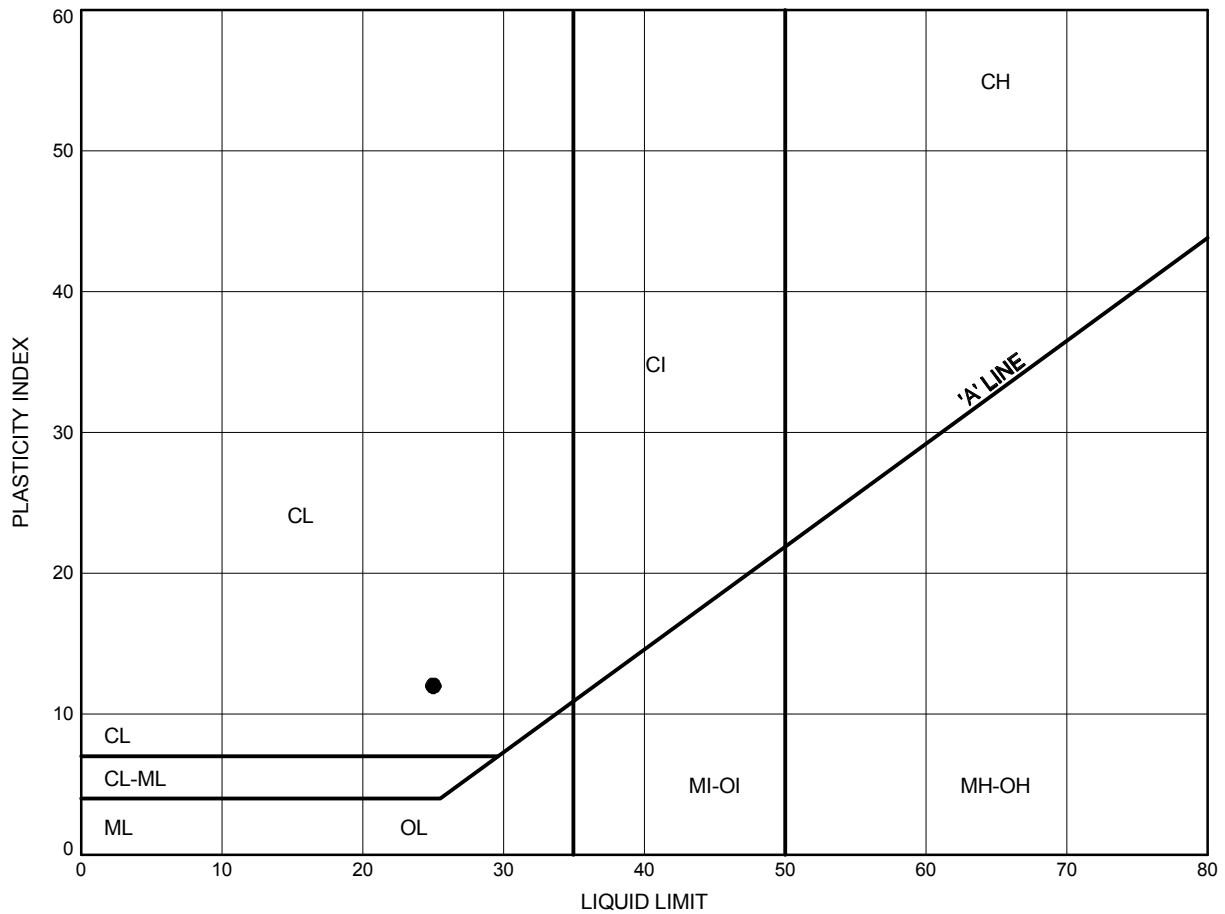


Prep'd KE
 Chkd. PC

Site 7-148/C Rideau Canal Backwater Culvert
ATTERBERG LIMITS TEST RESULTS

FIGURE 18

Clay (CL-CH)



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	19-02	9.4	85.1

Date May 2019
 GWP# 4185-13-00

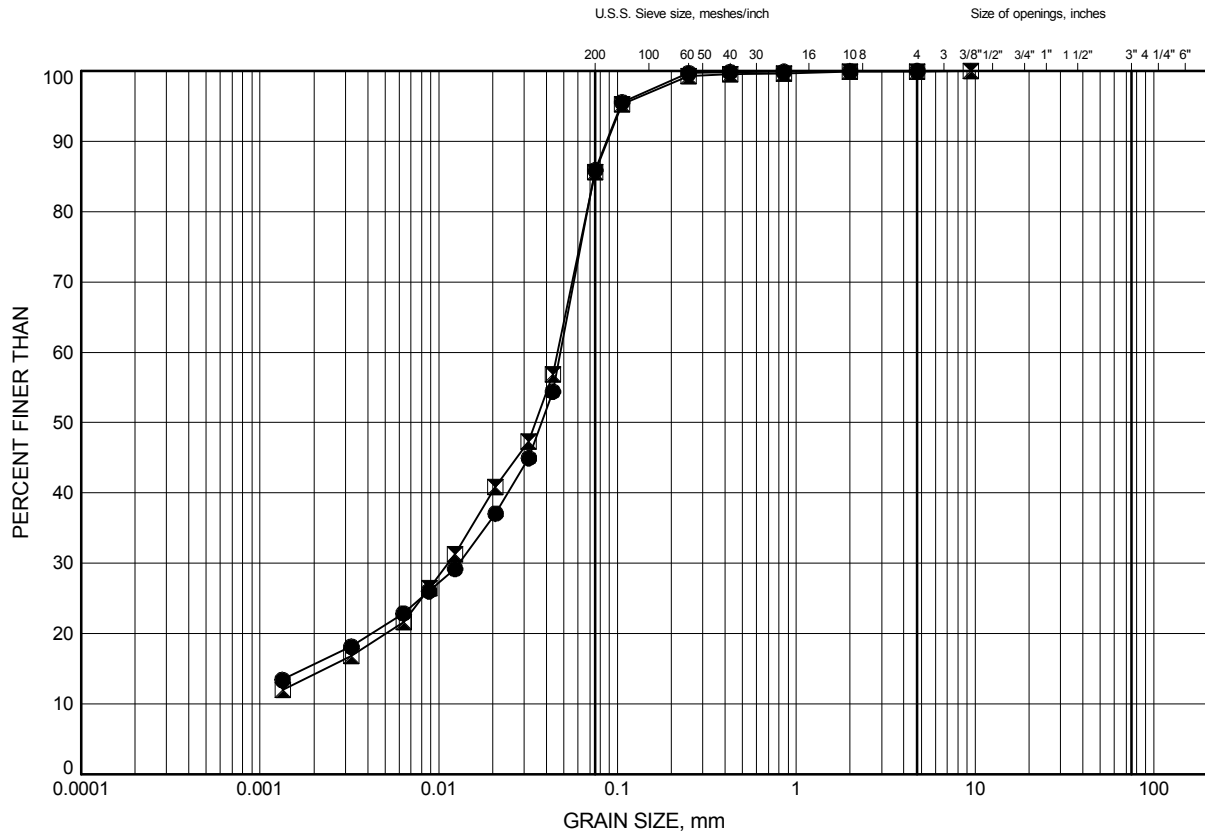


Prep'd KE
 Chkd. PC

Site 7-148/C Rideau Canal Backwater Culvert
GRAIN SIZE DISTRIBUTION

FIGURE 19

Silt (ML) Interlayer



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	101	7.9	86.6
⊠	103	5.0	87.8

Date May 2019
GWP# 4185-13-00

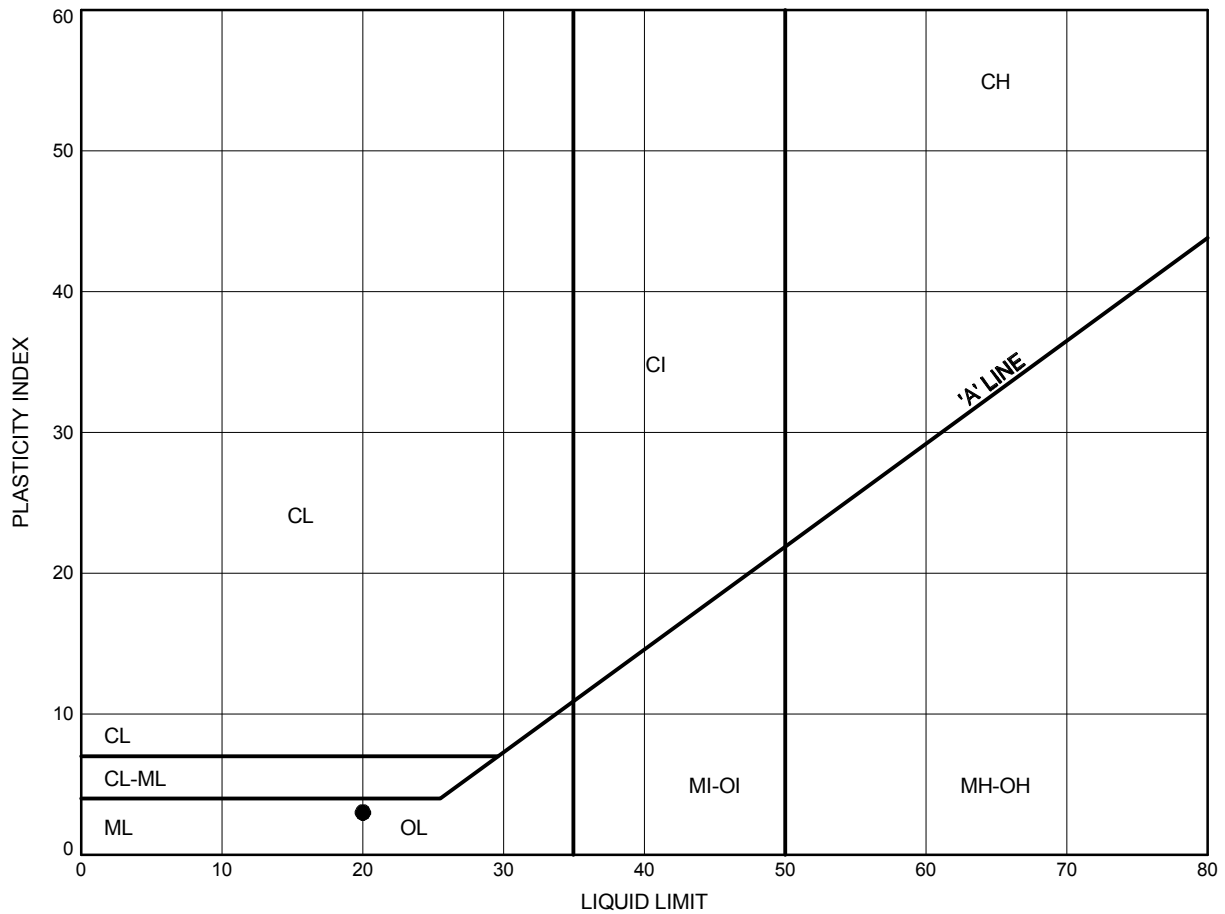


Prep'd KE
Chkd. PC

Site 7-148/C Rideau Canal Backwater Culvert
ATTERBERG LIMITS TEST RESULTS

FIGURE 20

Silt (ML) Interlayer



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	101	7.9	86.6

Date May 2019
 GWP# 4185-13-00

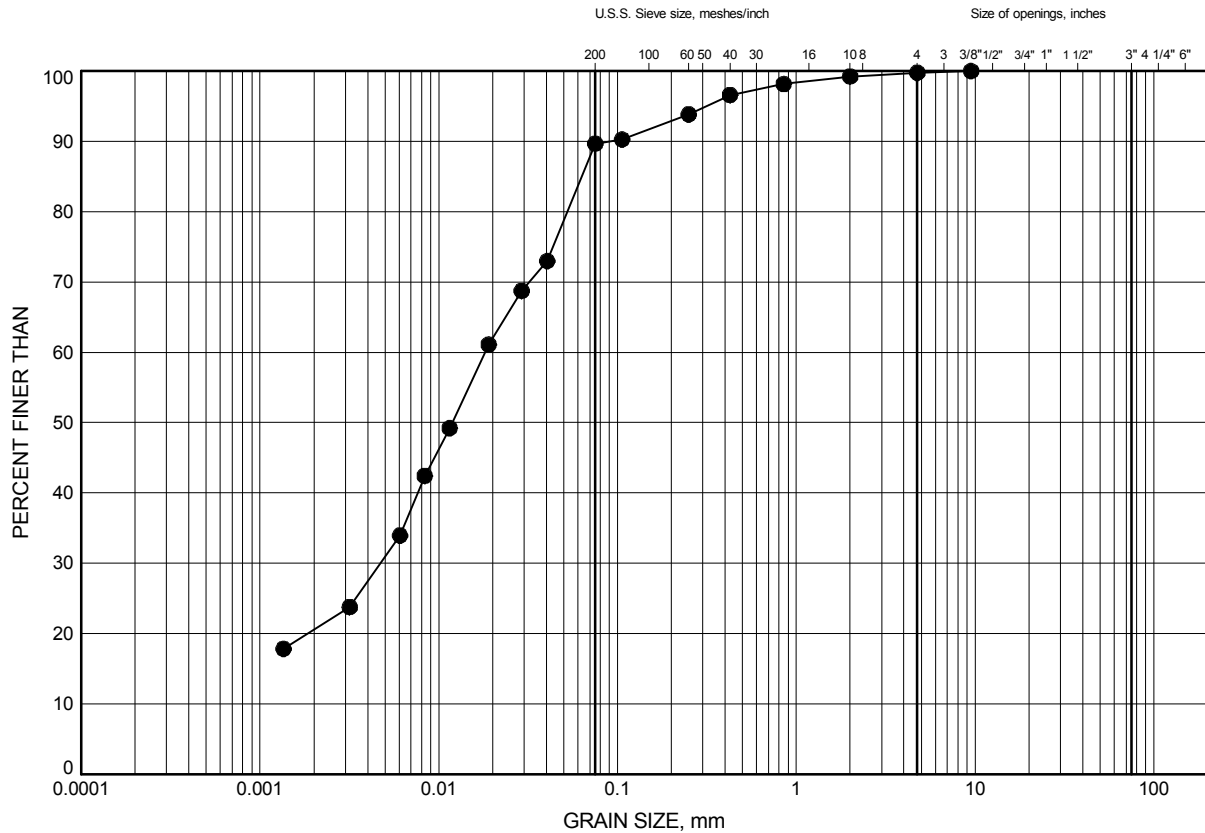


Prep'd KE
 Chkd. PC

Site 7-148/C Rideau Canal Backwater Culvert
GRAIN SIZE DISTRIBUTION

FIGURE 21

Silty Clay (CL-ML)



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	19-02	21.6	72.9

Date May 2019
GWP# 4185-13-00

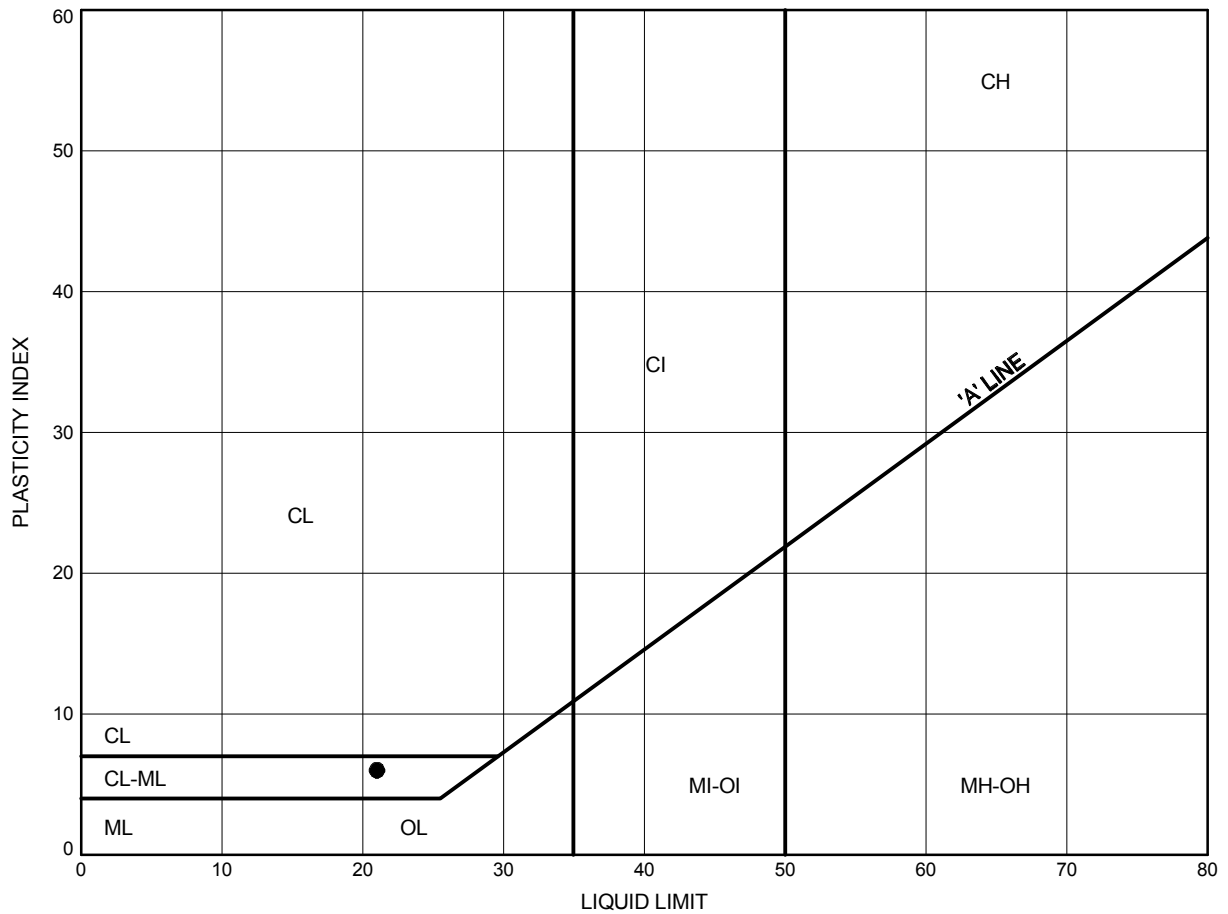


Prep'd KE
Chkd. PC

Site 7-148/C Rideau Canal Backwater Culvert
ATTERBERG LIMITS TEST RESULTS

FIGURE 22

Silty Clay (CL-ML)



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	19-02	21.6	72.9

Date May 2019
 GWP# 4185-13-00



Prep'd KE
 Chkd. PC

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO:

Report Date: 19-Oct-2017

Order Date: 16-Oct-2017

Project Description: 20482 Task 10

Client ID:	BH 17-5 SS7 17.5'-19.5'	BH 17-3 SS6 12.5'-14.5'	-	-
Sample Date:	03-Oct-17	22-Sep-17	-	-
Sample ID:	1742098-01	1742098-02	-	-
MDL/Units	Soil	Soil	-	-

Physical Characteristics

% Solids	0.1 % by Wt.	62.6	79.8	-	-
----------	--------------	------	------	---	---

General Inorganics

pH	0.05 pH Units	7.40	7.65	-	-
Resistivity	0.10 Ohm.m	17.6	10.6	-	-

Anions

Chloride	5 ug/g dry	29	555	-	-
Sulphate	5 ug/g dry	435	71	-	-

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 20482

Report Date: 31-May-2018

Order Date: 25-May-2018

Project Description: 20482 HWY15 Rideau Backwater

Client ID:	101, SS6 (12'6" - 14' 6")	-	-	-
Sample Date:	05/22/2018 12:00	-	-	-
Sample ID:	1821447-01	-	-	-
MDL/Units	Soil	-	-	-

Physical Characteristics

% Solids	0.1 % by Wt.	80.1	-	-	-
----------	--------------	------	---	---	---

General Inorganics

pH	0.05 pH Units	7.95	-	-	-
Resistivity	0.10 Ohm.m	24.7	-	-	-

Anions

Chloride	5 ug/g dry	131	-	-	-
Sulphate	5 ug/g dry	29	-	-	-



Stantec

Stantec Consulting Ltd
2781 Lancaster Rd, Suite 100 A&B
Ottawa, ON K1B 1A7
Tel: (613) 738-6075
Fax: (613) 722-2799

May 5, 2019
File: 122410864

Attention: Thurber Engineering Ltd., File #20482

Reference: ASTM D7012, Method C, Unconfined Compressive Strength of Intact Rock Core

The table below summarizes four (4) Rock Core compressive strength results.

Location	Sample Depth	Compressive Strength (MPa)	Description of Break
19-01	83'7"-84'2.5"	18.8	Well-formed cone on one end, vertical cracks running through caps
19-01	79'9"-80'2"	31.1	Well-formed cone on one end, vertical cracks running through caps
19-02	74'11"-75'7"	81.0	Well-formed cone on one end, vertical cracks running through caps
19-02	80'9"-82'	95.9	Well-formed cone on one end, vertical cracks running through caps

Sincerely,

Stantec Consulting Ltd

Brian Prevost
Laboratory Supervisor
Tel: 613-738-6075
brian.prevost@stantec.com

Borehole 19-01
Run 1 to 2 (of 3)
Elevation 71.3 m to 69.0 m



Borehole 19-01

Run 3 to 3 (of 3)

Elevation 69.0 m to 67.6 m



Borehole 19-02

Run 1 to 2 (of 3)

Elevation 72.7 m to 70.7 m



THURBER ENGINEERING LTD.

**Foundation Investigation
Hwy 15 Rideau Backwater Culvert
Foundations**

**GWP: 4185-13-00
Project No.: 20482**

Borehole 19-02

Run 3 to 3 (of 3)

Elevation 70.7 m to 69.2 m



APPENDIX D

SEISMIC CONE PENETRATION TEST RESULTS



Thurber Engineering Ltd.
104-2640 Lancaster Road
Ottawa, ON, K1B4S5
<http://thurber.ca>

THURBER ENGINEERING LTD.

Project: Rideau Canal Backwater Culvert

Location: Highway 15, Kingston, ON

CPT: 18-05033_SP107

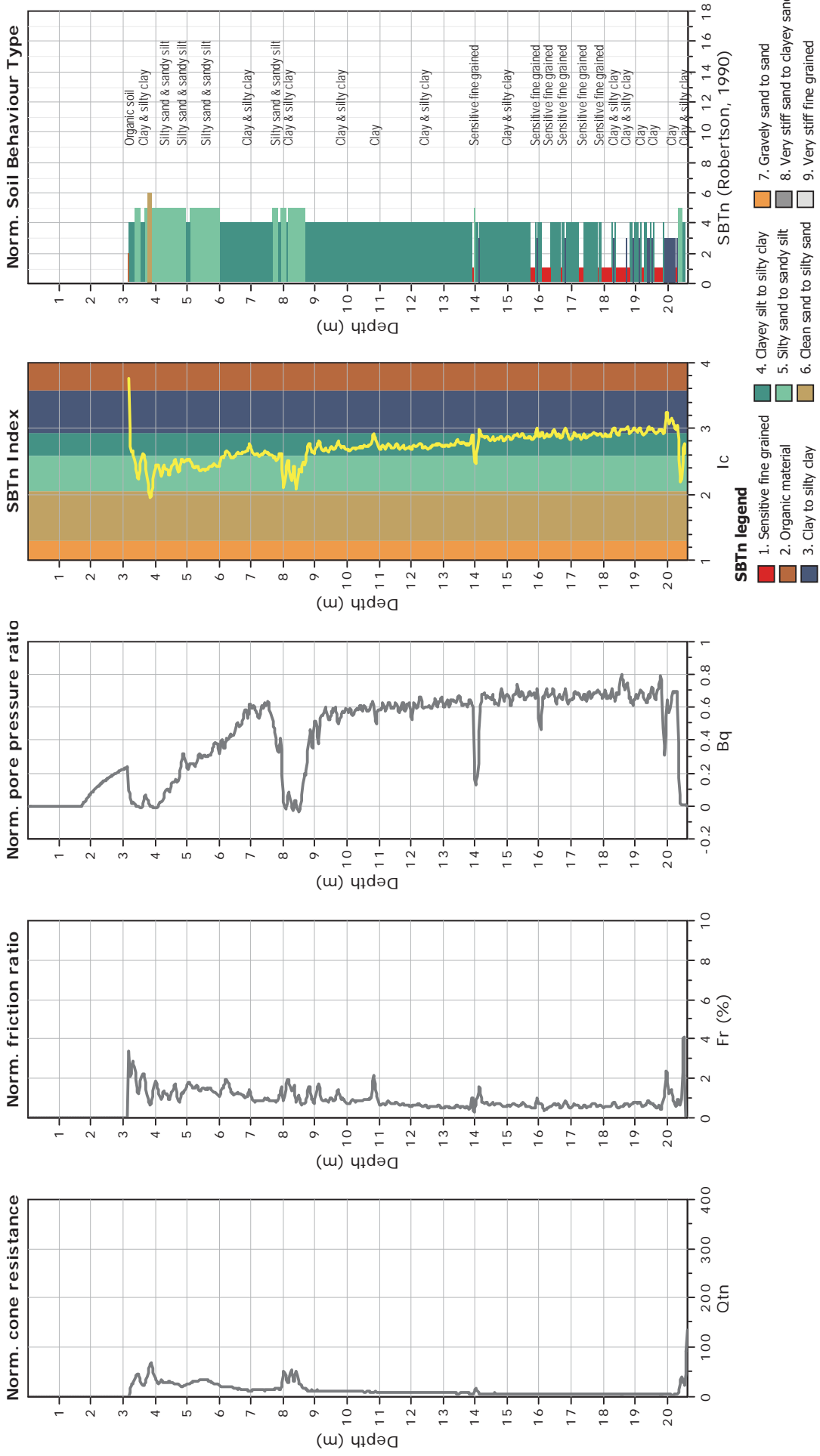
Total depth: 20.63 m, Date: 2018-07-18

Surface Elevation: 94.50 m

Coords: X:0.00, Y:0.00

Cone Type: Unknown

Cone Operator: ConeTEC





Job No: 18-05033
Client: Thurber
Project: Rideau Canal Backwater Culvert
Sounding ID: SCPT 107
Date: 18-Jul-2018

Seismic Source: Beam
Source Offset (m): 0.55
Source Depth (m): 0.00
Geophone Offset (m): 0.20

SCPT_u SHEAR WAVE VELOCITY TEST RESULTS - V_s

Tip Depth (m)	Geophone Depth (m)	Ray Path (m)	Ray Path Difference (m)	Travel Time Interval (ms)	Interval Velocity (m/s)
0.00	2.88				
2.88	2.68	2.74	2.74	10.00	274
3.88	3.68	3.72	0.99	6.79	145
4.88	4.68	4.71	0.99	5.71	174
5.88	5.68	5.71	0.99	5.21	191
6.88	6.68	6.70	1.00	5.59	178
7.88	7.68	7.70	1.00	5.34	187
8.88	8.68	8.70	1.00	5.09	196
9.88	9.68	9.70	1.00	5.53	181
10.88	10.68	10.69	1.00	5.46	183
11.88	11.68	11.69	1.00	5.90	169
12.88	12.68	12.69	1.00	5.84	171
13.88	13.68	13.69	1.00	5.63	178
14.88	14.68	14.69	1.00	5.21	192
15.88	15.68	15.69	1.00	5.02	199
16.88	16.68	16.69	1.00	4.71	212
17.88	17.68	17.69	1.00	4.77	209
18.88	18.68	18.69	1.00	4.46	224
19.88	19.68	19.69	1.00	4.21	238
20.63	20.43	20.44	0.75	2.57	291

APPENDIX E
SITE PHOTOGRAPHS



Photograph 1: Roadway platform at Culvert 07X-0142/C0 looking south along Highway 15 towards alternative alignment (2017-09-13)



Photograph 2: Looking west towards the existing culvert inlet. Note that right side of culvert has settled more than left side (2017-09-13)



Photograph 3: Looking east towards the existing culvert outlet (2017-09-13)



Photograph 4: Looking south along west embankment from existing culvert outlet towards the alternative alignment (2018-05-23)



Photograph 5: Outlet location of the alternative alignment (2018-05-23)



Photograph 6: Looking south along east embankment from existing culvert inlet towards the alternative alignment (2018-05-23)



Photograph 7: Inlet location of the alternative alignment looking north (2018-05-23)

APPENDIX F
COMPARISON OF CULVERT REPLACEMENT OPTIONS

Hwy 15 Rideau Canal Backwater Culvert, Site No. 07X-0142/C0
Foundation Engineering Assessment of Design Options

Option	Description	Advantages	Disadvantages	Risks/Consequences	Relative Cost	Conclusion
1	Replace on existing alignment with closed box and cast-in-place wing walls	<ul style="list-style-type: none">• Zero net stress increase beneath Hwy 15 embankment, therefore no long term settlement concerns.	<ul style="list-style-type: none">• Cast-in-place wingwalls require deeper excavation and increased excavation footprint, increasing quantities and costs for cofferdams, dewatering, excavation and backfill• Temporary by-pass culvert required• Sub-excavation required to remove poor soils at east end, increasing quantities and costs for cofferdams, dewatering, excavation and backfill	<ul style="list-style-type: none">• Organic material deeper than anticipated requiring deeper excavation / increased time and cost for cofferdams, dewatering, excavation and backfill	High	Feasible
2	Replace on existing alignment with closed box and sheet pile wing walls	<ul style="list-style-type: none">• Granular pad not required to support wing walls, therefore footprint of excavation is reduced, thereby reducing quantities for cofferdams, dewatering and excavation/backfill• Zero net stress increase beneath Hwy 15 embankment, therefore no long term settlement concerns.	<ul style="list-style-type: none">• Temporary by-pass culvert required• Sub-excavation required to remove poor soils at east end, increasing quantities and costs for cofferdams, dewatering, excavation and backfill• Exposed sheet pile wall may not meet environmental or aesthetic requirements		Medium	Feasible
3	Replace on existing alignment with culvert and wing walls supported on H-piles	<ul style="list-style-type: none">• Granular pad not required to support wing walls, therefore footprint of excavation is reduced, thereby reducing quantities for cofferdams, dewatering and excavation/backfill• Zero net stress increase beneath Hwy 15 embankment, therefore no long term settlement concerns.	<ul style="list-style-type: none">• Temporary by-pass culvert required• Pile caps require frost protection	<ul style="list-style-type: none">• Sloping bedrock / variation in pile length, piles deflect on rock surface. Risk reduced by specifying rock injector pile points and managing driving energy	High	Recommended

Option	Description	Advantages	Disadvantages	Risks/Consequences	Relative Cost	Conclusion
4	Replace on NEW alignment with closed box and cast-in-place wing walls	<ul style="list-style-type: none"> Water flow can be maintained through existing culvert during construction 	<ul style="list-style-type: none"> Abandonment of existing culvert requires concrete base plug, cofferdams and dewatering to place cellular concrete, yet will still result in unacceptable settlement that will require on-going maintenance Conflict between wingwalls for existing culvert and area required for granular pad to support new wingwalls Cast-in-place wingwalls require deeper excavation and increased excavation footprint, increasing quantities and costs for cofferdams/dewatering, excavation and backfill Very loose to compact sandy silt on east side offer limited bearing resistance for wing walls; sub-excavation for placement of thick granular pads (min 1 m) would be required. Requires deeper excavation and increased excavation footprint, increasing quantities and costs for cofferdams/dewatering, excavation and backfill 	<ul style="list-style-type: none"> Settlement of Highway 15 at the abandoned culvert alignment is greater than expected or takes longer than expected/ increased maintenance cost Organic material encountered and requires deeper excavation for cast-in-place wingwalls/ increased time and cost for cofferdams, dewatering, excavation and backfill 	High	Not Recommended
5	Replace on NEW alignment with closed box and sheet pile wing walls	<ul style="list-style-type: none"> Water flow can be maintained through existing culvert during construction Granular pad not required to support wing walls, therefore footprint of excavation is reduced, thereby reducing quantities for cofferdams, dewatering and excavation/backfill Depth of excavation would be reduced since no need for pile cap for sheet pile wing walls thereby reducing quantities for cofferdams, dewatering and excavation/backfill 	<ul style="list-style-type: none"> Abandonment of existing culvert requires concrete base plug, cofferdams and dewatering to place cellular concrete, yet will still result in unacceptable settlement that will require on-going maintenance 	<ul style="list-style-type: none"> Settlement of Highway 15 at the abandoned culvert alignment is greater than expected or takes longer than expected/ increased maintenance cost Shallow bedrock encountered on west side affects sheet pile embedment / anchors required 	High	Not Recommended
6	Replace on NEW alignment with culvert and wing walls supported on H-piles	<ul style="list-style-type: none"> Water flow can be maintained through existing culvert during construction Granular pad not required to support wing walls, therefore footprint of excavation is reduced, thereby reducing quantities for cofferdams, dewatering and excavation/backfill 	<ul style="list-style-type: none"> Abandonment of existing culvert requires concrete base plug, cofferdams and dewatering to place cellular concrete, yet will still result in unacceptable settlement that will require on-going maintenance Only 1 borehole to bedrock, 3 boreholes extended to DCPT/CPT refusal show at least 10 m variation in depth to competent ground. Further field investigation required to complete detailed design and to tender 	<ul style="list-style-type: none"> Settlement of Highway 15 at the abandoned culvert alignment is greater than expected or takes longer than expected/ increased maintenance cost Sloping bedrock / variation in pile length, piles deflect on rock surface. Risk reduced by specifying rock injector pile points and managing driving energy 	High	Not Recommended

APPENDIX G

2015 NBC SEISMIC HAZARD CALCULATION

2015 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

October 18, 2017

Site: 44.3944 N, 76.3182 W User File Reference: Rideau Canal Backwater Culvert

Requested by: , Thurber Engineering Ltd.

National Building Code ground motions: 2% probability of exceedance in 50 years (0.000404 per annum)

Sa(0.05)	Sa(0.1)	Sa(0.2)	Sa(0.3)	Sa(0.5)	Sa(1.0)	Sa(2.0)	Sa(5.0)	Sa(10.0)	PGA (g)	PGV (m/s)
0.142	0.187	0.177	0.148	0.118	0.069	0.036	0.0098	0.0039	0.108	0.101

Notes. Spectral ($S_a(T)$, where T is the period in seconds) and peak ground acceleration (PGA) values are given in units of g (9.81 m/s^2). Peak ground velocity is given in m/s . Values are for "firm ground" (NBCC 2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are specified in **bold** font. Three additional periods are provided - their use is discussed in the NBCC2015 Commentary. Only 2 significant figures are to be used. *These values have been interpolated from a 10-km-spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the directly calculated values.*

Ground motions for other probabilities:

Probability of exceedance per annum	0.010	0.0021	0.001
Probability of exceedance in 50 years	40%	10%	5%
Sa(0.05)	0.022	0.059	0.089
Sa(0.1)	0.032	0.083	0.122
Sa(0.2)	0.033	0.081	0.117
Sa(0.3)	0.028	0.069	0.099
Sa(0.5)	0.022	0.055	0.079
Sa(1.0)	0.011	0.031	0.046
Sa(2.0)	0.0047	0.015	0.023
Sa(5.0)	0.0010	0.0036	0.0056
Sa(10.0)	0.0006	0.0015	0.0024
PGA	0.018	0.047	0.070
PGV	0.014	0.042	0.063

References

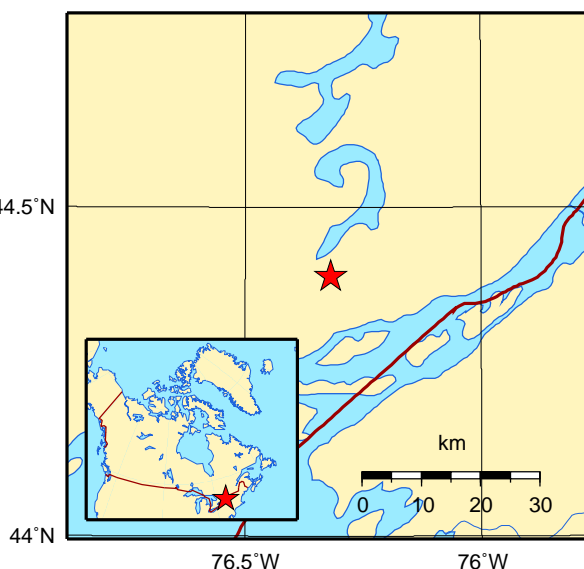
National Building Code of Canada 2015 NRCC no. 56190;
Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

User's Guide - NBC 2015, Structural Commentaries NRCC no. 44.5"N
xxxxxx (in preparation)
Commentary J: Design for Seismic Effects

Geological Survey of Canada Open File 7893 Fifth Generation
Seismic Hazard Model for Canada: Grid values of mean hazard to be
used with the 2015 National Building Code of Canada

See the websites www.EarthquakesCanada.ca
and www.nationalcodes.ca for more information

Aussi disponible en français



Natural Resources
Canada

Ressources naturelles
Canada

Canada

APPENDIX H

LIST OF REFERENCED SPECIFICATIONS NON-STANDARD SPECIAL PROVISIONS

1. The following Special Provisions and OPSS Documents are referenced in this report:

OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
OPSD 3090.101	Foundation, Frost Penetration Depths for Southern Ontario
OPSS.PROV 206	Construction Specification for Grading
OPSS.PROV 209	Construction Specification for Embankments Over Swamps and Compressible Soils
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS 902	Construction Specification for Excavating and Backfilling Structures
OPSS 805	Construction Specification for Temporary Erosion and Sediment Control Measures
OPSS 902	Construction Specification for Excavating and Backfilling-Structures
OPSS 903	Construction Specification for Deep Foundations
OPSS.PROV 1010	Material Specification for Aggregates-Base, Subbase, Select Subgrade, and Backfill Material
OPSS 1860	Material Specification for Geotextiles
OPSS.PROV 517	Construction Specification for Dewatering
SP FOUN0003	Dewatering Structure Excavations
SP 109S12	QVE, Backfilling, Compaction, and Certificate of Conformance

2. Suggested text for a NSSP on "Dewatering"

The excavation will extend below the groundwater level and could lead to instability and sloughing of the sides of the excavation and heaving of the base, accompanied by loss in geotechnical resistance of the soils. Appropriate means of dewatering must be implemented to depress the groundwater level sufficiently far below the base of the excavation to prevent any instability, sloughing, or heaving and so as to preserve the stability of the excavation and to allow the culvert subgrade preparation work to proceed in the dry. Temporary dewatering measures will be required to remain operational during construction until the culvert is installed and backfilled.

NOTICE TO CONTRACTOR - Existing Subsurface Conditions

Special Provision

The Contractor is notified that sloping bedrock was encountered during the foundations investigation. Titus HD Rock Injector points have been specified. The specified pile lengths are based on average expected pile lengths. The Contractor shall expect variation in the depth to bedrock and variation in pile length between individual pile locations.

The Contractor is notified that peat, organic and very loose to loose saturated materials overlying firm to very stiff clay were encountered during the foundations investigation. It is anticipated that excavations below the water level will need to be carried out within a sheet pile enclosure designed with sufficient embedment and supports/bracing to ensure lateral and base stability. Given the nature of the soils at this site, the Contractor is prohibited from using vibratory hammers/equipment for the installation and/or removal of the sheet piles.