



THURBER ENGINEERING LTD.

FINAL
FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 118 CULVERT STA. 18+245, OAKLEY TOWNSHIP
ASSIGNMENT NO. 5017-E-0003
G.W.P. 5287-14-00

Geocres No.: 31E-398

Report to:

McIntosh Perry Consulting Engineers Limited

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PART 1. FACTUAL INFORMATION

1 INTRODUCTION

This section of the report presents the factual findings obtained from a foundation investigation completed at a culvert at Sta. 18+245 on Highway 118. The culvert crossing is located approximately 0.4 km west of Bird Lake Road within Oakley Township in the District of Muskoka. Thurber Engineering Limited (Thurber) carried out the current field investigation as a sub-consultant to McIntosh Perry Consulting Engineers Ltd. (MPCE) under Assignment No. 5017-E-0003.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide a borehole location plan, records of boreholes, stratigraphic profile, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions influencing design and construction was developed in the course of the current investigation.

No previous foundation investigation information was available for the subject culvert site within the online Geocres Library. A Project Assessment Report (PAR) and a historical base plan survey was provided by MPCE which documented the culvert stationing and size.

2 SITE DESCRIPTION

The existing culvert conveys (unnamed) creek flow from the north to the south under a high fill embankment supporting Highway 118. As shown on the base plan drawings provided by MPCE, the existing culvert is a non-structural corrugated steel plate (SPCSP) culvert with a diameter of 1.8 m. The length of the culvert is 36.6 m and the inverts of the culvert are shown at elevation 291.1 and 290.7 m at the inlet (north) and outlet (south), respectively. No signs of erosion or slope instability were noted on the existing highway embankments during the field investigation. The roadway surface over the culvert was generally in good condition with no dips or bumps noted during the field investigation. The existing culvert, as assessed by MPCE, showed minor signs of corrosion and had significant sediment deposits inside.

At the location of the culvert, Highway 118 is a two-lane highway with paved shoulders. The Highway 118 fill height above the culvert is approximately 4.5 m with the road surface at approximate elevation 297.2 m. The existing embankment slopes are inclined at approximately 2.4H:1V. Steel guidewires with wooden posts are present on both sides of the highway in the vicinity of the culvert. Open water is present on the inlet side of the highway. The land adjacent to the highway and creek alignment is densely vegetated with shrubs and predominantly coniferous trees. A single dwelling is located approximately 200 m east of the culvert. Bedrock outcrops and rock cuts are present within close proximity to the culvert site. Overhead utility lines run parallel to the highway immediately north of Highway 118. Traffic volumes on this section of Highway 118 are understood to be 1,600 AADT (2016).

Select photographs showing the existing conditions in the area of the culvert at the time of the field investigation are included in Appendix D for reference.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing program was carried out on September 11th and 12th, 2018 for the on-road investigation and between September 12th to 15th, 2018 for the off-road investigation. The field investigation consisted of advancing four boreholes identified as 18-1 through 18-4. The drilling was carried out using portable equipment for off-road boreholes 18-1 and 18-4 and a truck mounted CME 75 drill rig for the on-road boreholes 18-2 and 18-3. Prior to commencement of drilling, utility clearances were obtained in the vicinity of the borehole locations.

The northing, easting and elevation of the boreholes are shown on the Borehole Location and Soil Strata Drawing No. 1 in Appendix A, the individual Record of Borehole sheets in Appendix B and in Table 3-1. The termination depth of each of the boreholes are also provided, below. The site is within MTM Zone 10. The borehole elevations were surveyed with a Nikon-AP-8 with an accuracy of +/- 1.5 mm. The survey referenced the top of the south end of the culvert, which has an elev. 292.544 m, as provided by MPCE. Horizontal locations were measured relative to existing site features.

Table 3-1: Borehole Summary

Borehole No.	Drilled Location	Northing (m)	Easting (m)	Ground Surface Elevation (m)	Termination Depth * (m)
18-1	Near Culvert Inlet	4 985 094.3	341 577.7	292.2	9.4
18-2	Westbound Lane HWY 118	4 985 082.9	341 593.1	297.2	18.7
18-3	Eastbound Lane HWY 118	4 985 077.0	341 589.2	297.3	16.2
18-4	Near Culvert Outlet	4 985 062.7	341 601.8	291.8	12.6

Note: () depths provided in table are from the ground surface*

Soil samples were obtained at select intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) following ASTM D1586. Boreholes 18-1 and 18-4, which were drilled with portable equipment, utilized a half-weight (32 kg) hammer for SPT testing. The N-values reported herein for the off-road boreholes have been corrected to an equivalent standard weight hammer (64 kg). The on-road boreholes utilized a standard weight hammer for SPT testing and no correction was necessary. Boreholes 18-1, 18-2 and 18-3 were advanced into bedrock with either NW or NWT casing in conjunction with coring techniques.

The drilling and sampling operations were supervised on a full time basis by an experienced member of Thurber's technical staff. The drilling supervisor logged the boreholes and processed the recovered soil samples for transport to Thurber's Ottawa geotechnical laboratory for further examination and testing.

A 19 mm diameter standpipe piezometer was installed in Borehole 18-4 to allow for measurements of the groundwater level after completion of drilling. The piezometer installation details are illustrated on the respective Record of Borehole sheet provided in Appendix B. The boreholes were backfilled in accordance with MOE requirements (O.Reg. 903 as amended). Boreholes 18-2 and 18-3 were backfilled with granulars within the depth of pavement structure and capped with 150 mm of cold patch asphalt to reinstate the travelling surface.

4 LABORATORY TESTING

The recovered soil samples were subjected to visual identification and to natural moisture content determination. Selected samples were also subjected to gradation analysis (hydrometer and/or sieve) and Atterberg Limit testing. The results of these tests are summarized on the Record of Borehole sheets included in Appendix B. One sample of soil



recovered from within each of Boreholes 18-1 and 18-4 was selected for analytical testing of corrosivity parameters. All laboratory test results are provided in Appendix C.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix B and the Borehole Location and Soil Strata drawing included in Appendix A. A general description of the stratigraphy, based on the conditions encountered in the boreholes, is given in the following paragraphs. However, the factual data presented on the Record of Borehole sheets takes precedence over this general description for interpretation of the site conditions. It must be recognized that the soil and groundwater conditions may vary between and beyond borehole locations.

In general terms, the site was found to be underlain by a pavement structure and granular fill overlying native deposits of silty sand, sand and silt over glacial till. Granite bedrock was encountered at varying elevations within the depth of investigation in Boreholes 18-1, 18-2 and 18-3.

5.1 Embankment

5.1.1 Asphalt

Boreholes 18-2 and 18-3 were drilled through the existing Highway 118 embankment and encountered a layer of asphalt with a thickness of 75 and 100 mm, respectively.

5.1.2 Fill: Sand with Silt and Gravel

Below the asphalt in Boreholes 18-2 and 18-3 was a layer of fill consisting of sand with silt and gravel. The underside of this fill was 3.7 and 1.5 m below the existing roadway surface (elev. 293.5 and 295.8 m) in Boreholes 18-2 and 18-3, respectively.

The SPT tests conducted in the sand fill gave N-values ranging from 13 to 46 blows, indicating a relative density of compact to dense.

Recorded moisture contents ranged from 5 to 15%. The results of grain size analyses conducted on two samples of the sand fill are summarized below and are provided on the Record of Borehole sheets in Appendix B and illustrated on Figure C1 in Appendix C.

Soil Particle	Percentage (%)
Gravel	21 – 22
Sand	66 – 69
Silt	10 – 12
Clay	

5.1.3 Fill: Silty Sand with Gravel

A layer of fill consisting of silty sand with gravel was encountered below the upper sand fill in Boreholes 18-2 and 18-3. Occasional to frequent cobbles and boulders were noted within this fill. The silty sand fill was 1.6 to 4.7 m thick with an underside elevation of 291.9 and 291.1 m in Boreholes 18-2 and 18-3, respectively. Coring techniques were required to advance through cobbles and boulders below a depth of 3.7 m.

The SPT tests conducted in this fill gave N-values ranging from 6 to 52 blows indicating a relative density of loose to very dense.

Recorded moisture contents ranged from 13 to 22%. The results of a grain size analysis conducted on one sample of the silty sand fill indicated this material to consist of 18% gravel, 68% sand and 14% fines. These results are provided on the Record of Borehole sheet in Appendix B and are also illustrated on Figure C1 in Appendix C.

5.2 Silty Sand (SM)

A native silty sand deposit was encountered at ground surface in Borehole 18-1 and below the fill in Borehole 18-3 with thicknesses of 2.1 and 1.4 m, respectively. The underside of the silty sand ranged in elevation from 289.7 to 290.1 m. Traces of organics were encountered in the upper 0.6 m in Borehole 18-1 and throughout the layer in Borehole 18-3.

SPT tests conducted in the silty sand deposits gave N-values typically ranging from 1 to 14 blows indicating a relative density of very loose to compact. A single blow count of 37 was recorded at ground surface in Borehole 18-01.

Recorded moisture contents of the silty sand typically ranged from 23 to 35%. The results of grain size analyses conducted on two samples of the silty sand are summarized below and are illustrated on Figure C2 in Appendix C.

Soil Particle	Percentage (%)	
Gravel	0 – 4	
Sand	71 – 73	
Silt	25	25
Clay	2	

5.3 Sand (SP to SP-SM)

A native deposit of sand with varying amounts of silt and traces of gravel was encountered at surface in Borehole 18-4, below the silty sand deposit in Boreholes 18-1 and 18-3 and below the fill material in Borehole 18-2. The sand in Borehole 18-2 transitioned to silty sand with depth. Traces of organics were encountered in the upper 0.6 m of the sand deposit in Borehole 18-4 and organics with wood fragments were noted near the surface of the layer

in Borehole 18-2. Occasional to frequent cobbles and boulders were encountered within the sand deposit in Boreholes 18-2 and 18-3 below elevation 289.6 m. The thickness of the sand deposit ranged from 2.3 to 6.9 m with a bottom elevation of 287.8 to 283.6 m. Coring techniques were required to advance through cobbles and boulders where encountered in this material.

The SPT N-values conducted in this layer ranged from 2 to greater than 100 blows indicating a variable relative density of very loose to very dense.

The moisture content of the samples tested typically ranged from 10 to 40% with a single moisture content of 71% recorded in Borehole 18-4. The results of grain size analyses conducted on five samples of the sand are summarized below and are illustrated on Figure C3 in Appendix C.

Soil Particle	Percentage (%)
Gravel	2 – 10
Sand	81 – 95
Silt	1 – 13
Clay	

5.4 Silt (ML)

Borehole 18-4 encountered a deposit of silt with trace of sand below the sand deposit. The thickness of this layer was 4.6 m with a base elevation of 281.3 m.

The SPT tests conducted in this layer gave N-values ranging from 24 to 40 blows indicating a relative density of compact to dense.

Recorded moisture contents ranged from 22 to 27%. The results of a grain size analysis conducted on one sample of the silt indicated this material to consist of 0% gravel, 5% sand, 86% silt and 9% clay. These results are provided on the Record of Borehole sheet in Appendix B and are illustrated on Figure C4 in Appendix C.

An Atterberg Limit test was completed on one sample and the results indicated the silt to exhibit low plasticity (ML) with a liquid limit of 24, a plasticity limit of 22 and a plasticity index of 2. The results are illustrated on Figure C6 in Appendix C.

5.5 Silty Sand (SM) with gravel – (Glacial Till)

Below the deposits noted above was a deposit of glacial till consisting of silty sand with varying amounts of gravel within all boreholes. Frequent cobbles and boulders were encountered throughout the till deposit. Borehole 18-4 was terminated within the till at a depth of 12.6 m below existing ground surface (elev. 279.2). This layer was fully penetrated in the remaining three boreholes and the thickness of the deposit ranged from 1.8 to 2.1 m

with an underside elevation ranging from 281.7 to 285.9 m. Coring techniques were frequently required to advance through cobbles and boulders throughout this deposit.

SPT tests conducted in the till deposits gave N-values ranging typically from 45 to greater than 100 blows indicating a relative density of dense to very dense, but predominantly consisted of very dense material. A single SPT N-value of 10 blows was encountered near the surface of the till layer in Borehole 18-4.

Recorded moisture contents of the till typically ranged from 6 to 13%. The result of grain size analyses conducted on two samples of the till are summarized below and are provided on the Record of Borehole sheets in Appendix B and are illustrated on Figure C5 in Appendix C.

Soil Particle	Percentage (%)
Gravel	27 – 28
Sand	53 – 60
Silt	13 – 19
Clay	

5.6 Bedrock

Bedrock was proven by coring in Boreholes 18-1 and 18-2. Probable bedrock was also encountered in Borehole 18-3, however, insufficient depth of bedrock was cored to confirm. Information on the bedrock surface encountered in the boreholes is summarized in the following table.

Table 5-1: Summary of Bedrock Elevations

Borehole No.	Depth to Bedrock (m)	Bedrock Elevation (m)
18-1	6.3	285.9
18-2	14.3	282.9
18-3	15.5	281.7
18-4	N/A	Not encountered above 279.2 m

The bedrock core samples consisted of slightly weathered to fresh granite. The Total Core Recovery (TCR) from all core samples was 100%, the Solid Core Recovery (SCR) ranged from 56 to 100% and the Rock Quality Designation (RQD) ranged from 76 to 100%. Based on the measured RQD values, the bedrock is classified as good to excellent in quality (Table 3.10, Canadian Foundation and Engineering Manual 2006).

Photographs of the bedrock core are provided in Appendix C. The intact granite bedrock is predominantly medium to very strong. Photographs of the bedrock core are provided in Appendix C.

5.7 Groundwater

Accurate water levels could not be recorded in the open boreholes due to water being introduced as part of the rock coring operations. The groundwater level measured in the standpipe piezometer installed in Borehole 18-4 was recorded at a depth of 0.2 m below the ground surface (elev. 291.6 m) on September 29, 2018. It is expected that the groundwater level will likely reflect the fluctuating water level in the creek.

These observations are considered short term and it should be noted that the groundwater level at the time of construction may be different and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant and/or prolonged precipitation.

5.8 Analytical Testing

Two samples of the native soils encountered at the site were submitted for analysis of pH, water soluble sulphate and chloride concentrations, and resistivity. The analysis results are summarized in the Table 5-2 and a copy of the test results is provided in Appendix C.

Table 5-2: Results of Chemical Analysis

Borehole (Sample)	Depth (mbgs)	Sulphate (µg/g)	pH (-)	Resistivity (Ohm-cm)	Conductivity (uS/cm)	Chloride (µg/g)	Sulphide (%)
18-1 (SS3)	1.3 – 1.9	129	5.86	4,410	227	40	<0.02
18-4 (SS3)	1.2 – 1.8	62	5.11	4,110	243	104	<0.02

6 MISCELLANEOUS

Borehole locations were selected by Thurber relative to existing site features and the existing culvert location. The as-drilled location and ground surface elevation of the boreholes were measured by Thurber following completion of drilling. Elevation benchmarks were provided by MPCE.

George Downing Estate Drilling Ltd. and Forage M3 Drilling Services Inc., both of Hawksbury, Ontario, supplied and operated the drilling equipment to conduct the drilling, soil sampling, in-situ testing, standpipe installation and decommissioning of the boreholes. NC Traffic Management Inc. of Kirkland Lake, Ontario supplied the traffic control for lane and shoulder closures required for the field work. The field investigation was supervised on

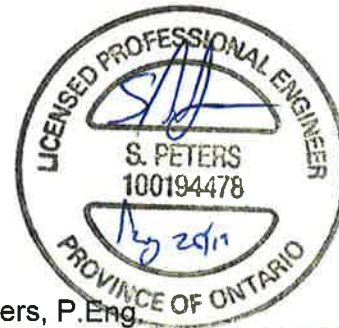


a full-time basis by Miss Allison Chow, EIT and Mr. Sean O'Bryan, C.E.T. of Thurber. Overall supervision of the investigation was provided by Miss Katya Edney, P.Eng.

Routine geotechnical laboratory testing was completed by Thurber's laboratory in Ottawa, Ontario. Analytical testing was completed by Paracel Laboratories in Ottawa, Ontario. Interpretation of the factual data and preparation of this report were carried out by Miss Katya Edney P.Eng. and Mr. Stephen Peters P.Eng. The report was reviewed by Dr. Fred Griffiths, P.Eng and Dr. P.K. Chatterji, P.Eng. a Designated Principal Contact for MTO Foundation Projects.

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PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 INTRODUCTION

This section of the report provides an interpretation of the factual data from Part 1 of this report and presents geotechnical recommendations to assist the project team in designing a suitable replacement of the existing culvert crossing Highway 118 at Station 18+245. The discussion and recommendations presented in this report are based on the information provided by McIntosh Perry Consulting Engineers Ltd. (MPCE) and on the factual data obtained during the course of the investigation.

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 existing culvert conveys creek flow from the north to the south under a high fill embankment supporting Highway 118. As shown on the base plan drawings provided by MPCE, the existing culvert is a non-structural corrugated steel plate (SPCSP) culvert with a diameter of 1.8 m. The length of the culvert is 36.6 m and the inverts of the culvert are shown at elevation 291.1 and 290.7 m at the inlet (north) and outlet (south), respectively. The Highway 118 fill height above the culvert is approximately 4.5 m with the road surface at approximate elevation 297.2 m. The existing embankment slopes are inclined at approximately 2.4H:1V. The groundwater was measured to be at an elevation of 291.6 m on September 29, 2018.

No previous foundation investigation information for the subject culvert was available within the online Geocres Library.

7.1 Proposed Structure

At the time of preparation of this Foundation Investigation and Design Report, it is expected that the existing culvert will be replaced with a non-structural culvert of similar size, length and alignment. It has also been assumed the invert elevations will be similar to that of the existing culvert. This culvert is located at a high fill embankment site, where the fill height above the culvert is approximately 4.4 m. As per the Culvert Reinstatement Typical Drawing of the 30% Drawing Package, received on May 28, 2019 from MPCE, the replacement will be carried out utilizing grade lowering.

7.2 Applicable Codes and Design Considerations

The geotechnical assessment presented below has been prepared based on the assumed replacement culvert and existing ground conditions and in accordance with the Canadian Highway Bridge Design Code (CHBDC), version CSA S6-14.

It is understood that if the culvert were to be replaced with a structural culvert, the new culvert would have a consequence classification of *Typical Consequence*, 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 factored geotechnical resistances. If the consequence classification changes, the geotechnical recommendations will need to be reviewed and revised.

The depth of frost and applicable recommendations are provided in Section 10.3.

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). The seismic hazard for this site has been obtained from the GSC calculator. The data includes a peak ground acceleration (PGA), peak ground velocity (PGV) and the 5% 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 475-year, 975-year and 2475-year events. The GSC seismic hazard calculated data sheet for this site is included in Appendix F.

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). The PGA at this site for a *reference* Site Class C with a 2% probability of exceedance in 50 years (2475-year event) is 0.070g. This value is to be scaled by the $F(PGA)$ based on the site-specific Site Class, discussed below.

8.2 Seismic Liquefaction Potential

Based on the low reference PGA, the subsurface conditions encountered at the drilled locations at this site and using the Seed & Idriss Simplified Method for liquefaction assessment, the soils below the culvert inverts are not considered susceptible to liquefaction during a design seismic event.

8.3 CHBDC Seismic Site Classification

In accordance with the CHBDC, the selection of the seismic site classification is based on the soil and rock conditions encountered in the upper 30 m of the stratigraphy. This site has been classified as a Site Class D in accordance with Section 4.4.3.2 of the CHBDC (S6-14) utilizing the harmonic mean of the recorded SPT N-values.

9 DESIGN OPTIONS

9.1 Culvert Type and Foundation Alternatives

Selection of the culvert type must consider the proposed construction procedures, staging requirements, geotechnical resistance available in the foundation soils, the depth to suitable bearing stratum and post-construction settlement criteria. From a geotechnical perspective, the following culvert types were considered:

- Circular Pipes (Concrete, HDPE, Steel)
From a foundation engineering perspective, a pipe culvert is a technically feasible alternative. It is assumed that an internal pipe diameter of similar size (1.83 m) or greater is likely to be proposed. The use of a circular pipe culvert would also facilitate a trenchless installation.
- Open Bottom Culvert (Box)
An open bottom culvert is not recommended for this site due to the anticipated size of the replacement culvert. An open bottom culvert would have the requirement for greater excavation depths and dewatering efforts during construction and there could be a potential for differential settlement following construction.
- Closed Bottom Culvert (Box)
A precast segmental box culvert is considered a feasible option from a foundation engineering perspective. Precast sections, rather than cast-in-place construction, can be installed expediently with less potential for disturbance of the founding soils during installation.
- Steel Sheet Pile Walls with Precast Concrete Slab
Sheet pile walls supporting precast concrete slabs are not considered feasible. Due to the depth to bedrock and presence of cobbles and boulders, installation of a contiguous sheet pile wall could encounter difficulties.

A comparison of these alternatives, based on their respective advantages and disadvantages, is included in Appendix E. It is not considered to be economical or practical to support a culvert on deep foundations at this site and therefore this option is not presented in this report.

9.2 Construction Methodology Alternative

For the proposed culvert replacement, the following construction methods were considered.

- Open Cut with Full Road Closure and Detour
Installation of a new culvert using open cut techniques and a full road closure would allow for an expedited construction schedule and could reduce costs associated with roadway protection and water flow diversion. However, it is understood that an acceptable detour is not available and therefore this option is not feasible.
- Open Cut with Staged Temporary Widening and/or Temporary Detour Embankment
Widening of the existing highway and/or construction of a temporary detour embankment to accommodate traffic passage during construction is considered feasible from a geotechnical perspective. However due to the proximity of overhead utilities, the embankment widening or detour embankment would need to be located south of Highway 118 alignment or the utilities may need to be relocated. Additionally, a review of the requirement for property acquisition and highway geometry is needed to assess this option. An additional borehole investigation may be required to determine the subsurface conditions along a temporary detour alignment.
- Open Cut and Temporary Protection System (TPS)
The use of open cut techniques in conjunction with staged culvert replacement is a feasible construction option from a geotechnical perspective. This option includes temporary protection system (TPS), as discussed further in Section 11.2, installed along the embankment centerline to maintain a single lane of traffic flow along the current highway alignment. The Contractor will need to consider the potential for cobbles/obstructions in the embankment fill and underlying deposits during the design and installation of the roadway protection. To reduce lateral deflections of the protection system, the roadway protection may need to include anchoring and/or bracing system. The TPS would need to support a temporary cut height in the order of 6 m. The height of the TPS could be reduced if a temporary grade lowering was also included.

The existing embankment at this culvert site is approximately 5.5 m high. Temporary grade lowering can be incorporated into the design to reduce the overall height of embankment above the base of the proposed excavation while maintaining traffic within the existing embankment footprint. However, the vertical road alignment and traffic speed constraints will need to be reviewed from a highway design perspective.

The project pavement engineer should be consulted if the grade lowering approach is to be carried forward.

- Temporary Modular Bridge

A temporary modular bridge (TMB) could provide a single lane of traffic passage while allowing for full excavation and replacement of the culvert without staged excavations. A reduced quantity of roadway protection is also anticipated. Additional boreholes will be required at the temporary abutment locations for the TMB for foundation design.

- Trenchless Techniques

Trenchless techniques would have the advantage of minimum disruption to traffic and would avoid a large excavation through the existing highway embankment. Open water was present at the culvert inlet which could cause difficulty with the installation of the exit pit. The soil face is expected to consist of saturated granular sand. The presence of cobbles, boulders and wood fragments will result in challenges. Due to the risks, this option is not recommended for this site.

9.3 Recommended Approach for the Culvert Replacement

From a foundation engineering perspective, the preferred approach is to replace the existing culvert with either a circular or a closed box culvert using open cut techniques. TPS would be needed to facilitate construction. Design of the TPS will need to account for the lateral capacity available in the native soils at this site and the need to anchor or brace the TPS. Grade lowering should be considered to reduce the height of the TPS.

10 FOUNDATION DESIGN RECOMMENDATIONS

Foundation design aspects for the replacement culvert includes subgrade conditions, geotechnical resistances, settlement of the founding soils, imposed loading pressures, erosion control, protection system design, groundwater control and design of staged construction. The culvert must be designed to resist loadings including lateral earth pressures, hydrostatic pressure, weight of embankment fill, traffic loading and any surcharge due to construction equipment and activities under static and seismic conditions.

10.1 Culvert Foundation Bearing Resistances

It is assumed that the existing culvert will be replaced on the same alignment and that the embankment will be reconstructed with no grade raise or widening (temporary or permanent). Therefore, it is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading.

10.1.1 Box Culvert

Pre-cast box culverts should be constructed in accordance with OPSS 422. The recommended geotechnical resistances at roadway centreline for a pre-cast box culvert

that is 2.0 m wide, has a 0.2 m thick base slab and is installed with invert elevations similar to the current culvert (approximate elev. 290.7 m at the outlet) on an undisturbed native sand subgrade are as follows:

- Factored Geotechnical Resistance at ULS of 300 kPa
- Factored Geotechnical Resistance at SLS of 200 kPa

The factored geotechnical resistances include the following factors:

- Consequence factor (Ψ) of 1.0 (as per CHBDC Table 6.1)
- Geotechnical resistance factors (as per CHBDC Table 6.2):
 - $\phi_{gu} = 0.5$ (static analysis; typical degree of understanding)
 - $\phi_{gs} = 0.8$ (static analysis; typical degree of understanding)

The bearing resistance values are for vertical, concentric loading. In the case of eccentric or inclined loading, the bearing resistance must be reduced in accordance with CHBDC Clause 6.10.3 and Clause 6.10.4. Foundation settlement, based on the above SLS resistance, is expected to be less than 25 mm.

Resistance to lateral forces/sliding resistance between the precast concrete and the underlying Granular 'A' bedding (Section 10.2) should be evaluated in accordance with the CHBDC assuming an unfactored coefficient of friction of 0.45. A geotechnical resistance factor against sliding (ϕ_{gu}) of 0.80 may be used.

Surface water diversion and dewatering (Section 11.3) should be provided as required to place the bedding material and install the culvert in the dry.

10.1.2 Pipe Culvert

Pipe culverts should be constructed in accordance with OPSS.PROV 421. Geotechnical resistance values are not typically required for pipe culverts. A modulus of subgrade reaction of 20 MN/m³ can be used for a pipe culvert installed at this site, if required.

10.2 Subgrade Preparation, Bedding and Backfilling

After excavation and removal of the existing culvert and existing fill, any organics, soft or loose deposits, disturbed soils, loose alluvial deposits and deleterious materials must be stripped from the footprint of the new culvert to expose competent native undisturbed subgrade material at or below the desired founding elevations. Given the loose conditions of the sand subgrade anticipated at the founding level in the areas near the inlet and outlet of the replacement culvert, construction equipment should not be permitted to travel on the exposed final subgrade.

The exposed final subgrade must be inspected to confirm that the subgrade is suitable and uniformly competent. Any deleterious materials at the subgrade level should be sub-excavated and backfilled with granular fill consisting of OPSS.PROV 1010 Granular A material as soon as practical to protect the subgrade from disturbance during construction.

The granular fill should be compacted as per OPSS.PROV 501. In order to provide a more uniform foundation subgrade condition for the culvert, a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A requirements must be provided under the base of the culvert as per OPSD 803.010 (box culvert) and OPSD 802.010 (pipe culvert).

It is noted that construction will extend below the ditch and creek elevation. Water diversion and dewatering will be required to prepare the subgrade in the dry. Please refer to Section 11.3 for additional comments on groundwater and surface water control.

For box culverts, it is recommended that culvert cover be in accordance with OPSD. 803.010 and OPSS 902 and consist of Granular A material meeting the requirements of OPSS.PROV 1010. Culvert backfill above the granular cover should be in accordance with OPSS 902 and consist of material meeting the requirements of OPSS Granular B Type I and should be compacted in regular lifts as per OPSS.PROV 501. Care must be exercised when compacting the fill adjacent to and above the culvert in order not to damage the culvert. Heavy compaction equipment, used near the culvert, must be restricted in accordance with OPSS.PROV 501.

For flexible pipe culverts it is recommended that culvert embedment and cover be in accordance with OPSD 802.010 and OPSS.PROV 401 and consist of OPSS Granular A material. Culvert backfill should meet the requirements of OPSS Granular B Type I and constructed in accordance with OPSS.PROV. 401.

10.3 Frost Depth

The depth of frost penetration at this site is 1.8 m (OPSD 3090.101). It is not necessary to found a closed box or pipe culvert at a depth below frost penetration. Frost taper treatment if needed, should be as directed within the Pavement Design Report.

10.4 Lateral Earth Pressures

Lateral earth pressures parameters provided in Table 10-1 and Table 10-2 in the sections below are based on the assumptions that any head or wing wall is vertical and 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 design. Where ground surfaces are horizontal or sloped at 2H:1V behind vertical walls, the corresponding coefficients provided in Table 10-1 and Table 10-2 should be used. For other backfill and wall geometries, the appropriate earth pressure coefficients can be provided upon request.

10.4.1 Static Lateral Earth Pressure Coefficients

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

$$\sigma_h = K * (\gamma d + q)$$

where:

σ_h	=	static lateral earth pressure on the wall at depth d (kPa)
K	=	static earth pressure coefficient (see table below) (K_A for yielding walls, K_o for non-yielding walls)
γ	=	unit weight of retained soil (see table below), use submerged unit weight below groundwater level
d	=	depth below top of fill where pressure is computed (m)
q	=	value of any surcharge (kPa)

A lateral earth pressure due to backfill compaction should be added to the calculated lateral earth pressure in accordance with Clause 6.12.3 of the CHBDC. Typical earth pressure coefficients for backfill on vertical structures are shown in Table 10-1.

Table 10-1. Earth Pressure Coefficients

Condition	Earth Pressure Coefficient					
	OPSS Granular A or Granular B Type II $\phi = 35^\circ$ $\gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ$ $\gamma = 21.2 \text{ kN/m}^3$		OPSS SSM and Existing Sand to Silty Sand Fill $\phi = 30^\circ$ $\gamma = 20.0 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active, K_A (Yielding Wall)	0.27	0.39	0.31	0.47	0.33	0.54
At Rest, K_o (Non-Yielding Wall)	0.43	-	0.47	-	0.50	-
Passive, K_P (Movement towards Soil Mass)	3.7	-	3.3	-	3.0	-
Soil Group(*)	"medium dense sand"		"loose to medium dense sand"		"loose sand"	

Note: (*) for use with Figure C6.16 of the Commentary to the CHBDC.

The use of a material with a high friction angle and low active earth pressure coefficient (Granular A or Granular B Type II) is preferred as it results in lower earth pressures acting on the culvert.

The parameters in the table correspond to full mobilization of active and passive earth pressures and require certain relative movements between the wall and adjacent soil to produce these conditions. The values to be used in design can be assessed from Figure C6.16 of the Commentary to the CHBDC using the soil group designation as outlined

in the table above. Active pressures should be used for any head walls or unrestrained walls. For rigid structures such as a concrete box culvert, it is recommended that at-rest/non-yielding horizontal earth pressures be used for design.

10.4.2 Combined Static and Seismic Lateral Earth Pressure Parameters

In accordance with Clause 4.6.5 of the CHBDC (S6-14), a structure should be designed using dynamic earth pressure coefficient that incorporate the effects of earthquake loading. 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 Mononobe-Okabe Method with:

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

The coefficients of horizontal earth pressure for combined static and seismic loading presented in Table 10-2 may be used for vertical walls. The provided earth pressure coefficients are for a Seismic Site Class D, PGA with a 2% probability of exceedance in 50 years (2475-year event) of 0.070g (Geological Survey of Canada – Fifth Generation) and an $F(PGA)$ of 1.29 as per Table 4.8 of the CHBDC (S6-14).

Table 10-2. Combined Static and Dynamic Earth Pressure Coefficients

Condition	Earth Pressure Coefficient			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)
Active, K_{AE} Yielding Wall	0.30	0.45	0.33	0.55
Active, K_{AE} Non-Yielding Wall	0.32	0.53	0.36	0.73

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 soils profile.

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

where:

σ_h	=	combined static and dynamic lateral earth pressure on the wall at depth d (kPa)
d	=	depth below the top of the wall where pressure is computed (m)
K	=	static earth pressure coefficient (see Table 10-1) (K_A for yielding walls, K_o for non-yielding walls)
γ	=	unit weight of retained soil, use submerged unit weight below groundwater level
K_{AE}	=	combined static and dynamic earth pressure coefficient
H	=	total height of the wall (m)

10.5 Embankment Design and Reinstatement

10.5.1 Embankment Reconstruction

Embankment reconstruction after culvert replacement should be carried out in accordance with OPSS.PROV 206. The embankment should be reinstated with side slopes of 2H:1V (or flatter) if constructed using Granular B Type I. The fill should be placed and compacted in accordance with OPSS.PROV 501.

Where new embankment fill is placed against existing embankment slopes or on a sloping ground surface steeper than 3H:1V, benching of the existing slope should be carried out in accordance with OPSD 208.010.

10.5.2 Embankment Settlement and Stability

The condition of the existing embankment slopes was examined in the field during the field investigation and no evidence of instability (tension cracks etc.) was noted at that time. The embankment slopes were vegetated including trees.

It is understood that no permanent grade raise is anticipated at this site and therefore negligible settlement of the soils beneath the embankment is expected to occur. If embankment widening is required as part of the construction activities for the culvert replacement, additional analysis may be required to estimate the induced settlement.

The magnitude of embankment compression for granular materials is in the order of 0.5% of the embankment height and is expected to occur following fill placement.

Provided no grade raise or embankment widening is required and proper construction methods are used, no long term or global stability issues are anticipated for embankments re-built at this site. Material stockpiling above the existing grades is a temporary construction measure and the associated stability implications are the responsibility of the Contractor. The selection and placement of construction equipment (such as heavy cranes) is also the Contractor's responsibility.

10.6 Cement Type and Corrosion Potential

Analytical tests were completed to determine the potential for degradation of concrete in the presence of soluble sulphates and the potential for corrosion of exposed steel. The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with soil and groundwater at the site. Soluble sulphate concentrations less than 1000 µg/g generally indicate that a low degree of sulphate attack is expected for concrete in contact with soil and groundwater. The class of concrete selected should consider the effects of road de-icing salts.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The tests results provided in Section 5.8 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects. The corrosive effects of road de-icing salts should also be considered.

11 CONSTRUCTION CONSIDERATIONS

11.1 Excavation

All excavation must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of OHSA, the existing fills may be classified as Type 3 soil. Fill and native soils below the groundwater level are classified as Type 4 soils.

Excavation for the culvert replacement must be carried out in accordance with OPSS 401 or OPSS 902 and will be carried out through the existing embankment fill and will extend into the underlying native sand deposits. The sides of temporary excavations must be sloped in accordance with the requirement of OHSA. Selection of the equipment and methodology to excavate and prepare the founding surface is the responsibility of the Contractor. Protection of adjacent utilities will need to be taken into consideration when evaluating the excavation limits.

At locations where there are space restrictions, where the excavation is near the toe of the embankment slope or where a slope has to be retained, the excavations need to be carried out within a protection system. Further discussion is presented in Section 11.2.

11.2 Temporary Protection Systems

Temporary Protection Systems may be required during various stages of construction and must be implemented in accordance with OPSS.PROV 539 and designed for Performance Level 2 (maximum 25 mm horizontal deflection). The actual pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall and these factors must be considered when designing the shoring system.

Lateral earth pressure coefficients, under fully mobilized conditions, that can be used in design of the protection system installed through the existing fill are provided in Table 10-1.

The lateral earth pressure coefficients for the native soil deposits assuming a vertical wall and horizontal soil slopes are given below:

$$\begin{aligned}\gamma &= 20 \text{ kN/m}^3 \text{ (use submerged unit weight below groundwater level)} \\ K_A &= 0.33 \\ K_P &= 3.0\end{aligned}$$

Temporary protection systems are the responsibility of the Contractor and should be designed by a licensed Professional Engineer experienced in such designs and retained by the Contractor. Cobbles and boulders were encountered during the drilling investigation, which may interfere with the installation of sheet piles. A suggested NSSP to alert the Contractor is provided in Appendix G. Therefore, soldier piles with lagging are considered a feasible option at this site from a geotechnical perspective. A suitable anchoring and/or bracing system may need to be incorporated into the temporary protection design to resist the lateral earth pressure loadings including traffic loading and surcharge loading due to construction equipment and operations and minimize lateral deflection of the protection system.

It is recommended that the TPS should be left in place and cut off in accordance with OPSS 539.

11.3 Surface and Groundwater Control

Creek diversion will be required as the depth of excavation will extend below the creek 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. For box culverts the dewatering system should be designed in accordance with SP FOUN0003 which amends OPSS 902. A preconstruction survey is recommended, thus Designer Fill-In ** in SP FOUN0003 should be "200 m".

For pipe culverts, the dewatering system is to be designed in accordance with OPSS.PROV 517 and SP517F01. It is not considered necessary that the design Engineer and design-checking Engineer have a minimum of 5 years of experience in designing systems of similar nature and scope to the required work, thus Designer Fill-In ***** in SP517F01 should be "No". A preconstruction survey is required, thus Designer Fill-In ***** in this SP should be "200 m".



The groundwater level will fluctuate and the minimum groundwater elevation for the site at the time of construction should be taken as the water level from the design storm period defined in SP517F01 and SP FOUN0003.

Construction of cofferdams may be required to divert flow away from the area of the new culvert. A sand bag cofferdam and sump pumps are anticipated to be sufficient if the groundwater conditions at the time of construction are as they were during the foundation investigation. Alternatively, a sheet piled cofferdam can be designed following the recommendations provided in Sections 11.1 and 11.2. Note that driving of sheet piles extending into the embankment may be difficult due to the potential of encountering cobbles and boulders in the fill. The use of vibration during the removal of sheet pile cofferdams could result in settlement of a new culvert particularly at the inlet and outlet and must be carried out cautiously. It may be prudent to cut off the sheet piles in accordance with OPSS.539.

Excavation below the groundwater level to replace the existing culvert without prior dewatering is not recommended since the inflow of groundwater will make it difficult to maintain a dry, sound base on which to work and base boiling may occur. Disturbance of the subgrade soils is considered to be a significant risk without proper consideration of groundwater lowering. The groundwater level should be lowered to 0.5 m below the planned base of excavation for each stage of excavation.

The need for a Permit to take Water (PTTW) should be carried out by specialists experienced in this field. It is anticipated that a vacuum well point system may need to be installed surrounding the work zone.

11.4 Scour Protection and Erosion Control

Scour and erosion protection should be provided for the culvert inlet and outlet areas. Design of the scour and erosion protection measures must consider hydrologic and hydraulic concerns and should be carried out by specialists experienced in this field.

Based on the subsurface conditions encountered at the drilled locations through the embankment at this site the embankment fill materials are considered to have low susceptibility to erosion as per the Wischmeier Nomograph. The native soils are considered to have moderate susceptibility to erosion.

Typically, rock protection should be provided over all earth surfaces in contact with flowing water. Treatment at the 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.

It is recommended that a concrete cut-off wall be used to minimize the potential for piping and erosion around the inlet of the culvert.

12 CONSTRUCTION CONCERNS

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

- Cobbles and boulders were encountered within the fill and native soils. Buried obstructions may be encountered during excavation in the embankment fill or interfere with driving of protection systems and/or sheet pile cofferdams.
- Groundwater levels will fluctuate. Excavation may require lowering the groundwater level below the excavation base to maintain a reasonably dry excavation and stable side slopes.
- The Contractor's selection of construction equipment and methodology must include assessment of the capability of the existing embankment to support the proposed construction equipment and any temporary structure fill (i.e., as a pad for crane support).

The successful performance of the culvert installation will depend largely upon good workmanship and quality control during construction. Subgrade examination in accordance with SP109S12 should be carried out by qualified geotechnical personal during construction to confirm that foundation recommendations are correctly implemented, and material specifications are met.

13 CLOSURE

Engineering analysis and preparation of this report were carried out by Miss Katya Edney, P.Eng. and Mr. Stephen Peters, P.Eng. The report was reviewed by Dr. Fred Griffiths, P.Eng and Dr. P.K. Chatterji, P.Eng a Designated Principal Contact for MTO Foundation Projects.

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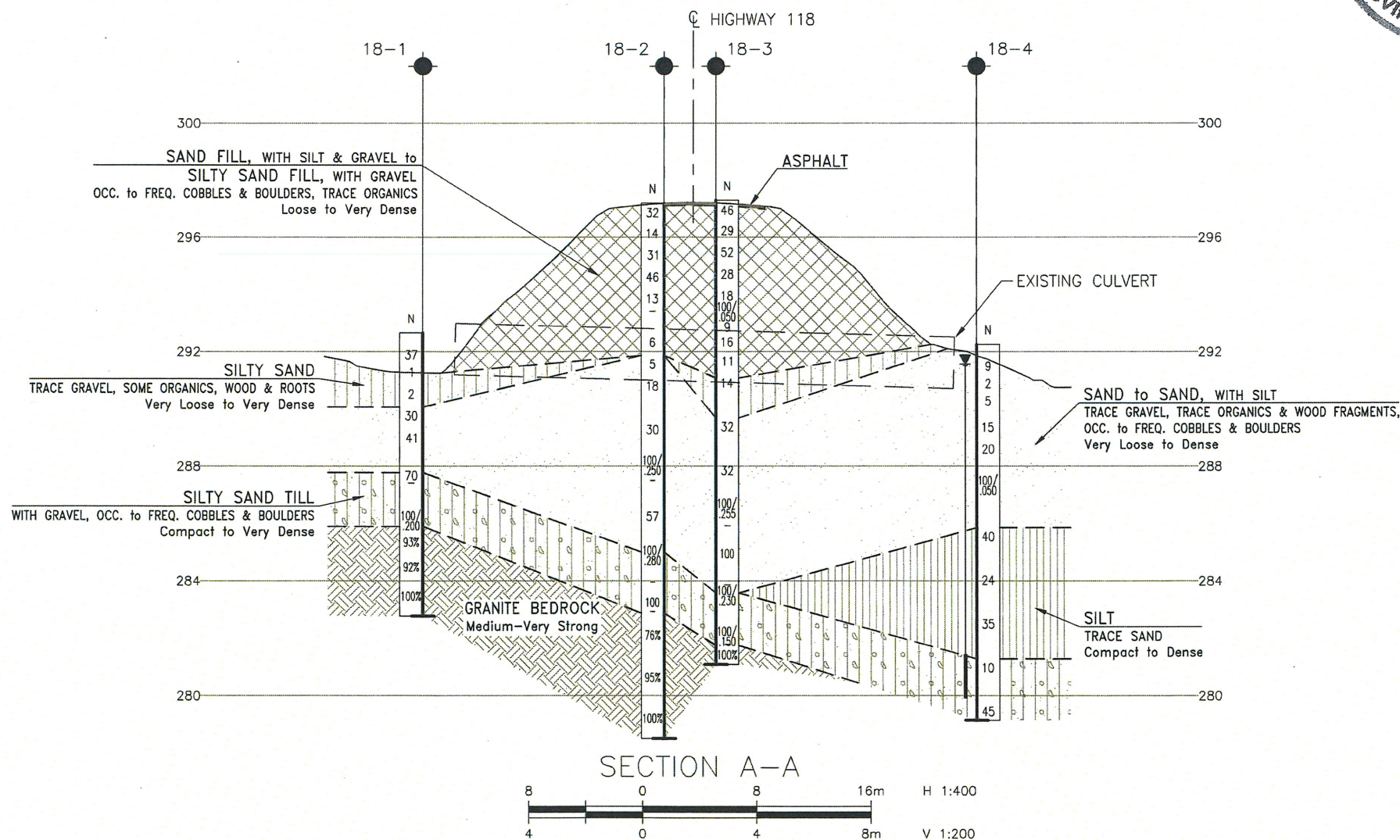
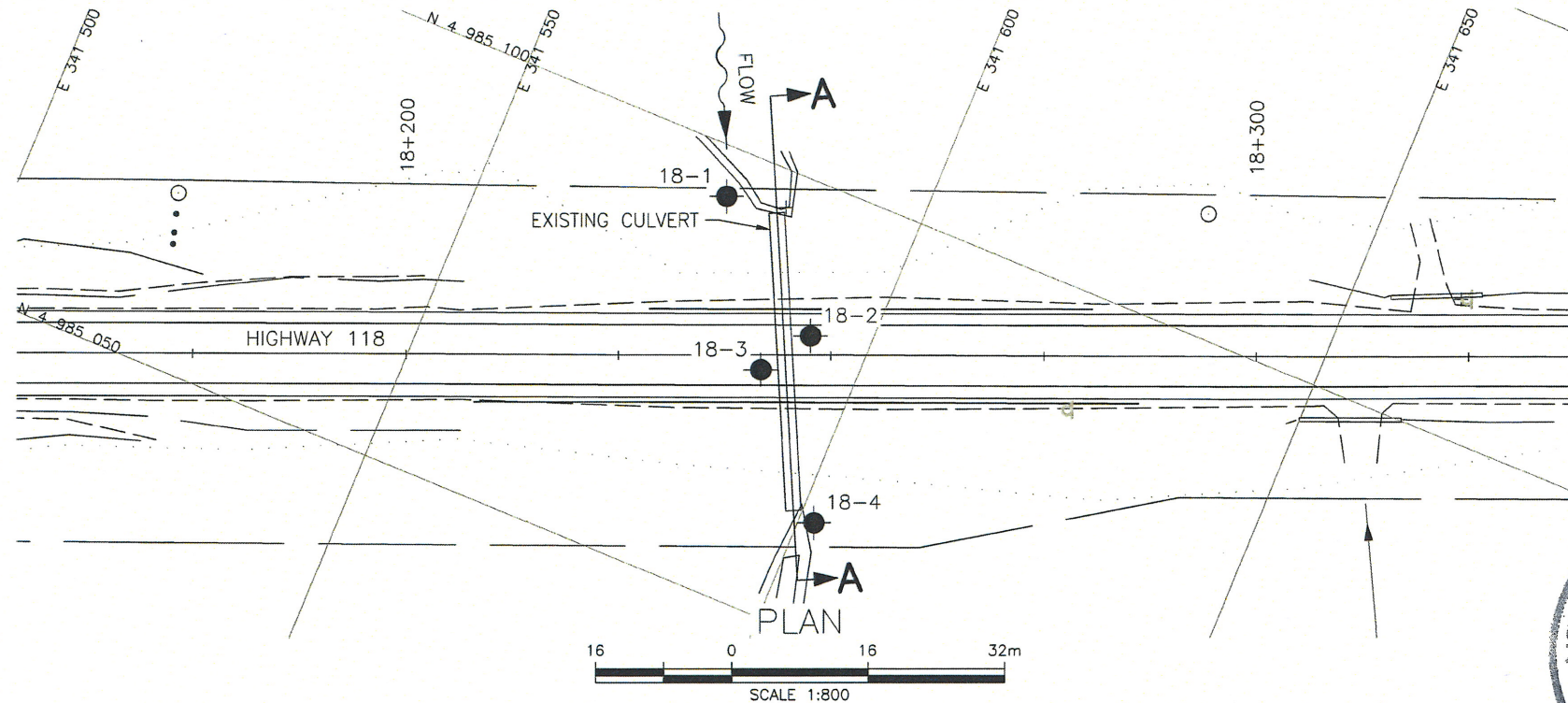


Dr. P.K. Chatterji, P.Eng.
Review Principal
Senior Geotechnical Engineer



Appendix A.

Borehole Location Plan and Stratigraphic Drawing

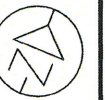


METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN



CONT No
GWP No 5287-14-00

HIGHWAY 118
STATION 18+245
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

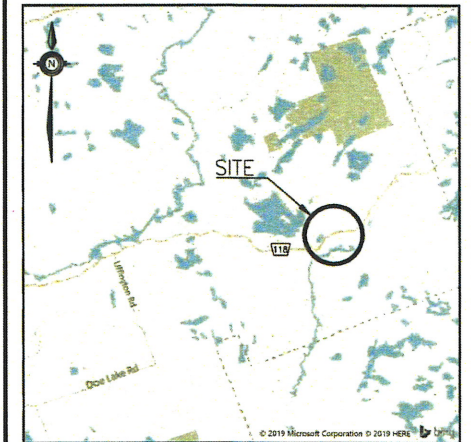


SHEET

McINTOSH PERRY



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

●	Current Borehole by Thurber
⊕	Previous Borehole by Others (Approx.)
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
W	Water Level
HA	Head Artesian Water
P	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
18-1	292.2	4 985 094.3	341 577.7
18-2	297.2	4 985 082.9	341 593.1
18-3	297.3	4 985 077.0	341 589.2
18-4	291.8	4 985 062.7	341 601.8

-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.
- Coordinate system is MTM NAD 83 Zone 10.

GEOCRES No. 31E-398

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	KE	CHK SP	CODE
DRAWN	MFA	CHK KE	SITE
			LOAD
			DATE APR 2019
			ISTRUCT
			DWG



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 18-1

1 OF 2

METRIC

GWP# 5287-14-00 LOCATION Lat: 45.004882°, Long: -79.033469° Sta. 18+245 N 4 985 094.3 E 341 577.7 ORIGINATED BY SOB
 HWY 118 BOREHOLE TYPE Portable NWT Washboring COMPILED BY AC
 DATUM Geodetic DATE 12.09.2018 - 13.09.2018 CHECKED BY KE

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				WATER CONTENT (%)				
								20 40 60 80 100	20 40 60							
292.7																
0.0	STAND															
292.2																
0.5	SILTY SAND (SM) trace organics dense brown		1	SS	37		292									
291.6																
1.1	SILTY SAND (SM) very loose brown		2	SS	1											
							291									
			3	SS	2											
290.1																
2.6	SAND (SP) trace gravel compact to dense brown		4	SS	30		290									
			5	SS	41		289									
287.8							288									
4.9	SILTY SAND with gravel TILL occasional to frequent cobbles and boulders very dense grey-brown		6	SS	70											
			7	NQ	-		287									
285.9			8	SS	100/		286									
6.8	BEDROCK GRANITE slightly weathered to fresh coarse grained medium strong to very strong red and grey		1	RUN	200 mm		285									
			2	RUN			284									
			3	RUN			283									
282.8																
9.9																

DOUBLE LINE ST 18+250.GPJ 2012TEMPLATE(MTO).GDT 23/8/19

Continued Next Page

+³ ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-1

2 OF 2

METRIC

GWP# 5287-14-00 LOCATION Lat: 45.004882°, Long: -79.033469°
Sta. 18+245 N 4 985 094.3 E 341 577.7 ORIGINATED BY SOB
HWY 118 BOREHOLE TYPE Portable NWT Washboring COMPILED BY AC
DATUM Geodetic DATE 12.09.2018 - 13.09.2018 CHECKED BY KE

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									
	Continued From Previous Page																
	End of Borehole																
	A half-weight (32 kg) drop hammer was used to advance the split-spoon sampler. The N values presented have been adjusted to provide an equivalent N value that would have been obtained with a standard 64 kg hammer.																

RECORD OF BOREHOLE No 18-2

1 OF 2

METRIC

GWP# 5287-14-00 LOCATION Lat: 45.004779°, Long: -79.033274° Sta. 18+245 N 4 985 082.9 E 341 593.1 ORIGINATED BY AC
 HWY 118 BOREHOLE TYPE NW Washboring/NQ Coring COMPILED BY AC
 DATUM Geodetic DATE 12.09.2018 - 12.09.2018 CHECKED BY KE

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			SHEAR STRENGTH kPa						
								20 40 60 80 100						
297.2														
0.0	ASPHALT (75 mm)													
0.1	SAND with silt and gravel compact to dense red-brown to grey FILL		1	SS	32		297							
			2	SS	14		296							
			3	SS	31		295							
			4	SS	46		294							22 66 12 (SI+CL)
			5	SS	13		293							
293.5			6	NQ	-		292							
3.7	SILTY SAND with gravel occasional to frequent cobbles and boulders loose grey-brown boulder at 3.8 m FILL		7	SS	6		291							
291.9			8	SS	5		290							
5.3	SAND (SP-SM) with silt trace gravel trace organics and wood loose to compact dark grey		9	SS	18		289							10 81 9 (SI+CL)
289.6			10	SS	30		288							
7.6	SAND (SP-SM) with silt trace gravel trace wood fragments occasional to frequent cobbles and boulders dense red-brown to brown		11	SS	100/ 250 mm									
	boulder at 9.5 m		12	NQ	-									

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 18-3

1 OF 2

METRIC

GWP# 5287-14-00 LOCATION Lat: 45.004726°, Long: -79.033324° Sta. 18+245 N 4 985 077.0 E 341 589.2 ORIGINATED BY AC
 HWY 118 BOREHOLE TYPE NW Washboring/NQ Coring COMPILED BY AC
 DATUM Geodetic DATE 11.09.2018 - 11.09.2018 CHECKED BY KE

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	W _P	W	W _L	WATER CONTENT (%)	20 40 60	kN/m ³			GR SA SI CL	
SHEAR STRENGTH kPa																		
○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE																		
297.3							20 40 60 80 100											
0.0	ASPHALT (100 mm)																	
0.1	SAND with silt and gravel compact to dense brown FILL		1	SS	46							○			21 69 10 (SI+CL)			
			2	SS	29							○						
295.8																		
1.5	SILTY SAND with gravel trace organics compact to very dense red-brown FILL		3	SS	52							○						
			4	SS	28							○						
			5	SS	18							○						
293.5			6	SS	100													
3.8	SILTY SAND with gravel loose to compact brown boulder at 3.9 m FILL		7	NQ	50 mm													
			8	SS	9							○						
			9	SS	16							○			18 68 14 (SI+CL)			
			10	SS	11							○						
291.1												○						
6.2	SILTY SAND (SM) with organics, roots and wood fragments compact dark grey		11	SS	14								○		0 73 25 2 non-plastic			
289.7																		
7.6	SAND (SP) trace gravel dense brown		12	SS	32							○						
			13	SS	32													
												○						

Continued Next Page

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

METRIC

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	20 40 60 80 100	20 40 60 80 100	W _P W W _L	20 40 60		
	Continued From Previous Page												
	SAND (SP) trace gravel occasional to frequent cobbles and boulders below 10.7 m dense brown												
			14	SS	100/255 mm								
			15	NQ	-								
			16	SS	100								
			17	NQ	-								
283.6 13.7	SILTY SAND (SM) with gravel TILL occasional to frequent cobbles and boulders very dense grey		18	SS	100/230 mm								
			19	SS	100/150 mm								
281.7 15.5	BEDROCK (probable) GRANITE fresh medium to coarse grained medium strong to very strong grey with black		20	NQ	-								
281.1 16.2	End of Borehole		1	RUN	-								

RECORD OF BOREHOLE No 18-4

1 OF 2

METRIC

GWP# 5287-14-00 LOCATION Lat: 45.004597°, Long: -79.033165° Sta. 18+245 N 4 985 062.7 E 341 601.8 ORIGINATED BY SOB
 HWY 118 BOREHOLE TYPE Portable NWT Washboring COMPILED BY AC
 DATUM Geodetic DATE 14.09.2018 - 15.09.2018 CHECKED BY KE

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 (%)								
								20 40 60 80 100					W _P W W _L								
292.3																					
0.0	STAND																				
291.8																					
0.5	SAND (SP) trace organics loose brown		1	SS	9																
291.2																					
1.1	SAND (SP) very loose to compact brown		2	SS	2																
			3	SS	5																
			4	SS	15																
288.9																					
3.4	SAND (SP) trace gravel occasional cobbles and boulders compact brown		5	SS	20																
			6	SS	100/ 50 mm																
285.9																					
6.4	SILT (ML) trace sand compact to dense grey		7	SS	40																
			8	SS	24																
			9	SS	35																
						</															

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-4

2 OF 2

METRIC

GWP# 5287-14-00 LOCATION Lat: 45.004597°, Long: -79.033165° Sta. 18+245 N 4 985 062.7 E 341 601.8 ORIGINATED BY SOB
 HWY 118 BOREHOLE TYPE Portable NWT Washboring COMPILED BY AC
 DATUM Geodetic DATE 14.09.2018 - 15.09.2018 CHECKED BY KE

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							
								20 40 60 80 100							
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE							
							WATER CONTENT (%) 20 40 60								
							PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT								
							W P W W L								



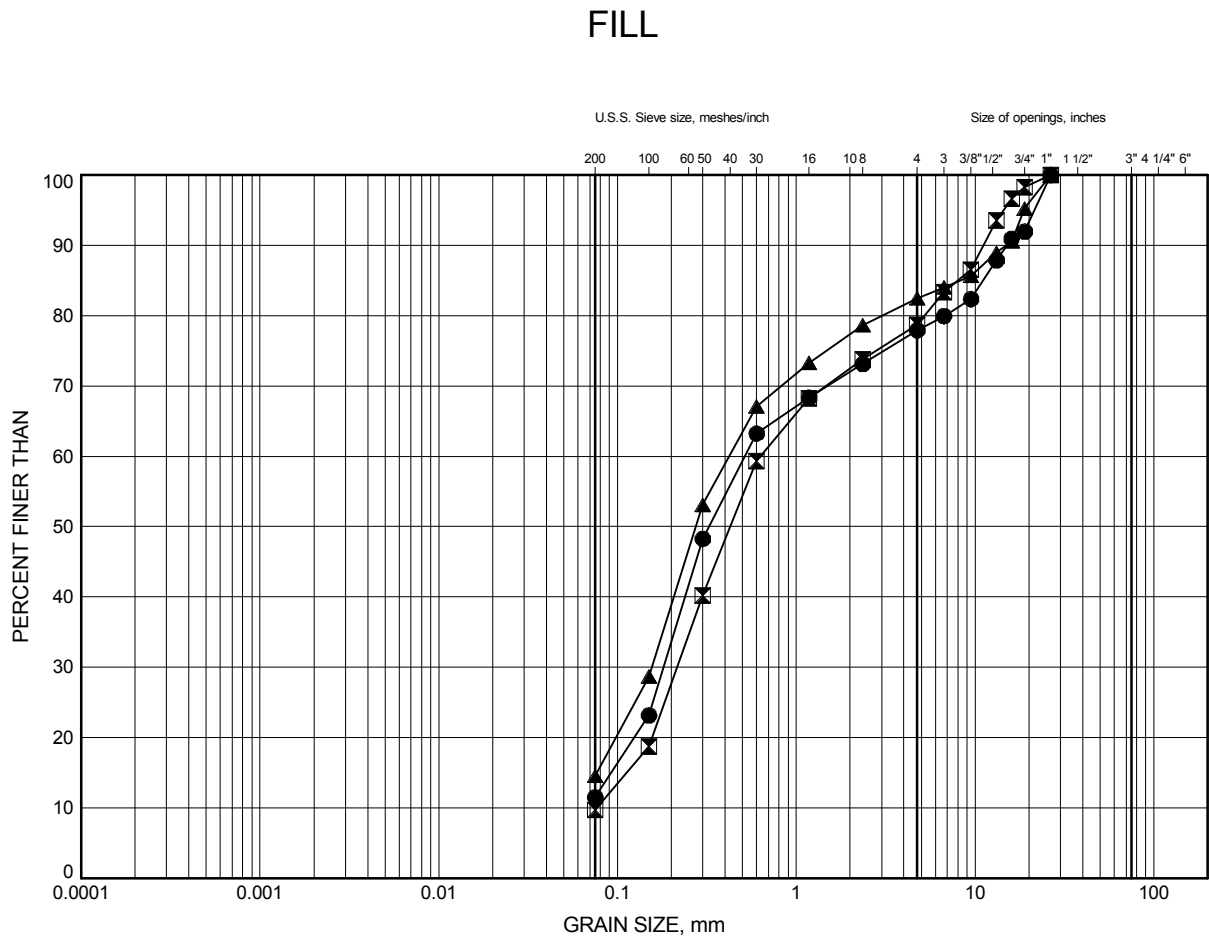
Appendix C.
Laboratory Testing



Appendix C.1
Particle Size Analysis Figures

HWY 118 Culverts Station 18+245 GRAIN SIZE DISTRIBUTION

FIGURE C1



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18-2	2.6	294.6
⊠	18-3	0.4	296.9
▲	18-3	5.0	292.3

Date ..October 2018.....
GWP# ..5287-14-00.....

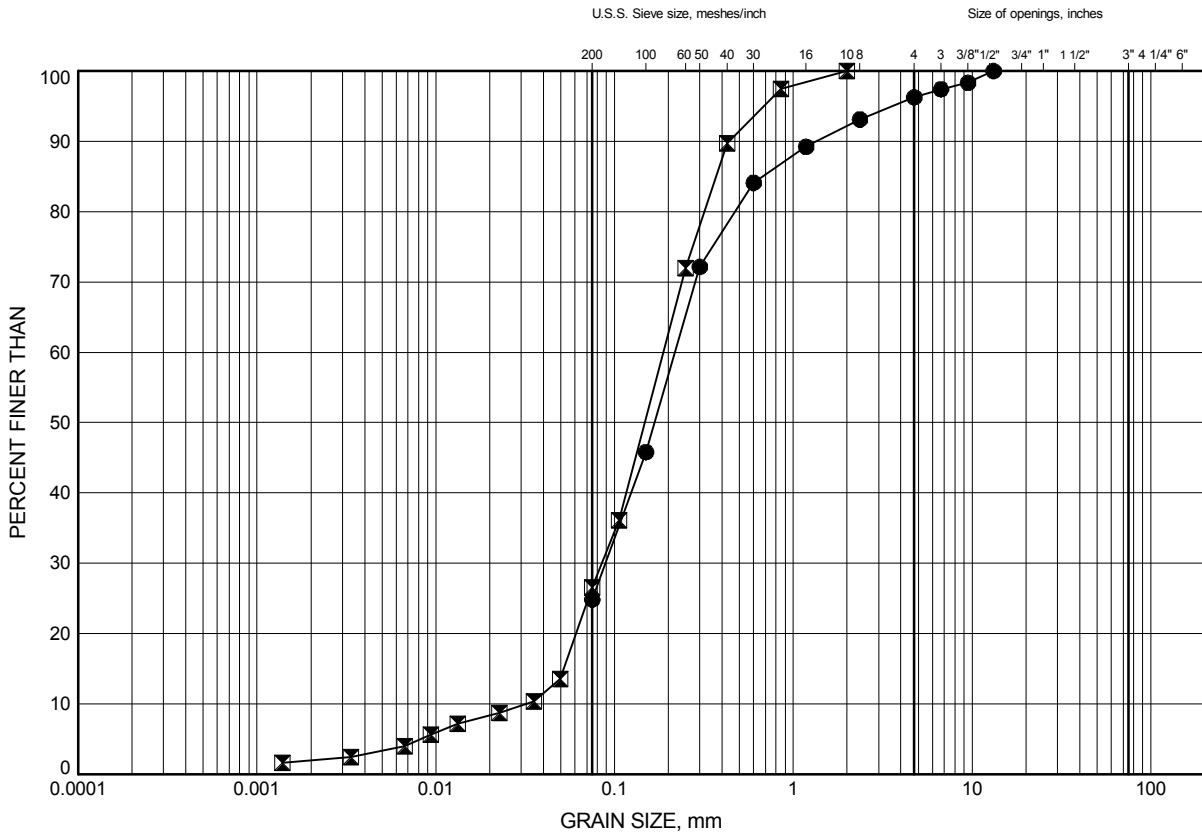


Prep'dAC.....
Chkd.KE.....

HWY 118 Culverts Station 18+245 GRAIN SIZE DISTRIBUTION

FIGURE C2

SILTY SAND (SM)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18-1	0.9	291.3
⊠	18-3	6.5	290.8

Date ..October 2018.....
GWP# ..5287-14-00.....

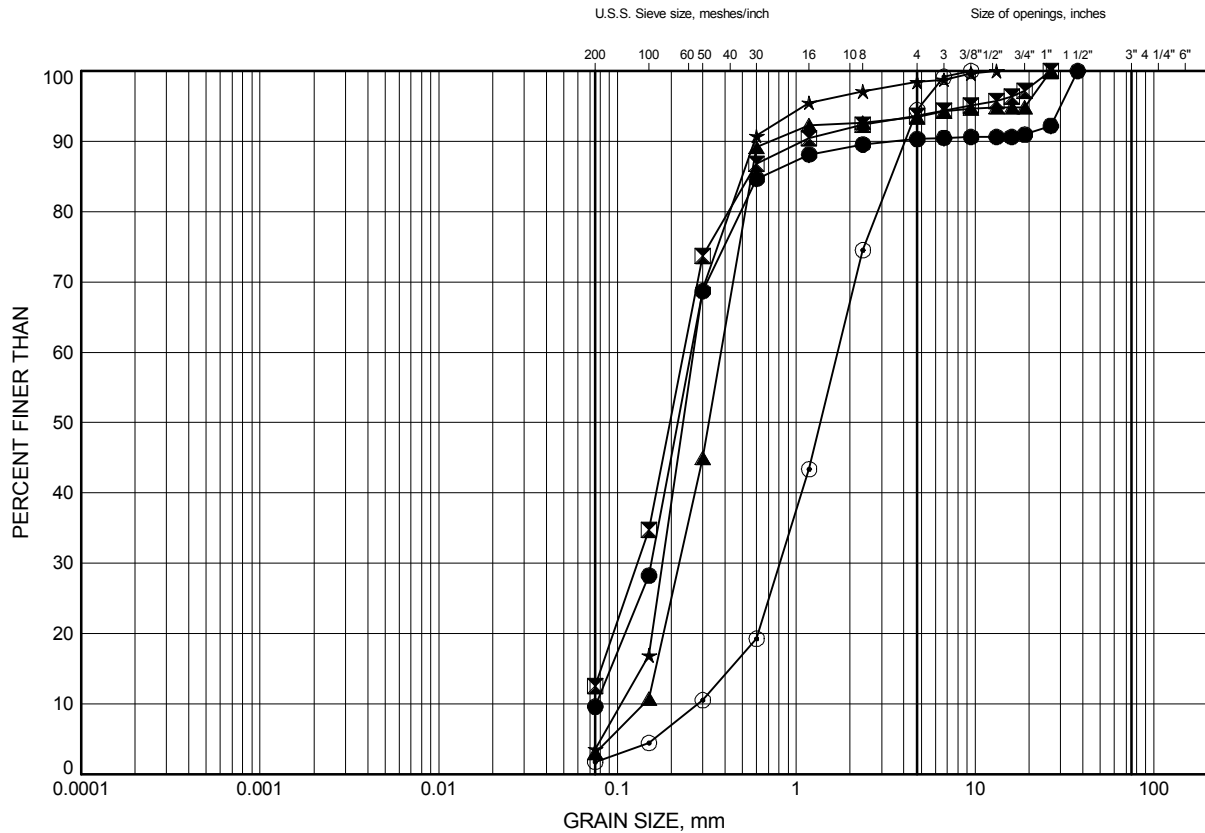


Prep'dAC.....
Chkd.KE.....

HWY 118 Culverts Station 18+245 GRAIN SIZE DISTRIBUTION

FIGURE C3

SAND (SP to SP-SM)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18-2	6.4	290.8
⊠	18-2	10.9	286.3
▲	18-3	12.3	284.9
★	18-4	2.4	289.4
⊙	18-4	4.5	287.3

Date ..October 2018.....

GWP# ..5287-14-00.....

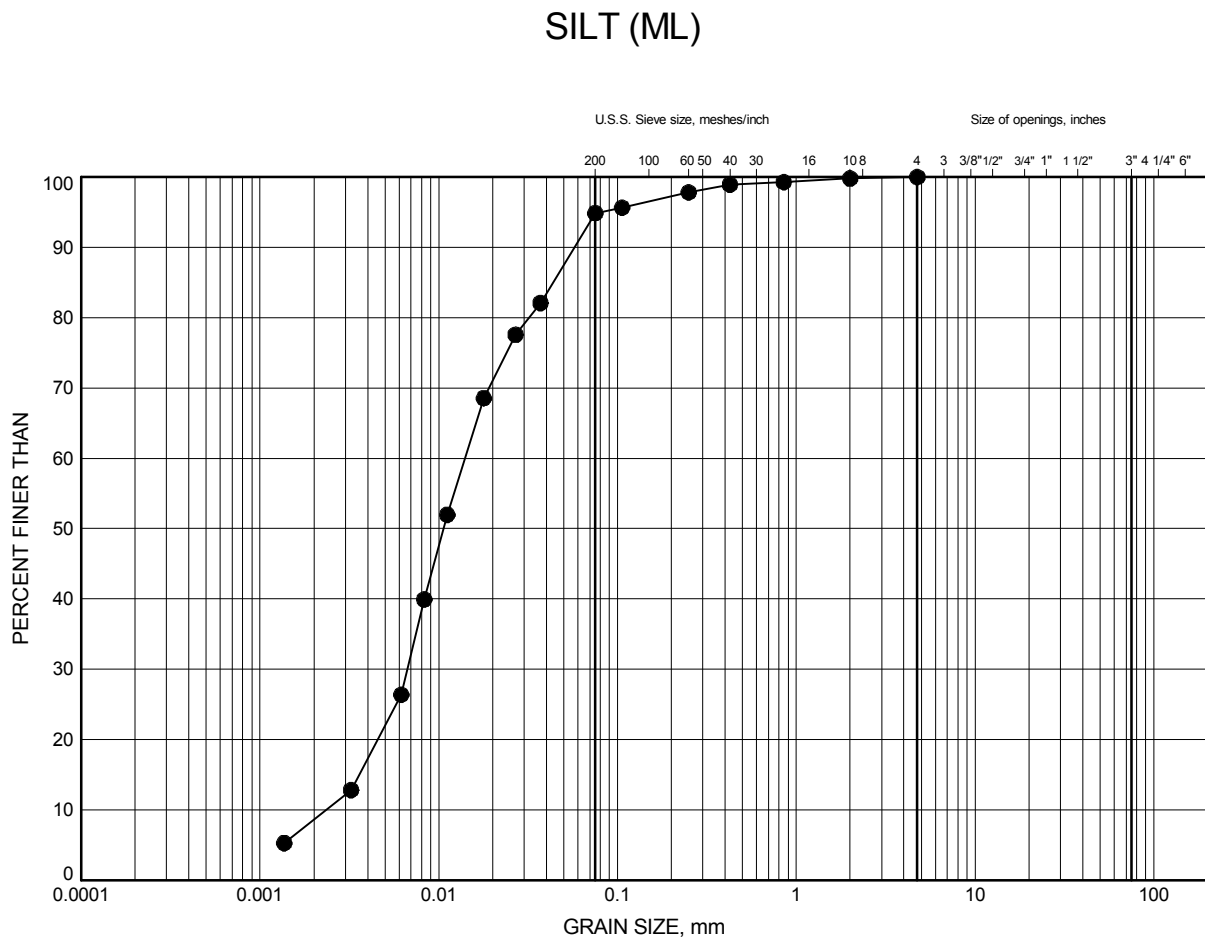


Prep'dAC.....

Chkd.KE.....

HWY 118 Culverts Station 18+245 GRAIN SIZE DISTRIBUTION

FIGURE C4



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18-4	9.3	282.5

Date ..October 2018.....
 GWP# ..5287-14-00.....

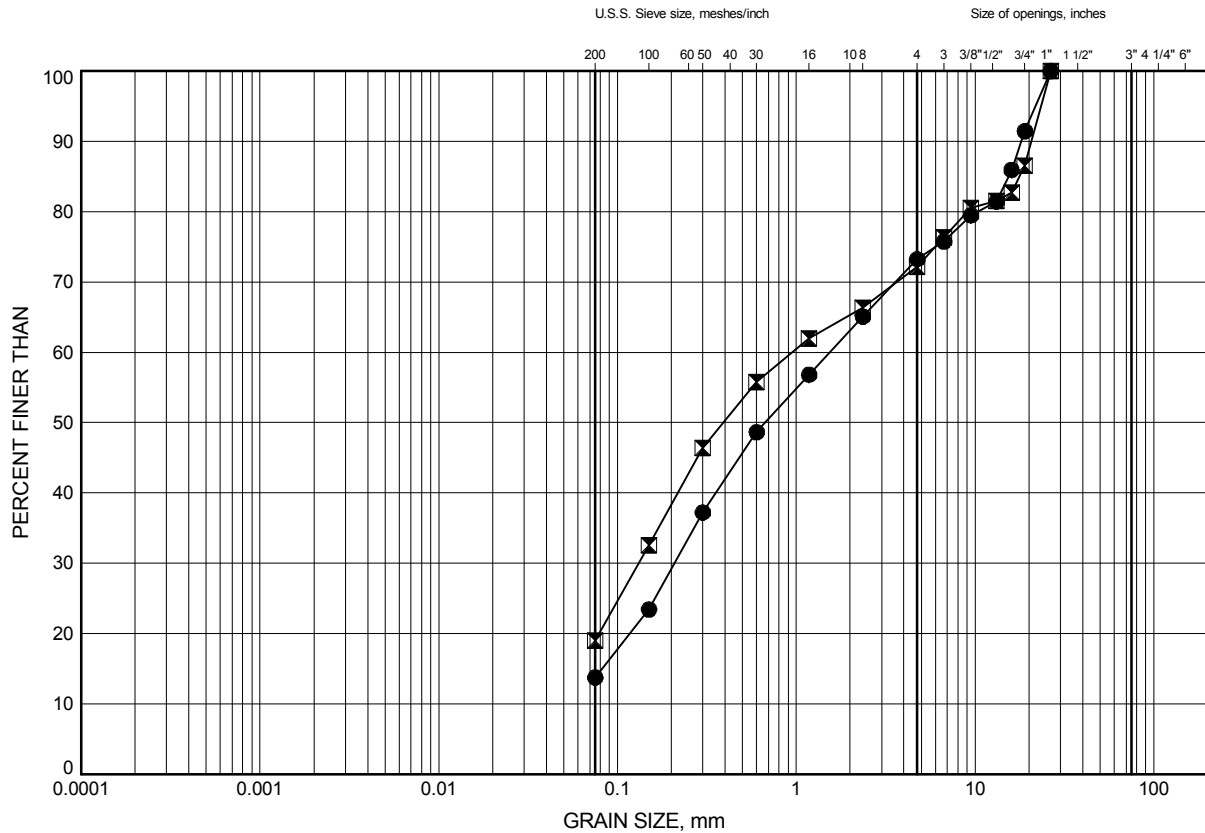


Prep'dAC.....
 Chkd.KE.....

HWY 118 Culverts Station 18+245 GRAIN SIZE DISTRIBUTION

FIGURE C5

SILTY SAND (SM) with gravel (GLACIAL TILL)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18-2	12.4	284.8
⊠	18-3	15.3	282.0

Date ..October 2018.....
GWP# ..5287-14-00.....



Prep'dAC.....
Chkd.KE.....

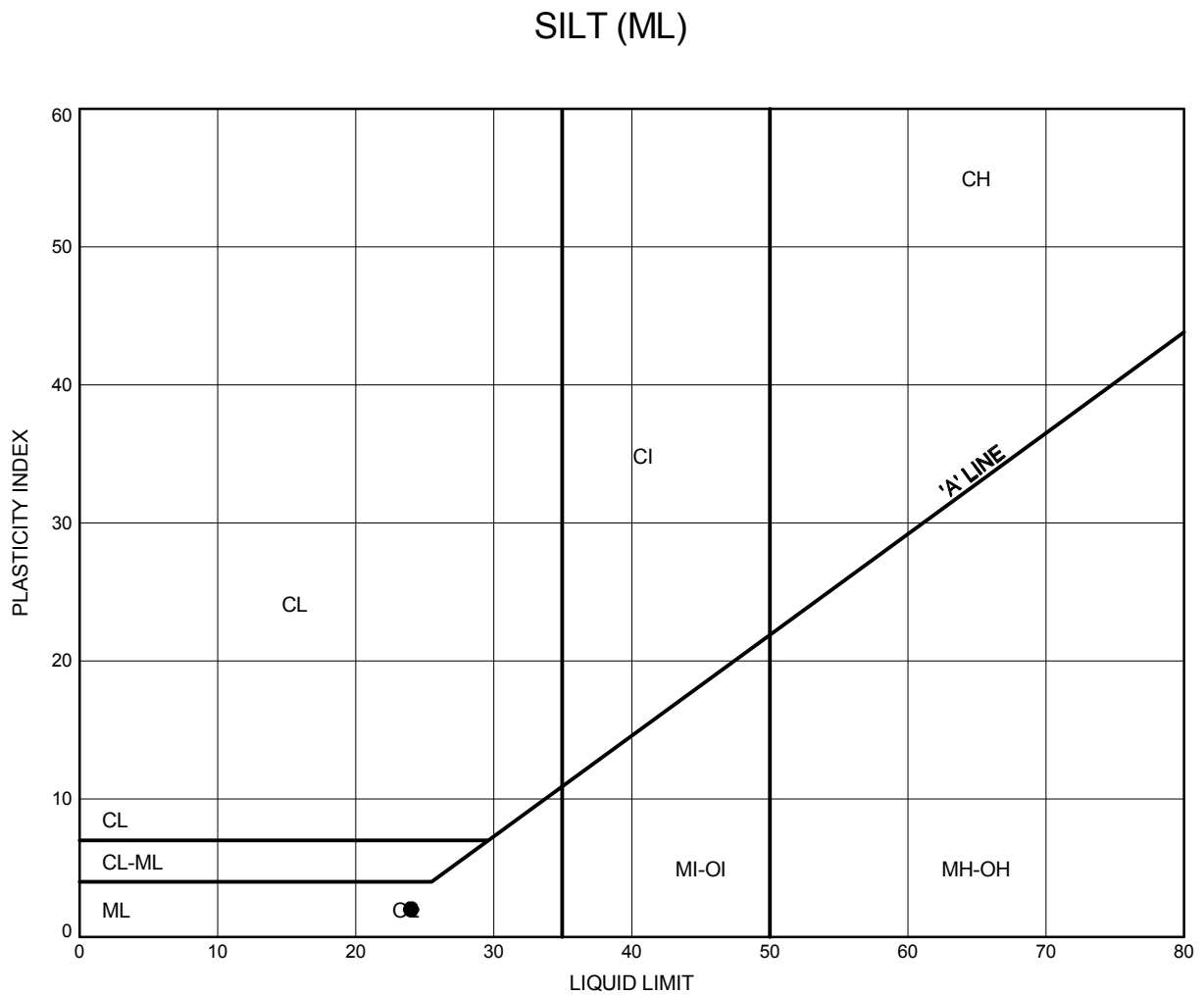


Appendix C.2
Atterberg Limit Testing Figure

HWY 118 Culverts Station 18+245

ATTERBERG LIMITS TEST RESULTS

FIGURE C6



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18-4	9.3	282.5

Date ..October 2018.....
 GWP# ..5287-14-00.....



Prep'dAC.....
 Chkd.KE.....



Appendix C.3
Rock Core Photos

Borehole 18-1
Run 1 to 3 (of 3)
Elevation 285.9 m to 282.8 m



Borehole 18-2
Run 1 to 3 (of 3)
Elevation 282.8 m to 278.5 m



THURBER ENGINEERING LTD.

Foundation Investigation
Hwy 118 Culverts St. 18+245
Foundations

GWP: 5287-14-00

Project No.: 20244

Borehole 18-3
Run 1 to 1 (of 1)
Elevation 281.7 m to 281.1 m



THURBER ENGINEERING LTD.

Foundation Investigation
Hwy 118 Culverts St. 18+245
Foundations

GWP: 5287-14-00

Project No.: 20244



Appendix C.4

Analytical Testing Results

Certificate of Analysis

Thurber Engineering Ltd.

2460 Lancaster Rd, Suite 104
Ottawa, ON K1B 4S5
Attn: Katya Edney

Client PO: 20244
Project: Hwy 11+118
Custody: 39862

Report Date: 28-Sep-2018
Order Date: 24-Sep-2018

Order #: 1839096

This Certificate of Analysis contains analytical data applicable to the following samples as submitted:

Paracel ID	Client ID
1839096-01	18+250 18-1 SS3 6-8'
1839096-02	18+250 18-4 SS3 5'6"-7-6"
1839096-03	18+875 18-2 SS8 17'6"-19'6"
1839096-04	11+490 18-01 SS3B 7-8'

Depths provided in results are measured from the top of the drilling platform which is not shown in the Record of Borehole Sheets. Platform height measured 0.5 m.

Approved By:



Mark Foto, M.Sc.
Lab Supervisor

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 20244

Report Date: 28-Sep-2018
Order Date: 24-Sep-2018
Project Description: Hwy 11+118

Analysis Summary Table

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	26-Sep-18	26-Sep-18
Conductivity	MOE E3138 - probe @25 °C, water ext	27-Sep-18	27-Sep-18
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	27-Sep-18	27-Sep-18
Resistivity	EPA 120.1 - probe, water extraction	27-Sep-18	27-Sep-18
Solids, %	Gravimetric, calculation	27-Sep-18	27-Sep-18

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 20244

Report Date: 28-Sep-2018

Order Date: 24-Sep-2018

Project Description: Hwy 11+118

Client ID:	18+250 18-1 SS3 6-8'	18+250 18-4 SS3 5'6"-7-6"	18+875 18-2 SS8 17'6"-19'6"	11+490 18-01 SS3B 7-8'
Sample Date:	09/12/2018 09:00	09/14/2018 09:00	09/19/2018 09:00	09/16/2018 09:00
Sample ID:	1839096-01	1839096-02	1839096-03	1839096-04
MDL/Units	Soil	Soil	Soil	Soil

Physical Characteristics

% Solids	0.1 % by Wt.	79.4	79.6	80.3	82.1
----------	--------------	------	------	------	------

General Inorganics

Conductivity	5 uS/cm	227	243	1340	383
pH	0.05 pH Units	5.86	5.11	4.82	5.32
Resistivity	0.10 Ohm.m	44.1	41.1	7.45	26.1

Anions

Chloride	5 ug/g dry	40	104	1260	236
Sulphate	5 ug/g dry	129	62	70	24

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 20244

Report Date: 28-Sep-2018
 Order Date: 24-Sep-2018
Project Description: Hwy 11+118

Method Quality Control: Blank

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	ND	5	ug/g						
Sulphate	ND	5	ug/g						
General Inorganics									
Conductivity	ND	5	uS/cm						
Resistivity	ND	0.10	Ohm.m						

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 20244

Report Date: 28-Sep-2018
Order Date: 24-Sep-2018
Project Description: Hwy 11+118

Method Quality Control: Duplicate

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	22.3	5	ug/g dry	23.2			4.1	20	
Sulphate	15.1	5	ug/g dry	15.6			3.3	20	
General Inorganics									
Conductivity	211	5	uS/cm	204			3.1	6.2	
pH	7.90	0.05	pH Units	7.93			0.4	10	
Resistivity	47.5	0.10	Ohm.m	48.9			3.1	20	
Physical Characteristics									
% Solids	79.2	0.1	% by Wt.	79.5			0.4	25	

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 20244

Report Date: 28-Sep-2018
Order Date: 24-Sep-2018
Project Description: Hwy 11+118

Method Quality Control: Spike

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	117	5	ug/g	23.2	93.8	78-113			
Sulphate	120	5	ug/g	15.6	104	78-111			

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 20244

Report Date: 28-Sep-2018
Order Date: 24-Sep-2018
Project Description: Hwy 11+118

Qualifier Notes:

None

Sample Data Revisions

None

Work Order Revisions / Comments:

None

Other Report Notes:

n/a: not applicable
ND: Not Detected
MDL: Method Detection Limit
Source Result: Data used as source for matrix and duplicate samples
%REC: Percent recovery.
RPD: Relative percent difference.

Soil results are reported on a dry weight basis when the units are denoted with 'dry'.
Where %Solids is reported, moisture loss includes the loss of volatile hydrocarbons.

Subcontracted Analysis

Thurber Engineering Ltd.2460 Lancaster Rd, Suite 104
Ottawa, ON K1B 4S5
Attn: Katya EdneyTel: (613) 247-2121
Fax: (613) 247-2185Paracel Report No **1839096**Client Project(s): **Hwy 11+118**Client PO: **20244**Reference: **Standing Offer**CoC Number: **39862**Order Date: 24-Sep-18
Report Date: 27-Sep-18

Sample(s) from this project were subcontracted for the listed parameters. A copy of the subcontractor's report is attached

Parcel ID	Client ID	Analysis
1839096-01	18+250 18-1 SS3 6-8'	Sulphide, solid
1839096-02	18+250 18-4 SS3 5'6"-7-6"	Sulphide, solid
1839096-03	18+875 18-2 SS8 17'6"-19'6"	Sulphide, solid
1839096-04	11+490 18-01 SS3B 7-8'	Sulphide, solid

**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - K0L 2H0
Phone: 705-652-2000 FAX: 705-652-6365

Paracel Laboratories

Attn : Dale Robertson

300-2319 St.Laurent Blvd.
Ottawa, ON
K1G 4K6, Canada

Phone: 613-731-9577
Fax:613-731-9064

27-September-2018

Date Rec. : 25 September 2018
LR Report: CA13421-SEP18
Reference: Project#: 1839096

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

Sample ID	Sample Date & Time	Sulphide %
1: Analysis Start Date		27-Sep-18
2: Analysis Start Time		12:40
3: Analysis Completed Date		27-Sep-18
4: Analysis Completed Time		13:39
5: QC - Blank		< 0.02
6: QC - STD % Recovery		83%
7: QC - DUP % RPD		ND
8: RL		0.02
9: 18+250 18-1 SS3 6-8'	12-Sep-18	< 0.02
10: 18+250 18-4 SS3 5'6"-7-6"	14-Sep-18	< 0.02
11: 18+875 18-2 SS8 17'6-19'6"	19-Sep-18	< 0.02
12: 11+490 18-01 SS3B 7-8'	16-Sep-18	< 0.02

RL - SGS Reporting Limit
ND - Not Detected

Kimberley Didsbury
Project Specialist
Environmental Services, Analytical



Appendix D.

Site Photographs



Photo 1. Looking North from Culvert 18+245 Inlet (2018/09/11)



Photo 2. Looking Southwest at Culvert 18+245 Inlet (2018/09/11)



Photo 3. Looking East on HWY 118 (2018/09/13)



Photo 4. Looking West on HWY 118 (2018/09/13)



Photo 5. Looking west at Culvert 18+245 Outlet with Piezometer 18-4 (2018/09/15)



Appendix E.

Foundation Comparison

COMPARISON OF ALTERNATIVE FOUNDATION TYPES

	<i>Circular Pipe or Closed Box Culvert</i>	<i>Circular Pipe Culvert Trenchless Installation</i>	<i>Open Bottom Culvert</i>	<i>Precast Concrete Slab on Steel Sheet Piles</i>
<i>Advantages</i>	Typically least costly culvert type. Relatively expedient installation if precast units are used. Smaller magnitude of settlement than open footing culvert due to lower bearing stress on subgrade.	Can tolerate larger magnitude of settlement than concrete (rigid frame) culverts). Avoids large open cuts Allows two lanes of traffic to be maintained throughout construction	Relatively expedient installation if precast units are used. Possibility to maintain work zone to span the existing waterway.	Potentially minimized volume of excavation and roadway protection Maintains water flow during construction Could allow for winter construction
<i>Disadvantages</i>	Requires large excavation and roadway protection. Requires water flow realignment or installation of a temporary by-pass culvert to maintain existing water flow alignment Disruption to traffic	Requires construction of entry and exit pits and access to toes of slope. Requires specialised construction equipment. Feasibility also depends on flow capacity and other hydraulic properties. Presence of occasional to frequent cobbles and boulders as well as wood fragments in the tunnel zone	Requires deeper excavation increasing excavation volume and dewatering concern. Requires roadway protection. Disruption to traffic	Quantity and cost of sheet piles Presence of occasional to frequent cobbles and boulders as well as wood fragments in the fill and till
<i>Risks/ Consequences</i>		Obstructions		Obstructions and varying refusal depths
<i>Relative Cost</i>	Low to Medium	Medium to High	Medium	<i>Medium to High</i>
<i>Recommendation</i>	Recommended	Not Recommended	Not Recommended	<i>Not Feasible</i>



Appendix F.

GSC 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 05, 2018

Site: 45.0048 N, 79.0333 W User File Reference: Site 18 250

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)
0.087	0.121	0.120	0.105	0.087	0.053	0.028	0.0070	0.0031	0.070	0.073

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)	0.013	0.037	0.055
Sa(0.1)	0.020	0.054	0.080
Sa(0.2)	0.022	0.056	0.081
Sa(0.3)	0.020	0.049	0.071
Sa(0.5)	0.015	0.041	0.059
Sa(1.0)	0.0077	0.024	0.035
Sa(2.0)	0.0033	0.012	0.018
Sa(5.0)	0.0007	0.0026	0.0042
Sa(10.0)	0.0005	0.0012	0.0018
PGA	0.011	0.031	0.046
PGV	0.0094	0.030	0.046

References

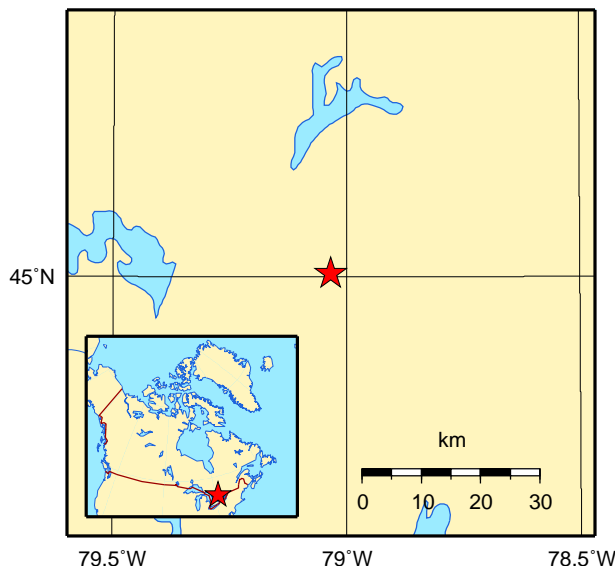
National Building Code of Canada 2015 NRCC no. 56190;
Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

User's Guide - NBC 2015, Structural Commentaries NRCC no. 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





Appendix G.

List of Special Provisions and OPSS Documents Referenced in this Report



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

OPSS.PROV 206	Construction Specification for Grading
OPSS.PROV 209	Construction Specification for Embankments over Swamps and Compressible Soils
OPSS.PROV 401	Construction Specification for Trenching, Backfilling, and Compacting
OPSS 421	Construction Specification for Pipe Culvert Installation in Open Cut
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts in Open Cuts
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 517	Construction Specification for Dewatering
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.PROV 1010	Material Specification for Aggregates Base, Subbase, Select Subgrade, and Backfill Material
OPSS.PROV 1205	Material Specification for Clay Seal
OPSS 1860	Material Specification for Geotextile
OPSD 208.010	Benching of Earth Slopes
OPSD 802.010	Flexible Pipe Embedment and Backfill Earth Excavation
OPSD 803.010	Backfill and Cover for Concrete Culverts with Span Less than or Equal to 3.0 m
OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
OPSD 3090.101	Foundation Frost Penetration Depths for Southern Ontario
SP 517F01	Design Storm Return Period and Preconstruction Survey
NSSP FOUN0003	Dewatering Structure Excavations



2. Suggested text for a NSSP on “Obstructions”

The Contractor is advised that cobbles and boulders are present within the existing embankment fill and the underlying glacial till. These materials may impact excavation as well as the installation of sheet piles to the required depths. The Contractor shall design the temporary works accordingly and/or be prepared to remove, drill through and/or penetrate these obstructions and extend the work to the design depths.