THURBER ENGINEERING LTD.

FINAL

FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 118 CULVERT STA. 18+550, DRAPER TOWNSHIP
ASSIGNMENT NO. 5017-E-0003
G.W.P. 5287-14-00

Geocres No.: 31E-400

Report to:

McIntosh Perry Consulting Engineers Limited

Latitude: 44.991287
Longitude: -79.197889

August 2019
Thurber File No.: 20244

TABLE OF CONTENTS

APPENDICES

THURBER

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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+550 on Highway 118. The culvert crossing is located approximately 0.2 km west of River Road within Draper Township in the District of Muskoka. Thurber Engineering Limited (Thurber) carried out the 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 drawing was provided by MPCE.

2 SITE DESCRIPTION

For project purposes, Highway 118 will be considered to be oriented east-west with chainage increasing to the east. The existing culvert conveys (unnamed) creek flow from the south to the north under a high fill embankment supporting Highway 118. As shown on the historical base plan drawings provided by MPCE, the existing culvert is a non-structural corrugated steel pipe (CSP) culvert with a diameter of 0.8 m and a length of 33.1 m. The invert of the culvert was surveyed at- approximate elevation of 307.8 and 306.9 m at the inlet (south) and outlet (north), 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.

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 312.8 m. The existing embankment slopes are inclined at approximately 2.4H:1V. A vertical curve in the highway profile exists west of the culvert. Cable guidewires with wooden posts are present on both sides of the highway in the vicinity of the culvert. The land adjacent to the highway and creek alignment is densely vegetated with shrubs and trees. Bedrock outcrops are present to the west of the site on the south side of the highway. Single family dwellings are located approximately 150 m west and 100 m east of the culvert. A dam with a spillway is present at Matthiasville Falls, located approximately 400 m northwest of the culvert. Overhead utility lines run parallel to the highway immediately south of Highway 118. Traffic volumes on this section of Highway 118 are understood to be 4,300 AADT (2016).

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 between September 17th and 23rd, 2018. 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 Benchmark MTCBM 828005 (elev. 314.169 m) shown on the historical baseplan drawing 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 Below Ground Surface (m)
18-1	Near Culvert Outlet	4 983 533.6	328 612.5	307.5	5.6
18-2	Westbound Lane HWY 118	4 983 521.4	328 619.1	312.8	10.1
18-3	Eastbound Lane HWY 118	4 983 515.5	328 623.1	312.7	10.7
18-4	Near Culvert Inlet	4 983 502.8	328 628.7	307.8	5.3

Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) following ASTM D1586. A half-weight (32 kg) hammer was used during SPT testing in Boreholes 18-1 and 18-4, which were drilled with portable equipment. The N-values reported herein for these off road boreholes have been corrected to an equivalent standard weight hammer (64 kg). Testing in the on road boreholes was carried out with a standard weight hammer and no correction was necessary. Boreholes 18-1 through 18-4 were advanced into bedrock with either NW or NWT 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 18-1 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 and submitted for analytical testing of corrosivity parameters. Select rock core samples were submitted for unconfined compression strength testing. All laboratory test results are provided in Appendix C.

5 GENERAL 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 governs any 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 sandy silt to silty sand over glacial till. Granite bedrock was encountered at relatively shallow depth in all boreholes.

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 at ground surface with a thickness of 100 mm.

5.1.2 Fill: Sand

Below the surficial asphalt in Boreholes 18-2 and 18-3 was a layer of fill consisting of sand with gravel to sand with silt and varying amounts of gravel. Frequent cobbles and boulders were encountered below a depth of 3.0 m (elev. 309.8 m). Coring techniques were required to advance through the cobbles and boulders below elevation 308.6 m. The underside of this fill was at 5.3 and 5.7 m below the existing roadway surface (elev. 307.5 and 307.0 m) in Boreholes 18-2 and 18-3, respectively.

The SPT tests conducted in the sand with silt fill gave N-values ranging from 4 to 61 blows, indicating a varying relative density of loose to very dense.

Recorded moisture contents ranged from 7 to 18%. The results of grain size analyses conducted on three samples of the sand fill are summarized in in the table below and are illustrated on Figure C1 in Appendix C.

Soil Particle	Percentage (%)
Gravel	9 – 33
Sand	66 – 82
Silt	1 – 10
Clay	

5.2 Sandy Silt (ML) to Silt (ML) with Sand

A native deposit of silt with sand to sandy silt was encountered at ground surface in off-road Boreholes 18-1 and 18-4 and below the fill in Borehole 18-2 with thicknesses ranging from 1.2 to 1.6 m. The underside of the silt ranged in elevation from 305.9 to 306.6 m. Gravel, cobbles, and boulders were noted in the sandy silt in Borehole 18-2 and some organics were encountered in the upper 0.6 m of the silt in Borehole 18-4.

SPT tests conducted this layer gave N-values ranging from 2 to 7 blows indicating a relative density of very loose to loose. Refusal blow counts were also encountered within the layer on probable cobbles.

Recorded moisture contents of the silt typically ranged from 15 to 32%. A moisture content of 42% was recorded in a sample containing organics from within Borehole 18-4. The results of grain size analyses conducted on three samples of the silt are summarized in **Error! Reference source not found.** and are illustrated on Figure C2 in Appendix C.

Soil Particle	Percentage (%)
Gravel	0 – 11
Sand	23 – 33
Silt	52 – 71
Clay	4 – 7

Atterberg Limit tests were completed on three samples of the deposit and indicated that the material is non-plastic.

5.3 Silty Sand (SM) – (Glacial Till)

A deposit of glacial till consisting of silty sand was encountered below the silt in Boreholes 18-1 and 18-4 and below the fill in Borehole 18-3. Frequent cobbles and boulders were encountered throughout the till deposit in Boreholes 18-1 and 18-4 and coring techniques

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were required to advance the borehole. The thickness of this layer ranged from 0.6 to 1.0 m with underside elevations ranging from 305.4 to 306.0 m.

The SPT tests conducted in this layer gave N-values ranging from 9 to 44 blows, indicating a relative density of loose to dense. Refusal blow counts were also encountered within the layer on probable cobbles.

Recorded moisture contents ranged from 12 to 29%. The results of a grain size analysis conducted on one sample of the till indicated this material to consist of 3% gravel, 59% sand, 33% silt and 5% clay. These results are illustrated on Figure C3 in Appendix C.An Atterberg Limit test was completed on one sample of the till and indicated that the material is non-plastic.

5.4 Bedrock

Bedrock was proven by coring in Boreholes 18-1 through 18-4. Information on the bedrock surface is summarized in Table 5-1.

Table 5-1: Summary of Bedrock Elevations

Borehole No.	Depth to Bedrock below Existing Ground Surface (m)	Bedrock Elevation (m)
18-1	2.1	305.4
18-2	6.9	305.9
18-3	6.7	306.0
18-4	2.2	305.6

The bedrock consisted of slightly weathered to fresh granite. The Total Core Recovery (TCR) measured on the recovered bedrock core ranged from 85 to 100%, the Solid Core Recovery (SCR) ranged from 63 to 100% and the Rock Quality Designation (RQD) ranged from 38 to 100%. Based on the measured RQD values, the bedrock is typically classified as very poor to excellent quality(Table 3.10, Canadian Foundation and Engineering Manual 2006). The surface of the bedrock in Borehole 18-3 was poor quality

Unconfined Compressive Strength (UCS) testing was carried out on two samples of the intact bedrock. UCS test results of 115 and 141 MPa were obtained, indicating the intact granite bedrock to be very strong. Photographs of the bedrock core are provided in Appendix C.

5.5 Groundwater

Representative water levels were not obtained in the open boreholes due to water being introduced as part of the coring operations. The groundwater water level measured in the standpipe piezometer installed within the bedrock in Borehole 18-1 was recorded at a depth of 3.6 m below the ground surface (elev. 303.9 m) on September 24, 2018. The culvert was dry at the time of the field investigation.

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.

5.6 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 Table 5-2. 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)	1.2 – 1.4	10	7.47	2,880	347	211	< 0.02
18-4 (SS4)	0.6 – 1.2	21	5.65	8,510	117	55	< 0.02

6 MISCELLANEOUS

Borehole locations were selected by Thurber relative to existing site features and the existing culvert location. The as-drilled locations and ground surface elevation of the boreholes were measured by Thurber following completion of the field program. Survey 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 borehole decommissioning. NC Traffic of Kirkland Lake, Ontario supplied the traffic control equipment and personnel for lane and shoulder closures required for the field. 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 program was provided by Ms. Katya Edney, P.Eng.

Routine geotechnical laboratory testing was completed by Thurber's laboratory in Ottawa, Ontario. UCS testing was completed by Stantec'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 Allison Chow, EIT, 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+550. 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 (unnamed) creek flow from the south to the north under a high fill embankment supporting Highway 118. As shown on the historical baseplan drawings provided by MPCE, the existing culvert is a non-structural corrugated steel pipe (CSP) culvert with a diameter of 0.8 m and a length of 33.1 m. The invert of the culvert was surveyed at- approximate elevation of 307.8 and 306.9 m at the inlet (south) and outlet (north), respectively. The Highway 118 fill height above the culvert is approximately 4.5 m with the road surface at approximate elevation 312.8 m. The existing embankment slopes are inclined at approximately 2.4H:1V. Groundwater was measured at an elevation of 303.9 m on September 24, 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 4.5 m. As per the Culvert Reinstatement Typicals 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, the 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, would be 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 online calculator. The data includes a peak ground acceleration (PGA), peak ground velocity (PGV) and the 5% spectral response acceleration values (Sa(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 0.068g. This value is to be scaled by the F(PGA) based on the site-specific Site Class, as discussed below.

8.2 Seismic Liquefaction Potential

Based on the depth of ground water, 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. Some local slope instability may be noted at the culvert inlet and outlet for a design seismic event during period of higher water levels and these should be readily repairable.

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:

- <u>Circular Pipes (Concrete, HDPE, Steel)</u>
  From a foundation engineering perspective, a pipe culvert is a technically feasible alternative. It is assumed that an internal pipe diameter of similar size to the existing or greater is likely to be proposed.
- <u>Open Bottom Culvert (Box)</u>
  An open bottom culvert bearing on till or bedrock is considered feasible from a foundation engineering perspective but is not recommended for this site due to the size of the anticipated replacement culvert and the requirement for greater excavation depths during construction
- <u>Closed Bottom Culvert (Box)</u>
  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 silt founding soils during installation.
- <u>Steel Sheet Pile Walls with Precast Concrete Slab</u>
  Sheet pile walls supporting precast concrete slabs are not considered feasible due to shallow bedrock and presence of cobbles and boulders.

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 located north of Highway 118 alignment or the utilities may need to be relocated. Bedrock outcrops are present in close proximity to the culvert and rock excavation may be required if the highway alignment is adjusted. 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 soil deposits during the design and installation of the roadway protection. The bedrock is relatively shallow at this site. To reduce lateral deflections of the protection system, the roadway protection may need to include an anchoring and/or bracing system or socketing into shallow bedrock. The TPS would need to support a temporary embankment height in the order of 5 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 5.1 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 would be required at the temporary abutment locations for the TMB to provide foundation design recommendations. The design length of the TMB must consider the need for stable temporary excavation slopes and a horizontal offset between the TMB footings and the crests of the temporary slopes.

- Trenchless Techniques

  A trenchless installation would likely encounter loose to dense sand fill with gravel, cobbles and boulders over very loose to loose sandy silt and silt with sand. Groundwater was observed below the pipe invert. It is highly likely that cobbles and boulders will be encountered in the embankment fill. Given the conditions, microtunneling would likely be the preferred trenchless approach, however, the presence of cobbles and boulders could 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 presence of shallow bedrock, the lateral capacity available in the native soils at this site and the need to anchor or brace the TPS. Obstructions are likely to be encountered in the embankment fill and in the native soils. Temporary grade lowering could be considered to reduce the height of the TPS.

10 FOUNDATION DESIGN RECOMMENDATIONS

Foundation design aspects for the replacement culvert include 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 up to 2 m wide with a 0.2 m thick base slab and installed with invert elevations similar to the current culvert (approximate elev. 307.3 m at the outlet) on an undisturbed native silt subgrade are as follows:

- Factored Geotechnical Resistance at ULS of 250 kPa
- Factored Geotechnical Resistance at SLS of 150kPa

Lower resistance values are available near the inlet and outlet due to the presence of loose silt and sand, however, the loads at these locations are also significantly lower and will not govern the design.

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):
  - ϕ_{gu} = 0.5 (static analysis; typical degree of understanding)
  - ϕ_{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 is expected to be less than 25 mm for subgrades prepared with good workmanship. If required, higher bearing resistances could be achieved by subexcavating the silt and constructing the culvert on a pad of Granular A.

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 0.8 (as per CHBDC Table 6.2) 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/m^3 can be used for a pipe culvert installed at this site, if required.

10.2 Subgrade Preparation, Bedding and Backfilling

For a replacement culvert constructed along the same alignment as the current culvert, the existing culvert and bedding materials should be removed. 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 silt subgrade anticipated at the founding level in the areas near the inlet and outlet of the replacement culvert, construction equipment should not travel on the exposed final subgrade. If the new culvert is to be installed adjacent to the existing culvert, the excavation should not undermine the existing culvert when used as a temporary by-pass culvert.

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).

The compaction of granular bedding directly above the loose silt subgrade may result in disturbance of the material with pumping of fines into the granular bedding and difficulty achieving the specified degree of compaction. Protection of the subgrade should include installation of Class II non-woven geotextile with a maximum FOS of 150 μm (OPSS 1860) installed beneath the Granular layer. The geotextile should have overlapping joints and be placed as soon as possible after reaching the subgrade level and following receipt of written notice to proceed in accordance with SP 109S12.

It is noted that the culvert was dry at the time of drilling, however, construction will extend below the ditch elevation and seasonal fluctuations of water level may occur. Water diversion and dewatering may 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 or Select Subgrade Material (SSM) 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 above the granular cover should meet the requirements of OPSS Granular B Type I or SSM and constructed in accordance with OPSS.PROV. 401.

10.3 Frost Depth

The depth of frost penetration at this site is 1.8 m (as per 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. The inclusion of wing walls would require a foundation founded below frost depth.

10.4 Lateral Earth Pressures

The lateral earth pressure parameters provided in Table 10-1 and Table 10-2 are based on the assumptions that the 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.

10.4.1 Static Lateral Earth Pressure Coefficients

Lateral earth pressures acting on structures should be computed in accordance with the CHBDC but under fully drained conditions, are given by the following general 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 the table below.

Table 10-1. Earth Pressure Coefficients

Condition	Earth Pressure Coefficient					
	OPSS Granular A or Granular B Type II ϕ = 35° γ = 22.8 kN/m^3		OPSS Granular B Type I ϕ = 32° γ = 21.2 kN/m^3		OPSS SSM and Existing Sand Fill ϕ = 30° γ = 20.0 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, at-rest/non-yielding horizontal earth pressures should 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 = ½ * 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 0.068g (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 $\phi = 35^o$, $\gamma = 22.8$ kN/m^3		OPSS Granular B Type I $\phi = 32^o$, $\gamma = 21.2$ 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	0.29	0.45	0.33	0.55
Active, K_{AE} Non-Yielding Wall	0.32	0.53	0.36	0.71

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 or SSM. 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 with a variety of plants 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 during and following fill placement.

Provided no grade raise or embankment widening is required and proper construction methods are used, no 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/settlement implications are the responsibility of the Contractor. The selection and placement of construction equipment (such as heavy cranes) are 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 5.6

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. very loose to loose native silt and native soils below the groundwater level and 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 silt and 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, the excavations will 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:

<u>SILT</u>

γ = 18 kN/m^3 (use submerged unit weight below groundwater level)

K_A = 0.38

K_P = 2.7

GLACIAL TILL:

γ	=	19 kN/m^3 (use submerged unit weight below groundwater level)
K_A	=	0.33
K_P	=	3.0

If needed, the ultimate passive resistance force that can be mobilized by the embedded portion of a socket within the granite bedrock is as follows:

$P_{P(ult)}$ = (1+1.4*z/D)*c*D*L (kN) for ≤3D

$P_{P(ult)}$ = 5*c*D*L (kN) for >3D

where z = depth of socket below rock surface (m)

D = socket diameter (m)

c = 2.0 MPa (equivalent rock mass strength within rock socket based on Hoek and Brown classification).

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. Bedrock is shallow at this site and the design of roadway protection must consider this issue. A suggested NSSP to alert the Contractor is provided in Appendix G. 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.

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

The culvert was dry at the time of the borehole investigations. The groundwater water level measured in the standpipe piezometer installed within the bedrock in Borehole 18-1 was recorded at an elevation of 303.9 m which is deeper than the culvert invert. However, this was a short term reading and the water level is expected to fluctuate. Accordingly, creek diversion may be required as the depth of excavation will extend below the ditch 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 NSSP FOUN0003 which amends OPSS 902. A preconstruction survey is not required, thus Designer Fill-In ** in NSSP FOUN0003 should be “N/A”.

For pipe culverts, the dewatering system is to be designed in accordance with OPSS.PROV 517 and SP517F01. The hydrogeology is not considered to be complex at this site, thus Designer Fill-In ***** in SP517F01 should be “No”. A preconstruction survey is not required, thus Designer Fill-In ****** in this SP should be “N/A”.

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 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. Sheet pile cofferdams would be difficult to install at this site due to the presence of cobbles and boulders and the presence of shallow bedrock.

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. 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.

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 to medium susceptibility to erosion as per the Wischmeier Nomograph. The native soils are considered to have high 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 for a box culvert 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 piles
- 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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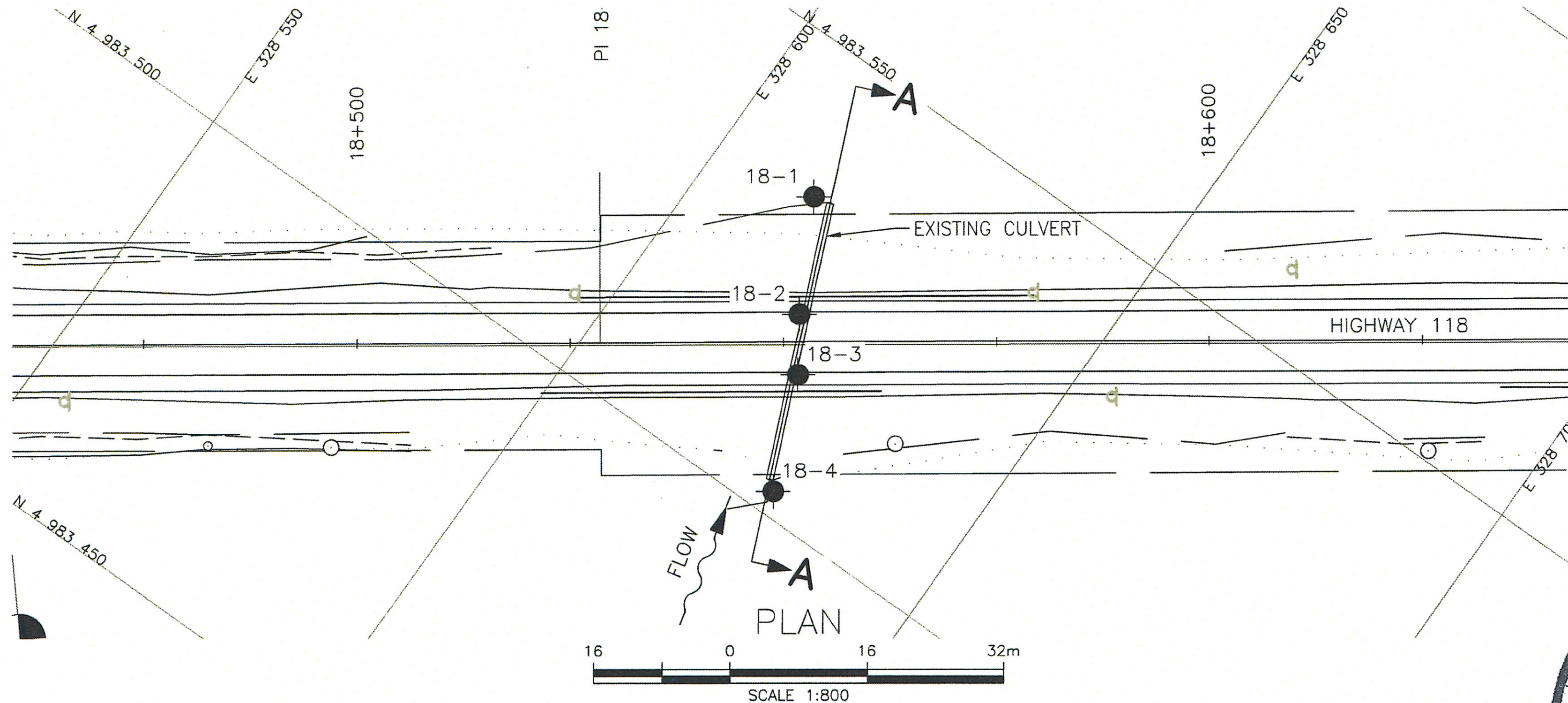
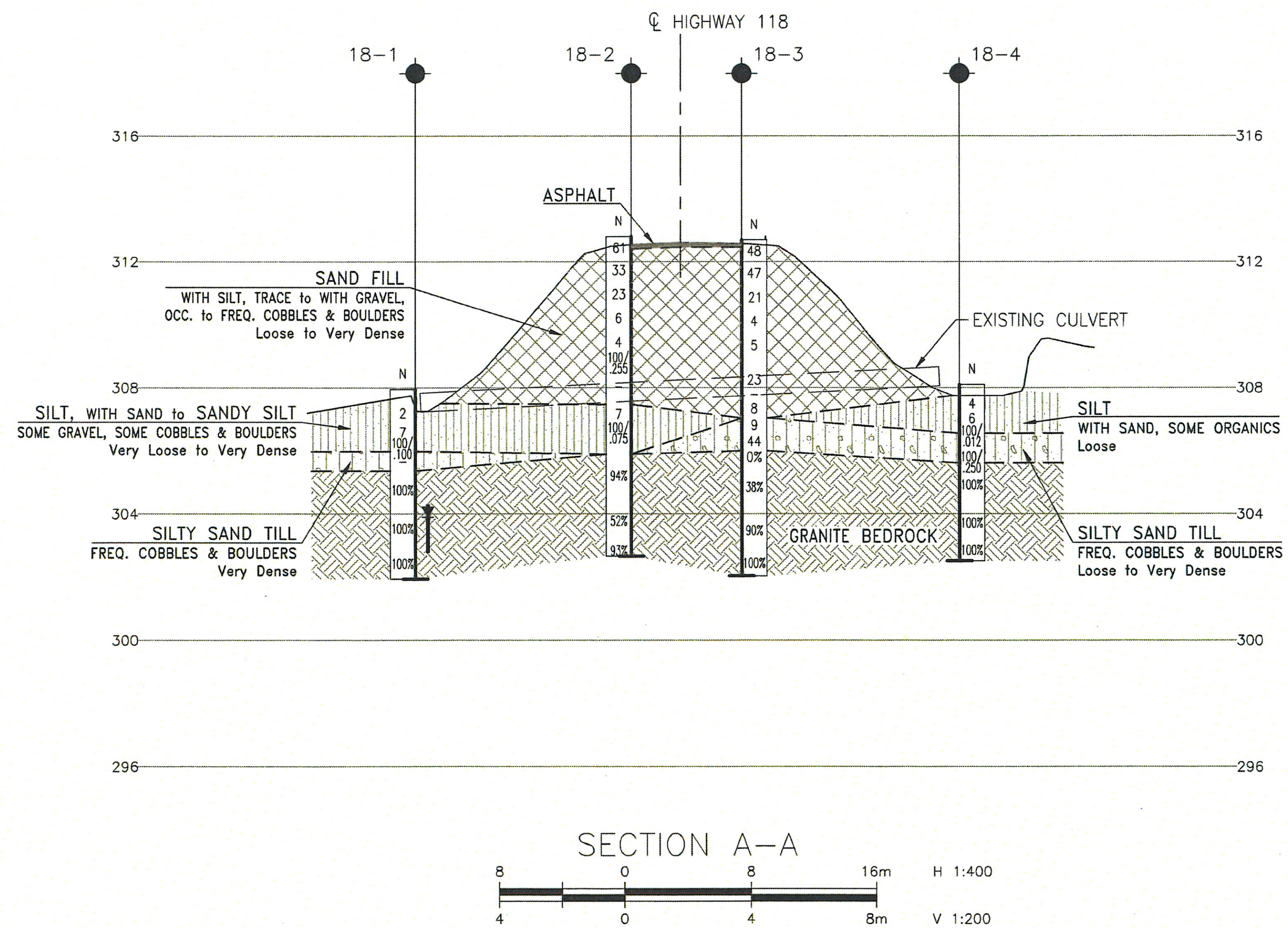
THURBER

Appendix A.

Borehole Location Plan and Stratigraphic Drawing





METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

LICENSED PROFESSIONAL ENGINEER
F. J. GRIFFITHS
90360280
Aug 26/19
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
Aug 26/19
PROVINCE OF ONTARIO

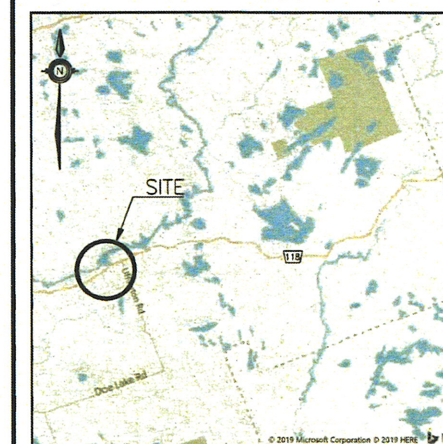
CONT No
GWP No 5287–14–00

HIGHWAY 118
STATION 18+550
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
▽	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
18–1	307.5	4 983 533.6	328 612.5
18–2	312.8	4 983 521.4	328 619.1
18–3	312.7	4 983 515.5	328 623.1
18–4	307.8	4 983 502.8	328 628.7

-NOTES-

1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
3) Coordinate system is MTM NAD 83 Zone 10.

GEOCRES No. 31E-400

REVISIONS	DATE	BY	DESCRIPTION

DESIGN KE	CHK SP	CODE	LOAD	DATE APR 2019
DRAWN MFA	CHK KE	SITE	STRUCT	DWG

FILENAME: H:\Drafting\20000\20244\TED-20244-BHPP-CVS.dwg
PLOTDATE: 8/20/2019 12:45 PM

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Appendix B.

Record of Borehole Sheets

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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.

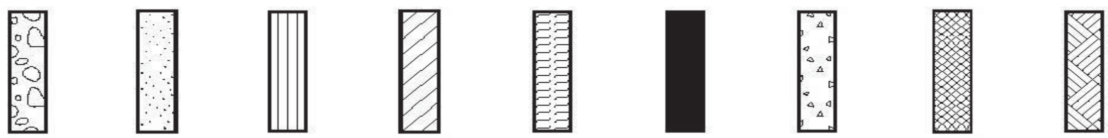
N-VALUE:

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

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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

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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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 18-1

METRIC

GWP# 5287-14-00 | LOCATION Lat: 44.991391°, Long: -79.198005° St. 18+550 N 4 983 533.6 E 328 612.5 | ORIGINATED BY SOB

HWY 118 | BOREHOLE TYPE Portable NWT Coring | COMPILED BY AC

DATUM Geodetic | DATE 23.09.2018 - 23.09.2018 | CHECKED BY KE

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
308.0 / 0.0	STAND					
307.5 / 0.5	**SILT (ML)** with sand, very loose to dense, brown	1	SS	2		
		2	SS	7		0 23 71 6 non-plastic
		3	SS	100/ 100 mm		
306.0 / 2.0	**SILTY SAND TILL** frequent cobbles and boulders, very dense, brown	4	NQ	-	FI	
305.4 / 2.6	**BEDROCK** GRANITE, fresh, coarse grained, very strong, grey and black	1	RUN		0, 0, 0, 0	RUN #1 TCR=100% SCR=100% RQD=100%
		2	RUN		1, 0, 1, 0	RUN #2 TCR=100% SCR=100% RQD=100%
		3	RUN		0, 0, 0	RUN #3 TCR=100% SCR=100% RQD=100%
301.9 / 6.0	End of Borehole					

Elevation scale: 307, 306, 305, 304 (water level ▼), 303, 302

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

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.

Water level in 19 mm diameter standpipe:
23/09/2018 at 0.0 mbgs (el. 307.5 m)
24/09/2018 at 3.6 mbgs (el. 303.9 m)

+³, ×³: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 18-2

METRIC

GWP#	5287-14-00	LOCATION	Lat: 44.991281°, Long: -79.197922° St. 18+550 N 4 983 521.4 E 328 619.1	ORIGINATED BY	AC
HWY	118	BOREHOLE TYPE	NW Washboring	COMPILED BY	AC
DATUM	Geodetic	DATE	17.09.2018 - 17.09.2018	CHECKED BY	KE

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT / FI	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
312.8								
0.0	**ASPHALT** (100 mm)							
0.1	SAND with silt and gravel, loose to very dense, grey to brown, **FILL**	1	SS	61		○		19 71 10 (SI+CL)
		2	SS	33	312	○		
		3	SS	23	311	○		
		4	SS	6	310	○		
309.8 / 3.0	SAND with gravel, cobbles and boulders, loose to very dense, brown, **FILL**	5	SS	4		○		33 66 1 (SI+CL)
		6	SS	100/ 255 mm	309	○		
		7	NQ	-	308			
307.5 / 5.3	**SANDY SILT (ML)** some gravel, cobbles and boulders, loose to very dense, brown	8	SS	7	307	○		11 33 52 4 non-plastic
		9	SS	100/ 75 mm				
305.9 / 6.9	**BEDROCK** GRANITE, slightly weathered to fresh, medium grained, very strong, grey with black and pink	1	RUN		306, 305		FI: 0, 1, 0, 1	RUN #1 TCR=94% SCR=94% RQD=94% UCS=115.0MPa
	vertical fracture from 9.3 to 9.8 m	2	RUN		304		5, 3, 0, 1	RUN #2 TCR=98% SCR=63% RQD=52%
		3	RUN		303		2, 2	RUN #3 TCR=100% SCR=100% RQD=93%

Chart headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; GROUND WATER CONDITIONS; STRAT PLOT.

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

DOUBLE LINE ST 18+550.GPJ 2012TEMPLATE(MTO).GDT 23/8/19

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 18-2

METRIC

GWP# 5287-14-00

LOCATION Lat: 44.991281°, Long: -79.197922° St. 18+550 N 4 983 521.4 E 328 619.1

ORIGINATED BY AC

HWY 118

BOREHOLE TYPE NW Washboring

COMPILED BY AC

DATUM Geodetic

DATE 17.09.2018 - 17.09.2018

CHECKED BY KE

ELEV / DEPTH	SOIL PROFILE: DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE) 20 40 60 80 100	PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
302.7 10.1	**BEDROCK** GRANITE										
	End of Borehole										

+ ³, × ³: Numbers refer to Sensitivity

15 ⊕ 5 (20 above, 10 below) (%) STRAIN AT FAILURE

DOUBLE LINE ST 18+550.GPJ 2012TEMPLATE(MTO).GDT 23/8/19

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 18-3

METRIC

GWP# 5287-14-00	LOCATION Lat: 44.991228°, Long: -79.197872° St. 18+550 N 4 983 515.5 E 328 623.1	ORIGINATED BY AC
HWY 118	BOREHOLE TYPE NW Washboring	COMPILED BY AC
DATUM Geodetic	DATE 19.09.2018 - 19.09.2018	CHECKED BY KE

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
312.7						
0.0 / 0.1	**ASPHALT** (100 mm)					
	SAND with silt trace gravel occasional to frequent cobbles and boulders, loose to dense, grey-brown to brown, **FILL**	1	SS	48		
					312	
		2	SS	47		9 82 9 (SI+CL)
					311	
		3	SS	21		
		4	SS	4	310	
		5	SS	5		
					309	
		6	SS	23		
					308	
	frequent cobbles and boulders below 4.8 m	7	NQ	-		
		8	SS	8		
307.0 / 5.7	**SILTY SAND (SM) TILL**, loose to dense, grey-brown to red-brown	9	SS	9	307	
		10	SS	44		3 59 33 5 non-plastic
306.0 / 6.7	**BEDROCK** GRANITE, slightly weathered to fresh, medium to coarse grained, very strong, grey with pink, vertical fracture from 6.7 to 7.0 m	1	RUN		306	RUN #1 TCR=100% SCR=0% RQD=0%
		2	RUN		305	RUN #2 TCR=85% SCR=63% RQD=38%
		3	RUN		304	RUN #3 TCR=98% SCR=90% RQD=90%
					303	

FI: >10, >10, 7, 6, 0, 1, 1, 0, 0, 1, 1

Chart headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE, 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; GROUND WATER CONDITIONS; STRAT PLOT; UNIT WEIGHT γ kN/m^3

Continued Next Page

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

RECORD OF BOREHOLE No 18-3

METRIC

GWP# 5287-14-00
LOCATION Lat: 44.991228°, Long: -79.197872°
St. 18+550 N 4 983 515.5 E 328 623.1
ORIGINATED BY AC
HWY 118
BOREHOLE TYPE NW Washboring
COMPILED BY AC
DATUM Geodetic
DATE 19.09.2018 - 19.09.2018
CHECKED BY KE

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
302.0 10.7	**BEDROCK** GRANITE fresh to slightly weathered medium to coarse grained very strong grey with pink		4	RUN						0 0	RUN #4 TCR=100% SCR=100% RQD=100%
	End of Borehole										

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 / 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-4

METRIC

GWP# 5287-14-00	LOCATION Lat: 44.991113°, Long: -79.197801° St. 18+550 N 4 983 502.8 E 328 628.7	ORIGINATED BY SOB
HWY 118	BOREHOLE TYPE Portable NWT Coring	COMPILED BY AC
DATUM Geodetic	DATE 22.09.2018 - 22.09.2018	CHECKED BY KE

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
308.1 / 0.0	STAND				308			
307.8 / 0.3	**SILT (ML)** with sand, some organics, loose, dark brown	1	SS	4		~40		0 26 67 7 non-plastic
307.2 / 0.9	**SILT (ML)** with sand, loose, brown	2	SS	6	307	~35		
306.6 / 1.5	**SILTY SAND TILL** frequent cobbles and boulders, very dense, brown	3	SS	100/ 12 mm				
		4	NQ	-	306			
		5	SS	100/ 250 mm		~15	FI	
305.6 / 2.5	**BEDROCK** GRANITE fresh coarse grained very strong grey and pink	1	RUN		305		0, 0, 0, 0, 3	RUN #1 TCR=100% SCR=100% RQD=100% UCS=141.6MPa
		2	RUN		304		2, 0, 0	RUN #2 TCR=100% SCR=100% RQD=100%
		3	RUN		303		0, 1	RUN #3 TCR=100% SCR=100% RQD=100%
302.5 / 5.6	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.

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; GROUND WATER CONDITIONS; STRAT PLOT.

+ 3, × 3 : Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

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Appendix C.

Laboratory Testing

THURBER

Appendix C.1

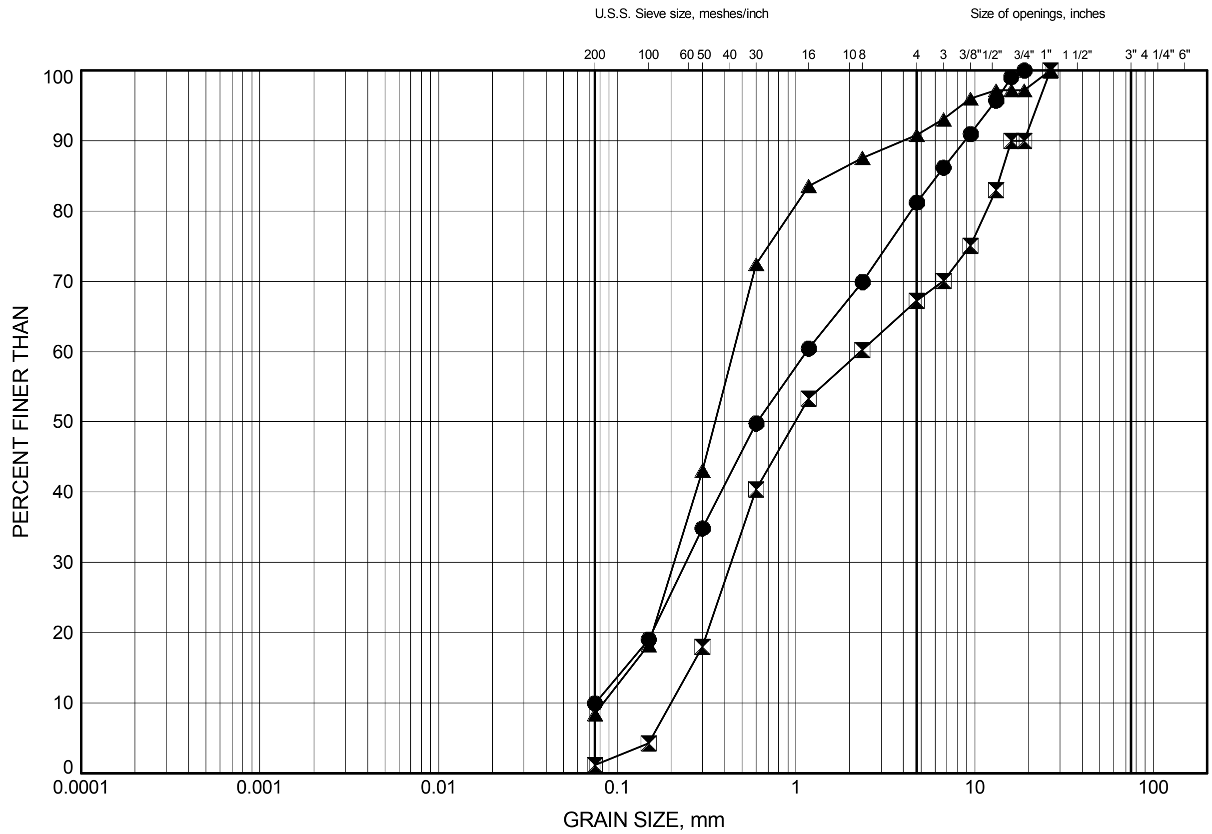
Particle Size Analysis Figures

HWY 118 Culverts Station 18+550

GRAIN SIZE DISTRIBUTION

FIGURE C1

FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18-2	0.4	312.4
⧗	18-2	3.4	309.4
▲	18-3	1.1	311.6

Date October 2018

GWP# 5287-14-00

THURBER

Prep'd AC

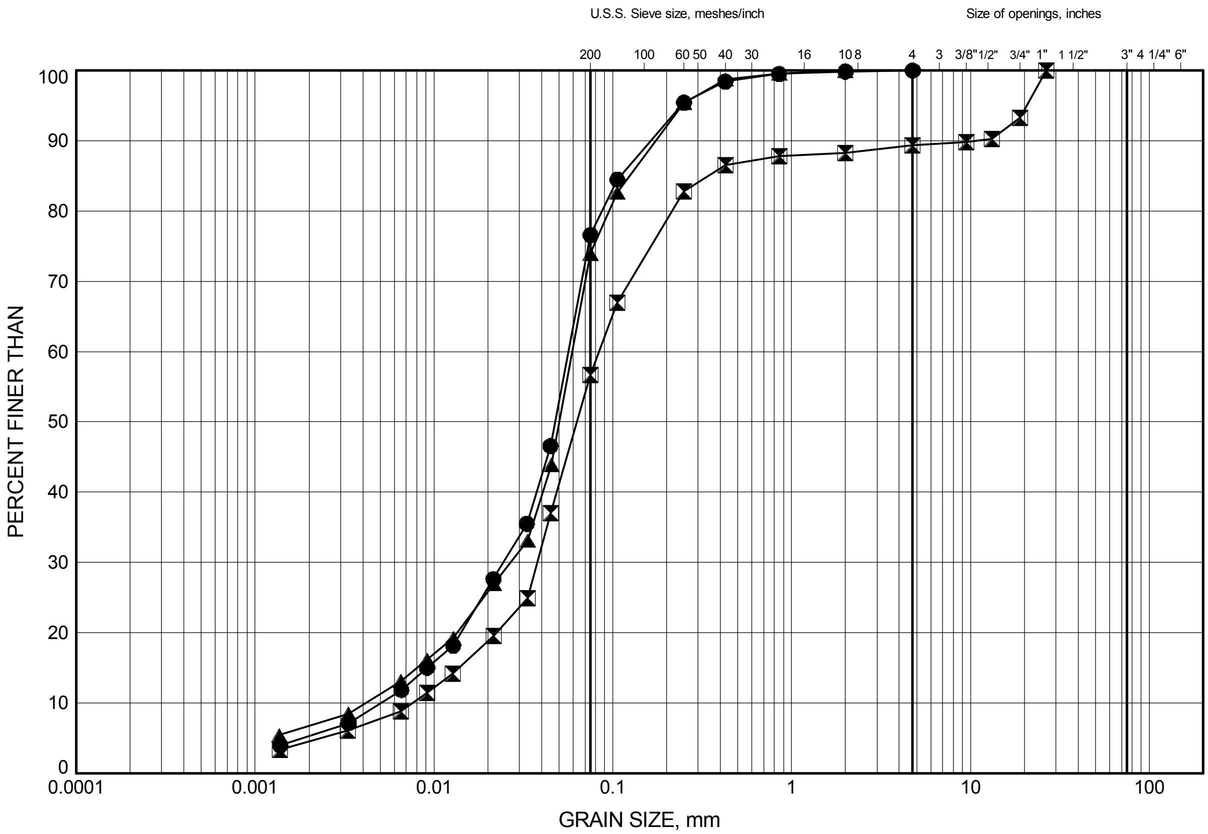
Chkd. KE

HWY 118 Culverts Station 18+550

GRAIN SIZE DISTRIBUTION

FIGURE C2

SANDY SILT (ML) to SILT (ML) with sand



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	306.6
⧗	18-2	5.6	307.2
▲	18-4	0.3	307.5

Date October 2018

GWP# 5287-14-00

THURBER

Prep'd AC

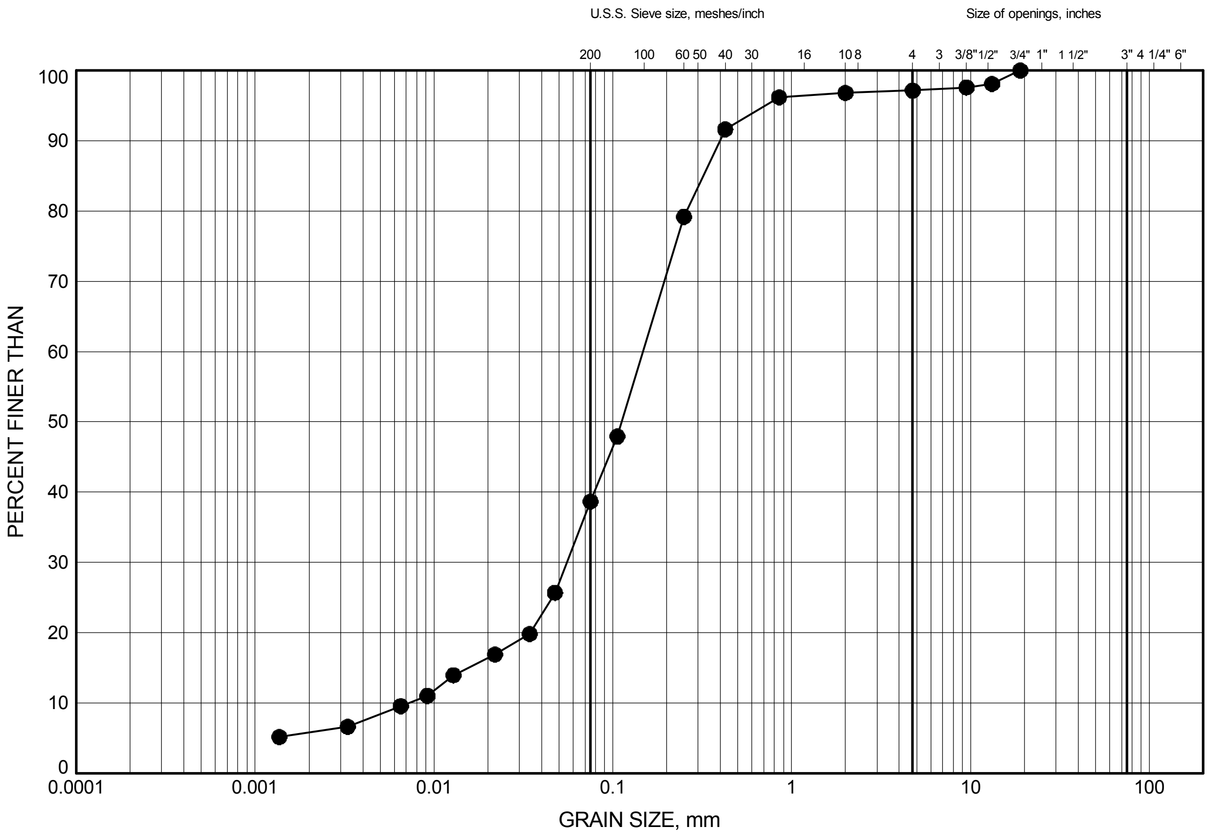
Chkd. KE

HWY 118 Culverts Station 18+550

GRAIN SIZE DISTRIBUTION

FIGURE C3

SILTY SAND (SM) (TILL)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18-3	6.4	306.3

Date October 2018

GWP# 5287-14-00

THURBER

Prep'd AC

Chkd. KE

GRAIN SIZE DISTRIBUTION - THURBER ST 18+550.GPJ 24/10/18

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Appendix C.2

Rock Core Photos

Rock Core Testing Results

Borehole 18-1

Run 1 to 3 (of 3)

Elevation 305.4 m to 301.9 m

THURBER ENGINEERING LTD.	**Foundation Investigation** **Hwy 118 Culverts St. 18+550** **Foundations**	**GWP: 5287-14-00** **Project No.: 20244**

Borehole 18-2
Run 1 to 3 (of 3)
Elevation 305.9 m to 302.7 m

THURBER ENGINEERING LTD.

Foundation Investigation
Hwy 118 Culverts St. 18+550
Foundations

GWP: 5287-14-00

Project No.: 20244

Borehole 18-3
Run 1 to 4 (of 4)
Elevation 306.0 m to 302.0 m

THURBER ENGINEERING LTD.

Foundation Investigation
Hwy 118 Culverts St. 18+550
Foundations

GWP: 5287-14-00

Project No.: 20244

Borehole 18-4

Run 1 to 3 (of 3)

Elevation 305.6 m to 302.5 m

THURBER ENGINEERING LTD.	**Foundation Investigation** **Hwy 118 Culverts St. 18+550** **Foundations**	**GWP: 5287-14-00** **Project No.: 20244**

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

October 17, 2018
File: 122410864

Attention: **Thurber Engineering Ltd., File #20244**

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

The table below summarizes five (5) rock core unconfined compressive strength results.

Location	Sample Depth	Compressive Strength (MPa)	Description of Break
18+550, 18-2 Run-1	26'1"-27'1"	115.0	Diagonal Fracture with no cracking through ends
18+550, 18-4 Run-1	11'6"-12'1"	141.6	Well-formed cone on one end. Vertical crack, no well-defined cone on the other end
18+875, 18-1 Run-2	7'7"-8'1"	127.8	Well-formed cone on one end. Vertical crack, no well-defined cone on the other end
18+875, 18-4 Run-1	7'2"-7'9"	76.2	Columnar vertical crack through both ends, no well-defined cones
11+490, 18-1 Run-2	23';7"-24'3"	88.4	Columnar vertical crack through both ends, no well-defined cones

Sincerely,

Stantec Consulting Ltd

Brian Prevost

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

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Appendix C.3

Analytical Testing Results

PARACEL LABORATORIES LTD. | TRUSTED. RESPONSIVE. RELIABLE.

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Certificate of Analysis

Thurber Engineering Ltd.

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

Client PO: 20244
Project: HWY11+118
Custody: 39863

Report Date: 9-Oct-2018
Order Date: 2-Oct-2018

Order #: 1840220

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

Paracel ID	Client ID
1840220-01	18+550 18-1 SS3 5'6"-6'2"
1840220-02	18+550 18-4 SS2 3-5
1840220-03	18+875 18-4 SS1 2'6"-4'6"
1840220-04	11+490 18-4 SS3 5-7
1840220-05	22+590 18-1 SS2 4-6
1840220-06	22+590 18-4 SS3 6-8'

Depths shown in results are measured from the top of the drilling platform not shown in the Record of Borehole Sheets. Platform height measured 0.5 m at Borehole 18-1 and 0.3 m at Borehole 18-4.

Approved By: Mark Foto

Mark Foto, M.Sc.
Lab Supervisor

Analysis Summary Table

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	5-Oct-18	5-Oct-18
Conductivity	MOE E3138 - probe @25 °C, water ext	4-Oct-18	5-Oct-18
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	5-Oct-18	5-Oct-18
Resistivity	EPA 120.1 - probe, water extraction	4-Oct-18	5-Oct-18
Solids, %	Gravimetric, calculation	3-Oct-18	3-Oct-18

Certificate of Analysis

Client: Thurber Engineering Ltd.

Client PO: 20244

Report Date: 09-Oct-2018

Order Date: 2-Oct-2018

Project Description: HWY11+118

Client ID:		18+550 18-1 SS3 5'6"-6'2"	18+550 18-4 SS2 3-5	18+875 18-4 SS1 2'6"-4'6"	11+490 18-4 SS3 5-7
Sample Date:		09/23/2018 09:00	09/22/2018 09:00	09/20/2018 09:00	09/28/2018 09:00
Sample ID:		1840220-01	1840220-02	1840220-03	1840220-04
	MDL/Units	Soil	Soil	Soil	Soil
Physical Characteristics					
% Solids	0.1 % by Wt.	85.4	79.7	90.5	82.8
General Inorganics					
Conductivity	5 uS/cm	347	117	124	225
pH	0.05 pH Units	7.47	5.65	6.26	6.22
Resistivity	0.10 Ohm.m	28.8	85.1	80.9	44.5
Anions					
Chloride	5 ug/g dry	211	55	19	124
Sulphate	5 ug/g dry	10	21	6	7

Client ID:		22+590 18-1 SS2 4-6	22+590 18-4 SS3 6-8'	-	-
Sample Date:		09/25/2018 09:00	09/26/2018 09:00	-	-
Sample ID:		1840220-05	1840220-06	-	-
	MDL/Units	Soil	Soil	-	-
Physical Characteristics					
% Solids	0.1 % by Wt.	86.5	85.5	-	-
General Inorganics					
Conductivity	5 uS/cm	302	15	-	-
pH	0.05 pH Units	6.44	5.59	-	-
Resistivity	0.10 Ohm.m	33.1	653	-	-
Anions					
Chloride	5 ug/g dry	168	<5	-	-
Sulphate	5 ug/g dry	11	<5	-	-

Certificate of Analysis

Client: Thurber Engineering Ltd.

Client PO: 20244

Report Date: 09-Oct-2018

Order Date: 2-Oct-2018

Project Description: HWY11+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						

Method Quality Control: Duplicate

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	205	5	ug/g dry	211			2.7	20	
Sulphate	9.29	5	ug/g dry	9.98			7.2	20	
General Inorganics									
Conductivity	364	5	uS/cm	347			4.6	6.2	
pH	11.69	0.05	pH Units	11.61			0.7	10	
Resistivity	27.5	0.10	Ohm.m	28.8			4.6	20	
Physical Characteristics									
% Solids	90.9	0.1	% by Wt.	94.3			3.8	25	

Method Quality Control: Spike

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	308	5	ug/g	211	97.2	78-113			
Sulphate	110	5	ug/g	9.98	100	78-111			

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.

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Subcontracted Analysis

Thurber Engineering Ltd.
2460 Lancaster Rd, Suite 104
Ottawa, ON K1B 4S5
Attn: Katya Edney

Tel: (613) 247-2121
Fax: (613) 247-2185

Paracel Report No	**1840220**
Client Project(s):	**HWY11+118**
Client PO:	**20244**
Reference:	**Standing Offer**
CoC Number:	**39863**

Order Date:	02-Oct-18
Report Date:	9-Oct-18

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

Paracel ID	Client ID	Analysis
1840220-01	18+550 18-1 SS3 5'6"-6'2"	Sulphide, solid
1840220-02	18+550 18-4 SS2 3-5	Sulphide, solid
1840220-03	18+875 18-4 SS1 2'6"-4'6"	Sulphide, solid
1840220-04	11+490 18-4 SS3 5-7	Sulphide, solid
1840220-05	22+590 18-1 SS2 4-6	Sulphide, solid
1840220-06	22+590 18-4 SS3 6-8'	Sulphide, solid

Depths shown in results are measured from the top of the drilling platform not shown in the Record of Borehole Sheets. Platform height measured 0.5 m at Borehole 18-1 and 0.3 m at Borehole 18-4.

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

10-October-2018

Paracel Laboratories
Attn : Dale Robertson

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

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

Date Rec. : 04 October 2018
LR Report: **CA12131-OCT18**
Reference: Project#:1840220

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

Sample ID	Sample Date & Time	Sulphide %
1: Analysis Start Date		05-Oct-18
2: Analysis Start Time		13:35
3: Analysis Completed Date		05-Oct-18
4: Analysis Completed Time		14:36
5: QC - Blank		< 0.02
6: QC - STD % Recovery		99%
7: QC - DUP % RPD		1%
8: RL		0.02
9: 18+550 18-1 SS3 5'6"-6'2"	23-Sep-18	< 0.02
10: 18+550 18-4 SS2 3-5	22-Sep-18	< 0.02
11: 18+875 18-4 SS1 2'6"-4'6"	20-Sep-18	< 0.02
12: 11+490 18-4 SS3 5-7	28-Sep-18	< 0.02
13: 22+590 18-1 SS2 4-6	25-Sep-18	< 0.02
14: 22+590 18-4 SS3 6-8'	26-Sep-18	< 0.02

RL - SGS Reporting Limit

Kimberley Didsbury
Project Specialist
Environmental Services, Analytical

OnLine LIMS

0001537088

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Appendix D.

Site Photographs

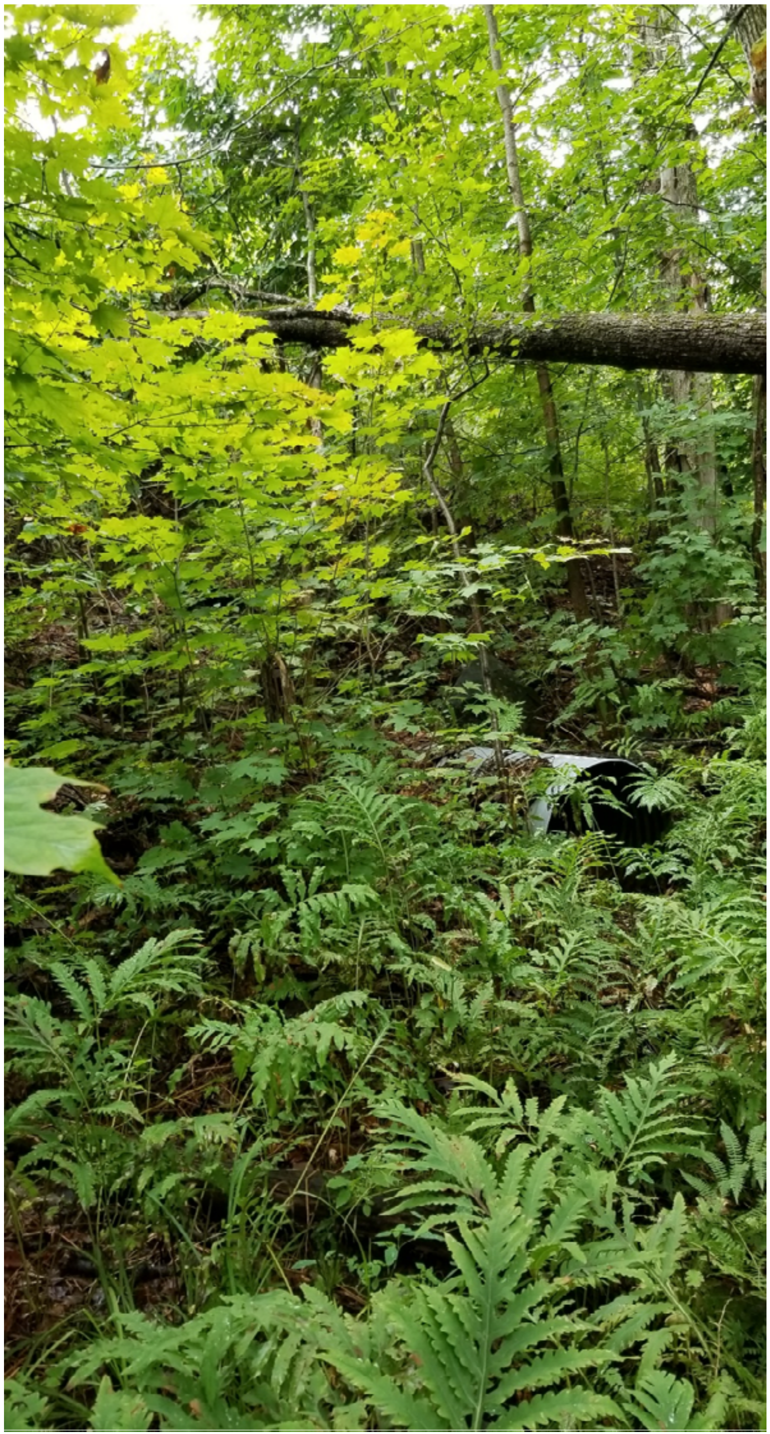

Photo 1. Looking Southwest at Culvert Outlet at Sta. 18+550 (2018/09/11)

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Photo 2. Looking Northeast at Culvert Inlet at Sta.18+550 (2018/09/11)

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Photo 3. Looking West on HWY 118 (2018/09/17)

Photo 4. Looking East on HWY 118 (2018/09/19)

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Appendix E.

Foundation Comparison

COMPARISON OF ALTERNATIVE FOUNDATION TYPES

	Circular Pipe or Closed Box Culvert	*Circular Pipe Culvert Trenchless Installation*	*Open Bottom Culvert*	*Precast Concrete Slab on Steel Sheet Piles*
Advantages	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
Disadvantages	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 in the tunnel zone	Requires deeper excavation increasing excavation volume and dewatering concern. Requires roadway protection. Disruption to traffic	Shallow bedrock and the presence of occasional to frequent cobbles and boulders in the fill and till Quantity and cost of sheet piles
Risks/ Consequences		Obstructions		Obstructions and shallow refusal depths
Relative Cost	**Low to Medium**	**Medium to High**	**Medium**	***Medium to High***
Recommendation	**Recommended**	**Not Recommended**	**Not Recommended**	***Not Feasible***

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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 26, 2018

Site: 44.9913 N, 79.1979 W   User File Reference: Culvert 18 550

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)**
0.084	0.117	**0.117**	0.102	**0.085**	**0.052**	**0.027**	**0.0069**	**0.0031**	**0.068**	**0.071**

Notes. Spectral (Sa(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	0.035	0.053
Sa(0.1)	0.020	0.052	0.077
Sa(0.2)	0.021	0.055	0.079
Sa(0.3)	0.019	0.048	0.069
Sa(0.5)	0.015	0.040	0.057
Sa(1.0)	0.0072	0.023	0.034
Sa(2.0)	0.0031	0.011	0.017
Sa(5.0)	0.0007	0.0025	0.0041
Sa(10.0)	0.0004	0.0011	0.0018
PGA	0.011	0.030	0.044
PGV	0.0089	0.029	0.045

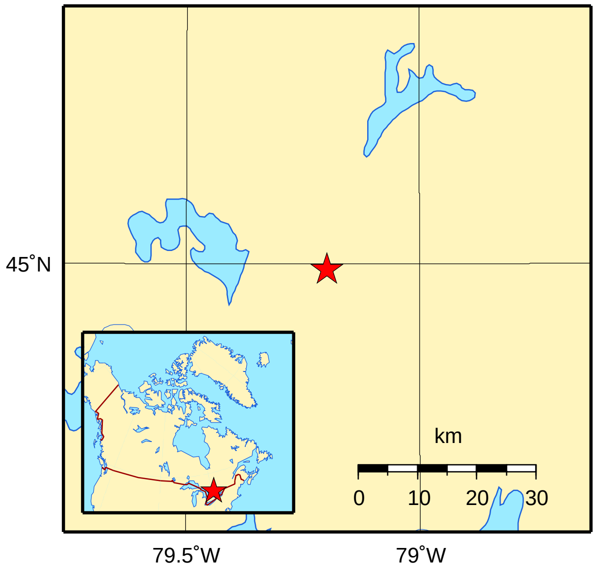
References

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

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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”

Obstructions such as cobbles and boulders may be encountered in the embankment and/or native till during excavation, installation of roadway protection systems and/or sheet pile coffee dams. Such obstructions may impede the work from reaching the design depth of installation. 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.

3. Suggested text for an NSSP on “Shallow Bedrock”

Bedrock was observed to be shallow at this site. The Contractor shall design and construct the temporary roadway protection systems accordingly.