



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 17 LITTLE CACHE CREEK CULVERT
5.6 KM WEST OF HWY 64, MUNICIPALITY OF WEST NIPISSING
SITE NO.: 43X-0361/C0
ASSIGNMENT NO. 5018-E-0014**

**G.W.P. 5198-13-00
W.P. 5177-12-01**

Geocres No.: 41I-364

Report to:

McIntosh Perry Consulting Engineers Limited

Latitude: 46.389744°
Longitude: -79.999437°

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TABLE OF CONTENTS

PART 1. FACTUAL INFORMATION

1	INTRODUCTION	1
2	SITE DESCRIPTION.....	1
3	SITE INVESTIGATION AND FIELD TESTING.....	2
4	LABORATORY TESTING	4
5	GENERAL DESCRIPTION OF SUBSURFACE CONDITIONS	4
5.1	Embankment Fill.....	4
5.1.1	Asphalt.....	4
5.1.2	Fill: Sand to Silty Sand with Gravel	4
5.1.3	Fill: Rockfill.....	5
5.2	Topsoil: Silt (ML) to Sandy Silt (ML)	6
5.3	Clayey Silt (CL) to Clay (CH).....	6
5.4	Silty Sand (SM)	7
5.5	Bedrock.....	7
5.6	Groundwater.....	8
5.7	Analytical Testing	9
6	MISCELLANEOUS	10

PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS

7	INTRODUCTION	11
7.1	Proposed Structure.....	11
7.2	Applicable Codes and Design Considerations	12
8	SEISMIC CONSIDERATIONS	12
8.1	Spectral and Peak Acceleration Hazard Values.....	12
8.2	Seismic Liquefaction.....	12
8.3	CHBDC Seismic Site Classification	12

9	DESIGN OPTIONS	13
9.1	Culvert Type and Foundation Alternatives	13
9.2	Construction Methodology Alternative	13
9.3	Recommended Approach for the Culvert Replacement	15
10	FOUNDATION DESIGN RECOMMENDATIONS	15
10.1	Culvert Foundation Bearing Resistances	15
10.1.1	Resistance factors	15
10.1.2	Open Bottom Culvert.....	16
10.1.3	Box Culvert	16
10.1.4	Pipe Culvert	16
10.2	Subgrade Preparation, Bedding and Backfilling.....	16
10.3	Frost Depth	17
10.4	Backfill and Earth Pressure	17
10.4.1	Static Lateral Earth Pressure	18
10.4.2	Combined Static and Seismic Lateral Earth Pressure	19
10.5	Headwalls and Wingwalls	20
10.6	Embankment Design and Reinstatement.....	20
10.6.1	Embankment Reconstruction	20
10.6.2	Embankment Settlement and Stability.....	20
10.7	Cement Type and Corrosion Potential	21
11	CONSTRUCTION CONSIDERATIONS	21
11.1	Excavation.....	21
11.2	Temporary Protection Systems.....	22
11.3	Surface and Groundwater Control	23
11.4	Scour Protection and Erosion Control.....	24
12	CONSTRUCTION CONCERNS	25
13	CLOSURE	26



APPENDICES

APPENDIX A.	BOREHOLE LOCATION PLAN AND STRATIGRAPHIC DRAWINGS
APPENDIX B.	RECORD OF BOREHOLE SHEETS
APPENDIX C.	LABORATORY TESTING
APPENDIX D.	SITE PHOTOGRAPHS
APPENDIX E.	FOUNDATION COMPARISON
APPENDIX F.	GSC SEISMIC HAZARD CALCULATION
APPENDIX G.	LIST OF SPECIAL PROVISIONS AND OPSS DOCUMENTS REFERENCED IN THIS REPORT SUGGESTED TEXT FOR NSSPS AND SPS



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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 for the replacement of the Little Cache Creek Culvert (Site No. 43X-0361/C0) on Highway 17 (latitude 46.389744; longitude -79.999437). The culvert crossing is located approximately 5.6 km west of the east junction with Highway 64 within the Municipality of West Nipissing. Thurber Engineering Limited (Thurber) carried out the field investigation as a sub-consultant to McIntosh Perry Consulting Engineers Ltd. (MPCE) under Assignment No. 5018-E-0014.

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.

2 SITE DESCRIPTION

In the area of the culvert, Highway 17 is oriented northwest-southeast and the existing culvert is oriented southwest-northeast; however, for project purposes, Highway 17 is herein described as being oriented east-west (with chainage increasing to the east) and the culvert is described as being oriented north-south.

The original culvert (construction date unknown) was extended on both ends under Contract 95-219.

The existing culvert conveys Little Cache Creek under a high fill embankment supporting Highway 17. Flow through the culvert is from north to south. The existing culvert is a single cell 6.7 m wide, 2.0 m high, 48.7 m long, open footing rigid frame cast-in-place concrete culvert. The invert elevation of the culvert is approximately 200.3 m at the inlet and 200.0 m at the outlet.

At the location of the culvert, Highway 17 is a two-lane highway with gravel shoulders and steel guiderails. The elevation of the road surface at the culvert is approximately 207.4 m. The fill height above the culvert is approximately 4.2 m. The existing embankment slopes are inclined at approximately 2H:1V. Bedrock outcrops are present at the inlet of the culvert. The land adjacent to the highway and creek is vegetated with trees, shrubs, and agricultural crops. Single family dwellings are located approximately 100 m north and 100 m south of the culvert. Overhead utility lines run parallel to the highway within the MTO right-of-way on the south side of the highway. Traffic volumes on this section of Highway 17 are understood to be 6,850 AADT (2016).

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.

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 August 9th and 21st, 2019. The field investigation consisted of advancing five boreholes identified as 19-01 through 19-05 and two secondary boreholes identified as 19-04B and 19-05B. On-road Boreholes 19-02, 19-03, 19-04 and 19-04B were drilled using a truck-mounted CME 55 drill rig, and off-road 19-01 and 19-05B were drilled using a track-mounted CME 850 drill rig. Off-road Borehole 19-05 was drilled using a portable Explo 220 drill. 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 Drawings 1 and 2 in Appendix A, the individual Record of Borehole sheets in Appendix B and in Table 3-1 below. The termination depth of each of borehole is also provided in Table 3-1. The site is located within MTM Zone 10. The ground surface elevations at the borehole locations were surveyed by Thurber using a rod and level relative to the northwest corner (top) of the existing culvert, which has a geodetic elevation of 203.48 m, as provided by MPCE. The 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)
19-01	Culvert Inlet	5 139 021.3	266 419.9	201.0	3.3
19-02	Eastbound Lane HWY 17	5 139 021.8	266 373.2	207.5	14.0
19-03	Westbound Lane HWY 17	5 139 011.2	266 399.6	207.4	8.1
19-04	Eastbound Lane HWY 17	5 138 989.2	266 421.5	207.4	2.3
19-04B	Eastbound Lane HWY 17	5 138 989.8	266 420.7	207.4	8.9
19-05	Culvert Outlet	5 139 003.0	266 367.2	201.2	4.5
19-05B	Culvert Outlet	5 139 013.6	266 359.8	203.3	6.6

Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) following ASTM D1586. Field vane testing was carried out in the cohesive deposits at selected depths using an MTO N vane. All of the Boreholes except 19-04 were advanced into bedrock using rotary diamond drilling techniques while collecting NQ sized bedrock core.

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

A 19 mm diameter standpipe piezometer was installed in Borehole 19-05B to allow for measurements of the groundwater level after completion of drilling. The piezometer installation details are illustrated on the Record of Borehole sheet provided in Appendix B. All other boreholes were backfilled with a low-permeability mixture of cuttings and bentonite pellets in accordance with Ontario MOE Regulation 903 as amended. Boreholes advanced within paved areas were capped with granular fill followed by 150 mm of cold patch asphalt to reinstate the travelling surface. The piezometer installed during the investigation was decommissioned in accordance with Ontario MOE Regulation 903 prior to demobilization from the site.

4 LABORATORY TESTING

Geotechnical laboratory testing consisted of natural moisture content determination and visual identification of all retained soil samples. Grain size distribution testing was also carried out on selected samples to MTO and ASTM standards. All rock cores were photographed and their total core recovery (TCR), solid core recovery (SCR) and rock quality designation (RQD) were measured. Three samples of the bedrock core were submitted for unconfined compressive strength (UCS) testing.

Chemical analysis for determination of pH, conductivity, resistivity, sulphate, sulphide and chloride concentrations was carried out on two soil samples.

The results of the geotechnical tests are summarized on the Record of Borehole sheets included in Appendix B and all laboratory results are presented on the figures included 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 drawings 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.

Soil descriptions are in accordance with the Unified Soil Classification System, ASTM D2487, as modified by current MTO standards for cohesionless soils.

In general terms, the site was found to be underlain by embankment fill overlying native deposits of clay and discontinuous silty sand. Relatively shallow biotite gneiss bedrock was encountered below the overburden in all boreholes (except 19-04B).

5.1 Embankment Fill

5.1.1 Asphalt

On-road Boreholes 19-02, 19-03, 19-04 and 19-04B were drilled through the travelled lanes of the Highway 17 embankment and encountered an approximately 150 mm thick layer of asphalt at ground surface.

5.1.2 Fill: Sand to Silty Sand with Gravel

A layer of embankment fill consisting of sand to sand with gravel to silty sand with gravel was encountered below the asphalt in all of the on-road boreholes (19-02, 19-03, 19-04 and 19-04B). Hydrocarbon odours were noted in various samples from this layer during lab

review. The underside of this layer ranged from 1.5 to 2.7 m below the existing roadway surface (elev. 204.7 to 205.9 m).

SPT tests conducted in the sand to silty sand fill gave N-values ranging from 14 to 79 blows, indicating a compact to very dense relative density.

Recorded moisture contents ranged from 6 to 17%.

Gradation analyses were completed on two samples of the sand to silty sand fill. The grain size distribution curves for these samples are included in Figure C1 of Appendix C. The results of the tests are summarized in Table 5-1 below and are presented on the corresponding Record of Borehole sheets in Appendix B.

Table 5-1: Gradation Results for Sand to Silty Sand with Gravel Fill

Soil Particle	Percentage (%)	
Gravel	32 – 38	
Sand	52 – 59	
Silt	12	3 – 16
Clay	4	

The results of Atterberg Limit testing conducted on one sample of the fill indicated the material to be non-plastic.

5.1.3 Fill: Rockfill

A layer of rockfill was encountered below the embankment fill in Boreholes 19-02, 19-04, and 19-04B. Borehole 19-04 was terminated upon encountering refusal in the rockfill layer at 2.3 m depth (elev. 205.1 m) and was subsequently redrilled as Borehole 19-04B. Boulders approximately 530 mm and 660 mm in size were encountered within the rockfill in Borehole 19-04B. The thickness of the rockfill ranged from 0.7 to 2.2 m. The underside of the rockfill was encountered at depths ranging from 3.0 to 3.7 m (elev. 203.7 to 204.5 m).

SPT tests conducted in the rockfill gave N-values ranging from 12 to 27 blows for 300 mm of penetration (indicating a compact relative density) to 100 blows for 0 mm of penetration, which likely represents refusal on a boulder within the rockfill.

Recorded moisture contents ranged from 1 to 11%.

5.2 Topsoil: Silt (ML) to Sandy Silt (ML)

A layer of silt to sandy silt topsoil, approximately 0.7 m thick, was encountered at ground surface in off-road Borehole 19-05. Organics and grassroots were encountered throughout this layer. An SPT test conducted in the topsoil gave an N-value of 7 blows, indicating a loose relative density. The recorded moisture content of the topsoil was 26%.

5.3 Clayey Silt (CL) to Clay (CH)

A native deposit of clayey silt to clay was encountered below the embankment fill in on-road Boreholes 19-02, 19-03, 19-04B, below the topsoil in off-road Borehole 19-05, and at ground surface in off-road Borehole 19-05B. Trace organics were encountered in this layer near the ground surface in off-road Borehole 19-05B, and trace sand and some gravel was encountered in this layer below a depth of 4.6 m (elev. 202.8 m) in Borehole 19-04B. The total thickness of the deposit ranged from 0.6 to 6.1 m. The underside of the deposit was encountered at depths ranging from 1.3 to 9.1 m (elev. 198.4 to 202.7 m).

SPT tests conducted in this deposit generally gave N-values ranging from weight-of-rods to 12 blows. Field vane testing performed within the deposit gave undrained shear strengths ranging from 30 to greater than 100 kPa, indicating a very stiff to firm consistency (generally decreasing with depth). Remolded field vane testing indicates that the clay is sensitive to extra-sensitive.

Recorded moisture contents ranged from 16 to 89%.

Gradation analyses were completed on three samples of the clayey silt to clay. The grain size distribution curves for these samples are included in Figure C2 of Appendix C. The results of the tests are summarized in Table 5-2 below and are presented on the corresponding Record of Borehole sheets in Appendix B.

Table 5-2: Gradation Results for Clayey Silt to Clay

Soil Particle	Percentage (%)
Gravel	0 – 5
Sand	0 – 2
Silt	23 – 70
Clay	29 – 77

Atterberg Limit testing was completed on five samples of the clayey silt to clay. The results of the Atterberg Limit testing are summarized in Table 5-3 below and are illustrated on Figure C4 in Appendix C. The laboratory results indicate that the deposit ranges from low to high plasticity (CL to CH).

Table 5-3: Atterberg Limit Results for Clayey Silt to Clay

Parameter	Value
Liquid Limit	32 – 70
Plastic Limit	18 – 26
Plasticity Index	14 – 44

5.4 Silty Sand (SM)

A deposit of silty sand trace gravel was encountered below the clay in Borehole 19-02. The silty sand had a thickness of 1.2 m, and the underside of the deposit was encountered at a depth of 10.3 m (elev. 197.2 m).

An SPT test conducted in the silty sand gave an N-value of 23 blows, indicating a compact relative density.

The recorded moisture content of the silty sand was 12%.

A gradation analysis was completed on one sample of the silty sand. The grain size distribution curve for this sample is included in Figure C3 of Appendix C. The results of grain size analysis indicated the material to consist of 7% gravel, 66% sand, 22% silt, and 5% clay.

The results of Atterberg Limit testing conducted on the same sample of silty sand indicated the material to be non-plastic.

5.5 Bedrock

Bedrock was proven by coring in all boreholes (except Borehole 19-04 which was terminated due to refusal within the rockfill). Information on the bedrock surface is summarized in Table 5-4 below.

Table 5-4: Summary of Bedrock Surface Depths and Elevations

Borehole No.	Bedrock Depth (mbgs)	Bedrock Elevation (masl)
19-01	0.0	201.0
19-02	10.3	197.2
19-03	4.7	202.7
19-04B	5.0	202.4
19-05	1.3	199.9
19-05B	3.5	199.8

The bedrock encountered consisted of fresh biotite gneiss with feldspar banding. The Total Core Recovery (TCR) measured on the recovered bedrock core ranged from 54 to 100%, the Solid Core Recovery (SCR) ranged from 54 to 100% and the Rock Quality Designation (RQD) ranged from 35 to 100%. Based on these measured RQD values, the bedrock is classified as poor to excellent quality; however, the low TCR, SCR, and RQD values are primarily related to an approximately 700 mm thick clay-infilled aperture in the rock that was encountered at approximately 6.0 m depth in Borehole 19-03. Otherwise, the TCR values ranged from 85 to 100%, the SCR ranged from 70 to 100%, and the RQD ranged from 61 to 100%, indicating that the rock is generally of fair to excellent quality.

Unconfined Compressive Strength (UCS) testing was carried out on three samples of the bedrock core, which gave results ranging from about 115 to 170 MPa, indicating the bedrock to be very strong. Photographs of the bedrock core are provided in Appendix C.

5.6 Groundwater

The groundwater level was measured in the standpipe piezometer installed within Borehole 19-05B at a depth of 2.5 m below the ground surface (elev. 200.8 m) on August 27th and 28th, 2019. Representative water levels were not obtained in the open boreholes due to water being introduced as part of the coring operations.

The water level in the creek at the culvert inlet was observed to be at an approximate elevation of 200.3 m on August 27, 2019.

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.

5.7 Analytical Testing

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

Table 5-5: Results of Chemical Analysis

Borehole (Sample)	Depth (mbgs)	Sulphate (µg/g)	pH (-)	Resistivity (Ohm-cm)	Conductivity (uS/cm)	Chloride (µg/g)	Sulphide (%)
19-03 (SS6)	4.3 – 4.6	90	7.86	416	2400	1440	< 0.02
19-05 (SS3)	1.2 – 1.6	50	7.87	1140	878	426	0.04

6 MISCELLANEOUS

Borehole locations were selected in consultation with the Ministry of Transportation and were located in the field by Thurber relative to existing site features. The as-drilled locations and ground surface elevation of the boreholes were surveyed by Thurber following completion of the field program. Survey elevation benchmarks were provided by MPCE.

Marathon Drilling Ltd. of Greely, Ontario supplied and operated the drilling equipment to conduct the drilling, soil sampling, in-situ testing, piezometer installation and borehole decommissioning. Traffic control was provided by Beacon Lite of Ottawa, Ontario. The field investigation was supervised on a full-time basis by Michel Johnston, E.I.T. and Sean O'Bryan, C.E.T. of Thurber. Overall supervision of the investigation program was provided by Stephen Dunlop, 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 Allison Chow, E.I.T., and Stephen Dunlop, P.Eng. The report was reviewed by Dr. Fred Griffiths, 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 foundation for the proposed replacement of the existing Little Cache Creek culvert crossing Highway 17. The discussion and recommendations presented in this report are based on the information provided by 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.

7.1 Proposed Structure

It is understood that the preferred replacement culvert is a 46.6 m long open footing culvert consisting of a 3-sided segmental precast concrete box with a clear span of 6.0 m and a rise of 2.4 m that is supported by cast-in-place concrete footings placed on bedrock. A cast-in-place concrete headwall and wingwall are required at the inlet end of the culvert. The invert level of the new culvert had not been indicated; however, it is assumed that it would be similar to the existing culvert (approximate elevation 200.0 m).

7.2 Applicable Codes and Design Considerations

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

It is assumed that the proposed culvert structure has 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 for this structural culvert.

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). At this site, the PGA for a reference Site Class C with a 2% probability of exceedance in 50 years (2475-year event) is 0.108g. This value is to be scaled by the $F(PGA)$ based on the site-specific Site Class.

8.2 Seismic Liquefaction

It is anticipated that the foundations for the new culvert will be placed directly on bedrock, or on a pad of compacted granular bedding placed directly on bedrock. As such, the foundation soils at this site are considered to be non-liquefiable.

8.3 CHBDC Seismic Site Classification

In accordance with the CHBDC, the selection of the seismic site classification is based on the soil conditions encountered in the upper 30 m of the stratigraphy. This site has been classified as a Site Class C in accordance with Section 4.4.3.2 of the CHBDC (S6-14). It is considered likely that a more favourable site class (e.g., A or B) would apply to this site due to the likelihood that the foundations will be directly on bedrock; however, this would need to be confirmed with site-specific shear wave velocity testing.

9 DESIGN OPTIONS

9.1 Culvert Type and Foundation Alternatives

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

- Circular Pipes (Concrete, HDPE, Steel)
From a foundation engineering perspective, pipe culverts are a feasible culvert option; however, it is anticipated that multiple smaller diameter pipe culverts would be required to achieve the hydraulic requirements. A large retaining wall at the inlet would also be required to provide a cut-off between the multiple pipe culverts.
- Closed Bottom Culvert (Box)
A precast segmental closed box culvert is considered a feasible option from a foundation engineering perspective, noting that the bedrock surface at this site is shallow and variable. To achieve a suitably flat bearing surface, significant amounts of bedrock removal may be required. A temporary diversion/bypass will also be required to divert the creek during construction.
- Open Bottom Culvert (Box, Arch)
Open bottom culverts (either a metal arch, cast-in-place concrete, or a 3-sided precast concrete box) are considered feasible for this site from a foundation engineering perspective. Each type of open-bottom culvert would be supported by cast-in-place concrete footings placed on bedrock. Some bedrock removal may be required with this type of culvert. Creek flow can be maintained on the current alignment during construction while the new culvert is constructed over top of the existing.

A comparison of these alternatives, based on their respective advantages and disadvantages, is included in Appendix E.

9.2 Construction Methodology Alternative

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

- Open Cut with Full Road Closure and Temporary 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 requiring roadway protection and ground/surface water control. However, it is

anticipated that an acceptable detour route is not available and therefore this option is not feasible.

- Open Cut with Temporary Modular Bridge Spanning Excavation

This option is feasible provided that a temporary platform widening is completed to the south to provide traffic flow (Stage 1) while a temporary modular bridge (TMB) is constructed to the north, which would carry traffic during Stage 2. Due to the presence of a compressible clay deposit, it is anticipated that deep foundations (i.e., driven piles) would be required to support a TMB. This option would also require the greatest alignment shift and amount of earthwork, and is therefore not preferred.

- Open Cut with Staged Temporary Widening

Temporary widening of the existing highway is considered feasible from a foundation perspective. However, it is understood that temporary grade lowering on the north side would also be required in conjunction with widening of the embankment to the south. Site preparation work would include removal of the surficial organics from within the footprint of the embankment widening. A review of the environmental acceptability for placing fill, the requirement for property acquisition, and alteration to highway geometry is needed to fully assess this option.

- Open Cut with Staged Replacement and Temporary Protection System

The use of open cut techniques in conjunction with staged culvert replacement is a feasible construction option from a foundation perspective. It is understood that this option will require a centreline roadway protection system in conjunction with either grade lowering to the north, or a second roadway protection system to the south (i.e., a double protection system). Roadway protection is discussed further in Section 11.2. Due to the shallow bedrock, it is anticipated that the roadway protection system would consist of soldier piles and lagging, with the soldier piles socketed into the bedrock for lateral support. Installation of sheet piles will be difficult due to the presence of rockfill and the requirement to provide lateral support with bedrock anchors. However, it may be possible to tie the double protection system together to provide the necessary lateral support.

- Trenchless Techniques

Tunneling would have the advantage of minimum disruption to traffic and would avoid a large excavation through the existing highway embankment. However, this option will have high risk due to the presence of shallow bedrock and the possibility of encountering obstructions (boulders in rockfill). The anticipated size of the replacement culvert will also limit the available installation methods. A trenchless installation is not considered feasible at this site.

9.3 Recommended Approach for the Culvert Replacement

From a foundation engineering perspective, a set of circular pipes, a precast segmental closed box culvert and an open footing box culvert, using open cut techniques, are all considered feasible culvert options, recognizing that the bedrock surface is variable and some level of bedrock removal will likely be required for each option. An open bottom culvert is preferred because creek flow can be maintained in the existing culvert during construction.

Temporary protection systems (TPS) or a temporary widening, possibly in conjunction with temporary embankment lowering, will be needed to facilitate construction.

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, temporary protection system design, groundwater control and stability of stage construction. The culvert must be designed to resist loading 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

10.1.1 Resistance factors

The geotechnical resistances provided in the section below 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 provided below 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.

The factored ULS geotechnical resistances provided in the sections below should not exceed the 28-day strength of the concrete.

For the calculation of horizontal resistance, a geotechnical resistance factor against sliding (Φ_{gu}) of 0.80 as per Table 6.2 of the CHBDC (static analysis – typical understanding) for frictional sliding of shallow foundations is to be applied to the calculated value.

10.1.2 Open Bottom Culvert

It is anticipated that footings for an open bottom culvert would be placed directly on bedrock. For footings on bedrock, the design can be based on a ULS factored geotechnical resistance value of 5000 kPa. SLS will not govern design for a footing founded on bedrock.

If undulations in the bedrock surface are encountered during construction, such that the bedrock surface is lower than the proposed founding level in some areas, the depressions should be filled with lean concrete to obtain a uniform founding level for the proposed footings.

Resistance to lateral forces/sliding resistance between cast-in-place concrete footings and the underlying bedrock should be evaluated in accordance with the CHBDC assuming an unfactored coefficient of 0.70. If greater lateral resistance is required, rock anchors/dowels could be utilized.

10.1.3 Box Culvert

For a box culvert up to 7.0 m wide on a 300 mm layer of Granular 'A' bedding placed on bedrock, the design can be based on the factored geotechnical resistance values as follows:

- Factored Geotechnical Resistance at ULS of 5000 kPa
- Factored Geotechnical Resistance at SLS of 3000 kPa

Foundation settlement, based on the supplied SLS resistance, is expected to be as much as 25 mm.

Resistance to lateral forces/sliding resistance between concrete and the underlying Granular 'A' bedding should be evaluated in accordance with the CHBDC assuming an unfactored coefficient of 0.45 for precast concrete.

10.1.4 Pipe Culvert

Geotechnical resistance values are not required for pipe culverts.

10.2 Subgrade Preparation, Bedding and Backfilling

Subgrade preparation for the culvert replacement should include excavation and removal of the existing culvert and backfill materials. All organics, soft or loose deposits, disturbed soils, and deleterious materials must be removed from the footprint of the foundation to expose a clean and sound bedrock subgrade at or below the desired founding elevations.

Care must be taken to avoid fracturing or disturbing the bedrock below the foundations. The exposed bedrock subgrade must be inspected to confirm that loose pieces have been removed and that the subgrade is suitable and uniformly competent. Groundwater and

surface water flow will need to be managed so that the bedrock subgrade can be adequately cleaned and inspected. Mass concrete can be used to fill any uneven bedrock surfaces to achieve the design founding level for the culvert.

For a circular pipe or closed box culvert, a minimum 300 mm thick layer of bedding material conforming to OPSS PROV 1010 Granular A requirements should be placed on the undisturbed subgrade and compacted per OPSS PROV 501. The bedding and backfill requirements should be consistent with Section 7 of the CHBDC, OPSS PROV 501, OPSS 902, and MTOD 803.021 (for precast box culverts). A 75 mm thick layer of uncompacted Granular A should be placed above the bedding layer as a levelling course to receive the placement of the culvert sections. For an open bottom culvert, a granular bedding layer is not required; the footings should be placed directly on the approved bedrock subgrade.

It is noted that construction will extend below the creek elevation. Water diversion and dewatering will be required. Refer to Section 11.3 for additional comments on groundwater and surface water control.

It is recommended that culvert cover be in accordance with OPSS 902 and consist of free-draining, non-frost susceptible granular materials such as 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 Select Subgrade Material or 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 adjacent to the culvert must be restricted in accordance with OPSS PROV 501.

10.3 Frost Depth

The depth of frost penetration at this site is estimated to be 2.0 m (OPSD 3090.101); however, foundations founded on bedrock are not required to be founded below frost depth. It is also not necessary to found a closed box or pipe culvert at a depth below frost penetration. Reference should be made to the Pavement Design Report regarding the requirement for frost tapers at this site.

10.4 Backfill and Earth Pressure

Lateral earth pressures parameters provided in Table 10-1 and Table 10-2 in the sections below are based on the assumptions that the wall is vertical and the backfill is fully drained so that there are no unbalanced hydrostatic pressures above the permanent groundwater level. 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 (for head walls or wing walls) behind vertical walls, the corresponding coefficients

provided in Tables 10-1 and 10-2 should be used. For other backfill and wall geometries, Thurber will need to calculate the appropriate earth pressure coefficients.

10.4.1 Static Lateral Earth Pressure

Lateral earth pressures acting on vertical 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 = lateral earth pressure at depth d (kPa)
- K = earth pressure coefficient (see table below)
- γ = unit weight of retained soil (adjusted for groundwater level)
- d = depth below top of fill where pressure is computed (m)
- q = stress from 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 are shown in Table 10-1.

Table 10-1: Static Earth Pressure Coefficients

Condition	Earth Pressure Coefficient (K)					
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$		OPSS SSM and Existing Sand Fill $\phi = 30^\circ, \gamma = 21.0 \text{ kN/m}^3$	
	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_0 (Non-Yielding Wall)	0.43	-	0.47	-	0.50	-
Passive, K_P (Movement towards Soil Mass)	3.7	-	3.3	-	3.0	-

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

For rigid structures, it is recommended that at-rest horizontal lateral earth pressures be used for design. Active pressures should be used for the design of unrestrained walls. The parameters in the table correspond to full mobilization of active and passive earth pressure and require certain relative movements between the wall and adjacent soil to produce these conditions, as provided in Table C6.6 of the commentary of the CHBDC.

10.4.2 Combined Static and Seismic Lateral Earth Pressure

In accordance with Clause 4.6.5 of the CHBDC, a structure should be designed using dynamic earth pressure coefficients that incorporate the effects of earthquake loading. The following recommendations are as 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:

$k_h = \frac{1}{2} * F(PGA) * PGA_{ref}$, for structures that allow lateral yielding, and

$k_h = F(PGA) * PGA_{ref}$, 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 structures. The earth pressure coefficients are provided for a Seismic Site Class C, a PGA_{ref} with a 2% probability of exceedance in 50 years (2475-year event) of 0.108 g (Geological Survey of Canada - Fifth Generation) and a $F(PGA)$ of 1.00 as per Table 4.8 of the CHBDC.

Table 10-2: Combined Static and Seismic Earth Pressure Coefficients

Condition	Earth Pressure Coefficient (K)					
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I and III $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$		OPSS SSM and Existing Sand Fill $\phi = 30^\circ, \gamma = 21.0 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)	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	*	0.34	*	0.37	*
Active, K_{AE} Non-Yielding Wall	0.33	*	0.37	*	0.40	*

* Requires project geometry and detailed analysis. Can be provided if required.

If a 2H:1V sloped surface behind a wall is required, K_{AE} values can be provided upon request once wall and slope geometries have been selected.

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	=	lateral earth pressure at depth d (kPa)
d	=	depth below top of fill where pressure is computed (m)
K	=	static earth pressure coefficient (K_A for yielding walls, K_o for non-yielding walls)
γ	=	unit weight of retained soil (adjusted for groundwater level)
K_{AE}	=	combined static and seismic earth pressure coefficient
H	=	total height of the wall (m)

10.5 Headwalls and Wingwalls

The foundations for headwalls and wingwalls should be designed in accordance with the recommendations and resistance values provided in Sections 10.1, 10.2 and 10.3. Lateral earth pressures should be in accordance with Section 10.4.

10.6 Embankment Design and Reinstatement

10.6.1 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 Select Subgrade Material (SSM) or Granular B Type I or Type II (OPSS.PROV 1010). The fill should be placed and compacted in accordance with OPSS.PROV 501.

Where newly placed 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.

10.6.2 Embankment Settlement and Stability

Provided the subgrade is prepared as outlined above and construction of the embankment is carried out in accordance with recommendations provided within this report, the embankment side slopes should remain stable.

It is understood that no grade raise is proposed; however, a permanent 1.0 m embankment widening will be required, and temporary embankment widening may be utilized for construction staging purposes. Based on the available staging drawings, the amount of fill required to temporarily widen the road platform could be up to about 2.0 m in height. With respect to settlement of the foundation soils, the magnitude of settlement during construction staging due to temporary embankment widening is estimated to be in the range of 5 to 15 mm, depending on the depth to bedrock, which is variable across the site.

Consolidation settlement of the underlying clay due to the 1.0 m widening is estimated to be in the range of 5 to 10 mm. Overall, the foundation settlement is estimated to be less than 25 mm and therefore within acceptable limits. Furthermore, the settlement of the native soils is expected to occur relatively quickly and will be 90% complete within a period of three to six months following fill placement.

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

10.7 Cement Type and Corrosion Potential

Analytical tests were completed to determine the potential for degradation of the 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 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 soil resistivity results are relatively low which can be indicative of a corrosive environment. The test results provided in Section 5.7 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects. The corrosion effects of road de-icing salts should also be considered.

11 CONSTRUCTION CONSIDERATIONS

11.1 Excavation

All excavations must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of OHSA, the fill and native soils above the groundwater table may be classified as Type 3 soil. Below the water table (i.e., if the groundwater flow is not controlled), the non-cohesive soils would be classified as Type 4 soils. Excavations in the bedrock can be carried out using near vertical slopes provided that loose rock is removed from the sidewalls for worker safety.

Excavations for the culvert replacement must be carried out in accordance with OPSS 902 and will be carried out through the existing embankment fill and extend into the underlying native clay. Bedrock removal will likely be required. Selection of the equipment and methodology to excavate and prepare the founding surface is the responsibility of the Contractor; however, for bedrock removal it is noted that the use of explosives has the potential to cause significant issues, such as over-excavation, damage to the existing culvert or roadway protection systems, impacts to fish habitat, and vibration related damage

to nearby structures. Therefore, it is recommended that the use of explosives not be permitted. Suggested wording for an NSSP precluding the use of explosives is provided in Appendix G. Given that the amount of bedrock removal will likely be limited, it is anticipated that the contractor can remove the bedrock using mechanical methods such as hoe-ramming, potentially in conjunction with line drilling. However, the contractor should be notified that the bedrock is very strong and hard and that appropriate equipment will be required. Suggested wording for an NSSP in this regard is provided in Appendix G.

Due to the presence of rockfill observed in some of the boreholes, recommended wording for an NSSP alerting bidders to their presence has been provided in Appendix G.

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 as amended by SSP 105S09 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 embankment fill and culvert backfill are provided in Table 10-1. The lateral earth pressure coefficients for the existing native soils are given below in Table 11-1:

Table 11-1: Lateral Earth Pressure Coefficients for Native Soils

Soil	Drainage Case	γ (kN/m ³)	K_A	K_P	c'
Very stiff to stiff red to brown clayey silt to clay	Undrained	19.0	1	1	100
	Drained		0.31	3.3	5
Firm grey clay	Undrained	16.5	1	1	40
	Drained		0.36	2.8	2
Silty Sand	Drained	22.0	0.31	3.3	0

Submerged unit weight should be used below the groundwater level.

The design of roadway protection is the responsibility of the Contractor. All protection systems should be designed by a licensed Professional Engineer experienced in such designs and retained by the Contractor. The design of the roadway protection system must incorporate traffic loading and surcharge loading due to construction equipment and operations.

It is anticipated that soldier piles will need to be socketed into the bedrock for lateral support to achieve the specified performance level. Deadman or bedrock anchors, struts and/or raker supports could also be considered to achieve the required lateral support. It may also be feasible to tie the double protection system together to provide lateral support.

It is recommended that an NSSP be included in the tender documents to alert the Contractor to the potential for cobbles and boulders and obstructions within the fill. Suggested text for the NSSP is provided in Appendix G.

11.3 Surface and Groundwater Control

Culvert construction, subgrade preparation and placement and compaction of granular bedding (if required) should be carried out in the dry. The depth of excavations required to construct the culvert will extend below the creek level observed at the time of the investigation. Furthermore, groundwater and surface runoff will tend to seep into and accumulate into the excavations. The Contractor must make all reasonable efforts to control groundwater and creek/surface water flow at the site to permit the replacement of the culvert in a dry and stable excavation.

Subgrade preparation, placement and compaction of granular bedding, and culvert construction must be carried out with a properly designed dewatering system to control groundwater and creek/surface water and may include cofferdams, creek diversion, pumping etc. The dewatering system will be required to remain operational and effective until the temporary excavations are backfilled and then should be decommissioned and removed.

The design of dewatering systems is the responsibility of the Contractor. The Contract Documents must alert the Contractor to this responsibility and to design the system in accordance with SP No. FOUN0003 which amends OPSS 902. A preconstruction survey is not recommended, thus Designer Fill-In ** in this SP should be "NA".

The groundwater level will fluctuate and the minimum groundwater elevation at the time of the proposed work should be taken as the creek water level of the design storm return period defined by the contract documents for the temporary dewatering system.

If circular pipes or a closed box option are used, it is anticipated that a water course diversion will be required and will be carried out with a cofferdam directing creek water through a temporary pipe culvert.

It is anticipated that pumping from sumps will likely be sufficient to extract water from the excavation. Excavation below the creek level without prior installation and operation of the dewatering system is not recommended. If dewatering the bedrock subgrade is impractical, consideration could be given to placing a layer of mass concrete over the clean sound

bedrock subgrade using tremie methods up to a level that is higher than the drawn-down water level. The culvert could then be constructed on the surface of the mass concrete.

Further assessment of dewatering requirements and the need for a PTTW should be carried out by specialists experienced in this field.

11.4 Scour Protection and Erosion Control

The Contractor should provide silt fences and erosion control blankets as per OPSS 805 throughout the duration of construction to prevent transport of silt/sediment. Slope protection and drainage measures will be required to ensure the long-term surficial stability of the embankment slopes. Slope vegetation should be established as soon as possible after completion of the embankment fills in order to limit surficial erosion.

Particle size analyses in conjunction with the Wischmeier Nomograph indicate that the granular fill encountered on site has a low erosion potential and that the native clay has a moderate erosion potential.

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.

Typically, rock protection should be provided over all earth surfaces subjected to flowing water in accordance with OPSS 511. 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 clay seal and/or a concrete cut-off wall be used to minimize the potential for piping and erosion around the inlet of the culvert. The clay seal must extend to approximately 300 mm above the high water level and laterally for the width of the granular material, and have a minimum thickness of 500 mm. For pipe or closed box culverts, the clay seal should also extend below the bedding and scour level (i.e., to the bedrock surface) if a concrete cut-off wall is not also used. For an open bottom culvert, the clay seal would only be required laterally outside the culvert walls to prevent piping through the granular backfill. The material requirements for a clay seal should be in accordance with OPSS.PROV 1205. A geosynthetic clay liner may be used as a clay seal. A concrete cut-off wall should be constructed per OPSD 812.010 for CSP culverts.

12 CONSTRUCTION CONCERNS

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

- Cobbles/boulders and/or buried obstructions may be encountered in the existing embankment fill (e.g., boulders in rockfill) at this site and could interfere with installation of the roadway protection system.
- Creek water levels will fluctuate. Excavation will involve lowering the water level below the excavation base to maintain a reasonably dry excavation and stable side slopes. The dewatering scheme will be critical for culvert construction at this site.
- Bedrock removal will be required and the vibrations induced by hoe-ramming have the potential to cause damage to sensitive structures or utilities.
- 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 should be carried out by qualified geotechnical personal during construction in accordance with SP109S12 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 Deanna Pizycki, P.Eng. and Stephen Dunlop, P.Eng. The report was reviewed by Dr. Fred Griffiths, P.Eng., who is approved in RAQS for MTO Foundation Projects.



Deanna Pizycki, P,Eng.
Geotechnical Engineer



Stephen Dunlop, P.Eng.
Associate, Senior Geotechnical Engineer

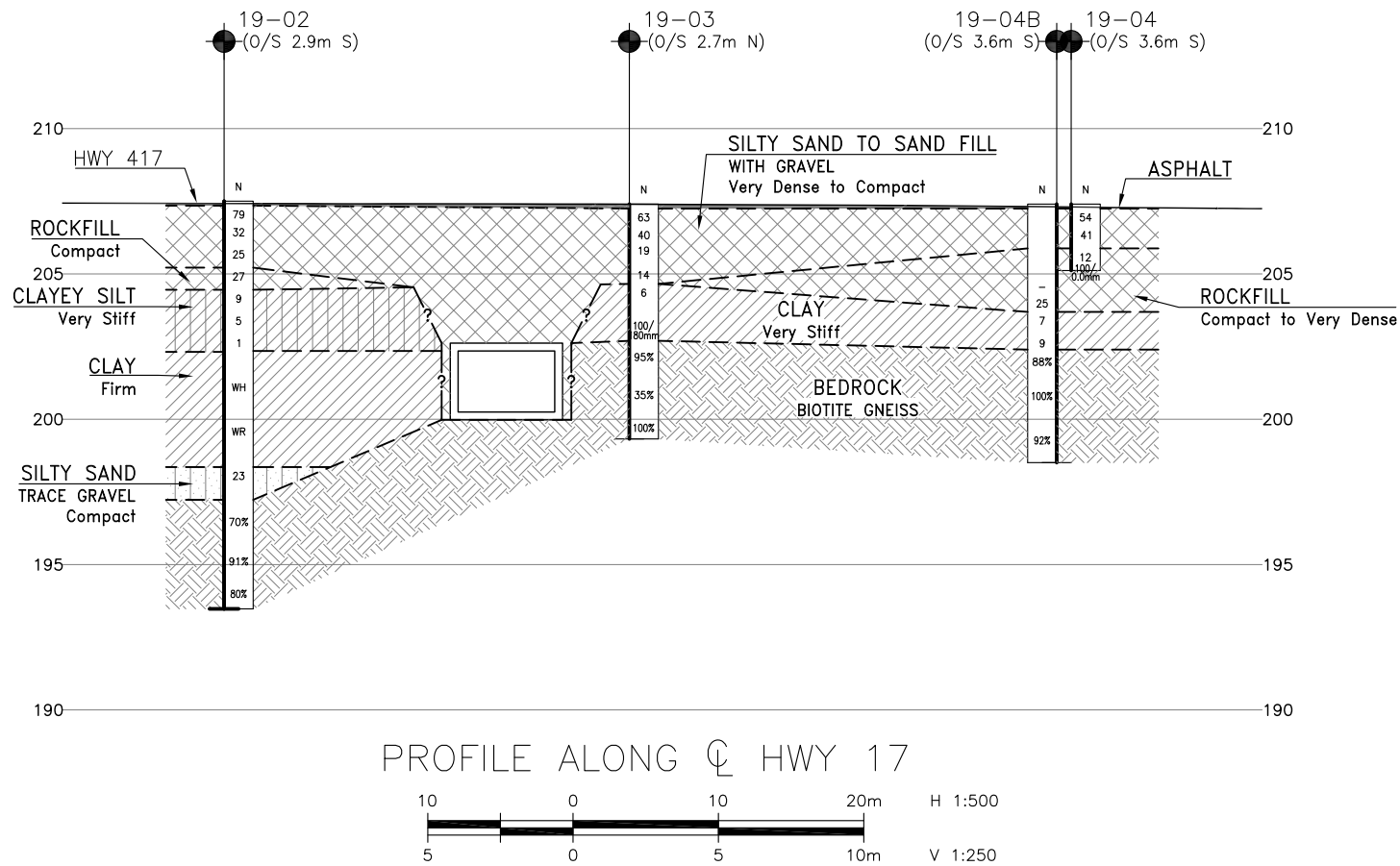
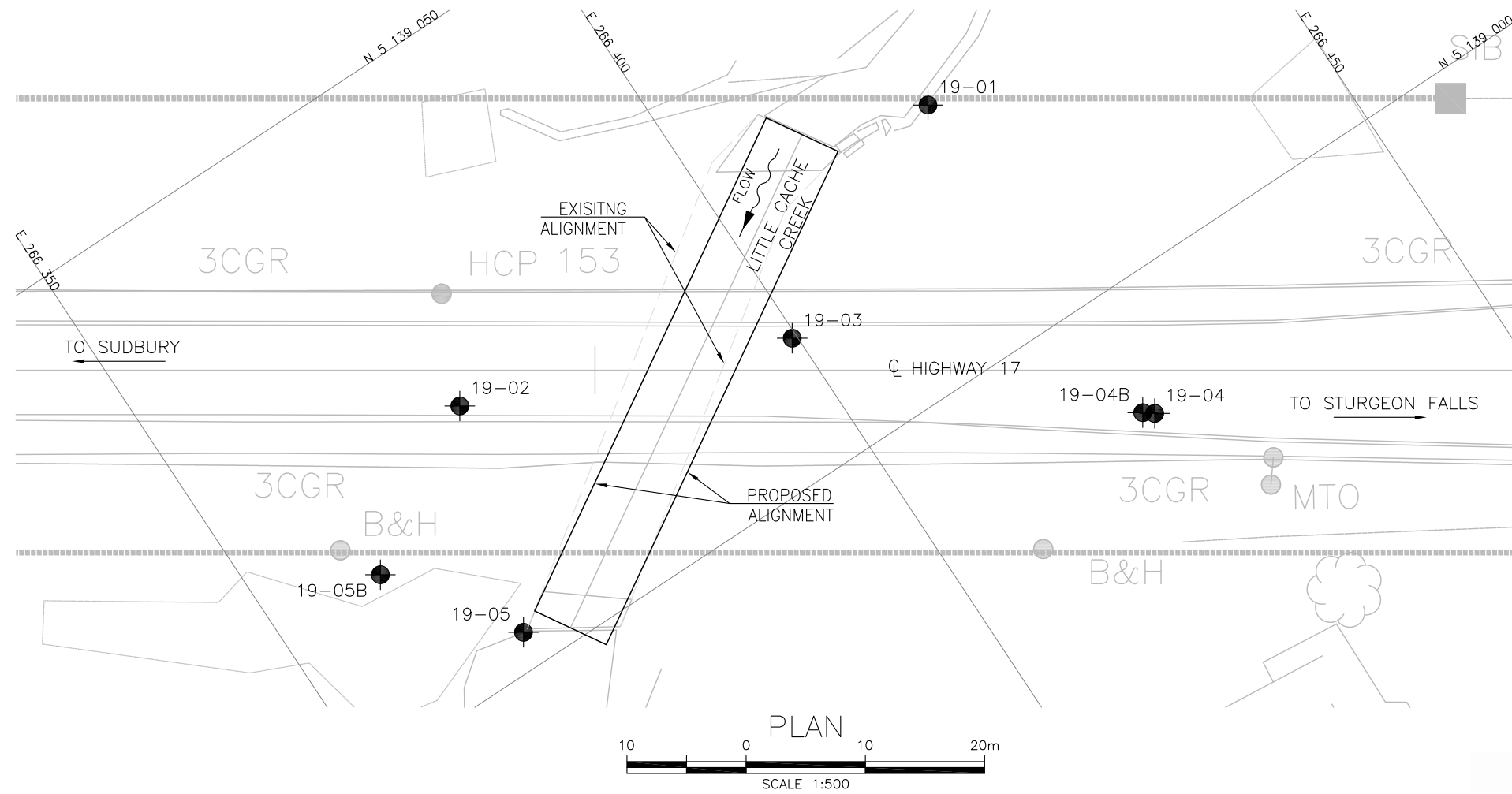


Fred Griffiths, Ph.D., P.Eng.
Senior Associate
Senior Geotechnical Engineer



Appendix A.

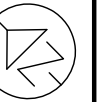
Borehole Location Plan and Stratigraphic Drawings



METRIC
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AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No
GWP No 5198-13-00

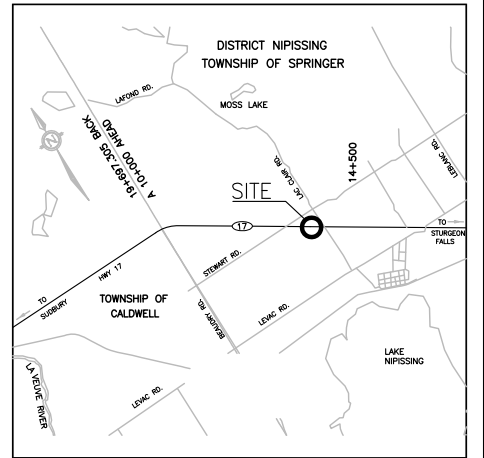
HIGHWAY 17
LITTLE CACHE CREEK
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

	Borehole
	Borehole and Cone
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

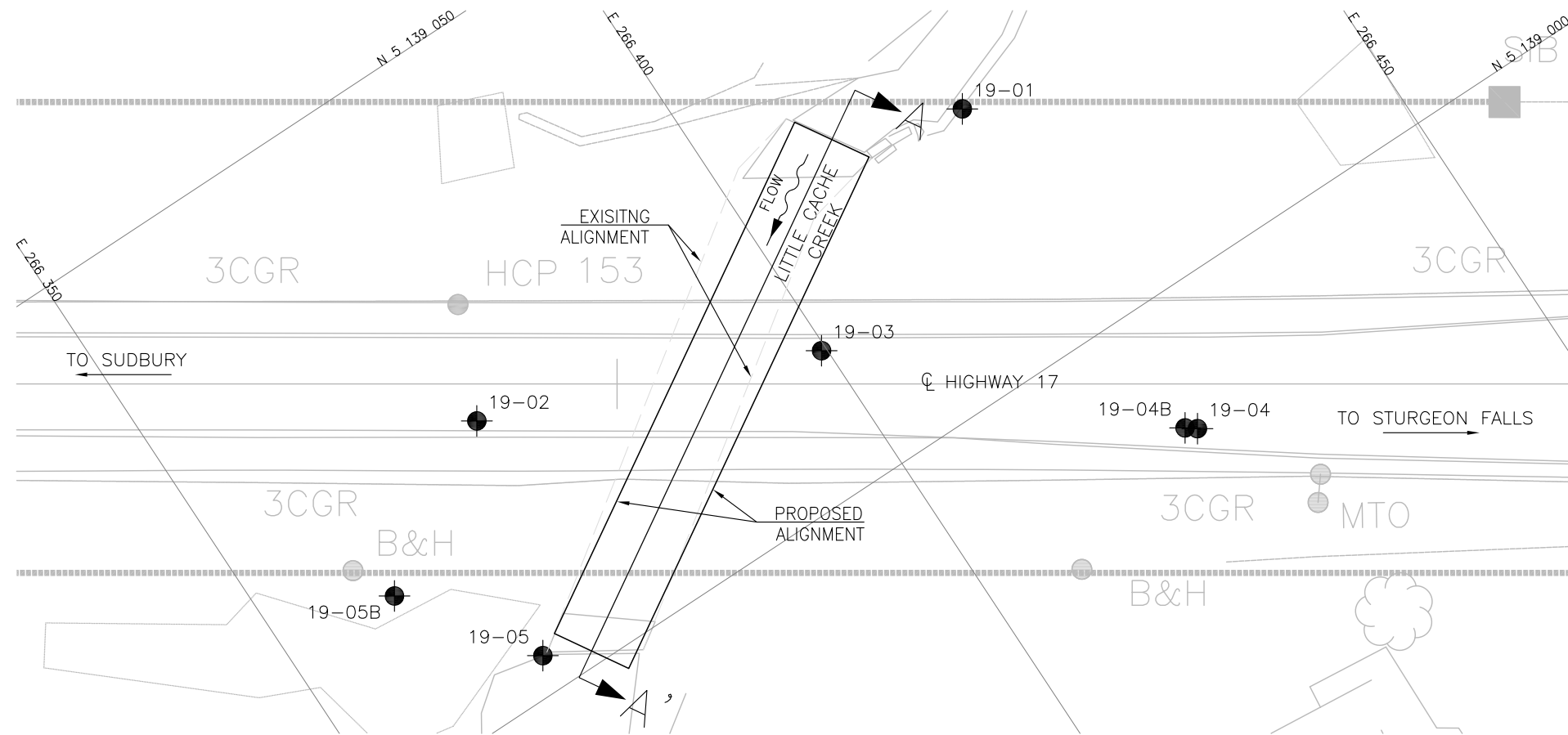
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19-02	207.5	5 139 021.8	266 373.2
19-03	207.4	5 139 011.2	266 399.6
19-04	207.4	5 138 989.2	266 421.5
19-04B	207.4	5 138 989.8	266 420.7
19-05	201.2	5 139 003.0	266 367.2
19-05B	203.3	5 139 013.6	266 359.8

-NOTES-

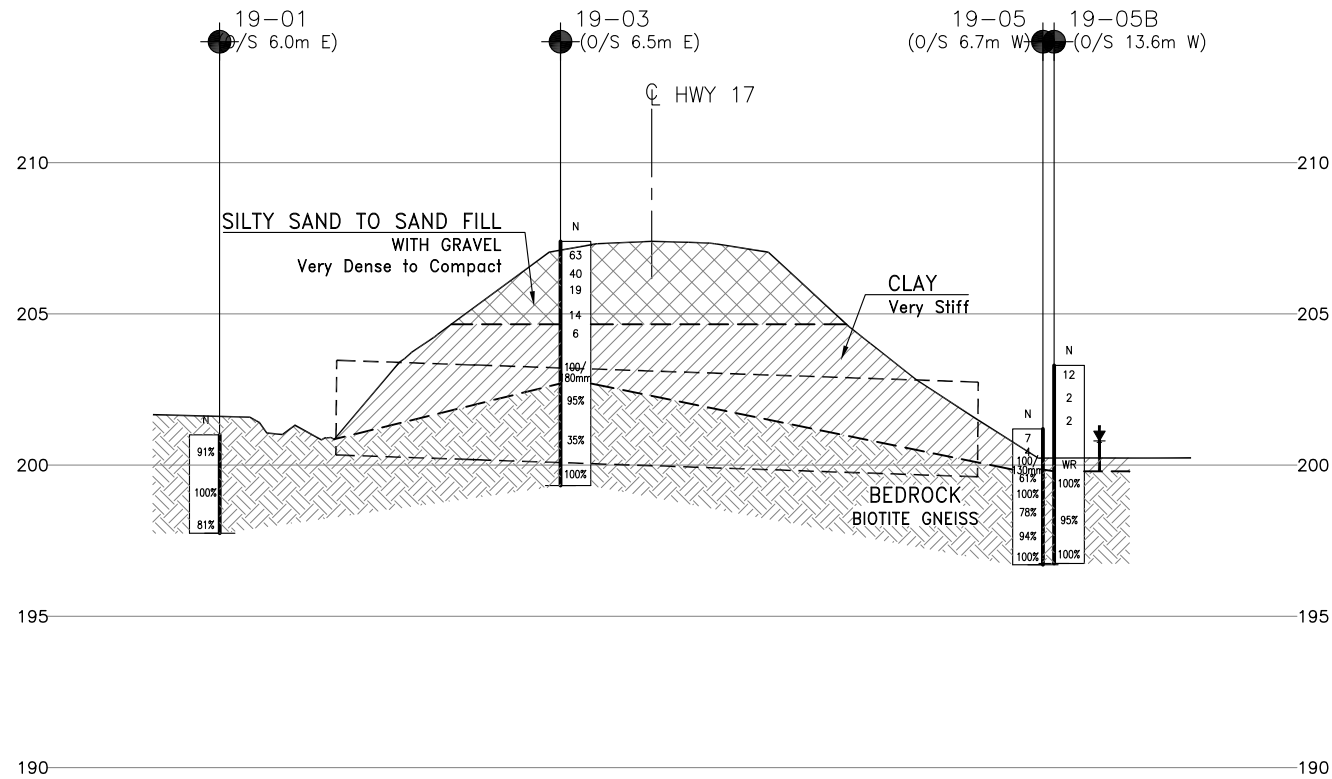
- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Coordinate system is MTM NAD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

GEOCRES No. 411-364

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	DP	CHK SD	CODE
DRAWN	AN	CHK DP	SITE
			LOAD
			STRUCT
			DWG 1
			DATE JUN 2020



PLAN
SCALE 1:500



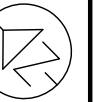
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SCALE 1:500
SCALE 1:250

METRIC
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AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

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GWP No 5198-13-00

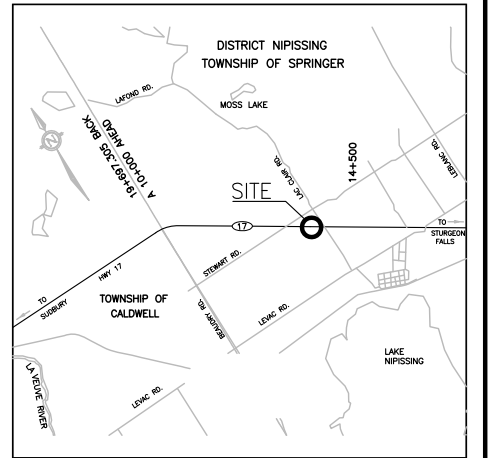
HIGHWAY 17
LITTLE CACHE CREEK
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

●	Borehole
⊙	Borehole and Cone
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
19-01	201.0	5 139 021.3	266 419.9
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19-04B	207.4	5 138 989.8	266 420.7
19-05	201.2	5 139 003.0	266 367.2
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-NOTES-

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GEOCRES No. 411-364

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	DP	CHK SD	CODE
DRAWN	AN	CHK DP	SITE
			LOAD
			DATE JUN 2020
			STRUCT
			DWG 2



Appendix B.
Record of Borehole Sheets



SYMBOLS, ABBREVIATIONS AND TERMS USED ON TEST HOLE RECORDS

TERMINOLOGY DESCRIBING COMMON SOIL GENESIS

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

TERMINOLOGY DESCRIBING SOIL STRUCTURE:

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

RECOVERY:

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

N-VALUE:

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

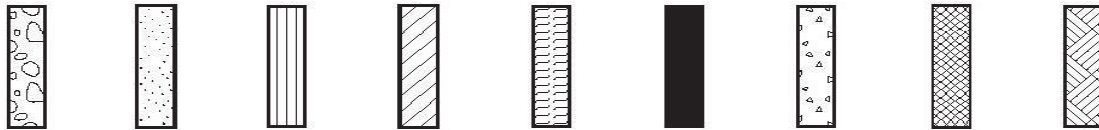
DYNAMIC CONE PENETRATION TEST (DCPT):

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



STRATA PLOT:

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



Boulders
Cobbles
Gravel Sand Silt Clay Organics Asphalt Concrete Fill Bedrock

TEXTURING CLASSIFICATION OF SOILS

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

TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

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

SAMPLE TYPES

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

TERMS DESCRIBING CONSISTENCY (COHESIONLESS SOILS ONLY)

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

MODIFIED UNIFIED SOIL CLASSIFICATION

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

Note - W_L = Liquid Limit



EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

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

TERMS

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

DISCONTINUITY SPACING

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

STRENGTH CLASSIFICATION

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

RECORD OF BOREHOLE No 19-01

1 OF 1

METRIC

WP# 812-76-01 LOCATION Lat: 46.3898°, Long: -79.999028°
Little Cache Creek Culvert N 5 139 021.3 E 266 419.9 ORIGINATED BY MJJ
HWY 17 BOREHOLE TYPE CME 850 Trackmount, NQ Coring COMPILED BY MW
DATUM Geodetic DATE 2019.08.21 - 2019.08.21 CHECKED BY FG

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 (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
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RECORD OF BOREHOLE No 19-02

1 OF 2

METRIC

WP# 812-76-01 LOCATION Lat: 46.389802°, Long: -79.999635°
Little Cache Creek Culvert N 5 139 021.8 E 266 373.2 ORIGINATED BY SOB
HWY 17 BOREHOLE TYPE CME 55 Truckmount, NW Casing / NQ Coring COMPILED BY MW
DATUM Geodetic DATE 2019.08.09 - 2019.08.09 CHECKED BY FG

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	W _P W W _L	SHEAR STRENGTH kPa			WATER CONTENT (%)			
207.5																
0.0	ASPHALT (150 mm)															
0.2	SAND with gravel Very dense to compact Brown Dry Hydrocarbon odour from 0.8 to 2.1 m FILL		1	SS	79		207									
			2	SS	32											
			3	SS	25		206									
205.2																
2.3	ROCKFILL Compact		4	SS	27		205									
204.5																
3.0	CLAYEY SILT (CL) Very stiff to firm Grey/red		5	SS	9		204									
			6	SS	5		203									
			7	SS	1											
202.3																
5.2	CLAY (CH) Firm Grey						202	4.7								
			8	SS	WH		201		4.9							
							200	6.0								
								11.0								
			9	SS	WR											
							199									
								10.0								
								13.3								
198.4																
9.1	SILTY SAND (SM) trace gravel Compact Grey Wet		10	SS	23		198									

Continued Next Page

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

DOUBLE LINE 23411 LITTLE CACHE.GPJ 2012TEMPLATE(MTO).GDT 15/6/20

RECORD OF BOREHOLE No 19-02

2 OF 2

METRIC

WP# 812-76-01 LOCATION Lat: 46.389802°, Long: -79.999635°
Little Cache Creek Culvert N 5 139 021.8 E 266 373.2 ORIGINATED BY SOB
HWY 17 BOREHOLE TYPE CME 55 Truckmount, NW Casing / NQ Coring COMPILED BY MW
DATUM Geodetic DATE 2019.08.09 - 2019.08.09 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)								
								20 40 60 80 100	○ UNCONFINED + FIELD VANE			w _P w w _L								
								20 40 60 80 100	● QUICK TRIAXIAL × LAB VANE											
	Continued From Previous Page																			
197.2	SILTY SAND (SM) trace gravel													FI						
10.3	BIOTITE GNEISS BEDROCK with white/pink feldspar banding Slightly weathered to fresh Fine to coarse grained Very strong White, black and pink		1	RUN	-		197								>10	RUN #1 TCR=100% SCR=70% RQD=70%				
															1					
															>10					
			2	RUN	-		196										1	RUN #2 TCR=100% SCR=91% RQD=91%		
															0					
															2					
			3	RUN	-		195												1	RUN #3 TCR=100% SCR=95% RQD=80%
															1					
															0					
			194											5						
											1									
											1									
193.5																				
14.0	End of Borehole																			

RECORD OF BOREHOLE No 19-03

1 OF 1

METRIC

WP# 812-76-01 LOCATION Lat: 46.389708°, Long: -79.999291°
Little Cache Creek Culvert N 5 139 011.2 E 266 399.6 ORIGINATED BY SOB
HWY 17 BOREHOLE TYPE CME 55 Truckmount, NW Casing / NQ Coring COMPILED BY MW
DATUM Geodetic DATE 2019.08.16 - 2019.08.16 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT CONTENT CONTENT				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									
						○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE															
207.4								20	40	60	80	100									
0.0	ASPHALT (150 mm)																				
0.2	SILTY SAND with gravel Very dense to compact Dark brown to brown Dry to moist Slight hydrocarbon odour from 0.8 to 1.8 m FILL		1	SS	63		207														
			2	SS	40																
			3	SS	19		206														
205.3																					
2.1	SAND Compact Brown Wet FILL		4	SS	14		205														
204.7																					
2.7	CLAY (Cl) Very stiff Light brown		5	SS	6																
							204														
			6	SS	100/ 180 mm		203														
202.7																					
4.7	BIOTITE GNEISS BEDROCK with white/pink feldspar banding Fresh Fine to coarse grained Very strong White, black and pink 700 mm clay infill at 6.0 m		1	RUN	-		202														
			2	RUN	-		201														
			3	RUN	-		200														
199.3																					
8.1	End of Borehole																				

+³, ×³: Numbers refer to
Sensitivity

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15
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(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 19-04

1 OF 1

METRIC

WP# 812-76-01 LOCATION Lat: 46.389512°, Long: -79.999004°
Little Cache Creek Culvert N 5 138 989.2 E 266 421.5 ORIGINATED BY SOB
HWY 17 BOREHOLE TYPE CME 55 Truckmount, NW Casing / NQ Coring COMPILED BY MW
DATUM Geodetic DATE 2019.08.15 - 2019.08.15 CHECKED BY FG

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						
207.4														
0.0	ASPHALT (150 mm)													
0.2	SAND with gravel Occasional clayey seams Very dense to dense Dark brown Dry to moist Slight odour from 0.2 to 0.8 m FILL		1	SS	54		207							
			2	SS	41									
205.9							206							
1.5	ROCKFILL Compact		3	SS	12									
205.1			4	SS	100/									
2.3	End of Borehole due to equipment breakdown when trying to advance through probable boulder. Continue on Borehole 19-04B				0 mm									

RECORD OF BOREHOLE No 19-04B

1 OF 1

METRIC

WP# 812-76-01 LOCATION Lat: 46.389517°, Long: -79.999014°
Little Cache Creek Culvert N 5 138 989.8 E 266 420.7 ORIGINATED BY SOB
HWY 17 BOREHOLE TYPE CME 55 Truckmount, NW Casing / NQ Coring COMPILED BY MW
DATUM Geodetic DATE 2019.08.15 - 2019.08.15 CHECKED BY FG

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 (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE				w P w w L				
								● QUICK TRIAXIAL × LAB VANE								
						20	40	60	80	100	20	40	60			
207.4																
0.0	Refer to Borehole 19-04 for upper stratigraphy															
205.9																
1.5	ROCKFILL Compact															
	660 mm boulder at 2.5 m SS6 100 blows / 0 mm		5	NQ	-											
	530 mm boulder at 3.2 m		7	NQ	-											
203.7																
3.7	CLAY (CH) trace sand Very stiff Light brown		8	SS	7											
	Some gravel below 4.6 m		9	SS	9											
202.4																
5.0	BIOTITE GNEISS BEDROCK with white/pink feldspar banding Fresh Fine to coarse grained Very strong White, black and pink		1	RUN	-											
			2	RUN	-											
			3	RUN	-											

DOUBLE LINE 23411 LITTLE CACHE.GPJ 2012TEMPLATE(MTO).GDT 15/6/20

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

RECORD OF BOREHOLE No 19-05

1 OF 1

METRIC

WP# 812-76-01 LOCATION Lat: 46.389633°, Long: -79.999711°
Little Cache Creek Culvert N 5 139 003.0 E 266 367.2 ORIGINATED BY MJJ
HWY 17 BOREHOLE TYPE Portable, NW Casing / NQ Coring COMPILED BY MW
DATUM Geodetic DATE 2019.08.21 - 2019.08.21 CHECKED BY FG

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						
201.2								20 40 60 80 100						
0.0								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						
200.5						20 40 60 80 100					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W P W W L			
0.7						20 40 60 80 100					WATER CONTENT (%)			
199.9						20 40 60 80 100								
1.3						20 40 60 80 100								
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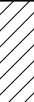


+³, ×³: Numbers refer to Sensitivity
20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 19-05B

1 OF 1

METRIC

WP# 812-76-01 LOCATION Lat: 46.389728°, Long: -79.999808°
Little Cache Creek Culvert N 5 139 013.6 E 266 359.8 ORIGINATED BY MJJ
HWY 17 BOREHOLE TYPE CME 850 Trackmount, NW Casing / NQ Coring COMPILED BY MW
DATUM Geodetic DATE 2019.08.21 - 2019.08.21 CHECKED BY FG

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 (%)										
							PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT w _P w w _L										
203.3																	
0.0	CLAYEY SILT (CL), trace organics Very stiff to stiff Brown Dry to moist		1	SS	12		203										
			2	SS	2												
							202										
201.8																	
1.5	CLAY (CH) Stiff Light brown to grey		3	SS	2												
							201										
								6.0 +									
								8.0 +									
			4	SS	WR		200										
199.8																	
3.5	BIOTITE GNEISS BEDROCK with white/pink feldspar banding Fresh Fine to coarse grained Very strong White, black and pink		1	RUN	-										RUN #1 TCR=100% SCR=100% RQD=100%		
					2	RUN	-										RUN #2 TCR=95% SCR=95% RQD=95%
							198										
			3	RUN	-										RUN #3 TCR=100% SCR=100% RQD=100%		
196.7							197										
6.6	End of Borehole																
	19 mm diameter PVC Monitoring Well installed.																
	Well Readings:																
	Date: Depth (m): Elev. (m):																
	08/27/2019 2.5 200.8																
	08/28/2019 2.5 200.8																

DOUBLE LINE 23411 LITTLE CACHE.GPJ 2012TEMPLATE(MTO).GDT 15/6/20



Appendix C.

Laboratory Testing



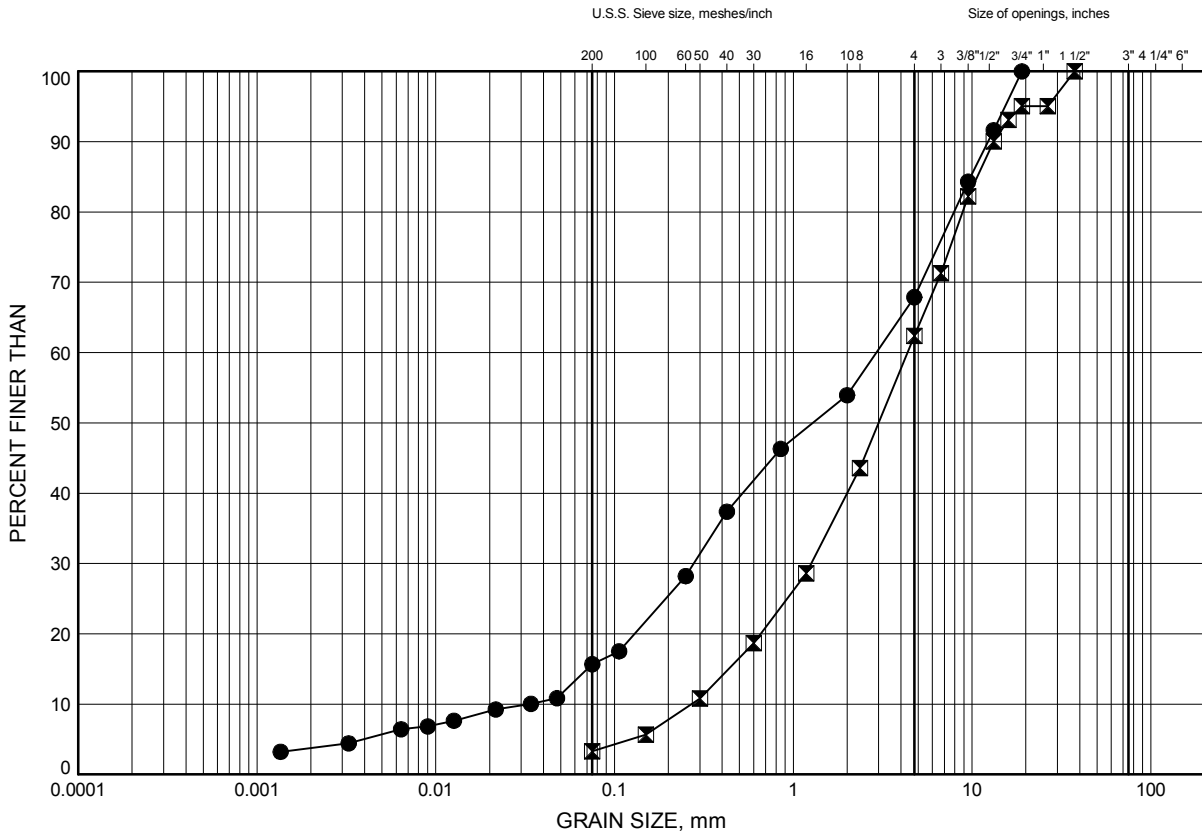
Appendix C.1

Particle Size Analysis and Atterberg Limits Figures

Highway 17 Little Cache Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE C1

FILL: SAND TO SILTY SAND with gravel



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	19-03	1.5	205.9
⊠	19-04	0.5	206.9

Date August 2020
WP# 812-76-01

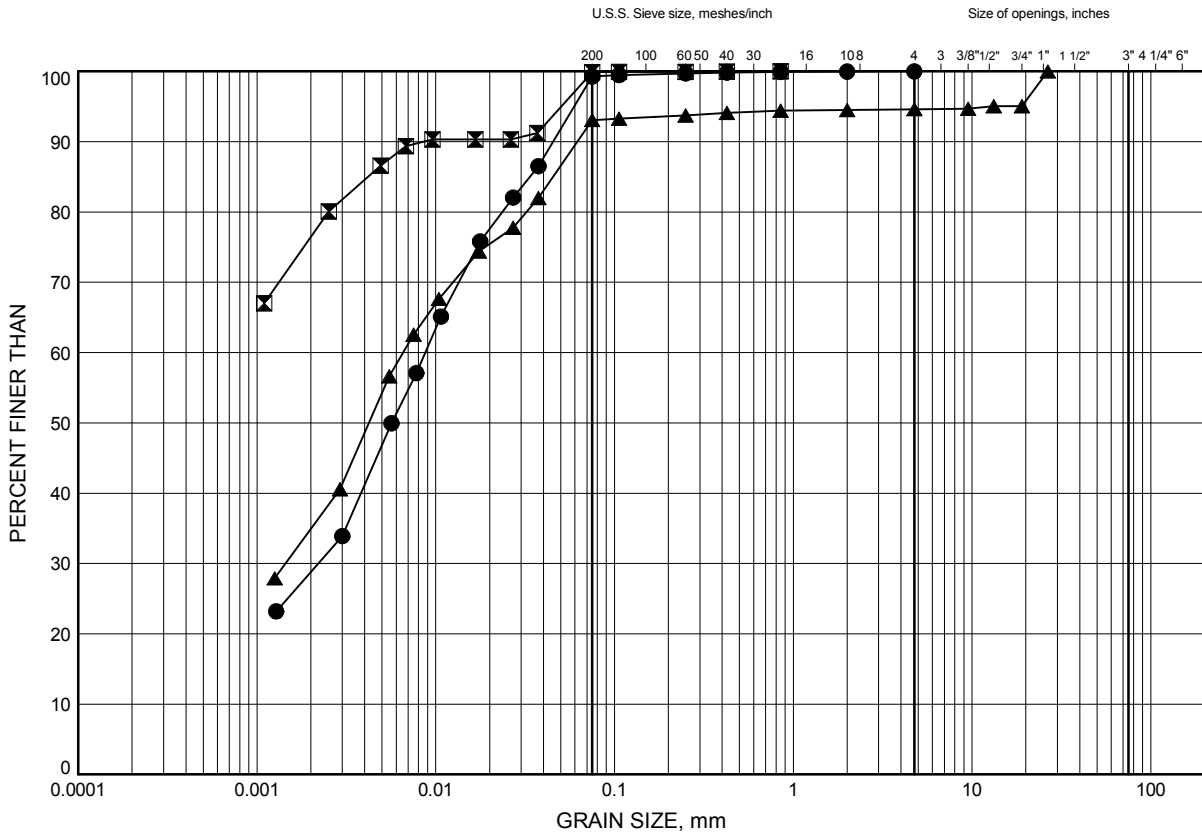


Prep'd DJP
Chkd. FG

Highway 17 Little Cache Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE C2

CLAYEY SILT to CLAY (CL to CH)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	19-02	4.1	203.4
⊠	19-02	7.9	199.6
▲	19-03	3.0	204.4

Date August 2020
WP# 812-76-01

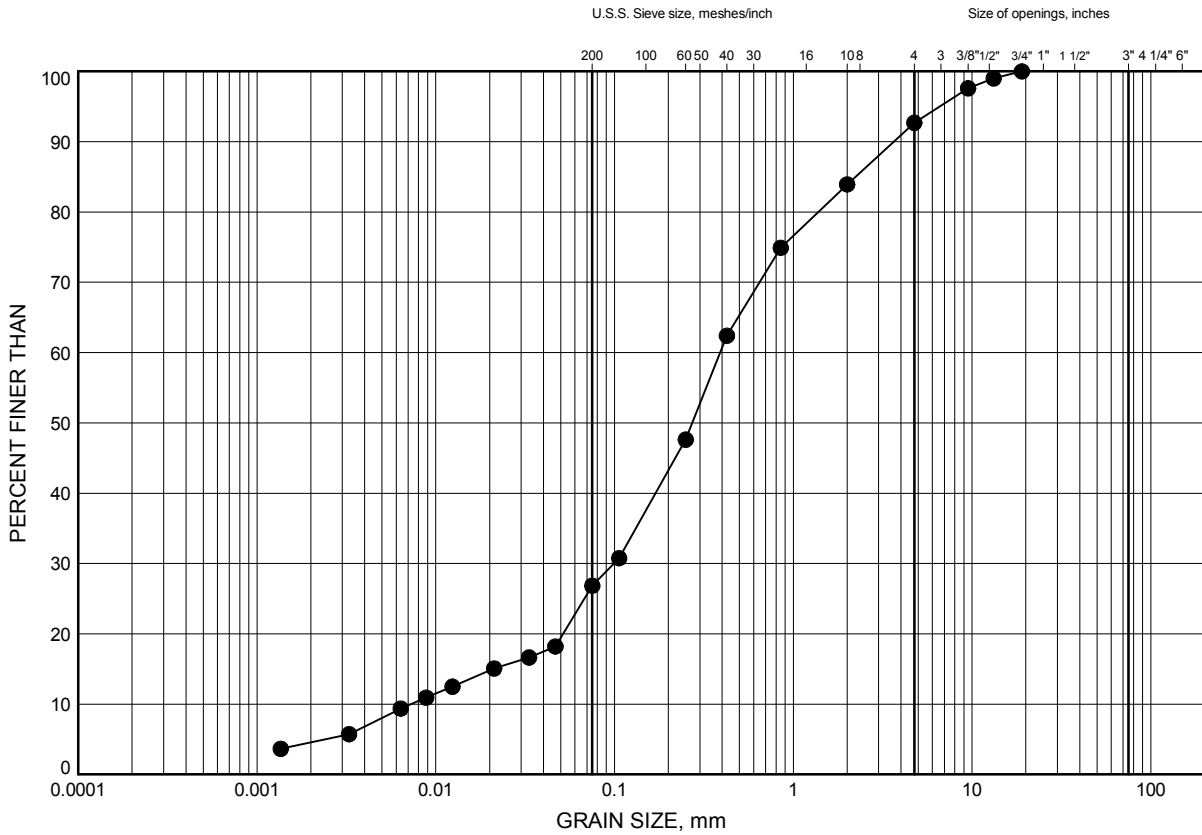


Prep'd DJP
Chkd. FG

Highway 17 Little Cache Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE C3

SILTY SAND (SM)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	19-02	9.4	198.1

Date August 2020
WP# 812-76-01

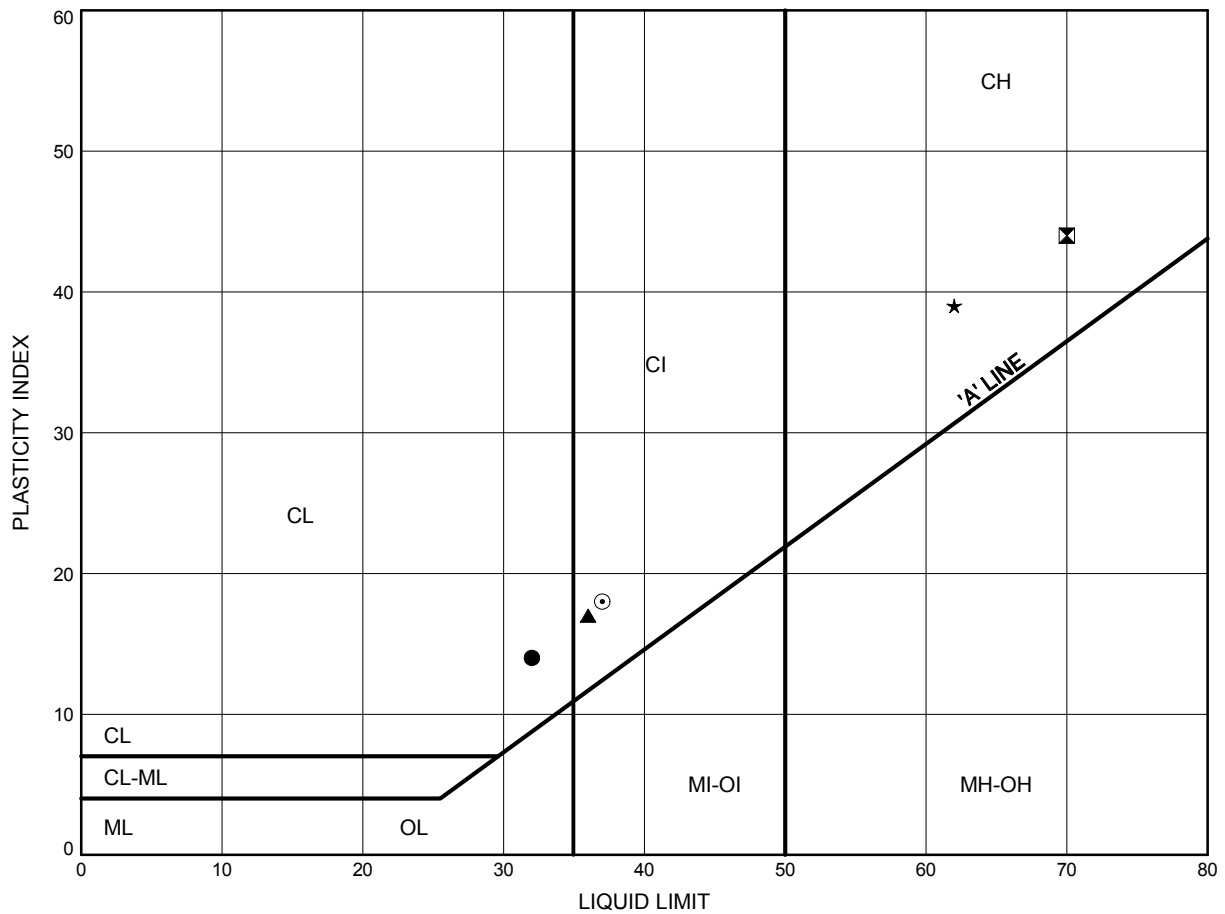


Prep'd DJP
Chkd. FG

Highway 17 Little Cache Creek Culvert ATTERBERG LIMITS TEST RESULTS

FIGURE C4

CLAYEY SILT TO CLAY (CL to CH)



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	19-02	4.1	203.4
⊠	19-02	7.9	199.6
▲	19-03	3.0	204.4
★	19-04B	4.0	203.4
⊙	19-05	0.9	200.3

Date August 2020
 WP# 812-76-01



Prep'd DJP
 Chkd. FG



Appendix C.2
Rock Core Photos
Rock Core Testing Results

Borehole 19-01
Run 1 to 3 (of 3)
Elevation 201.0 m to 197.7 m



Borehole 19-02
Run 1 to 1 (of 3)
Elevation 197.2 m to 195.7 m

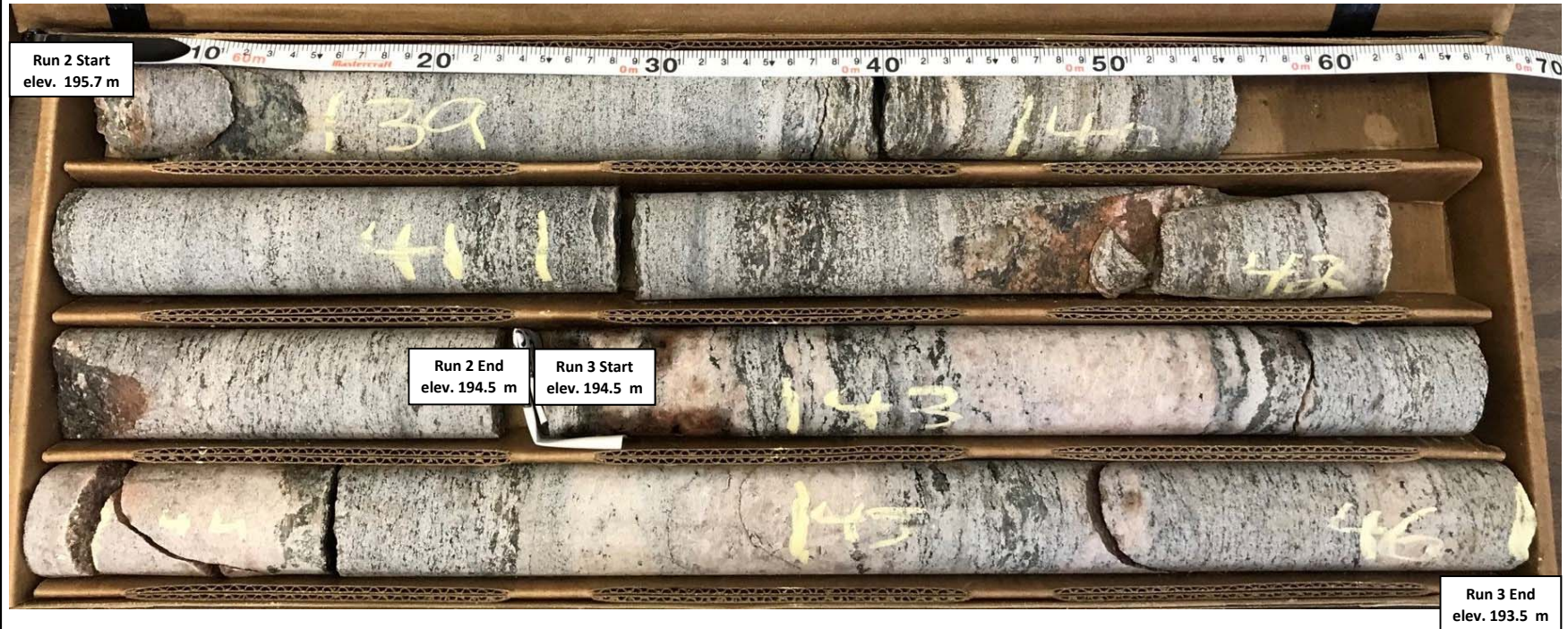


THURBER ENGINEERING LTD.

Foundation Investigation
HWY 17 Little Cache Creek Culvert

BH 19-02
Project No.: 23411

Borehole 19-02
Run 2 to 3 (of 3)
Elevation 195.7 m to 193.5 m



Borehole 19-03
Run 1 to 2 (of 3)
Elevation 202.7 m to 200.1 m



Borehole 19-03
Run 3 to 3 (of 3)
Elevation 200.1 m to 199.3 m



THURBER ENGINEERING LTD.

Foundation Investigation
HWY 17 Little Cache Creek Culvert

BH 19-03
Project No.: 23411

Borehole 19-04B
Run 1 to 2 (of 3)
Elevation 202.4 m to 200.0 m



THURBER ENGINEERING LTD.

Foundation Investigation
HWY 17 Little Cache Creek Culvert

BH 19-04B
Project No.: 23411

Borehole 19-04B
Run 3 to 3 (of 3)
Elevation 200.0 m to 198.5 m



THURBER ENGINEERING LTD.

Foundation Investigation
HWY 17 Little Cache Creek Culvert

BH 19-04B
Project No.: 23411

Borehole 19-05
Run 1 to 3 (of 4)
Elevation 199.9 m to 197.8 m



Borehole 19-05
Run 3 to 4 (of 4)
Elevation 197.8 m to 196.7 m



THURBER ENGINEERING LTD.

Foundation Investigation
HWY 17 Little Cache Creek Culvert

BH 19-05
Project No.: 23411

Borehole 19-05B
Run 1 to 2 (of 3)
Elevation 199.8 m to 197.4 m



Borehole 19-05B
Run 3 to 3 (of 3)
Elevation 197.4 m to 196.7 m





Stantec

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

September 05, 2019
File: 122410864

Attention: Thurber Engineering, File #23411

Reference: ASTM D7012, Method C, Unconfined Compressive Strength of Intact Rock Core
Highway 17 Little Cache

The following table summarizes three rock core compressive strength results.

Location	Sample Depth	Compressive Strength (MPa)	Description of Break
19-1	13'8"-15'1"	161.6	Well-formed cones at both ends
19-3 UCS-5	16'6.5"-17'4"	115.1	Vertical cracking through both ends
19-4B UCS-4	19'2"-19'10"	170.4	Well-formed cones at both ends

Sincerely,

Stantec Consulting Ltd

Brian Prevost

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



Appendix C.3

Analytical Testing Results

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

Report Date: 06-Sep-2019

Order Date: 3-Sep-2019

Project Description: 23411 (Little Cache)

Client ID:	19-3 SS6 14'-15'1"	19-5 SS3 4'-5'3"	-	-
Sample Date:	16-Aug-19 09:00	21-Aug-19 09:00	-	-
Sample ID:	1936024-01	1936024-02	-	-
MDL/Units	Soil	Soil	-	-

Physical Characteristics

% Solids	0.1 % by Wt.	75.7	69.9	-	-
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General Inorganics

Conductivity	5 uS/cm	2400	878	-	-
pH	0.05 pH Units	7.86	7.87	-	-
Resistivity	0.10 Ohm.m	4.16	11.4	-	-

Anions

Chloride	5 ug/g dry	1440	426	-	-
Sulphate	5 ug/g dry	90	50	-	-

**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

13-September-2019

Date Rec. : 10 September 2019

LR Report: CA12211-SEP19

Reference: Project#: 1936024

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

Sample ID	Sample Date & Time	Sulphide %
1: Analysis Start Date		13-Sep-19
2: Analysis Start Time		13:06
3: Analysis Completed Date		13-Sep-19
4: Analysis Completed Time		13:21
5: QC - Blank		< 0.02
6: QC - STD % Recovery		115%
7: QC - DUP % RPD		ND
8: RL		0.02
9: 19-3 SS6 14'-15'1"	16-Aug-19	< 0.02
10: 19-5 SS3 4'-5'3"	21-Aug-19	0.04

RL - SGS Reporting Limit
ND - Not Detected

Kimberley Didsbury
Project Specialist,
Environment, Health & Safety



Appendix D.
Site Photographs



Photo 1. Looking South at Culvert Inlet during Summer (08/27/2019)



Photo 2. Looking South at Culvert Inlet during Fall (10/26/2018)



Photo 3. Looking Inside Culvert from Inlet (10/26/2018)



Photo 4. Looking Northeast at Culvert Outlet (08/28/2019)



Photo 5. Looking West on HWY 17 from Culvert (08/29/2019)



Photo 6. Looking East on HWY 17 from Culvert (08/29/2019)



Appendix E.
Foundation Comparison

COMPARISON OF ALTERNATIVE FOUNDATION TYPES

Type	Circular Pipe Culvert	Closed Box Culvert	Open Bottom Culvert
Advantages	<ul style="list-style-type: none"> • Can tolerate larger magnitude of settlement than concrete (rigid frame) culverts. • Relatively expedient installation. 	<ul style="list-style-type: none"> • Relatively expedient installation if precast units are used. • Typically, smaller magnitude of settlement than open footing foundation due to lower bearing stress on subgrade. • Minimized differential settlement between culvert and approach fills. 	<ul style="list-style-type: none"> • Limits disturbance to streambed. Typically, favourable from an aquatic habitat perspective. • Relatively expedient installation if precast units are used. • Eliminates the need for a diversion channel. • Less bedrock excavation likely required compared to closed box.
Disadvantages	<ul style="list-style-type: none"> • Feasibility also depends on flow capacity and other hydraulic properties. May need multiple pipes. • A large retaining wall would be required at the inlet for multiple pipes • Requires large excavation. • Roadway protection or temporary widening will be required. • Groundwater control is required. Staged temporary flow control is likely required. 	<ul style="list-style-type: none"> • Requires large excavation. • Roadway protection or temporary widening will be required. • Groundwater control is required. A temporary flow diversion/bypass may be required. 	<ul style="list-style-type: none"> • Requires large excavation. • Roadway protection or temporary widening will be required. • Groundwater control is required.
Risks/ Consequences	<ul style="list-style-type: none"> • Bedrock removal may be required. • Groundwater inflow can disturb a soil subgrade, or make it difficult to clean and inspect a bedrock subgrade. Compaction of granular bedding could be challenging • Rockfill and shallow bedrock present a challenge for installing roadway protection. Pre-drilling may be required to advance soldier piles, which will likely need to be socketed into the bedrock. 	<ul style="list-style-type: none"> • Significant amounts of bedrock removal may be required to achieve a uniform subgrade level beneath the footprint of the culvert. • Groundwater inflow can make it difficult to clean and inspect a bedrock subgrade. Compaction of granular bedding could be challenging. • Rockfill and shallow bedrock present a challenge for installing roadway protection. Pre-drilling may be required to advance soldier piles, which will likely need to be socketed into the bedrock. 	<ul style="list-style-type: none"> • Will likely require bedrock removal to achieve the design foundation level. • Groundwater inflow can make it difficult to clean and inspect a bedrock subgrade. Placement of tremie concrete in the wet could be required. • Rockfill and shallow bedrock present a challenge for installing roadway protection. Pre-drilling may be required to advance soldier piles, which will likely need to be socketed into the bedrock.
Relative Cost	Low to Moderate	Moderate	Moderate
Recommendation	Feasible	Feasible	Feasible - Preferred



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

Site: 46.390N 79.999W

User File Reference: Little Cache Creek Culvert, Hwy 17

2019-10-11 14:47 UT

Requested by: Thurber Engineering Ltd.

Probability of exceedance per annum	0.000404	0.001	0.0021	0.01
Probability of exceedance in 50 years	2 %	5 %	10 %	40 %
Sa (0.05)	0.146	0.088	0.055	0.016
Sa (0.1)	0.190	0.119	0.076	0.024
Sa (0.2)	0.175	0.110	0.071	0.024
Sa (0.3)	0.142	0.090	0.058	0.020
Sa (0.5)	0.109	0.068	0.044	0.015
Sa (1.0)	0.061	0.038	0.025	0.007
Sa (2.0)	0.030	0.019	0.012	0.003
Sa (5.0)	0.008	0.004	0.003	0.001
Sa (10.0)	0.003	0.002	0.001	0.000
PGA (g)	0.108	0.066	0.042	0.013
PGV (m/s)	0.088	0.052	0.032	0.010

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" (NBCC2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are highlighted in yellow. 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.**

References

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

Structural Commentaries (User's Guide - NBC 2015: Part 4 of Division B)
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



Natural Resources
Canada

Ressources naturelles
Canada

Canada



Appendix G.

List of Special Provisions and OPSS Documents Referenced in this Report

Suggested Text for NSSPs and SPs

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

OPSS.PROV 206	Construction Specification for Grading
OPSS.PROV 501	Construction Specification for Compacting
OPSS 511	Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS 805	Construction Specification for Temporary Erosion and Sediment Control Measures
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
OPSD 208.010	Benching of Earth Slopes
MTOD 803.021	Bedding and Backfill for Precast Concrete Box Culverts
OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
OPSD 812.010	Cut Off Wall for Structural Plate Pipe Arch and Circular CSP
OPSD 3090.101	Foundation Frost Depths for Southern Ontario
SSP105S09	Amendment to OPSS 539 – QVE, Temporary Protection Systems, and Certificate of Conformance
SP109S12	Amendment to OPSS 902 – QVE, Backfilling Compaction, and Certificate of Conformance
SPFOUN0003	Amendment to OPSS 902 – Dewatering Structure Excavations

2. Suggested text for a NSSP on “Obstructions”

Obstructions such as cobbles and boulders (i.e., rockfill) may be encountered in the fill. Such obstructions may impede the progress of open-cut excavations, and/or installation of temporary protection systems. The contractor must use appropriate equipment and methodologies to penetrate the obstructions.

3. Suggested text for a NSSP on “Bedrock Removal and Exclusion of Blasting”

The bedrock at this site is very strong, hard, and abrasive. Greater than normal equipment wear shall be expected during bedrock removal activities (e.g., drilling, hoe-ramming, etc.). The contractor must use appropriate equipment and methodologies to remove the bedrock. Due to the potential negative impacts/complications of blast-related damage, blasting will not be permitted to remove bedrock.

4. Suggested SP – Vibration Monitoring

VIBRATION MONITORING

Item No.

Special Provision

1.0 SCOPE

This special provision describes requirements to carry out vibration monitoring during the bedrock excavations required for the construction of the Highway 17 Little Cache Creek Culvert replacement.

2.0 REFERENCES – Not Used

3.0 DEFINITIONS

For the purpose of this specification, the following definitions apply:

Peak Particle Velocity (PPV) means the maximum component velocity in millimetres per second that ground particles move as a result of energy released from explosive detonations.

Preconstruction Survey means a detailed record, accompanied by film or video, as necessary, of the condition of private or public property, prior to the commencement of construction activities that may cause undue ground vibrations.

4.0 DESIGN AND SUBMISSION REQUIREMENTS

4.1 Vibration Monitoring Plan Submission

The Contractor shall submit details of the vibration monitoring plan to the Contract Administrator for review at least three (3) weeks prior to the start of rock excavation. All submissions shall bear the signature and seal of Professional Engineer licensed to practice in the Province of Ontario. The submittals shall satisfy the specifications and at a minimum contain the following specific information:

- a) Equipment and methods used by the Contractor to perform the work that may cause undue vibration
- b) Qualifications of the vibration monitoring specialist.
- c) Details regarding the proposed instrumentation.
- d) Proposed location of instruments on the existing culvert, nearby utilities and building structures.
- e) Method of monitoring, proposed frequency of readings and proposed frequency of submission of readings to Contract Administrator.
- f) Proposed methods for adjusting construction methods if readings show vibrations exceeding the specified limits.

4.2 Preconstruction Survey

When construction activities such as rock excavation that may cause significant ground vibrations will be carried out, a condition survey of property and structures that may be affected by the work shall be carried out.

The condition survey shall include the location and condition of adjacent properties, buildings, underground structures, water wells, utilities, and structures, within a distance of 100 metres from the construction activity. In addition, all water wells used as a supply of drinking water and located within this distance shall be tested for compliance with Ontario Drinking Water Quality Standards.

Water wells within the preconstruction survey distance can be located using the website

<https://www.ontario.ca/environment-and-energy/map-well-records> or its successor site.

Copies of the condition survey and water quality test results shall be submitted to the Contract Administrator prior to the operation of the groundwater control system.

5.0 MATERIALS – Not Used

6.0 EQUIPMENT

7.2 Monitoring Equipment

All monitoring equipment shall be capable of measuring and recording ground vibration (PPV) up to 200 mm/s in the vertical, transverse, and radial directions. The equipment shall have been calibrated within the last 12 months either by the manufacturer or other qualified agent. Proof of calibration shall be submitted to the Contract Administrator prior to commencement of any monitoring operations.

7.0 CONSTRUCTION

7.1 Monitoring

7.1.1 General

The Contractor shall employ a vibration monitoring consultant to carry out monitoring for PPV. During rock excavation, deep foundation construction or other construction activities that may cause undue ground vibration, ground vibration (PPV) shall be monitored at the closest portion of any utility, residence, structure, or facility. The monitoring equipment shall be repositioned as required.

7.1.2 Ground Vibration

Ground vibration as measured by PPV shall be limited to the maximum levels shown in Table 1.

TABLE 1
Maximum Peak Particle Velocity (PPV) Values

Element	Frequency (Hz)	PPV (mm/s)
Structures and Pipelines	≤ 40	20
	> 40	50
Concrete and Grout < 72 hours from placement	N/A	10

If the vibration readings are not within the limits stated above, the Contractor must alter construction methods until the vibrations at the existing culvert structure, residential buildings and/or utilities, as applicable, are within acceptable levels.

7.2 Records

The results of ground vibration monitoring shall be made available to the Contract Administrator for site review at the end of each working day that rock excavation, or other construction activities that may cause undue ground vibration was carried out.

7.3 Damage

Upon completion of bedrock excavation, or immediately following the receipt of a complaint, a site condition survey shall be performed to determine if any damage has resulted. The Contractor shall record all incidents of any damage, which shall be reported immediately in writing to the Contract Administrator. All other complaints shall be reported to the Contract Administrator in writing within 24 hours of receipt. Each complaint report shall include the name and address of the complainant, time received, and description of the circumstances that led to the complaint.

8.0 QUALITY ASSURANCE – Not Used

9.0 MEASUREMENT FOR PAYMENT – Not Used

10.0 BASIS OF PAYMENT

Payment at the lump sum contract price for this tender item shall be full compensation for all labour, equipment and materials for completion of the work.