

**FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 527 ROUSSEAU LAKE CULVERT
81.0 KM NORTH OF HIGHWAY 11/17, THUNDER BAY UNORGANIZED
SITE NO.: 48C-242/C
ASSIGNMENT NO. 6017-E-0013**

G.W.P. 6827-14-00

Geocres No.: 52H-46

Report to:

Hatch Corporation

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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 Rousseau Lake Culvert on Highway 527. The culvert is located approximately 81.0 km north of Highway 11/17 within the Unorganized Thunder Bay District and conveys an unnamed creek between Rousseau Lake and Curzon Lake. Thurber Engineering Limited (Thurber) carried out the current investigation as a sub-consultant to Hatch Corporation (Hatch) under Assignment No. 6017-E-0013.

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

The existing culvert, conveying an unnamed creek under Highway 527 from Rousseau Lake to Curzon Lake, is a twin cell timber culvert with an unknown construction date. A site survey plan from Hatch indicates that each cell is approximately 2.2 m wide, 1.5 m high and approximately 18 m long. The culvert alignment is generally west to east with the flow through the culvert toward the west.

At the location of the culvert, Highway 527 is a two-lane highway with a rural cross-section and gravel shoulders. The embankment fill height above the culvert is approximately 1.5 m. The elevation of the road surface at the centreline is approximately 448.2 m. The existing embankment slopes are approximately inclined between 1.8H:1V and 2.6H:1V. The land adjacent to the highway is undeveloped and densely vegetated with trees. Traffic volumes on this section of Highway 527 are understood to be between 170 and 420 AADT (2016).

Photographs showing the existing conditions in the area of the culvert are included in Appendix D for reference.

3 SITE INVESTIGATION AND FIELD TESTING

Thurber contacted Ontario One Call in advance of the field investigation to obtain utility locate clearances in the vicinity of the intended boreholes.

The site investigation and field testing program was carried out between May 30th and June 16th, 2018. The northing, easting and elevation of the boreholes are shown on the Borehole Location and Soil Strata Drawing No. 1 in Appendix A and are summarized in Table 3-1. The site is within MTM Zone 15.

Table 3-1: Borehole Summary

Borehole No.	Drilled Location	Northing (m)	Easting (m)	Ground Surface Elevation (m)	Termination Depth (m)
18-101A	South of culvert – SB Lane	5 441 649.9	355 009.2	448.2	5.2
18-101B	South of culvert – SB Lane	5 441 649.4	355 009.4	448.2	15.6
18-102	Bypass culvert – NB Lane	5 441 670.5	355 006.8	448.1	13.1
18-103	East end – culvert inlet	5 441 653.0	355 021.9	446.4	3.7
18-104	West end – culvert outlet	5 441 656.2	354 997.7	446.0	6.2

The drilling was carried out using a truck mounted CME 75 drill rig for on-road Boreholes 18-101A, 18-101B and 18-102 and portable drilling equipment for off-road Boreholes 18-103 and 18-104.

An obstruction was encountered in Borehole 18-101A which caused the casing to deflect at a depth of 5.2 m, prohibiting advancing past elevation 443.0 m and therefore the borehole was terminated at this elevation. To continue, Borehole 18-101B was advanced 0.6 m south of Borehole 18-101A and continued sampling below a depth of 5.2 m.

Boreholes 18-103 and 18-104 were terminated at depths of 3.7 and 6.2 m, respectively, upon encountering practical refusal of the portable drilling equipment within the very dense glacial till layer.

Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). Boreholes 18-103 and 18-104, which were drilled with portable equipment, also utilized a full-weight hammer for SPT testing. Bedrock was cored and collected in Boreholes 18-101B and 18-102 using NQ coring equipment where encountered.

A 19 mm diameter standpipe piezometer was installed in Borehole 18-103 to allow for measurements of the groundwater level after completion of drilling. The piezometer installation details are illustrated on the respective Record of Borehole sheet provided in

Appendix B. 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 on August 11, 2018.

The drilling and sampling operations were supervised on a full-time basis by a 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 laboratory for further examination and testing.

4 LABORATORY TESTING

Geotechnical laboratory testing consisted of natural moisture content determination and visual identification of all retained soil samples. Testing for grain size distribution and Atterberg Limits 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. Chemical analysis for determination of pH, conductivity, resistivity, sulphate and chloride concentrations was carried out on two soil samples and one surface water sample. Chemical analysis for determination of sulphide concentration was carried out on one soil sample.

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

In general terms, subsurface conditions at the site consist of pavement structure and granular embankment fill overlying a native silt deposit, which is underlain by glacial till over bedrock.

5.1 Embankment Fill

5.1.1 Asphalt

Boreholes 18-101A and 18-102 were drilled through the travelled lanes of the Highway 527 embankment and encountered a layer of asphalt with a thickness ranging from 75 mm to 125 mm.

5.1.2 Fill: Sand

Below the asphalt pavement within the on-road boreholes were layers of granular base (sand with gravel) over silty sand embankment fill. The underside of the embankment fill was at 2.4 to 3.7 m below the existing roadway surface (elev. 444.5 to 445.7 m).

The SPT tests conducted in the fill typically gave N-values ranging from 31 to 94 blows indicating a relative density of dense to very dense. A single N-value of 4 was recorded below the groundwater table near the base of the embankment fill in Borehole 18-101A. Recorded moisture contents ranged from 2 to 29%.

Gradation analyses were completed on two samples of the embankment 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 Embankment Fill

Soil Particle	Percentage (%)
Gravel	1 to 26
Sand	59 to 62
Silt and Clay	12 to 40

5.2 Silty Sand with Organics

A thin layer of silty sand with organics was encountered from surface in off-road Boreholes 18-103 and 18-104. The underside of this layer ranged from 0.6 to 1.2 m below the existing ground surface (elev. 444.8 to 445.8 m). SPT tests conducted in the silty sand gave N-values ranging from 2 to 10 blows indicating relative density of very loose to compact. Very poor sample recovery within the split spoon sampler was noted within this layer. A single moisture content of 47% was measured.

5.3 Peat

A thin layer of fine fibrous peat was encountered directly below the embankment fill in Borehole 18-102 at the culvert bypass location. This layer had a thickness of 1.0 m and an underside depth of 3.4 m below the existing ground surface (elev. 444.7 m). The recorded moisture contents of the peat ranged from 153% to 188%.

5.4 Silt to Sandy Silt

A deposit of silt to sandy silt was encountered below the fill in Borehole 18-101A, below the peat in Borehole 18-102, and below the silty sand in Boreholes 18-103 and 18-104. The thickness of this layer ranged from 0.9 to 3.1 m with underside depths ranging from 1.9 to 5.3 m below ground surface (elev. 444.5 to 441.7 m).

SPT tests conducted in this deposit gave N-values ranging from 3 to 39 blows were recorded within the layer indicating a relative density of very loose to dense. The recorded moisture contents ranged from 24 to 49%.

Gradation analyses were completed on three samples of the silt to sandy silt layer. The grain size distribution curves 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 Silt to Sandy Silt

Soil Particle	Percentage (%)
Gravel	0 to 6
Sand	0 to 29
Silt	56 to 88
Clay	9 to 12

Atterberg Limit testing was completed on three samples of the native silt deposit. Two of the samples were found to be non-plastic; one sample was found to have a liquid limit of 34%, a plastic limit of 27% and a plasticity index of 7% indicating a low plasticity (ML). The results of the Atterberg Limit testing are summarized on the Record of Borehole sheets in Appendix B and the plasticity chart included in Figure C5 of Appendix C.

5.5 Silty Sand to Sandy Clay (Glacial Till)

A deposit of glacial till was encountered below the silt to sandy silt layers in all boreholes. The glacial till varies in composition from silty sand with gravel, to sandy silt with gravel, to sandy clay some gravel, to silty clay. Cobbles were noted in the till in all boreholes and boulders were noted in in Boreholes 18-101A, 18-101B, 18-103 and 18-104.

Boreholes 18-103 and 18-104 were terminated within the glacial till layer at base elevations of 442.7 and 439.8 m respectively upon SPT and/or casing advancement refusal. Where fully penetrated, the thickness of the glacial till deposit ranged from 4.5 to 7.5 m and the underside depth ranged from 9.8 to 12.1 m below the existing ground surface (elev. 436.1 to 438.3 m).

SPT tests conducted in the non-cohesive till deposits gave N-values ranging from 9 blows for 300 mm of penetration to 100 blows for 100 mm indicating a relative density of loose to very dense; but typically dense to very dense. SPT tests conducted in the cohesive till deposit gave N-values ranging from 72 to 140 blows indicating a hard consistency. The recorded moisture contents ranged from 9 to 23% within the glacial till layers.

Gradation analyses were completed on four samples of the non-cohesive till and two samples of the cohesive till. The grain size distribution curves are included in Figures C3 and C4 of Appendix C. The results of the tests are summarized in Table 5-3 below and are presented on the corresponding Record of Borehole sheets in Appendix B.

Table 5-3: Gradation Results for Glacial Till

Soil Particle	Percentage (%)	
	Non-Cohesive Sand/Silt Till	Cohesive Clay Till
Gravel	9 to 26	0 to 11
Sand	28 to 46	1 to 21
Silt	35 to 53	42 to 57
Clay	3 to 6	26 to 42

Atterberg limit testing completed on three samples of the non-cohesive till indicate that the material is non-plastic. Atterberg limit testing completed on two samples of the cohesive clay till indicate a low plasticity (CL-ML to CL). The results are summarized in Table 5-4 below, on the Record of Borehole sheets in Appendix B and on the plasticity chart in Figure C6 of Appendix C.

Table 5-4: Atterberg Limit Results for Clay Till

Parameter	Water Content (%)
Liquid Limit	21 to 22
Plastic Limit	13 to 15
Plasticity Index	7 to 8

5.6 Refusal and Bedrock

Practical refusal to advancement of the portable drilling equipment was encountered at off-road Boreholes 18-103 and 18-104 within the very dense glacial till present at this site. Bedrock was not cored in these boreholes since practical refusal occurred prior to encountering bedrock.

Bedrock was proven by coring in on-road Boreholes 18-101B and 18-102. Information on the confirmed bedrock surface is summarized in Table 5-5 below:

Table 5-5: Summary of Bedrock Depth/Elevation

Borehole No.	Depth to Bedrock Surface (mbgs)	Bedrock Surface Elevation (m)
18-101B	12.1	436.1
18-102	9.8	438.3

The bedrock encountered within Boreholes 18-101B and 18-102 consisted of fine to medium grained mafic metavolcanic bedrock. The Total Core Recovery (TCR) measured on the recovered bedrock core was 100%, the Solid Core Recovery (SCR) ranged from 55 to 100% and the Rock Quality Designation (RQD) ranged from 33 to 89%. Based on the

measured RQD values, the bedrock is classified as poor to good quality. The bedrock is estimated to be very strong. Photographs of the bedrock core are provided in Appendix C.

5.7 Groundwater

The water level was measured in the piezometer installed in Borehole 18-103 and is presented in Table 5-6 below:

Table 5-6: Groundwater Level Observations

Borehole	Groundwater Level		Date of Measurement
	Depth (mbgs)	Elevation (m)	
18-103	0.3	446.1	June 15, 2018
	0.3	446.1	August 11, 2018

The creek water level was surveyed at the culvert inlet and outlet and the measured elevations are provided in Table 5-7 below:

Table 5-7: Creek Water Level Observations

Location	Surface Water Elevation (m)	Date of Measurement
Culvert Inlet	446.0	June 1, 2018
Culvert Outlet	446.0	June 1, 2018

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

5.8 Analytical Testing

Two samples of soil were submitted to Paracel Laboratories in Ottawa, Ontario for analysis of pH, water soluble sulphate and chloride concentrations, resistivity and conductivity. One of the submitted samples was also tested for sulphide. The analysis results are provided in Appendix C and are summarized in Table 5-8 below:

Table 5-8: Analytical Results Summary (Soil)

Borehole	18-101A	18-103
Sample	SS6	SS5
Depth (m)	3.8 – 4.4	2.5 – 3.1
Chloride (µg/g)	9	8
Sulphate (µg/g)	16	12
Sulphide (%)	< 0.02	-
pH (-)	7.8	7.4
Resistivity (Ohm-cm)	7430	7610
Conductivity (uS/cm)	135	131

A surface water sample was obtained on November 30, 2018 upstream of the existing culvert and was also submitted to Paracel Laboratories in Ottawa, Ontario for analysis of conductivity, pH, resistivity, chloride and sulphate. The analysis results are provided in Appendix C and are summarized in Table 5-9 below.

Table 5-9: Analytical Results Summary (Surface Water)

Parameter	Result
Chloride (mg/L)	7
Sulphate (mg/L)	1
pH (-)	7.5
Resistivity (Ohm-cm)	7,990
Conductivity (μ S/cm)	125

6 MISCELLANEOUS

Borehole locations were selected in consultation with Hatch and the Ministry of Transportation relative to the existing culvert and the existing site features. The as-drilled locations and ground surface elevations were surveyed by Thurber.

George Downing Estate Drilling Ltd. of Hawkesbury, Ontario and OGS Drilling of Almonte, Ontario supplied and operated the drilling equipment for the on-road and off-road boreholes respectively, to carry out the drilling, soil sampling, in-situ testing, piezometer installation and borehole decommissioning. Traffic control was provided by NC Traffic Management Inc of Kirkland Lake, Ontario. The field investigation was supervised on a full-time basis by Mr. Nick Weil and Mr. Sean O'Bryan, C.E.T., of Thurber. Overall supervision of the investigation program was conducted by Mr. Stephen Dunlop, P.Eng.

Routine geotechnical laboratory testing was completed by Thurber's laboratory in Ottawa, Ontario. Analytical testing was completed by Paracel Laboratories in Ottawa, Ontario.

Interpretation of the factual data and preparation of this report were carried out by Mr. Christopher Murray, P.Eng. and Mr. Stephen Dunlop, P.Eng. The report was reviewed by Dr. Fred Griffiths, P.Eng., a Designated Principal Contact for MTO Foundation Projects.



Christopher Murray, M.A.Sc., P.Eng.
Geotechnical Engineer



Stephen Dunlop, M.A.Sc., P.Eng.
Senior Geotechnical Engineer



Dr. Fred Griffiths, P.Eng.
Senior Associate
Senior Geotechnical Engineer

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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 Rousseau Lake culvert crossing Highway 527. The discussion and recommendations presented in this report are based on the information provided by Hatch and on the factual data obtained during the course of the investigation.

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

The existing culvert, conveying an unnamed creek from Rousseau Lake under Highway 527, is a twin cell timber culvert with an unknown construction date. A site survey plan from Hatch indicates that each cell is approximately 2.2 m wide, 1.5 m high and approximately 18 m long. The culvert alignment is generally west to east with the flow through the culvert toward the west.

Creek bottom elevations of 445.3 m and 445.4 m at the outlet and inlet, respectively were surveyed by Thurber during the field investigation. The embankment fill height above the culvert is approximately 1.5 m. The elevation of the road surface at the centreline is approximately 448.2 m. The existing embankment slopes are inclined between approximately 1.8H:1V and 2.6H:1V.

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

7.1 Preferred Structure

It is understood that the preferred replacement culvert will consist of twin 2.74 m diameter corrugated steel pipes (CSP) with a clear separation of 1.0 m. It is also understood that the new culvert will be installed on the same alignment as the existing culvert. The proposed

invert elevations are 444.6 and 444.5 m at the upstream and downstream ends of the culvert, respectively.

Other potential culvert types (e.g., box, open-bottom, and steel sheet piles) are also discussed in this report from a feasibility perspective.

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 0.038g. This value is to be scaled by the $F(PGA)$ based on the site specific Site Class.

8.2 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 D in accordance with Section 4.4.3.2 of the CHBDC (S6-14).

8.3 Seismic Liquefaction

The Seed & Idriss Simplified Method was used to assess the potential for liquefaction at this site. Based on the low reference PGA and the subsurface conditions encountered at the drilled locations at this site, the non-cohesive foundation soils are considered not susceptible to liquefaction during a seismic event.

The cohesive foundation soil encountered at this site is classified as not susceptible to cyclic mobility based on the criteria presented by Bray et al (2004) and the measured moisture contents and Atterberg limits of the three tested samples.

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, the depth to suitable bearing stratum and post-construction settlement criteria. From a geotechnical perspective, the following culvert types were considered:

- Circular Pipes (Concrete, HDPE, Steel)
From a foundation engineering perspective, pipe culverts are a feasible culvert option. It is understood that two pipes with internal diameters of 2.74 m would be required at this site to meet the hydraulic requirements.
- Closed Bottom Culvert (Box)
A precast segmental box culvert is considered a feasible option from a foundation engineering perspective. Precast sections, rather than cast-in-place construction, can be installed expediently with less potential for disturbance of the founding soils during installation.
- Open Bottom Culvert (Box, Arch)
Open bottom culverts are considered feasible for this site from a foundation engineering perspective but would require greater excavation and dewatering efforts during construction to place the foundation in the dry. Local subexcavation and replacement of silt soils would likely be necessary to ensure a consistent footing subgrade.
- Steel Sheet Pile Walls with Precast Concrete Slab
A culvert consisting of two rows of parallel sheet pile walls supporting precast concrete slabs is not considered feasible at this site because of the high risk of the sheet piles refusing at an insufficient depth in the very dense glacial till, which contains cobbles and boulders.

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

9.2 Construction Methodology Alternative

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

- Open Cut with Full Road Closure and 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 understood that an acceptable detour route is not available and therefore this option is not feasible.

- Open Cut with Temporary Modular Bridge Spanning Excavation

It is anticipated that it will not be feasible at this site to complete a culvert replacement within a full width open cut excavation with a single lane temporary modular bridge (TMB) spanning the excavation since the fill heights are not high enough to allow working space below the TMB.

- Open Cut with Staged Temporary Widening

Widening of the existing highway and/or construction of a temporary detour embankment to accommodate traffic passage during construction is considered feasible from a geotechnical perspective with a preference for widening to the east of the existing embankment. However, placement of new fill could generate settlement under the footprint of the embankment widening as well as the existing embankment, with larger settlements expected on the west side of the existing embankment versus the east. A review of the environmental acceptability for placing fill within the creek, the requirement for property acquisition, and alteration to highway geometry is also needed to 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 potentially feasible construction option from a geotechnical perspective. This option will require roadway protection, as discussed further in Section 11.2, installed along the embankment centerline to maintain a single lane of traffic flow along the current highway alignment. Installation of sheet piles will be difficult through the dense till with cobbles and boulders. Due to the required height of soil to be retained, the roadway protection may require lateral support in the form of rakers, struts, or deadman/bedrock anchors to reduce lateral deflections.

- Trenchless Techniques

Trenchless techniques would have the advantage of minimum disruption to traffic and would avoid a large excavation through the existing highway embankment. However, this option will be high risk due to the possibility of encountering obstructions. The low cover is also problematic and presents a significant risk. The anticipated size of replacement culvert will also limit the available installation methods. A trenchless installation is not recommended at this site due to the high risk involved.

9.3 Recommended Approach for the Culvert Replacement

From a foundation engineering perspective, the recommended culvert replacement options are a circular pipe (e.g. corrugated steel) or a precast segmental box culvert using open cut techniques. Temporary protection systems (TPS) or a temporary widening would be needed to facilitate construction. An open bottom culvert is also technically feasible, but will require frost protection and therefore deeper excavations with additional dewatering requirements. The open-bottom culvert option is therefore not preferred.

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

Provided the replacement culvert will be constructed along the same alignment as the existing culvert and the embankment will be reconstructed with no grade raise or widening (temporary or permanent), it is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading.

10.1.1 Box Culvert

A closed pre-cast box culvert may be founded on a bedding layer (see Section 10.2) in a dewatered temporary excavation overlying the existing compact native, undisturbed layers (e.g. silt or glacial till) at or below the elevation of the existing culvert (invert at approximately 445.3 m). Assuming a base slab thickness of 0.3 m, the existing stratigraphy at the anticipated founding elevation of 445.0 m consists of compact silt and glacial till. A closed box culvert would not need to be founded below the depth of frost (Section 10.3). For a box culvert up to 5.0 m wide, the design can be based on the factored geotechnical resistance values as follows.

- Factored Geotechnical Resistance at ULS of 160 kPa
- Factored Geotechnical Resistance at SLS of 110 kPa

If higher bearing resistance values are required, consideration can be given to subexcavating the silt down to the surface of the glacial till (approximate elevation 443.5 m but varies along culvert length) and constructing compacted engineered fill up to the bedding level. In that case, the factored geotechnical resistance values are:

- Factored Geotechnical Resistance at ULS of 350 kPa
- Factored Geotechnical Resistance at SLS of 250 kPa

These values can be refined once the width of the culvert is known. The factored geotechnical resistances include the following factors:

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

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

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

It is noted that construction will extend below the observed creek water level. Water diversion and dewatering (Section 11.3) will be required to place the bedding material and install the culvert in the dry.

10.1.2 Open Bottom Culvert

Based on an assumed invert elevation of 445.3 m and 2.5 m of frost penetration (Section 10.3), the anticipated founding elevation for an open bottom culvert is 442.8 m. At this level, footings would be bearing primarily on glacial till, but possibly also on silt at the west end of the culvert. From a geotechnical perspective, an open bottom culvert is not preferred at this site due to the depth of excavation required, however, this option is technically feasible provided that the excavation is adequately dewatered. As a preliminary guideline, the bearing resistance values provided in Section 10.1.1 may be used to assess feasibility. These values can be refined once additional details on the culvert are provided. If the bearing resistances for glacial till are preferred, there should be an allowance in the contract to sub-excavate the silt (where encountered at founding level) down to the surface of the glacial till and to fill the excavation back up to founding level with granular fill consisting of OPSS.PROV 1010 Granular A compacted as per OPSS. PROV 501.

10.1.3 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 stripped from the footprint of the foundation to expose competent subgrade at or below the desired founding elevations. It should be noted that unsuitable silty sand with organics was observed in off-road Borehole 18-104 to as deep as elevation 444.8 m. This silty sand with organics must be removed from below the culvert and replaced with compacted granular fill.

The exposed final subgrade must be inspected to confirm that the subgrade is suitable and uniformly competent. Any soft or organic materials at the subgrade level should be sub-excavated and backfilled with granular fill consisting of OPSS.PROV 1010 Granular A material as soon as practical to protect the subgrade from disturbance during construction. The granular fill should be compacted as per OPSS.PROV 501.

The bedding and backfill requirements for pipe and box culverts should be consistent with Section 7 of the CHBDC, OPSS.PROV 401, OPSS.PROV 501, OPSS 902, and MTOD 803.021 (for precast box culverts). In order to provide a more uniform foundation subgrade condition for the culvert, a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A, or Granular B Type II with a maximum particle size of 26.5 mm, requirements should be placed on the undisturbed subgrade and compacted per

OPSS.PROV 501. 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.

The silt subgrade may be easily disturbed when saturated and should be protected from disturbance from both construction traffic and weather. Construction equipment should not be permitted to travel on the exposed subgrade. Protection of the subgrade should include a Class II non-woven geotextile with a maximum FOS of 75 to 150 μm (OPSS 1860). The geotextile should be placed as soon as possible after reaching the final subgrade level and receipt of written notice to proceed in accordance with SP109S12.

It is noted that construction will extend below the creek elevation. Water diversion and dewatering will be required to prepare the subgrade in the dry. 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.PROV 401 and OPSS 902 and consist of free-draining, non-frost susceptible granular materials such as Granular A, or Granular B Type II with a maximum particle size of 26.5 mm, 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/III 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 2.5 m (OPSD 3090.100), which will need to be considered for open bottom culverts and wing walls, if required. However, it is not necessary to found a closed box or pipe culvert at a depth below frost penetration.

A frost taper is not considered necessary at this site since the existing granular embankment fill has a low susceptibility to frost and there does not appear to be any frost related pavement issues at the site. Additional details on the pavement investigation for the frost taper are provided within the Pavement Design Report.

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 structures should be computed in accordance with the CHBDC. Under drained conditions the lateral earth pressure is generally given by the following expression:

$$p_h = K * (\gamma h + q)$$

where:

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

A lateral earth pressure due to backfill compaction should be added to the calculated lateral earth pressure in accordance with Clause 6.12.3 of the CHBDC. Typical earth pressure coefficients for backfill 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 or 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	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active, K_A (Yielding Wall)	0.27	0.39	0.31	0.47	0.33	0.54
At Rest, K_o (Non-Yielding Wall)	0.43	-	0.47	-	0.50	-
Passive, K_P (Movement towards Soil Mass)	3.7	-	3.3	-	3.0	-
Soil Group(*)	"medium dense sand"		"loose to medium dense sand"		"loose sand"	

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

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

The parameters in the table correspond to full mobilization of active and passive earth pressures and require certain relative movements between the wall and adjacent soil to produce these conditions. The values to be used in design can be assessed from Figure C6.16 of the Commentary to the CHBDC using the soil group designation as outlined in Table 10-1. Active earth pressures should be used for any head/wing walls or unrestrained walls. For rigid structures such as a concrete box culvert, at-rest horizontal earth pressures would apply for design.

10.4.2 Combined Static and Seismic Lateral Earth Pressure

In accordance with Clause 4.6.5 of the CHBDC (S6-14), retaining structures should be designed using dynamic earth pressure coefficients that incorporate the effects of earthquake loading. The following recommendations are per Section C4.6.5 of the Commentary of the CHBDC which states that seismically induced lateral soil pressures may be calculated using the Mononobe-Okabe Method with:

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

The ratio of wall movement to wall height required to mobilize the active conditions would be approximately 0.002 for a yielding structure with respect to the assessment of seismically induced lateral earth pressures.

The coefficients of horizontal earth pressure for seismic loading presented in Table 10-2 may be used. The provided earth pressure coefficients are based on a Seismic Site Class D and a PGA with a 2% probability of exceedance in 50 years of 0.038g (Geological Survey of Canada – Fifth Generation) and a $F(PGA)$ of 1.29 as per Table 4.8 of the CHBDC (S6-14 update No. 2, July 2017).

Table 10-2. Dynamic 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 or III $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)
Active, K_{AE} Yielding Wall	0.28	0.42	0.32	0.51
Active, K_{AE} Non-Yielding Wall	0.30	0.46	0.34	0.56

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 the top of the wall (m)
K	=	static earth pressure coefficient (K_A for yielding walls, K_o for non-yielding walls)
γ	=	unit weight of retained soil, use submerged unit weight below groundwater level
K_{AE}	=	combined static and seismic earth pressure coefficient
H	=	total height of the wall (m)

10.5 Embankment Design and Reinstatement

10.5.1 Embankment Reconstruction

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

10.5.2 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 or widening is anticipated along the alignment of Highway 527 and therefore negligible foundation settlement is expected to occur. Further assessment of foundation stability and settlement should be carried out where construction staging dictates the requirement for additional loading or if a temporary alignment is constructed.

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.

10.6 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 in soil samples of less than 1000 $\mu\text{g/g}$ 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 test results provided in Section 5.8 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects. The corrosion effects of road de-icing salts should also be considered.

11 CONSTRUCTION CONSIDERATIONS

11.1 Excavations

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 may be classified as Type 3 soil. Below the water table, the soils are classified as Type 4 soils.

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 deposits (silty sand with organics, and silt). Selection of the equipment and methodology to excavate and prepare the founding surface is the responsibility of the Contractor. Stockpiling or surface surcharge should not be allowed on the embankment or side slopes.

At locations where there are space restrictions or where a slope has to be retained, the excavations will need to be carried out within a protection system. Further discussion on temporary protection systems (TPS) is presented in Section 11.2.

11.2 Temporary Protection Systems

Temporary Protection Systems may be required during various stages of construction and must be implemented in accordance with OPSS.PROV 539 and designed for Performance Level 2 (maximum 25 mm horizontal deflection). The actual pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall and these factors must be considered when designing the shoring system. The protection system near the culvert could be left in place and cut off in accordance with OPSS.PROV 539 to limit the disturbance of subgrade under the new culvert during removal of the TPS. Vibratory equipment should not be permitted at this site for installation or removal of the temporary protection systems; otherwise, the silt layer may liquefy which could result in settlement of the newly placed culvert. Suggested wording for an NSSP is provided in Appendix G.

Lateral earth pressure coefficients, under fully mobilized conditions, that can be used in design for the embankment fill and culvert backfill are provided in Table 10-1. The lateral earth pressure coefficients for the underlying native soils are given below for a vertical wall and a horizontal backslope:

Silt

γ	=	19	(kN/m ³ , bulk unit weight of soil)
K_A	=	0.38	
K_P	=	2.7	

Glacial Till

γ	=	21	(kN/m ³ , bulk unit weight of soil)
K_A	=	0.31	
K_P	=	3.3	

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 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 and glacial till. Deadman or bedrock anchors, struts and/or raker supports may be required to achieve the specified performance level.

11.3 Surface and Groundwater Control

Culvert construction, subgrade preparation and placement and compaction of granular bedding must 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 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 coffer dams, 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.

It is anticipated that the water course diversion will be carried out with a cofferdam directing creek water through a temporary pipe culvert located to the north of the permanent alignment. The comments on installation and extraction of temporary protection systems are also relevant for cofferdams. The temporary pipe culvert should be supported with a bedding layer that is at least 300 mm in thickness.

It is also anticipated that sump pumps will likely be sufficient to extract water from the excavation for the replacement culvert. Excavation below the creek level without prior dewatering is not recommended since the inflow of water will cause base heave/boiling and sloughing of the soil below the water level, making it difficult to maintain a dry, sound base on which to work. The groundwater level within the work zone should be lowered by pumping from sumps to a minimum of 500 mm below the underside of the planned excavation base prior to each stage of excavation.

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 has a low to moderate erosion potential, both the cohesive and non-cohesive glacial tills have a moderate potential for soil erodibility and the native silt has a high potential for soil erodibility.

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. The clay seal should also extend below the bedding and scour level if a concrete cut-off wall is not also used. 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:

- Disturbance of the soil subgrade. Where fine-grained soils (e.g. silt) are exposed at the culvert subgrade following excavation, these areas will be soft and moisture sensitive. Construction traffic must not be allowed on the final subgrade. The final subgrade should be protected with a geotextile and bedding granular materials.

- Cobbles/boulders and/or buried obstructions may be encountered in the existing embankment fill and in the native tills 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.
- 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 Mr. Christopher Murray, P.Eng. and Mr. Stephen Dunlop, P.Eng. The report was reviewed by Dr. Fred Griffiths, P.Eng., a Designated Principal Contact for MTO Foundation Projects.

Thurber Engineering Ltd.
Report Prepared By:



Christopher Murray, M.A.Sc., P.Eng.
Geotechnical Engineer



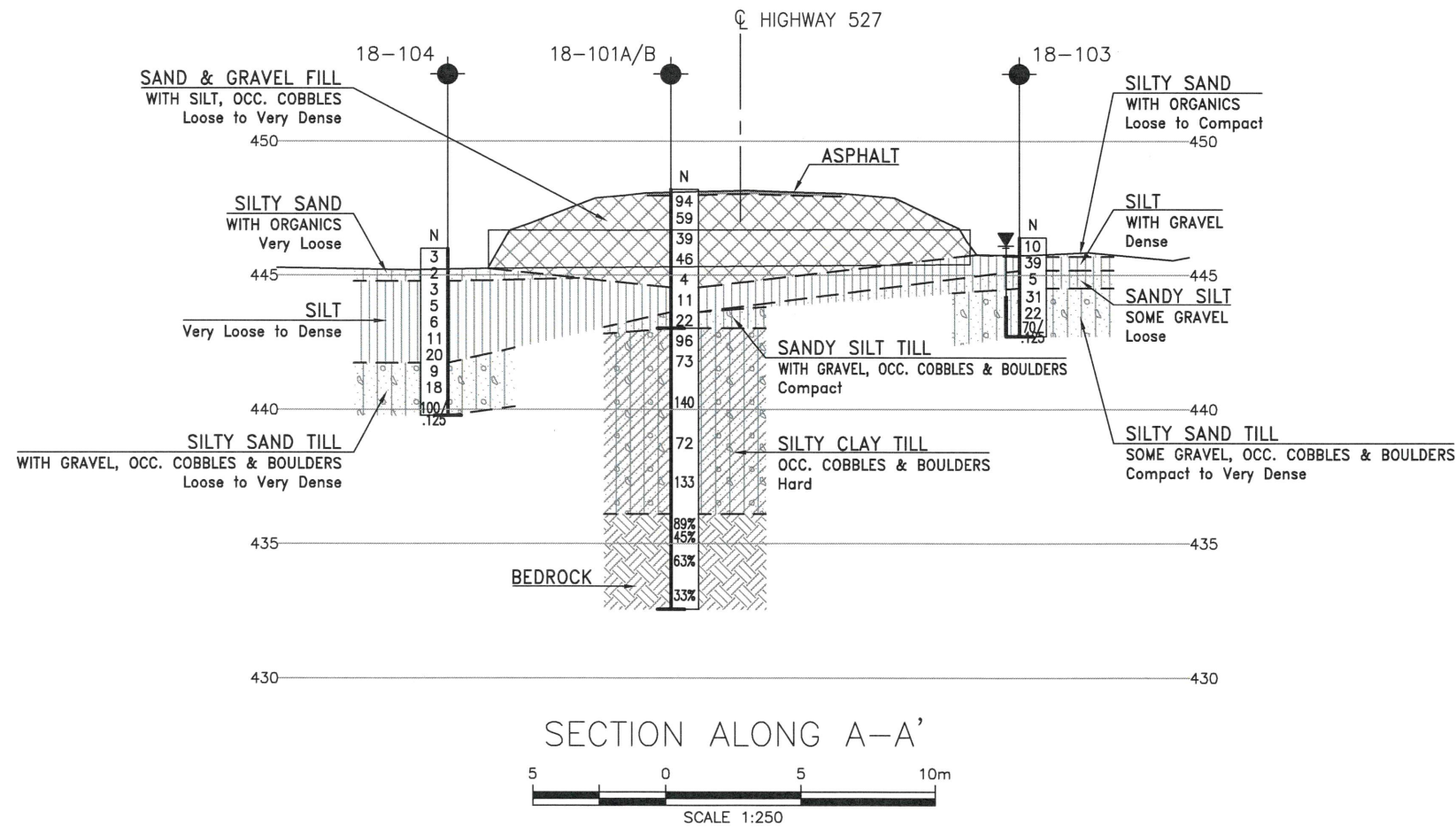
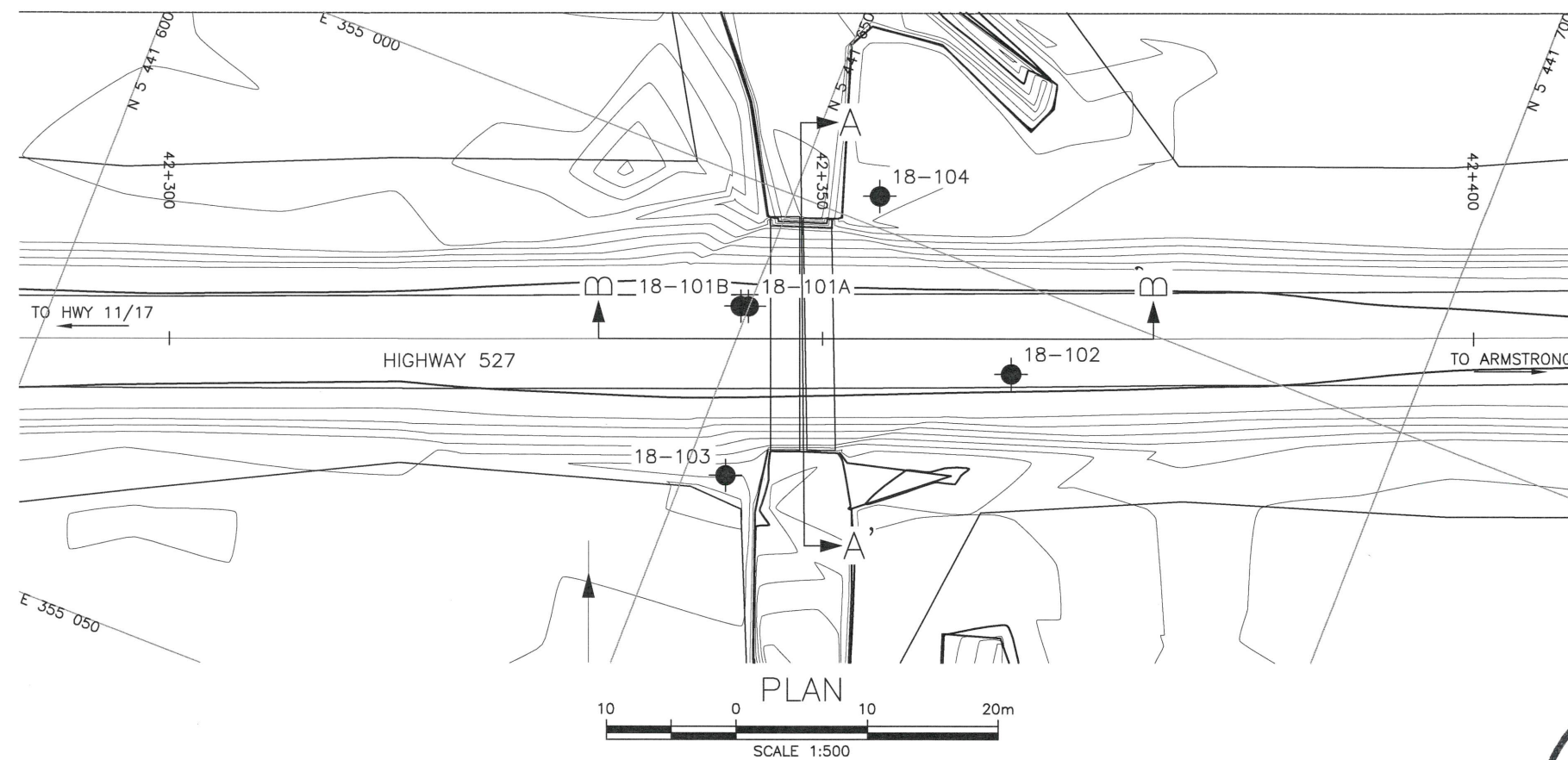
Stephen Dunlop, M.A.Sc., P.Eng.
Senior Geotechnical Engineer



Dr. Fred Griffiths, P.Eng.
Senior Associate
Senior Geotechnical Engineer

Appendix A.

Drawings



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

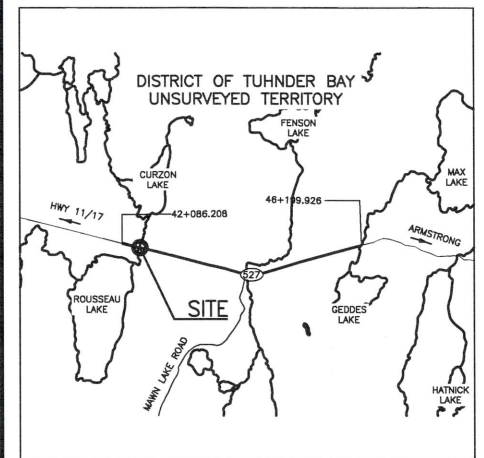
CONT No
GWP No 6827-14-00

HIGHWAY 527
ROUSSEAU LAKE CULVERT
REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

HATCH



THURBER ENGINEERING LTD.



LEGEND

●	Borehole
⊙	Borehole & 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

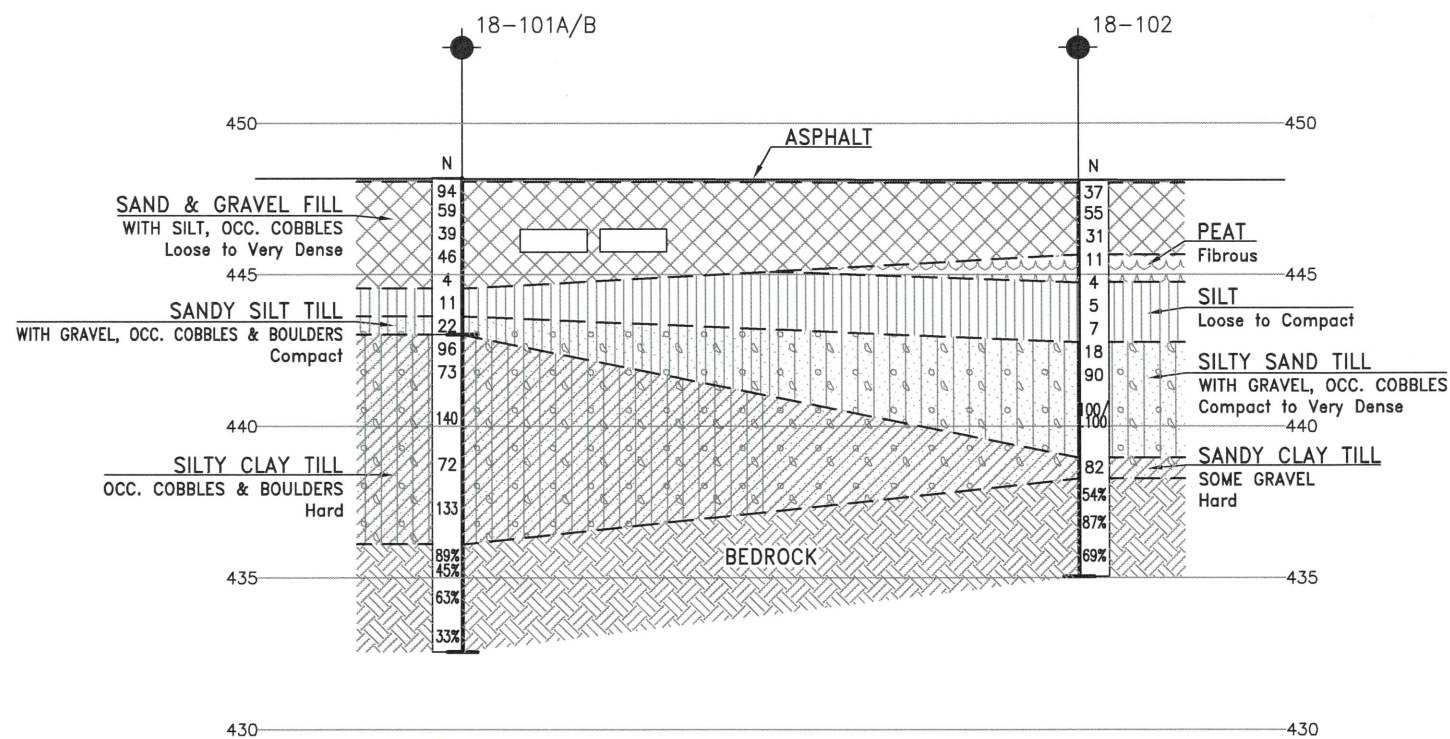
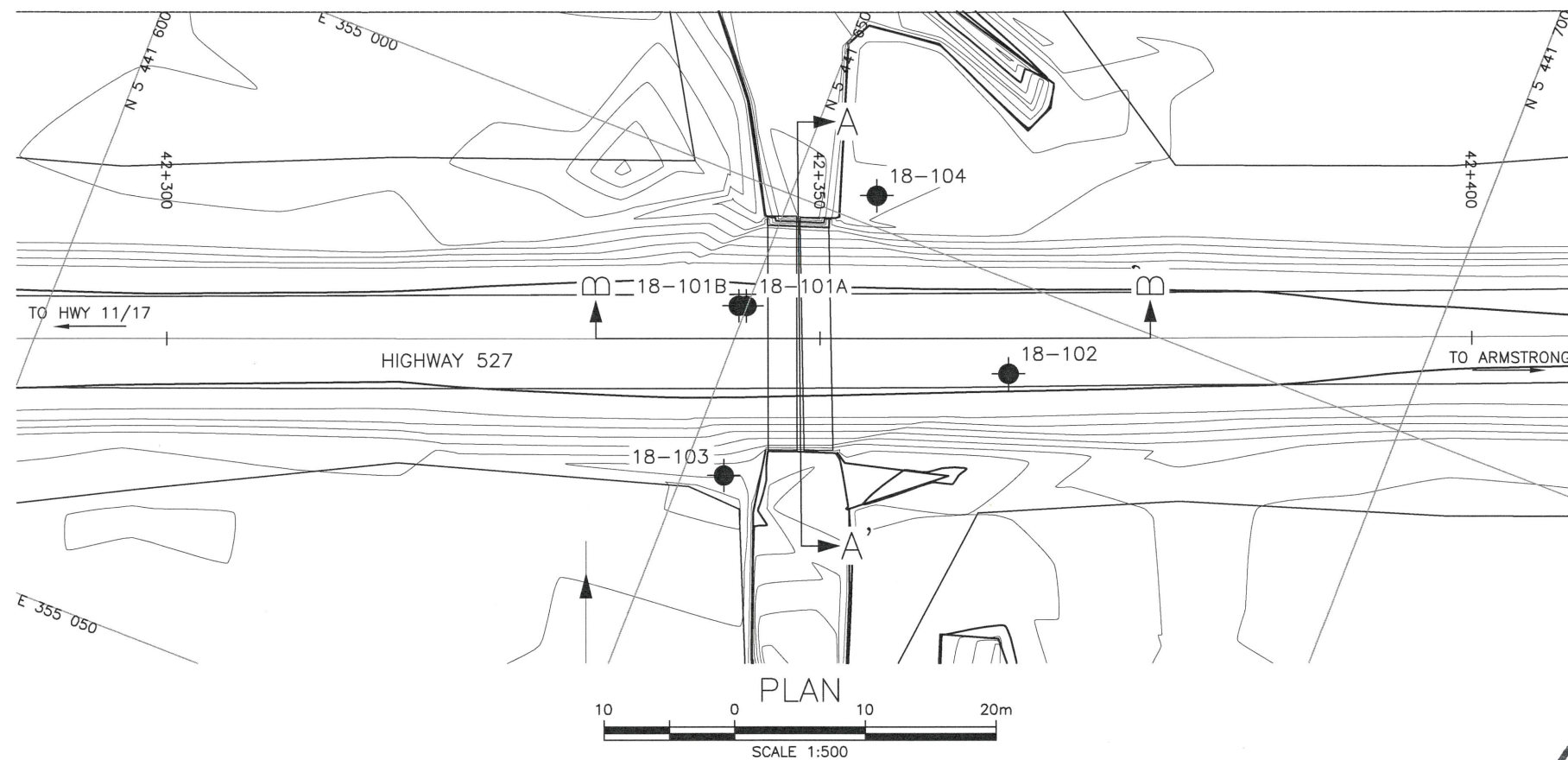
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18-101B	448.2	5 441 649.4	355 009.4
18-102	448.1	5 441 670.5	355 006.8
18-103	446.4	5 441 653.0	355 021.9
18-104	446.0	5 441 656.2	354 997.7

-NOTES-

- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- 3) Coordinate system is MTM NAD 83 Zone 15.

GEOCRES No. 52H-46

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	DP	CHK SP	CODE
DRAWN	MFA	CHK CM	SITE
LOAD	DATE	DEC 2018	
STRUCT	DWG	1	



PROFILE ALONG B-B'



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

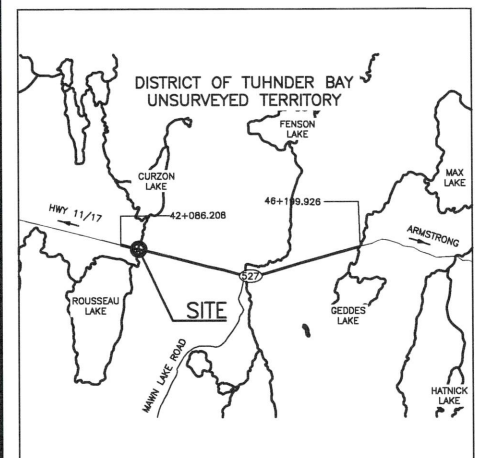
CONT No
GWP No 6827-14-00

HIGHWAY 527
ROUSSEAU LAKE CULVERT
REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

HATCH



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

●	Borehole
⊙	Borehole & 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

NO	ELEVATION	NORTHING	EASTING
18-101A	448.2	5 441 649.9	355 009.2
18-101B	448.2	5 441 649.4	355 009.4
18-102	448.1	5 441 670.5	355 006.8
18-103	446.4	5 441 653.0	355 021.9
18-104	446.0	5 441 656.2	354 997.7

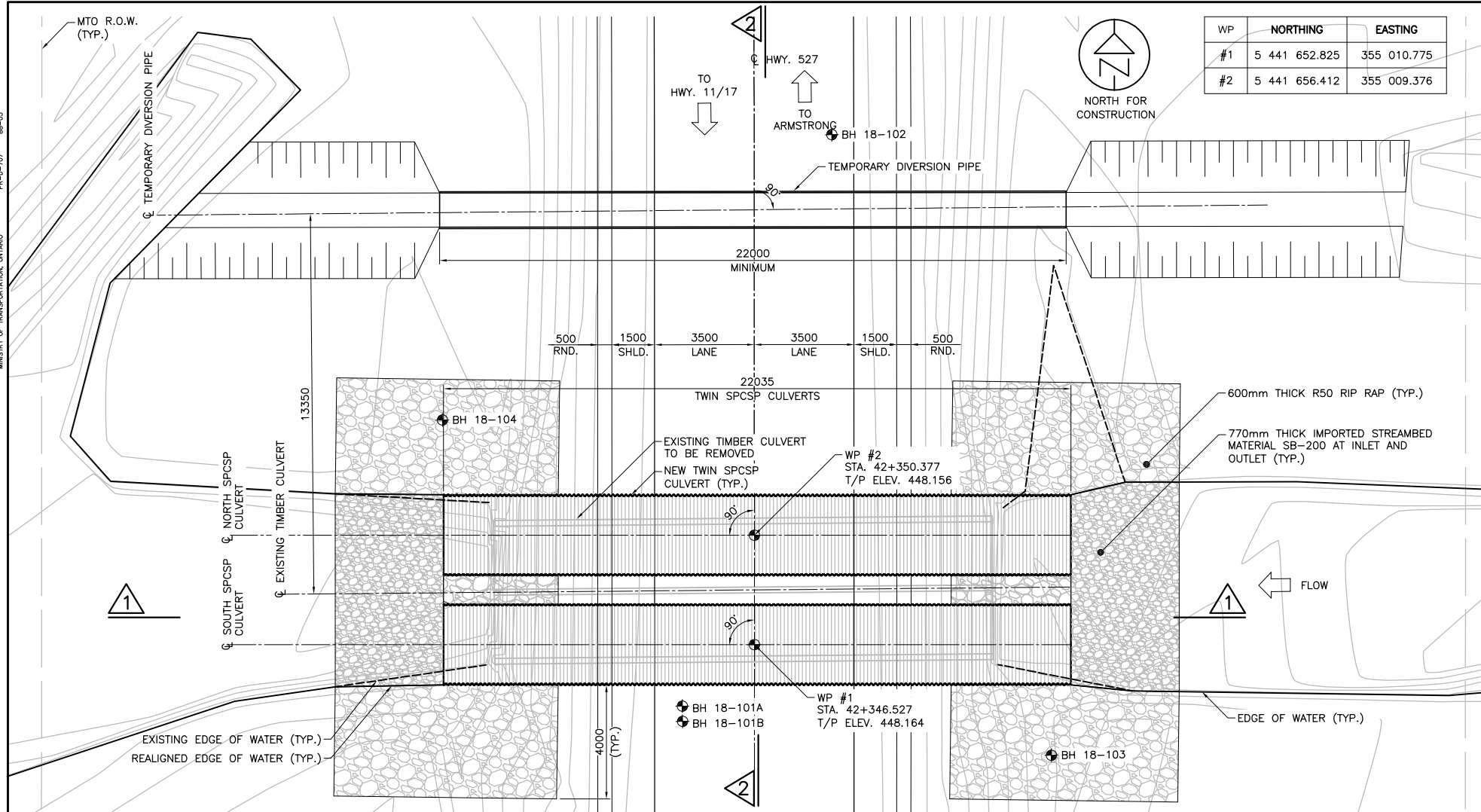
-NOTES-

- 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 15.

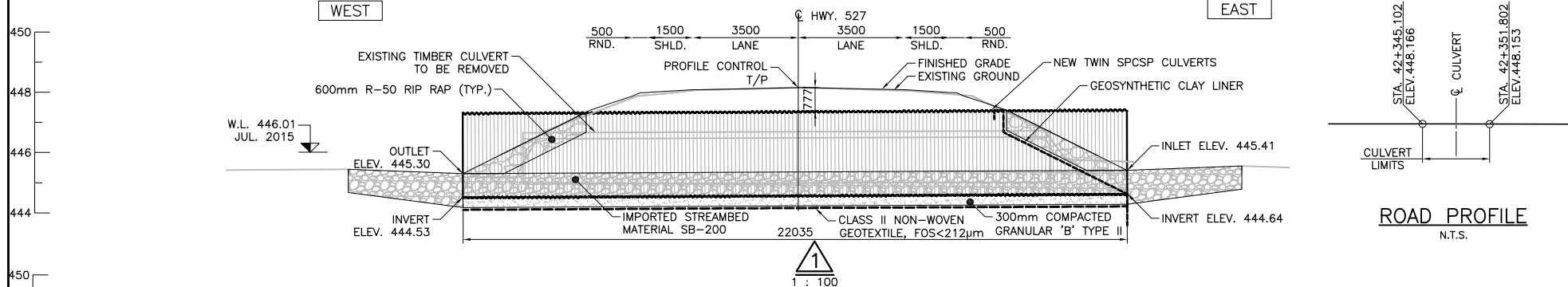
GEOCRES No. 52H-46

REVISIONS	DATE	BY	DESCRIPTION
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DRAWN	MFA	CHK CM	SITE
			LOAD
			STRUCT
			DWG 2
			DATE DEC 2018

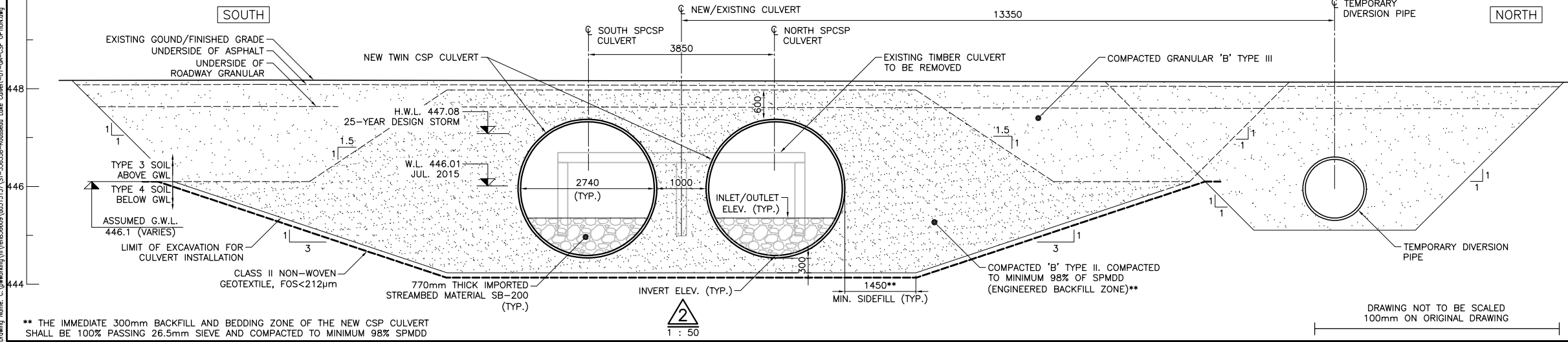
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Dec 06, 2018, 2:55pm



PLAN
1 : 100



ROAD PROFILE
N.T.S.



2
1 : 50

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#2	5 441 656.412	355 009.376

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

CONSTRUCTION NOTES

1. THE CONTRACTOR IS ADVISED NOT TO RELY ON THE WATER LEVEL SHOWN ON DRAWINGS. THE WATER LEVEL IS SUBJECT TO VARIATIONS.
2. CULVERT ASSEMBLY AND BACKFILLING OPERATIONS SHALL BE CARRIED OUT IN ACCORDANCE WITH THE SUPPLIER'S RECOMMENDATIONS.
3. THE CONTRACTOR SHALL VERIFY ALL DIMENSIONS OF THE PROPOSED WORK AND ALL DETAILS ON SITE AND REPORT ANY DISCREPANCIES TO THE CONTRACT ADMINISTRATOR BEFORE PROCEEDING WITH THE WORK.
4. CONTRACTOR IS RESPONSIBLE FOR STABILITY OF BOTH EXISTING AND NEW STRUCTURES AT ALL TIMES THROUGHOUT CONSTRUCTION INCLUDING EXCAVATION, BACKFILL, REMOVALS, INSTALLATIONS, ETC. CONTRACTOR TO DESIGN AND PROVIDE ANY TEMPORARY SUPPORT SYSTEMS FOR EXISTING AND NEW STRUCTURES AT VARIOUS STAGES OF CONSTRUCTION AS REQUIRED TO SUIT THEIR METHOD OF CONSTRUCTION.
5. CONTRACTOR IS FULLY RESPONSIBLE FOR THE DESIGN, CONSTRUCTION METHODS AND PERFORMANCE OF THE TEMPORARY SLOPES, PROTECTION SYSTEM AND ASSOCIATED WORKS.
6. SURFACE WATER CONTROL MEASURES MAY BE REQUIRED. A SUITABLE DEWATERING SCHEME SHALL BE USED. SUBGRADE PREPARATION AND COMPACTION OF BEDDING AND GRANULAR FILL MUST BE CARRIED OUT IN THE DRY.
7. CONTRACTOR IS RESPONSIBLE FOR TEMPORARY DIVERSION OF THE FLOW AROUND THE SITE DURING CONSTRUCTION AS PER THE CONTRACT DOCUMENTS. ALL DETAILS OF THE TEMPORARY DIVERSION PIPE ARE SHOWN FOR INFORMATION PURPOSES ONLY.
8. THE LOCATION AND LENGTH OF DEWATERING EQUIPMENT IS THE RESPONSIBILITY OF THE CONTRACTOR.
9. ELEVATION OF DEWATERING SHALL BE 500mm BELOW SUBEXCAVATION.
10. CULVERT SUBGRADE TO BE INSPECTED FOLLOWING SUB-EXCAVATION TO ENSURE THAT ALL ORGANICS AND OTHER UNSUITABLE MATERIALS HAVE BEEN REMOVED.
11. SUBGRADE SHALL BE PROTECTED AGAINST FREEZING AT ALL TIMES UNTIL COMPLETION OF BACKFILLING. BEDDING MATERIAL SHALL NOT BE PLACED ON A DISTURBED OR FROZEN EARTH GRADE.
12. NO HIGHWAY TRAFFIC SHALL BE ALLOWED OVER CULVERT UNTIL THE MINIMUM DESIGN COVER IS ACHIEVED. CONTRACTOR SHALL COMPLY WITH MANUFACTURER'S SHOP DRAWINGS FOR OTHER RESTRICTIONS WITH REGARDS TO EQUIPMENT DURING CONSTRUCTION LOADING.
13. BACKFILL AND COMPACTION SHALL BE AS PER MANUFACTURER'S INSTRUCTIONS AND AS PER OPSS PROV 501, WHICHEVER IS MORE STRINGENT.
14. BACKFILL SHALL BE PLACED SIMULTANEOUSLY BEHIND BOTH SIDES OF CULVERT WITH LIFT HEIGHTS NOT EXCEEDING 200mm AND KEEPING THE HEIGHT OF THE BACKFILL APPROXIMATELY THE SAME. AT NO TIME SHALL THE DIFFERENCE IN ELEVATION BE GREATER THAN 200mm.
15. ALL DISTURBED EARTH SLOPES SHALL BE REINSTATED TO THEIR ORIGINAL GROUND CONTOUR UPON COMPLETION OF THE WORK (EXCEPT WHERE OTHERWISE NOTED) AND BE TREATED WITH TOPSOIL, EROSION CONTROL BLANKET, AND SEED, IN ACCORDANCE WITH OPSS 802, OPSS 804 AND OPSS PROV 182.
16. ALL DISTURBED CREEK BANKS TO BE REINSTATED WITH MINIMUM 300mm THICK RIP RAP.
17. FOR AREAS OF IMPORTED STREAMBED MATERIAL, GRANULAR 'A' SHALL BE WASHED INTO THE VOIDS. GRANULAR 'A' MATERIAL SHALL CONFORM TO THE REQUIREMENTS OF OPSS 1010. CONTRACTOR TO ENSURE THAT VOIDS WITHIN THE ENTIRE DEPTH OF IMPORTED STREAMBED MATERIAL ARE FILLED WITH GRANULAR 'A'.

CONT No.
WP No. 6827-14-01

ROUSSEAU LAKE
CULVERT REPLACEMENT
GENERAL ARRANGEMENT

SHEET
9

HATCH

GENERAL NOTES:

1. THE CULVERTS SHALL BE DOUBLE CORRUGATED STEEL PIPE CULVERTS EACH WITH 2740mm DIA. (MIN. WALL THICKNESS=4.0mm CORRUGATION PROFILE IS 152mm X 51mm). CONTRACTOR IS RESPONSIBLE TO DESIGN, SUPPLY, ASSEMBLE AND ERECT THE NEW CULVERT. CULVERT DESIGN SHALL BE IN ACCORDANCE WITH CHBDC S6-14, LIVE LOAD SHALL BE CL-625-ONT.
2. DIMENSIONS AND DETAILS SHOWN ON DRAWINGS ARE BASED ON A TYPICAL MULTI-PLATE ROUND PIPE AND SHALL BE VERIFIED PRIOR TO COMMENCEMENT OF THE CONSTRUCTION.
3. PERMANENT CSP CULVERTS SHALL BE POLYMER LAMINATE COATED, CULVERTS TO BE DESIGNED FOR A 75 YEAR SERVICE LIFE. WATER RESISTIVITY AT THIS SITE IS MEASURED TO BE XXXXX 0%cm. REFER TO FOUNDATION INVESTIGATION REPORT FOR MORE INFORMATION ON CHEMICAL ANALYSES.

ABBREVIATIONS

BH	BOREHOLE
CL	CENTRELINE
ELEV.	ELEVATION
G.W.L.	GROUND WATER LEVEL
H.W.L.	HIGH WATER LEVEL
HWY	HIGHWAY
MAX	MAXIMUM
MIN	MINIMUM
MTO	MINISTRY OF TRANSPORTATION OF ONTARIO
R.O.W.	RIGHT OF WAY
RND	ROUNDING
SHLD	SHOULDER
STA	STATION
SPMDD	STANDARD PROCTOR MAXIMUM DRY DENSITY
SPCSP	STRUCTURAL PLATE CORRUGATED STEEL PIPE
T/P	TOP OF PAVEMENT
INV.	TYPICAL
W.L.	WATER LEVEL
WP	WORKING POINT

APPLICABLE STANDARD DRAWINGS

OPSD 219.110	LIGHT DUTY SILT FENCE BARRIER
OPSD 219.240	SEDIMENT TRAP FOR DEWATERING
OPSD 802.010	FLEXIBLE PIPE EMBEDMENT AND BACKFILL
OPSD 810.010	EARTH EXCAVATION
	GENERAL RIP-RAP LAYOUT FOR SEWER AND CULVERT OUTLETS

LIST OF DRAWINGS

1. GENERAL ARRANGEMENT
2. BOREHOLE LOCATIONS AND SOIL STRATA I
3. BOREHOLE LOCATIONS AND SOIL STRATA II
4. REMOVALS
5. CONSTRUCTION STAGING
6. GEOSYNTHETIC CLAY LINER DETAILS

PRELIMINARY
NOT FOR CONSTRUCTION

REVISIONS	DATE	REV.	DESCRIPTION
18/12/10	A0		DESIGN COMPLETE SUBMISSION (100%)
DESIGN	AK/CHK	CP/CODE	CAN/CSA S6-14/LOAD CL-625-ONT/DATE DEC. 2018
DRAWN	CP/CHK	AK/SITE	48C-242/C/DWG 1

DRAWING NOT TO BE SCALED
100mm ON ORIGINAL DRAWING

Appendix B.

Record of Borehole Sheets



SYMBOLS, ABBREVIATIONS AND TERMS USED ON TEST HOLE RECORDS

TERMINOLOGY DESCRIBING COMMON SOIL GENESIS

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

TERMINOLOGY DESCRIBING SOIL STRUCTURE:

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

RECOVERY:

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

N-VALUE:

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

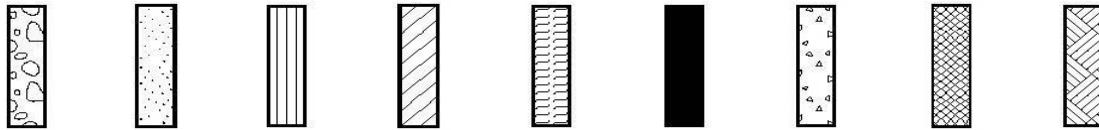
DYNAMIC CONE PENETRATION TEST (DCPT):

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



STRATA PLOT:

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



Boulders
Cobbles
Gravel Sand Silt Clay Organics Asphalt Concrete Fill Bedrock

TEXTURING CLASSIFICATION OF SOILS

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

TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

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

SAMPLE TYPES

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

TERMS DESCRIBING CONSISTENCY (COHESIONLESS SOILS ONLY)

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



MODIFIED UNIFIED SOIL CLASSIFICATION

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

Note - W_L = Liquid Limit



EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

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

TERMS

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

DISCONTINUITY SPACING

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

STRENGTH CLASSIFICATION

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

RECORD OF BOREHOLE No 18-101A

1 OF 1

METRIC

GWP# 6827-14-00 LOCATION Lat: 49.1109485°, Long: -89.3122175°
Rousseau Lake Culvert, MTM z15: N 5 441 649.9 E 355 009.2 ORIGINATED BY NW
HWY 527 BOREHOLE TYPE HSA / NW Casing COMPILED BY SOB
DATUM Geodetic DATE 2018.05.30 - 2018.05.30 CHECKED BY SD

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					
448.2													
0.0	125 mm ASPHALT												
0.1	SAND with Gravel, FILL		1	SS	94								
447.7	Very Dense												
0.5	Brown												
	Silty SAND with Gravel, FILL		2	SS	59								
	Dense to Loose												
	Brown												
			3	SS	39								
			4	SS	46								
			5	SS	4								
444.5													
3.7	SILT (ML)		6	SS	11								
	Compact												
	Grey												
443.6													
4.6	Sandy SILT (ML) with Gravel,		7	SS	22								
	occasional Cobbles and Boulders,												
	TILL												
443.0	Compact												
5.2	Grey												
	Casing deflected at 5.2 m depth and could not be advanced, Borehole Terminated at 5.2 m Continued in BH 18-101B												

DOUBLE LINE 19773 ROUSSEAU LAKE GPJ 2012TEMPLATE(MTO).GDT 12/12/18

METRIC

SOIL PROFILE				SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
448.2 0.0	Refer to BH 18-101A for Stratigraphy						○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					w _p w w _L					
443.0 5.2	Silty CLAY (CL-ML), occasional Cobbles and Boulders, TILL Hard Grey - 90 mm Cobble at 6.6 m		8	SS	96		448					448					
			9	SS	73		447					447					
			10	SS	140		446					446					
			11	SS	72		445					445					
							444					444					
							443					443					
							442					442					
							441					441					
							440					440					
							439					439					

+³, ×³: Numbers refer to Sensitivity

DOUBLE LINE 19773 ROUSEAU LAKE.GPJ 2012TEMPLATE(MTO).GDT 12/12/18

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 18-102

1 OF 2

METRIC

GWP# 6827-14-00 LOCATION Lat: 49.111338°, Long: -89.3122485°
Rousseau Lake Culvert, MTM z15: N 5 441 670.5 E 355 006.8 ORIGINATED BY NW
HWY 527 BOREHOLE TYPE NW Casing / NQ Coring COMPILED BY SOB
DATUM Geodetic DATE 2018.06.01 - 2018.06.01 CHECKED BY SD

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					
								20 40 60 80 100					
						<div><div></div><div></div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div><div></div><div></div></div>				
448.1													
0.0	75 mm ASPHALT												
0.1													
447.8	SAND with Gravel, FILL		1	SS	37								
0.3	Dense Brown												
	Silty SAND some Gravel, FILL		2	SS	55								
	Very Dense Brown												
446.6													
1.5	Silty SAND, FILL		3	SS	31								1 59 40 (SH+CL)
	Dense Grey												
445.7													
2.4	Fine Fibrous PEAT		4	SS	11								
444.7			5	SS	4								
3.4	SILT (ML)												
	Loose Grey		6	SS	5								0 0 88 12 Non-plastic
			7	SS	7								
442.8													
5.3	Silty SAND (SM) with Gravel, occasional Cobbles, TILL		8	SS	18								26 43 31 (SH+CL)
	Compact to Very Dense Grey												
			9	SS	90								
			10	SS	100/ 100mm								
439.0													
9.1	Sandy CLAY (CL) some Gravel, TILL		11	SS	82								11 21 42 26
	Hard Grey												
438.3													
9.8	Mafic Metavolcanic Bedrock												

Continued Next Page

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

DOUBLE LINE 19773 ROUSSEAU LAKE.GPJ 2012TEMPLATE(MTO).GDT 12/12/18

RECORD OF BOREHOLE No 18-102

2 OF 2

METRIC

GWP# 6827-14-00 LOCATION Lat: 49.1111338°, Long: -89.3122485°
Rousseau Lake Culvert, MTM z15: N 5 441 670.5 E 355 006.8 ORIGINATED BY NW
HWY 527 BOREHOLE TYPE NW Casing / NQ Coring COMPILED BY SOB
DATUM Geodetic DATE 2018.06.01 - 2018.06.01 CHECKED BY SD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
	Continued From Previous Page							20 40 60 80 100 PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W P W W L WATER CONTENT (%) 20 40 60						
	Mafic Metavolcanic Bedrock Fresh Fine to Medium Grained Dark Grey to Black Very Strong		1	RUN			438						3	RUN #1 TCR=100% SCR=78% RQD=54%
			2	RUN			437						2	
			3	RUN			436						1	
435.0													1	RUN #2 TCR=100% SCR=100% RQD=87%
													1	
													1	RUN #3 TCR=100% SCR=100% RQD=69%
													1	
13.1	End of Borehole												4	

DOUBLE LINE 19773 ROUSSEAU LAKE GPJ 2012TEMPLATE(MTO).GDT 12/12/18

RECORD OF BOREHOLE No 18-103

1 OF 1

METRIC

GWP# 6827-14-00 LOCATION Lat: 49.1109752°, Long: -89.3120427°
Rousseau Lake Culvert, MTM z15: N 5 441 653.0 E 355 021.9 ORIGINATED BY SOB
HWY 527 BOREHOLE TYPE Portable / NW Casing COMPILED BY SOB
DATUM Geodetic DATE 2018.06.15 - 2018.06.15 CHECKED BY SD

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					W P W W L							
								20 40 60 80 100												
								○ UNCONFINED + FIELD VANE												
								● QUICK TRIAXIAL × LAB VANE												
								20 40 60 80 100					20 40 60							
446.4																				
0.0	Silty SAND (SM) with Organics Loose to Compact Brown		1	SS	10		446													
445.8																				
0.6	SILT (ML) with Gravel Dense Grey Brown		2	SS	39															
445.2																				
1.2	Sandy SILT (ML) some Gravel Loose Grey Brown		3	SS	5		445													
444.5																				
1.9	Silty SAND (SM) some Gravel, occasional Cobbles and Boulders, TILL Compact to Very Dense Grey		4	SS	31		444													
			5	SS	22															
			6	SS	100/ 275mm		443													
442.7																				
3.7	End of Borehole on Practical Refusal Standpipe Readings: DATE DEPTH (m) ELEV. (m) 2018.06.15 0.3 446.1 2018.08.11 0.3 446.1																			

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

RECORD OF BOREHOLE No 18-104

1 OF 1

METRIC

GWP# 6827-14-00 LOCATION Lat: 49.1110058°, Long: -89.3123745°
Rousseau Lake Culvert, MTM z15: N 5 441 656.2 E 354 997.7 ORIGINATED BY SOB
HWY 527 BOREHOLE TYPE Portable / NW Casing COMPILED BY SOB
DATUM Geodetic DATE 2018.06.15 - 2018.06.16 CHECKED BY SD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL LIMIT 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 (%)								
446.0								20	40	60	80	100		W _p	W	W _L				
0.0	Silty SAND (SM) with Organics Very Loose Brown		1	SS	3															
			2	SS	2															
444.8							445													
1.2	SILT (ML) Very Loose to Compact Grey		3	SS	3															
			4	SS	5															
			5	SS	6															
			6	SS	11															
			7	SS	20															
441.7							442													
4.3	Silty SAND (SM) with Gravel, occasional Cobbles and Boulders, TILL Loose to Very Dense Grey		8	SS	9															
			9	SS	18															
439.8							440													
6.2	End of Borehole on Practical Refusal				125mm															

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

Appendix C.

Laboratory Testing

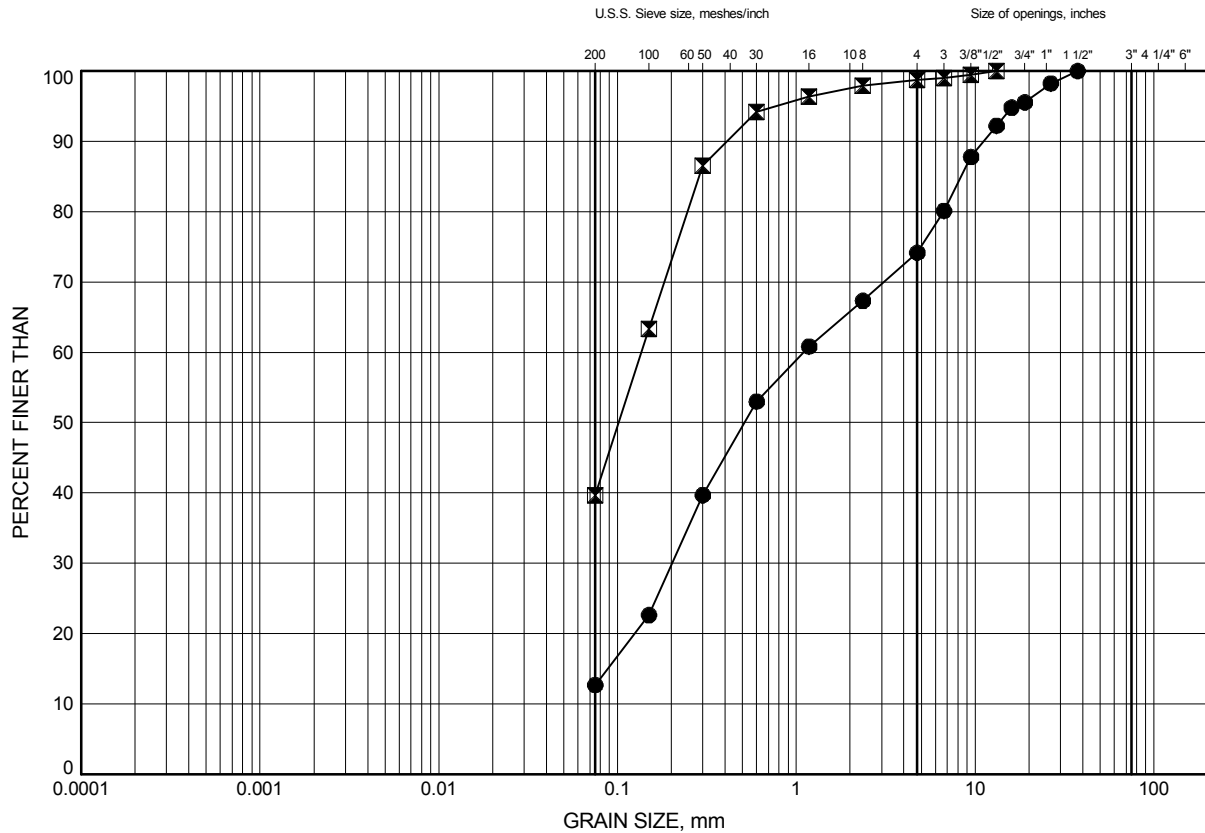
Appendix C.1

Particle Size Analysis Figures

Rousseau Lake Culvert GRAIN SIZE DISTRIBUTION

FIGURE C1

Embankment Fill



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18-101A	1.07	447.13
◻	18-102	1.83	446.27

Date July 2018
GWP# 6827-14-00

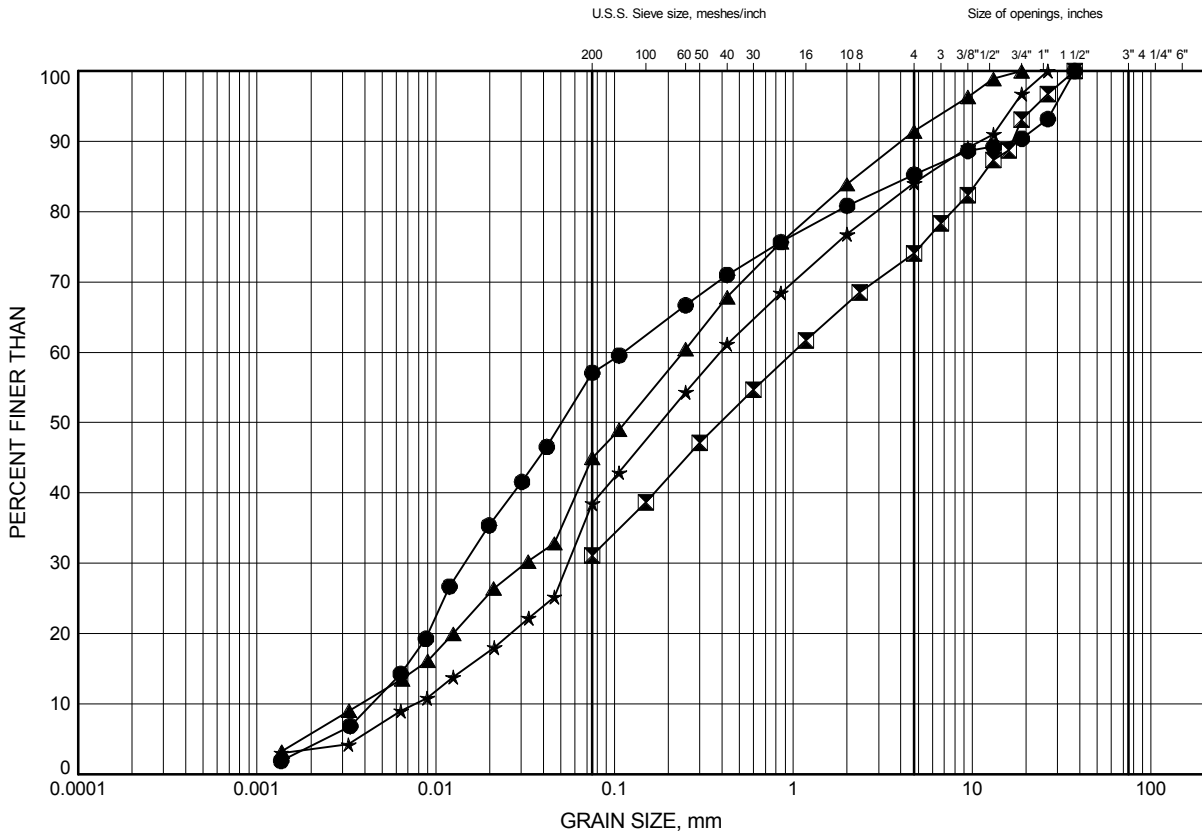


Prep'd CM
Chkd. SD

Rousseau Lake Culvert GRAIN SIZE DISTRIBUTION

FIGURE C3

Non-Cohesive Till



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18-101A	4.88	443.32
⊠	18-102	5.64	442.46
▲	18-103	3.39	443.01
★	18-104	4.57	441.43

Date July 2018

GWP# 6827-14-00



Prep'd CM

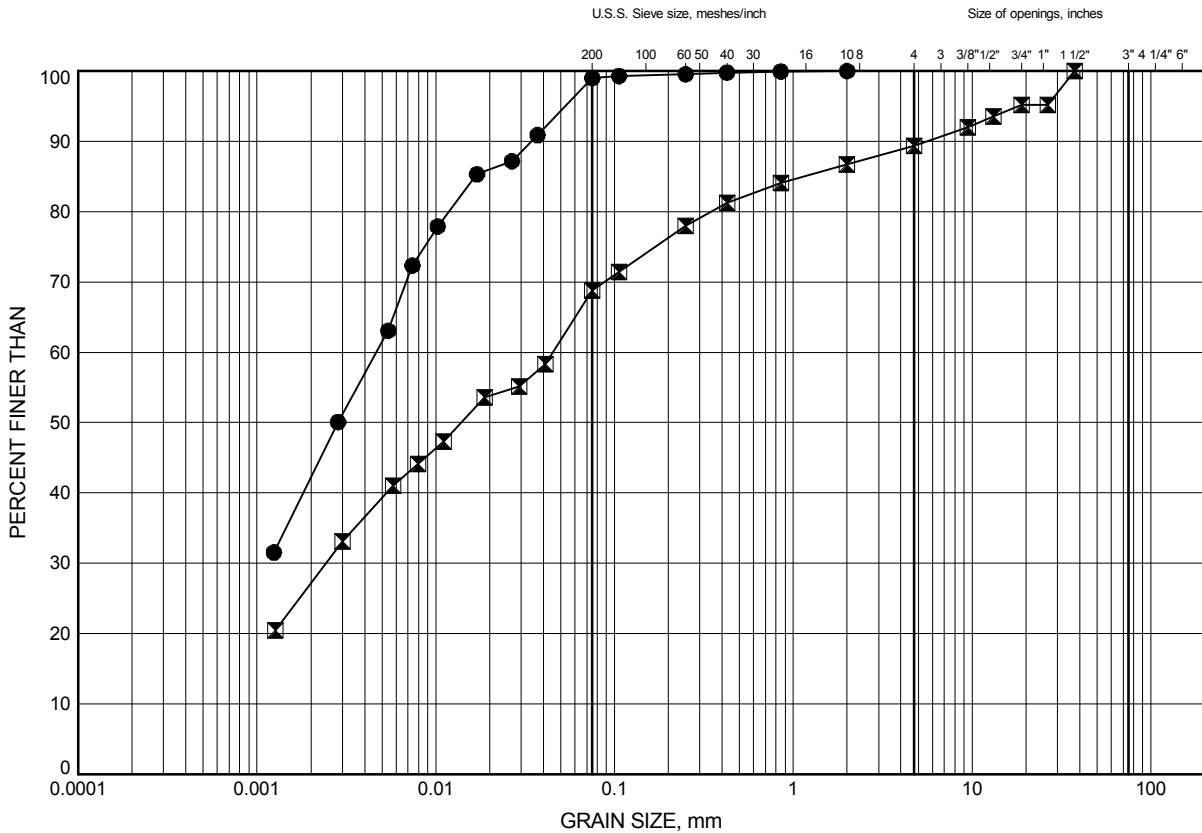
Chkd. SD

Rousseau Lake Culvert

GRAIN SIZE DISTRIBUTION

FIGURE C4

Cohesive Till



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18-101B	9.45	438.75
⊠	18-102	9.45	438.65

Date July 2018
GWP# 6827-14-00



Prep'd CM
Chkd. SD

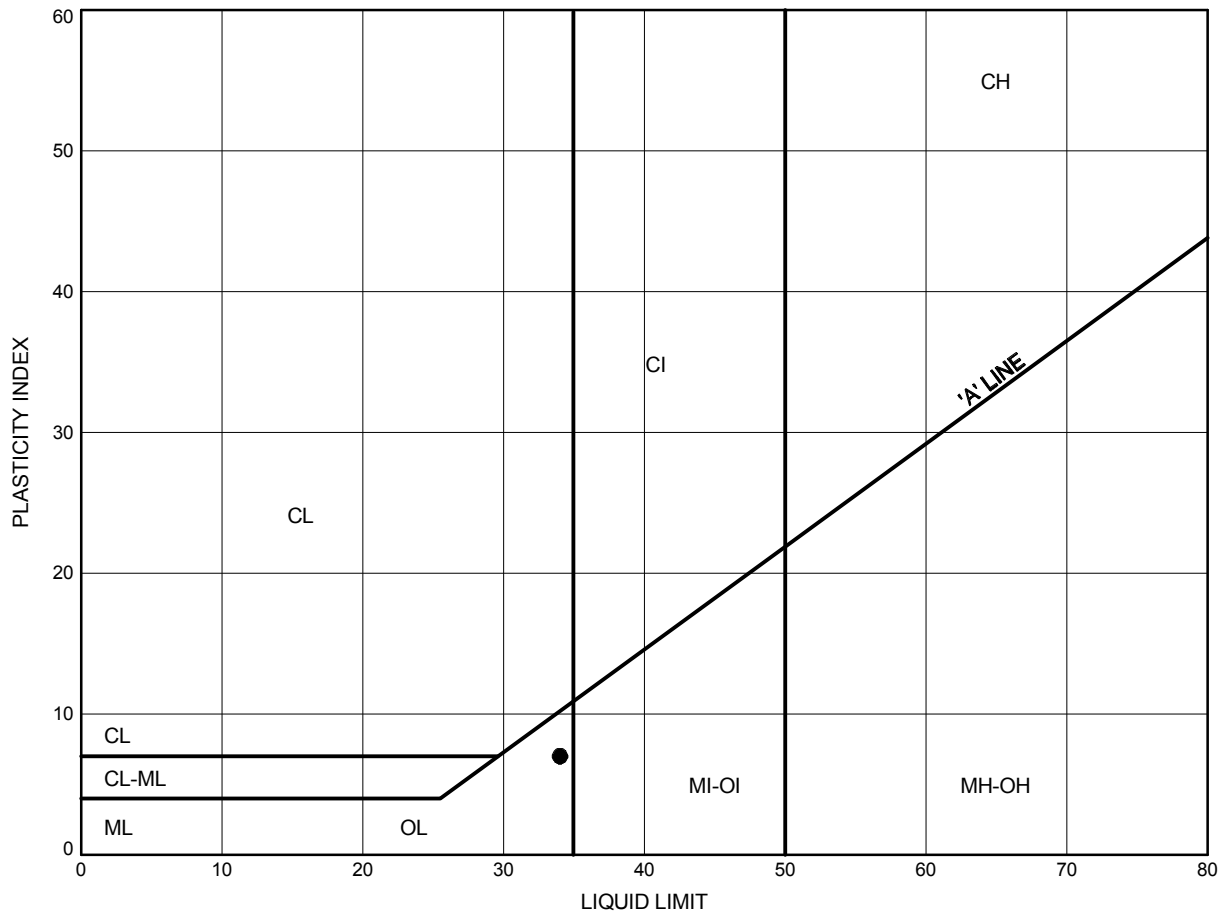
Appendix C.2

Atterberg Limit Analysis Figures

Rousseau Lake Culvert
ATTERBERG LIMITS TEST RESULTS

FIGURE C5

Sandy Silt



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18-103	1.52	444.88

Date July 2018
 GWP# 6827-14-00

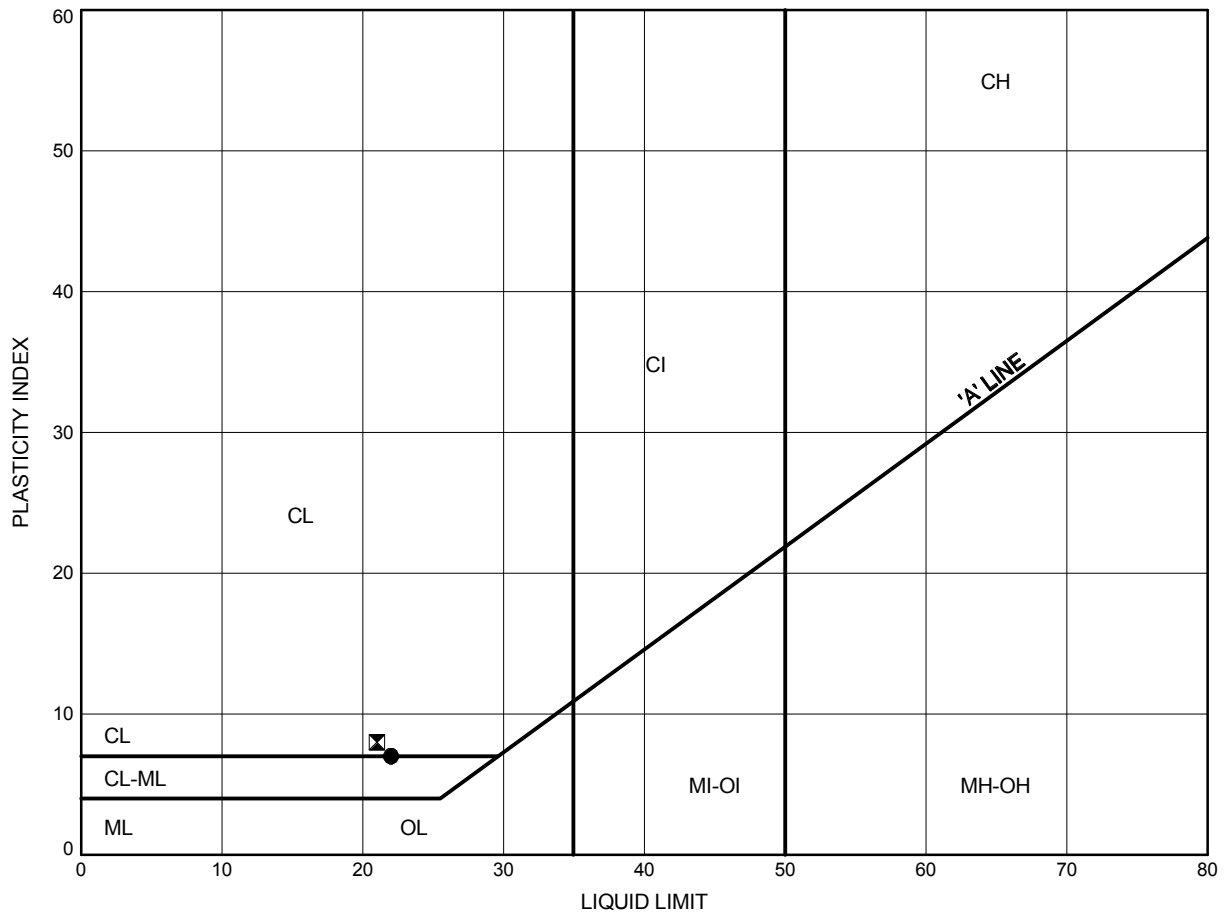


Prep'd CM
 Chkd. SD

Rousseau Lake Culvert ATTERBERG LIMITS TEST RESULTS

FIGURE C6

Cohesive Till



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18-101B	9.45	438.75
⊠	18-102	9.45	438.65

Date July 2018
GWP# 6827-14-00

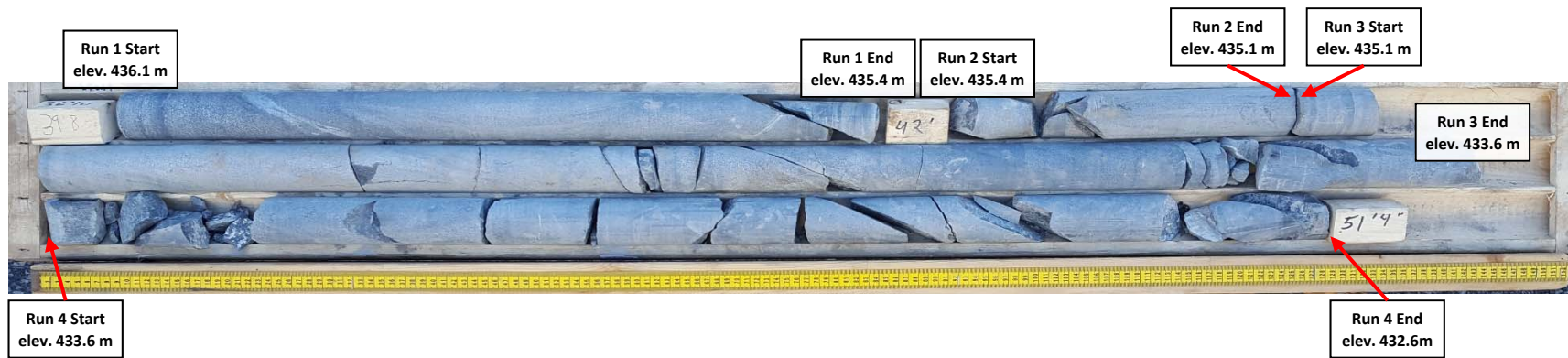


Prep'd CM
Chkd. SD

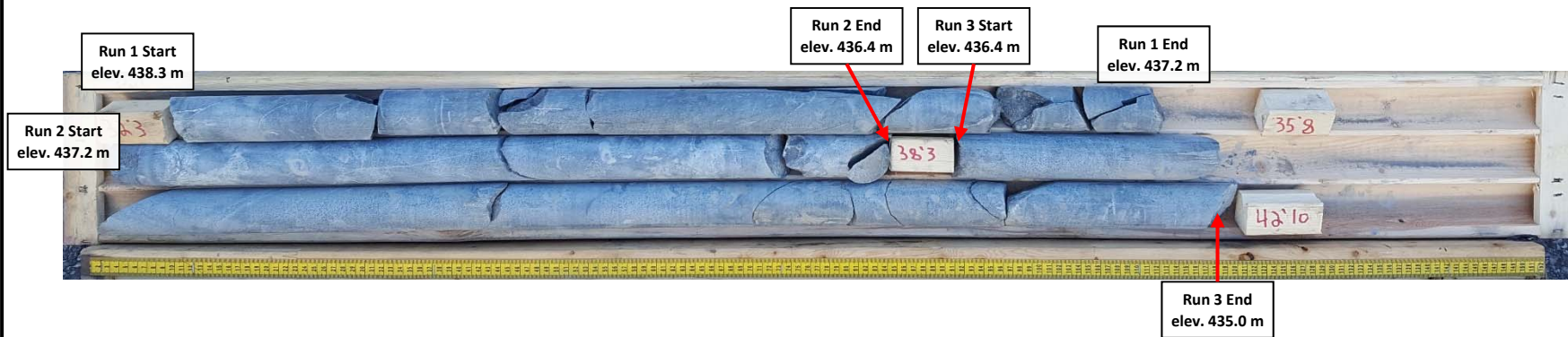
Appendix C.3

Rock Core Photos

Borehole 18-101B
Run 1 to 4 (of 4)
Elevation 436.1 m to 432.6 m



Borehole 18-102
Run 1 to 3 (of 3)
Elevation 438.3 m to 435.0 m



Appendix C.4

Analytical Testing Results

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

Report Date: 26-Jun-2018

Order Date: 20-Jun-2018

Project Description: 19773

Client ID:		18-101, SS6, 12'6"-14'6"	18-203, SS3, 5'10"-7'10"	18-204, SS4, 10'4"-12'4"	18-401, SS5, 10'-12'
Sample Date:		05/30/2018 11:00	06/12/2018 14:30	06/13/2018 09:45	06/07/2018 13:30
Sample ID:		1825441-01	1825441-02	1825441-03	1825441-04
MDL/Units		Soil	Soil	Soil	Soil
Physical Characteristics					
% Solids	0.1 % by Wt.	80.0	88.0	89.3	92.4
General Inorganics					
Conductivity	5 uS/cm	135	156	98	90
pH	0.05 pH Units	7.81	7.76	7.76	7.56
Resistivity	0.10 Ohm.m	74.3	64.3	102	111
Anions					
Chloride	5 ug/g dry	9	25	29	9
Sulphate	5 ug/g dry	16	46	7	28
Client ID:		18-502, SS8, 17'6"-19'6"	18-301, SS8A, 17'6"-19'4"	-	-
Sample Date:		06/12/2018 11:15	06/05/2018 15:30	-	-
Sample ID:		1825441-05	1825441-06	-	-
MDL/Units		Soil	Soil	-	-
Physical Characteristics					
% Solids	0.1 % by Wt.	89.9	90.0	-	-
General Inorganics					
Conductivity	5 uS/cm	47	50	-	-
pH	0.05 pH Units	7.14	7.38	-	-
Resistivity	0.10 Ohm.m	213	198	-	-
Anions					
Chloride	5 ug/g dry	13	19	-	-
Sulphate	5 ug/g dry	10	6	-	-

**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,

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

28-June-2018

Date Rec. : 22 June 2018
LR Report: CA12773-JUN18
Reference: Project#:1825441

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

Sample ID	Sample Date & Time	Sulphide %
1: Analysis Start Date		28-Jun-18
2: Analysis Start Time		13:23
3: Analysis Completed Date		28-Jun-18
4: Analysis Completed Time		14:45
5: QC - Blank		< 0.02
6: QC - STD % Recovery		105%
7: QC - DUP % RPD		ND
8: RL		0.02
9: 18-101,SS6, 12'6"-14'16"	30-May-18	< 0.02
10: 18-204,SS4, 10'4"-12'4"	13-Jun-18	< 0.02
11: 18-401,SS5, 10'-12'	07-Jun-18	< 0.02
12: 18-502,SS8, 17'6"-19'6"	12-Jun-18	< 0.02
13: 18-301,SS8A, 17'6"-19'4"	05-Jun-18	< 0.02

RL - SGS Reporting Limit
ND - Not Detected

Kimberley Didsbury
Project Specialist
Environmental Services, Analytical

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

Report Date: 06-Jul-2018

Order Date: 29-Jun-2018

Project Description: 19773

Client ID:	18-103,SS5, 8'2"-10'2"	18-304,SS5,8'10"	-	-
Sample Date:	06/15/2018 10:00	06/16/2018 12:15	-	-
Sample ID:	1826630-01	1826630-02	-	-
MDL/Units	Soil	Soil	-	-

Physical Characteristics

% Solids	0.1 % by Wt.	82.2	78.1	-	-
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General Inorganics

Conductivity	5 uS/cm	131	181	-	-
pH	0.05 pH Units	7.44	7.28	-	-
Resistivity	0.10 Ohm.m	76.1	55.1	-	-

Anions

Chloride	5 ug/g dry	8	26	-	-
Sulphate	5 ug/g dry	12	52	-	-

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

Report Date: 07-Dec-2018

Order Date: 3-Dec-2018

Project Description: 19773

Client ID:	Rousseau	Max	Rinker	Wabikon
Sample Date:	11/30/2018 12:00	11/30/2018 11:45	11/30/2018 11:30	11/30/2018 11:00
Sample ID:	1849062-01	1849062-02	1849062-03	1849062-04
MDL/Units	Water	Water	Water	Water

General Inorganics

Conductivity	5 uS/cm	125	74	52	84
pH	0.1 pH Units	7.5	7.4	7.3	7.5
Resistivity	0.01 Ohm.m	79.9	135	193	119

Anions

Chloride	1 mg/L	7	2	1	4
Sulphate	1 mg/L	1	1	1	1

Client ID:	Waweig	-	-	-
Sample Date:	11/30/2018 10:00	-	-	-
Sample ID:	1849062-05	-	-	-
MDL/Units	Water	-	-	-

General Inorganics

Conductivity	5 uS/cm	56	-	-	-
pH	0.1 pH Units	7.4	-	-	-
Resistivity	0.01 Ohm.m	180	-	-	-

Anions

Chloride	1 mg/L	1	-	-	-
Sulphate	1 mg/L	<1	-	-	-

Appendix D.

Site Photographs



Photo 1. Looking northward at culvert inlet (2018/05/30)



Photo 2. Looking southward at culvert outlet (2018/06/16)



Photo 3. Looking north along Highway 527 from culvert (2018/05/30)



Photo 4. Looking south along Highway 527 from culvert (2018/05/30)

Appendix E.

Foundation Comparison

COMPARISON OF ALTERNATIVE FOUNDATION TYPES

Type	Circular Pipe Culvert	Closed Box Culvert	Open Bottom Culvert	Precast Concrete Slab on Sheet Pile 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. 	<ul style="list-style-type: none"> • Minimized volume of excavation compared to other options. • Allows for winter construction. • Eliminates the need for an offline diversion channel.
Disadvantages	<ul style="list-style-type: none"> • Feasibility also depends on flow capacity and other hydraulic properties. May need multiple pipes. • Requires large excavation. • Roadway protection or temporary widening will be required. • Requires geotextile on silt subgrade. • Groundwater control is required. 	<ul style="list-style-type: none"> • Requires large excavation. • Roadway protection or temporary widening will be required. • Requires geotextile on silt subgrade. • Groundwater control is required. 	<ul style="list-style-type: none"> • Requires deeper excavation for frost protection increasing excavation volume and dewatering efforts. • Potential for post construction settlement. • Roadway protection or temporary widening will be required. 	<ul style="list-style-type: none"> • Quantity and cost of sheet piles. • Cannot penetrate obstructions. • Differential settlement will occur between non-yielding culvert and approach fills. A geogrid may be needed to strengthen the pavement structure.
Risks/Consequences	<ul style="list-style-type: none"> • Groundwater inflow can disturb silt subgrade. Subexcavation to glacial till may be required if inflow is not managed. • Cobbles and boulders present a challenge for installing roadway protection. Pre-drilling may be required to advance soldier piles. 	<ul style="list-style-type: none"> • Groundwater inflow can disturb silt subgrade. Subexcavation to glacial till may be required if inflow is not managed. • Cobbles and boulders present a challenge for installing roadway protection. Pre-drilling may be required to advance soldier piles. 	<ul style="list-style-type: none"> • Increased risk of basal instability of footing excavation due to depth of excavation below water table. • Cobbles and boulders present a challenge for installing roadway protection. Pre-drilling may be required to advance soldier piles. 	<ul style="list-style-type: none"> • High risk of encountering obstructions and having inadequate lateral support due to a shallow refusal.
Relative Cost	Low	Low	Moderate	Moderate to High
Recommendation	Feasible	Feasible	Feasible / Not Recommended	Not Recommended

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

July 17, 2018

Site: 49.111 N, 89.3121 W User File Reference: Rousseau Lake Culvert

Requested by: C.Murray, Thurber Engineering

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

Sa(0.05)	Sa(0.1)	Sa(0.2)	Sa(0.3)	Sa(0.5)	Sa(1.0)	Sa(2.0)	Sa(5.0)	Sa(10.0)	PGA (g)	PGV (m/s)
0.052	0.071	0.064	0.051	0.037	0.019	0.0080	0.0016	0.0008	0.038	0.026

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

Ground motions for other probabilities:

Probability of exceedance per annum	0.010	0.0021	0.001
Probability of exceedance in 50 years	40%	10%	5%
Sa(0.05)	0.0022	0.013	0.025
Sa(0.1)	0.0038	0.019	0.036
Sa(0.2)	0.0044	0.020	0.035
Sa(0.3)	0.0039	0.017	0.029
Sa(0.5)	0.0029	0.013	0.021
Sa(1.0)	0.0012	0.0058	0.011
Sa(2.0)	0.0005	0.0023	0.0043
Sa(5.0)	0.0002	0.0005	0.0009
Sa(10.0)	0.0002	0.0004	0.0005
PGA	0.0021	0.011	0.019
PGV	0.0014	0.0075	0.014

References

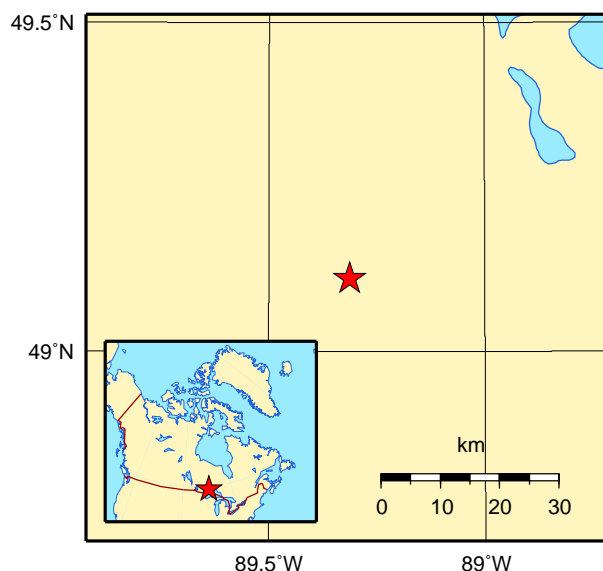
National Building Code of Canada 2015 NRCC no. 56190;
Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

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

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

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

Aussi disponible en français



Natural Resources
Canada

Ressources naturelles
Canada

Canada

Appendix G.

List of Special Provisions and OPSS Documents Referenced in this Report

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

OPSS.PROV 206	Construction Specification for Grading
OPSS.PROV 401	Construction Specification for Trenching, Backfilling, and Compacting
OPSS.PROV 501	Construction Specification for Compacting
OPSS 511	Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting
OPSS.PROV 517	Construction Specification for Dewatering of Pipeline, Utility and Associated Structure Excavation
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
OPSS 1860	Material Specification for Geotextiles
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 3090.100	Foundation Frost Depths for Northern Ontario
SP109S12	Amendment to OPSS 902 - QVE, Backfilling Compaction, and Certificate of Conformance
SP517F01	Amendment to OPSS 517 - Dewatering System
SPFOUN0003	Amendment to OPSS 902 – Dewatering Structure Excavations

2. Suggested text for a NSSP on “Installation of Temporary Protection System”

Vibratory equipment is not permitted for installation or removal of temporary protection systems.

3. Suggested text for a NSSP on “Obstructions”

Obstructions such as cobbles and boulders may be encountered within the glacial till. These obstructions may also be present in the fill. Such obstructions may impede the progress of open-cut excavations, and/or installation of temporary protection systems. The contractor shall use appropriate equipment and methodologies to penetrate and/or advance past the obstructions.