



THURBER ENGINEERING LTD.

**FINAL REVISION 1
FOUNDATION INVESTIGATION AND DESIGN REPORT
REPLACEMENT OF STRUCTURAL CULVERT No. 46-327/C
BIG PINE LAKE CULVERT UNDER HIGHWAY 101
PETERS TOWNSHIP
G.W.P. 91-97-00
5015-E-0027**

GEOCRES NUMBER: 41O-31

**SUBMITTED TO
MCINTOSH PERRY CONSULTING ENGINEERS**

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual data obtained from a foundation investigation conducted by Thurber Engineering Ltd. (Thurber) for the proposed replacement of the Big Pine Lake Culvert crossing Highway 101, within Peters Township. Thurber carried out the investigation as a subconsultant to McIntosh Perry Consulting Engineers (MPCE) as part of Agreement No. 5015-E-0027.

This report is the same as the Final Foundation Investigation Report submitted in October 2018 but has been reissued as a revision to reflect the new G.W.P. number.

No previous foundation investigation information for the subject culvert was available in the online Geocres library. A base plan survey drawing was provided by MPCE for the preparation of this report.

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

2 SITE DESCRIPTION

Culvert 46-327/C is located on Highway 101, approximately 34.7 km west of the south junction of Highway 129 south of Chapleau, Ontario. The location of the culvert is shown on the inset Key Plan on Drawing No. 1 in Appendix A. For project orientation purposes, Highway 101 within the project limits, will be described to run east-west.

Within the project limits, Highway 101 is a two-lane, rural, undivided highway. The base plan drawing indicates that the roadway cross-section consists of two, 3.50 m wide lanes, and gravel shoulders with a width of 1.4 m and 1.5 m on the north and south sides respectively. The culvert is located within a fill section. Steel cable guide rails are located on both sides of the highway.

Culvert 46-327/C carries Big Pine Lake outflow from north to south below the highway. The existing culvert is a three cell, wood, non-rigid frame culvert with an internal height of 2.4 m. Each cell spans 1.8 m. The top of the stream bed was noted to be at elevation 444.58 m and 444.44 m at the inlet and outlet respectively. The total length of structure is approximately 22 m.

The embankments adjacent to the culvert are approximately 2.2 m in height. The embankment slopes are approximately 2H:1V at the location of the culvert and are covered with a mix of vegetation and granular treatment. Based on the base plan drawing, the elevation of the

highway center line is approximately 447.71 m and the elevation of the top of culvert at the inlet and outlet are 446.82 m and 446.76 m respectively. The maximum height of the road embankment from the top of the culvert is approximately 0.9 m.

The topography at the site is generally flat. The lands adjacent to the culvert include forest of predominantly coniferous trees and swampy areas adjoining the banks of the waters edge.

Site photographs showing the general conditions at the site along the highway and of the culvert inlet and outlet areas during the time of the field investigation are presented in Appendix D.

3 SITE INVESTIGATION AND FIELD TESTING

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

The field investigation for this site included four boreholes drilled between October 21, 2016 and November 6, 2016. 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.

Table 3-1: Borehole Summary

Borehole Identification	Location	Northing (m)	Easting (m)	Ground Surface Elevation (m)	Termination Depth Below Ground Surface (m)
16-01	Culvert Inlet	5 301 327.3	321 990.8	445.5	12.8
16-02	Highway 101 Westbound	5 301 314.0	321 999.9	447.8	15.8
16-03	Highway 101 Eastbound	5 301 311.7	321 989.8	447.6	8.1
16-04	Culvert Outlet	5 301 301.7	322 000.6	446.3	7.7

Borehole 16-02 and 16-03, were advanced through the roadway embankment with a truck mounted CME 75 drill rig equipped with hollow stem augers and NW casing. Boreholes 16-01 and 16-04 were advanced with portable drilling equipment with BW casing. The subsurface stratigraphy encountered in the boreholes was recorded in the field by Thurber personnel. Split spoon samples were collected at regular depth intervals in the boreholes in conjunction with the completion of Standard Penetration Tests (SPT), following the methods described in ASTM Standard D1586-11. All soil samples recovered from the boreholes were placed in labelled containers and transported to Thurber's geotechnical laboratory in Ottawa for further examination and testing.

A 19 mm inside diameter PVC standpipe piezometer was installed in Borehole 16-04 to allow for measurement of the groundwater level after completion of drilling. The piezometer installation details are illustrated on the Record of Borehole sheet for Borehole 16-04, provided in Appendix

B. The piezometer was decommissioned on November 6, 2016 upon completion of the field investigation.

The remaining boreholes were backfilled with a low-permeability mixture of bentonite pellets and auger cuttings and in accordance with Ontario MOE Regulation 903. Boreholes 16-02 and 16-03 were capped with 150 mm of cold patch asphalt to reinstate the traveling surface.

The ground surface elevations at the proposed location of the boreholes were surveyed by MPCE in October 2016.

3.1 LABORATORY TESTING

Geotechnical laboratory testing consisted of natural moisture content determination and visual identification of all retained soil samples in accordance with current MTO standards. Grain size distribution analyses testing were also carried out on selected samples to MTO and ASTM standards. Chemical analysis for determination of pH, resistivity, soluble sulphate and chloride concentrations was carried out on a sample of fill and native soil.

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

4 DESCRIPTION OF SUBSURFACE CONDITIONS

4.1 Overview / General

Reference is made to the Record of Borehole sheets in Appendix B for details of the soil stratigraphy encountered in the boreholes. A stratigraphic profile for the culvert area is presented on Drawing No. 1 in Appendix A for illustrative purposes. An overall description of the stratigraphy is given in the following paragraphs; however, the factual data presented in the Record of Boreholes governs any interpretation of the site conditions.

For reference, the stratigraphy through the embankment boreholes is generally characterized by asphalt pavement structure and granular fill overlying native sand with gravel.

4.2 Asphalt

Boreholes 16-02 and 16-03 were advanced from the surface of the Highway 101 and encountered asphalt with a thickness ranging from 75 mm to 150 mm.

4.3 Embankment Fill

Granular fill consisting predominantly of sand with gravel was encountered below the asphalt in Boreholes 16-02 and 16-03. This layer has a thickness ranging from 1.9 m to 2.0 m (bottom elevation of 445.6 m to 445.5 m). The SPT 'N' values ranged from 23 to 69 blows in the embankment fill; indicating a compact to very dense condition. Cobbles and boulders were noted in the fill.

The moisture content of the samples tested ranged from 3% to 5%. The results of grain size analysis conducted on two samples of this material are summarized in Table 4-1 and are illustrated on Figure C1 in Appendix C.

Table 4-1: Gradation Results for Embankment Fill

Soil Particle	%
Gravel	42 to 49
Sand	46 to 54
Silt and Clay	4 to 5

4.4 Topsoil

A topsoil layer with a thickness of 25 to 100 mm was encountered at surface in the off road Boreholes 16-01 and 16-04. A single moisture content from this layer was recorded at 126%.

4.5 Silty Sand with Gravel (SM)

A layer of sand with gravel was encountered below the topsoil/organics in Boreholes 16-01 and 16-04. This layer has a thickness of 1.3 m and 1.5 m with a bottom elevation of 444.1 m and 444.8m. The SPT 'N' values ranged from 8 to 16 blows; indicating a loose to compact condition.

The moisture content of the samples tested ranged from 12% to 23%. The results of a gradation test on one sample are illustrated on Figure C2 and indicate 17% gravel, 63% sand and 20% fines. This material can be classified as an SM material.

4.6 Silty Sand (SM)

A thin layer of silty sand was encountered below the silty sand with gravel in Borehole 16-01 and Borehole 16-04. This layer was 0.3 m to 0.4 m thick (bottom elevation of 443.7 m to 444.5 m). The moisture content of the samples tested ranged from 15% to 24%.

4.7 Sand with Gravel (SW) to Sand (SP)

A layer consisting predominantly of sand with gravel was encountered in all boreholes below the layers noted above. The surface of this deposit ranged in elevation from 443.7 m to 445.6 m. All boreholes were terminated in this stratum at a depth of 7.7 to 15.8 m below the ground surface. Borehole 16-01 was advanced with portable equipment and the hydrostatic head above than the ground surface during drilling resulted in sand flowing into the borehole at an elevation below 442.5 m. The SPT 'N' values throughout this layer typically ranged from weight of hammer to 48 blows indicating very loose to dense conditions with localized N-values as high as 84 blows. Boreholes 16-03 and 16-04 were terminated at SPT refusal at depths of 8.1 m and 7.7 m (elevation 439.5 m and 438.6 m).

The moisture content for the samples tested ranged from 8% to 20%. The results of grain size analysis conducted on eight samples of this material are summarized in Table 4-2 and are illustrated on Figure C3 and C4 in Appendix C.

Table 4-2: Gradation Results for Sand (SW) with Gravel to Sand (SP)

Soil Particle	%
Gravel	5 to 59
Sand	39 to 93
Silt and Clay	2 to 10

Although not encountered during drilling, this layer is anticipated to contain cobbles and boulders based on visual observation of terrain surrounding the culvert site. The SPT refusal observed in Boreholes 16-03 and 16-04 may also be due to the presence of boulders.

4.8 Groundwater

The groundwater level was measured at 0.7 m below the ground surface (elevation 445.6 m) within the standpipe piezometer in Borehole 16-04. An artesian pressure at 0.3 m *above* the ground surface (elevation 445.9 m) was observed within the casing during drilling in Borehole 16-01. The creek water level within the culvert was surveyed during the time of investigation at an elevation of 445.4 m.

Located approximately 11 m north of the culvert inlet was a beaver dam controlling the water level with a surveyed water level upstream of the beaver dam at an elevation of 445.8 m. It is expected that the beaver dam locally controls the groundwater level in the foundation soils.

These observations are considered short-term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after the spring snowmelt or after periods of heavy and/or prolonged precipitation.

5 MISCELLANEOUS

Thurber selected the borehole locations in the field relative to site features and obtained utility clearances prior to drilling. MPCE surveyed the borehole locations and ground surface elevations. Ohlmann Geotechnical Services (OGS) Inc. of Almonte, Ontario and Downing George Estate Drilling Ltd. of Hawkesbury, Ontario supplied and operated the drilling equipment to carry out the drilling, sampling, in-situ testing and borehole decommissioning. The drilling, and sampling operations in the field were supervised on a full-time basis by Mr. Christopher Murray of Thurber. Laboratory testing was carried out by Thurber in its MTO-approved geotechnical laboratory in Ottawa.

Overall project management and direction of the field program was provided by Mr. Stephen Peters, P.Eng. Interpretation of the field data and preparation of this report was completed by Mr. Christopher Murray, P.Eng. The report was reviewed by Dr. Fred Griffiths, P.Eng. and Dr. P.K. Chatterji, P.Eng., the Designated Principal Contact for MTO Foundations Projects.



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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

6 GENERAL

This section of the report presents the interpretation of the factual data from Part 1 for the proposed replacement of the Big Pine Lake outflow culvert crossing Highway 101, in Peters Township, Ontario. Geotechnical assessment and recommendations are provided to assist the project team in designing a suitable foundation for the proposed replacement culvert.

This report is the same as the Final Foundation Investigation and Design Report submitted in October 2018 but has been reissued as a revision to reflect the new G.W.P. number.

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.

No previous foundation investigation information for the subject culvert was available within the Geocres library. General Arrangement (GA) drawings and base plan mapping were provided by McIntosh Perry Consulting Engineers (MPCE) for the preparation of this report.

The following sections address the foundation aspects of the installation of a new culvert. The discussions and recommendations presented in this report are based on the information provided by MPCE including the 30% Contract drawings dated October 2017 and on the factual data obtained during the course of this investigation.

6.1 Proposed Structure

At the time of preparation of this Foundation Investigation and Design Report, the proposed culvert structures are shown on Sheet 10 of the 30% Contract Drawings to consist of a pair of 3.0 x 1.8 m precast concrete box culverts. The new culverts are shown to be constructed along the same alignment of the existing culverts with a 60 mm gap between the culverts. The invert elevations are shown at elevation 444.45 m and 444.34 m at the culvert inlet and outlet respectively. A 1.2 m precast cut-off wall is shown to extend the width of the culvert.

6.2 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 understood that the 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.

The frost penetration depth at this site is 2.3 m as per OPSD 3090.100.

7 SEISMIC CONSIDERATIONS

7.1 Spectral and Peak Acceleration Hazard Values

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

The site coefficients used to determine the design spectral acceleration and displacement values are a function of the Site Class and the peak ground acceleration (PGA). The PGA value at this site for a *reference* Site Class C with a 2% probability of exceedance in 50 years (2475-year event) is 0.039g. This value is to be scaled by the site-specific Site Class as discussed below.

7.2 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. The seismic site classification for this site has been classified as a Seismic Site Class D in accordance with Table 4.1 of the CHBDC.

7.3 Seismic Liquefaction

Based on the subsurface conditions encountered at this site in conjunction with cyclic stress ratio (CSR) and cyclic resistance ratio (CRR) analysis, and the low PGA values, the native sand with gravel to sand foundation soil is not considered to be susceptible to liquefaction.

8 DESIGN OPTIONS

Based on the soil stratigraphy and the existing stream bed elevations which range from 444.6 m at the inlet to 444.4 m at the outlet, it is expected that the replacement culvert will be founded on native sand with gravel to sand. If organics, soft or loose deposits are encountered in the area of the culvert foundation subgrade it should be excavated and removed in accordance with OPSS 209.

Culvert/foundation alternatives and construction approaches are presented and evaluated in the following sections and a preferred replacement alternative from a foundation engineering perspective is identified.

8.1 Culvert Type/Foundation Alternatives

Common culvert and foundation types are listed below along with a comparison of these alternatives from a foundations perspective. Their respective advantages and disadvantages are outlined below, and are summarized in the table provided in Appendix E.

8.1.1 Circular Pipes

From a foundation engineering perspective, circular pipes installed with appropriate granular bedding over the native, undisturbed sand with gravel to sand subgrade are feasible. However, it is understood that multiple circular pipes would be required to provide the equivalent hydraulic opening.

8.1.2 Closed Bottom (Concrete)

From a foundation engineering standpoint, a closed bottom culvert such as a concrete box culvert is considered feasible at this site. Furthermore, it would not have to be founded below the frost depth and would therefore require less excavation and dewatering effort in the cohesionless soils in comparison to an open bottom culvert.

8.1.3 Open Bottom (Steel/Concrete Arch or Concrete Rigid Frame)

An open bottom culvert founded on the compact to dense sand with gravel to sand is feasible at this site. The open bottom culvert could consist of a rigid frame open bottom (RFOB) culvert or an arch structure (steel or precast concrete) provided a suitable thickness of cover is available.

The founding elevation for an open bottom structure will be lower than for a closed box option, thereby requiring a deeper excavation and increased dewatering effort in the cohesionless soils.

8.2 Construction Methodology Alternatives

This section presents discussions from a foundation perspective on alternative construction methods for the replacement of Big Pine Lake Culvert. Further comparison of these options is provided in the table provided in Appendix E.

The following options have been considered.

1. Trenchless techniques
2. Open cut with staged construction and roadway protection
3. Open cut with staged construction and platform widening
4. Open cut with full road closure and temporary detour

8.2.1 Trenchless Techniques

The limited cover over the existing culvert, the proposed culvert type/geometry and the site conditions are considered not conducive to trenchless methods.

8.2.2 Open Cut with Staged Construction and Temporary Protection Systems

The culvert could be replaced using open cut techniques with staged construction (half and half). Temporary protection systems parallel to the highway centerline would be required in order to keep one lane of traffic open throughout the construction period.

8.2.3 Open Cut with Staged Construction with Platform Lowering/Embankment Widening

Due to the low height of the embankment, it is considered that the embankment lowering would not be feasible. Temporary embankment widening will be difficult at this site due to the open water present to the north of the highway and wet conditions observed to the south. These options are not considered feasible for this site.

8.2.4 Open Cut with Full Road Closure and Temporary Detour

Installation of a new culvert using open cut techniques with a full road closure would allow for an expedient construction schedule and reduced costs associated with both roadway protection and creek diversion. If an acceptable detour route around the site is available, this option should be considered.

8.3 Recommended Approach for the Culvert Replacement

From a foundation engineering perspective, replacement of the culvert with a rigid frame open bottom culvert using open cut with staged construction and temporary protection systems is considered feasible. However, from a geotechnical perspective a closed box culvert installed with staged construction is preferred as it would require less excavation and dewatering.

9 FOUNDATION DESIGN RECOMMENDATIONS

9.1 Culvert Foundation Bearing Resistances

An open bottom culvert structure may be founded on native, undisturbed sand with gravel to sand at or below the depth of frost and can be designed based on the factored geotechnical resistances values provided in Table 9-1.

Also provided in Table 9-1 are factored geotechnical resistance values for closed box culverts with a total width of 6 m founded on undisturbed sand and gravel to sand. A closed box culvert would not need to be founded below frost depth.

Table 9-1: Factored Geotechnical Resistances for Concrete Box Culverts

Footing Width (m)		ULS (kPa)	SLS (kPa)
Open bottom culvert(*)	1.5	230	170
	2.0	250	130
	2.5	265	110
Closed box culvert(s)	6.0 (total width)	225	100

* For intermediate footing sizes the factored geotechnical resistances values may be interpolated.

The factored geotechnical resistances include the following factors:

- Consequence factor (Ψ) of 1.0
- Geotechnical resistance factors (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 geotechnical resistances are for vertical concentric loading and will need to be adjusted for the effects of inclined or eccentric loading, if applicable. The geotechnical resistance should be calculated as illustrated in the CHBDC Clause 6.10.3 and Clause 6.10.4. Foundation settlement, based on the above noted SLS resistance and a subgrade prepared with good workmanship, is expected to be less than 25 mm.

Resistance to lateral forces through sliding resistance between concrete and native granular or bedding materials should be evaluated using an unfactored coefficient of 0.50 for cast-in-place concrete and 0.45 for pre-cast concrete (Table 24.4 of the CFEM 4th edition and Table 1, page 7.2-63, September 1986 of the NAVFAC Design Manual 7.02).

9.2 Subgrade Preparation, Culvert Bedding and Backfilling

Excavation and backfilling for installation of the new culvert should be carried out in accordance OPSS 902.

Subgrade preparation for the culvert replacement should include excavation and removal of the existing culvert, culvert foundations and backfill materials from beneath the founding elevation of the new culvert. MPCE's environmental report should be reviewed with respect to potential contamination of the existing backfill adjacent to the timber culverts and for handling and disposal requirements of the timbers and excavated soils. The existing fill and any soft or organic materials must be removed and replaced with compacted Granular A. The native subgrade within the footprint of the culvert should consist of undisturbed native sand with gravel. Boulders were noted at the base of the embankment fill and if encountered at the subgrade elevation should be removed and replaced with Granular A.

The new structure should be founded at or below the existing culvert foundations to avoid destabilizing the new culvert.

If organic material is encountered it should be excavated and removed in accordance with OPSS 209.

Bedding and backfill for a closed box culvert replacement structure should consist of OPSS Granular A material with the bedding and cover at least 300 mm thick (OPSD 803.010)

The subgrade will be easily disturbed when saturated and should be protected from disturbance from construction traffic and weather elements.

Backfill should be in accordance with OPSS 902. Backfill for the culvert must consist of free draining granular material conforming to OPSS Granular A material specifications.

Compaction should be carried out in accordance with OPSS.PROV 501. Heavy compaction equipment, used adjacent to the structure, must be restricted in accordance with OPSS.PROV 501.

9.3 Embankment Design and Reinstatement

Embankment reinstatement, after culvert replacement, should be carried out in accordance with OPSS.PROV 206. The embankment material should consist of Granular A, Granular B Type I or Granular B Type II material. MPCE's environmental report should be referenced with regards to the extent of contaminated soils to be excavated and replaced.

Granular fill should be placed and compacted in accordance with OPSS.PROV 501.

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

Provided the subgrade is prepared as outlined above and embankment fill is placed as recommended herein, an embankment slope inclined at 2H:1V or flatter to match the existing embankment side slopes, will remain stable. Negligible settlement of the soils beneath the embankment is anticipated.

9.4 Lateral Earth Pressures

The lateral earth pressure parameters provided in Table 9-2 and 9-3 are based on the assumption that the backfill is fully drained so that there are no unbalanced hydrostatic pressures. If adequate drainage cannot be confirmed, the potential for buildup of hydrostatic pressures should be considered in the design.

9.4.1 Static Lateral Earth Pressure Coefficients

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

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

where:

σ_h = static lateral pressure on the wall at depth, d (kPa)
K = static earth pressure coefficient (see Table 9-2)

γ = unit weight of retained soil (kN/m³), adjusted for water level
 d = depth below top of fill where pressure is computed (m)
 q = value of any surcharge (kPa)

The recommended lateral earth pressure parameters for use in the design for a vertical wall with a horizontal back-slope are provided in Table 9-2.

Table 9-2: Static Lateral Earth Pressure Coefficient

Parameter	OPSS Granular A & B Type II	Existing Embankment Fill (OPSS Granular B Type I)	Sand (SW) with Gravel to Sand (SP)
Soil Unit Weight, kN/m ³ , γ	21.0	20.0	19.0
Angle of Internal Friction, ϕ	35°	30°	30°
Coefficient of at Rest Earth Pressure, K_o (Restrained Wall)	0.43	0.50	0.50
Coefficient of Active Earth Pressure, K_a (Unrestrained Wall)	0.27	0.33	0.33

For rigid structures it is recommended that at-rest horizontal lateral earth pressures be used for design. Active pressures should be used for the design of unrestrained walls. The parameters in the table correspond to full mobilization of active and passive earth pressure and require certain relative movements between the wall and adjacent soil to produce these conditions. The values used in design can be assessed from Figure C6.16 of the Commentary to the CHBDC. Where ground surfaces are sloped behind structure walls, the coefficients for sloping ground should be used and these coefficients can be provided upon request.

For static analysis, passive earth resistance should be ignored, and therefore have not been provided. A lateral pressure due to backfill compaction should be added to the calculated lateral earth pressure in accordance with Section 6.12.3 of the CHBDC.

9.4.2 Combined Static and Seismic Lateral Earth Pressure Parameters

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

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

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

The recommended seismic lateral earth pressure parameters for use in the design that are provided in Table 9-3 assume the following:

- Horizontal back-slope behind a vertical wall
- Seismic Site Class of D, and a *reference* PGA with a 2% probability of exceedance in 50 years of 0.039g; as outlined in Section 7.0

Table 9-3: Lateral Earth Pressure (Under Seismic Loads)

Parameter	OPSS Granular A & B Type II	Existing Embankment Fill (OPSS Granular B Type I)	Sand (SW) with Gravel to Sand (SP)
Soil Unit Weight, kN/m ³ , γ	21.0	20.0	19.0
Angle of Internal Friction, ϕ	35°	30°	30°
Non-Yielding Wall			
Dynamic Active Earth Pressure Coefficient, K_{AE}	0.30	0.36	0.36
Yielding Wall			
Dynamic Active Earth Pressure Coefficient, K_{AE}	0.28	0.35	0.35

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

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

where:

- σ_h = seismic lateral earth pressure at depth, d (kPa)
- d = depth below the top of the wall where pressure is computed (m)
- K = static earth pressure coefficient
(K_o for non-yielding and K_a for yielding walls)
- γ = unit weight of the backfill soil (kN/m³), adjusted for water level
- K_{AE} = combined static and seismic earth pressure coefficient
- H = total height of the wall (m)

9.5 Cement Type and Corrosion Potential

Two samples were submitted to Paracel Laboratories in Ottawa, Ontario for analysis of pH, water soluble sulphate and chloride concentrations, and resistivity. The analysis was completed to determine the potential for degradation of concrete in the presence of soluble sulphates and the potential for corrosion of exposed steel used in foundations and buried infrastructure. The analysis results are summarized in the Table 9-4. A copy of the test results is provided in Appendix C.

Table 9-4: Results of Chemical Analysis

Borehole	Sample	Depth (m)	pH	Resistivity (Ohm-cm)	Chloride (µg/g)	Sulphate (µg/g)
16-01	SS2	0.9	7.4	9150	16	19
16-04	SS1 & SS2 (composite)	0.6	6.4	9170	15	14

The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with soil and groundwater at the site. Soluble sulphate concentrations less than 1000 µg/g generally indicate that a low degree of sulphate attack is expected for concrete in contact with soil and groundwater. Type GU Portland Cement should therefore be suitable for use in concrete at this site.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The soil pH measured was within what is considered the normal range for soil pH of 5.5 to 9.0. The test results provided in the Table 9-4 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects.

10 CONSTRUCTION CONSIDERATIONS

10.1 Excavations

All excavations must be conducted in accordance with the requirements of the Occupational Health & Safety Act & Regulations (OHSA) for Construction Projects. The fills and native soils at the site should be classified as Type 3 above the groundwater table and Type 4 below the groundwater table in accordance with OHSA. As indicated in the OHSA, if an excavation contains more than one type of soil, the soil type for the excavation shall be classified as the type with the largest number among the soil types present within the excavation.

Subgrade preparation and placement of culvert bedding or foundations must be carried out in the dry.

Selection of the equipment and methodology to excavate and prepare the founding surface is the responsibility of the Contractor. As cobbles and boulders were observed in the boreholes, it is recommended that the contract include an NSSP alerting bidders to their presence. We suggest the following wording:

“Excavations and installation of temporary protection systems at the site may be impeded by obstructions within the existing fills. The contractor shall be prepared to dislodge and remove, these obstructions to achieve the design depths.”

Excavation and removal of the organic material encountered in the area of the inlet and/or outlet should be carried out in accordance with OPSS 209.

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.

10.2 Temporary Protection Systems

If required, temporary protection systems should be provided in accordance with OPSS.PROV 539 and designed for Performance Level 2 (maximum 25 mm horizontal deflection). The design of protection systems is the responsibility of the Contractor. All protection systems should be designed by a Professional Engineer experienced in such designs and be retained by the Contractor. Lateral earth pressure coefficients, under fully mobilized conditions, that can be used in design are provided in Table 9-2.

The designer of the roadway protection system should ensure that the penetration depth is sufficient to provide base fixity and the design should incorporate traffic loading and surcharge loading due to construction equipment and operations. A sheet pile wall is considered to be feasible at this site with some potential for subexcavation of cobbles and/or boulders within the fill. Alternatively, drilled in soldier piles with lagging may be used to reduce the interference with cobbles and boulders. A suitable anchor or bracing system may need to be incorporated into the roadway protection design. The temporary protection systems should be left in place and cut-off in accordance with OPSS 539 to limit disturbance to the newly placed fills and culvert.

10.3 Dewatering

The Contractor must be prepared to control the groundwater and surface water flow at the site to permit the proposed culvert replacement to be constructed in a dry and stable excavation. The groundwater level for the site at the time of the proposed replacement should be taken as the water level in the creek or as retained behind the beaver dam, if still present. It is recommended that the culvert replacement be conducted during a drier season such as after the spring freshet or prior to the fall season to facilitate easier dewater requirements.

Temporary water course diversion will be required to replace the culvert in the dry. Depending on the surface flow and structure type, options may include by-pass pumping from behind sheet pile cut-off wall cofferdams and through the existing culvert, if removed in stages. Water from either surface flow and/or groundwater must be diverted away from the excavation at all times. Groundwater perched within the embankment fill, surface runoff and/or the water from the creek will tend to seep into, and accumulate in proposed excavations.

Excavations below the groundwater level are anticipated. Dewatering must be initiated prior to commencement of excavating. Pumping with sump pumps will be required in order to maintain the groundwater level at least 0.5 m below the final subgrade elevation. Dewatering and surface water diversion must remain operational and effective until the culvert is replaced and backfilled. Dewatering systems must be designed by a dewatering specialist and should be designed, operated and removed in accordance with OPSS.PROV 517 and Special Provision No. 517F01 with the following inputs for Table A: Note 1 = Yes and ***** = N/A. The presence of the beaver dam in close proximity to the culvert may significantly increase the volume of water. The assessment for the need for a Permit to take Water (PTTW) should be carried out by a specialist experienced in this field.

10.4 Erosion Protection

Slope protection and drainage measures will be required to ensure the long-term surficial stability of the embankment slopes. The embankment material consists of silty sand, sand and gravel and is considered to have a low erosion potential. Normal slope vegetation should be established as soon as possible after completion of the embankment fills in order to control surficial erosion. The contractor should provide silt fences and erosion control blankets, as required, throughout the duration of the construction to prevent silt/sediments from running off the site as per OPSS 805.

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

Typically, rock protection should be provided over all surfaces which flowing water is likely to contact. Treatment at the outlets 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 be used to minimize the potential for erosion near the inlet area. The clay seal should extend a minimum of 0.3 m above the high water level and laterally for the width of the granular material, and have a minimum thickness of 0.5 m. The material requirements should be in accordance with OPSS.PROV 1205. A geosynthetic clay liner may be used as a clay seal.

A cut-off wall should be provided for a closed box replacement culvert.

10.5 Construction Concerns

The planned construction methodology includes an open cut excavation for the installation of a new culvert. Potential construction concerns include, but are not necessarily limited to, the following:

- Construction will extend below the water level in the creek. An adequate and effective surface water management and dewatering plan must be implemented to construct the replacement culvert and possibly footings and subgrade in the dry.
- Excavation within the highway embankment and subgrade is expected to encounter cobbles and boulders which will need to be removed

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

11 CLOSURE

Overall project management and direction of the field program was provided by Mr. Stephen Peters, P.Eng. Interpretation of the field data and preparation of this report was completed by Mr. Christopher Murray, P.Eng. The report was reviewed by Dr. Fred Griffiths, P.Eng. and Dr. P.K. Chatterji, P.Eng., the Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.
Report Prepared By:



Christopher Murray, P.Eng.
Geotechnical Engineer



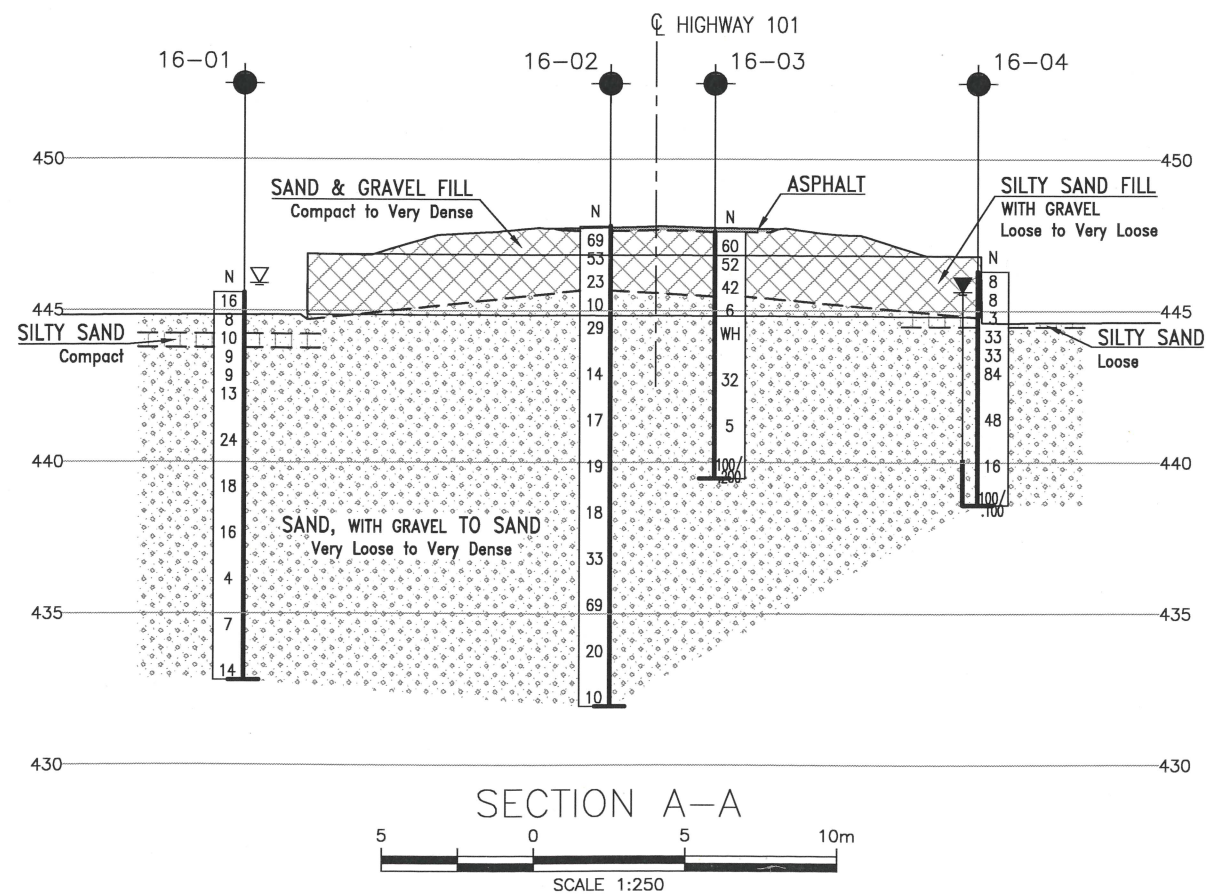
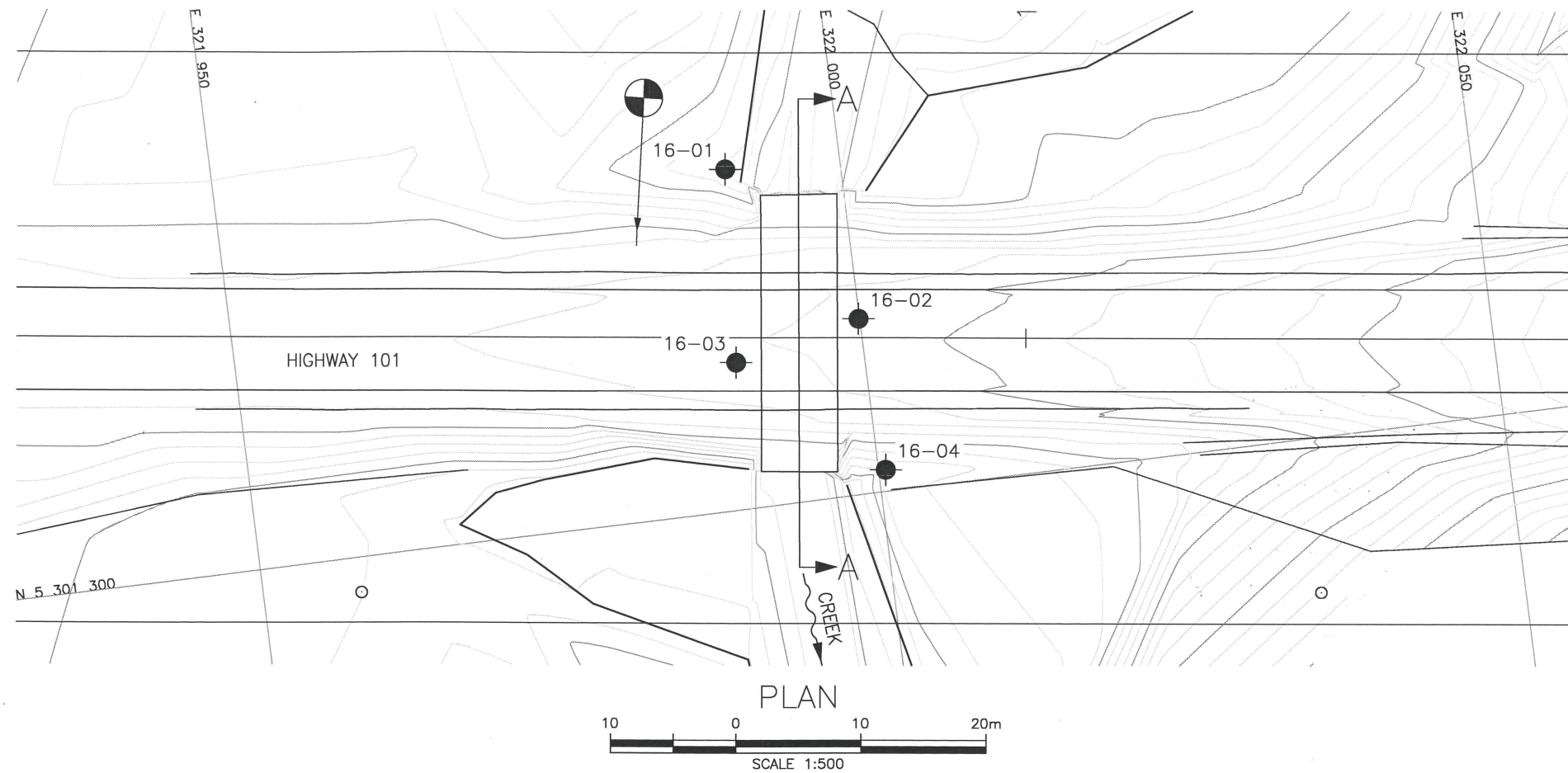
Fred Griffiths, P.Eng., Ph.D.
Senior Associate
Senior Geotechnical Engineer



P.K. Chatterji, P.Eng., Ph.D.
MTO Review Principal
Senior Geotechnical Engineer

APPENDIX A

BOREHOLE LOCATIONS AND SOIL STRATA DRAWINGS



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



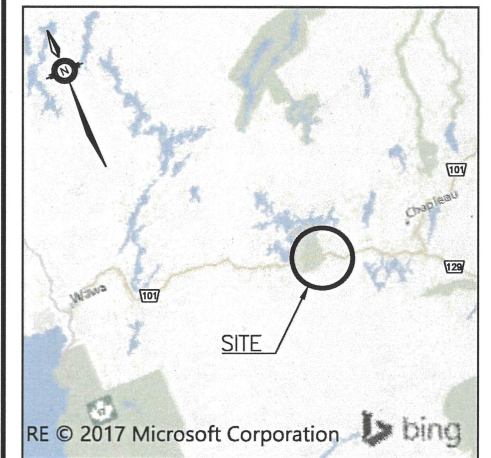
CONT No
GWP No 91-97-00

HIGHWAY 101
BIG PINE LAKE
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

McINTOSH PERRY



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

●	Borehole
⊕	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
▽	Water Level
⊕	Head Artesian Water
⊕	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
16-01	445.6	5 301 327.3	321 990.8
16-02	447.8	5 301 314.0	321 999.9
16-03	447.6	5 301 311.7	321 989.8
16-04	446.3	5 301 301.7	322 000.6

-NOTES-

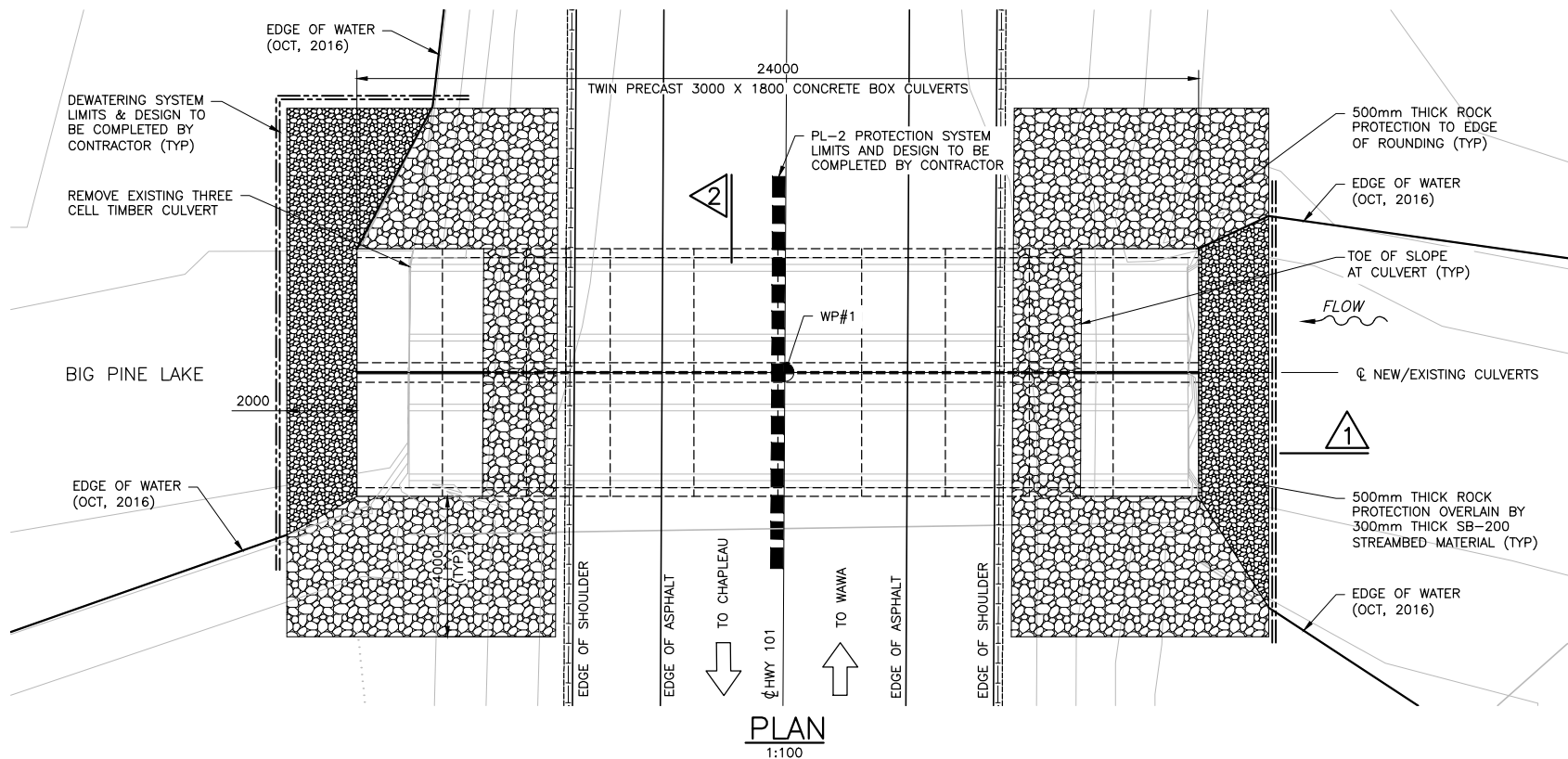
- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Borehole locations are shown in MTM Zone 13 coordinates.

GEOCRES No. 410-31

REVISIONS	DATE	BY	DESCRIPTION
1	9/20/19	BH	UPDATED GWP NUMBER
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CAD FILE LOCATION AND NAME: \\192.168.3.1\mp\02-Documents\2016\OKM-16-7040 - MTO NER - 3 Str Replace + 1 Str Rehab Hwy 101 & 129\12 CAD\B Contract Drawings\Structure\CV-01_46-327.c - Big Pine\516-7040_CV-01_0010A.dwg
MODIFIED: 8/21/2019 12:50:19 PM BY: D5MMMS
DATE PLOTTED: 8/21/2019 12:56:10 PM BY:

PR-D-707 86-05
MINISTRY OF TRANSPORTATION, ONTARIO

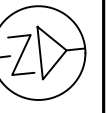


LEGEND:

- GRANULAR 'A'
- ROCK PROTECTION
- STREAMBED MATERIAL
- GRANULAR B TYPE I
- GUIDERAIL

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

HIGHWAY 101
CONT. No. 2020-XXXX
GWP NO. 91-97-00



BIG PINE LAKE CULVERT REPLACEMENT

SHEET

GENERAL ARRANGEMENT

13

McINTOSH PERRY

GENERAL NOTES:

1. CLASS OF CONCRETE

PRECAST 40 MPa

2. CLEAR COVER TO REINFORCING STEEL

PRECAST 50 ± 10 mm

3. REINFORCING STEEL

REINFORCING STEEL SHALL BE GRADE 400W.

UNLESS SHOWN OTHERWISE, TENSION LAP SPLICES FOR REINFORCING STEEL BARS SHALL BE CLASS 'B'.

BAR HOOKS SHALL HAVE STANDARD HOOK DIMENSIONS USING MINIMUM BEND DIAMETERS, WHILE STIRRUPS AND TIES SHALL HAVE MINIMUM HOOK DIMENSIONS. ALL HOOKS SHALL BE IN ACCORDANCE WITH THE STRUCTURAL STANDARD DRAWING SS12-1, UNLESS INDICATED OTHERWISE.

4. GEOTEXTILE

NON-WOVEN, CLASS II, FOS 75 TO 150um. AND FREE OF FOLDS, TEARS AND WRINKLES.

5. CONSTRUCTION NOTES

THE CONTRACTOR SHALL VERIFY ALL DIMENSIONS, DETAILS AND ELEVATIONS OF THE EXISTING STRUCTURE THAT ARE RELEVANT TO THE WORK SHOWN ON THE DRAWINGS PRIOR TO COMMENCEMENT OF THE WORK. ANY DISCREPANCIES SHALL BE REPORTED TO THE CONTRACT ADMINISTRATOR AND THE PROPOSED ADJUSTMENT OF THE WORK REQUIRED TO MATCH THE EXISTING STRUCTURE SHALL BE SUBMITTED FOR APPROVAL.

THE CONTRACTOR SHALL CARRY OUT SITE SURVEYS TO DETERMINE THE EXISTING ELEVATIONS OF ASPHALT PRIOR TO REMOVALS.

THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE DESIGN OF THE DEWATERING AND TEMPORARY FLOW PASSAGE SYSTEMS. THE DEWATERING SYSTEM INDICATED ARE SCHEMATIC ONLY.

THE TEMPORARY FLOW CONTROL SHALL BE DESIGNED FOR A TWO (2) YEAR DESIGN STORM RETURN PERIOD OF 3.02 m³/s.

PROTECTION SYSTEMS SHALL MEET REQUIREMENTS FOR PERFORMANCE LEVEL 2 AS SPECIFIED IN THE CONTRACT DOCUMENTS.

BACKFILLING ON EACH SIDE OF THE BOX CULVERT SHALL BE COMPLETED SIMULTANEOUSLY. AT NO TIME SHALL THE LEVELS ON EACH SIDE DIFFER BY MORE THAN 400 mm.

ALL AREAS AFFECTED BY CONSTRUCTION ACTIVITIES SHALL BE FULLY REINSTATED TO PRE-CONSTRUCTION OR BETTER CONDITIONS TO THE SATISFACTION OF THE CONTRACT ADMINISTRATOR INCLUDING THE REINSTATEMENT OF ALL VEGETATION, PATHWAYS, FENCES, AND AREAS USED FOR SITE ACCESS.

6. FOUNDATION DESIGN

FACTORED GEOTECHNICAL RESISTANCE AT SLS 110 kPa
FACTORED GEOTECHNICAL RESISTANCE AT ULS 225 kPa

LIST OF DRAWINGS:

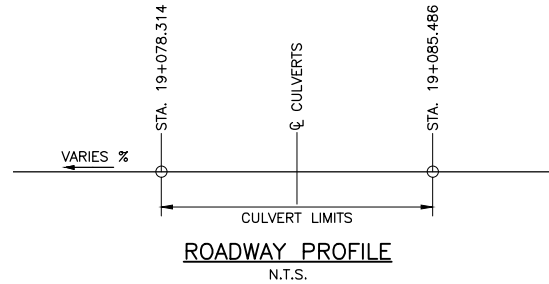
- GENERAL ARRANGEMENT
- BOREHOLE LOCATIONS AND SOIL STRATA
- STRUCTURAL REMOVALS
- CONSTRUCTION STAGING
- MISCELLANEOUS DETAILS

APPLICABLE STANDARD DRAWINGS:

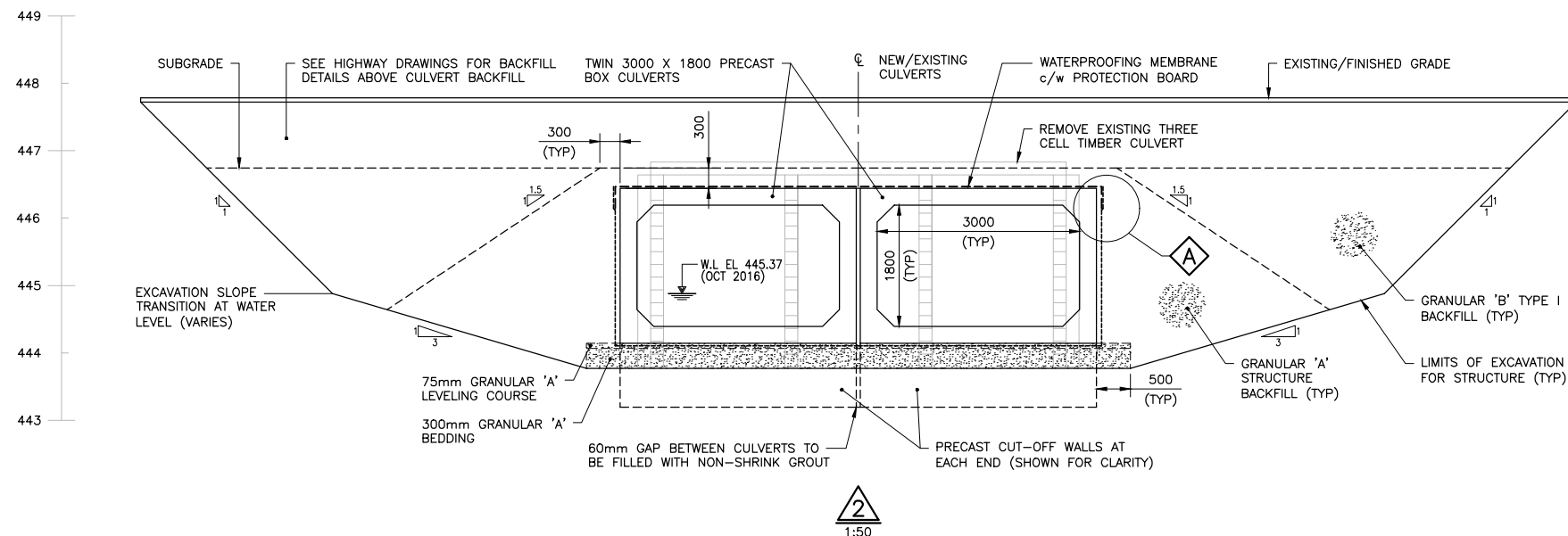
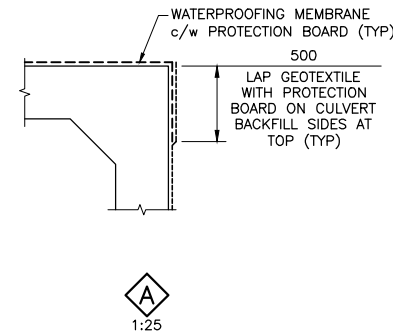
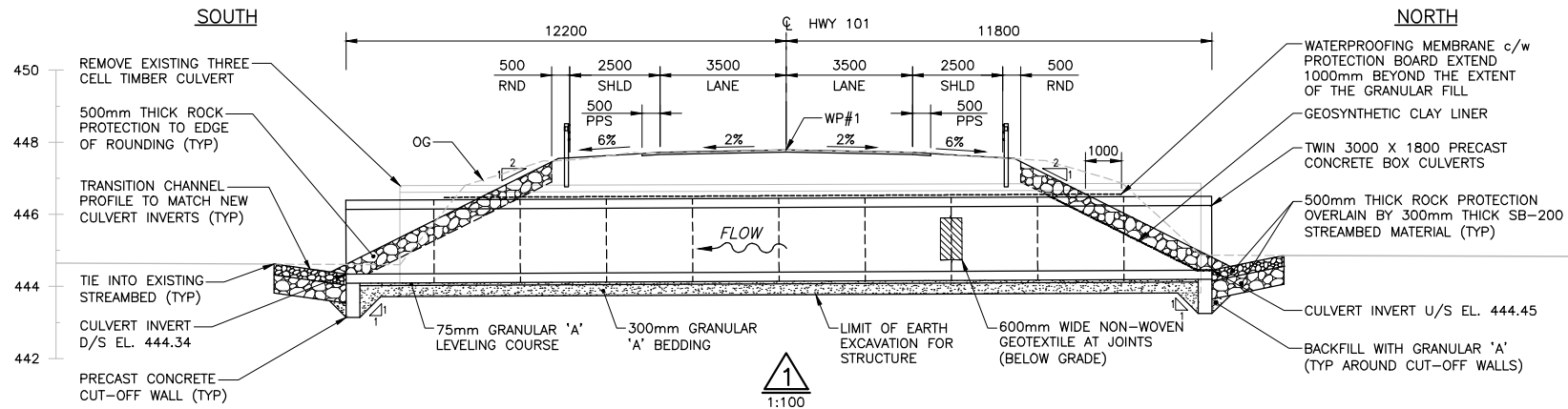
MTOD 3941.2100 FIGURES IN CONCRETE SITE NUMBER AND LAYOUT

LIST OF ABBREVIATIONS:

CL	CENTRELINE	c/w	COMPLETE WITH
DIA	DIAMETER	D/S	DOWNSTREAM
DWG	DRAWING	EL	ELEVATION
EX	EXISTING	MAX	MAXIMUM
MIN	MINIMUM	NTS	NOT TO SCALE
OG	ORIGINAL GROUND	RND	ROUNDING
ROW	RIGHT OF WAY	SHLD	SHOULDER
STA	STATION	TYP	TYPICAL
U/S	UPSTREAM	WL	WATER LEVEL



COORDINATES OF WORK POINTS				
WP #	STATION	NORTH COORDINATE	EAST COORDINATE	ELEVATION
1	19+081.9	5301313.0693	321995.0300	447.7830



DRAWING NOT TO BE SCALED
100mm ON ORIGINAL DRAWING

REVISIONS		DESCRIPTION	
DESIGN	AS	CHK	TT
DRAWN	DS	CHK	AS
CODE CHBDC 2014		LOAD CL-625-ONT	
SITE 46X-0327/C0		STRUCTURE SCHEME	
DATE AUG/19		DWG 01	

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 16-01

1 OF 2

METRIC

GWP# 91-97-00 LOCATION Big Pine Lake Culvert N 5 301 327.3 E 321 990.8 ORIGINATED BY CM
 HWY 101 BOREHOLE TYPE Portable w/ BW Casing COMPILED BY JM
 DATUM Geodetic DATE 2016.10.21 - 2016.10.22 CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W _P	W	W _L				
SHEAR STRENGTH kPa								WATER CONTENT (%)											
○ UNCONFINED + FIELD VANE														kN/m ³	GR	SA	SI	CL	
● QUICK TRIAXIAL × LAB VANE																			
445.5																			
0.0	100 mm Topsoil		1	SS	16														
0.1																			
	Silty SAND with Gravel Brown Compact to Loose		2	SS	8														
444.1																			
1.4	Silty SAND Grey Compact		3	SS	10														
443.7																			
1.8	SAND (SW) with Gravel to SAND (SP) Grey Loose to Compact - Running sand below 3.1 m		4	SS	9														
													</						

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity


20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 16-01

2 OF 2

METRIC

GWP# 91-97-00 LOCATION Big Pine Lake Culvert N 5 301 327.3 E 321 990.8 ORIGINATED BY CM
 HWY 101 BOREHOLE TYPE Portable w/ BW Casing COMPILED BY JM
 DATUM Geodetic DATE 2016.10.21 - 2016.10.22 CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	Continued From Previous Page							20	40	60	80	100					
	SAND (SW) with Gravel to SAND (SP) Grey Loose to Compact		11	SS	7		435										
							434										
432.7			12	SS	14		433										
12.8	End of borehole Water measured to be 0.3 m above ground surface on completion of drilling																

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 16-02

1 OF 2

METRIC

GWP# 91-97-00 LOCATION Big Pine Lake Culvert N 5 301 314.0 E 321 999.9 ORIGINATED BY CM
 HWY 101 BOREHOLE TYPE HSA / NW Casing COMPILED BY JM
 DATUM Geodetic DATE 2016.11.05 - 2016.11.05 CHECKED BY SP



SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				W P W W L				GR SA SI CL			
								20 40 60 80 100	20 40 60	20 40 60	20 40 60								
447.8																			
0.0																			
0.1	75 mm ASPHALT																		
	SAND with Gravel Compact to Very Dense Grey FILL		1	SS	69														
			2	SS	53														
			3	SS	23														
445.6	- Difficulty augering around 2.0 m (cobbles)																		
2.1	SAND (SW) with Gravel to SAND (SP) Compact to Very Dense Grey		4	SS	10														
			5	SS	29														
			6	SS	14														
			7	SS	17														
			8	SS	19														
			9	SS	18														
	- becoming sandy gravel at 428.7 m																		

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

METRIC

ELEV DEPTH	SOIL PROFILE		SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					WATER CONTENT (%)	
								○ UNCONFINED ● QUICK TRIAXIAL						+ FIELD VANE × LAB VANE
	Continued From Previous Page						20 40 60 80 100	20 40 60				GR SA SI		

[illegible]

ONTMT4S 13624 - 101 AND 129 - BIG PINE LAKE.GPJ 2012TEMPLATE(MTO).GDT 24/9/19

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 16-03

1 OF 1

METRIC

GWP# 91-97-00 LOCATION Big Pine Lake Culvert N 5 301 311.7 E 321 989.8 ORIGINATED BY CM
 HWY 101 BOREHOLE TYPE HSA / NW Casing COMPILED BY JM
 DATUM Geodetic DATE 2016.11.06 - 2016.11.06 CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	W _P W W _L	SHEAR STRENGTH kPa					WATER CONTENT (%)						
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE													
447.6																					
0.0	150 mm ASPHALT																				
0.2	SAND with Gravel to GRAVEL with sand Dense to Very Dense Brown FILL		1	SS	60		447														
			2	SS	52																
	- boulder at 1.5 m						446														
			3	SS	42																
445.5																					
2.1	SAND (SW) with Gravel to SAND (SP) Very Loose to Dense Grey		4	SS	6		445														
			5	SS	WH		444														
			6	SS	32		443														
							442														
			7	SS	5		441														
			8	SS	100/ 200mm		440														
439.5																					
8.1	End of Borehole																				

ONTMT4S 13624 - 101 AND 129 - BIG PINE LAKE.GPJ 2012TEMPLATE(MTO).GDT 24/9/19

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

RECORD OF BOREHOLE No 16-04

1 OF 1

METRIC

GWP# 91-97-00 LOCATION Big Pine Lake Culvert N 5 301 301.7 E 322 000.6 ORIGINATED BY CM
 HWY 101 BOREHOLE TYPE Portable w/ BW Casing COMPILED BY JM
 DATUM Geodetic DATE 2016.10.22 - 2016.10.23 CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT w _P	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								20 40 60 80 100								
446.3																
0.0	25 mm TOPSOIL															
	Silty SAND with Gravel		1	SS	8		446									
	Brown		2	SS	8											
	Loose to Very Loose															
444.8			3	SS	3		445									17 63 20 (SI+CL)
1.5	Silty SAND															
444.5	Grey															
1.8	Loose															
	SAND (SW) with Gravel to		4	SS	33		444									
	SAND (SP)		5	SS	33											
	Grey		6	SS	84		443									25 66 9 (SI+CL)
	Very Dense to Compact															
			7	SS	48		442									
			8	SS	16		440									

ONTMT4S 13624 - 101 AND 129 - BIG PINE LAKE.GPJ 2012TEMPLATE(MTO).GDT 24/9/19

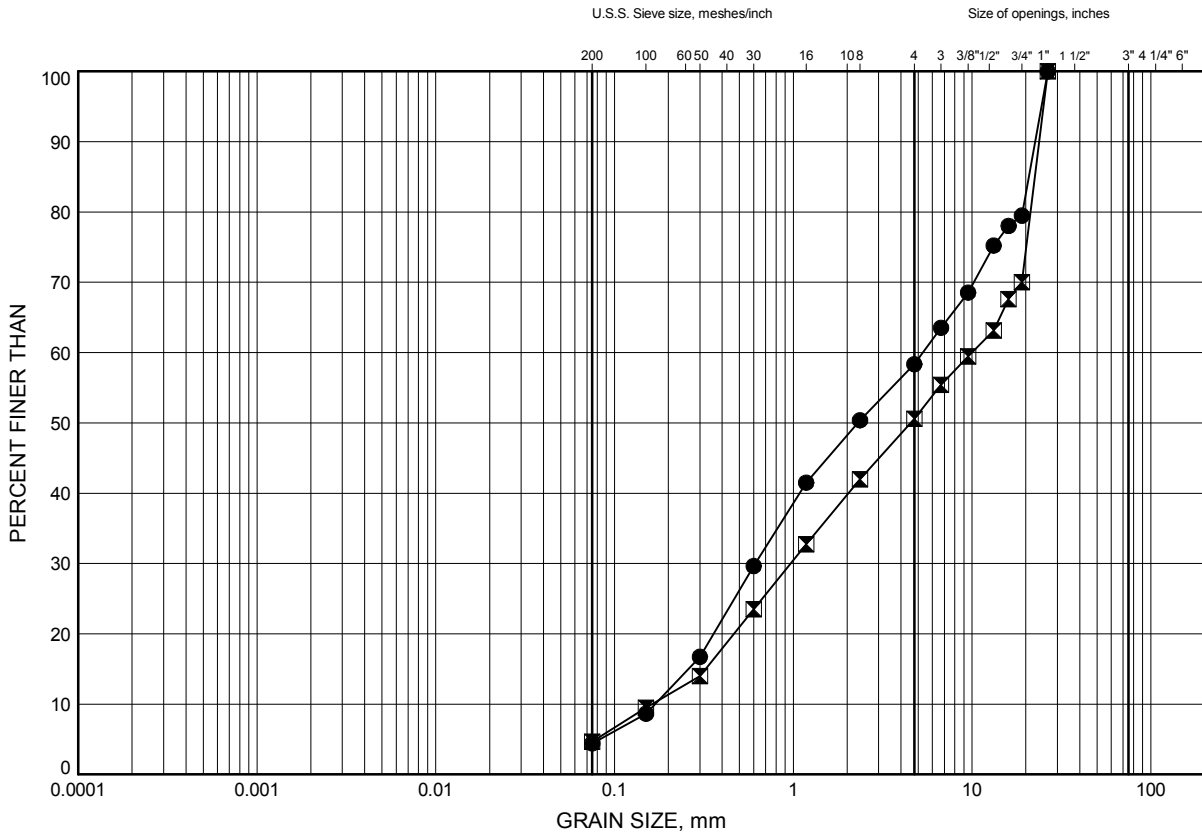
APPENDIX C

LABORATORY TEST RESULTS

Big Pine 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)
●	16-02	1.1	446.7
◻	16-03	1.8	445.8

Date September 2019

GWP# 91-97-00



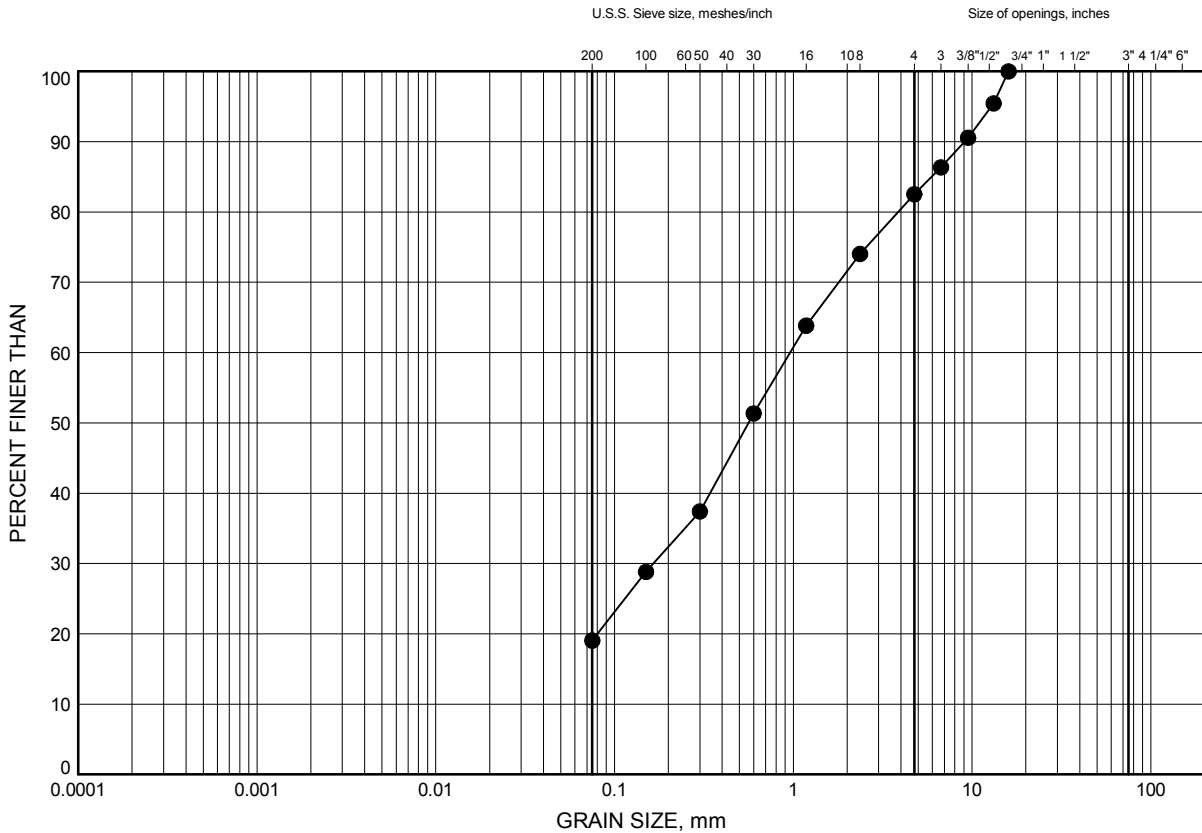
Prep'd CM

Chkd. FJG

Big Pine Lake Culvert GRAIN SIZE DISTRIBUTION

FIGURE C2

Silty Sand with Gravel (SM)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-04	1.4	444.9

Date September 2019
GWP# 91-97-00

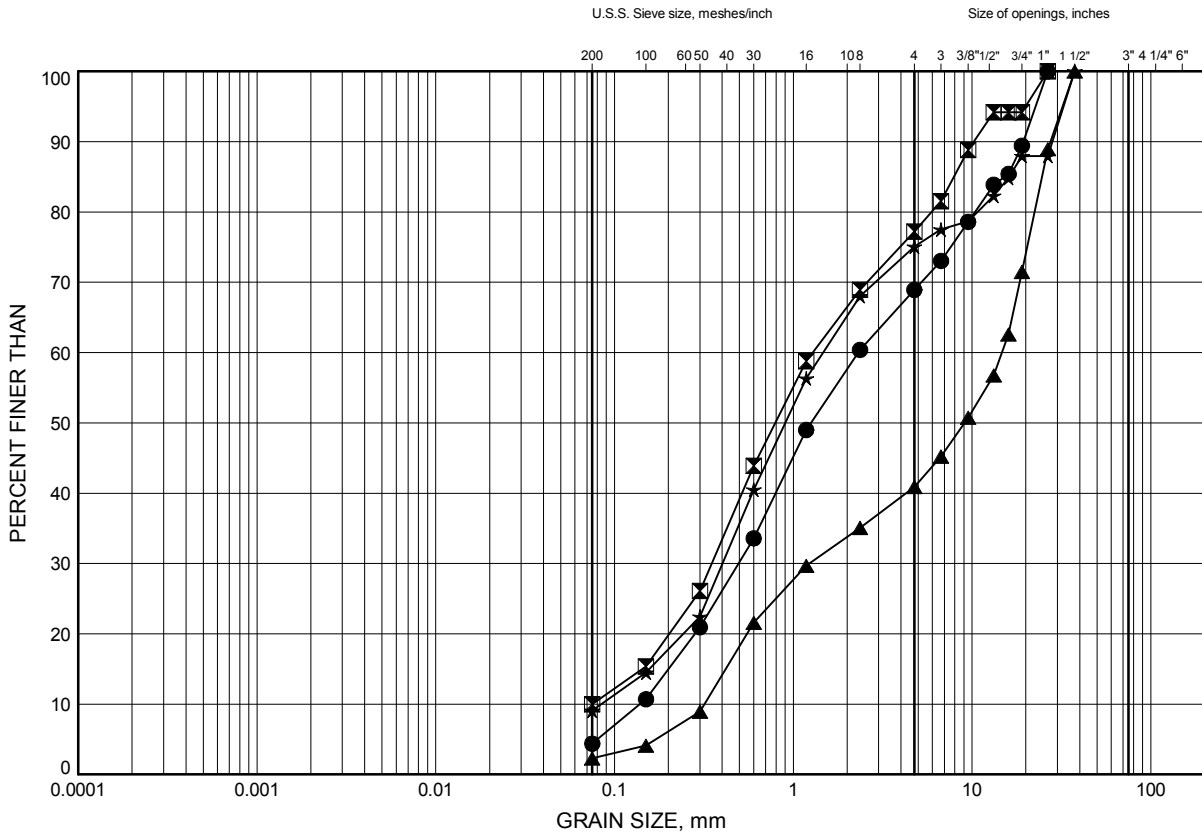


Prep'd CM
Chkd. FJG

Big Pine Lake Culvert GRAIN SIZE DISTRIBUTION

FIGURE C3

Sand (SW) with Gravel to Sand (SP)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-01	2.1	443.4
⊠	16-02	2.6	445.2
▲	16-02	9.4	438.3
★	16-04	2.7	443.6

Date September 2019

GWP# 91-97-00



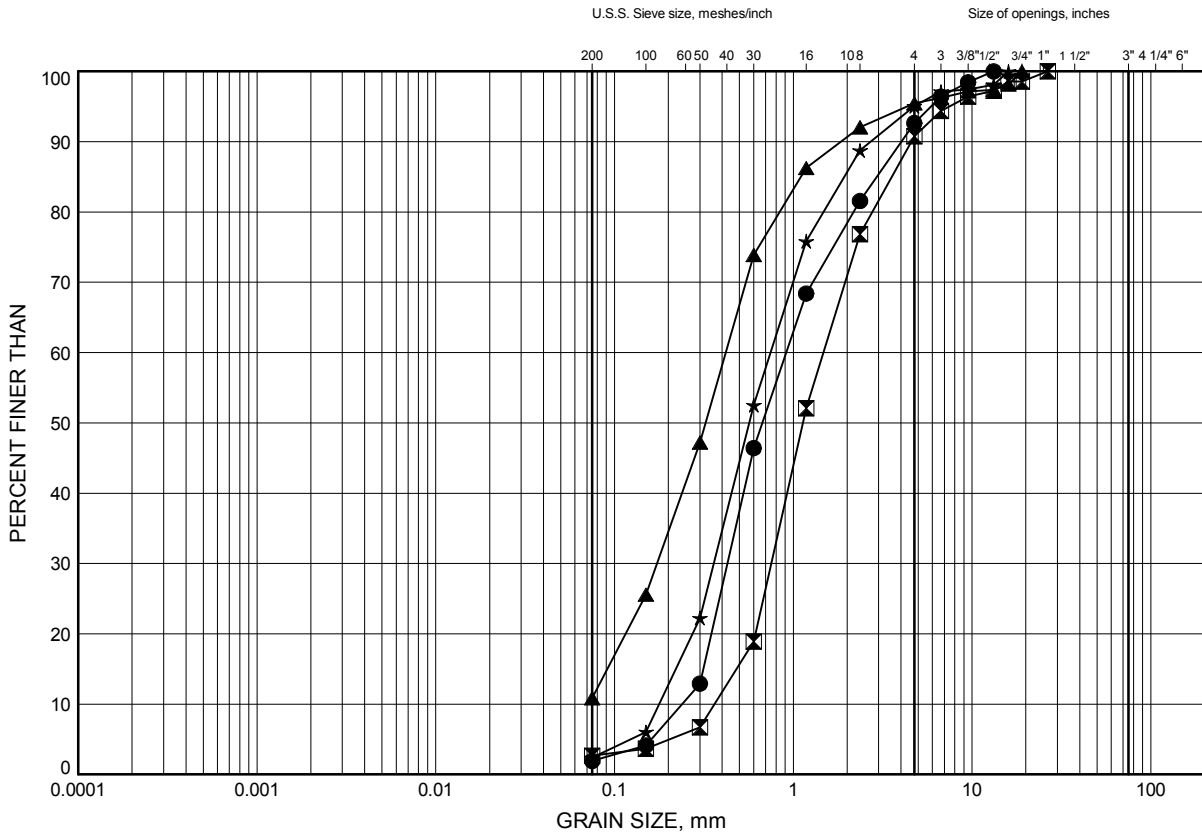
Prep'd CM

Chkd. FJG

Big Pine Lake Culvert GRAIN SIZE DISTRIBUTION

FIGURE C4

Sand (SW) with Gravel to Sand (SP)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-01	4.9	440.6
⊠	16-02	15.5	432.2
▲	16-03	4.9	442.7
★	16-03	6.4	441.2

Date September 2019

GWP# 91-97-00



Prep'd CM

Chkd. FJG

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

Report Date: 17-Nov-2016

Order Date: 11-Nov-2016

Project Description: 13624

	Client ID:	16-1 SS2 (2'-4')	16-4 (1-4)	16-6 SS3 (5'-7')	16-8 SS4 (7'-9')
	Sample Date:	21-Oct-16	23-Oct-16	27-Oct-16	28-Oct-16
	Sample ID:	1646369-01	1646369-02	1646369-03	1646369-04
	MDL/Units	Soil	Soil	Soil	Soil
Physical Characteristics					
% Solids	0.1 % by Wt.	81.8	85.3	96.7	92.0
General Inorganics					
Conductivity	5 uS/cm	109	109	385	728
pH	0.05 pH Units	7.41	6.41	7.89	7.89
Resistivity	0.10 Ohm.m	91.5	91.7	26.0	13.7
Anions					
Chloride	5 ug/g dry	16	15	159	346
Sulphate	5 ug/g dry	19	14	10	31
	Client ID:	16-15 SS6 (40-41-4)	16-18 SS6 (15-17)	-	-
	Sample Date:	31-Oct-16	03-Nov-16	-	-
	Sample ID:	1646369-05	1646369-06	-	-
	MDL/Units	Soil	Soil	-	-
Physical Characteristics					
% Solids	0.1 % by Wt.	89.1	84.1	-	-
General Inorganics					
Conductivity	5 uS/cm	171	351	-	-
pH	0.05 pH Units	7.78	6.84	-	-
Resistivity	0.10 Ohm.m	58.4	28.5	-	-
Anions					
Chloride	5 ug/g dry	24	171	-	-
Sulphate	5 ug/g dry	54	18	-	-

APPENDIX D
SELECTED PHOTOGRAPHS



Figure 1: Roadway Platform at Culvert 46-327/C looking East toward Borehole 16-2 [taken October 2016]



Figure 2: Roadway Platform at Culvert 46-327/C looking West toward Borehole 16-3 [taken October 2016]



**Figure 3: Upstream from North end of Culvert 46-327/C (note location of beaver dam)
[taken October 2016]**



Figure 4: Looking downstream from South end of Culvert 46-327/C [taken October 2016]



Figure 5: North Embankment looking East towards Culvert 46-327/C [taken October 2016]



Figure 6: North Embankment looking East towards Culvert 46-327/C [taken October 2016]



Figure 7: Looking South towards North end of Culvert 46-327/C [taken October 2016]



Figure 8: Looking Northwest towards South end of Culvert 46-327/C [taken October 2016]

APPENDIX E

COMPARISON OF CULVERT TYPE/FOUNDATION ALTERNATIVES COMPARISON OF CONSTRUCTION METHODOLOGY OPTIONS

Comparison of Culvert Type/Foundation Alternatives

Comment	Circular Pipes	Open Footing Culvert	Closed Box Culvert
<i>Advantages</i>	<p>Readily available materials and simpler installation methods</p> <p>Can tolerate larger magnitude of settlement</p>	<p>Existing timber cells could be used for surface water diversion during foundation construction</p> <p>Relatively expedient installation if precast units are used</p>	<p>Smaller magnitude of settlement than open footing culvert due to lower bearing stress on subgrade</p> <p>Less prone to effects of scour and erosion</p>
<i>Disadvantages</i>	<p>Multiple pipes may be required to provide hydraulic opening equivalent to existing culvert.</p> <p>Feasibility depends on flow capacity and other hydraulic properties</p>	<p>Founding elevation is deeper than with closed box increasing excavation volumes and protection system height.</p> <p>Increased dewatering efforts due to depth of footings</p>	<p>Existing culvert must be removed early in each stage so cannot be used for surface water diversion.</p>
<i>Risks / Consequences</i>		<p>Increased risk of basal instability of footing excavation due to depth of excavation below water table</p>	
<i>Relative Cost</i>	Moderate	Moderate	Moderate
	NOT RECOMMENDED	FEASIBLE	RECOMMENDED

Comparison of Construction Methodology Options

Comment	Trenchless	Staged, with Roadway Protection	Staged Construction with Platform Widening	Open Cut with Full Road Closure with Temporary Detour
<i>Advantages</i>	Avoids open cut	Maintains one lane of traffic	Avoids need for installation of protection system	Quicker installation than staged construction Avoids need for roadway protection
<i>Disadvantages</i>	Requires specialized equipment and Contractor Obstructions in embankment fill hard to tunnel through Open water at inlet not favourable for entry/exit pit	Boulders in fill and native soil could impede installation of protection system Traffic Impacts Requires water/ groundwater control	Open water at or near existing toe of slope makes fill placement/compaction more difficult and may have environmental impacts Potentially requires further geotechnical investigation Requires longer culvert	Traffic Impacts Requires a detour on side roads around project site to be setup and maintained throughout construction
<i>Risks/ Consequences</i>	Obstructions/delays Limited cover over installation could result in heave or settlement of roadway	Difficulty installing protection system/delays	Settlement of widened portion of embankment/ increased maintenance	
<i>Relative Cost</i>	High	Moderate	Moderate	Moderate
	NOT FEASIBLE	RECOMENDED	NOT FEASIBLE	FEASIBLE

APPENDIX F

GSC SEISMIC HAZARD CALCULATION LIST OF REFERENCED SPECIFICATIONS

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

December 19, 2015

Site: 47.8506 N, 83.7702 W User File Reference: Big Pine

Requested by: Chris 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)
0.050	0.070	0.068	0.058	0.048	0.030	0.015	0.0035	0.0015	0.039	0.037

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)	0.0046	0.016	0.026
Sa(0.1)	0.0077	0.025	0.039
Sa(0.2)	0.0093	0.027	0.041
Sa(0.3)	0.0085	0.025	0.037
Sa(0.5)	0.0066	0.021	0.031
Sa(1.0)	0.0033	0.012	0.019
Sa(2.0)	0.0013	0.0053	0.0091
Sa(5.0)	0.0004	0.0012	0.0020
Sa(10.0)	0.0003	0.0007	0.0010
PGA	0.0043	0.014	0.022
PGV	0.0037	0.014	0.022

References

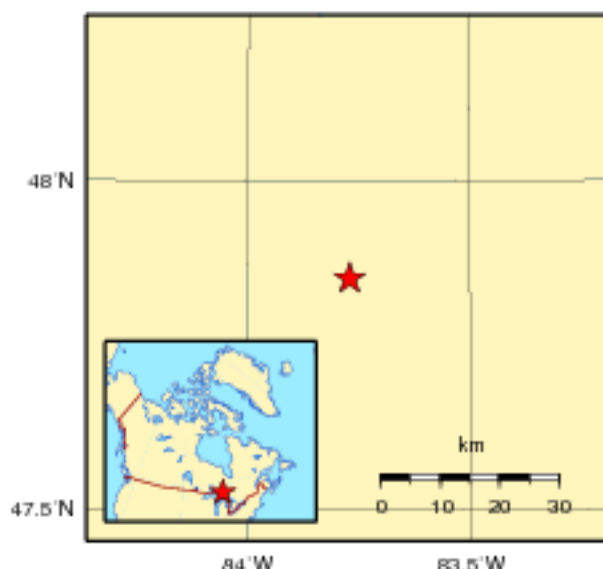
National Building Code of Canada 2015 NRCC no. 58190;
Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

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



LIST OF REFERENCED SPECIFICATIONS

OPSS.PROV 206	Construction Specification for Grading
OPSD 208.010	Benching of Earth Slopes
OPSS 209	Construction Specification for Embankments over Swamps and Compressible Soils
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 517	Construction Specification for Dewatering
OPSS 539	Construction Specification for Temporary Protection Systems
OPSD 803.010	Backfill and Cover for Concrete Culverts with Spans Less than or Equal to 3.0 m
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS 805	Construction Specification for Temporary Erosion and Sediment Control Measures
OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
OPSS 902	Construction Specification for Excavating and Backfilling-Structures
OPSS.PROV 1010	Material Specification for Aggregates-Base, Subbase, Select Subgrade, and Backfill Material
OPSS.PROV 1205	Material Specification for Clay Seal
OPSD 3090.100	Foundation, Frost Penetration Depths for Northern Ontario
SP 109S12	
SP 517F01	