

**FINAL
FOUNDATION INVESTIGATION AND DESIGN REPORT
FINLAYSON CREEK CULVERT REPLACEMENT
HWY 72, 23.1 KM NORTH OF HWY 17, MCAREE TOWNSHIP
SITE NO.: 41S-149/C**

6015-E-0033

Geocres No.: 52F-54

Report to:

Planmac Engineering Inc.

Location:

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April 2017

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PART 1. FACTUAL INFORMATION

1 INTRODUCTION

This section of the report presents the factual findings obtained from a foundation investigation completed for the proposed replacement of the existing Finlayson Creek Culvert crossing Highway 72, approximately 23.1 km north of the Highway 72 and Highway 17 intersection in McAree Township, District of Kenora. Thurber Engineering Limited (Thurber) carried out the current investigation as a sub-consultant to Planmac Engineering Inc. (Planmac) under Contract No. 6015-E-0033.

The purpose of this investigation was to explore the subsurface conditions at this site and, based on the data obtained, to present a borehole location plan, record of boreholes, stratigraphic profile, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions was developed of the anticipated geotechnical conditions influencing design and construction of the culvert replacement.

An earlier foundation investigation report was completed in the vicinity of the Finlayson Creek Culvert for a proposed Highway 72 realignment and has been obtained from the Geocres Library; as follows:

Route Borings, Proposed Highway 72 Realignment North of Dinorwic
(GEOCRES 52F00-11), dated March 1965 and prepared by H.Q. Golder &
Associates Ltd.

2 SITE DESCRIPTION

The existing culvert is located near Station 18+035 on Highway 72 in McAree Township. The culvert consists of a 3 cell concrete closed footing rigid frame culvert with approximate dimensions for width, height and length of 9.1, 2.1 and 16.8 m, respectively. The flow through the culvert is from north to south connecting Tablerock Lake to Big Sandy Lake. At the location of the culvert, Highway 72 is a two-lane highway with gravel shoulders, cable guiderails and a rural cross-section. The road surface of the Highway 72 embankment is approximately 2.0 m above the top of the culvert at an elevation of 368.8 m. The embankment side slopes are at approximately 1.8H:1V with some locations as steep as 1H:1V (over the culvert outlet).

The terrain in the area of the culvert is generally level and consists of wide, grass covered creek banks with treed areas bordering both sides of the highway and creek. Select

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

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing program was carried out between August 22nd and September 12th, 2016 and consisted of drilling and sampling four boreholes identified as FL16-01 through FL16-04.

Prior to commencement of drilling, utility clearances were obtained in the vicinity of the borehole locations. Drilling for the on-road boreholes was carried out using a CME-750 drill rig utilizing hollow stem augers and the off-road boreholes were drilled with a CME-55 and portable tri-pod equipment. Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). Borehole FL16-04, which was advanced with the tri-pod equipment, utilized a half weight hammer for the SPT testing. A correction for the use of a half-weight hammer has been included in the reported values. The boreholes were sampled to a maximum depth of 15.8 m below the existing ground surface and Borehole FL16-02 was extended to a depth of 28.3 m with a Dynamic Cone Penetration Test (DCPT). The boreholes were decommissioned following the field investigation in general accordance with MOEE requirements.

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

The approximate borehole locations are shown on the Borehole Locations and Soil Strata Drawing included in Appendix A. The coordinates and elevations of the boreholes are also provided on the drawing.

4 LABORATORY TESTING

The recovered soil samples were subjected to visual identification and to natural moisture content determination. Selected samples were also subjected to Atterberg Limit testing and gradation analysis (hydrometer and/or sieve). The results of these tests are summarized on the Record of Borehole sheets included in Appendix B. Surface water and soil samples were submitted for analytical testing. The laboratory results are 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 Location and Soil Strata drawing included in Appendix A. A general description of the stratigraphy, based on the conditions encountered in the boreholes, is given in the following paragraphs. However, the factual data presented on the Record of Borehole sheets takes precedence over this general description for interpretation of the site conditions. It must be recognized that soil conditions may vary between and beyond borehole locations.

In general terms, the site stratigraphy was found to consist of pavement structure and embankment fill underlain by a deposit of clay. Adjacent to the embankment, a surficial organic layer and topsoil was present in both of the off-road boreholes. SPT refusal or bedrock was not encountered with the sampled depth of investigation.

5.1 Asphalt Pavement

In BH FL16-2 and FL16-3, a thin layer of asphalt pavement was encountered at ground surface.

5.2 Embankment Fill

The granular embankment fill consisted of silty sand to silty sand with gravel and varied in thickness from 1.5 to 2.6 m (underside elevation of 367.3 m to 366.2 m). SPT tests carried out in the granular fill gave N-values ranging from 10 to 34 blows per 300 mm of penetration indicating a compact to dense relative density. An N value of greater than 50 was noted at the base of the fill in Borehole FL16-3 and is interpreted to indicate the presence of a cobble. The measured moisture contents were recorded between 1 and 11%.

A 0.7 m thick layer of sandy clay fill was encountered directly below the silty sand fill within Borehole FL16-02 (underside elevation of 366.6 m). A single SPT test gave an N-Value of 13 blows per 300 mm of penetration and a measured moisture content of 25%.

Gradation analyses were completed on three samples of the embankment fill. The results are summarized on the Record of Borehole sheets in Appendix B and the grain size distribution curves for these samples are included in Figure C1 of Appendix C. The results of the laboratory test are summarized as follows:

Soil Particle	Percentage (%)
Gravel	0 - 17
Sand	39 - 65
Silt	17 - 31
Clay	4 - 31

5.3 Topsoil

A 150 mm thick layer of topsoil was encountered at the ground surface at Borehole FL16-01.

5.4 Organic Silt

An 800 mm thick layer of an organic silt material with wood pieces and rootlets was encountered at the ground surface in Borehole FL16-04. An SPT test carried out in the organic silt gave an N-value of 4 blows for 300 mm of penetration indicating a loose consistency.

A gradation analysis was completed on one sample of the organic silt. The results are summarized on the Record of Borehole sheets in Appendix B and the grain size distribution curve for this sample is included in Figure C2 of Appendix C. The results of the laboratory test are summarized as follows:

Soil Particle	Percentage (%)
Gravel	0
Sand	7
Silt	64
Clay	29

5.5 Clay

The topsoil, organic silt, and embankment fill were underlain by a native deposit of clay. Organics were noted within the clay near the surface of Borehole FL16-01. The sampling within the deposit was terminated at a depth ranging from 11.3 to 15.8 m (elev. 355.6 to 353.0 m) below the existing ground surface.

SPT tests gave N-values typically ranging from weight of hammer to 33 blows per 300 mm of penetration. Field vane tests were performed within the deposit and recorded undrained shear strengths ranging from 23 to 58 kPa indicating a soft to stiff consistency. The measured moisture content of the clay ranged from 25 to 84%.

Gradation analyses were completed on nine samples of the clay. The results are summarized on the Record of Borehole sheets in Appendix B and the grain size distribution curves for these samples are included in Figures C3 and C4 of Appendix C. The results of the laboratory tests are summarized as follows:

Soil Particle	Percentage (%)
Gravel	0
Sand	0 - 8
Silt	31 - 70
Clay	30 - 69

Atterberg limit testing was carried out on ten samples. The results are shown on Figures C5 and C6 in Appendix C and are summarized as follows:

Test	Percentage (%)
Liquid Limit	23 - 53
Plasticity Index	7 - 32

The clay soil ranges from low to high plasticity but can generally be classified as a clay of intermediate plasticity (CI).

5.6 Inferred Silt

Borehole FL16-02 encountered an inflow of cohesionless soils into the augers near a depth of 16.8 m (elev. 352.0 m). The sampling was discontinued at this point and the borehole was further advanced with a Dynamic Cone Penetration Test (DCPT). The DCPT blows counts typically ranged from 0 to 10 blows per 0.3 m of penetration to a depth of 25.3 m (elev. 343.5 m) and then increased to 15 to 31 blows per 300 mm of penetration between a depth of 25.3 and 28.0 m below the ground surface. DCPT refusal was reached at an elevation of 340.5 m. It is inferred that the clay deposit is underlain by a deposit of silt.

5.7 Groundwater

No artesian pressures were encountered during drilling within the clay foundation soils. Upon completion of the DCPT in Borehole FL16-02 an artesian pressure was observed but was readily sealed off by backfilling the borehole with bentonite.

The water level within the creek was reported to be at elevation 365.69 m at the inlet in April 2016. It is expected that the groundwater level will largely be controlled by the water level in Finlayson Creek. It should be noted seasonal fluctuations of the groundwater level are to be expected and that the groundwater level at the time of construction may vary. In particular, the groundwater level may be at a higher elevation after periods of significant and/or prolonged precipitation events.

6 MISCELLANEOUS

The borehole locations were selected relative to existing site features and proposed culvert location. After completion of drilling, the borehole locations were surveyed by Thurber personnel relative to the existing culvert and ground surface elevations were obtained from topographic drawings provided by Planmac.

RPM Drilling Limited from Thunder Bay, Ontario supplied the drilling equipment and conducted the drilling, sampling and in-situ testing for the field program. The field investigation was supervised on a full time basis by Mr. Troy Mackinnon of Thurber. Overall supervision of the investigation program was provided by Mr. Stephen Peters, P.Eng.

Routine geotechnical laboratory testing was carried out by Thurber's laboratory in Oakville, Ontario. Analytical testing was completed by SGS Canada Inc and AGAT Laboratories on the water and soil samples respectively. Interpretation of the data and preparation of this report were carried out by Dr. Fred Griffiths, P.Eng. and Mr. Stephen Peters, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng, a Designated Principal Contact for MTO Foundation Projects.

Thurber Engineering Ltd.
Report Prepared By:



Stephen Peters, P.Eng.
Geotechnical Engineer



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



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

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PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This section of the report provides an interpretation of the factual data and geotechnical recommendations for the replacement of the existing Finlayson Creek Culvert. The culvert crosses Highway 72, approximately 23.1 km north of Highway 17 in McAree Township, District of Kenora. Geotechnical assessment and recommendations are provided to assist the design team in designing a suitable foundation for the proposed replacement culvert. The plans and profiles used for preparation of this report were provided by Planmac Engineering Inc (Planmac).

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 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 Finlayson Creek under Highway 72, is a 3 cell concrete closed footing rigid frame culvert which is 9.1 m wide by 2.1 m high and approximately 16.8 m long. The top of the culvert is reported to be at elevation 366.83 and 366.77 m at the inlet and outlet, respectively. The embankment fill height above the culvert is in the order of 2.0 m high. The creek flows from north to south at this site and drains into Big Sandy Lake.

Thurber Engineering Limited (Thurber) carried out the current investigation as a sub-consultant to Planmac under Contract No. 6015-E-0033.

7.1 Proposed Structure

A General Arrangement (GA) drawing dated November 2016 indicates that the proposed culvert replacement structure is twin 2.743 x 4.877 m concrete closed box culverts. The 16.75 m long replacement culvert is proposed to be constructed along the same alignment as the existing culvert with invert elevations of 364.40 and 364.34 m for the inlet and outlet, respectively. A temporary flow passage will be required during construction.

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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 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. If the consequence classification changes, the geotechnical assessment will need to be reviewed and revised.

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). 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 reference peak ground acceleration (PGA_{ref}).

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. The Seismic Site Class for this culvert is a Site Class E in accordance with Table 4.1 of the CHBDC.

8.3 Seismic Liquefaction

Based on the subsurface conditions encountered at the drilled locations at this site the foundation soils are considered to be not susceptible to liquefaction during a seismic event due to the low PGA values.

9 DESIGN OPTIONS

Based on the soil stratigraphy and the existing stream bed elevation, it is expected that the culvert replacement will be founded on the native clay. 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.

9.1 Culvert Type and Foundation Alternatives

The culvert types considered are discussed below from a geotechnical perspective and a comparison, based on their respective advantages and disadvantages, is included in Appendix E.

- Open Bottom Culvert (Box, Arch)

Concrete or metal, open footing culverts are not recommended for this site from a foundation engineering perspective since the available geotechnical resistance will be low, the post construction settlement would be greater than alternative options and greater dewatering efforts would be required during construction to place the foundations in the dry. Supporting an open bottom structure on deep foundations has also been considered. The clay material present beneath this site will provide only limited frictional resistance (ULS approximately 250 kN, SLS of approximately 200 kN), with an anticipated pile toe elevation of approximately 340.0 m which is approximately 25 m below the stream bed. The pile caps would need to be protected with 2.5 m of frost cover thus the pile length would be approximately 22.5m. A deep foundation approach is not recommended for this site.

- Steel Sheet Pile Walls with Precast Concrete Slab

A sheet pile wall supporting precast concrete slabs is not recommended at this site due to the anticipated width of the replacement culvert, the limited lateral capacity available from the foundation soils and the depth to a suitable end bearing stratum.

- Closed Bottom Culvert

Given the subsurface conditions, a rigid frame, close bottom (RFCB), concrete culvert is considered feasible at this site. Precast sections, rather than cast-in-place construction, can be installed expediently with less potential for disturbance of the founding soils during installation.

- Pipe Culvert (Concrete, HDPE, Steel)

From a foundation engineering perspective, pipe culverts are a technically feasible alternative, provided that other design issues including flow capacity, hydraulic properties and durability can be satisfied.

9.2 Construction Methodology Alternatives

For the feasible culvert replacement options listed in Section 9.1, the following construction methods have been considered.

9.2.1 Trenchless Techniques

Trenchless techniques would have the advantage of minimum disruption to traffic and would avoid an excavation through the existing highway embankment. However, considering the size of the replacement culvert, the limited cover over the existing culvert and limited area for entry/exit pits without a permanent realignment of the creek, trenchless replacement is not considered suitable at this site.

9.2.2 Open Cut with Full Road Closure

Installation of a new culvert using open cut techniques with a full road closure would allow for an expedited construction schedule and reduced costs associated with requiring roadway protection and creek diversion. However, this method would induce significant traffic disruptions which makes this alternative not feasible.

9.2.3 Open Cut with Staged Temporary Widening (or Lowering)

Widening of the existing highway and/or construction of a detour embankment to accommodate a temporary traffic passage is considered feasible. However, placement of additional fill will cause an increase in the loading on the subgrade soils and will induce time-dependent settlement for both the temporary detour and existing embankment. Additionally, property acquisition may be required for this option.

9.2.4 Open Cut with Staged Construction and Temporary Protection System

The preferred construction option is open cut in conjunction with staged culvert replacement. This option will require roadway protection, as discussed in Section 11.2, installed along the embankment centerline to maintain a single lane of traffic flow along the current highway alignment.

9.3 Recommended Approach for the Culvert Replacement

From a foundation engineering perspective, replacement of the culvert with a closed box precast culvert using open cut techniques and temporary traffic protection to maintain traffic flow is the recommended approach.

It is noted that a pipe culvert installed with a similar approach is also viewed as a feasible alternative. If a pipe culvert is selected it should be designed and constructed in accordance with OPSS 421, OPSD 802.010 (with Granular A used as bedding and embedment material) and OPSD 803.031 (with a frost depth of 2.5m). The recommendations of Sections 10.2, 10.4, 10.5, 10.6 and 11 should be applied.

10 FOUNDATION DESIGN RECOMMENDATIONS

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

10.1 Culvert Foundation Bearing Resistances

Provided the replacement culvert is constructed on the same alignment as the existing culvert and that there is negligible grade raise, it is anticipated that the subgrade soils within the existing culvert footprint will not be subjected to any significant additional loading.

10.1.1 Box Culvert

The recommended geotechnical resistance for a pre-cast box culvert installed along the existing alignment at the proposed founding elevation are as follows:

At centerline of embankment

- Factored Geotechnical Resistance at ULS of 150 kPa
- Factored Geotechnical Resistance at SLS of 65 kPa

Outside of embankment footprint (inlet/outlet of culvert)

- Factored Geotechnical Resistance at ULS of 100 kPa
- Factored Geotechnical Resistance at SLS of 40 kPa

The factored geotechnical resistances include the following factors:

- Consequence Factor 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 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.

Resistance to lateral forces/sliding resistance between the precast concrete and the underlying Granular 'A' bedding (Section 10.2) should be evaluated in accordance with the CHBDC assuming an unfactored coefficient of friction of 0.45.

10.1.2 Wingwalls

If wingwalls are required as part of the culvert design, the footing should be founded on a leveling pad with a minimum thickness of 0.5 m consisting of Granular 'A' material at or below the depth of frost. The engineered pad should be placed on a geotextile separation (Class II non-woven FOS 50 to 150 μ m) on the native subgrade provided that it is undisturbed, uniformly competent and free of any soft and deleterious materials. The top of the Granular 'A' pad must extend to 0.5 m beyond the outside edge of all sides of the footing and sloped at 1H:1V, or flatter. The following geotechnical resistance values are recommended for wingwalls at this site:

- Factored Geotechnical Resistance at ULS of 125 kPa
- Factored Geotechnical Resistance at SLS of 50 kPa

The recommended values presented above are for an assumed vertical concentric loading only. Effects of load eccentricity and inclination need to be taken into account. Higher bearing capacity can be obtained, if required, by increasing the thickness of the Granular 'A' pad.

10.1.3 Frost Depth

The depth of frost penetration at this site is 2.5 m, as per OPSD 3090.100, and all footings must be protected from frost with a minimum of 2.5 m of earth cover or thermal equivalent. It is not necessary to found a box culvert at a depth below frost penetration however, frost treatment for a culvert, if required, should be as per OPSD 803.010.

10.2 Subgrade Preparation and Bedding

All organics, soft or loose creek bed deposits, disturbed soils and deleterious materials must be removed from the footprint of the culvert to expose competent native subgrade material at or below the design founding elevations. The exposed subgrade must be inspected to confirm that the subgrade is suitable and uniformly competent. Any soft or organic materials should be sub-excavated and backfilled with granular soil consisting of OPSS.PROV 1010 Granular A material compacted as per OPSS.PROV 501 as soon as practical to protect the subgrade from disturbance during construction. In order to provide a more uniform foundation subgrade condition for the culvert, a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A requirements must be provided under the base of the culvert as per OPSS 422 and OPSD 803.010.

Given the firm conditions anticipated at the founding level of the replacement culvert, construction equipment should not be permitted to travel on the exposed subgrade. In addition, the compaction of granular bedding directly above the subgrade is likely to result in disturbance of the material with pumping of fines into the granular bedding and difficulty achieving the specified degree of compaction. Protection of the subgrade should include installation of a non-woven geotextile installed beneath the 300 mm thick Granular A bedding layer. The geotextile should be placed as soon as possible after reaching the subgrade level and following confirmation of QVE acceptance in order to protect the subgrade. An NSSP is provided in Appendix G to include in the contract documents to alert the Contractor of the soft and sensitive nature of the foundation clay soils

It is noted that construction will extend below the water level in the creek. Creek diversion and dewatering will be required to place the bedding material and install the culvert in the dry. Please refer to Section 11.3 for additional comments on groundwater and surface water control.

10.3 Backfill and Earth Pressure

It is recommended that backfill to the culvert consist of free-draining, non-frost susceptible granular materials such as Granular A or Granular B Type II material meeting the requirements of OPSS.PROV 1010. The backfill must be in accordance with OPSS 902 and placed to the extent shown on OPSD 3101.150.

The backfill should be compacted in regular lifts. Heavy compaction equipment, used adjacent to and above the structure, must be restricted in accordance with OPSS.PROV 501. The top of the backfill elevation should be within 400 mm on both sides of the culvert at all times. Care must be exercised when compacting the fill adjacent to and above the culvert in order not to damage the culvert.

10.3.1 Static Lateral Earth Pressure Coefficient

Earth pressures acting on a box culvert may be assumed to be triangular and to be governed by the characteristics of the backfill. For a fully drained condition, the pressures should be computed in accordance with the CHBDC but generally are 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)
- γ = unit weight of retained soil (see table below)
- 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 CHBDC Clause 6.12.3. Earth pressure coefficients for backfill to the box culvert are dependent on the material used as backfill and the inclination of the ground surface behind the wall. Typical values are shown in Table 10-1.

Table 10-1. Earth Pressure Coefficients

Condition	Earth Pressure Coefficient (K)					
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ, \gamma = 20.0 \text{ kN/m}^3$		Existing Silty Sand Fill and Clay Fill $\phi = 30^\circ, \gamma = 20.0 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)
Active, K_A (Yielding Wall)	0.27	0.40	0.31	0.48	0.33	0.54
At Rest, K_O (Non-Yielding Wall)	0.43	-	0.47	-	0.5	-
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: (*) Figure C6.16 of the Commentary to the CHBDC.

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

The parameters in the table correspond to full mobilization of active and passive earth pressures and require certain relative movements between the wall and adjacent soil to produce these conditions. The values to be used in design can be assessed from Figure C6.16 of the Commentary to the CHBDC using the soil group designation as outlined in Table 10-1. Active pressures should be used for any head walls or unrestrained walls. For rigid structures such as a concrete box culvert, it is recommended that at-rest earth pressures be used in design. Where ground surfaces are sloped behind the walls, the corresponding coefficients provided in Table 10-1 should be used.

The culvert must be designed to withstand full hydrostatic pressure assuming a water level at least equal to the design creek water level. This is applicable when the water level behind the culvert is higher than the creek level.

10.3.2 Combined Static and Seismic Lateral Earth Pressure Parameters

The following recommendations are per Section C4.6.5 of the Commentary to 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 condition would be approximately 0.002 for the yielding structure with respect to the assessment of seismically induced lateral earth pressures.

The recommended seismic lateral earth pressure parameters for seismic loading are provided in Table 10-2. The provided earth pressure coefficients are based on a PGA with a 2% probability of exceedance in 50 years of 0.044g (Geological Survey of Canada – Fifth Generation) and a $F(PGA)$ of 1.81 as per Table 4.8 of the CHBDC (S6-14 update No. 1, April 2016)

Table 10-2. Earth Pressure Coefficients (Under Seismic Loads)

Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ, \gamma = 20.0 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)
Yielding Wall, K_{AE}	0.29	0.43	0.33	0.51
Non-Yielding Wall, K_{AE}	0.32	0.49	0.35	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 soil profile:

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

where:

σ_h	=	horizontal pressure at depth d (kPa)
d	=	depth below top of the wall (m)
K	=	static earth pressure coefficient (K_A for yielding walls, K_o for non-yielding walls)
K_{AE}	=	combined static and seismic earth pressure coefficient
H	=	total height of wall (m)

10.4 Embankment Design and Construction

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. No material or stockpiling should be allowed above the existing grades without further analysis.

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 no grade raise or embankment widening beyond achieving 2H:1V side slopes is required and proper construction methods are used, no long term or global stability issues are anticipated for approach embankments built at this site. The magnitude of the embankment compression in embankments constructed with granular materials due to compression of the compacted fill is in the order of 0.5% of the embankment height and is expected to be completed after completion of fill placement.

10.5 Scour Protection and Erosion Control

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

Typically, rock protection should be provided over all earth surfaces which could be contacted by flowing water. Treatment at the outlet should be in accordance with OPSD 810.010. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS.PROV 804.

It is recommended that a clay seal and 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 material requirements should be in accordance with OPSS.PROV 1205. A geosynthetic clay liner may be used as a clay seal.

10.6 Cement Type and Corrosion Potential

Two soil samples were submitted to AGAT Laboratories in Mississauga, Ontario for analysis of pH, water soluble sulphate and chloride concentrations, and resistivity. The analysis was 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 analysis results are summarized in the Table 10-3. A copy of the test results is provided in Appendix C.

Table 10-3: Results of Chemical Analysis

Borehole	Sample	Depth (m)	pH	Resistivity (Ohm-m)	Chloride (µg/g)	Sulphate (µg/g)
FL16-1	SS2	1.1	8.4	15.8	264	17
FL16-3	SS4	2.4	11.4	7.58	383	65

The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with soil and groundwater at the site. Soluble sulphate concentrations less than 1000 µg/g generally indicate that a low degree of sulphate attack is expected for concrete in contact with soil and groundwater.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The soil pH measured in FL16-3 was not within what is considered the normal range for soil pH of 5.5 to 9.0. The pH level of the tested soil from FL16-3 indicates a corrosive environment. The test results provided may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects.

11 CONSTRUCTION CONSIDERATIONS

11.1 Excavations

All excavation must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of OHSA, the fill and native soils above the water table may be classified as Type 3 soil. The organics soils, alluvial deposits as well as any native cohesionless soils below the water table are classified as Type 4 soils.

Excavation 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. The sides of temporary excavations must be sloped in accordance with the requirement of the OHSA. 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, discussed in Section 11.2.

11.2 Temporary Protection System

Roadway protection will be required during various stages of construction. Roadway protection 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 design the shoring system. The protection system should be installed at a suitable distance away from the new culvert to limit the disturbance to subgrade associated with removal of the protection system following completion of construction. Alternatively, the sheet piles could be left in place and cut off at or below 2.5 m beneath the finished pavement grade. Vibratory equipment is not permitted at this site for installation or removal of the temporary protection system. 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 clays soils are given below:

γ_w	=	10	(kN/m ³ , unit weight of water)
γ	=	19	(kN/m ³ , bulk unit weight of soil)
K_A	=	0.39	
K_P	=	2.6	

The design of the roadway protection is the responsibility of the Contractor. The designer of the roadway protection system should ensure the penetration depth is sufficient to provide base fixity and incorporate traffic loading and surcharge loading due to construction equipment and operations. All shoring should be designed by a licensed Professional Engineer experienced in such designs. The Contractors design should include an assessment of the foundation soils ability to support the weight of the crane used during installation of the protection system.

11.3 Surface and Groundwater Control

Culvert construction and subgrade preparation must be carried out in the dry. A temporary flow passage will be required to convey creek flow around the construction site. Construction of cofferdams will be required to divert the creek flow away from the culvert subgrade area.

Excavation below the groundwater level to construct the culvert foundation will be required. Excavation below the groundwater level without prior dewatering is not recommended since the inflow of groundwater will cause heave and sloughing of the soil below the water level, making it difficult to maintain a dry, sound base on which to work. Temporary groundwater and surface water control measures will be required to remain operational during construction until the culvert is installed and backfilled. The design of a dewatering system is the responsibility of the Contractor and dewatering systems must be designed by a dewatering specialist.

Based on the groundwater and soil conditions, special attention must be paid to construction dewatering. The groundwater level within the enclosure should be lowered by pumping from sumps prior to excavation to a minimum of 500 mm below the underside of the final subgrade. As indicated in Section 10.2, a mud slab should be poured with lean mix concrete to protect the exposed saturated subgrade surface from disturbance.

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

12 CONSTRUCTION CONCERNS

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

- The thickness and extent of organic and soft streambed deposits may vary at locations away from the boreholes.
- Disturbance of the soil subgrade within the culvert foundation footprint. Where fine-grained soils are exposed following, clearing, grubbing and stripping activities, these areas will be soft and moisture sensitive and may become heavily disturbed when subjected to construction traffic. Site and subgrade drainage will be critical to maintain subgrade conditions. The contractor must be aware of the issue so that he may adjust his operation to suit the subgrade conditions.
- Although not encountered during drilling, buried obstructions may be encountered during excavation in the existing embankment fill or interfere with driving of sheet piles. Obstructions within the fill could also interfere during excavation activities
- Water levels may fluctuate. Excavation will involve lowering the groundwater 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). An NSSP should be included in the contract alerting the Contractor to these conditions.

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

13 CLOSURE

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

Thurber Engineering Ltd.
Report Prepared By:



Stephen Peters, P.Eng.
Geotechnical Engineer



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

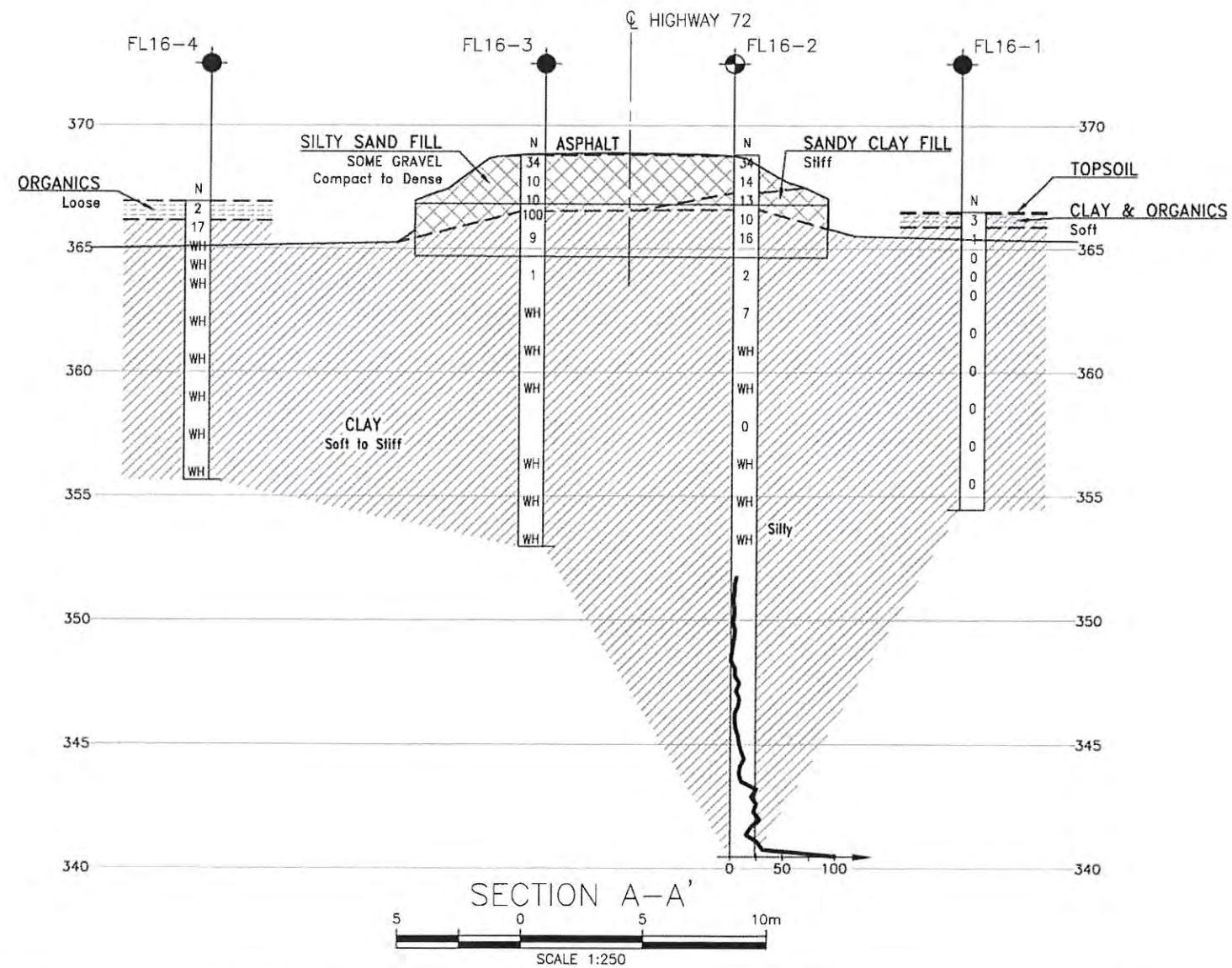
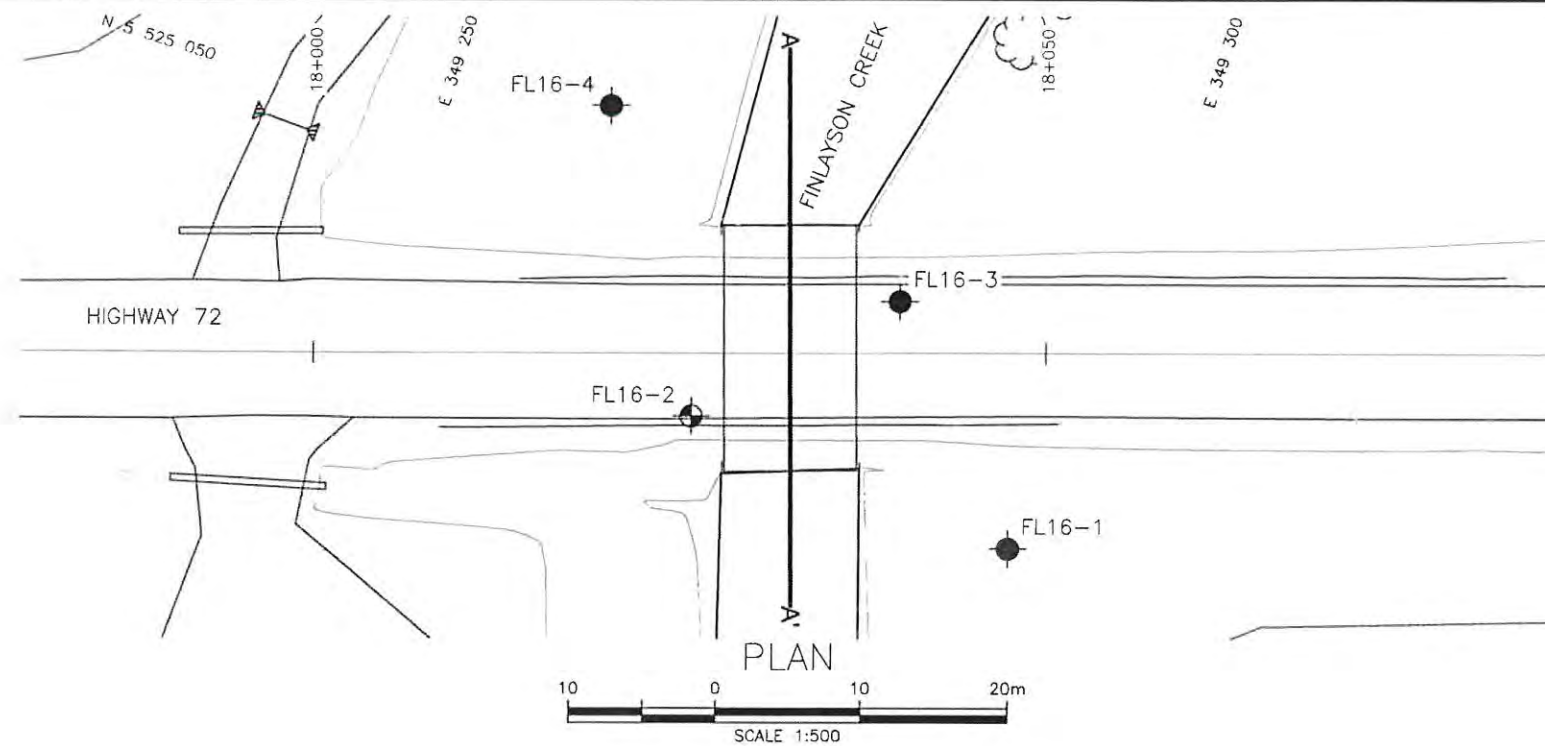


P.K. Chatterji, P.Eng., Ph.D.
Review Principal
Senior Geotechnical Engineer

FINAL

Appendix A.

Borehole Location Plan and Stratigraphic Drawing



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

CONT No
GWP No 6359-14-00

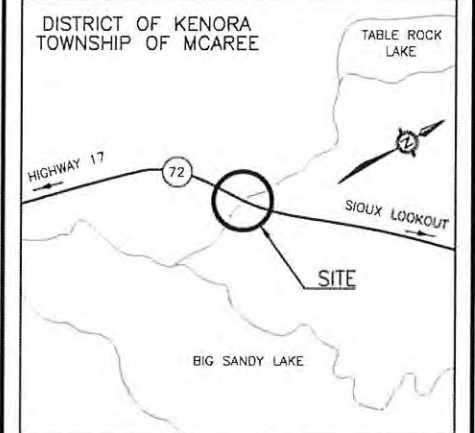


HIGHWAY 72
FINLAYSON CREEK
CULVERT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

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

NO	ELEVATION	NORTHING	EASTING
FL16-1	366.5	5 525 034.4	349 296.4
FL16-2	368.8	5 525 036.6	349 273.0
FL16-3	368.8	5 525 048.3	349 284.3
FL16-4	366.9	5 525 055.2	349 261.3

-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) Borehole locations are shown in MTM Zone 16 coordinates.

GEOCRES No. 52F-54



REVISIONS	DATE	BY	DESCRIPTION
DESIGN	CM	CHK -	CODE
DRAWN	MFA	CHK CM	SITE
STRUCT			
DWG			

Appendix B.

Record of Borehole Sheets



SYMBOLS, ABBREVIATIONS AND TERMS USED ON TEST HOLE RECORDS

TERMINOLOGY DESCRIBING COMMON SOIL GENESIS

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

TERMINOLOGY DESCRIBING SOIL STRUCTURE:

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

RECOVERY:

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

N-VALUE:

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

DYNAMIC CONE PENETRATION TEST (DCPT):

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

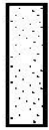


STRATA PLOT:

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



Boulders
Cobbles
Gravel



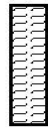
Sand



Silt



Clay



Organics



Asphalt



Concrete



Fill



Bedrock

TEXTURING CLASSIFICATION OF SOILS

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

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 (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.

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 FL16-1

1 OF 2

METRIC

GWP# 6359-14-00 LOCATION Hwy 72 - Finlayson Creek Culvert N 5 525 034.4 E 349 296.4 ORIGINATED BY TM
 HWY 72 BOREHOLE TYPE HSA / CME 750 COMPILED BY JM
 DATUM Geodetic DATE 2016.08.26 - 2016.08.26 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								WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE												
								● QUICK TRIAXIAL × LAB VANE												
366.5																				
0.0	TOPSOIL		1	SS	3		366								0 0 47 53					
365.9	CLAY (Cl) and Organics Soft Grey		2	SS	1		365													
0.6	CLAY (Cl to CH) Firm to soft Grey		3	SS	WH		364								0 0 40 60					
			4	SS	WH		363													
			5	SS	WH		362													
			6	SS	WH		361								0 0 38 62					
			7	SS	WH		360													
			8	SS	WH		359													
			9	SS	WH		358													
							357													

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No FL16-1

2 OF 2

METRIC

GWP# 6359-14-00 LOCATION Hwy 72 - Finlayson Creek Culvert N 5 525 034.4 E 349 296.4 ORIGINATED BY TM
 HWY 72 BOREHOLE TYPE HSA / CME 750 COMPILED BY JM
 DATUM Geodetic DATE 2016.08.26 - 2016.08.26 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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
	Continued From Previous Page																
	CLAY (Cl to CH)																
			10	SS	WH											0 0 42 58	
354.5																	
12.0	End of Borehole																

ONTMT4S 12356 FINLAYSON CULVERT.GPJ 2012TEMPLATE(MTO).GDT 10/4/17

RECORD OF BOREHOLE No FL16-2

1 OF 3

METRIC

GWP# 6359-14-00 LOCATION Hwy 72 - Finlayson Creek Culvert N 5 525 036.6 E 349 273.0 ORIGINATED BY TM
HWY 72 BOREHOLE TYPE HSA / CME 750 COMPILED BY JM
DATUM Geodetic DATE 2016.08.23 - 2016.08.23 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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
368.8								20	40	60	80	100					
0.0	ASPHALT																
	Silty SAND (SM) Compact to Dense Brown FILL		1	SS	34												
			2	SS	14												0 65 31 4
367.3																	
1.5	Sandy CLAY Stiff Grey FILL		3	SS	13												8 39 22 31
366.6																	
2.2	CLAY (CL to CH) Stiff to Soft Grey		4	SS	10												
			5	SS	16												
			6	SS	2												0 0 31 69
										2.4							
			7	SS	7												
										1.7							
			8	SS	WH												
										2.2							
			9	SS	WH												
														</			

Continued Next Page

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

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No FL16-2

3 OF 3

METRIC

GWP# 6359-14-00 LOCATION Hwy 72 - Finlayson Creek Culvert N 5 525 036.6 E 349 273.0 ORIGINATED BY TM
HWY 72 BOREHOLE TYPE HSA / CME 750 COMPILED BY JM
DATUM Geodetic DATE 2016.08.23 - 2016.08.23 CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	W P W W L	20 40 60			
	Continued From Previous Page													
343.5	25.3 Inferred SILT													
340.5	28.3 End of Borehole Artesian pressure was encountered when the augers were removed from the hole													

ONTMT4S 12356 FINLAYSON CULVERT.GPJ 2012TEMPLATE(MTO).GDT 10/4/17

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No FL16-3

2 OF 2

METRIC

GWP# 6359-14-00 LOCATION Hwy 72 - Finlayson Creek Culvert N 5 525 048.3 E 349 284.3 ORIGINATED BY TM
 HWY 72 BOREHOLE TYPE HSA / CME 750 COMPILED BY JM
 DATUM Geodetic DATE 2016.08.22 - 2016.08.22 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								
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE								
	Continued From Previous Page							20	40	60	80	100				
353.0 15.8	CLAY (CL to CI)															
			10	ST			358									
							357									
			11	SS	WH		356									0 8 51 41
			12	SS	WH		355									
							354									
			13	SS	WH											
	End of Borehole															

ONTMT4S 12356 FINLAYSON CULVERT.GPJ 2012TEMPLATE(MTO).GDT 10/4/17

RECORD OF BOREHOLE No FL16-4

1 OF 2

METRIC

GWP# 6359-14-00 LOCATION Hwy 72 - Finlayson Creek Culvert N 5 525 055.2 E 349 261.3 ORIGINATED BY TM
 HWY 72 BOREHOLE TYPE Tripod COMPILED BY JM
 DATUM Geodetic DATE 2016.09.12 - 2016.09.12 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 (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)				GR	SA	SI	CL																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
366.9								20	40	60	80	100																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No FL16-4

2 OF 2

METRIC

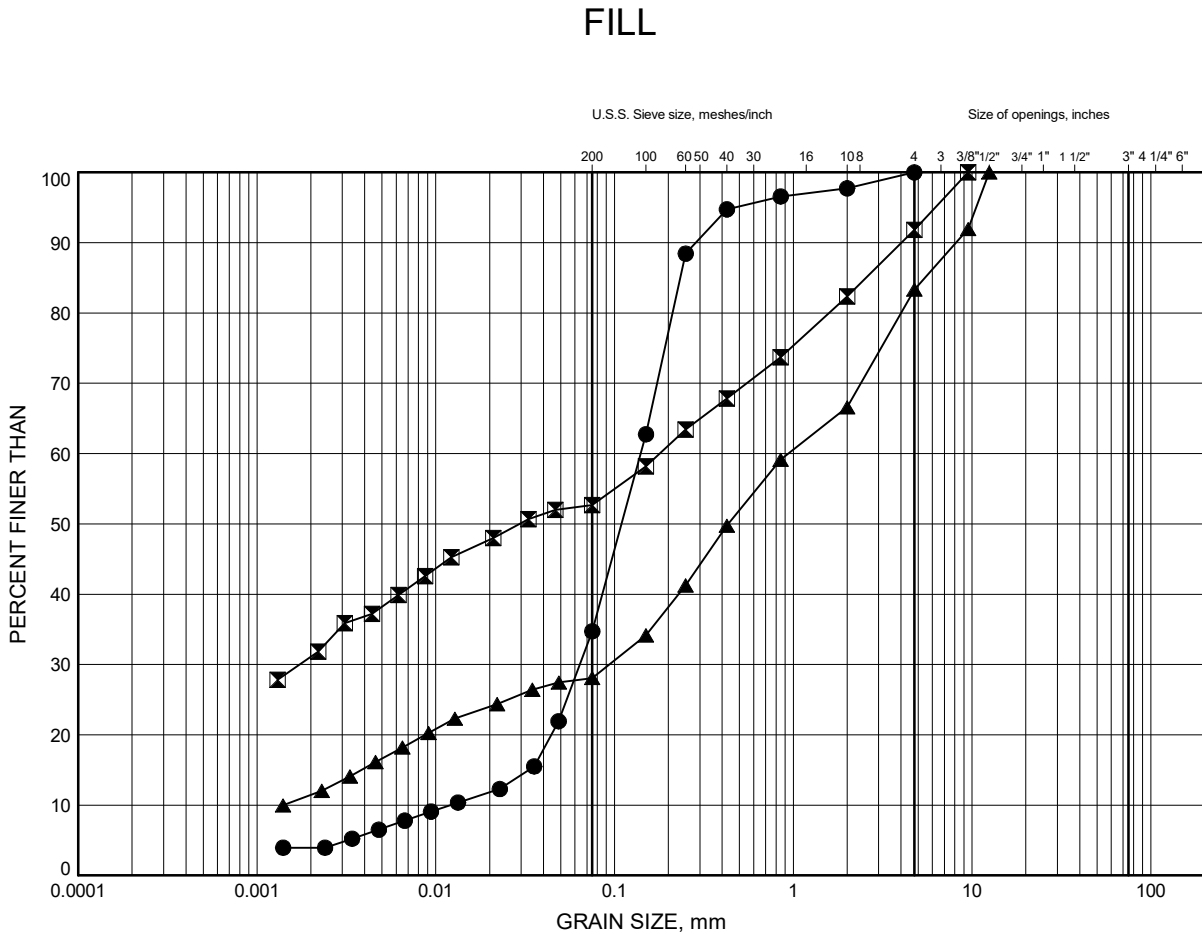
GWP# 6359-14-00 LOCATION Hwy 72 - Finlayson Creek Culvert N 5 525 055.2 E 349 261.3 ORIGINATED BY TM
 HWY 72 BOREHOLE TYPE Tripod COMPILED BY JM
 DATUM Geodetic DATE 2016.09.12 - 2016.09.12 CHECKED BY SP

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 (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
						20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100					W P W W L WATER CONTENT (%) 20 40 60						
	Continued From Previous Page																
355.6	CLAY (CH)		10	SS	WH		356								o	0 0 37 63	
11.3	End of Borehole Groundwater level at 0.9 m																

Appendix C.
Laboratory Testing

Finlayson Culvert GRAIN SIZE DISTRIBUTION

FIGURE C1



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	FL16-2	1.07	367.73
⊠	FL16-2	1.83	366.97
▲	FL16-3	1.83	366.97

Date November 2016

GWP# 6359-14-00



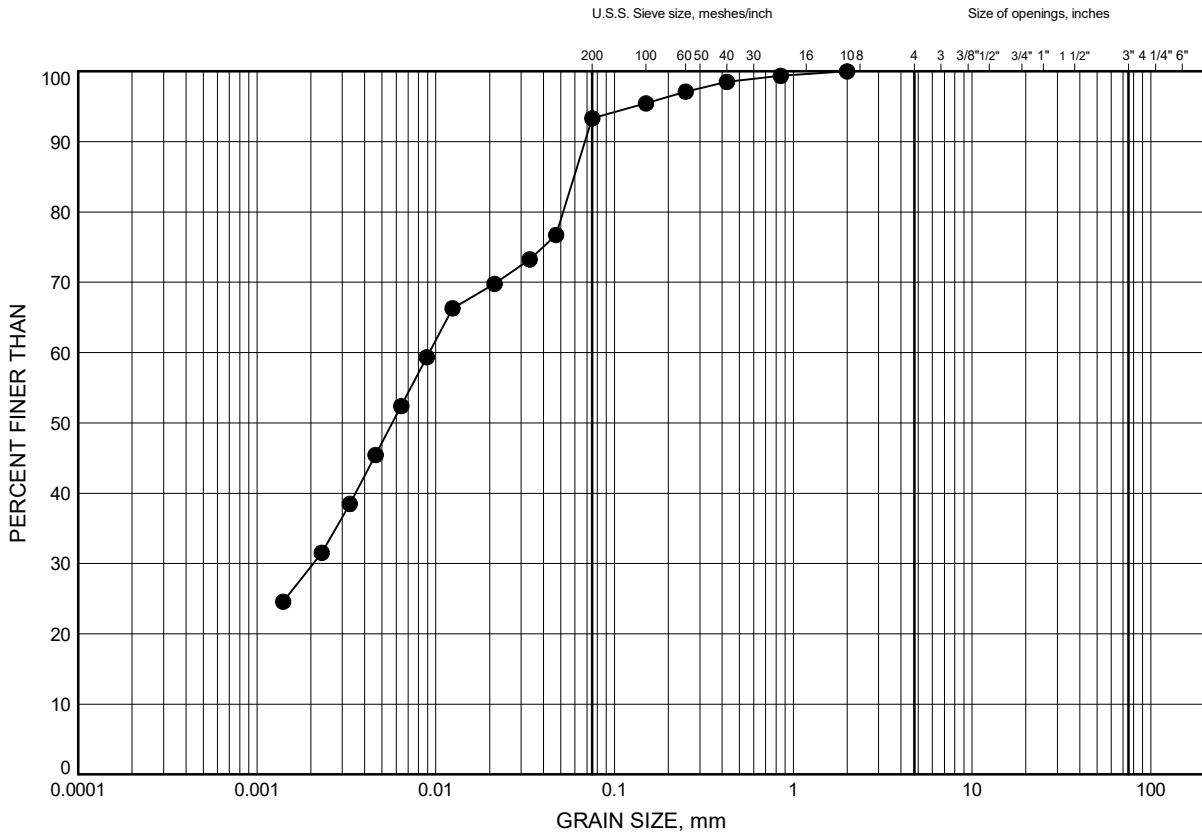
Prep'd JM

Chkd. FJG

Finlayson Culvert GRAIN SIZE DISTRIBUTION

FIGURE C2

ORGANIC SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	FL16-4	0.30	366.60

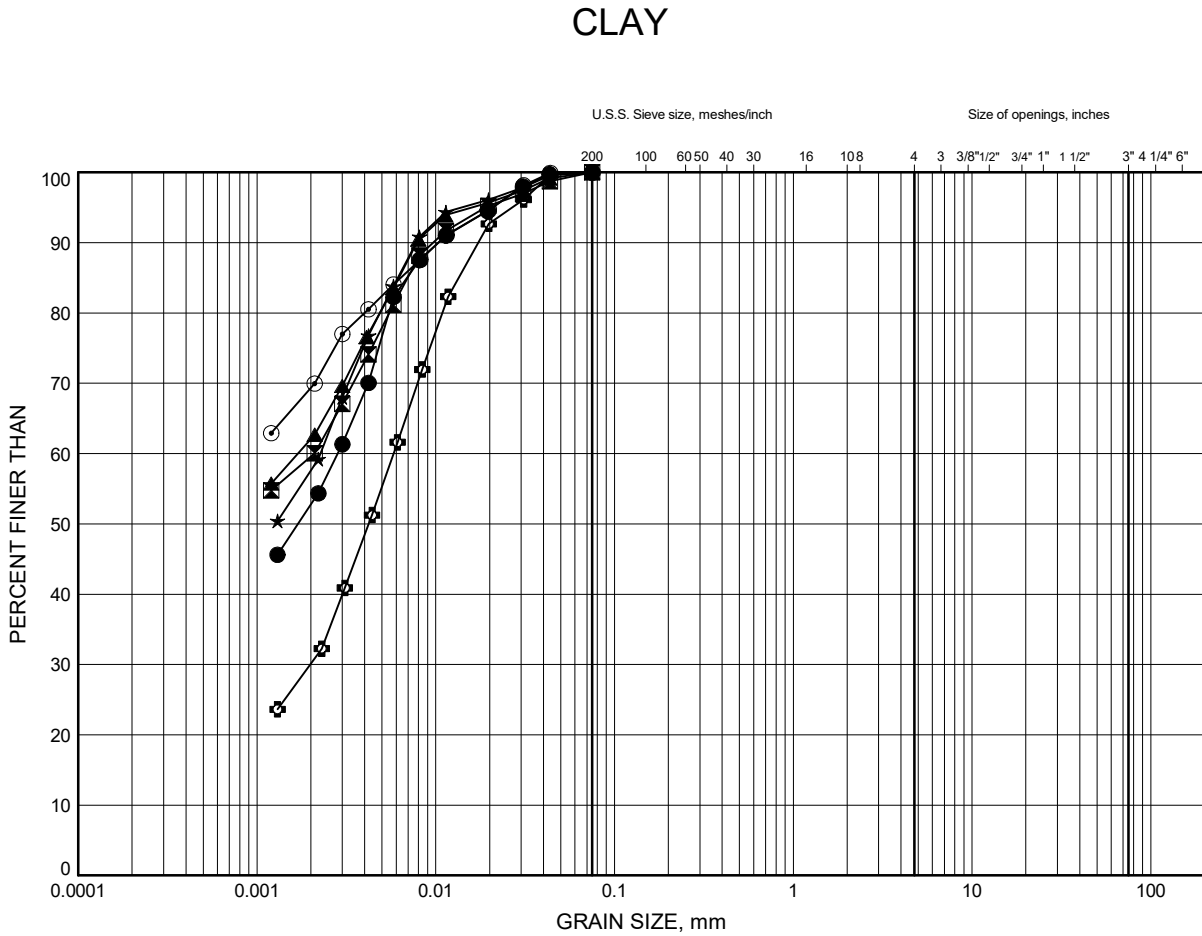
Date November 2016
GWP# 6359-14-00



Prep'd JM
Chkd. FJG

Finlayson Culvert GRAIN SIZE DISTRIBUTION

FIGURE C3



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	FL16-1	0.30	366.20
⊠	FL16-1	1.83	364.67
▲	FL16-1	4.88	361.62
★	FL16-1	10.97	355.53
⊙	FL16-2	4.88	363.92
⊕	FL16-2	15.54	353.26

Date November 2016

GWP# 6359-14-00

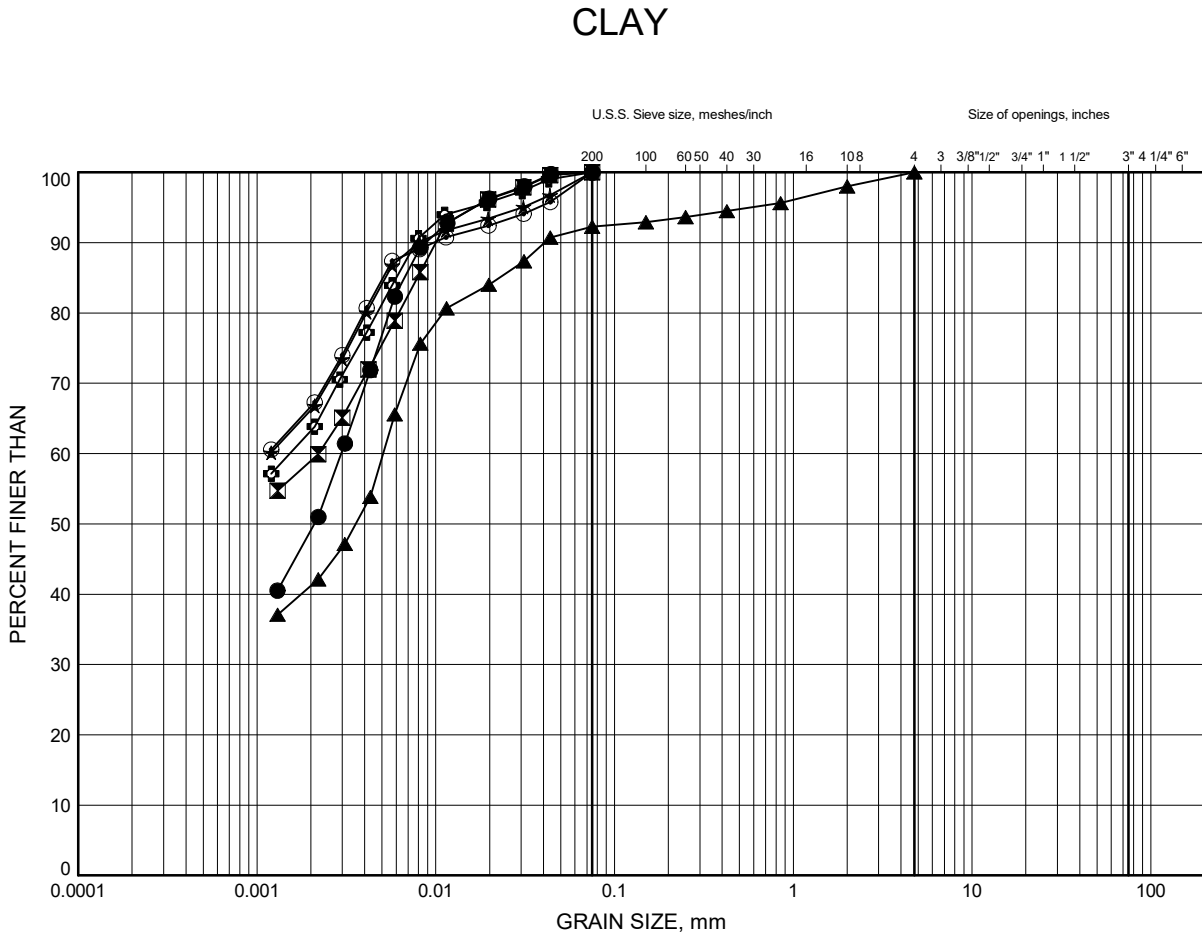


Prep'd JM

Chkd. FJG

Finlayson Culvert GRAIN SIZE DISTRIBUTION

FIGURE C4



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	FL16-3	3.35	365.45
⊠	FL16-3	7.92	360.88
▲	FL16-3	12.50	356.30
★	FL16-4	1.83	365.07
⊙	FL16-4	6.40	360.50
⊕	FL16-4	10.97	355.93

Date November 2016

GWP# 6359-14-00

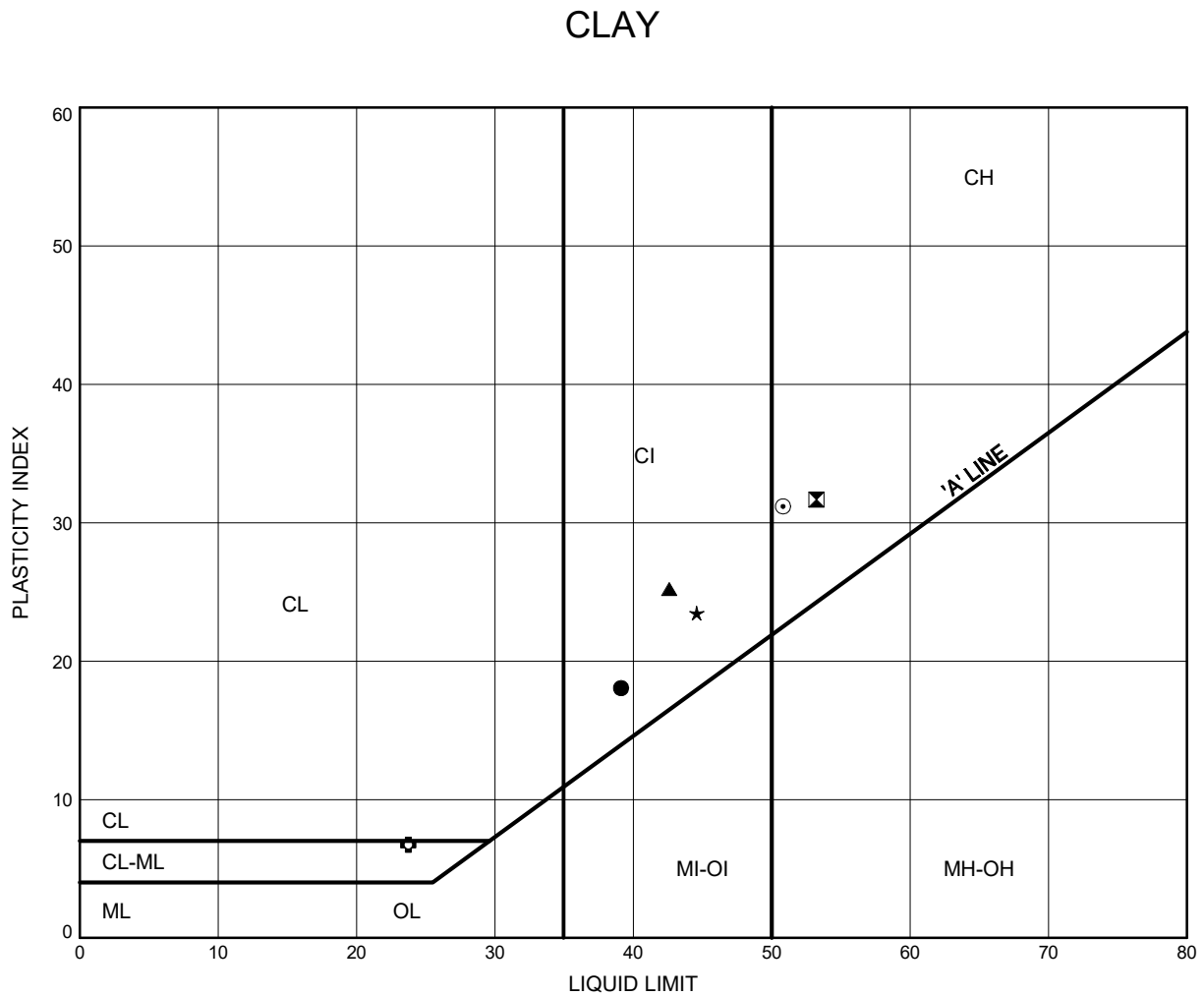


Prep'd JM

Chkd. FJG

Finlayson Culvert ATTERBERG LIMITS TEST RESULTS

FIGURE C5



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	FL16-1	0.30	366.20
⊠	FL16-1	1.83	364.67
▲	FL16-1	4.88	361.62
★	FL16-1	10.97	355.53
⊙	FL16-2	4.88	363.92
⊕	FL16-2	15.54	353.26

Date November 2016

GWP# 6359-14-00

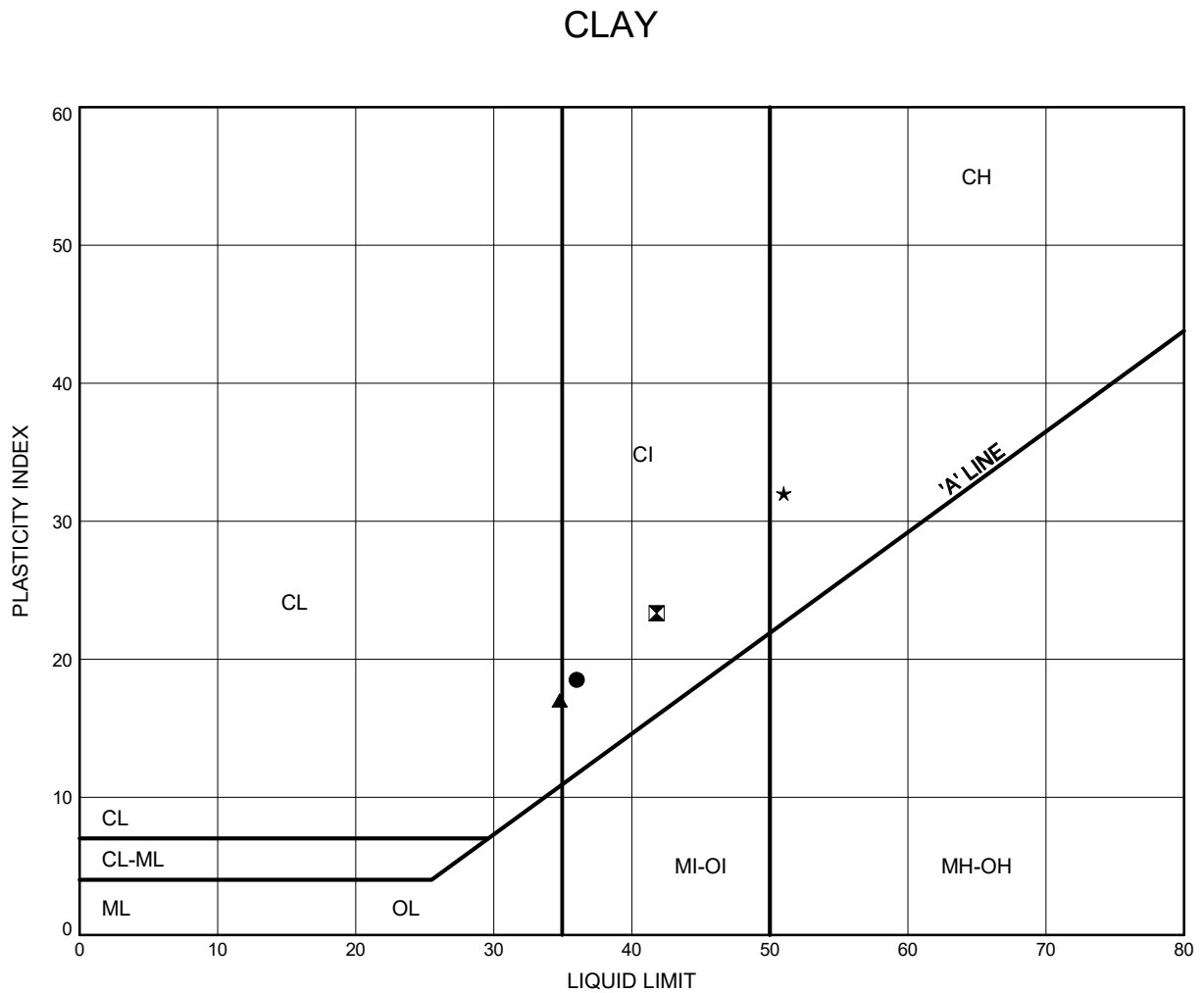


Prep'd JM

Chkd. FJG

Finlayson Culvert ATTERBERG LIMITS TEST RESULTS

FIGURE C6



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	FL16-3	3.35	365.45
⊠	FL16-3	7.92	360.88
▲	FL16-3	12.50	356.30
★	FL16-4	6.40	360.50

Date November 2016

GWP# 6359-14-00



Prep'd JM

Chkd. FJG

**CLIENT NAME: THURBER ENGINEERING LTD
SUITE 103, 2010 WINSTON PARK DRIVE
OAKVILLE, ON L6H5R7
(905) 829-8666**

ATTENTION TO: WEISS MEHDAWI

PROJECT: 12356

AGAT WORK ORDER: 16T139310

SOIL ANALYSIS REVIEWED BY: Amanjot Bhela, Inorganic Coordinator

DATE REPORTED: Sep 27, 2016

PAGES (INCLUDING COVER): 5

VERSION*: 1

Should you require any information regarding this analysis please contact your client services representative at (905) 712-5100

***NOTES**

All samples will be disposed of within 30 days following analysis. Please contact the lab if you require additional sample storage time.

Certificate of Analysis

AGAT WORK ORDER: 16T139310

PROJECT: 12356

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
<http://www.agatlabs.com>

CLIENT NAME: THURBER ENGINEERING LTD

SAMPLING SITE:

ATTENTION TO: WEISS MEHDAWI

SAMPLED BY:

Corrosivity Package

DATE RECEIVED: 2016-09-20

DATE REPORTED: 2016-09-27

		FL-1/SS2 (2.5-4.5')			FL-3/SS4 (7.5-8.5')			AB-2/SS3 (5-7')		
SAMPLE DESCRIPTION:		Soil			Soil			Soil		
SAMPLE TYPE:		Soil			Soil			Soil		
DATE SAMPLED:		8/22/2016			8/22/2016			8/22/2016		
Parameter	Unit	G / S	RDL	7861502	RDL	7861508	RDL	7861509		
Sulphide	%		0.05	<0.05	0.05	0.06	0.05	<0.05		
Chloride (2:1)	µg/g		2	264	4	383	2	15		
Sulphate (2:1)	µg/g		2	17	4	65	2	4		
pH (2:1)	pH Units		NA	8.44	NA	11.4	NA	9.36		
Electrical Conductivity (2:1)	mS/cm		0.005	0.633	0.005	1.32	0.005	0.141		
Resistivity (2:1)	ohm.cm		1	1580	1	758	1	7090		
Redox Potential (2:1)	mV		5	232	5	88	5	211		

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard

7861502 EC/Resistivity, pH, Chloride, Sulphate and Redox Potential were determined on the extract obtained from the 2:1 leaching procedure (2 parts DI water: 1 part soil). Please note that samples were analyzed past hold time.

7861508 EC/Resistivity, pH, Chloride, Sulphate and Redox Potential were determined on the extract obtained from the 2:1 leaching procedure (2 parts DI water: 1 part soil). Please note that samples were analyzed past hold time.

Elevated RDL indicates the degree of sample dilution prior to the analysis for Anions in order to keep analytes within the calibration range of the instrument and to reduce matrix interference.

7861509 EC/Resistivity, pH, Chloride, Sulphate and Redox Potential were determined on the extract obtained from the 2:1 leaching procedure (2 parts DI water: 1 part soil). Please note that samples were analyzed past hold time.

Certified By:



Quality Assurance

CLIENT NAME: THURBER ENGINEERING LTD

PROJECT: 12356

SAMPLING SITE:

AGAT WORK ORDER: 16T139310

ATTENTION TO: WEISS MEHDAWI

SAMPLED BY:

Soil Analysis

RPT Date: Sep 27, 2016

DUPLICATE

REFERENCE MATERIAL

METHOD BLANK SPIKE

MATRIX SPIKE

PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD	Method Blank	Measured Value	Acceptable Limits		Recovery	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper		Lower	Upper

Corrosivity Package

Sulphide	7861502	7861502	< 0.05	< 0.05	NA	< 0.05	100%	80%	120%	NA			NA		
Chloride (2:1)	7862971		<2	<2	NA	< 2	93%	80%	120%	98%	80%	120%	99%	70%	130%
Sulphate (2:1)	7862971		23	24	4.3%	< 2	92%	80%	120%	96%	80%	120%	98%	70%	130%
pH (2:1)	7861508	7861508	11.4	11.4	0.0%	NA	100%	90%	110%	NA			NA		
Electrical Conductivity (2:1)	7861508	7861508	1.32	1.32	0.0%	< 0.005	99%	90%	110%	NA			NA		
Redox Potential (2:1)	7861508	7861508	88	88	0.0%	< 5	102%	70%	130%	NA			NA		

Comments: NA signifies Not Applicable.

Duplicate Qualifier: As the measured result approaches the RL, the uncertainty associated with the value increases dramatically, thus duplicate acceptance limits apply only where the average of the two duplicates is greater than five times the RL.

Certified By:

Amanjot Bhela

Method Summary

CLIENT NAME: THURBER ENGINEERING LTD

AGAT WORK ORDER: 16T139310

PROJECT: 12356

ATTENTION TO: WEISS MEHDAWI

SAMPLING SITE:

SAMPLED BY:

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Soil Analysis			
Sulphide	MIN-200-12025	ASTM E1915-09	GRAVIMETRIC
Chloride (2:1)	INOR-93-6004	McKeague 4.12 & SM 4110 B	ION CHROMATOGRAPH
Sulphate (2:1)	INOR-93-6004	McKeague 4.12 & SM 4110 B	ION CHROMATOGRAPH
pH (2:1)	INOR 93-6031	MSA part 3 & SM 4500-H+ B	PH METER
Electrical Conductivity (2:1)	INOR-93-6036	McKeague 4.12, SM 2510 B	EC METER
Resistivity (2:1)	INOR-93-6036	McKeague 4.12, SM 2510 B, SSA #5 Part 3	CALCULATION
Redox Potential (2:1)		McKeague 4.12 & SM 2510 B	REDOX POTENTIAL ELECTRODE

Appendix D.
Site Photographs



Photo 1. Outlet (east side of Highway 72)



Photo 2. Inlet (west side of Highway 72)

Appendix E.

Foundation Comparison

COMPARISON OF ALTERNATIVE FOUNDATION TYPES

<i>Open Bottom Culvert, Concrete or Metal</i>	<i>Steel Sheet Pile Walls with Precast Concrete Slab</i>	<i>Closed Bottom Culvert</i>	<i>Pipe Culvert</i>
<i>Advantages:</i> <i>i.</i> Relatively expedient installation if precast units are used.	<i>Advantages:</i> <i>i.</i> Ease of construction. <i>ii.</i> Potentially minimized volume of excavation and roadway protection required. <i>iii.</i> Maintains water flow throughout construction. <i>iv.</i> Minimizes potential for disturbance of streambed.	<i>Advantages:</i> <i>i.</i> Relatively expedient installation if precast units are used. <i>ii.</i> Smaller magnitude of settlement than open footing culvert due to lower bearing stress on subgrade.	<i>Advantages:</i> <i>i.</i> Can tolerate larger magnitude of settlement than concrete (rigid frame) culverts. <i>ii.</i> Lower cost than concrete (rigid frame) culverts.
<i>Disadvantages:</i> <i>i.</i> Spread footing foundation subgrade will provide low geotechnical resistances and potential for post construction settlement. <i>ii.</i> Requires deeper excavation increasing volume and dewatering concern <i>iii.</i> Deep foundations could be used but would have limited capacity & would need to be more than 20m in length, greatly impacting costs	<i>Disadvantages:</i> <i>i.</i> Foundation subgrade will provide low geotechnical resistances. <i>ii.</i> High cost of sheet piles <i>iii.</i> Unconventional design <i>iv.</i> Span exceeds 9 m.	<i>Disadvantages:</i> <i>i.</i> Requires compacted granular pad on subgrade. <i>ii.</i> Requirement for temporary by-pass culvert or pumped diversion to maintain water flow	<i>Disadvantages:</i> <i>i.</i> CSP and HDPE pipes not as durable as concrete culverts. <i>ii.</i> Feasibility also depends on flow capacity and other hydraulic properties.
Not Recommended	Not Recommended	Recommended	Feasible

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

November 11, 2015

Site: 49.8611 N, 92.3814 W User File Reference: Finlayson Creek

Requested by: ,

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)
0.060	0.081	0.073	0.057	0.040	0.020	0.0078	0.0015	0.0007	0.044	0.028

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)	0.0023	0.015	0.029
Sa(0.1)	0.0038	0.022	0.042
Sa(0.2)	0.0044	0.022	0.039
Sa(0.3)	0.0038	0.018	0.031
Sa(0.5)	0.0028	0.013	0.022
Sa(1.0)	0.0011	0.0058	0.011
Sa(2.0)	0.0005	0.0022	0.0041
Sa(5.0)	0.0002	0.0005	0.0008
Sa(10.0)	0.0001	0.0003	0.0005
PGA	0.0021	0.012	0.022
PGV	0.0014	0.0077	0.015

References

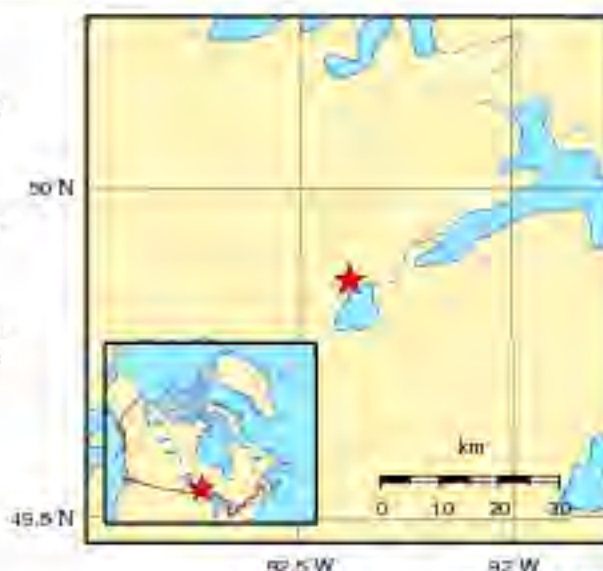
National Building Code of Canada 2015 NRCC no. 58190;
Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

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

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
 - OPSS.PROV 421
 - OPSS.PROV 422
 - OPSS.PROV 501
 - OPSS.PROV 539
 - OPSS.PROV 804
 - OPSS 902
 - OPSS.PROV 1010
 - OPSS.PROV 1205
-
- OPSD 208.010
 - OPSD 802.010
 - OPSD 803.010
 - OPSD 803.031
 - OPSD 810.010
 - OPSD 3090.100
 - OPSD 3101.150

2. Suggested text for a NSSP on “Foundation Support”

The site is underlain by soft clays. Any additional embankment loading or foundation loading due to embankment widening to support a crane pad is expected to be difficult at this site. The Contractor must retain an experienced geotechnical consultant to design their temporary works such as crane pads.

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

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

4. Suggested text for a NSSP on “Protection of Soft and Sensitive Foundation Soils”

The Contractor is advised that the native clay will that will be exposed at the subgrade following removal of existing culvert is moisture sensitive and may become disturbed or otherwise negatively impacted when subjected to construction or personnel traffic, freeze-thaw actions, ingress or ponding water. The Contractor shall be responsible for implementing adequate groundwater control measures and to minimize construction and personnel traffic on the founding subgrade.

The base of the excavation should be inspected by a QVE that is experienced in geotechnical inspection to confirm that the exposed subgrade surface conforms to the design requirements. Once approved the subgrade should be protected with a non-woven geotextile placed between the native subgrade and granular bedding.