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FINAL

FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 637 MASSEY CREEK CULVERT REPLACEMENT
10.5 KM WEST OF HIGHWAY 69, SUDBURY
SITE NO.: 46-196/C

5015-E-0035

Geocres No.: 41L-344

Report to:

McIntosh Perry

February 2017
File: 12030

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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 culvert replacement at the Highway 637 crossing of Massey Creek, GWP 6359-14-00. The structure is located approximately 10.5 km west of Highway 69, Sudbury. Thurber Engineering Limited (Thurber) carried out the current investigation as a sub-consultant to McIntosh Perry under Contract No. 5015-E-0035.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide a borehole location plan, records of boreholes, stratigraphic profile, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions was developed in the course of the current investigation.

An earlier foundation investigation report that has been provided to Thurber and reviewed in preparation of this report is as follows:

> "Foundation Investigation Report for Massey Creek Culvert, W.P. 99-79-01, Site 46-196, Highway 637, District 17, Ontario, Sudbury (GEOCRES 41I-114), dated January 1980

2 SITE DESCRIPTION

The existing culvert is located at approximately Sta. 10+000 on Highway 637 and consists of a 4.5 m diameter Corrugated Steel Pipe (CSP) culvert in an approximate north to south alignment with flow through the culvert ultimately draining into Wanapitei River to the south.

At the location of the culvert, Highway 637 is a two-lane highway with a rural cross-section and gravel shoulders. The road surface of the Highway 637 embankment is approximately 2.5 m above the top of the culvert at an elevation of 195.5 m. Cable guiderails are present on both sides of Highway 637 in the area of the culvert site. The land adjacent to the highway is undeveloped and heavily vegetated with trees and shrubs. Traffic volumes are understood to be less than 1000 AADT.

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

3 SITE INVESTIGATION AND FIELD TESTING

The current site investigation and field testing program was carried out between July 4th and 7th, 2016. Drilling consisted of advancing four boreholes identified as 16-01 through 16-04 and was carried out using portable equipment for the off road boreholes and a track mounted drill rig for the boreholes advanced from the road surface. Prior to commencement of drilling, utility clearances were obtained in the vicinity of the borehole locations.

Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). A single Thin Walled (Shelby) Tube sample of a clay deposit was retrieved from Borehole 16-03 to obtain a relatively undisturbed soil sample for further laboratory testing. The boreholes were extended to depths ranging from 14.3 to 18.9 m (elev. 177.2 to 176.9 m) below the existing ground surface.

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 Ottawa, Ontario for further examination and testing.

A standpipe piezometer, consisting of 38 mm Schedule 40 PVC pipe with a 3.0 m long slotted screen, was installed within borehole 16-01 to observe groundwater conditions after completion of drilling operations. The standpipe screen was installed at a tip elevation of 177.8 m within a filter sand to permit groundwater level monitoring. Following completion of the field investigation the standpipe piezometer was sealed and decommissioned in accordance with MOEE requirements.

The approximate borehole locations are shown on the Borehole Locations and Soil Strata Drawing included in Appendix A. The coordinates and elevation of the boreholes are provided on this drawing and on the individual Record of Borehole sheets.

A supplementary field investigation was completed on January 12, 2017 to observe the subgrade response and included a test pit adjacent to the north side of the highway embankment. The methodology and observations from this investigation are summarized in a memo provided in Appendix E and the Record of Test Pit sheet is included in Appendix B.

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. A single soil sample, obtained with a Thin Walled (Shelby) Tube, underwent one-dimensional consolidation testing. Two samples of soil recovered from within the boreholes were selected and submitted for analytical testing. All laboratory test results are provided 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 the soil and groundwater conditions may vary between and beyond borehole locations.

In general terms, the site was found to be underlain by a pavement structure and embankment fill overlying a deposit of predominantly clay followed by an underlying deposit of silt. Adjacent to the embankment, a surficial organic layer was present in both off road boreholes. SPT refusal or bedrock was not encountered within the depth of investigation.

5.1 Fill: Sand and Silt

Boreholes 16-02 and 03 were drilled through the existing Highway 637 approaches and encountered a layer of asphalt approximately 30 mm in thickness. The asphalt was underlain by a layer of granular fill ranging in composition from sand with silt to sand. Frequent cobbles were noted in the lower portion of the fill. Boulders were observed in the fill layer in the test pit. The thickness of the fill layer was 7.0 m with an underside elevation at 188.8 to 188.4 m.

SPT tests recorded N-values as high as 67 blows per 300 mm of penetration but typically ranging from 5 to 31 blows per 300 mm of penetration indicating a loose to compact relative density. The recorded moisture contents varied from 2 to 15%

Gradation analyses were completed on two samples of the fill layer. The grain size distribution curves for these samples are included in Figure C1 of Appendix C. The results of the tests are summarized below and are presented on the corresponding Record of Borehole sheets in Appendix B and indicate an SP-SM material.

Soil Particle	Percentage (%)
Gravel	1 to 6
Sand	84 to 88
Silt	10 to 11
Clay	

5.2 Organics

Boreholes 16-01 and 16-04 were drilled adjacent to the embankment footprint and encountered a 75 mm thick layer of organics at the surface. A single moisture of 39% was recorded within this layer.

5.3 Silt with Sand

Directly below the organic layer in Borehole 16-01 was a deposit of silt with sand. Pieces of wood were noted within the deposit. The thickness of silt was 1.4 m with an underside elevation of 190.0 m.

SPT tests recorded N-values of 3 and 4 blows per 300 mm of penetration indicating a very loose to loose relative density. Recorded moisture contents within the deposit ranged from 6 to 27%.

A single gradation analysis was completed on a sample of the silt. The grain size distribution curve for this sample is included in Figure C2 of Appendix C. The results of the test is summarized below and is presented on the corresponding Record of Borehole sheet in Appendix B.

Soil Particle	Percentage (%)
Gravel	0
Sand	28
Silt	62
Clay	10

5.4 Clay

Beneath the materials noted above, a deposit of clay was encountered in all four boreholes. The investigated thickness of the deposit ranged from 8.2 to 13.6 m (base elev. 180.8 to 179.4 m).

SPT tests performed within the clay gave N-values typically ranging from weight of hammer to 2 blows per 300 mm of penetration. A single blow count as high as 10 blows per 300 mm of penetration was recorded locally at the surface of Borehole 16-04. Field vane tests were performed within the deposit and recorded undrained shear strengths typically ranging from 25 to 50 kPa indicating a firm consistency. The measured sensitivity, from remolded field vane testing, ranged from 2.8 to 12 indicating that the clay can be classified as medium sensitive to extra sensitive, generally decreasing in sensitivity with depth.

Moisture contents generally increased with depth from a minimum value of 18% near the surface of Borehole 16-04 (elev. 192.8 m) to a maximum value of 88% near elevation 186.0 m in Borehole 16-03 and then consistently decreased with depth to a moisture content of approximately 40% at the base of the layer.

Gradation analyses were completed on eight samples of the clay deposit. The grain size distribution curves for these samples are included in Figure C3 and C4 of Appendix C. The results of the tests are summarized below and are presented on the corresponding Record of Borehole sheets in Appendix B. The percentage of clay consistently decreases with depth below an elevation of 188 m.

Soil Particle	Percentage (%)
Gravel	0
Sand	0 - 6
Silt	36 - 65
Clay	30 - 64

Atterberg Limit testing was completed on nine samples of the clay layer. The results are summarized on the Record of Borehole sheets in Appendix B and the Atterberg Limit graphs are included in Figure C6 and C7 of Appendix C. The laboratory results are summarized below and indicate that the clay varies from low to high plasticity (CL to CH).

Parameter	Value
Liquid Limit	26 to 85
Plastic Limit	15 to 26
Plasticity Index	9 to 59

An Oedometer (one-dimensional consolidation) test was carried out on a relatively undisturbed sample obtained from a Thin Walled (Shelby) tube sampler. The results are presented in Appendix C and summarized as follows:

Borehole and Sample	Soil Type	w_n (%)	γ (kN/m^3)	e_o (-)	p_c' (kPa)	p_0 (kPa)	c_c (-)	c_r (-)
16-03 (elev. 186.0 m)	CH	88	15.0	2.05	145	135	1.82	0.20

The ratio of preconsolidation pressure to vertical effective stress (OCR = p_c'/p_o) derived from the oedometer test results indicates that the silty clay is near normally consolidated with an OCR at approximately 1.07. The vertical coefficient of consolidation, c_v, recorded during the Oedometer test is approximately 1.8 to 5.0 x 10^{-4} cm^2/s in the normally consolidated range and 1.3 to 4.0 x 10^{-3} cm^2/s for the overconsolidated range. The compressibility characteristics will vary with depth in accordance with the moisture content and stress history.

5.5 Silt

Directly below the clay deposit was layer of cohesionless silt. All four boreholes were terminated in this layer at final depths ranging from 14.3 to 18.9 m (elev. 177.2 to 176.9 m).

SPT tests gave N-values typically increasing with depth and ranging from weight of hammer to 15 blows per 300 mm of penetration indicating a very loose increasing to compact relative density. A single N-value as high as 22 blows per 300 mm of penetration was recorded at the base of Borehole 16-04. The moisture content within the cohesionless silt deposit ranged between 23 and 37%

Atterberg Limit testing indicated a non-plastic material. Gradation analysis were completed on three samples of the silt deposit. The grain size distribution curves for these samples are included in Figure C5 of Appendix C. The results of the tests are summarized below and are presented on the corresponding Record of Borehole sheets in Appendix B. The percentage of clay consistently decreases with depth.

Soil Particle	Percentage (%)
Gravel	0 -1
Sand	0 -1
Silt	78 - 94
Clay	4 - 22

5.6 Groundwater

Observations for water levels were completed in the open boreholes during and upon completion of drilling. A single standpipe piezometer was installed Borehole 16-01 within the underlying silt layer to monitor groundwater levels after drilling. Groundwater seepage from a sand layer at elevation 190.1 to 189.9 m was noted in test pit 16-05. The measured groundwater levels are summarized in the table below.

Table 5-1. Measured Groundwater Levels

Borehole / Test Pit No.	Date	Base of Borehole / Test Pit (Stratum)	Groundwater Level		Comment
			Depth (m)	Elevation (m)	
16-01	Jul. 5, 2016	177.2 (Silt)	> 0.6(*)	above 192.1	Piezometer
	Jul. 7, 2016	176.9 (Silt)	> 2.2(*)	above 193.7	Piezometer
16-02	Jul. 6, 2016	176.5 (Silt)	> 1.0(*,**)	above 196.8	Open Borehole
16-03	Jul. 7, 2016	177.3 (Silt)	>1.0(*,**)	above 196.4	Open Borehole
16-05	Jan. 12, 2017	188.4 (Clay)	1.9(***)	189.9	Open Test Pit

Note: (*) Groundwater level was measured from within the underlying silt layer and noted to be above the existing ground surface (artesian flow conditions), (**) Water height was recorded at top of casing at completion of drilling. (***) as observed from seepage within sand layer

It should be noted that the values shown above are considered short-term readings and may not reflect groundwater levels at the time of construction and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant and/or prolonged precipitation events.

The water level within the creek was near elevation 190.5 m during the time of the field investigation.

6 MISCELLANEOUS

Borehole locations were selected relative to existing site features and proposed foundation locations. After completion of drilling, the borehole locations and ground surface elevation were measured by Thurber relative to benchmarks provided by McIntosh Perry.

Landcore Drilling from Chelmsford, Ontario supplied the drill rigs and conducted the drilling, soil sampling, in-situ testing and standpipe piezometer installation and decommissioning for the field program. The field investigation was supervised on a full time basis by Mr. Chris Murray, E.I.T. of Thurber. Overall supervision of the investigation program was conducted by Mr. Stephen Peters, P.Eng.

Routine geotechnical laboratory testing was carried out by Thurber's laboratory in Ottawa, Ontario. One-dimensional consolidation testing was completed by Stantec's laboratory in Ottawa, Ontario. Analytical testing was completed by Paracel Laboratories. Interpretation of the factual 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.

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PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 INTRODUCTION

This section of the report provides an interpretation of the factual data and also presents geotechnical recommendations provided to assist the design team in designing a suitable foundation for the proposed replacement of the existing Massey Creek culvert crossing Highway 637. The discussion and recommendations presented in this report are based on the information provided by McIntosh Perry and on the factual data obtained during the course of the investigation.

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

The existing culvert, conveying Massey Creek under Highway 637, is a Corrugated Steel Pipe (CSP) culvert which is 4.5 m in diameter and approximately 30 m long. The embankment fill height above the culvert is in the order of 2.5 m high. The creek flows in a north to south direction at this site and drains into the Wanapitei River.

Thurber Engineering Limited (Thurber) carried out the current investigation as a sub-consultant to McIntosh Perry under Contract No. 5015-E-0035.

8 APPLICABLE CODES AND DESIGN CONSIDERATIONS

The geotechnical assessment presented below has be prepared 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. The degree of site and prediction model understanding is considered to be “typical” in accordance with the CHBDC Section 6.5.3.2.

9 CULVERT FOUNDATIONS

9.1 General

A General Arrangement (GA) drawing of the proposed culvert replacement structure was not available at time of writing this report. It is understood that the replacement culvert is proposed to be constructed along the same alignment as the existing culvert and a temporary flow passage will be required during construction.

In general terms, the site was found to be underlain by a pavement structure and embankment fill overlying a deposit of predominantly clay over a deposit of silt. Adjacent to the embankment, a surficial organic layer was present in both off road boreholes. Groundwater level measurements indicated artesian pressures from within the underlying silt deposit. No evidence of basal instability was noted during the excavation of the test pit to elevation 188.3 m on January 12, 2017.

9.2 Construction Methodology Alternative

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

- 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, potential to encounter obstruction within the existing embankment fill, characteristics of the subgrade soils, and the topography of the surrounding terrain, tunneling for trenchless replacement is not considered as a feasible option.

- Open Cut with Full Road Closure

  Installation of a new culvert using open cut techniques and 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.

  Widening of the existing highway and/or construction of a detour embankment to accommodate a temporary traffic passage should be avoided due to the compressibility characteristics of the clay subgrade. Placement of additional fill will cause an increase in loading on the subgrade soils and will induce time-dependant settlement for both the temporary detour and existing embankment. Additionally, property acquisition may also be required for this option.

- Open Cut with Staged Road Closure (Half and Half)

  The preferred construction staging option is open cut techniques in conjunction with staged culvert replacement. This option will require roadway protection, as discussed in Section 14, installed along the embankment centerline to maintain a single lane of traffic flow along the current highway alignment.

9.3 Culvert Type and Foundation Alternatives

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

- Circular Pipes (Concrete, HDPE, Steel)
  From a foundation engineering perspective, pipe culverts are a technically feasible alternative, provided that other design issues including flow capacity, hydraulic properties and durability can be satisfied.
- Open Bottom Culvert (Box, Arch)
  Open bottom culverts are not recommended for this site from a foundation engineering perspective since the available geotechnical resistance for footings will be low and the post construction settlement from this type of culvert would be greater than alternative options and would also require greater dewatering efforts during construction to place the foundation in the dry.
- Closed Culvert (Box)
  Precast segmental box culverts are considered a feasible option from a foundation engineering perspective and in view of the anticipated construction sequencing. Precast sections, rather than cast-in-place construction, can be installed expediently with less potential for disturbance of the founding soils during installation.

A comparison of these alternatives, based on their respective advantages and disadvantages, is included in Appendix F. It is not considered to be economical or practical to support a culvert on deep foundations at this site and therefore this option is not presented in this report. This report will focus on providing foundation recommendations on the design and construction of pipe and box culverts.

9.4 Foundation Design

Foundation design aspects for the replacement culvert includes subgrade conditions, geotechnical resistances, settlements of founding soils, imposed loading pressures, erosion control, protection system design, groundwater control, staged excavation and stability of detour embankment. 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.

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.

9.4.1 Box Culvert Geotechnical Resistances

The recommended geotechnical resistances for a 4.5 m wide pre-cast box culvert installed along the existing alignment at the current founding elevation are as follows:

At centerline of embankment

- Factored Geotechnical Resistance at ULS of 175 kPa

- Geotechnical Resistance as SLS of 100 kPa

Outside of embankment footprint (inlet/outlet of culvert)

- Factored Geotechnical Resistance at ULS of 100 kPa
- Geotechnical Resistance as SLS of 45 kPa

The factored geotechnical resistances include the following factors:

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

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

Resistance to lateral forces/sliding resistance between the precast concrete and the underlying Granular 'A' bedding (Section 9.5) should be evaluated in accordance with the CHBDC Section 6.10.5 based on an angle of friction of 35^{o} and an ultimate coefficient of friction of 0.45.

9.4.2 Pipe Culvert Geotechnical Resistances

Geotechnical resistance values are not required for pipe culverts. A modulus of subgrade reaction of 7 MN/m^3 can be used for a pipe culvert installed at this site.

9.4.3 Wingwalls

If wingwalls are required as part of the culvert design, the footings should be founded on a leveling pad with a minimum thickness of 0.5 m consisting of Granular 'A' material with the base of the footing founded at or below the depth of frost. The engineered pad can bear on the native subgrade provided 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. The engineered fill pad must be placed in maximum 150 mm lifts and compacted to 100% standard proctor maximum dry density (SPMDD) with a placement moisture content ±2% of optimum. The following geotechnical resistance values are recommended for wingwalls at this site:

- Factored Geotechnical Resistance at ULS of 100 kPa
- Geotechnical Resistance as SLS of 45 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.

9.5 Subgrade Preparation and Bedding

After excavation and removal of the existing culvert and existing fill, all organics, soft or loose creek bed deposits, disturbed soils and deleterious materials must be stripped from the footprint of the foundation to expose competent native subgrade material at or below the desired founding elevations. 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.

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 and compacted as per OPSS.PROV 501 with granular fill consisting of OPSS.PROV 1010 Granular A or B Type II material 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 (box culvert) or OPSD 802.010 (pipe culvert).

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 over excavation to allow placement of a mud slab 100 mm thick beneath the 300 mm thick Granular A bedding layer.

Please refer to Section 12 for additional comments on groundwater and surface water control.

9.6 Frost Depth

The depth of frost penetration at this site is 1.9 m. It is not necessary to found box or pipe culverts at a depth below frost penetration however, frost treatment should be as per OPSD 803.010 (box culvert) or OPSD 803.030 (pipe culvert).

10 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 (box culvert) or OPSD 802.010 (pipe culvert).

The backfill should be compacted in regular lifts. Heavy compaction equipment, used adjacent to 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.

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 Clause 6.12.3 of the CHBDC

Earth pressure coefficients for backfill to the box culvert wall 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 $\phi = 35^o$, $\gamma = 22.8$ kN/m^3		Existing Fill or OPSS Granular B Type I $\phi = 32^o$, $\gamma = 21.2$ kN/m^3	
	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)
Active, K_A (Yielding Wall)	0.27	0.40	0.31	0.48
At Rest, K_O (Non-Yielding Wall)	0.43	-	0.47	-
Passive, K_P (Movement towards Soil Mass)	3.7	-	3.3	-
Soil Group(*)	"medium dense sand"		"loose to medium dense 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 horizontal earth pressures be used for 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.

11 SEISMIC CONSIDERATIONS

The soil profile at this site has been classified as a Site Class E in accordance with Section 4.4.3.2 of the CHBDC (S6-14). The seismic hazard for this site has been obtained from the Geological Survey of Canada (GSC). The data includes a peak ground acceleration (GPA), peak ground velocity (PGV) and the 5% spectral response acceleration values (Sa(T)) for the reference ground condition (Site Class C) for a range of periods (T) and for a range of return periods including 475-year, 975-year and 2475-year events. The GSC seismic hazard calculated data sheet for this site is included in Appendix G.

In accordance with Clause 4.6.5 of the CHBDC (S-14), retaining structures should be designed using dynamic earth pressure coefficient that incorporate the effects of earthquake loading. The coefficients of horizontal earth pressure for seismic loading presented in Table 11-1 may be used. The provided earth pressure coefficients are based on a PGA with a 2% probability of exceedance in 50 years of 0.062g (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 11-1. Dynamic Earth Pressure Coefficients

Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^o$, $\gamma = 22.8$ kN/m^3		Existing Fill or OPSS Granular B Type I $\phi = 32^o$, $\gamma = 21.2$ kN/m^3	
	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)
Active, K_{AE} Yielding Wall	0.34	0.46	0.37	0.52
Active, K_{AE} Non-Yielding Wall	0.41	0.58	0.46	0.66

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

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

where:

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

Based on the subsurface condition encountered at the drilled locations at this site, the potential for liquefaction of the foundation soils during a seismic event is considered low in accordance with CHBDC (S6-14) Clause C4.6.6. Therefore liquefaction is not considered to be a concern at this site. Some toe failure may occur but it is expected to be of limited nature and readily repairable.

12 EXCAVATION AND GROUNDWATER CONTROL

12.1 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 the native 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 clay and silt deposits. The sides of temporary excavations must be sloped in accordance with the requirement of the OHSA.

At locations where there is space restrictions or where a slope has to be retained, the excavations will need to be carried out within a protection system. Any protection system must be designed by a licensed Professional Engineer experienced in such design. Further discussion is presented in Section 14 below.

12.2 Surface and Groundwater Control

Culvert construction and subgrade preparation must be carried out in the dry. A temporary flow passage must be constructed adjacent to the proposed culvert alignment 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. The culvert subgrade will be formed in the native firm clay under a head of approximately 2 m. In addition the underlying silt soil was observed to exhibit artesian conditions with an estimated head of as much as 8.3 m. No evidence of basal instability was noted during the test pit investigation to elevation 188.3 m of January 12, 2017.

Excavation below the groundwater level without prior dewatering is not recommended since the inflow of groundwater will cause base 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. Dewatering systems must be designed by a dewatering specialist.

Based on the groundwater and soil conditions, special attention must be paid to construction dewatering. It is recommended that the excavation be enclosed within a water tight sheet pile enclosure. 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. It is expected that approximately 7 m of clay will be present between the underlying artesian silt layer and the base of the excavation, therefore the artesian pressure within the underlying silt deposit should not need to be depressurized prior to embankment removal and subexcavation provided the excavation's horizontal extents are limited and the silt layer is not penetrated by the temporary protection systems (see also Section 15). As indicated in Section 9.5, a mud slab should be poured with lean mix concrete to protect the exposed 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.

13 EMBANKMENT DESIGN AND RECONSTRUCTION

Embankment reconstruction after culvert replacement should be carried out in accordance with OPSS.PROV 206. The embankment should be reinstated with side slopes of 2H:1V (or flatter) if constructed using Select Subgrade Material (SSM) or Granular B Type I. Embankment slopes must be provided with erosion protection in accordance with OPSS.PROV 804. Material stockpiling above the existing grades is a temporary construction measure and the stability implication should be reviewed by the Contractor.

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. Construction of embankments should be carried out in accordance with OPSS.PROV 209 “Construction Specification for Embankments over Swamps and Compressible Soils”

Provided no grade raise or embankment widening is required and proper construction methods are used, no long term or global stability issues are anticipated for embankments built at this site. The magnitude of settlement 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 o occur during fill placement.

14 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 with which water flow is likely to be in contact. 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 or a concrete cut-off wall be used to minimize the potential for piping and erosion around the inlet of the culvert. The clay seal must extend to the order of 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.

15 ROADWAY PROTECTION

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 designing the shoring system.

Roadway protection is the responsibility of the Contractor and should be designed by a licensed Professional Engineer experienced in such designs and retained by the Contractor. The design of the roadway protection system should ensure the base of the sheet pile does not penetrate into with the underlying artesian silt layer. A suitable bracing system will need to be incorporated into the protection system design to provide the required lateral capacities including traffic loading and surcharge loading due to construction equipment and operations. It is also recommended that the sheet piles be left in place upon completion of construction and cut off at or below the depth of frost from beneath the finished pavement grade.

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 clay soils are given below:

γ_w	=	10	(kN/m^3, unit weight of water)
γ	=	15	(kN/m^3, bulk unit weight of soil)
K_A	=	0.39	
K_P	=	2.6	

16 CONSTRUCTION CONCERNS

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

- Disturbance of the soil subgrade. 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 condition. The contractor must be aware of the issue so that he may adjust his operations to suit the difficult subgrade conditions

- Cobbles, boulders or other buried obstructions may be encountered in the existing embankment fill. Obstructions within the fill could interfere during excavation activities and/or interfere with installing roadway protection. An NSSP should be included in the contract alerting the Contractor to these conditions.
- Groundwater 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. An NSSP should be included in the contract alerting the Contractor to the groundwater conditions.
- The Contractor's selection of construction equipment and methodology must include assessment of the capability of the existing embankment to support the proposed construction equipment and any temporary structure fill (i.e., as a pad for crane support).

The successful performance of the culvert 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.

17 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:

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Senior Geotechnical Engineer

Appendix A.

Test Hole Location Plan and Stratigraphic Drawings

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

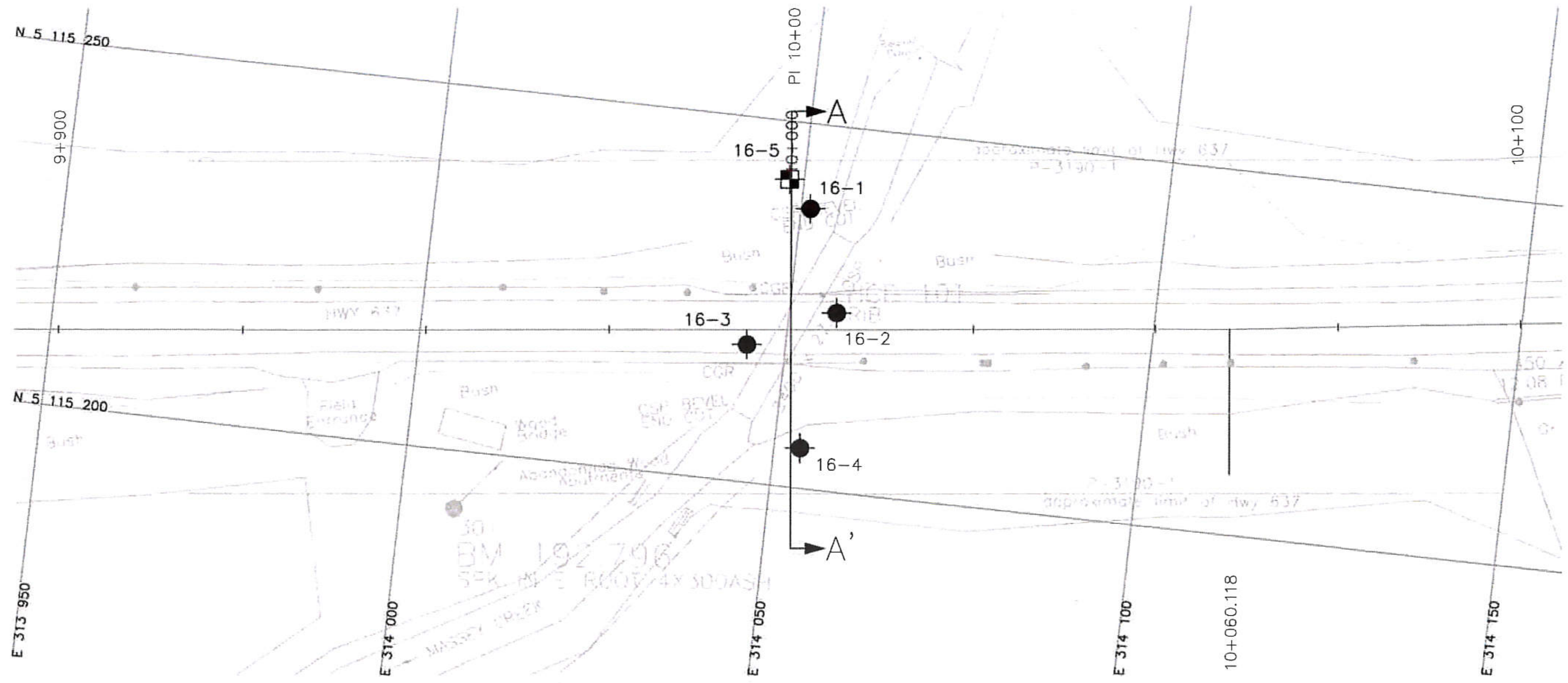
CONT No
GWP No 5380-11-00

HIGHWAY 637
MASSEY CREEK
CULVERT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

McINTOSH PERRY

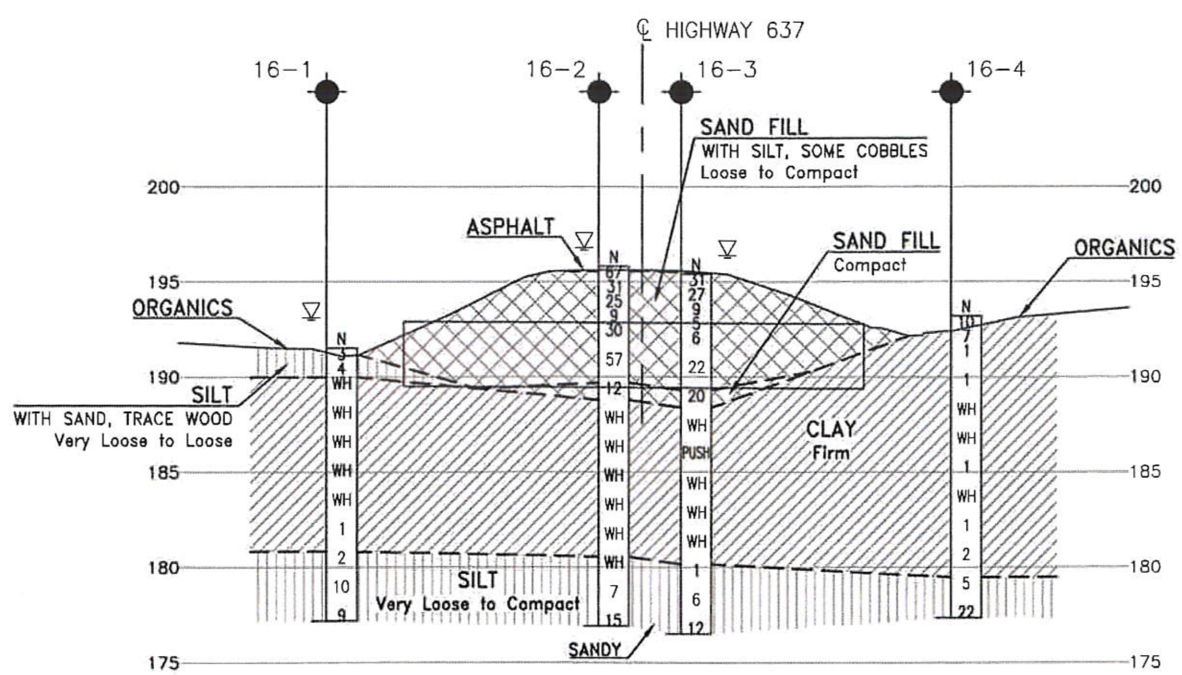
THURBER ENGINEERING LTD.



PLAN

16 0 16 32m

SCALE 1:800



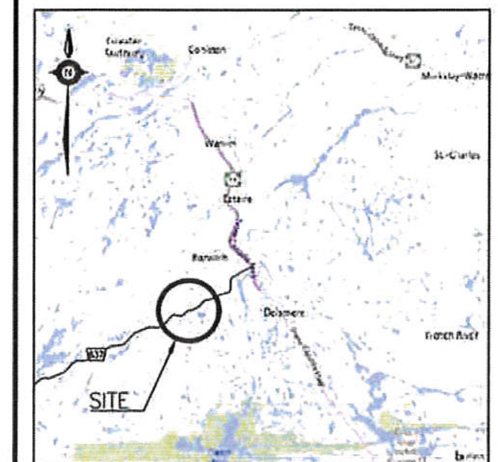
SECTION A-A'

8 0 8 16m

SCALE 1:400

LICENSED PROFESSIONAL ENGINEER
F. J. GRIFFITHS
Feb 7/17
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
Feb 7/2017
PROVINCE OF ONTARIO



KEYPLAN

LEGEND

⊕	Borehole
⊞	Test Pit
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
16-1	191.5	5 115 238.3	314 051.3
16-2	195.8	5 115 224.5	314 056.5
16-3	195.4	5 115 218.8	314 044.7
16-4	193.2	5 115 205.5	314 053.6
16-5	191.8	5 115 242.0	314 048.0

-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 13 coordinates.

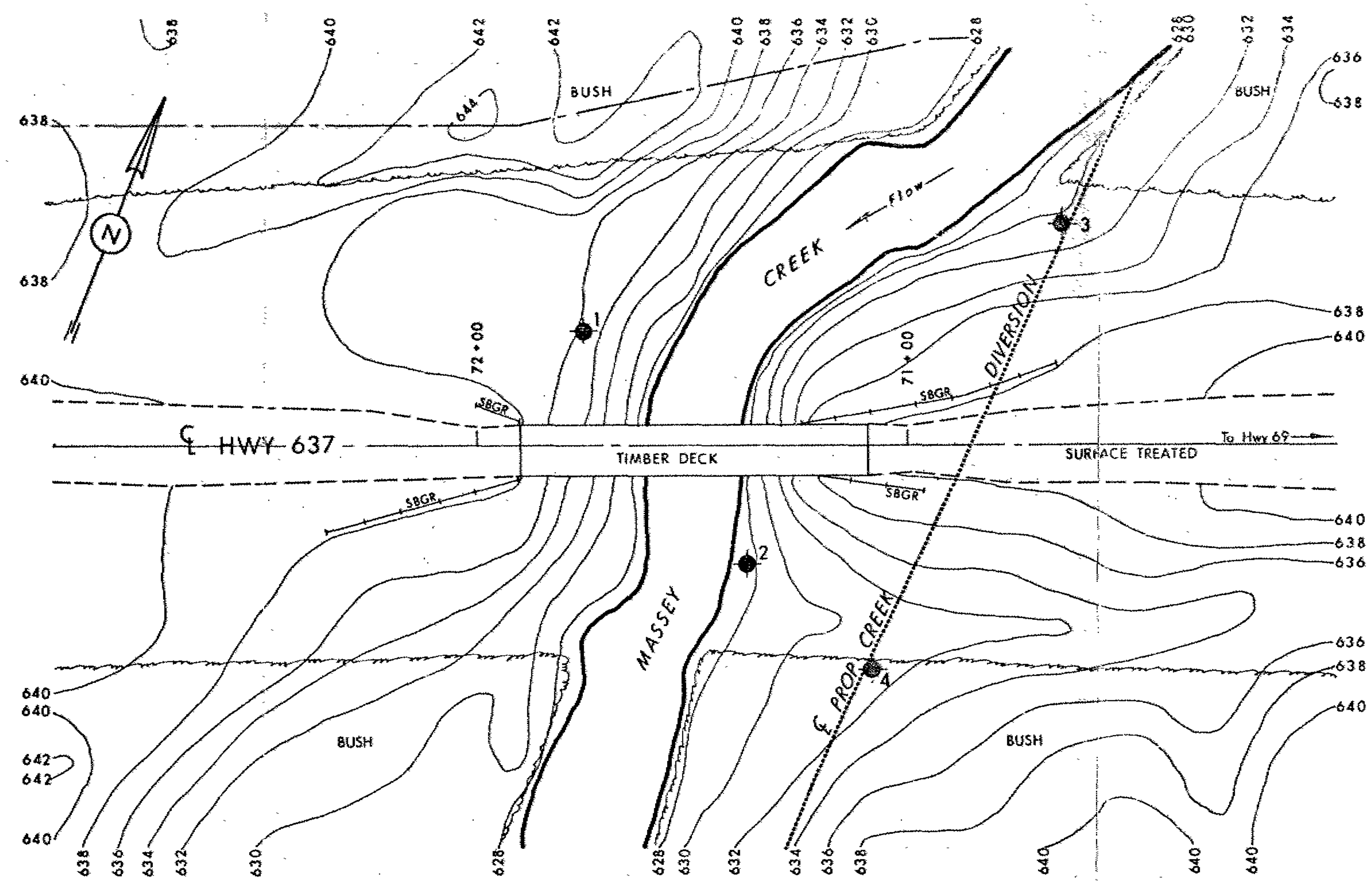
GEOCRES No. 41L-344

REVISIONS	DATE	BY	DESCRIPTION	
DESIGN CM	CHK FGJ	CODE	LOAD	DATE FEB 2017
DRAWN MFA	CHK CM	SITE 38S-126	STRUCT	DWG 1

FILENAME: H:\Drafting\12000\12030\TED-12030-PLSC.dwg
PLOTDATE: 2/7/2017 3:52 PM

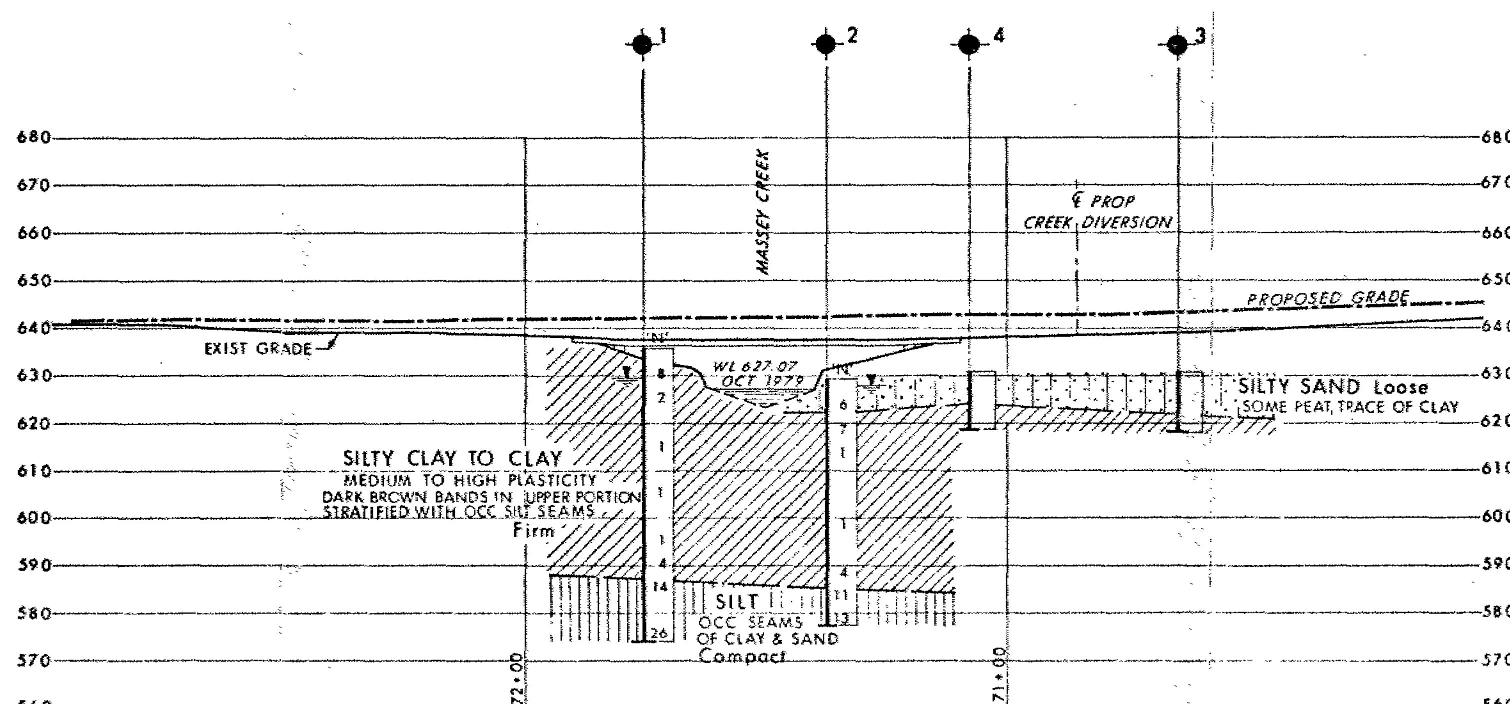
MINISTRY OF TRANSPORTATION, ONTARIO

CONT No WP No 99-79-01	
MASSEY CREEK	SHEET
BORE HOLE LOCATIONS & SOIL STRATA	



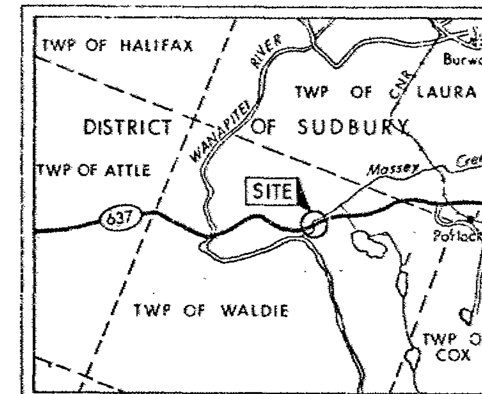
PLAN

SCALE 20 10 0 20 FT



℄ PROFILE-SEC HWY 637

SCALE 20 10 0 20 FT



KEY PLAN

2 1 0 2 Miles

LEGEND

- Bore Hole
- Dynamic Cone Penetration Test (Cone)
- Bore Hole & Cone
- 'N' Blows/ft (Std Pen Test 350 ft lbs energy)
- CONE Blows/ft (60° Cone, 350 ft lbs energy)
- WL at time of investigation Nov 1979
- WL NOT Established for B Holes 3 & 4

No	ELEVATION	STATION	OFFSET
1	635.8	71+75	27' RT
2	629.1	71+37	28' LT
3	631.0	70+64	52' RT
4	631.0	71+08	52' LT

-NOTE-

The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.

REVISIONS		
May 28, 80	R S	BORE HOLES 3 & 4 ADDED
DATE	BY	DESCRIPTION

GEOCRES No 41I-114

HWY No 637 (SECONDARY)		DIST 17
SUBM'D T K	CHECKED	DATE Jan 8, 1980	SITE 46-196
DRAWN R S	CHECKED		DWG 997901-A

REF No E-5094-1, Dec 1979

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:

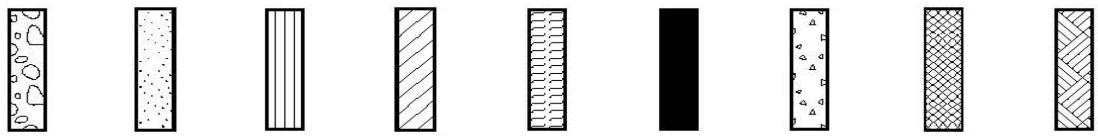
Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 63.5 kg hammer falling 0.76 m, required to drive a 50 mm O.D. split spoon sampler 0.3 m into undisturbed soil. For samples where insufficient penetration was achieved and N-value cannot be presented,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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 16-1

METRIC

GWP# 6359-14-00	LOCATION Hwy 637 - Massey Creek Culvert N 5 115 238.3 E 314 051.3	ORIGINATED BY CM
HWY 637	BOREHOLE TYPE Portable / NW Casing	COMPILED BY JM
DATUM Geodetic	DATE 2016.04.07 - 2016.04.07	CHECKED BY SP

ELEV / DEPTH	DESCRIPTION (SOIL PROFILE)	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
191.5							
0.0 / 0.1	**ORGANICS**						
	SILT with Sand, Very Loose to Loose, Brown to Grey	1	SS	3	191		
	trace wood	2	SS	4			0 28 62 10
190.0 / 1.5	**CLAY**, Firm, Grey	3	SS	WH	190		
		4	SS	WH	189, 188	wP–wL range plotted	0 0 37 63
		5	SS	WH	187, 186		
		6	SS	WH	185		
		7	SS	WH	184, 183		
		8	SS	1	182		

SHEAR STRENGTH kPa (field vane values plotted): 12.0, 10.0, 9.0, 7.0, 6.0, 6.7, 7.0, 7.0, 9.0, 9.0, 6.0

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

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

UNIT WEIGHT γ kN/m³

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 16-1

METRIC

GWP# 6359-14-00	LOCATION Hwy 637 - Massey Creek Culvert N 5 115 238.3 E 314 051.3	ORIGINATED BY CM
HWY 637	BOREHOLE TYPE Portable / NW Casing	COMPILED BY JM
DATUM Geodetic	DATE 2016.04.07 - 2016.04.07	CHECKED BY SP

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	SHEAR STRENGTH kPa (FIELD VANE, sensitivity)	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
	CLAY Firm Grey					+ 4.5						
					181							
180.8 10.7	**SILT** Very Loose to Compact Grey	9	SS	2			○		0	0	78	22
					180	+ 4.3						
						+ 4.0						
		10	SS	10	179		○					
					178							
		11	SS	9			○					
177.2 14.3	End of BH at 14.3 m artesian conditions >2.2 m above road surface											

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

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

REMARKS & GRAIN SIZE DISTRIBUTION (%): GR SA SI CL

ONTMT4S 12030 MASSEY CREEK.GPJ 2012TEMPLATE(MTO).GDT 14/2/17

+ 3, × 3: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 16-2

METRIC

GWP# 6359-14-00 | LOCATION Hwy 637 - Massey Creek Culvert N 5 115 224.5 E 314 056.5 | ORIGINATED BY CM

HWY 637 | BOREHOLE TYPE SSA / NW Casing | COMPILED BY JM

DATUM Geodetic | DATE 2016.06.07 - 2016.06.07 | CHECKED BY SP

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	SHEAR STRENGTH kPa	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
195.8								
0.0	**ASPHALT (30mm)**							
	SAND with SILT, Loose to Compact, Brown, **FILL**	1	SS	67				
		2	SS	31	195			
		3	SS	25	194			6 84 10 (SI+CL)
		4	SS	9	193			
		5	SS	30	192			
	-frequent Cobbles below 3.7 m							
		6	SS	57	191			
					190			
189.7 / 6.1	**SAND**, Compact, Brown, **FILL**	7	SS	12	189			
188.8 / 7.0	**CLAY**, Firm, Grey							
		8	SS	WH	188			0 0 36 64
						4.7 (field vane)		
					187	7.0 (field vane)		
		9	SS	WH	186	4.0 (field vane)		

Continued Next Page

+3, ×3: Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

ONTMT4S 12030 MASSEY CREEK.GPJ 2012TEMPLATE(MTO).GDT 14/2/17

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 16-2

METRIC

GWP# 6359-14-00	LOCATION Hwy 637 - Massey Creek Culvert N 5 115 224.5 E 314 056.5		ORIGINATED BY CM
HWY 637	BOREHOLE TYPE SSA / NW Casing		COMPILED BY JM
DATUM Geodetic	DATE 2016.06.07 - 2016.06.07		CHECKED BY SP

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

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
	CLAY Firm Grey							
		10	SS	WH	0	0	42	58
		11	SS	WH				
		12	SS	WH				
180.5 / 15.2	**SILT** Very Loose to Compact Grey	13	SS	WH				
		14	SS	7	0	0	89	11
	Sandy below 18.3 m	15	SS	15				
176.9 / 18.9	End of BH at 18.9 m artesian conditions >1.0 m above road surface							

Elevation scale: 185, 184, 183, 182, 181, 180, 179, 178, 177

Field vane sensitivity values (from top to bottom of plot): 5.1, 2.8, 3.7, 3.3, 4.4, 2.8, 3.8, 2.0, 2.7

+ 3, × 3 : Numbers refer to Sensitivity

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

ONTMT4S 12030 MASSEY CREEK.GPJ 2012TEMPLATE(MTO).GDT 14/2/17

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 16-3

METRIC

GWP# 6359-14-00 LOCATION Hwy 637 - Massey Creek Culvert N 5 115 218.8 E 314 044.7 ORIGINATED BY CM

HWY 637 BOREHOLE TYPE SSA / NW Casing COMPILED BY JM

DATUM Geodetic DATE 2016.07.07 - 2016.07.07 CHECKED BY SP

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	SHEAR STRENGTH kPa	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
195.4								
0.0	**ASPHALT (30 mm)**							
	SAND with SILT, Loose to Compact, Brown, **FILL**	1	SS	31	195		○	
		2	SS	27	194		○	
		3	SS	9			○	
	- Cobbles below 2.3 m	4	SS	5	193		○	
		5	SS	6	192		○	
					191			
		6	SS	22			○	1 88 11 (SI+CL)
					190			
189.3 / 6.1	**SAND**, Compact, Brown, **FILL**	7	SS	20	189		○	
188.4 / 7.0	**CLAY**, Firm, Grey				188			
		8	SS	WH			○	
					187	+ 4.7; + 4.7		
		9	TW	PUSH	186		⊢ >> 88	
						+ 7.2		

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 16-3

METRIC

GWP# 6359-14-00
LOCATION Hwy 637 - Massey Creek Culvert N 5 115 218.8 E 314 044.7
ORIGINATED BY CM
HWY 637
BOREHOLE TYPE SSA / NW Casing
COMPILED BY JM
DATUM Geodetic
DATE 2016.07.07 - 2016.07.07
CHECKED BY SP

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
	CLAY Firm Grey							
		10	SS	WH	0	0	45	55
		11	SS	WH				
		12	SS	WH	0	0	65	35
180.2 / 15.2	**SILT** Very Loose to Loose Grey	13	SS	1				
		14	SS	6				
	- Sandy below 18.3 m	15	SS	12	1	1	94	4
176.5 / 18.9	End of BH at 18.9 m artesian conditions >1.0 m above road surface							

Elevation scale: 185, 184, 183, 182, 181, 180, 179, 178, 177

Field vane shear strength (kPa) with sensitivity values plotted: 5.0, 8.7, 5.5, 7.0, 6.0, 5.3, 5.3, 4.5, 5.3

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE: 20 40 60 80 100
PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L
WATER CONTENT (%): 20 40 60
UNIT WEIGHT γ kN/m³
REMARKS & GRAIN SIZE DISTRIBUTION (%)

$+^3$, $\times^3$: Numbers refer to Sensitivity; 20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

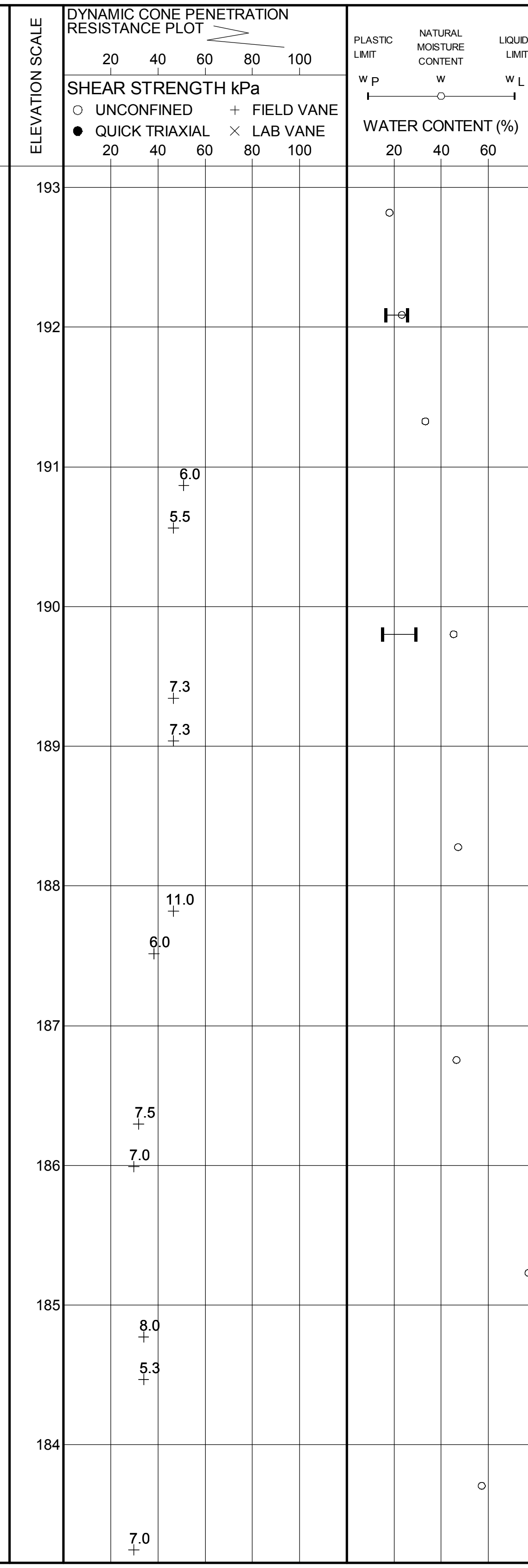
THURBER

RECORD OF BOREHOLE No 16-4

METRIC

GWP#	6359-14-00	LOCATION	Hwy 637 - Massey Creek Culvert N 5 115 205.5 E 314 053.6	ORIGINATED BY	CM
HWY	637	BOREHOLE TYPE	Portable / NW Casing	COMPILED BY	JM
DATUM	Geodetic	DATE	2016.05.07 - 2016.05.07	CHECKED BY	SP

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	GR	SA	SI	CL
193.2									
0.0 / 0.1	**ORGANICS**								
	CLAY Firm Grey	1	SS	10					
		2	SS	7		0	1	61	38
		3	SS	1					
		4	SS	1		0	6	64	30
		5	SS	WH					
		6	SS	WH					
		7	SS	1					
		8	SS	WH					



UNIT WEIGHT γ kN/m³

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

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

RECORD OF BOREHOLE No 16-4

METRIC

GWP# 6359-14-00	LOCATION Hwy 637 - Massey Creek Culvert N 5 115 205.5 E 314 053.6	ORIGINATED BY CM
HWY 637	BOREHOLE TYPE Portable / NW Casing	COMPILED BY JM
DATUM Geodetic	DATE 2016.05.07 - 2016.05.07	CHECKED BY SP

SOIL PROFILE — Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	CLAY Firm Grey		9	SS	1		0 0 51 49
			10	SS	2		
179.4 / 13.7	**SILT** Loose to Compact Grey		11	SS	5		
			12	SS	22		
177.3 / 15.8	End of BH at 15.8 m unable to take water level on completion due to wash boring						

Elevation scale: 183, 182, 181, 180, 179, 178

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

Field vane sensitivity values plotted: 7.3, 5.0, 5.3, 3.3, 6.7, 6.0

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L

WATER CONTENT (%): 20 40 60

UNIT WEIGHT γ kN/m³

+ 3, × 3: Numbers refer to Sensitivity

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

RECORD OF TEST PIT TP16-5

PROJECT : Hwy 637 - Massey Creek Culvert
LOCATION :
STARTED : 12.01.2017
COMPLETED : 12.01.2017

N 5 115 242.0 E 314 048.0

Project No. 6359-14-00
SHEET 1 OF 1
DATUM Geodetic

DEPTH SCALE (metres)	BORING METHOD	SOIL PROFILE – DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES – NUMBER	TYPE	BLOWS/0.3m	COMMENTS / DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100)	SHEAR STRENGTH: Cu, KPa (nat V - ✚, rem V - ●, Q - ✖, Cpen ▲; 40 80 120 160) / WATER CONTENT, PERCENT (wp, w, wl; 10 20 30 40)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		191.80							
		Vegetation and Rootmat		191.70 / 0.10							
		SILT with frequent cobbles and boulders brown -construction sign found buried within layer									
1				190.70 / 1.10							
		SILTY CLAY grey		190.10 / 1.70							
		SAND grey -water seepage at 1.9m		189.90 / 1.90							
2		**CLAY** grey firm									
3				188.40 / 3.40							
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											

GROUNDWATER ELEVATIONS

▽ SHALLOW/SINGLE INSTALLATION
WATER LEVEL (date)

▼ DEEP/DUAL INSTALLATION
WATER LEVEL (date)

LOGGED : CM
CHECKED : SP

THURBER

Appendix C.

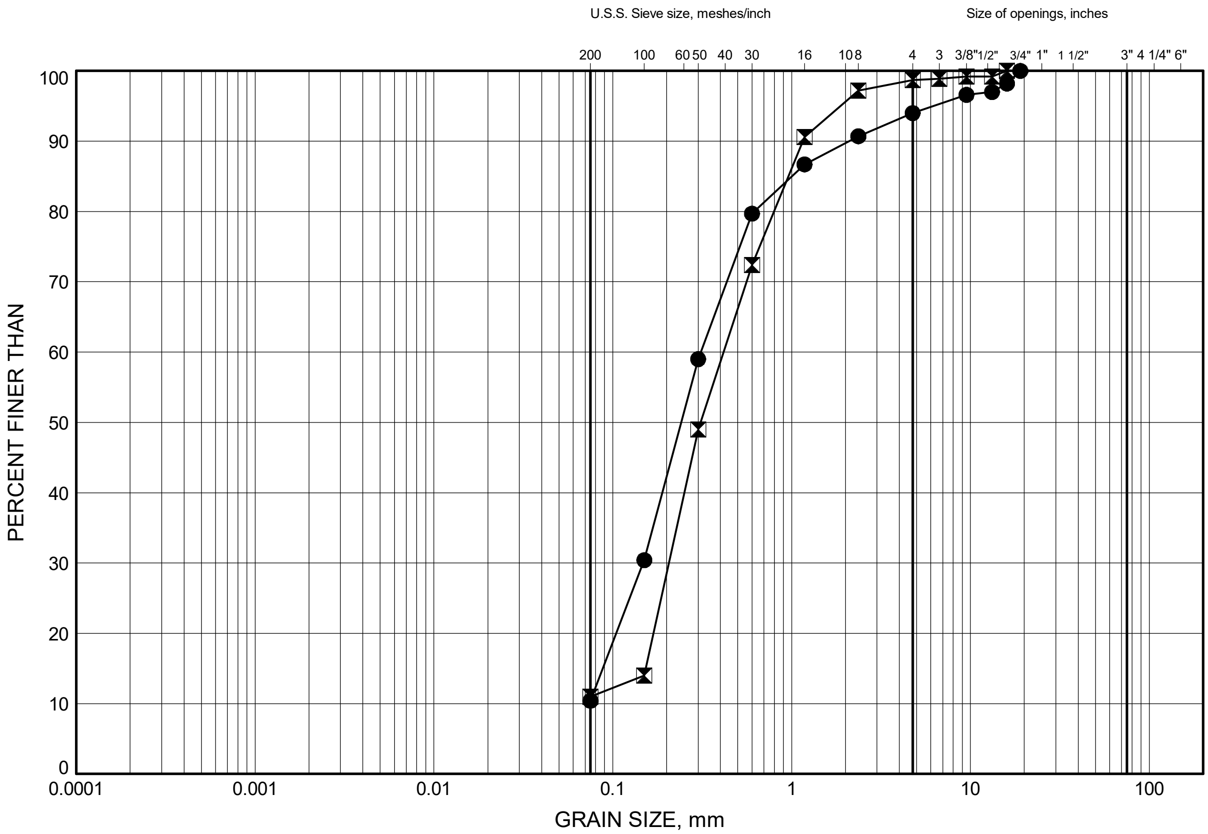
Laboratory Testing

Hwy 637 - Massey Creek Culvert

GRAIN SIZE DISTRIBUTION

FIGURE C1

FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-2	1.83	193.96
⧗	16-3	4.88	190.56

Date August 2016

GWP# 6359-14-00

THURBER

Prep'd SBP

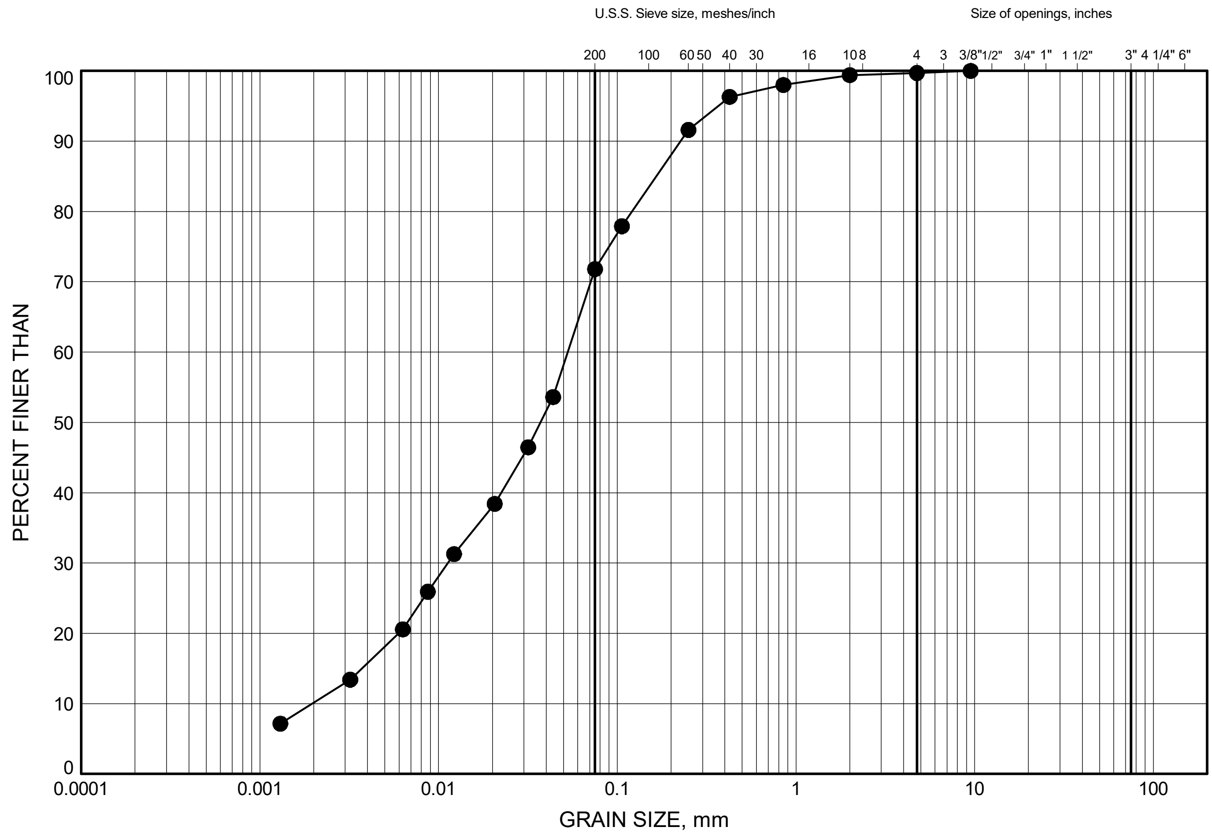
Chkd.

Hwy 637 - Massey Creek Culvert

GRAIN SIZE DISTRIBUTION

FIGURE C2

SILT with Sand



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-1	1.07	190.44

Date August 2016

GWP# 6359-14-00

THURBER

Prep'd SBP

Chkd.

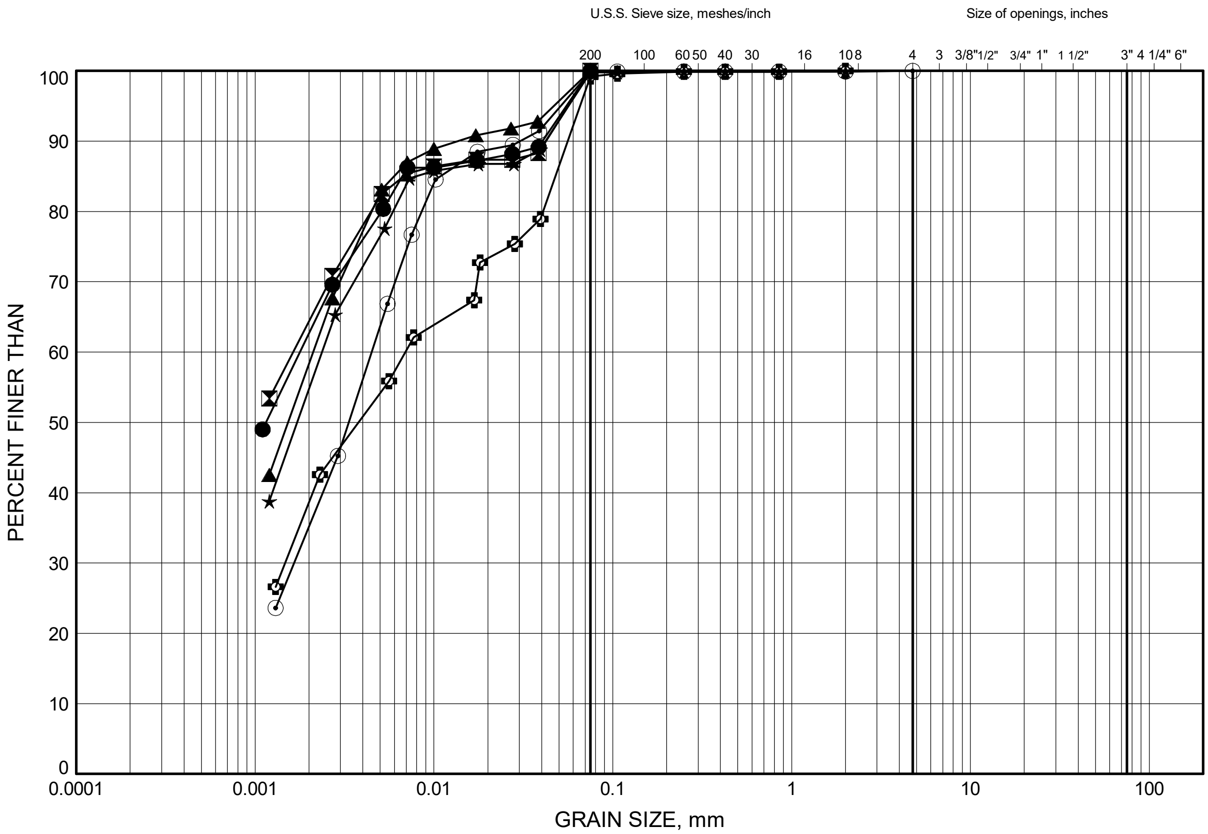
GRAIN SIZE DISTRIBUTION - THURBER 12030 MASSEY CREEK.GPJ 17/8/16

Hwy 637 - Massey Creek Culvert

GRAIN SIZE DISTRIBUTION

FIGURE C3

CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-1	3.35	188.15
⧗	16-2	7.92	187.86
▲	16-2	10.97	184.81
★	16-3	10.97	184.46
⊙	16-3	14.02	181.41
✪	16-4	1.07	192.09

Date August 2016

GWP# 6359-14-00

THURBER

Prep'd SBP

Chkd.

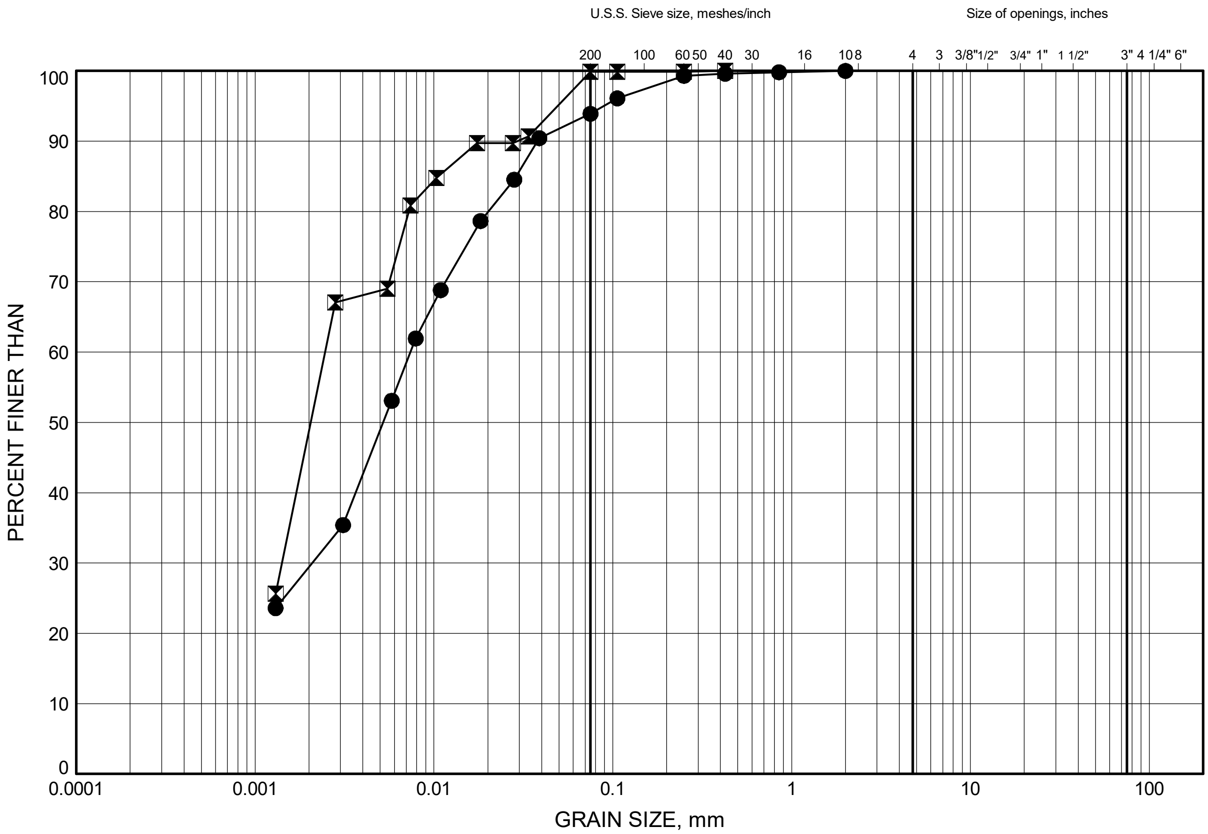
GRAIN SIZE DISTRIBUTION - THURBER 12030 MASSEY CREEK.GPJ 17/8/16

Hwy 637 - Massey Creek Culvert

GRAIN SIZE DISTRIBUTION

FIGURE C4

CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-4	3.35	189.80
⧗	16-4	10.97	182.18

Date August 2016

GWP# 6359-14-00

THURBER

Prep'd SBP

Chkd.

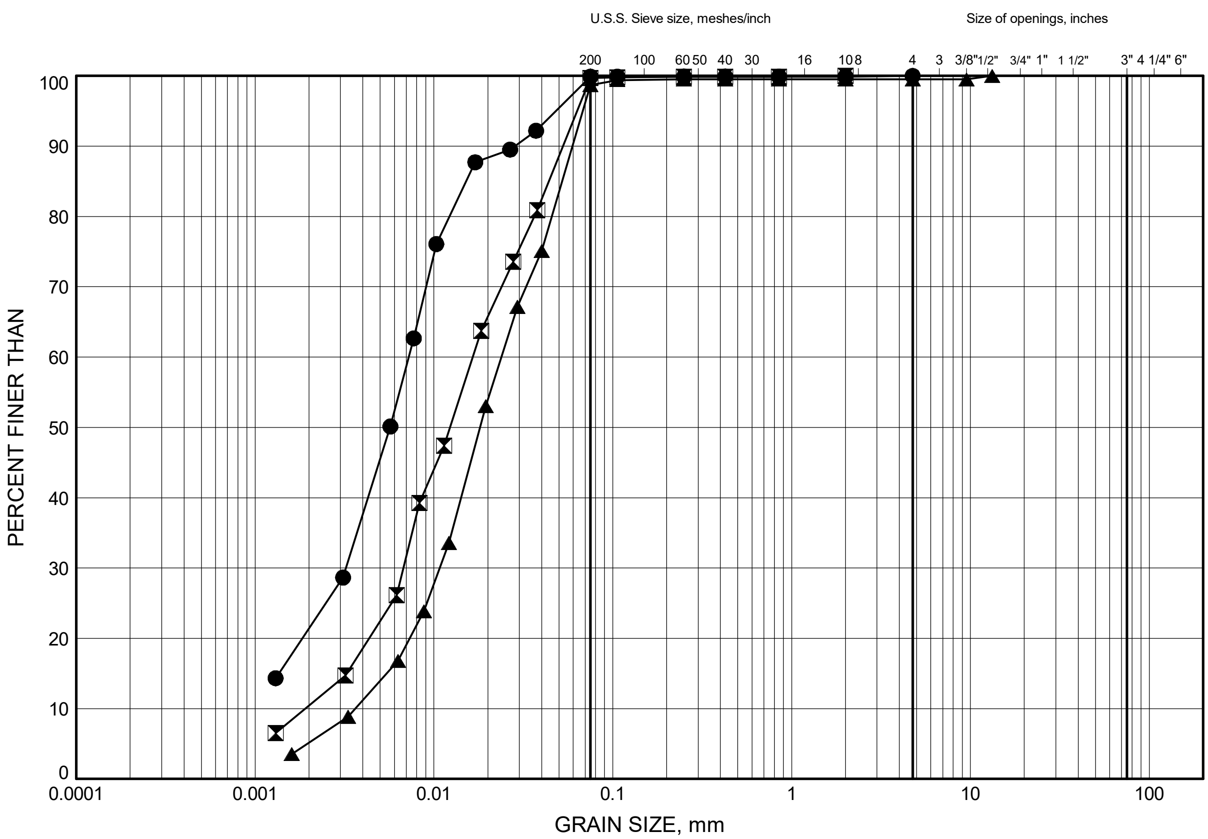
GRAIN SIZE DISTRIBUTION - THURBER 12030 MASSEY CREEK.GPJ 17/8/16

Hwy 637 - Massey Creek Culvert

GRAIN SIZE DISTRIBUTION

FIGURE C5

SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-1	10.97	180.53
⧗	16-2	17.07	178.72
▲	16-3	18.59	176.84

GRAIN SIZE DISTRIBUTION - THURBER 12030 MASSEY CREEK.GPJ 17/8/16

Date August 2016

GWP# 6359-14-00

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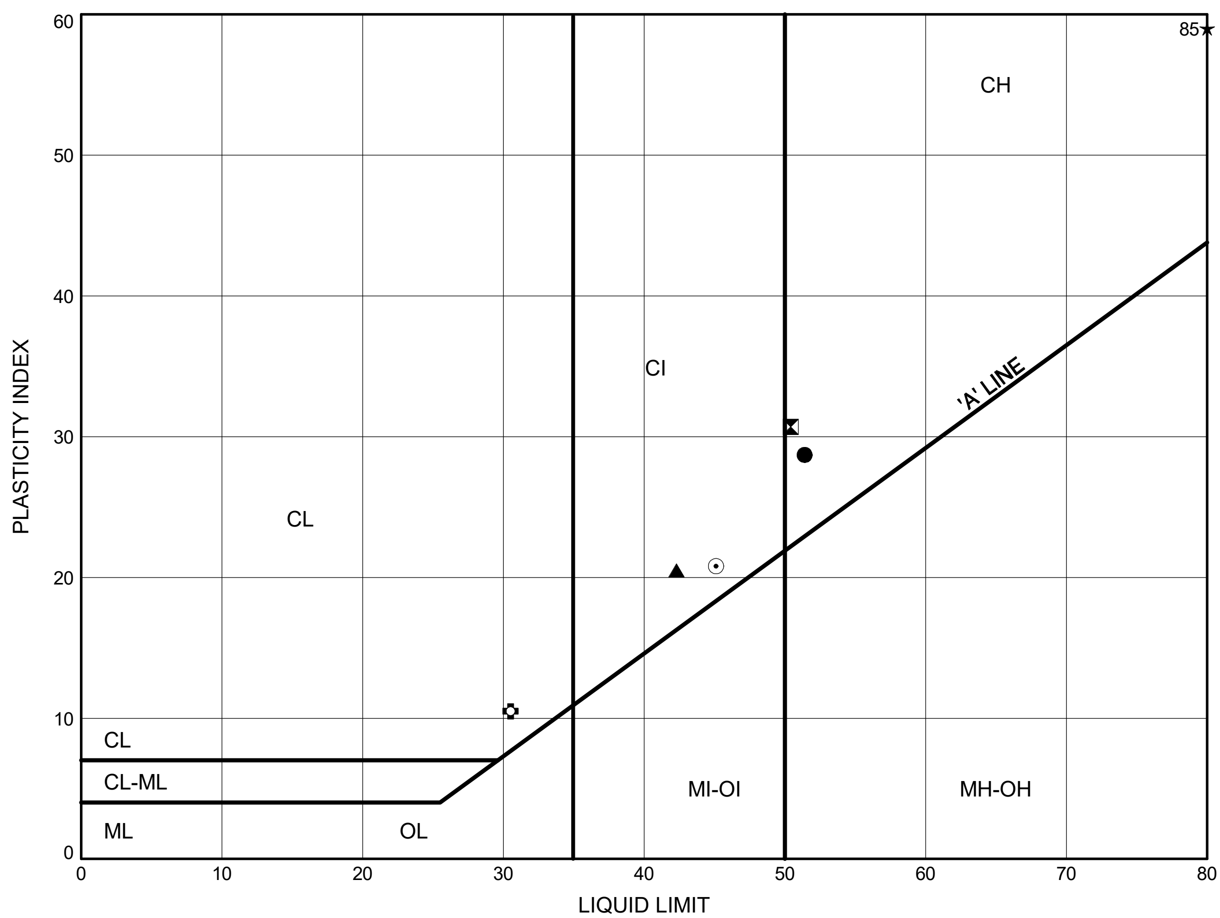
Chkd.

Hwy 637 - Massey Creek Culvert

ATTERBERG LIMITS TEST RESULTS

FIGURE C6

CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-1	3.35	188.15
⧗	16-2	7.92	187.86
▲	16-2	10.97	184.81
★	16-3	9.37	186.06
⊙	16-3	10.97	184.46
✪	16-3	14.02	181.41

THURBALT 12030 MASSEY CREEK.GPJ 17/8/16

Date August 2016

GWP# 6359-14-00

THURBER

Prep'd SBP

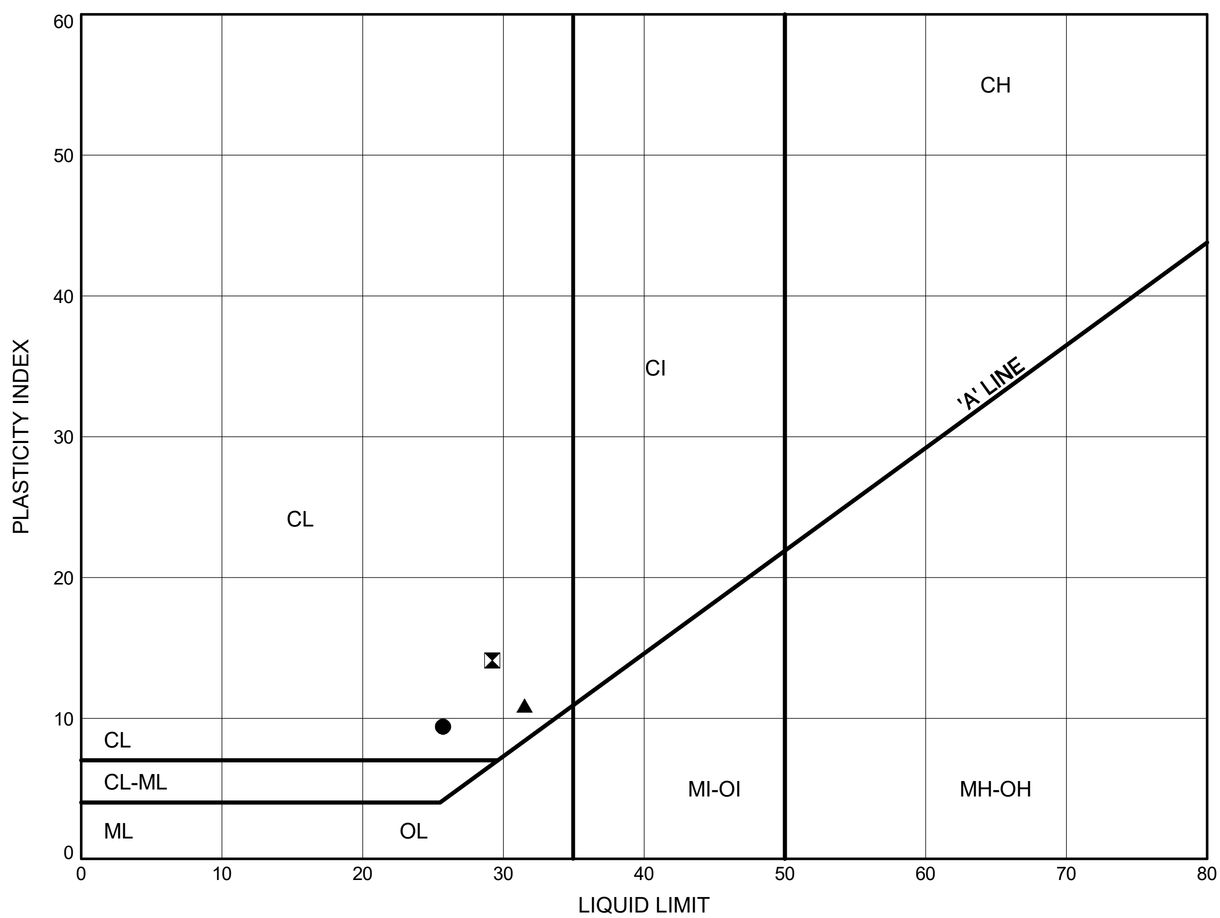
Chkd.

Hwy 637 - Massey Creek Culvert

ATTERBERG LIMITS TEST RESULTS

FIGURE C7

CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-4	1.07	192.09
⧗	16-4	3.35	189.80
▲	16-4	10.97	182.18

Date August 2016

GWP# 6359-14-00

THURBER

Prep'd SBP

Chkd.

THURBALT 12030 MASSEY CREEK.GPJ 17/8/16

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Certificate of Analysis

Thurber Engineering Ltd.

2460 Lancaster Rd, Suite 104
Ottawa, ON K1B4S5
Attn: Stephen Peters

Client PO:
Project: 12030
Custody: 27354

Report Date: 19-Aug-2016
Order Date: 15-Aug-2016

Order #: 1634061

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

Paracel ID	Client ID
1634061-01	BH16-02 SS7 20-221
1634061-02	BH16-04 SS1 0-21

Approved By: Mark Foto

Mark Foto, M.Sc.
Lab Supervisor

Analysis Summary Table

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	16-Aug-16	17-Aug-16
Conductivity	MOE E3138 - probe @25 °C, water ext	18-Aug-16	18-Aug-16
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	19-Aug-16	19-Aug-16
Resistivity	EPA 120.1 - probe, water extraction	18-Aug-16	18-Aug-16
Solids, %	Gravimetric, calculation	18-Aug-16	18-Aug-16

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

Report Date: 19-Aug-2016
Order Date: 15-Aug-2016
Project Description: 12030

	Client ID:	BH16-02 SS7 20-221	BH16-04 SS1 0-21	-	-
	Sample Date:	07-Jul-16	05-Jul-16	-	-
	Sample ID:	1634061-01	1634061-02	-	-
	MDL/Units	Soil	Soil	-	-
Physical Characteristics					
% Solids	0.1 % by Wt.	89.3	84.2	-	-
General Inorganics					
Conductivity	5 uS/cm	108 [1]	113 [1]	-	-
pH	0.05 pH Units	7.56 [1]	7.64 [1]	-	-
Resistivity	0.10 Ohm.m	92.4	88.3	-	-
Anions					
Chloride	5 ug/g dry	14 [1]	8 [1]	-	-
Sulphate	5 ug/g dry	8 [1]	7 [1]	-	-

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

Report Date: 19-Aug-2016
Order Date: 15-Aug-2016
Project Description: 12030

Method Quality Control: Blank

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	ND	5	ug/g						
Sulphate	ND	5	ug/g						
General Inorganics									
Conductivity	ND	5	uS/cm						
Resistivity	ND	0.10	Ohm.m						

Method Quality Control: Duplicate

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	53.2	5	ug/g dry	53.1			0.2	20	
Sulphate	72.7	5	ug/g dry	74.5			2.4	20	
General Inorganics									
Conductivity	2170	5	uS/cm	2190			0.6	6.2	
pH	7.61	0.05	pH Units	7.64			0.4	10	
Resistivity	44.5	0.10	Ohm.m	44.5			0.0	20	
Physical Characteristics									
% Solids	84.9	0.1	% by Wt.	84.5			0.4	25	

Method Quality Control: Spike

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	141	5	ug/g	53.1	88.4	78-113			
Sulphate	166	5	ug/g	74.5	91.6	78-111			

Qualifier Notes:

Login Qualifiers :

Sample - One or more parameter received past hold time -
Applies to samples: BH16-02 SS7 20-221, BH16-04 SS1 0-21

Sample Qualifiers :

1 : Holding time had been exceeded upon receipt of the sample at the laboratory.

Sample Data Revisions

None

Work Order Revisions / Comments:

None

Other Report Notes:

n/a: not applicable
ND: Not Detected
MDL: Method Detection Limit
Source Result: Data used as source for matrix and duplicate samples
%REC: Percent recovery.
RPD: Relative percent difference.

Soil results are reported on a dry weight basis when the units are denoted with 'dry'.
Where %Solids is reported, moisture loss includes the loss of volatile hydrocarbons.

Appendix D.

Site Photographs

Photo 1. Looking South.

Photo 2. Looking North.

Appendix E.

Supplementary Field Investigation

MEMORANDUM

To:	Steven Pilgrim, P.Eng. McIntosh Perry Consulting Engineers	Date:	February 7, 2017
From:	Fred Griffiths, P.Eng. (Reviewed By: P.K. Chatterji P. Eng.)	File:	12030

2015-E-0035
HIGHWAY 637 MASSEY CREEK CULVERT REPLACEMENT
WP 5380-11-01, SITE NO.: 46-196
SUDBURY

SUPPLEMENTARY FOUNDATION INVESTIGATION

A supplementary field investigation at the Massey Creek site was completed by Thurber Engineering Limited (Thurber) on January 12, 2017 in general accordance with the revised proposal letter dated November 22, 2016. The supplementary field investigation included a test pit adjacent to the north side of the highway embankment excavated to the approximate foundation level of the proposed culvert, observation of the subgrade response and surveying. The location of the test pit is shown schematically on Drawing 1 in Appendix A.

Thurber was on site and supervised the operation on a full time basis. The ambient air temperature during the time of the excavation was around -6°C. Some vegetation clearing was required to reach the toe of the embankment slope. The excavation was completed utilizing a 308D Cat excavator supplied and operated by Bruce Tait Construction Ltd. from Sudbury, Ontario. Elevations were surveyed on site using a Nikon Nivo Total Station with reference to the existing top of culvert on the north side of the embankment which is understood to be at elevation 192.93 m. The ground surface elevation at the excavation was determined to be 191.8 m. The excavation was advanced in stages to depths of 1.1 m, 2.1 m and 3.4 m below the existing ground surface (equivalent to ~0.5m below the invert of the proposed culvert). The top of the excavation had lateral dimensions in the order of ~5 to 6 m and the side walls were sloped to the base of the excavation. A wooden stake with a reflective survey target was installed into the base of the excavation with the use of the excavator and elevations were surveyed at regular intervals. Following completion of the monitoring, the excavation was backfilled in lifts with the excavated materials tamped with the excavator bucket. The cobbles and boulders were replaced near the surface.

The stratigraphy encountered within the excavation is detailed on the Test Pit Record provided in Appendix B. A 1.0 m thick layer of fill consisting of silt and frequent cobbles and boulders was observed below a thin roomat layer. A 0.6 m thick layer of silty clay soil was noted below the fill it was underlain by a 0.2 m thick sand layer over a deposit of firm clay extending to the base of the excavation at an underside depth of 3.4 m

Surface water was diverted away from the excavation via a hand dug trench. Groundwater seepage was noted from the sand layer at a depth of 1.7 m. The groundwater seepage continued throughout the time of the open excavation and the water level in the excavation rose at a rate of approximately 1 to 2 mm/minute.

The base of the excavation was observed to rise less than 5 mm during a period of 2.5 hours. It should be noted that approximately 40 minutes elapsed between the time of reaching the base of the excavation and the first survey measurement. The sidewalls of the excavation remained relatively stable except for localized areas affected by the infiltration of water. The base of the excavation was probed during the 2.5 hour period and the clay was observed to be consistently firm.

Elapsed Time (min)	Change in Elevation (mm)
0	0
20	1
40	2
160	2

We trust this information provided in this memorandum meets your present purposes. Please let us know if you have any questions or need additional information.

Thurber Engineering Ltd.

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

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

Attachments:

1. Drawing of test pit location
2. Photos

Photo 1. Looking northwest at the site conditions prior to the excavation.

Photo 2. Looking northwest at the site conditions following backfilling.

Photo 3. Excavation at 3.4 m depth.

Photo 4. Site setup showing the location of the excavation and survey equipment in relation to toe of highway embankment slope and culvert/creek alignment.

Photo 5. Excavated boulders.

Appendix F.

Foundation Comparison

COMPARISON OF ALTERNATIVE FOUNDATION TYPES

	Closed Culvert	***Circular Pipe Culvert***	***Open Bottom Culvert***
Advantages	i. Smaller magnitude of settlement than open footing culvert due to lower bearing stress on subgrade. ii. Relatively expedient installation if precast units.	i. Can tolerate larger magnitude of settlement than concrete (rigid frame) culverts). ii. Lower cost than concrete (rigid frame) culverts.	i. Relatively expedient installation if precast units are used.
Disadvantages	i. Requires compacted granular pad on subgrade.	i. CSP and HDPE pipes not as durable as concrete culverts. ii. Feasibility also depends on flow capacity and other hydraulic properties.	i. Compressible founding subgrade will provide very low geotechnical resistances. ii. Potential for post construction settlement. iii. Requires deeper excavation increasing excavation volume and dewatering concern
Recommendation	**Recommended**	**Generally Feasible**	**Not Recommended**
Risks/ Consequences	**i.** Groundwater control may require sheet pile enclosed excavation	**i.** Groundwater control may require sheet pile enclosed excavation	**i.** Groundwater control may require sheet pile enclosed excavation **ii.** Increased risk of basal instability of footing excavation due to artesian conditions in underlying silt
Relative Cost	**Medium**	**Lowest**	**High**

Appendix G.

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

August 16, 2016

Site: 46.1783 N, 80.8755 W User File Reference:

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)**
0.079	0.109	**0.108**	0.092	**0.076**	**0.046**	**0.024**	**0.0059**	**0.0026**	**0.063**	**0.062**

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

Ground motions for other probabilities:

Probability of exceedance per annum	0.010	0.0021	0.001
Probability of exceedance in 50 years	40%	10%	5%
Sa(0.05)	0.0098	0.030	0.048
Sa(0.1)	0.015	0.045	0.069
Sa(0.2)	0.017	0.047	0.070
Sa(0.3)	0.015	0.041	0.061
Sa(0.5)	0.012	0.034	0.050
Sa(1.0)	0.0058	0.020	0.030
Sa(2.0)	0.0024	0.0093	0.015
Sa(5.0)	0.0006	0.0020	0.0035
Sa(10.0)	0.0004	0.0010	0.0015
PGA	0.0084	0.026	0.039
PGV	0.0069	0.024	0.038

References

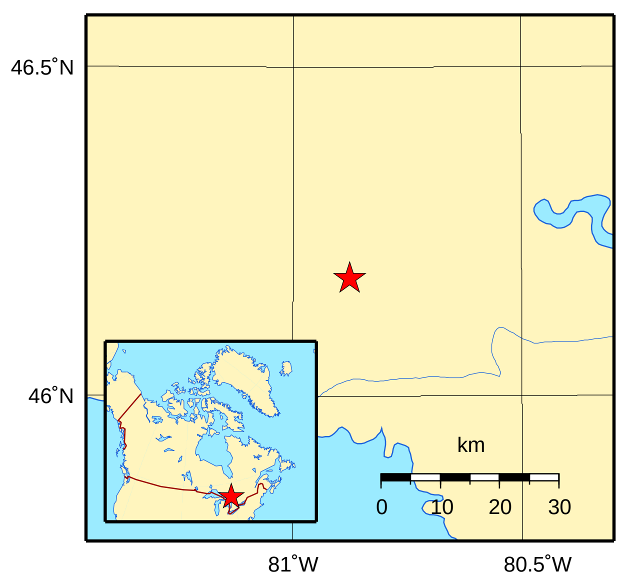
National Building Code of Canada 2015 NRCC no. 56190; Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

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

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

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

Aussi disponible en français



Appendix H.

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 209
   - OPSS 422
   - OPSS.PROV 501
   - OPSS.PROV 539
   - OPSS.PROV 804
   - OPSS 902
   - OPSS.PROV 1004
   - OPSS.PROV 1010
   - OPSS.PROV 1205

   - OPSD 208.010
   - OPSD 802.010
   - OPSD 803.010
   - OPSD 810.010
   - OPSD 3101.150

2. Suggested text for a NSSP on "Obstructions"

   "*Installation of roadway protection system could encounter obstructions such as cobbles and boulders embedded in the fill. Such obstructions may impede sheetpile installation and prohibit the sheetpiles from reaching the design depth of installation. The Contractor shall be prepared to remove, drill through and/or penetrate these obstructions and extend the sheetpiles to the design depths.*"

3. Suggested text for a NSSP on "Dewatering"

   "*The excavation will extend below the groundwater level and could lead to instability and sloughing of the sides of the excavation and heaving of the base, accompanied by loss in geotechnical resistance of the soils. Appropriate means of dewatering must be implemented to depress the groundwater level sufficiently below the base of the excavation to prevent any instability, sloughing, or heaving and so as to preserve the stability of the excavation and to allow the culvert subgrade preparation work to proceed in the dry. In addition, artesian conditions were observed in a lower silt layer at this site. Temporary dewatering measures will be required to remain operational during construction until the culvert is installed and backfilled*"