



**THURBER** ENGINEERING LTD.



**FOUNDATION INVESTIGATION AND DESIGN REPORT  
HIGHWAY 11 MIGNET CREEK CULVERT REPLACEMENT  
20.1 KM NORTH OF HIGHWAY 11/HIGHWAY 17 JUNCTION  
NIPIGON, ON  
SITE NO.: 48C-337/C**

**4015-E-0015, ASSIGNMENT NO. 3  
GWP 6316-14-00**

Geocres No.: 52H-42

Report to:

**McIntosh Perry Consulting Engineers Ltd. / LEA Consulting Ltd.  
JOINT VENTURE**

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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 11 crossing of Mignet Creek, GWP 6316-14-00. The structure is located approximately 20.1 km north of the Junction of Highway 11 and Highway 17. Thurber Engineering Limited (Thurber) carried out the current investigation as a sub-consultant to McIntosh Perry Consulting Engineers Ltd. - LEA Consulting Ltd. Joint Venture (MPCE-LEA) under Agreement No. 4015-E-0015, Assignment No. 3.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide a borehole location plan, records of boreholes, stratigraphic profile, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions influencing design and construction was developed in the course of the current investigation. No previous foundation investigation information was available for the subject culvert site.

**2 SITE DESCRIPTION**

The existing culvert is a cast-in-place rigid frame concrete culvert located near Sta. 14+888 on Highway 11 in the township of Ledger. The culvert is reported to be 3.0 m wide by 1.9 m high and approximately 48 m long with a generally east to west alignment. The flow through the culvert is to the west.

At the location of the culvert, Highway 11 is a two-lane highway with a rural cross-section and gravel shoulders. The road surface of the Highway 11 embankment is approximately 8.0 m above the top of the culvert at an elevation of 238.4 m. The existing slopes are inclined at approximately 1.8H:1V and 2.0H:1V for the west and east embankment slopes, respectively. Steel cable guiderails are present on both sides of the highway in the area of the culvert. The land adjacent to the highway is undeveloped with vegetation consisting of grasses on the upper embankment slopes and with shrubs and trees located further from the highway. Traffic volumes are understood to be 1650 AADT (2010).

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 August 13<sup>th</sup> and August 17<sup>th</sup>, 2016. Drilling consisted of advancing four boreholes identified as MC16-1 through MC16-4. The drilling was carried out using portable tripod equipment for off road boreholes MC16-1 and MC16-4, and a truck-mounted CME 750 drill for the on-road boreholes MC16-2 and MC16-3. 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). Borehole MC16-1 and MC 16-4 which were drilled with a portable tripod equipment utilized a half-weight hammer for SPT testing. The boreholes were sampled to depths ranging from 8.9 to 21.9 m (elev. 216.4 to 219.5 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 for further laboratory examination and testing. Following completion of the field investigation the boreholes were backfilled in general accordance with MOEE requirements (O.Reg. 903).

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.

### **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. Two samples of soil recovered from within the boreholes were selected and submitted for analytical testing of corrosivity parameters and sulphate content. All laboratory test results from the field investigation 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 sandy silt over a clay deposit over a silty sand deposit. A layer of topsoil was present at the surface of the inlet off-road borehole. Bedrock was not encountered within the depth of investigation.

## 5.1 Topsoil

Borehole MC16-4 was drilled adjacent to the culvert inlet. A 150 mm thick layer of topsoil was identified at the surface of the borehole.

## 5.2 Embankment

### 5.2.1 Asphalt

Boreholes MC16-2 and MC16-3 were drilled through the exiting Highway 11 embankment and encountered a layer of asphalt varying in thickness from 100 to 175 mm.

### 5.2.2 Fill: Sand

Below the asphalt structure within the on-road boreholes was a layer of granular fill consisting of silty sand some gravel, and occasional cobbles. The granular fill had an underside depth of 6.4 m (elev. 231.9 to 232.0 m) below the existing roadway surface.

SPT test N-values in the granular fill ranged from 14 to 89 blows indicating a relative density of compact to very dense. Recorded moisture contents ranged from 2 to 11%.

Gradation analyses were completed on four samples of granular 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 SM material.

Soil Particle	Percentage (%)
Gravel	7 – 23
Sand	56 - 76
Silt and Clay	15 - 33

## 5.3 Silty sand

A native deposit of silty sand containing variable amounts of wood and organics was encountered at surface or immediately below the surficial topsoil in the off-road boreholes with a thickness ranging from 0.4 to 1.1 m.

SPT tests in Boreholes MC16-1 and MC16-4 gave N-values of 6 to 18 blows. The recorded moisture contents were 7 to 30%.

A gradation analysis was completed on one sample of the silty sand. The grain size distribution curve for this sample is included in Figure C2 of Appendix C. The results of the test are summarized below and are presented on the corresponding Record of Borehole sheets in Appendix B.

Soil Particle	Percentage (%)
Gravel	0
Sand	54
Silt	38
Clay	8

#### 5.4 Sandy Silt

A deposit of silt was encountered below the silty sand in both off-road boreholes, and below the embankment fill in both on-road boreholes. This layer ranged from a silt with sand in the inlet borehole (MC16-4) to sandy silt in the three remaining boreholes. This layer contained trace amounts of wood and organics. The deposit ranged from 2.4 to 6.0 m thick with base elevations ranging from 223.6 to 228.1 m.

SPT tests gave N-values ranging from 9 to 29 blows indicating a loose to compact relative density. The recorded moisture contents typically ranged between 12 to 39%. A higher moisture content of 62% was found in SS2 of Borehole MC16-1, this high value is an indication of the organics found within the sample.

Gradation analyses were completed on four samples of the sandy silt deposit. The grain size distribution curves for these samples are included in Figure C3 of Appendix C. The results of the tests are summarized below and are presented on the corresponding Record of Borehole sheets in Appendix B.

Soil Particle	Percentage (%)
Gravel	0 – 5
Sand	21 – 50
Silt	29 – 58
Clay	16 – 24

#### 5.5 Clay

A deposit of clay was encountered beneath the silt in all boreholes. Organic and wood fiber layers between 50 mm and 75 mm thick were observed within Boreholes MC16-2 and MC16-3. The thickness of the deposit ranged from 0.6 to 6.0 m (base elev. 221.4 to 224.4 m).

SPT tests performed within the clay deposit gave N-values typically ranging from 6 to 14 blows. The clay is firm to stiff in consistency. The recorded moisture contents varied from 17 to 46%.

Gradation analyses were completed on five samples of the clay deposit. The grain size distribution curves for these samples are included in Figure 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.

Soil Particle	Percentage (%)
Gravel	0
Sand	0 – 5
Silt	60 – 84
Clay	16 – 40

Atterberg Limit testing was completed on four samples of the clay deposit. The results are summarized on the Record of Borehole sheets in Appendix B and the Atterberg Limit graphs are included in Figure C6 of Appendix C. The laboratory results are summarized below and indicate that the clay is of low plasticity (CL).

Parameter	Value
Liquid Limit	25 – 28
Plastic Limit	16 – 18
Plasticity Index	8 - 12

## 5.6 Sand

A sand deposit was encountered directly below the clay in all boreholes. The deposit was a sand with silt in all boreholes except MC16-4 where it was noted as a sand trace silt. Occasional cobbles were noted within the sand layer. All boreholes were terminated in the sand layer at a depth ranging from 8.9 to 21.9 m (elev. 216.4 to 219.5 m) below the existing ground surface.

SPT tests gave N-values ranging from 29 to 59 blows indicating a compact to very dense relative density. The moisture content within the sand deposit ranged between 2 to 25%

A gradation analysis was completed on one sample of the sand deposit. The grain size distribution curve for this sample is included in Figure C5 of Appendix C. The result of the test is summarized below and is presented on the corresponding Record of Borehole sheets in Appendix B.

Soil Particle	Percentage (%)
Gravel	10
Sand	84
Silt & Clay	6

## 5.7 Groundwater

Water inflow was noted in the silt layer (elev. 226.9 to 225.4 m) during drilling of Borehole MC16-4. It is expected that the groundwater level will largely be controlled by the water level in Mignet Creek, which is identified on the base plans as being at elevation 227.20 m at the culvert outlet in September 2014. It should be noted that the groundwater level 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.

## 6 MISCELLANEOUS

Borehole locations were selected relative to existing site features and the proposed foundation locations and the drilled locations were measured by Thurber after completion of drilling. Ground surface elevation were interpreted from topographic drawings provided by McIntosh Perry.

RPM Drilling Limited from Thunder Bay, Ontario supplied the portable tripod, and CME750 drilling equipment. The drilling subcontractor conducted the drilling, soil sampling, in-situ testing and borehole decommissioning.

The field investigation was supervised on a full-time basis by Tim Sivak, of Thurber. Overall supervision of the investigation program was conducted by Mr. Stephen Peters, P.Eng.

Routine geotechnical laboratory testing was completed by Thurber's laboratory in Oakville, Ontario. Analytical testing was completed by AGAT Laboratories in Mississauga, Ontario. Interpretation of the factual data and preparation of this report were carried out by Mr. Paul Carnaffan, P.Eng. and Mr. Justin Gray, E.I.T. 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 from Part 1 and presents geotechnical recommendations to assist the design team in designing a suitable foundation for the proposed replacement of the existing Mignet Creek culvert crossing Highway 11. The discussion and recommendations presented in this report are based on the information provided by MPCE-LEA and on the factual data obtained during the course of the investigation.

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

The existing culvert, conveying Mignet Creek under Highway 11, is a cast-in-place rigid concrete culvert approximately 48 m long with an opening of 3.0 by 1.9 m. The top of the existing culvert is reported to be at elevation 229.01 m and 228.76 m at the inlet and outlet respectively. The embankment fill height above the culvert is in the order of 9.0 m. No previous foundation investigation information for the subject culvert was available in the Geocres Library.

Thurber Engineering Limited (Thurber) carried out the current investigation as a sub-consultant to MPCE-LEA under Contract No. 4015-E-0015, Assignment No. 3.

**7.1 Proposed Structure**

The General Arrangement (GA) drawing, dated April 2017, indicates replacement of the existing culvert with twin 2.4 x 2.4 m (3.0 m exterior width) concrete box culverts with invert elevations of 227.176 and 226.929 m for the inlet and outlet of the culverts, respectively. One of the new culverts is proposed to be constructed north of the existing culvert alignment with a separation of 1.2 m from the current culvert. The existing culvert is indicated to remain operational during installation of the first of the new twin box culverts. Flow will then be diverted through the new culvert during installation of the second box culvert along the

existing culvert alignment. The second culvert is shown to be installed along the same alignment of the existing culvert with a 1.5 m separation from the first culvert.

## **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 ( $\Psi$ ) 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). The seismic hazard for this site has been obtained from the GSC calculator. The data includes a peak ground acceleration (PGA), peak ground velocity (PGV) and the 5% spectral response acceleration values ( $S_a(T)$ ) for the reference ground condition (Site Class C) for a range of periods (T) and for a range of return periods including 475-year, 975-year and 2475-year events. The GSC seismic hazard calculated data sheet for this site is included in Appendix F

The site coefficients used to determine the design spectral acceleration and displacement values are a function of the Site Class and the peak ground acceleration (PGA), which is 0.034 at this site.

### **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 soil profile at this site has been classified as a Site Class D in accordance with Section 4.4.3.2 of the CHBDC (S6-14).

### **8.3 Seismic Liquefaction**

Based on the subsurface condition 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**

### **9.1 Culvert Type and Foundation Alternatives**

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

- Circular Pipes (Concrete, HDPE, Steel)  
From a foundation engineering perspective, pipe culverts are a technically feasible alternative, provided that other design issues including flow capacity, hydraulic properties and durability can be satisfied. Pipe culverts would allow the use of trenchless installation methods.
- Open Bottom Culvert (Box, Arch)  
Open bottom culverts are not recommended for this site from a foundation engineering perspective since the post construction settlement in the foundation clay from this type of culvert would be greater than alternative options and would also require greater excavation and dewatering efforts during construction to place the foundation in the dry.
- Closed Bottom Culvert (Box)  
Precast segmental box culvert in an open cut construction is considered a feasible option from a foundation engineering perspective. Precast sections, rather than cast-in-place construction, can be installed expediently with less potential for disturbance of the founding soils during installation. However, the open cut construction would require a very deep excavation through the embankment and a robust roadway protection design.

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

### **9.2 Construction Methodology Alternative**

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

- Open Cut with Full Road Closure and Detour  
Installation of a new culvert using open cut techniques and a full road closure would allow for an expedited construction schedule and could reduce costs associated with requiring roadway protection and water diversion. However, it is understood that a detour is not available and therefore this option is not feasible.
- Open Cut with Staged Temporary Widening  
Widening of the existing highway and/or construction of a detour embankment to accommodate a temporary traffic passage is considered feasible from a geotechnical perspective. However, placement of additional fill will require additional field investigation to assess the impacts of an increase in loading on the

subgrade soils and the potential for time-dependant settlement for both the temporary detour and existing embankment. Additionally, a review of the detour embankment slope stability and the requirement for property acquisition will need to be assessed to complete this option.

- Open Cut with Staged Temporary Lowering and Temporary Protection System

The use of open cut techniques in conjunction with lowering and staged culvert replacement is a potentially feasible construction staging option from a geotechnical perspective. This option will require roadway protection, as discussed further in Section 11.2, installed along the embankment centerline to maintain a single lane of traffic flow along the current highway alignment. Cobbles were noted within the fill but did not impede drilling the contractor will need to consider the potential for cobbles/obstructions in the embankment fill during the design and installation of roadway protection. Due to the required height, the roadway protection may need bracing such as struts, deadman and anchors to reduce lateral deflections as well as adequate embedment depth of the protection system.

- Trenchless Techniques

Trenchless techniques would have the advantage of minimum disruption to traffic and would avoid a large excavation through the existing highway embankment. However, the size and type of replacement culvert, potential to encounter obstruction within the existing embankment fill, characteristics of the subgrade soils, and the topography of the surrounding terrain will need to be taken into consideration. Trenchless techniques are not recommended for this site.

### **9.3 Recommended Approach for the Culvert Replacement**

Foundation design aspects for a 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.

From a foundation engineering perspective, the alternative of replacing the existing culvert with a closed box culvert using open cut techniques with staged construction and a temporary embankment lowering in conjunction with temporary protection systems is the recommended culvert replacement option. This report will focus on providing foundation recommendations on the design and construction for a closed box culvert.

## 10 FOUNDATIONS DESIGN RECOMMENDATIONS

### 10.1 Culvert Foundation Bearing Resistances

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

The recommended geotechnical resistances for twin 3.0 m wide pre-cast concrete box culverts installed at an invert elevation of 227.176 and 226.929 m for the inlet and outlet of the culvert, respectively on an undisturbed native subgrade are as follows:

- Factored Geotechnical Resistance at ULS of 350 kPa
- Factored Geotechnical Resistance at SLS of 220 kPa

The factored geotechnical resistances include the following factors:

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

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

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 ultimate coefficient of friction of 0.45.

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

### 10.2 Subgrade Preparation, Bedding and Backfilling

All organics, existing fill, soft or loose deposits, disturbed soils, alluvial deposits 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. The exposed subgrade must be inspected to confirm that the subgrade is suitable and uniformly competent. Any soft or organic materials at the subgrade level should be sub-excavated and backfilled and compacted as per OPSS.PROV 501 with granular fill consisting of OPSS.PROV 1010 Granular A 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.

Given the 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 over excavation to allow placement of a mud slab 100 mm thick beneath the 300 mm thick Granular A bedding layer. The mud slab should be placed as soon as possible after reaching the subgrade level and following confirmation of QVE acceptance. An NSSP is provided in Appendix G to include in the contract documents to alert the Contractor to the sensitive nature of the foundation soils.

Dewatering will be required to prepare the subgrade in the dry. Please refer to Section 11.3 for additional comments on groundwater and surface water control.

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

Culvert backfill above the granular cover should be in accordance with OPSS 902 and consist of material meeting the requirements of OPSS Select Subgrade Material or better and should be compacted in regular lifts as per OPSS.PROV 501. Heavy compaction equipment, used adjacent to structure, must be restricted in accordance with OPSS.PROV 501. Care must be exercised when compacting the fill adjacent to and above the culvert in order not to damage the culvert.

### **10.3 Frost Depth**

The depth of frost penetration at this site is 2.3 m. It is not necessary to found a closed box culvert at a depth below frost penetration. Backfill, cover and frost tapers should be as per OPSD 803.010. It is noted that the top of the culverts is below the depth of frost penetration and therefore a frost taper need not be incorporated into the cover material. Pavement reinstatement and transitions are addressed in the pavement design memorandum.

### **10.4 Embankment Design and Reinstatement**

#### **10.4.1 Embankment Reconstruction**

Embankment reconstruction after culvert replacement should be carried out in accordance with OPSS.PROV 206. The embankment should be reinstated with side slopes of 2H:1V (or flatter) if constructed using Select Subgrade Material (SSM) or Granular B Type I. It is understood that locally steeper slopes (between 1.5H:1V and 2H:1V) will be required to match the existing side slopes. In this case, Granular B Type II or rock fill should be used.

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 construction of embankment and cut slopes are carried out in accordance with recommendations provided within this report, the minimum required factor of safety will be maintained for seismic loading conditions.

#### 10.4.2 Embankment Settlement and Stability

The condition of the embankment slopes was examined in the field during the field investigation; no evidence of instability (tension cracks etc.) was noted, at that time.

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. Material stockpiling above the existing grades is a temporary construction measure and the stability implications are the responsibility of the Contractor. In addition, the Contractor's selection and placement of construction equipment (such as heavy cranes) are the Contractor's responsibility.

It is understood that no grade raise is anticipated along the alignment of Highway 11 and therefore negligible foundation settlement is expected to occur. Further assessment should be carried out where construction staging dictates the requirement for additional loading and the proximity of the temporary alignments.

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

### 10.5 Backfill and Earth Pressure

Lateral earth pressures parameters provided in Table 10-1 and Table 10-2 in the sections below are based on the assumption that the backfill is fully drained so that there are no unbalanced hydrostatic pressures. If adequate drainage cannot be confirmed, the potential for buildup of hydrostatic pressures should be considered.

#### 10.5.1 Static Lateral Earth Pressure Coefficients

Lateral earth pressures acting on structures should be computed in accordance with the CHBDC but generally are given by the 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)
$\gamma$	=	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. Typical earth pressure coefficients for backfill 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 $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$		OPSS SSM and Existing Silty Sand Fill $\phi = 30^\circ, \gamma = 21.0 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active, $K_A$ (Yielding Wall)	0.27	0.40	0.31	0.48	0.33	0.54
At Rest, $K_O$ (Non-Yielding Wall)	0.43	-	0.47	-	0.50	-
Passive, $K_P$ (Movement towards Soil Mass)	3.7	-	3.3	-	3.0	-
Soil Group(*)	"medium dense sand"		"loose to medium dense sand"		"loose sand"	

Note: (\*) 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 the Table 10-1 should be used.

#### 10.5.2 Combined Static and Seismic Lateral Earth Pressure Parameters

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

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

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

The coefficients of horizontal earth pressure for seismic loading presented in Table 10-2 may be used. The provided earth pressure coefficients are based on a Seismic Site Class D, PGA with a 2% probability of exceedance in 50 years of 0.034g (Geological Survey of Canada – Fifth Generation) and a F(PGA) of 1.29 as per Table 4.8 of the CHBDC (S6-14 update No. 1, April 2016).

**Table 10-2. Dynamic Earth Pressure Coefficients**

Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)
Active, $K_{AE}$ Yielding Wall	0.28	0.42	0.32	0.51
Active, $K_{AE}$ Non-Yielding Wall	0.30	0.45	0.33	0.54

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:

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

## 11 CONSTRUCTION CONSIDERATIONS

### 11.1 Excavation

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 clays above as well as the clay soils below the water table may be classified as Type 3 soil. The organic soils, native silts and any cohesionless soils below the groundwater level and alluvial deposits are classified as Type 4 soils. All excavation must not encroach within 1H:1V from the base of the excavation to the existing culvert foundation.

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 Contractor must consider the potential for unbalanced

lateral earth pressure on the existing and proposed culverts while installing the new culverts. The sides of temporary excavations must be sloped in accordance with the requirement of the OHSA. The Contractor should carry out a detailed embankment stability assessment prior to construction when the preferred culvert replacement strategy and methodology has been determined. Stockpiling or surface surcharge should not be allowed within a horizontal distance encompassed with a 1H:1V inclination from the perimeter of the base of the excavation

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. Design of the temporary protection system is the responsibility of the Contractor. Any protection system must be designed by a licensed Professional Engineer experienced in such design and retained by the Contractor. Further discussion is presented in Section 11.2.

## 11.2 Temporary Protection Systems

Temporary Protection Systems will be required during various stages of construction and must be implemented in accordance with OPSS.PROV 539 and designed for Performance Level 2 (maximum 25 mm horizontal deflection). The actual pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall and these factors must be considered when designing the shoring system. It is recommended that an NSSP be included in the tender documents to alert the Contractor to the height of the protection system required, potential for cobbles and boulders and obstructions within the fill and the potential need for deadman tie-backs, struts and/or raker supports to achieve the specified performance level. The protection system should be installed at a sufficient distance away from the new culvert to limit the disturbance to the subgrade associated with removal of the protection system. Alternatively, the sheet pile could be left in place and cut off at or below 2.5 m beneath the finished pavement grade. Due to possible disturbance to the subgrade soils, vibration must not be used for installation or extraction of sheet piling.

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 sandy silt and clay soils are given below:

$$\begin{aligned}\gamma &= 18 && (\text{kN/m}^3, \text{ bulk unit weight of soil}) \\ K_A &= 0.39 \\ K_P &= 2.6\end{aligned}$$

Lateral earth pressure coefficients for the native sand soils beneath the clay are given below:

$$\begin{aligned}\gamma &= 21 && (\text{kN/m}^3, \text{ bulk unit weight of soil}) \\ K_A &= 0.31 \\ K_P &= 3.3\end{aligned}$$

The design of roadway protection is the responsibility of the Contractor. The designer of the roadway protection system should ensure that the penetration depth is sufficient to provide base fixity and the design should incorporate traffic loading and surcharge loading

due to construction equipment and operations. A suitable anchor or bracing system may need to be incorporated into the roadway protection design. All shoring should be designed by a licensed Professional Engineer experienced in such designs.

### **11.3 Surface and Groundwater Control**

Culvert construction, subgrade preparation and placement and compaction of granular bedding must be carried out in the dry. Provided the existing culvert is maintained operational during construction, a temporary flow passage is not expected to 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 base heave/boiling and sloughing of the soil below the water level, making it difficult to maintain a dry, sound base on which to work. 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. Dewatering systems should be designed, operated and removed in accordance with OPSS.PROV 517.

Based on the groundwater and soil conditions, special attention must be paid to construction dewatering. It is recommended that excavations 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. As indicated in Section 10.2, a mud slab should be poured with lean mix concrete to protect the exposed subgrade surface within the excavation from disturbance.

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

### **11.4 Scour Protection and Erosion Control**

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

Typically, rock protection should be provided over all earth surfaces subjected to flowing water. 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 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.

## **12 CONSTRUCTION CONCERNS**

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

- Disturbance of the soil subgrade. Where fine-grained soils are exposed at the culvert subgrade following excavation, 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 subgrade conditions
- Cobbles, boulders, or other buried obstructions may be encountered in the existing embankment fill. Wood was also noted below the fill. Obstructions could interfere with excavation and/or roadway protection installation. 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 these 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 personnel 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 Mr. Paul Carnaffan, 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.

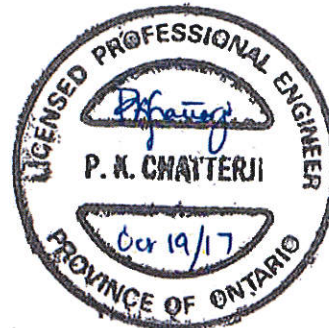
Thurber Engineering Ltd.  
Report Prepared By:



Stephen Peters, P.Eng.  
Geotechnical Engineer



Paul Carnaffan, P.Eng.  
Principal, Branch Manager  
Senior Geotechnical Engineer

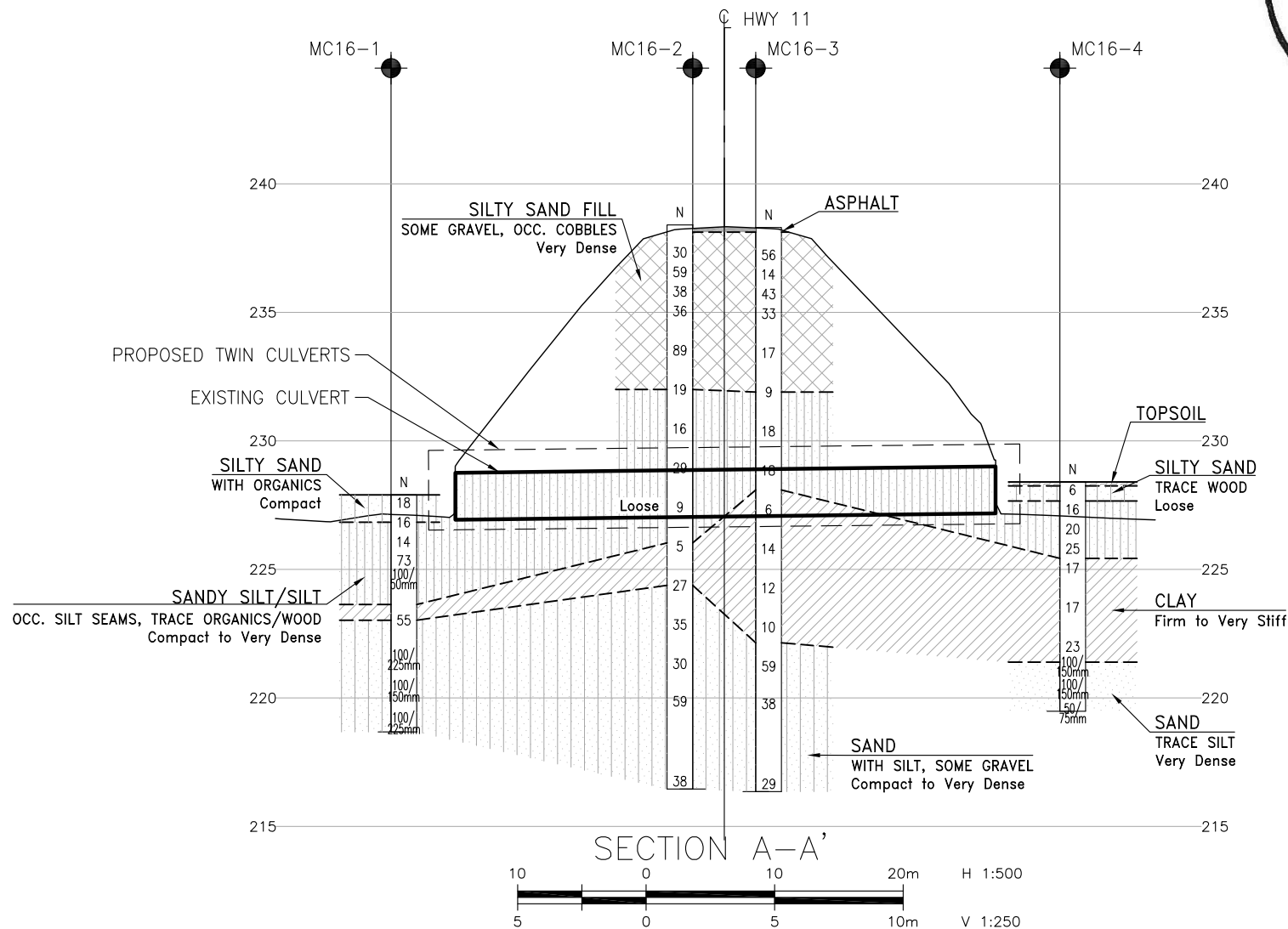
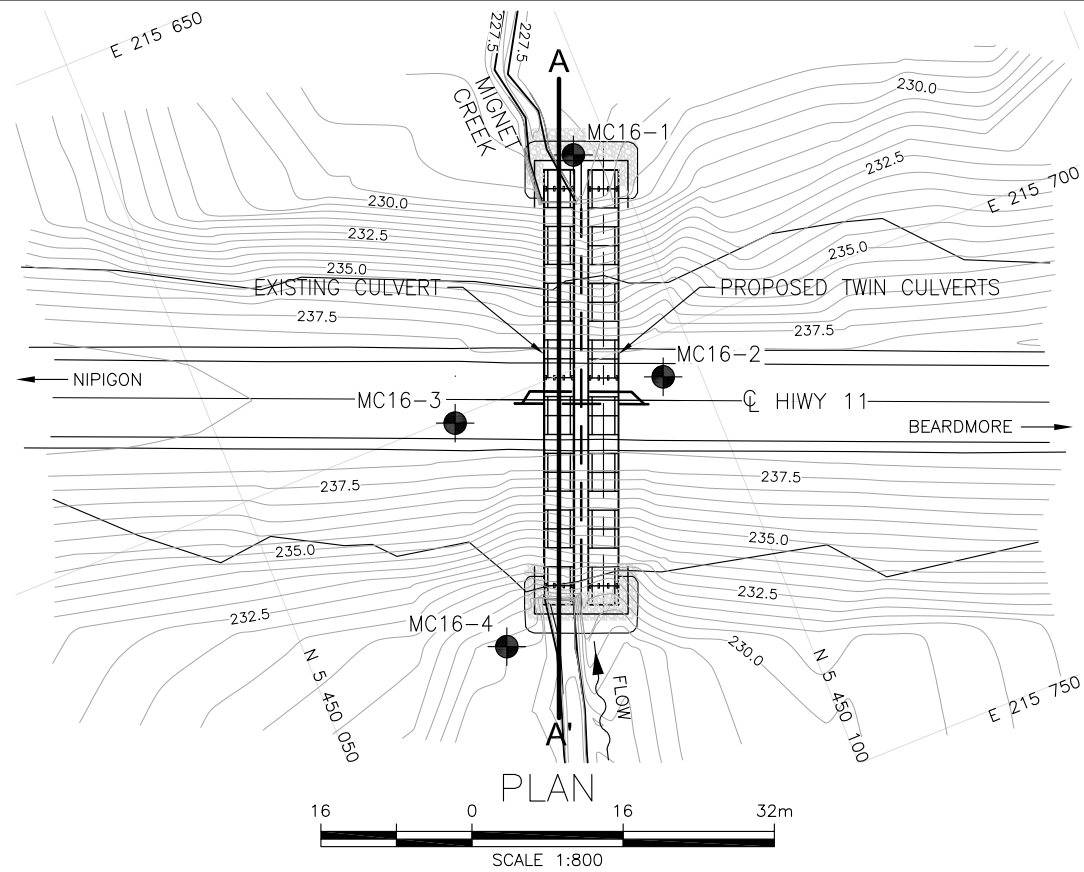


P.K. Chatterji, P.Eng., Ph.D.  
Review Principal,  
Senior Geotechnical Engineer

HIGHWAY 11 MIGNET CREEK CULVERT REPLACEMENT  
20.1 KM NORTH OF HIGHWAY 11/HIGHWAY 17 JUNCTION NIPIGON, ON

**Appendix A.**

**Borehole Location Plan and Stratigraphic Drawings**

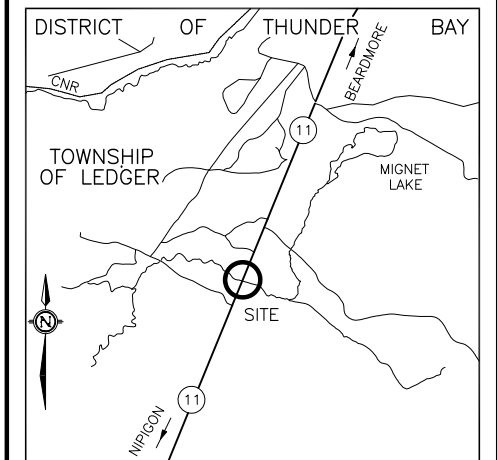


METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN



CONT No  
GWP No 6316-14-00

HIGHWAY 11  
MIGNET CREEK TRIBUTARY  
CULVERT CROSSING  
BOREHOLE LOCATIONS AND SOIL STRATA



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
MC16-1	227.9000	5450096.1661	215678.9568
MC16-2	238.4000	5450096.1661	215704.2884
MC16-3	238.3000	5450073.9164	215700.5738
MC16-4	228.4000	5450070.1231	215724.5557

NOTES

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

GEOCRES No. 52H-42

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	SBP	CHK -	CODE
DRAWN	AN	CHK SBP	SITE
LOAD	DATE	OCT 2017	
STRUCT	DWG	1	



HIGHWAY 11 MIGNET CREEK CULVERT REPLACEMENT  
20.1 KM NORTH OF HIGHWAY 11/HIGHWAY 17 JUNCTION NIPIGON, ON

## **Appendix B.**

### **Record of Borehole Sheets**

## SYMBOLS, ABBREVIATIONS AND TERMS USED ON TEST HOLE RECORDS

### TERMINOLOGY DESCRIBING COMMON SOIL GENESIS

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

### TERMINOLOGY DESCRIBING SOIL STRUCTURE:

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

### RECOVERY:

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

### N-VALUE:

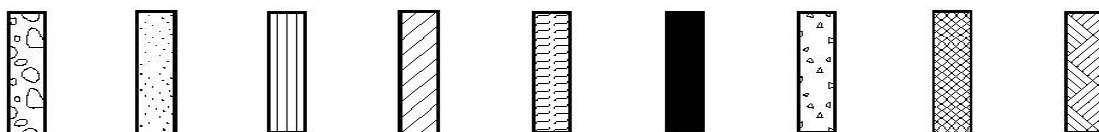
Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 63.5 kg hammer falling 0.76 m, required to drive a 50 mm O.D. split spoon sampler 0.3 m into undisturbed soil. For samples where insufficient penetration was achieved and N-value cannot be presented,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

### DYNAMIC CONE PENETRATION TEST (DCPT):

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

### STRATA PLOT:

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



Boulders  
Cobbles  
Gravel      Sand      Silt      Clay      Organics      Asphalt      Concrete      Fill      Bedrock

### TEXTURING CLASSIFICATION OF SOILS

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

### TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

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

### SAMPLE TYPES

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

### TERMS DESCRIBING CONSISTENCY (COHESIONLESS SOILS ONLY)

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

**MODIFIED UNIFIED SOIL CLASSIFICATION**

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

Note -  $W_L$  = Liquid Limit

## EXPLANATION OF ROCK LOGGING TERMS

### ROCK WEATHERING CLASSIFICATION

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

### TERMS

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

### DISCONTINUITY SPACING

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

### STRENGTH CLASSIFICATION

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

# RECORD OF BOREHOLE No MC16-1

1 OF 1

METRIC

GWP# 6316-14-00 LOCATION Hwy 11 - Mignet Creek Culvert ORIGINATED BY TS  
 HWY 11 BOREHOLE TYPE Tripod COMPILED BY JM  
 DATUM Geodetic DATE 2016.08.17 - 2016.08.17 CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT  $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								WATER CONTENT (%)						
227.9														
0.0	<b>SILTY SAND</b> , with organics Compact Brown Moist		1	SS	18									0 54 38 8
226.8			2	SS	16									
1.1	<b>SANDY SILT</b> , trace organics/wood Compact to Very Dense Brown		3	SS	14									0 37 39 24
			4	SS	73									
			5	SS	100/ 50mm									
223.6														
4.3	<b>CLAY (CL)</b> Stiff Grey		6	SS	55									0 5 69 26
223.0														
4.9	<b>SAND</b> with silt, trace organics Very Dense Brown		7	SS	100/ 225mm									
			8	SS	100/ 150mm									
			9	SS	100/ 225mm									
218.7														
9.2	End of Borehole "N" Values shown are blows per 300 mm of penetration with a half weight hammer													

ONTMT4S 13163 HWY 11 MIGNET CRK CULVERT.GPJ 2012TEMPLATE(MTO).GDT 19/12/16

# RECORD OF BOREHOLE No MC16-2

1 OF 3

METRIC

GWP# 6316-14-00 LOCATION Hwy 11 - Mignet Creek Culvert ORIGINATED BY TS  
 HWY 11 BOREHOLE TYPE HSA COMPILED BY JG  
 DATUM Geodetic DATE 2016.07.13 - 2016.07.13 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  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				W P      W      W L								
								○ UNCONFINED      + FIELD VANE				WATER CONTENT (%)								
								● QUICK TRIAXIAL      × LAB VANE												
238.4							20	40	60	80	100									
0.0																				
0.1																				

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

ONTMT4S 13163 HWY 11 MIGNET CRK CULVERT.GPJ 2012TEMPLATE(MTO).GDT 19/12/16

# RECORD OF BOREHOLE No MC16-2

2 OF 3

METRIC

GWP# 6316-14-00 LOCATION Hwy 11 - Mignet Creek Culvert ORIGINATED BY TS  
 HWY 11 BOREHOLE TYPE HSA COMPILED BY JG  
 DATUM Geodetic DATE 2016.07.13 - 2016.07.13 CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT  $\gamma$ kN/m <sup>3</sup>	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					
PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W P W W L WATER CONTENT (%) 20 40 60													
	Continued From Previous Page												
226.0	<b>SANDY SILT</b> , occasional silt seams, trace organics/wood compact to loose grey		10	SS	9		228						
							227						
12.4	<b>CLAY (CL)</b> firm to stiff grey wet -50 mm thick organic/wood at 12.4 m		11	SS	5		226						0 0 77 23
							225						
224.4			12	SS	27		224						
14.0	<b>SAND</b> with silt, some gravel compact to very dense brown						223						
			13	SS	35		222						
	- occasional cobbles						221						10 84 6 (SI+CL)
			14	SS	30		220						
			15	SS	59		219						

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity 20  
15 10 5  
(%) STRAIN AT FAILURE

ONTMT4S 13163 HWY 11 MIGNET CRK CULVERT.GPJ 2012TEMPLATE(MTO).GDT 19/12/16



# RECORD OF BOREHOLE No MC16-2

3 OF 3

METRIC

GWP# 6316-14-00 LOCATION Hwy 11 - Mignet Creek Culvert ORIGINATED BY TS  
 HWY 11 BOREHOLE TYPE HSA COMPILED BY JG  
 DATUM Geodetic DATE 2016.07.13 - 2016.07.13 CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	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	WATER CONTENT (%) 20 40 60								
	Continued From Previous Page																
	SAND with silt, some gravel compact to very dense brown						218										
							217										
216.5			16	SS	38												
21.9	End of Borehole Borehole open upon completion																

ONTMT4S 13163 HWY 11 MIGNET CRK CULVERT.GPJ 2012TEMPLATE(MTO).GDT 19/12/16

# RECORD OF BOREHOLE No MC16-3

1 OF 3

METRIC

GWP# 6316-14-00 LOCATION Hwy 11 - Mignet Creek Culvert ORIGINATED BY TS  
 HWY 11 BOREHOLE TYPE HSA COMPILED BY JG  
 DATUM Geodetic DATE 2016.07.14 - 2016.07.14 CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
								20 40 60 80 100					
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					
WATER CONTENT (%)				20 40 60									
238.3													
0.0	ASPHALT (175 mm)												
0.2	SILTY SAND some gravel very dense brown FILL		1	GS			238						
			2	SS	56								
			3	SS	14		237						
235.9							236						
2.4	SILTY SAND with gravel to SILTY SAND, occasional cobbles compact to dense brown FILL		4	SS	43								23 60 17 (SI+CL)
			5	SS	33		235						
			6	SS	17		234						
							233						
			7	SS	9		232						
231.9													
6.4	SANDY SILT, occasional silt seams, trace organics/wood loose to compact grey						231						
			8	SS	18								0 50 29 21
							230						
			9	SS	18		229						

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE



ONTMT4S 13163 HWY 11 MIGNET CRK CULVERT.GPJ 2012TEMPLATE(MTO).GDT 19/12/16

# RECORD OF BOREHOLE No MC16-3

2 OF 3

METRIC

GWP# 6316-14-00 LOCATION Hwy 11 - Mignet Creek Culvert ORIGINATED BY TS  
 HWY 11 BOREHOLE TYPE HSA COMPILED BY JG  
 DATUM Geodetic DATE 2016.07.14 - 2016.07.14 CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT  W <sub>P</sub>	NATURAL MOISTURE CONTENT  W	LIQUID LIMIT  W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)			
								20 40 60 80 100									20 40 60			
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE												
Continued From Previous Page							228													
10.2	CLAY (CL) stiff grey -75 mm thick organic/wood fiber at 10.7 m		10	SS	6		227													
							226													
							225													
							224													
							223													
							222													
	-50 mm thick organic/wood fiber at 15.2 m		13	SS	10		221													
222.1	SAND with silt, trace gravel compact to very dense brown		14	SS	59		220													
16.2							219													

Continued Next Page

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

ONTMT4S 13163 HWY 11 MIGNET CRK CULVERT.GPJ 2012TEMPLATE(MTO).GDT 19/12/16

# RECORD OF BOREHOLE No MC16-3

3 OF 3

METRIC

GWP# 6316-14-00 LOCATION Hwy 11 - Mignet Creek Culvert ORIGINATED BY TS  
 HWY 11 BOREHOLE TYPE HSA COMPILED BY JG  
 DATUM Geodetic DATE 2016.07.14 - 2016.07.14 CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	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	20	40	60	80					
	Continued From Previous Page																
	SAND with silt, trace gravel compact to very dense brown						218										
							217										
216.4			16	SS	29												
21.9	End of Borehole Borehole open upon completion																

ONTMT4S 13163 HWY 11 MIGNET CRK CULVERT.GPJ 2012TEMPLATE(MTO).GDT 19/12/16

# RECORD OF BOREHOLE No MC16-4

1 OF 1

METRIC

GWP# 6316-14-00 LOCATION Hwy 11 - Mignet Creek Culvert ORIGINATED BY TS  
 HWY 11 BOREHOLE TYPE Tripod COMPILED BY JM  
 DATUM Geodetic DATE 2016.08.17 - 2016.08.17 CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT  $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
								20 40 60 80 100					
								20 40 60 80 100					
228.4													
0.0	TOPSOIL												
0.2	SILTY SAND, trace wood		1	SS	6								
227.8	Loose to Compact												
0.6	Brown												
	SILT with sand, trace wood		2	SS	16								
	Compact												
	Wet												
	Grey												
	- water inflow at 1.5 m		3	SS	20								
			4	SS	25								
225.4													
3.0	CLAY (CL)		5	SS	17								
	Stiff												
	Grey												
	Wet												
			6	SS	17								
			7	SS	23								
221.4													
7.0	SAND, trace silt		8	SS	100/ 150mm								
	Very Dense												
	Brown		9	SS	100/ 150mm								
	Moist												
219.5			10	SS	50/ 75mm								
8.9	End of Borehole												
	"N" Values shown are blows per 300 mm of penetration with a half weight hammer												

ONTMT4S 13163 HWY 11 MIGNET CRK CULVERT.GPJ 2012TEMPLATE(MTO).GDT 19/12/16

## **Appendix C.**

### **Laboratory Testing**

## **Appendix C.1**

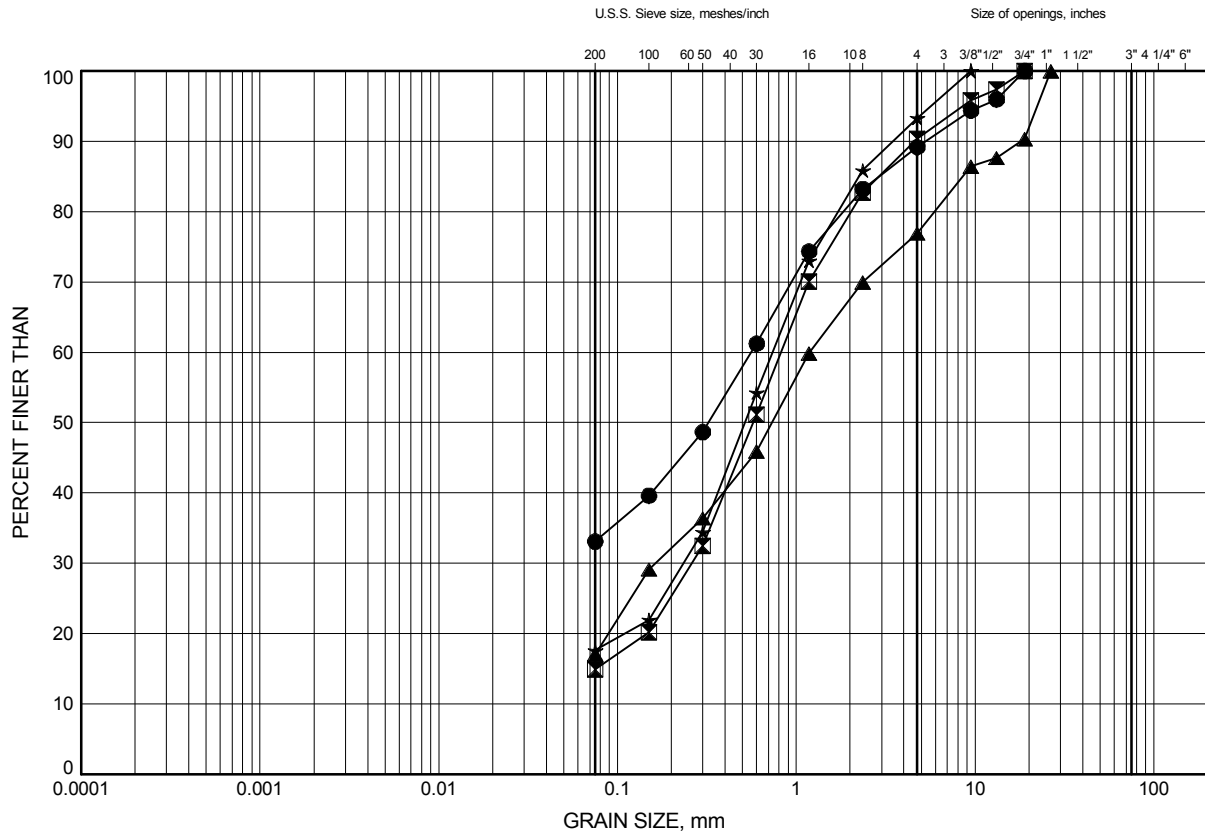
### **Particle Size Analysis Figures**

# Hwy 11 - Mignet Creek Culvert

## GRAIN SIZE DISTRIBUTION

FIGURE C1

FILL: Silty SAND



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MC16-2	1.07	237.33
⊠	MC16-2	3.35	235.05
▲	MC16-3	2.59	235.71
★	MC16-3	4.88	233.42

Date December 2016  
GWP# 6316-14-00



Prep'd SBP  
Chkd.

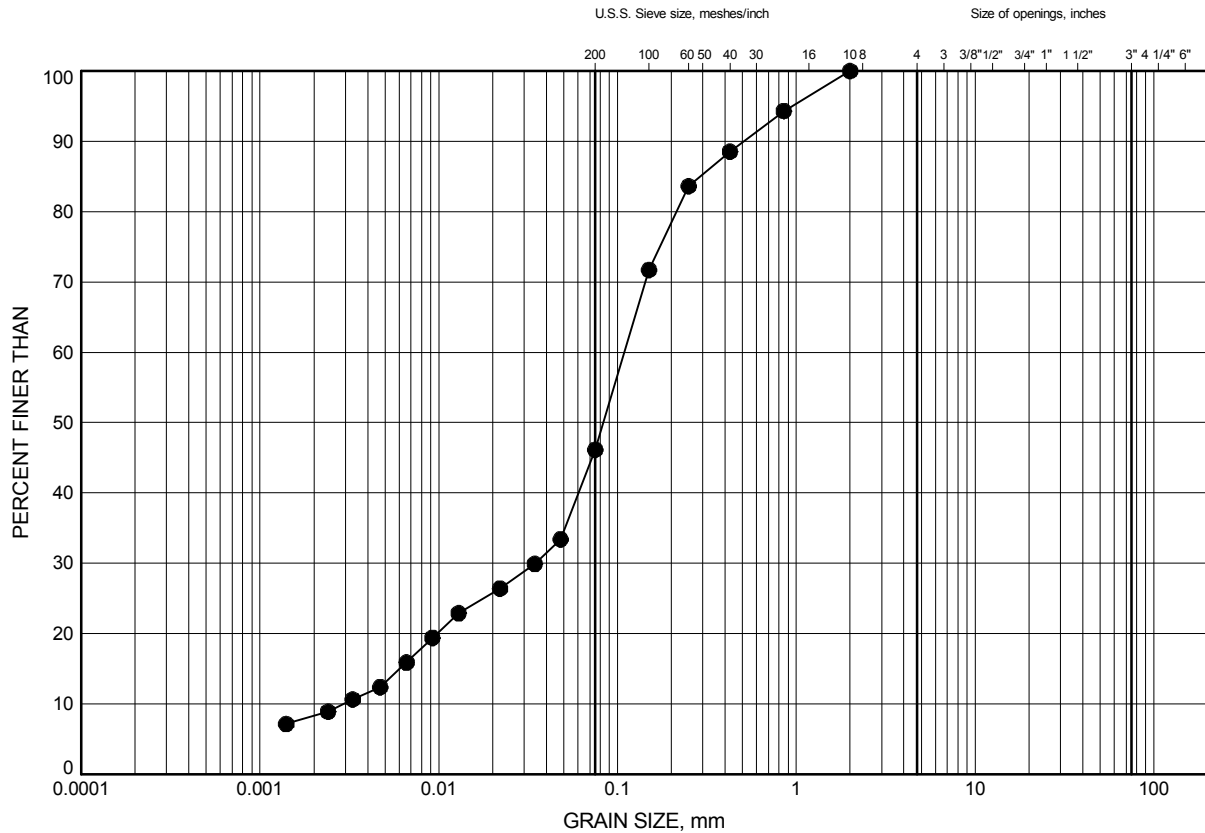


# Hwy 11 - Mignet Creek Culvert

## GRAIN SIZE DISTRIBUTION

FIGURE C2

### Silty SAND



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MC16-1	0.30	227.59

Date December 2016  
GWP# 6316-14-00



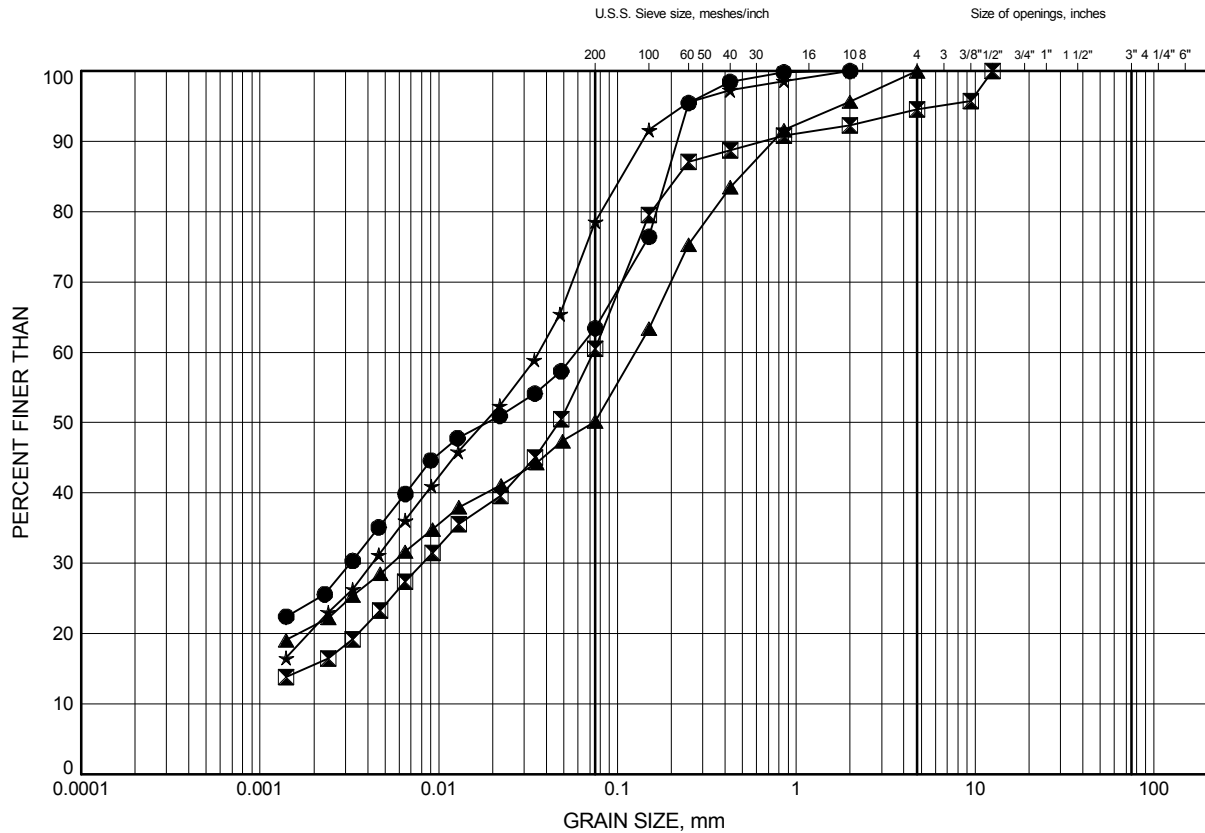
Prep'd SBP  
Chkd.

# Hwy 11 - Mignet Creek Culvert

## GRAIN SIZE DISTRIBUTION

FIGURE C3

### Sandy SILT



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MC16-1	1.83	226.07
⊠	MC16-2	7.92	230.47
▲	MC16-3	7.92	230.37
★	MC16-4	1.07	227.33

Date December 2016

GWP# 6316-14-00



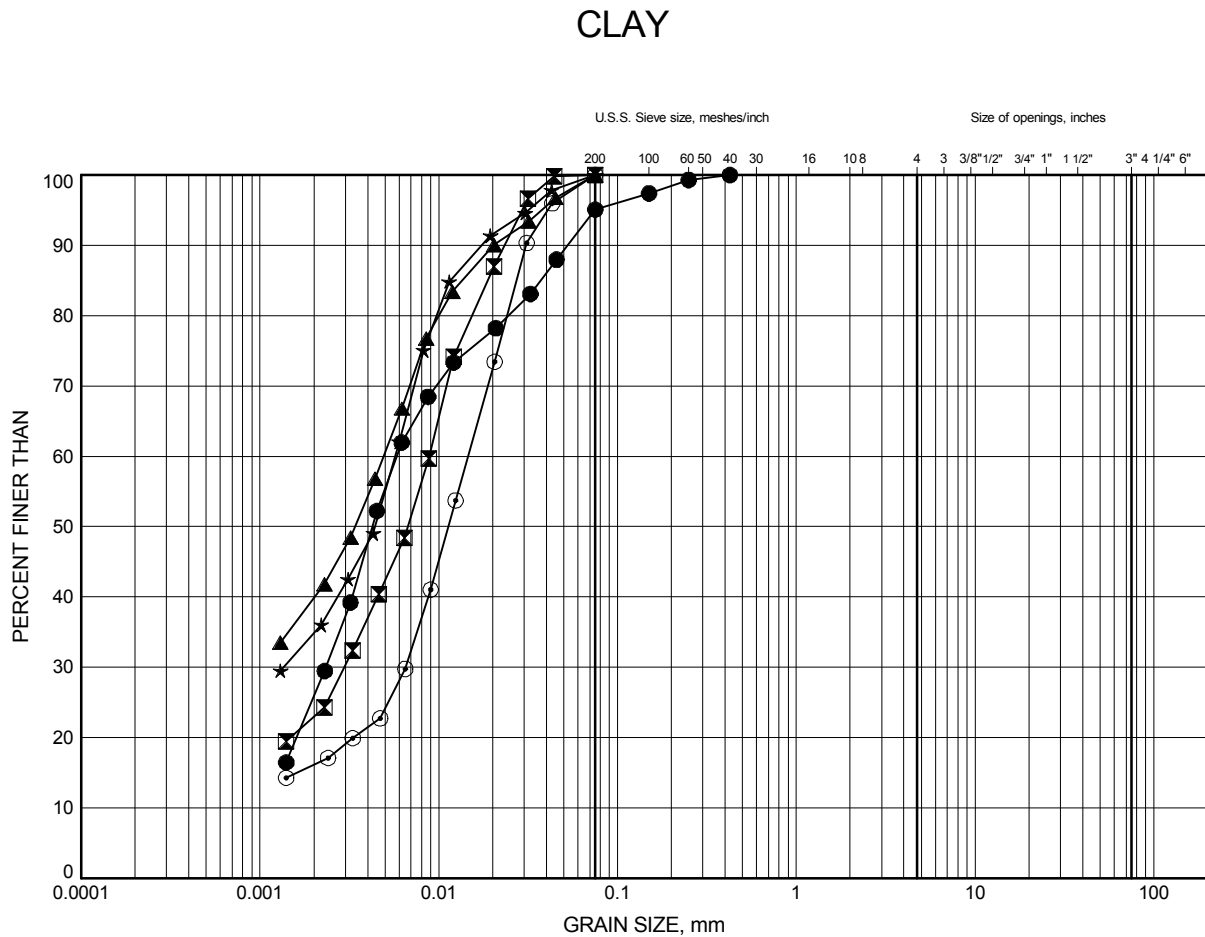
Prep'd SBP

Chkd.

# Hwy 11 - Mignet Creek 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)
●	MC16-1	4.72	223.17
⊠	MC16-2	12.57	225.83
▲	MC16-3	10.97	227.33
★	MC16-3	15.54	222.75
⊙	MC16-4	4.88	223.52

Date December 2016

GWP# 6316-14-00

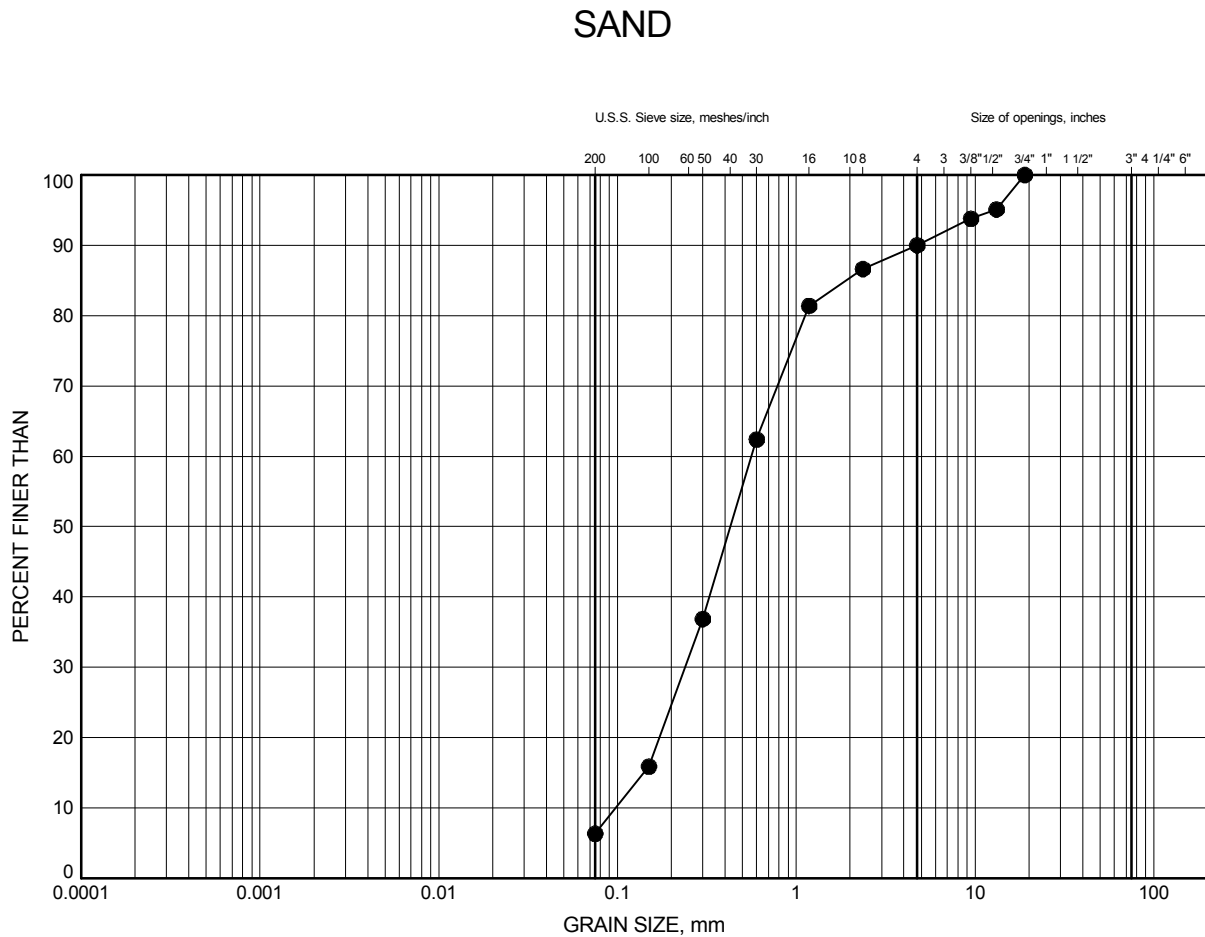


Prep'd SBP

Chkd.

# Hwy 11 - Mignet Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE C5



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MC16-2	17.07	221.33

Date December 2016  
GWP# 6316-14-00



Prep'd SBP  
Chkd.

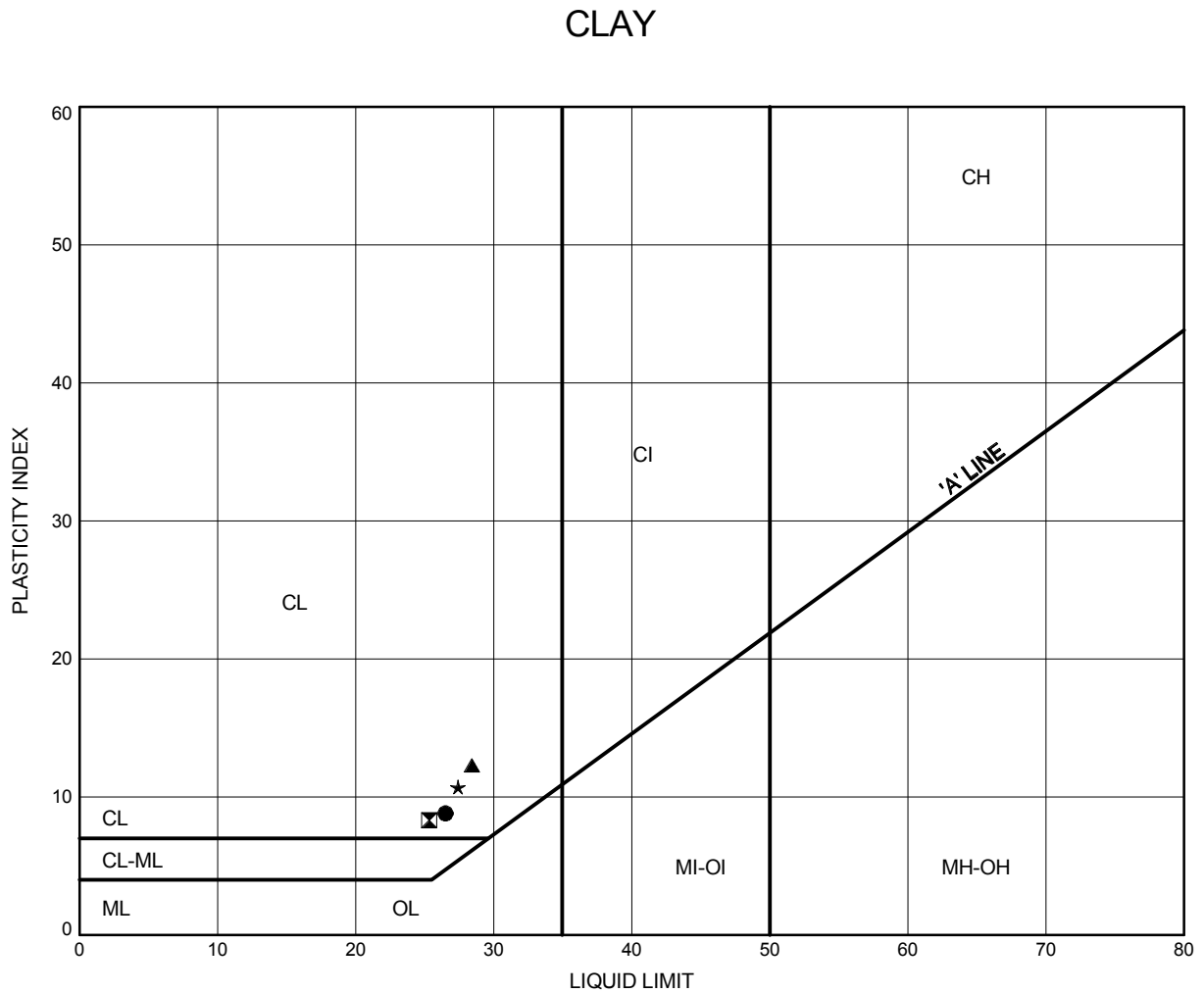
## **Appendix C.2**

### **Atterberg Limit Analysis Figures**

# Hwy 11 - Mignet Creek Culvert

## ATTERBERG LIMITS TEST RESULTS

FIGURE C6



### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MC16-1	4.72	223.17
⊠	MC16-2	12.57	225.83
▲	MC16-3	15.54	222.75
★	MC16-4	4.88	223.52

Date December 2016

GWP# 6316-14-00



Prep'd SBP

Chkd.

**Appendix C.3**  
**Analytical Testing Results**

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

**ATTENTION TO: WEISS MEHDAWI**

**PROJECT: 13163**

**AGAT WORK ORDER: 16T139313**

**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.**





**AGAT** Laboratories

## Certificate of Analysis

AGAT WORK ORDER: 16T139313

PROJECT: 13163

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

ATTENTION TO: WEISS MEHDAWI

SAMPLING SITE:

SAMPLED BY:

### Corrosivity Package

DATE RECEIVED: 2016-09-20

DATE REPORTED: 2016-09-27

MC-1/SS2B(3.5-4.5')				
SAMPLE DESCRIPTION: 5-4.5'				
SAMPLE TYPE: Soil				
DATE SAMPLED: 8/17/2016				
Parameter	Unit	G / S	RDL	7861547
Sulphide	%		0.05	<0.05
Chloride (2:1)	µg/g		4	562
Sulphate (2:1)	µg/g		4	94
pH (2:1)	pH Units		NA	8.39
Electrical Conductivity (2:1)	mS/cm		0.005	1.16
Resistivity (2:1)	ohm.cm		1	862
Redox Potential (2:1)	mV		5	205

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

**7861547** 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 sample was 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.

Certified By:

*Amanjot Bhela*

## Quality Assurance

CLIENT NAME: THURBER ENGINEERING LTD

PROJECT: 13163

SAMPLING SITE:

AGAT WORK ORDER: 16T139313

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	7861547	7861547	< 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	7.9%	< 2	92%	80%	120%	96%	80%	120%	98%	70%	130%
pH (2:1)	7861508		11.4	11.4	0.0%	NA	100%	90%	110%	NA			NA		
Electrical Conductivity (2:1)	7861508		1.32	1.32	0.2%	< 0.005	99%	90%	110%	NA			NA		
Redox Potential (2:1)	7861508		88	88	0.7%	< 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:** 16T139313

**PROJECT:** 13163

**ATTENTION TO:** WEISS MEHDAWI

**SAMPLING SITE:**

**SAMPLED BY:**

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
<b>Soil Analysis</b>			
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

HIGHWAY 11 MIGNET CREEK CULVERT REPLACEMENT  
20.1 KM NORTH OF HIGHWAY 11/HIGHWAY 17 JUNCTION NIPIGON, ON

**Appendix D.**

**Site Photographs**

HIGHWAY 11 MIGNET CREEK CULVERT REPLACEMENT  
20.1 KM NORTH OF HIGHWAY 11/HIGHWAY 17 JUNCTION NIPIGON, ON



**Photo 1. Looking east along Highway 11.**



**Photo 2. Looking west along Highway 11.**

**Appendix E.**

**Foundation Comparison**

**COMPARISON OF ALTERNATIVE FOUNDATION TYPES**

	<b><i>Closed Culvert</i></b>	<b><i>Circular Pipe Culvert (Trenchless Installation)</i></b>	<b><i>Open Bottom Culvert</i></b>
<b><i>Advantages</i></b>	<ul style="list-style-type: none"> <li>i. Relatively expedient installation if precast units are used.</li> <li>ii. Smaller magnitude of settlement than open footing culvert due to lower bearing stress on subgrade.</li> </ul>	<ul style="list-style-type: none"> <li>i. Can tolerate larger magnitude of settlement than concrete (rigid frame) culverts).</li> <li>ii. Avoids open cut</li> <li>iii. Possibly allows two lanes of traffic to be maintained throughout construction</li> </ul>	<ul style="list-style-type: none"> <li>i. Relatively expedient installation if precast units are used.</li> </ul>
<b><i>Disadvantages</i></b>	<ul style="list-style-type: none"> <li>i. Requires large excavation and roadway protection.</li> <li>ii. Requires compacted granular pad on subgrade.</li> <li>iii. Requires installation of a temporary by-pass culvert to maintain existing creek alignment</li> </ul>	<ul style="list-style-type: none"> <li>i. Requires construction of entry and exit pits and access to toes of slope.</li> <li>ii. Requires specialised construction equipment.</li> <li>iii. Feasibility also depends on flow capacity and other hydraulic properties.</li> <li>iv. Obstructions in fill mean many techniques not feasible</li> <li>v. Mixed soil face conditions</li> </ul>	<ul style="list-style-type: none"> <li>i. Requires deeper excavation increasing excavation volume and dewatering concern.</li> <li>ii. Founding subgrade will provide lower geotechnical resistances.</li> <li>iii. Potential for post construction settlement.</li> </ul>
<b><i>Risks/ Consequences</i></b>	<ul style="list-style-type: none"> <li>i. Groundwater control may require sheet pile enclosed excavation</li> </ul>	<ul style="list-style-type: none"> <li>i. Groundwater control may require sheet pile enclosed excavation</li> <li>ii. Possibility of encountering obstructions</li> </ul>	<ul style="list-style-type: none"> <li>i. Groundwater control may require sheet pile enclosed excavation</li> <li>ii. Increased risk of basal instability of footing excavation due to depth of excavation below water table.</li> </ul>
<b><i>Recommendation</i></b>	<b>Recommended</b>	<b>High Risk / Not Recommended</b>	<b>Not Feasible</b>

**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

October 21, 2016

Site: 49.1823 N, 88.2222 W User File Reference: Mignet Creek Culvert

Requested by: ,

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

Sa(0.05)	Sa(0.1)	<b>Sa(0.2)</b>	Sa(0.3)	<b>Sa(0.5)</b>	<b>Sa(1.0)</b>	<b>Sa(2.0)</b>	<b>Sa(5.0)</b>	<b>Sa(10.0)</b>	<b>PGA (g)</b>	<b>PGV (m/s)</b>
0.045	0.063	<b>0.058</b>	0.047	<b>0.035</b>	<b>0.019</b>	<b>0.0080</b>	<b>0.0016</b>	<b>0.0008</b>	<b>0.034</b>	<b>0.025</b>

**Notes.** Spectral ( $S_a(T)$ , where  $T$  is the period in seconds) and peak ground acceleration (PGA) values are given in units of  $g$  ( $9.81 \text{ m/s}^2$ ). Peak ground velocity is given in  $\text{m/s}$ . Values are for "firm ground" (NBCC 2015 Site Class C, average shear wave velocity  $450 \text{ m/s}$ ). 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)	0.0024	0.012	0.022
Sa(0.1)	0.0040	0.018	0.032
Sa(0.2)	0.0047	0.019	0.032
Sa(0.3)	0.0042	0.017	0.027
Sa(0.5)	0.0032	0.013	0.021
Sa(1.0)	0.0013	0.0061	0.011
Sa(2.0)	0.0005	0.0025	0.0044
Sa(5.0)	0.0002	0.0006	0.0009
Sa(10.0)	0.0002	0.0004	0.0005
PGA	0.0022	0.010	0.018
PGV	0.0015	0.0075	0.014

## 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](http://www.EarthquakesCanada.ca) and [www.nationalbuildingcode.ca](http://www.nationalbuildingcode.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**

HIGHWAY 11 MIGNET CREEK CULVERT REPLACEMENT  
20.1 KM NORTH OF HIGHWAY 11/HIGHWAY 17 JUNCTION NIPIGON, ON

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

- OPSS.PROV 206
- OPSS 422
- OPSS.PROV 501
- OPSS.PROV 517
- OPSS.PROV 539
- OPSS.PROV 804
- OPSS 902
- OPSS.PROV 1010
- OPSS.PROV 1205
  
- OPSD 208.010
- OPSD 803.010
- OPSD 810.010
- OPSD 3101.150

2. Suggested text for NSSP on “Protection of Sensitive Foundation Soils”

The Contractor is advised that the soil that will be exposed at the subgrade following removal of the 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 mud slab placed between the native subgrade and granular bedding.

3. Suggested text for NSSP on “Obstructions”

Excavation or installation of sheet piled protection system could encounter obstructions such as cobbles or boulders. Such obstructions may impede excavation and sheet pile installation and prohibit reaching the designed installation. The Contractor shall be prepared to remove, drill through and/or penetrate these obstructions and extend the sheet piles to the design depths.

HIGHWAY 11 MIGNET CREEK CULVERT REPLACEMENT  
20.1 KM NORTH OF HIGHWAY 11/HIGHWAY 17 JUNCTION NIPIGON, ON

4. Suggested text for 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 of 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. Temporary dewatering measures will be required to remain operation during construction until the culvert is installed and backfilled.