THURBER ENGINEERING LTD.

FINAL

FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 11 MELOCHE CREEK CULVERT REPLACEMENT
10.1 KM SOUTH OF HIGHWAY 572 EAST, TOWNSHIP OF COOK
SITE NO.: 39E-222/C

G.W.P. 5054-01-00

Geocres No.: 42A00-117

Report to:

McIntosh Perry Consulting Engineers Limited

Latitude: 48.36789°
Longitude: -80.25409°

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Thurber File No.: 13058

104, 2460 Lancaster Road, Ottawa ON K1B 4S5 T. 613 247 2121 F. 613 247 2185
thurber.ca

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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 Meloche Creek. The structure is located approximately 10.1 km south of Highway 572 East within the Township of Cook (approximate Sta. 12+670). Thurber Engineering Limited (Thurber) carried out the current investigation as a sub-consultant to McIntosh Perry Consulting Engineers Ltd. (MPCE) under Agreement No. 5015-E-0041.

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

2 SITE DESCRIPTION

The existing structure is a single barrel reinforced concrete rigid frame culvert noted to be constructed in 1960. The culvert is reported to be 3.0 m wide by 1.8 m high and approximately 43 m long with a generally east to west alignment. The flow through the culvert is to the east.

At the location of the culvert (Linear Highway Referencing System Base Point: 17435, Offset: 10.1), Highway 11 is a two-lane highway with a rural cross-section and gravel shoulders. The Highway 11 embankment fill height is approximately 7.8 m with the road surface at approximate elevation of 316.5 m. The existing embankment side slopes are inclined at approximately 2H:1V. Wooden posts with 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 and densely vegetated with shrubs and trees. Traffic volumes are understood to be 3250 AADT (2012).

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 October 12th and October 16th, 2016. Drilling consisted of advancing six boreholes identified as MC16-1 through MC16-6. The drilling was carried out using portable equipment for off road boreholes MC16-3 through MC16-6, and a rubber tired CME 550 drill rig for the on-road boreholes MC16-1 and MC16-2. 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 MC16-3 through MC16-6 which were drilled with portable equipment also utilized a full-weight hammer for SPT testing. The boreholes were sampled to refusal depths ranging from 2.3 to 8.4 m (elev. 308.6 to 302.3 m) below the existing ground surface. Coring was not completed as part of this assignment. Boreholes MC16-3 and MC16-4 were extended during Dynamic Cone Penetration Testing (DCPT).

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.

A 19 mm diameter standpipe piezometer was installed in Borehole MC16-5 to allow for measurements of the groundwater level after completion of drilling. The piezometer installation details are illustrated on the Record of Borehole sheet for Borehole MC16-5, provided in Appendix B. Following completion of the field investigation the remaining boreholes were backfilled in accordance with MOE requirements (O.Reg. 903). Boreholes MC16-1 and MC16-2 were capped with 150 mm of cold patch asphalt to reinstate the traveling surface.

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

In general terms, the site was found to be underlain by a pavement structure and granular and silt embankment fill overlying deposits of native, non-cohesive soils. A veneer of topsoil was present at the surface of the off-road boreholes over a thin layer of silty clay in two locations over sand and silty sand deposits. Bedrock was not encountered within the depth of investigation, although all boreholes terminated at SPT or DCPT refusal.

5.1 Embankment

5.1.1 Asphalt

Boreholes MC16-1 and MC16-2 were drilled through the existing Highway 11 embankment and encountered a layer of asphalt with a thickness of 180 mm.

5.1.2 Fill

Below the asphalt pavement within the on-road boreholes was a layer of non-cohesive fill varying in composition from gravel with sand to sand with silt and gravel to silt trace clay and organics. Cobbles were noted within the fill in MC16-02 between 2.3 and 6.1 m depth. The underside of the fill was 6.1 m (elev. 310.6 to 310.4 m) below the existing roadway surface. A buried layer of asphalt was observed at a depth of 1.0 m in Borehole MC16-2 and organics were present near a depth of 3.2 m in Borehole MC16-1.

The SPT tests conducted in the fill typically gave N-values ranging from 8 to 63 blows indicating a relative density of loose to very dense. SPT tests with results as high as 100 blows per 225 mm of penetration were recorded near the surface. Recorded moisture contents ranged from 6 to 21%.

Gradation analyses were completed on five samples of the 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 to SP-SM material.

Soil Particle	Percentage (%)
Gravel	2 - 78
Sand	21 - 70
Silt and Clay	1 to 28

5.2 Silty Clay, Sandy (CL-ML)

A layer of native silty clay, sandy was encountered at ground surface in Boreholes MC16-03 and MC16-04 located near the inlet of the culvert. The layer was 0.6 m thick with an underside elevation of 309.5 to 309.1 m. SPT N-values ranged from weight of hammer to 7 blows, indicating a soft to stiff consistency. Moisture contents of the retained samples ranged from 20 to 47%. A single gradation analysis was completed and indicated a material with 38% sand, 49% silt and 13% clay. The results of the grain size analysis are illustrated on Figure C2 in Appendix C. An Atterberg Limit test, shown in Figure C5, was completed on one sample and yielded a Liquid Limit of 24% and a Plastic Limit of 18%, indicating a CL-ML material.

5.3 Sand (SM to SP-SM)

A native deposit of sand varying in composition from sand with silt and gravel to silty sand with gravel to silty sand was observed at the ground surface in Boreholes MC16-05 and MC16-06 and underlying the soil layers noted above in the remaining boreholes. All boreholes were terminated in the sand layer (elev. 308.6 to 302.3 m) upon SPT and/or casing advancement refusal.

SPT tests gave N-values ranging from 1 to 67 blows. N-values of greater than 100 blows were observed near the base of the layer in all boreholes. The recorded moisture contents ranged from 9 to 23%.

Gradation analyses was completed on eight samples of the sand. The grain size distribution curves 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 and indicate an SM to SP-SM material.

<table>
<tr><th>Soil Particle</th><th colspan="2">Percentage (%)</th></tr>
<tr><td>Gravel</td><td colspan="2">1 - 26</td></tr>
<tr><td>Sand</td><td colspan="2">53 - 91</td></tr>
<tr><td>Silt</td><td>15 - 16</td><td rowspan="2">5 - 22</td></tr>
<tr><td>Clay</td><td>5 - 6</td></tr>
</table>

5.4 Groundwater

The groundwater level was measured at 0.3 m (elev. 309.1 m) below the ground surface in the standpipe piezometer installed in Borehole MC16-05 on April 17, 2017. It is expected that the groundwater level will largely be controlled by the water level in Meloche Creek. The water level in the creek was near elevation 309.1 m during the time of the site investigation in October 2016. It should be noted that the groundwater level at the time of construction may be higher 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.

5.5 Analytical Testing

Two samples of the native soils were submitted to Paracel Laboratories in Ottawa, Ontario for analysis of pH, water soluble sulphate and chloride concentrations, resistivity and conductivity. The analysis results are summarized in the table below:

Borehole	Sample	Depth (m)	Sulphate (µg/g)	pH (-)	Resistivity (Ohm-cm)	Chloride (µg/g)
MC16-4	SS1	0 – 0.6	30	6.21	1370	328
MC16-6	SS3	1.5 – 2.1	7	6.35	17900	9

6 MISCELLANEOUS

Borehole locations were selected by Thurber relative to existing site features. The as-drilled locations and ground surface elevations were measured by McIntosh Perry following completion of the field program.

Landcore Drilling of Chelmsford, Ontario supplied and operated the drilling equipment to conduct the drilling, soil sampling, in-situ testing and borehole decommissioning. The field investigation was supervised on a full-time basis by Mr. Jeff Morrison, E.I.T. and Mr. Sean O'Bryan. 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 Ottawa, Ontario. Analytical testing was completed by Paracel Laboratories in Ottawa, Ontario. Interpretation of the factual data and preparation of this report were carried out by 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.

For
Stephen Peters, P.Eng.
Geotechnical Engineer

LICENSED PROFESSIONAL ENGINEER
F. J. GRIFFITHS
Oct 2/18
PROVINCE OF ONTARIO

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

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
Oct 2/18
PROVINCE OF ONTARIO

Dr. P.K. Chatterji, P.Eng.
Review Principal
Senior Geotechnical Engineer

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PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 INTRODUCTION

This section of the report provides an interpretation of the factual data from Part 1 of this report and presents geotechnical recommendations to assist the project team in designing a suitable foundation for the proposed replacement of the existing Meloche Creek Culvert crossing Highway 11. The discussion and recommendations presented in this report are based on the information provided by MPCE 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 Meloche Creek under Highway 11, is a single barrel reinforced concrete rigid frame culvert noted to have been constructed in 1960. The culvert is reported to be 3.05 m wide by 1.83 m high and approximately 43 m long with a generally east to west alignment. The invert of the existing culvert is reported to be at elevation 308.95 m and 308.80 m at the inlet and outlet, respectively. The embankment fill height is in the order of 7.8 m with the road surface at approximate elevation 316.5 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 McIntosh Perry Consulting Engineers Ltd. (MPCE) under Agreement No. 5015-E-0041.

7.1 Proposed Structure

Based on drawings provided by MPCE's, it is understood that the preferred replacement culvert is a 48.6 m long, 3.6 m x 2.4 m precast concrete box culvert with precast cut-off walls to 1.2 m below the inverts. The culvert inverts are shown at elevation 308.65 m and

308.50 m at the inlet and outlet respectively. The culvert is shown at a 26 degree skew to Highway 11.

It is understood that the preferred culvert replacement will be constructed in an open cut with traffic diverted to a temporary modular bridge (TMB). A separate Foundation Investigation and Design Report (Geocres 42A00-123) has been prepared to support the design of the TMB.

7.2 Applicable Codes and Design Considerations

The geotechnical assessment presented below has been prepared based on the available data regarding the proposed foundations and existing ground conditions and in accordance with the Canadian Highway Bridge Design Code (CHBDC), version CSA S6-14.

It is understood that the culvert structure has a consequence classification of *Typical Consequence*, in accordance with Section 6.5.1 of the CHBDC. Accordingly, a consequence factor (Ψ) of 1.0, as per Table 6.1 of the CHBDC, has been used in assessing factored geotechnical resistances.

The frost penetration depth and associated recommendations are provided in Section 10.3.

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 (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 F.

The site coefficients used to determine the design spectral acceleration and displacement values are a function of the Site Class and the peak ground acceleration (PGA). The PGA value at this site for a *reference* Site Class C with a 2% probability of exceedance in 50 years (2475-year event) is 0.097g. This value is to be scaled by the F(PGA) based on the site-specific Site Class, discussed below.

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.

Based on the soil conditions encountered below the anticipated culvert foundation elevation, the 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 low PGA values and the subsurface condition encountered at the drilled locations at this site, the foundation soils beneath the embankment are considered to be not susceptible to liquefaction during the design seismic event.

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:

- <u>Circular Pipes (Concrete, HDPE, Steel)</u>
  From a foundation engineering perspective, pipe culverts are a feasible alternative. It is anticipated that an internal pipe with a diameter of approximately 3.0 m or multiple pipes may need to be provided so that other design issues including flow capacity and hydraulic properties can be satisfied.
- <u>Open Bottom Culvert (Box, Arch)</u>
  Open bottom culverts are considered feasible for this site from a foundation engineering perspective but would require greater excavation and dewatering efforts during construction to place the foundation in the dry.
- <u>Closed Bottom Culvert (Box)</u>
  A 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.
- <u>Steel Sheet Pile Walls with Precast Concrete Slab</u>
  A sheet pile wall supporting precast concrete slabs is not recommended at this site due to the shallow depth to refusal and the resulting low lateral resistance that would be available.

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 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.

- <u>Open Cut with Full Road Closure and Detour</u>
  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 creek diversion. However, it is understood that an acceptable detour route is not available and therefore this option is not feasible.

- Open Cut with Temporary Modular Bridge

  It is considered feasible at this site to complete a culvert replacement within a full width open cut excavation with a single lane temporary modular bridge spanning the excavation to allow for movement of traffic across the site. A borehole investigation to confirm the design of the modular bridge foundation was completed and documented in Geocres 42A00-123.

- Open Cut with Staged Temporary Widening

  Widening of the existing highway and/or construction of a temporary detour embankment to accommodate traffic passage during construction is considered feasible from a geotechnical perspective with a preference for widening to the east of the existing embankment. Placement of new fill on the west side of the embankment where clay soils are present could generate settlement under the footprint of the embankment widening as well as the existing embankment. Furthermore, due to the depth of excavation the width of widening would be excessive without a temporary protection system or grade lowering. A review of the requirement for property acquisition and highway geometry is needed to assess this option.

- Open Cut with Staged Temporary Lowering and Temporary Protection System

  The use of open cut techniques in conjunction with grade lowering and staged culvert replacement is a potentially feasible construction option from a geotechnical perspective. The presence of a higher silt content in the fills observed in Borehole MC16-01 may limit the depth of a temporary lowering to approximately 2 m unless over excavation is carried out to allow construction of a new temporary pavement structure. This option will require a temporary protection system (TPS), as discussed further in Section 12.2, installed along the embankment centerline to maintain a single lane of traffic flow along the current highway alignment. The TPS design and installation could be affected by the presence of cobbles in the fill and shallow refusal. Due to the required height of soil to be retained and the shallow depth to refusal, the TPS may need to include struts, deadman and/or rock anchors to reduce lateral deflections.

- Trenchless Techniques

  Trenchless techniques would have the advantage of minimum disruption to traffic and would avoid a large excavation through the existing highway embankment. However, the presence of loose cohesionless soils at the pipe invert limits the available techniques to closed faced systems. Micro-tunneling or pipe ramming is available in Ontario for inside diameters up to 2.4 m and 3.6 m respectively. Additional geometric constraints to the feasibility of the trenchless installation method are provided in the comparison table provided in Appendix E. A new installation of this size is feasible but may require inclusion of a second pipe to achieve hydraulic capacity. The feasibility of installing the second pipe within the existing culvert and grouting the annulus should be explored.

9.3 Recommended Approach for the Culvert Replacement

From a foundation engineering perspective, the alternative of replacing the existing culvert with a closed box culvert using open cut techniques is the recommended culvert replacement option. It is considered feasible to facilitate the open cut construction with the use of a temporary modular bridge. Temporary grade lowering and temporary protection systems (TPS) could also be used to facilitate construction. However, design of the TPS would need to account for the shallow depth to refusal observed at this site.

An alternate approach which is also considered feasible is to install a new suitable diameter culvert on a new alignment using trenchless techniques and possibly a second smaller pipe within the opening of the existing box.

10 OPEN CUT FOUNDATIONS DESIGN RECOMMENDATIONS

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

10.1 Culvert Foundation Bearing Resistances

A closed box culvert may be founded on the native, undisturbed sand and silty sand and can be designed based on the factored geotechnical resistance values provided below. It should be noted that during the field investigation, refusal was obtained within the anticipated depth of a footing and the Contractor should be prepared to remove/dislodge any obstructions that are encountered.

The recommended geotechnical resistances for a pre-cast box culvert installed on a bedding layer (see Section 10.2) overlying undisturbed native compact to dense sand subgrade is provided below. The new culvert should be founded at or below the elevation of the existing culvert. A closed box culvert would not need to be founded below the depth of frost. For a 3.6 m wide box culvert founded at or below elevation 308.8 m, the geotechnical resistance vales are as follows.

- Factored Geotechnical Resistance at ULS 300 kPa
- Factored Geotechnical Resistance at SLS or 225 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):
  - o ϕ_{gu} = 0.5 (static analysis; typical degree of understanding)
  - o 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. Foundation settlement, based on the supplied SLS resistance, is expected to be less than 25 mm.

Resistance to lateral forces/sliding resistance between concrete and native granular or the underlying Granular 'A' bedding (Section 10.2) should be evaluated in accordance with the CHBDC assuming an unfactored coefficient of 0.45 for precast concrete and 0.5 for cast-in-place concrete.

It is noted that construction will extend below the observed creek water level. Water diversion and dewatering (Section 12.3) will be required to place the bedding material and install the culvert in the dry.

10.2 Subgrade Preparation, Bedding and Backfilling

Subgrade preparation for the culvert replacement should include excavation and removal of the existing culvert, culvert foundations (if interfering with installation of the new culvert) and backfill materials. 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 sand subgrade at or below the desired founding elevations. The exposed subgrade must be inspected in accordance with SP109S12 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 closed box 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.

The subgrade may be easily disturbed when saturated and should be protected from disturbance from both construction traffic and weather. Construction equipment should not be permitted to travel on the exposed subgrade. Dewatering will be required to prepare the subgrade in the dry. Please refer to Section 12.3 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.

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 the 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 2.4m. It is not necessary to found a closed box culvert at a depth below frost penetration. Frost taper treatment, if required, should be as per OPSD 803.010 and as directed within the Pavement Design Report.

10.4 Backfill and Earth Pressure

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

10.4.1 Static Lateral Earth Pressure Coefficients

Lateral earth pressures acting on structures should be computed in accordance with the CHBDC. Under drained conditions the lateral earth pressure acting on a wall is generally given by the following expression:

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

where:

- σ_h = lateral pressure on the wall at depth d (kPa)
- K = static earth pressure coefficient (see table below) (K_A for yielding walls, K_o for non-yielding walls)
- γ = unit weight of retained soil (see table below), use submerged unit weight below groundwater level
- d = 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 on vertical walls 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 ϕ = 35°, γ = 22.8 kN/m³		OPSS Granular B Type I ϕ = 32°, γ = 21.2 kN/m³		OPSS SSM and Existing Silty Sand Fill ϕ = 30°, γ = 21.0 kN/m³	
	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: (*) to be used with 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 earth 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 at 2H:1V behind the walls, the corresponding coefficients provided in the Table 10-1 should be used.

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

10.4.2 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 = ½ * F(PGA) * PGA, for structures that allow 25 to 50 mm of movement, and
- k_h = F(PGA) * PGA, for non-yielding walls

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

The coefficients of horizontal earth pressure for seismic loading presented in Table 10-2 may be used for vertical walls. The provided earth pressure coefficients are based on a Seismic Site Class D, PGA with a 2% probability of exceedance in 50 years of 0.097g (Geological Survey of Canada – Fifth Generation) and an 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 $\phi = 35^o$, $\gamma = 22.8$ kN/m^3		OPSS Granular B Type I $\phi = 32^o$, $\gamma = 21.2$ kN/m^3	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active, K_{AE} Yielding Wall	0.31	0.48	0.34	0.60
Active, K_{AE} Non-Yielding Wall	0.34	0.63	0.39	0.84

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

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

where:

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

10.5 Embankment Design and Reinstatement

10.5.1 Embankment Reconstruction

Embankment reconstruction after culvert replacement should be carried out in accordance with OPSS.PROV 206. The embankment should be reinstated with side slopes of 2H:1V (or flatter) if constructed using Select Subgrade Material (SSM) or Granular B Type I. The granular fills should be placed and compacted in accordance with OPSS.PROV 501.

It is understood that slopes as steep as 1.5H:1V are required to a horizontal distance of 4.05 m from either side of the culvert, from the toe of the embankment to the top of the culvert. In this zone, the embankment should be reconstructed with rockfill or OPSS Granular B Type II. It is understood that a transition to a 2H:1V slope will be within this width. Additional requirements are provided within Section 12.4.

The portions of the existing sand and silty sand fill material that are compactable, unfrozen, free of organics and meet the requirements for OPSS Select Subgrade Material could be considered for reuse as backfill in the areas with a slope no steeper than 2H:1V and above the culvert cover/embedment provided there is sufficient space to stockpile adjacent to the culvert and embankment footprint and moisture within the soil is controlled to allow compaction. This will require further material testing and proper separation and handling of the existing fills by the Contractor. Note there is a risk that the excavated material becomes unsuitable for reuse leading to the need to import extra backfill at additional cost during construction. The risk of a claim could be minimized by specifying the use of SSM material and accepting a Contractor change proposal to use Native Materials.

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

Provided the subgrade is prepared as outlined above and construction of the embankment is carried out in accordance with recommendations provided within this report, the embankment side slopes should remain stable.

It is understood that no grade raise is anticipated along the alignment of Highway 11 and therefore negligible settlement of the underlying soils is expected to occur. Further assessment of embankment stability and settlement should be carried out where construction staging dictates the requirement for additional loading or if a temporary alignment is constructed.

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

10.5.2 Temporary Detour

A foundation assessment for a temporary detour alignment was not completed as part of this assignment and would necessitate further field investigation with recommendations provided in a separate report if required.

10.6 Cement Type and Corrosion Potential

Analytical tests were completed to determine the potential for degradation of the concrete in the presence of soluble sulphates and the potential for corrosion of exposed steel. The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with soil and groundwater at the site. Soluble sulphate concentrations less than 1000 μg/g generally indicate a low degree of sulphate attack is expected for concrete in contact with soil and groundwater. The class of concrete selected should consider the effects of road de-icing salts.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The test results provided in Section 5.5 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects. The corrosion effects of road de-icing salts should also be considered.

11 TRENCHLESS DESIGN RECOMMENDATIONS

It is anticipated that the soils which will be encountered during a trenchless installation will consist of granular fill and native soils varying from silty sand to sand with silt to gravel. The soils at the front face of the trenchless excavation will predominantly be wet sands and silts and based on the Tunnelman's Ground Classification System (modified by Heuer 1974 from Terzaghi 1950) the soils are described as 'running'. Based on the soil and groundwater conditions closed face tunneling techniques are preferred.

Trenchless methods that are typically considered to install pipes under highways include: jack and bore, pipe ramming, microtunneling (MTBM), hand mining and horizontal directional drilling. A table with comparisons of the different trenchless installation methods has been provided in Appendix E Selection of the appropriate trenchless method is the responsibility of the Contractor and will depend on the relative costs associated with each method. The experience of the Contractor is of primary importance for trenchless installation. Based on the results of the investigation and the size and invert elevation of the culvert, pipe ramming is generally feasible. Microtunneling (MTBM) with pipe jacking is also feasible but would likely require multiple pipes.

Trenchless installation should be completed in accordance with the requirements of the Non-Standard Special Provision (NSSP) "Pipe Installation by Trenchless Methods" provided in Appendix G. Amongst the important issues discussed in the NSSP are maintenance of alignment, handling of obstructions and disposal of cuttings.

Monitoring of the roadway surface would be required during trenchless installation. The settlement monitoring program and condition survey should follow Section 7.06 of the NSSP in Appendix G.

The design of safe and stable entry and exit pits for the trenchless installation would be the responsibility of the Contractor. Available geotechnical bearing resistances at the base of entry and exit pits should follow recommendations and values provided in Section 10. Entry and exit pits should be cut with side slopes that follow the recommendations provided in Section 12.1 or, where space restrictions exist, temporary protection systems may be used to support temporary excavations. The temporary excavation support system should be designed and constructed as outlined in Section 12.2. Dewatering and surface water control must be employed as necessary to keep the entry and exit pits dry as discussed further in Section 12.3.

12 CONSTRUCTION CONSIDERATIONS

12.1 Excavation

All excavation must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of OHSA, the fills and native soils above the water table may be classified as Type 3 soil. The organic soils, alluvial deposits and native soils below the groundwater level are classified as Type 4 soils. All excavations must not encroach within an area encompassed within 1H:1V from the base of the excavation to the existing culvert foundation or embankment to not undermine the foundations.

Excavation for the culvert replacement must be carried out in accordance with OPSS 902 and will be carried out through the existing embankment fill and extend into the underlying native deposits. The sides of temporary excavations must be sloped in accordance with the requirement of the OHSA. Selection of the equipment and methodology to excavate and prepare the founding surface is the responsibility of the Contractor. Stockpiling or surface surcharge should not be allowed on the embankment or side slopes.

At locations where there are space restrictions or where a slope has to be retained, the excavations will need to be carried out within a protection system. Further discussion on temporary protection systems (TPS) is presented in Section 12.2.

12.2 Temporary Protection Systems

Temporary Protection Systems may be required during various stages of construction and must be implemented in accordance with OPSS.PROV 539 and designed for Performance Level 2 (maximum 25 mm horizontal deflection). The actual pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall and these factors must be considered when designing the shoring system.

The design of roadway protection is the responsibility of the Contractor. All protection systems should be designed by a licensed Professional Engineer experienced in such designs and retained by the Contractor. The design of the roadway protection system must incorporate traffic loading and surcharge loading due to construction equipment and operations.

It is recommended that an NSSP be included in the tender documents to alert the Contractor to the potential for cobbles and boulders and obstructions within the fill and the potential need for deadman tie-backs, struts and/or raker supports to achieve the specified performance level due to the shallow depth of refusal noted during the field investigation. Consideration can be given to lowering the highway alignment during construction stages to reduce the overall height of the traffic protection required.

The protection system should be installed at a sufficient distance away from the new culvert to limit disturbance to the culvert subgrade during removal of the protection system. The protection system should not be removed until backfilling of the culvert is complete. Alternatively, the protection system near the culvert could be left in place and cut off in accordance with OPSS.PROV 539.

Lateral earth pressure coefficient, under fully mobilized conditions, that can be used in design of the protection system installed through the embankment fill and culvert backfill are provided in Table 10-1 and Table 10-2. The lateral earth pressure coefficient for the exiting native sand to silty sand foundation soils are given below for a vertical wall with a horizontal backslope:

γ = 20 (kN/m^3, bulk unit weight of retained soil)
K_A = 0.30
K_P = 3.3

Submerged unit weight should be used below the groundwater level.

The native silty clay located along the west side of the embankment should be considered to provide negligible lateral resistance.

12.3 Surface and Groundwater Control

Culvert construction, subgrade preparation and placement and compaction of granular bedding must be carried out in the dry. The depth of excavations required to construct the culvert will extend below the creek level observed at the time of the investigation. Furthermore, groundwater and surface runoff will tend to seep into and accumulate into the excavations. The Contractor must control groundwater and creek/surface water flow at the site to permit the replacement of the culvert in a dry and stable excavation.

Subgrade preparation, placement and compaction of granular bedding, and culvert construction must be carried out with a properly designed dewatering system to control groundwater and creek/surface water and may include coffer dams, creek diversion, pumping etc. The dewatering system will be required to remain operational and effective until the temporary excavations are backfilled and then should be decommissioned and removed.

The design of dewatering systems is the responsibility of the Contractor. The Contract Documents must alert the Contractor to this responsibility and to design the system in accordance with SP No. FOUN0003 which amends OPSS 902. A preconstruction survey is not recommended, thus Designer Fill-In ** in this SP should be “NA”. The Design Requirements of SP FOUN0003 should be amended by requiring an experienced design engineer as indicated in Appendix G.

The groundwater level will fluctuate and the minimum groundwater elevation at the time of the proposed work should be taken as the creek water level of the design storm return period defined by the contract documents for the temporary dewatering system.

A temporary flow passage is expected to be required to convey creek flow around the construction site. Construction of cofferdams will be required to divert the creek flow into the temporary flow passage. A sheet piled cofferdam may be required to limit flow through the underlying silty sand with gravel and can be designed following the recommendations provided in Sections 12.1 and 12.2. The groundwater level in the work zone should be lowered by pumping from sumps prior to excavation to a minimum of 500 mm below the underside of each excavation stage. The need for a PTTW should be assessed by specialists experienced in this field.

12.4 Scour Protection and Erosion Control

The Contractor should provide silt fences and erosion control blankets as per OPSS 805 throughout the duration of construction to prevent transport of silt/sediment. Slope protection and drainage measures will be required to ensure the long-term surficial stability of the embankment slopes. The existing materials encountered in the embankment are considered to be relatively non-erodible with the exception of a layer of silt fill which is moderately erodible. Slope vegetation should be established as soon as possible after completion of the embankment fills in order to limit surficial erosion.

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 is provided over all earth surfaces subjected to flowing water in accordance with OPSS 511. Treatment at the outlet should be in accordance with OPSD 810.010.

It is understood that the embankment slope in the area directly adjacent to the culvert at each end could be reinstated as steep as 1.5H:1V. Consideration of the localised embankment steepness should be taken into account when designing the scour and erosion protection. The rock protection thickness should be a minimum or 1 m at this site. The streambed material thickness should be increased to a minimum of 0.5 m at this site.

A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS.PROV 804.

It is recommended that a clay seal be used to minimize the potential for piping and erosion around the culvert inlet and outlet. The clay seal should have a minimum thickness of 500 mm and must extend to 300 mm above the high-water level. Since a reinstated embankment slope as steep as 1.5H:1V is proposed within 4.05 m of either side of the culvert, the clay seal should also extend this full width. The material requirements should be in accordance with OPSS.PROV 1205. A geosynthetic clay liner is not considered to be a suitable replacement for a clay seal due to the proposed inclination of the reinstated embankment.

A concrete cut-off wall is also recommended at both the inlet and outlet of the culvert. The cut-off walls should extend beyond the culvert to the limits of excavation and bedding.

13 CONSTRUCTION CONCERNS

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

- Buried obstructions may be encountered in the existing embankment fill and could interfere with tunneling, excavation and/or roadway protection installation.
- Shallow depth of refusal may interfere with installation of roadway protection installation
- 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.

- 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 in accordance with SP109S12 to confirm that foundation recommendations are correctly implemented, and material specifications are met.

14 CLOSURE

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

Thurber Engineering Ltd.
Report Prepared By:

Christopher Murray, P.Eng.
Geotechnical Engineer

Stephen Peters, P.Eng.
Geotechnical Engineer

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

Dr. P.K. Chatterji, P.Eng.
Review Principal,
Senior Geotechnical Engineer

Appendix A.

Drawings

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

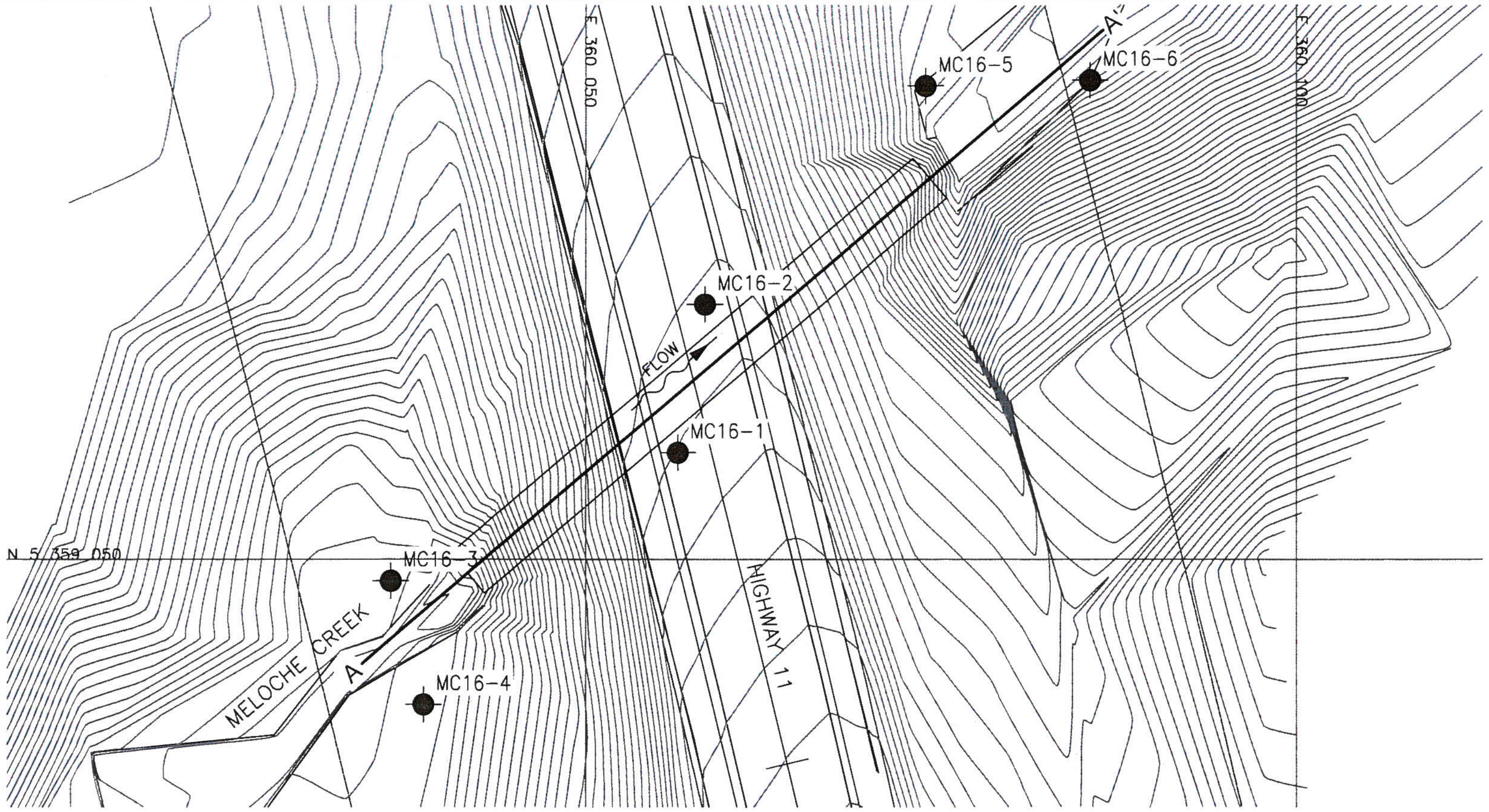
CONT No
GWP No 5054-01-00

HIGHWAY 11
MELOCHE CREEK CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

McINTOSH PERRY

THURBER ENGINEERING LTD.

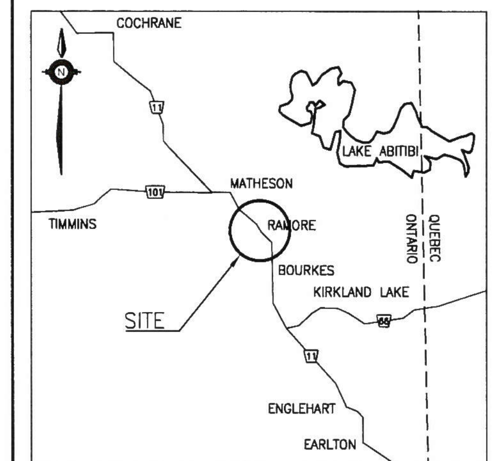


PLAN

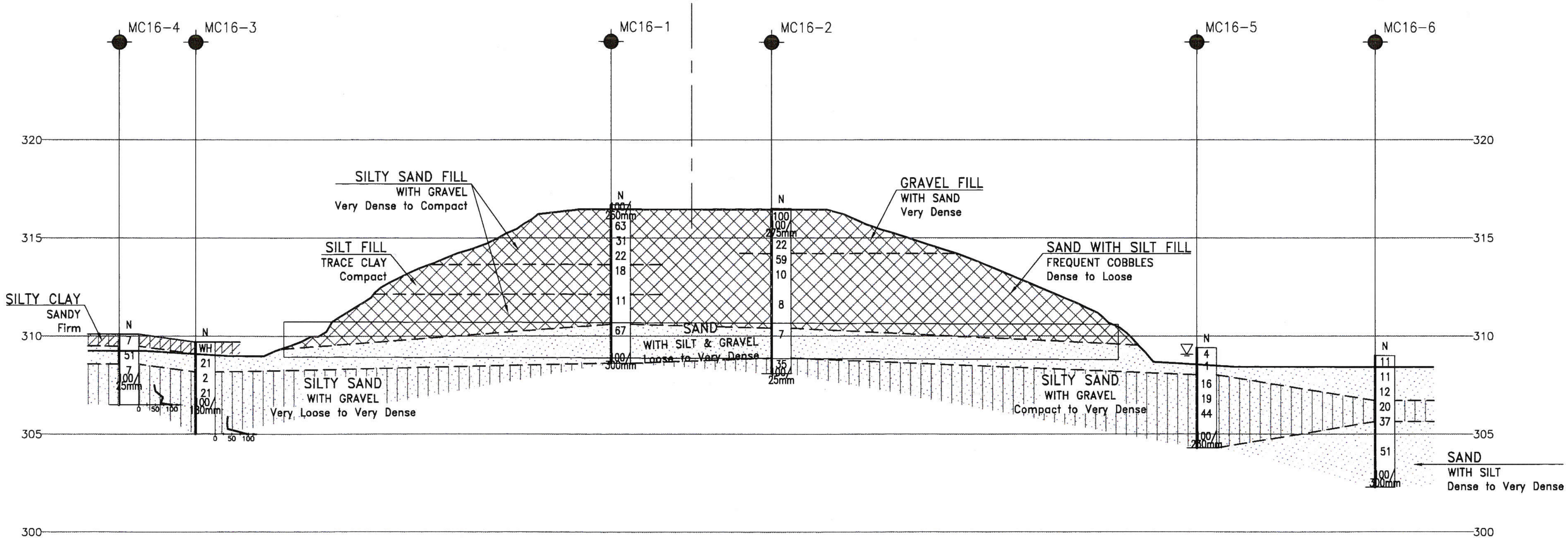
10 0 10 20m
SCALE 1:500

LICENSED PROFESSIONAL ENGINEER
F. J. GRIFFITHS
Sept 21/18
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
Sep 21/18
PROVINCE OF ONTARIO



KEYPLAN



SECTION A–A'

5 0 5 10m
SCALE 1:250

LEGEND

Symbol	Description
●	Borehole (Current Investigation)
⊕	Borehole (Previous Investigation)
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	316.7	5 359 057.5	360 056.5
MC16-2	316.5	5 359 067.9	360 058.4
MC16-3	309.7	5 359 048.5	360 036.3
MC16-4	310.1	5 359 039.8	360 038.6
MC16-5	309.4	5 359 083.2	360 073.9
MC16-6	309.0	5 359 083.6	360 085.5

-NOTES-

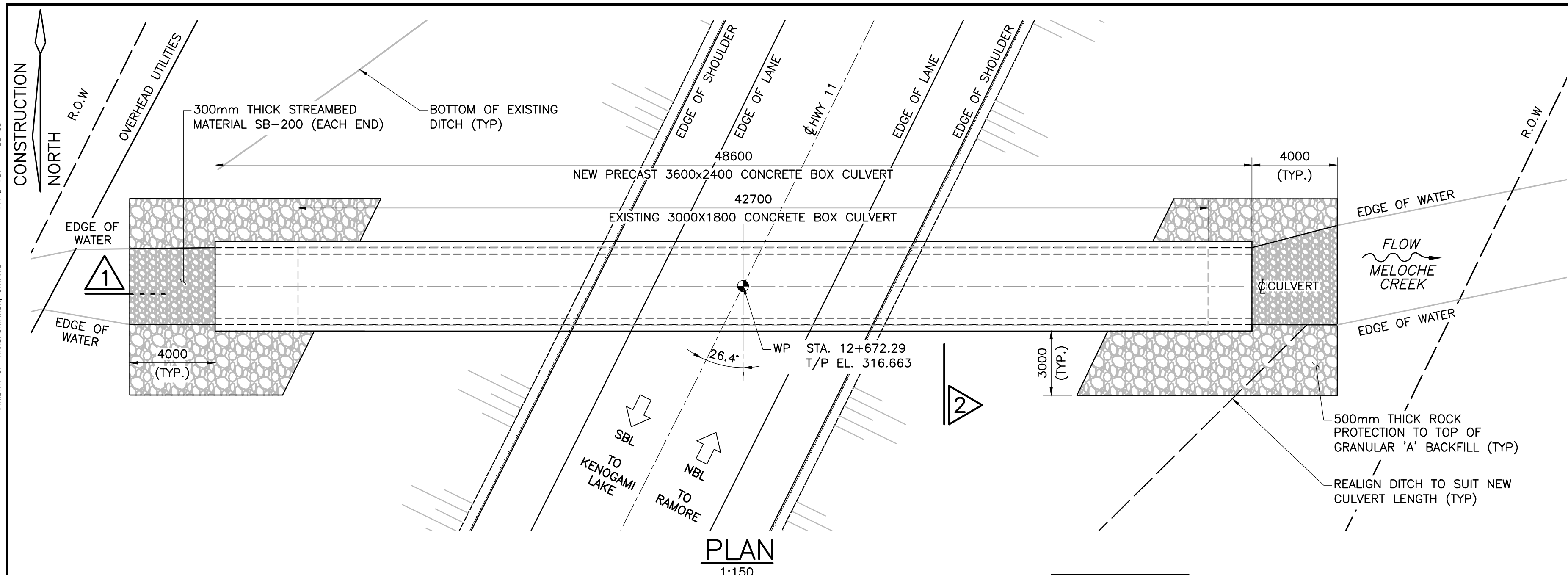
1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCRES No. 42A00-117

REVISIONS	DATE	BY	DESCRIPTION
DESIGN SBP	CHK FJG	CODE	LOAD	DATE SEPT 2018
DRAWN AN	CHK SBP	SITE	STRUCT	DWG 1

FILENAME: H:\Projects\10000 to 20000\13058 - Hwy 11, 6 Culverts\CAD\from Oakville (Sept20-18)\TED-13058-BHPP (MelocheCreek).dwg
PLOTDATE: 9/21/2018 12:57 PM

METRIC DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN	CONT. No. WP No. 5218-13-01	
	HIGHWAY 11 MELOCHE CREEK CULVERT REPLACEMENT	SHEET 93
	GENERAL ARRANGEMENT	
	McINTOSH PERRY	



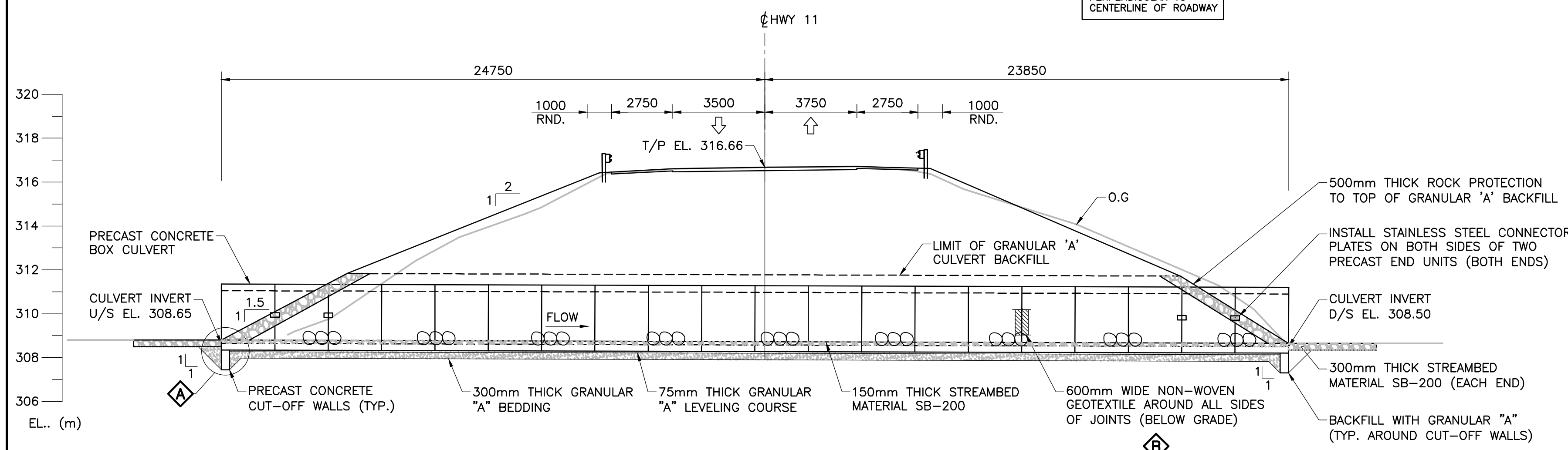
PLAN
1:150

LEGEND:
- GRANULAR
- ROCK PROTECTION
- STREAMBED MATERIAL
- GUIDERAIL
- ROCK BAFFLES

LIST OF ABBREVIATIONS:

℄	CENTRELINE	MIN.	MINIMUM
DWG.	DRAWINGS	STA.	STATION
EL.	ELEVATION (METERS)	W.L.	WATER LEVEL
EX.	EXISTING	TYP.	TYPICAL
U/S	UPSTREAM	D/S	DOWNSTREAM
OG	ORIGINAL GROUND	ROW	RIGHT OF WAY

*DIMENSIONS MEASURED PERPENDICULAR TO CENTERLINE OF ROADWAY



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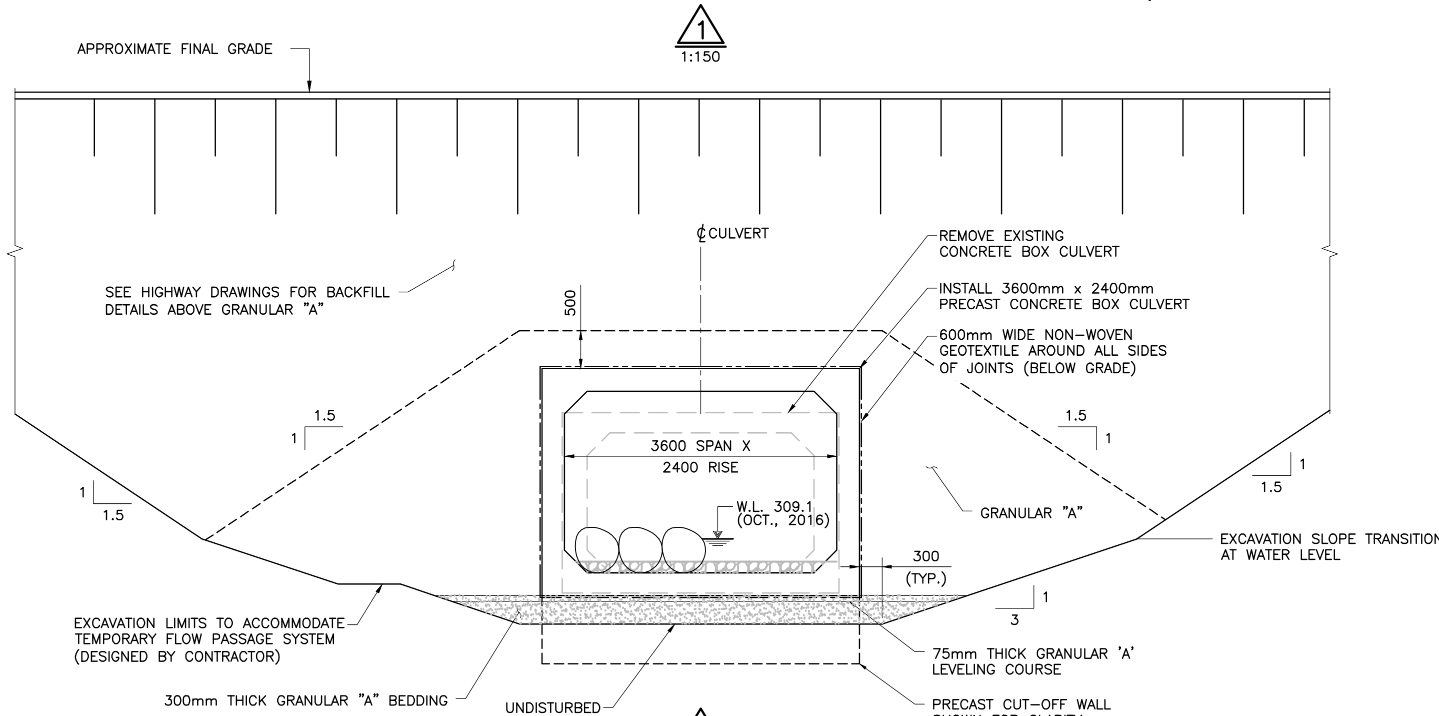
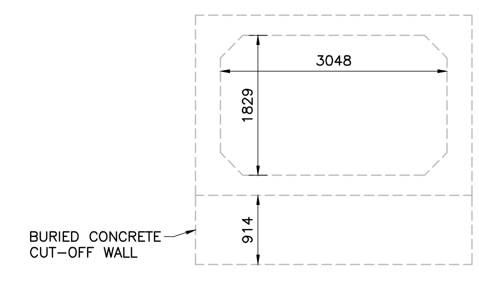
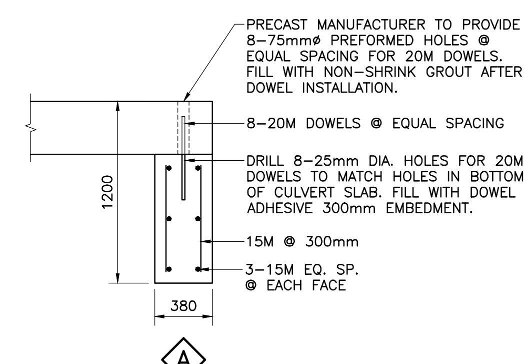


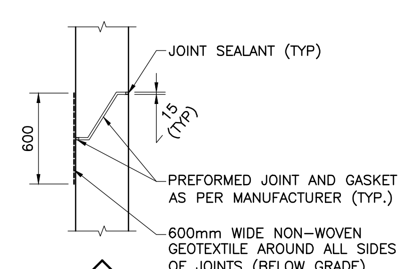
2
1:50



EXISTING CULVERT
1:50



A
N.T.S.



B
N.T.S.

GENERAL NOTES:

1. CLASS OF CONCRETE

PRECAST 40 MPa

2. CLEAR COVER TO REINFORCING STEEL

PRECAST 50 ± 10mm

3. REINFORCING NOTES

- REINFORCING STEEL SHALL BE GRADE 400W.
- UNLESS SHOWN OTHERWISE, TENSION LAP SPLICES FOR REINFORCING STEEL BARS SHALL BE CLASS B.
- BAR HOOKS SHALL HAVE STANDARD HOOK DIMENSIONS USING MINIMUM BEND DIAMETERS, WHILE STIRRUP AND TIES SHALL BE IN ACCORDANCE WITH THE STRUCTURAL STANDARD DRAWING SS12-1 UNLESS INDICATED OTHERWISE.

4. GEOTEXTILE

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

5. CONSTRUCTION NOTES

- THE CONTRACTOR SHALL VERIFY ALL DIMENSIONS AND SITE CONDITIONS BEFORE PROCEEDING WITH WORK AND REPORT ANY DISCREPANCIES TO THE CONTRACT ADMINISTRATOR BEFORE COMMENCING THE WORK.
- THE CONTRACTOR SHALL CARRY OUT SITE SURVEYS TO DETERMINE THE EXISTING ELEVATIONS OF ASPHALT PRIOR TO REMOVALS.
- THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE DESIGN OF THE DEWATERING AND TEMPORARY FLOW PASSAGE SYSTEMS.
- THE TEMPORARY FLOW CONTROL SHALL BE DESIGNED FOR A TWO (2) YEAR DESIGN STORM RETURN PERIOD OF 1.57 m^3/s.
- LENGTH OF PRECAST UNITS MAY BE MODIFIED AS PER MANUFACTURERS REQUIREMENTS. TOTAL LENGTH OF THE CULVERT SHALL NOT BE LESS THAN WHAT IS SHOWN AND MAXIMUM LENGTH OF CULVERT WILL BE WITHIN 300MM OF WHAT IS SHOWN.
- BACKFILL SHALL BE PLACED SIMULTANEOUSLY BEHIND BOTH CULVERT WALLS KEEPING THE HEIGHT OF THE BACKFILL APPROXIMATELY THE SAME. AT NO TIME SHALL THE DIFFERENCE IN THE ELEVATION BE GREATER THAN 400mm.
- THE CONTRACTOR SHALL SELECT EQUIPMENT, MATERIALS AND TYPES OF CONSTRUCTION TO SUIT CONSTRAINTS, SUCH AS THE TEMPORARY MODULAR BRIDGE.
- ALL AREAS AFFECTED BY CONSTRUCTION ACTIVITIES SHALL BE FULLY REINSTATED TO PRE-CONSTRUCTION OR BETTER CONDITIONS TO THE SATISFACTION OF THE CONTRACT ADMINISTRATOR INCLUDING THE REINSTATEMENT OF ALL VEGETATION, PATHWAYS, FENCES, AND AREAS USED FOR SITE ACCESS.

5. FOUNDATION DESIGN

FACTORED GEOTECHNICAL RESISTANCE AT SLS 225 kPa
FACTORED GEOTECHNICAL RESISTANCE AT ULS 300 kPa

APPLICABLE STANDARD DRAWINGS:

1. MTOD 3941.2100 – FIGURES IN CONCRETE SITE NUMBER AND LAYOUT

LIST OF DRAWINGS:

1. GENERAL ARRANGEMENT
2. BOREHOLE LOCATIONS AND SOIL STRATA CULVERT
3. BOREHOLE LOCATIONS AND SOIL STRATA TMB
4. CONSTRUCTION STAGING I
5. CONSTRUCTION STAGING II
6. MISCELLANEOUS DETAILS

DRAWING NOT TO BE SCALED
100mm ON ORIGINAL DRAWING

REVISIONS	DATE	BY	REV	DESCRIPTION		
DESIGN LD	CHK QI	CODE CHBDC-14	LOAD CL-625-ONT	DATE SEP/18		
DRAWN DS	CHK LD	SITE 39E-0222/C0		DWG 01		

Appendix B.

Record of Borehole Sheets

THURBER

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.

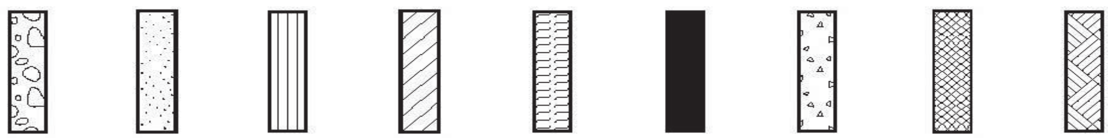
N-VALUE:

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

THURBER

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

THURBER

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

METRIC

GWP# 5054-01-00

LOCATION: Lat: 48.3677991°, Long: -80.2541546°, Meloche Creek Culvert, MTM z12: N 5 359 057.5 E 360 056.5

ORIGINATED BY: SOB

HWY: 11

BOREHOLE TYPE: NW Casing

COMPILED BY: JM

DATUM: Geodetic

DATE: 2016.10.12 - 2016.10.12

CHECKED BY: SP

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
316.7 / 0.0	**180 mm ASPHALT**				
0.1	Silty SAND with gravel, Brown, Very dense to compact, **FILL**	1	SS	100/ 250mm	
		2	SS	63	
		3	SS	31	26 60 14 (SI+CL)
		4	SS	22	
313.7 / 3.0	SILT, trace clay and organics, Grey, Compact, **FILL**	5	SS	18	
312.1 / 4.6	Silty SAND some gravel, Brown, Compact, **FILL**	6	SS	11	12 68 20 (SI+CL)
310.6 / 6.1	**SAND** with silt and gravel, Brown, Very dense	7	SS	67	19 69 12 (SI+CL)
		8	SS	100/ 300mm	
308.6 / 8.1	End of Borehole				

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (316, 315, 314, 313, 312, 311, 310, 309); 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.

+ ³, × ³ : Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No MC16-2

METRIC

GWP# 5054-01-00
LOCATION Lat: 48.3678925°, Long: -80.2541275° Meloche Creek Culvert, MTM z12: N 5 359 067.9 E 360 058.4
ORIGINATED BY SOB

HWY 11
BOREHOLE TYPE NW Casing
COMPILED BY JM

DATUM Geodetic
DATE 2016.10.12 - 2016.10.12
CHECKED BY SP

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%) (approx.)	GR	SA	SI	CL
316.5										
0.0 / 0.1	**ASPHALT (180mm)**					~3				
	GRAVEL with sand, Brown, Very dense to compact, **FILL**	1	SS	100	316					
	- asphalt layer at 1.0 m	2	SS	100/ 275mm		~5	78	21	1 (SI+CL)	
		3	SS	22	315	~5				
314.2 / 2.3	SAND with silt and gravel, frequent cobbles, Brown, Very dense to loose, **FILL**	4	SS	59	314	~8	44	50	6 (SI+CL)	
		5	SS	10	313					
		6	SS	8	312	~20	2	70	28 (SI+CL)	
310.4 / 6.1	**SAND** with silt and gravel, Brown, Loose	7	SS	7	311 / 310	~21				
308.9 / 7.6	**Silty SAND (SM)** with gravel, Brown, Compact to very dense	8	SS	35	309	~15				
308.1 / 8.4	End of Borehole	9	SS	100/ 25mm						

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/m^3; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

+ 3, × 3: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No MC16-3

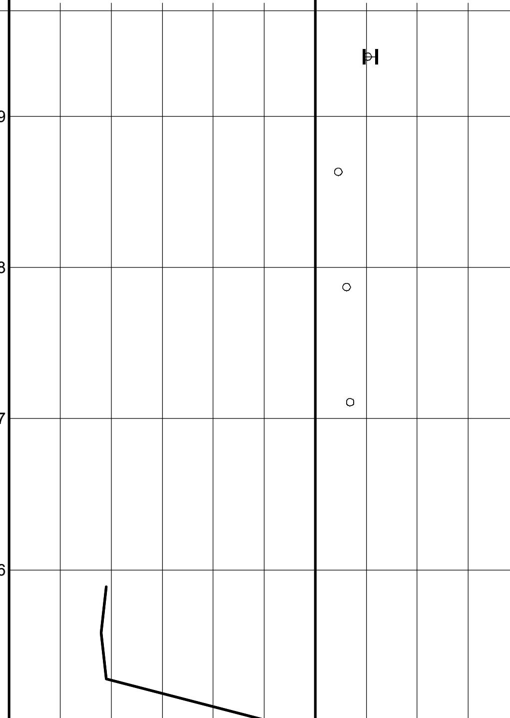
METRIC

GWP#	5054-01-00	LOCATION	Lat: 48.36772°, Long: -80.2544284° Meloche Creek Culvert, MTM z12: N 5 359 048.5 E 360 036.3	ORIGINATED BY	JM
HWY	11	BOREHOLE TYPE	Portable w/ NW Casing	COMPILED BY	JM
DATUM	Geodetic	DATE	2016.10.12 - 2016.10.12	CHECKED BY	SP

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
309.7								
0.0	**Silty CLAY (CL-ML)**, sandy Brown to grey Firm		1	SS	WH			0 38 49 13
309.1 / 0.6	**SAND** with silt and gravel Grey Compact		2	SS	21		309	
308.2 / 1.5	**Silty SAND (SM)** with Gravel Grey to brown Very loose to very dense		3	SS	2		308	26 53 15 6
			4	SS	21		307	
			5	SS	100/ 180mm			
306.5 / 3.2							306	
305.0 / 4.7	End of Borehole Note: DCPT data from approximately 1 m away							

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

+ ³, × ³: Numbers refer to Sensitivity

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

RECORD OF BOREHOLE No MC16-4

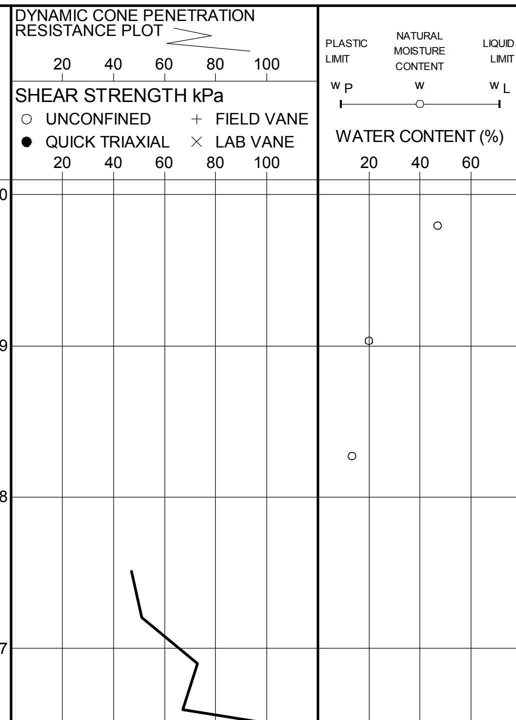
METRIC

GWP# 5054-01-00 | LOCATION Lat: 48.3676415°, Long: -80.2543985° Meloche Creek Culvert, MTM z12: N 5 359 039.8 E 360 038.6 | ORIGINATED BY JM

HWY 11 | BOREHOLE TYPE Portable w/ NW Casing | COMPILED BY JM

DATUM Geodetic | DATE 2016.10.12 - 2016.10.12 | CHECKED BY SP

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
310.1						
0.0	**Silty CLAY (CL-ML)**, sandy Brown Firm	1	SS	7		
309.5 / 0.6	**SAND** with silt and gravel, frequent cobbles Grey Very dense	2	SS	51		
308.6 / 1.5	**Silty SAND (SM)** with gravel Grey Loose to very dense	3	SS	7		18 60 16 6
307.8 / 2.3		4	SS	100/ 25mm		
306.5 / 3.6	End of Borehole					



+ 3, × 3: Numbers refer to Sensitivity

20 15 5 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No MC16-5

METRIC

GWP#	5054-01-00	LOCATION	Lat: 48.3680285°, Long: -80.253916° Meloche Creek Culvert, MTM z12: N 5 359 083.2 E 360 073.9	ORIGINATED BY	JM
HWY	11	BOREHOLE TYPE	Portable w/ NW Casing	COMPILED BY	JM
DATUM	Geodetic	DATE	2016.10.12 - 2016.10.12	CHECKED BY	SP

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
309.4 / 0.0	**Sand (SM)** with silt some gravel Loose to very loose Brown to grey	1	SS	4	309		
		2	SS	1		~20	12 76 12 (SI+CL)
308.0 / 1.4	**Silty SAND (SM)** with gravel Grey to brown Compact to very dense	3	SS	16	308	~14	
		4	SS	19	307	~17	
		5	SS	44	306	~14	26 53 21 (SI+CL)
		6	SS	100/ 230mm	305	~17	
304.3 / 5.1	End of Borehole						

End of Borehole

DATE	DEPTH (m)	ELEV. (m)
2016.10.20	0.5	308.9
2017.04.17	0.3	309.1

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; 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

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No MC16-6

METRIC

GWP# 5054-01-00	LOCATION Lat: 48.368031°, Long: -80.2537597° Meloche Creek Culvert, MTM z12: N 5 359 083.6 E 360 085.5	ORIGINATED BY JM
HWY 11	BOREHOLE TYPE Portable w/ NW Casing	COMPILED BY JM
DATUM Geodetic	DATE 2016.10.16 - 2016.10.16	CHECKED BY SP

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI+CL
309.0 / 0.0	**SAND (SP)** with silt trace gravel, Grey, Compact	1	SS	11		8	87	5 (SI+CL)
		2	SS	11	308			
		3	SS	12	307			
306.7 / 2.3	**Silty SAND** with Gravel, Grey, Compact	4	SS	20	306			
305.6 / 3.4	**SAND (SP)** with silt, Brown, Compact to very dense	5	SS	37		25	53	22 (SI+CL)
		6	SS	51	305 / 304			
302.3		7	SS	100/300mm	303	1	91	8 (SI+CL)
6.7	End of Borehole							

Column headings: SOIL PROFILE; SAMPLES; 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

$+^3, \times^3$: Numbers refer to Sensitivity

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

DOUBLE LINE 13058 MELOCHE.GPJ 2012TEMPLATE(MTO).GDT 14/9/18

Appendix C.

Laboratory Testing

Appendix C.1

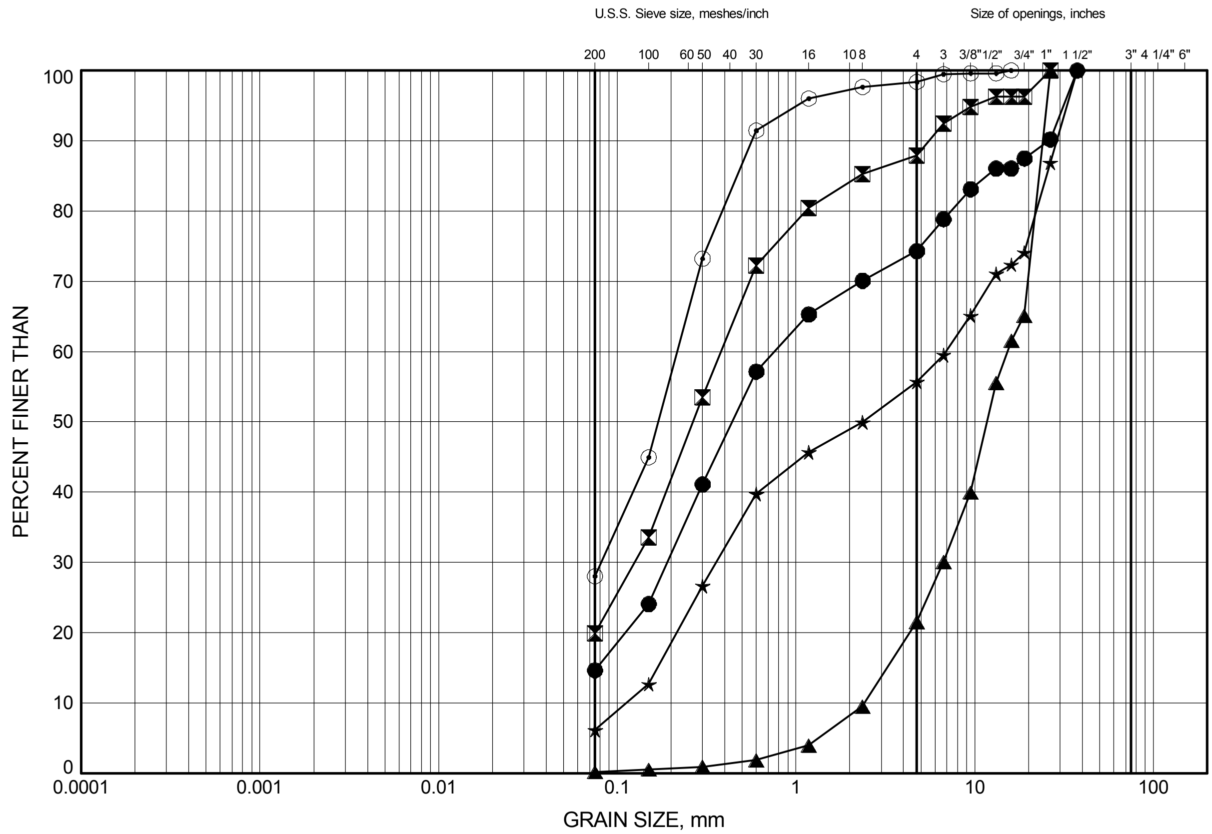
Particle Size Analysis Figures

Meloche 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)
●	MC16-1	1.83	314.87
⧗	MC16-1	4.88	311.82
▲	MC16-2	0.91	315.59
★	MC16-2	2.59	313.91
⊙	MC16-2	4.88	311.62

Date September 2018

GWP# 5054-01-00

THURBER

Prep'd CM

Chkd. SP

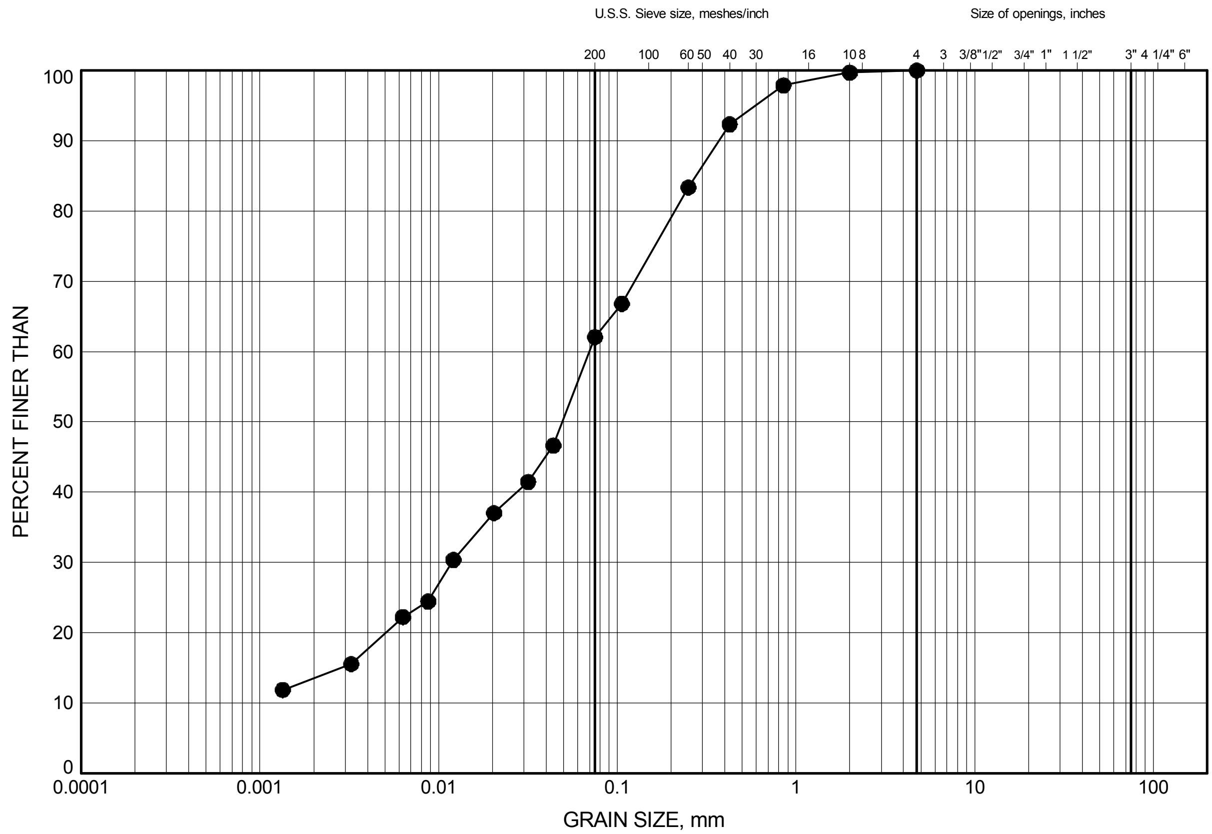
GRAIN SIZE DISTRIBUTION - THURBER 13058 MELOCHE.GPJ 14/9/18

Meloche Creek Culvert

GRAIN SIZE DISTRIBUTION

FIGURE C2

Silty CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MC16-3	0.30	309.40

GRAIN SIZE DISTRIBUTION - THURBER 13058 MELOCHE.GPJ 14/9/18

Date September 2018

GWP# 5054-01-00

THURBER

Prep'd CM

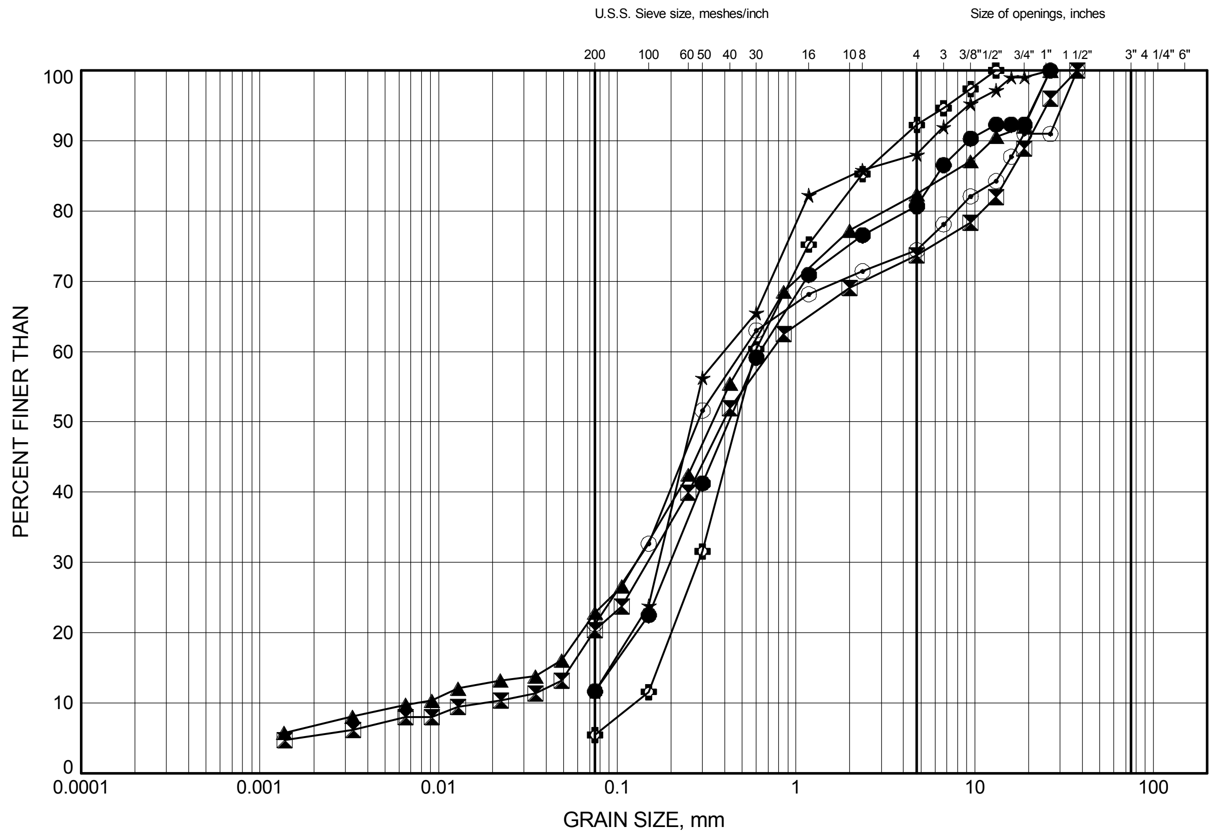
Chkd. SP

Meloche Creek Culvert

GRAIN SIZE DISTRIBUTION

FIGURE C3

Silty SAND to SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MC16-1	6.40	310.30
⧗	MC16-3	1.83	307.87
▲	MC16-4	1.83	308.27
★	MC16-5	0.91	308.49
⊙	MC16-5	3.35	306.05
✥	MC16-6	0.30	308.70

Date September 2018

GWP# 5054-01-00

THURBER

Prep'd CM

Chkd. SP

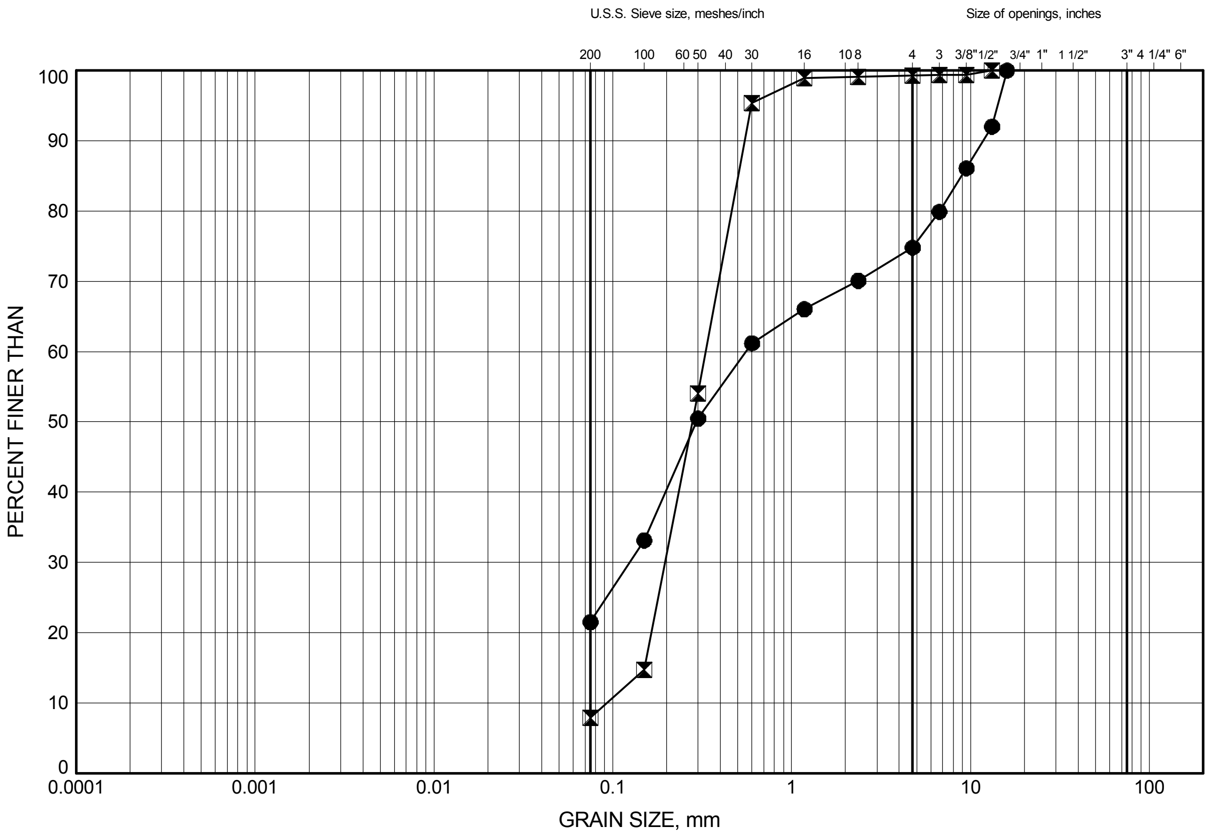
GRAIN SIZE DISTRIBUTION - THURBER 13058 MELOCHE.GPJ 14/9/18

Meloche Creek Culvert

GRAIN SIZE DISTRIBUTION

FIGURE C4

Silty SAND to SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MC16-6	3.20	305.80
⧗	MC16-6	6.40	302.60

Date September 2018

GWP# 5054-01-00

THURBER

Prep'd CM

Chkd. SP

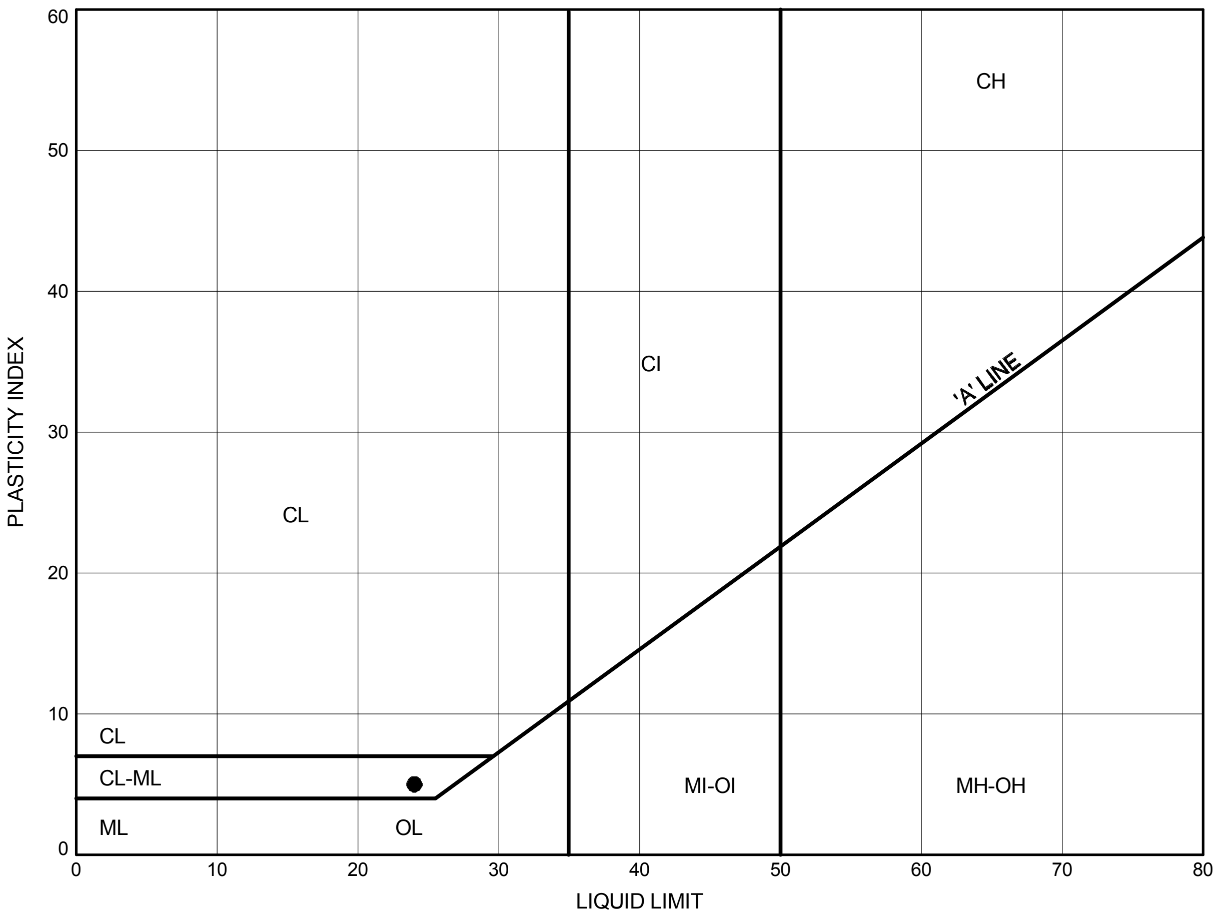
GRAIN SIZE DISTRIBUTION - THURBER 13058 MELOCHE.GPJ 14/9/18

Meloche Creek Culvert

ATTERBERG LIMITS TEST RESULTS

FIGURE C5

Silty CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MC16-3	0.30	309.40

THURBALT 13058 MELOCHE.GPJ 14/9/18

Date September 2018

GWP# 5054-01-00

THURBER

Prep'd CM

Chkd. SP

Appendix C.2

Analytical Testing Results

Certificate of Analysis

Client: Thurber Engineering Ltd.

Client PO:

Report Date: 02-Nov-2016

Order Date: 28-Oct-2016

Project Description: 13058

	MDL/Units	C2-3 SS1 0'-2'	C2-4 SS3 5'-7'	C6-3 SS2 2'6-4'6	C6-4 SS3A 5'-6'
Client ID:		C2-3 SS1 0'-2'	C2-4 SS3 5'-7'	C6-3 SS2 2'6-4'6	C6-4 SS3A 5'-6'
Sample Date:		18-Oct-16	18-Oct-16	18-Oct-16	18-Oct-16
Sample ID:		1644497-01	1644497-02	1644497-03	1644497-04
		Soil	Soil	Soil	Soil
Physical Characteristics					
% Solids	0.1 % by Wt.	74.7	79.6	76.7	74.5
General Inorganics					
Conductivity	5 uS/cm	357	494	795	344
pH	0.05 pH Units	7.59	7.52	7.54	7.60
Resistivity	0.10 Ohm.m	28.0	20.2	12.6	29.1
Anions					
Chloride	5 ug/g dry	49	236	314	67
Sulphate	5 ug/g dry	11	8	21	14

	MDL/Units	C7-3 SS2 2'6-4'6	C7-4 SS3 5'-7'	MC16-4 SS1 0'-2'	MC16-6 SS3 5'-7'
Client ID:		C7-3 SS2 2'6-4'6	C7-4 SS3 5'-7'	MC16-4 SS1 0'-2'	MC16-6 SS3 5'-7'
Sample Date:		18-Oct-16	18-Oct-16	18-Oct-16	18-Oct-16
Sample ID:		1644497-05	1644497-06	1644497-07	1644497-08
		Soil	Soil	Soil	Soil
Physical Characteristics					
% Solids	0.1 % by Wt.	64.7	72.9	65.0	88.2
General Inorganics					
Conductivity	5 uS/cm	226	616	729	56
pH	0.05 pH Units	7.52	7.62	6.21	6.35
Resistivity	0.10 Ohm.m	44.3	16.2	13.7	179
Anions					
Chloride	5 ug/g dry	11	187	328	9
Sulphate	5 ug/g dry	19	21	30	7

	MDL/Units	C28-3 SS2 2'6-4'6	C28-4 SS1 0'-2'	C34-3 SS3 5'-7'	C34-4 SS1 0'-2'
Client ID:		C28-3 SS2 2'6-4'6	C28-4 SS1 0'-2'	C34-3 SS3 5'-7'	C34-4 SS1 0'-2'
Sample Date:		18-Oct-16	18-Oct-16	18-Oct-16	18-Oct-16
Sample ID:		1644497-09	1644497-10	1644497-11	1644497-12
		Soil	Soil	Soil	Soil
Physical Characteristics					
% Solids	0.1 % by Wt.	71.3	70.8	79.9	91.9
General Inorganics					
Conductivity	5 uS/cm	765	999	233	208
pH	0.05 pH Units	7.47	7.60	7.65	6.95
Resistivity	0.10 Ohm.m	13.1	10.0	42.8	48.2
Anions					
Chloride	5 ug/g dry	343	493	13	18
Sulphate	5 ug/g dry	15	21	36	24

Appendix D.

Site Photographs

Photo 1. Looking north along Highway 11.

Photo 2. Looking south along Highway 11.

Appendix E.

Foundation Comparison

COMPARISON OF ALTERNATIVE FOUNDATION TYPES

Type	Closed Box Culvert	Circular Pipe Culvert (Trenchless Installation)	Open Bottom Culvert	Precast Concrete Slab on Sheet Pile Culvert
Advantages	Typically least costly culvert type. Relatively expedient installation if precast units are used. Smaller magnitude of settlement than open footing culvert due to lower bearing stress on subgrade. Minimized differential settlement between culvert and approach fills.	Can tolerate larger magnitude of settlement than concrete (rigid frame) culverts. Avoids open cut. Allows two lanes of traffic to be maintained throughout construction.	Relatively expedient installation if precast units are used. Possibility to maintain work zone outside of existing waterway.	Potentially minimized volume of excavation and roadway protection. Maintains water flow throughout construction and minimizes potential for disturbance of streambed. Allows for winter construction.
Disadvantages	Requires large excavation and roadway protection. Requires compacted granular pad on subgrade. Requires installation of a temporary by-pass culvert to maintain existing creek alignment.	Requires construction of entry and exit pits and access to toes of slope. Requires specialised construction equipment. Feasibility also depends on flow capacity and other hydraulic properties. May need a second pipe. Obstructions in fill mean many techniques not feasible.	Requires deeper excavation increasing excavation volume and dewatering efforts. Founding subgrade could provide lower geotechnical resistances. Potential for post construction settlement.	Quantity and cost of sheet piles. Unconventional design. Differential settlement will occur between non-yielding culvert and approach fills.
Risks/ Consequences	Groundwater control may require enclosed excavation.	Groundwater control may require enclosed excavation. Possibility of encountering obstructions.	Groundwater control may require sheet pile enclosed excavation. Increased risk of basal instability of footing excavation due to depth of excavation below water table.	Possibility of encountering obstructions and inadequate lateral support due to shallow refusal.
Relative Cost	Low	High	Medium	Medium to High
Recommendation	**Recommended**	**Generally Feasible**	**Generally Feasible**	**High Risk / Not Feasible**

FINAL

COMPARISON OF ALTERNATIVE TRENCHLESS INSTALLATION METHODS

Method	Jack and Bore	Pipe Ramming	Microtunelling (MTBM)	Hand Mining	Horizontal Directional Drilling
Advantages	Equipment and crew readily available	Able to access the tunnel face (depending on pipe diameters) Suitable for pipe diameters between 0.5 and 3.6 m and length < 100 m	High precision in alignment Worker safety is enhanced Allows access to tunnel face to deal with obstructions	Equipment and crew readily available	Limited requirement for shafts and pits
Disadvantages	Incapable of handling unforeseen obstructions Prone to misalignment Not suitable for loose cohesionless soils and/or high groundwater	Worker safety issues during tunnel face access Minimal precision in alignment control May need to lower groundwater level during construction	Unforeseen oversized obstruction may slow progress High operator skill required May require multiple pipes to achieve capacity	Unsuitable for small diameter pipes. Worker safety issues during tunnel face access Slow process Not suitable for loose cohesionless soils and/or high groundwater	Diminishing accuracy Suitable for pipes diameter < 2 m Not suitable for loose cohesionless soils and/or high groundwater
Risks/ Consequences	MODERATE	MODERATE	LOW to MODERATE	HIGH	HIGH
Recommendation	**Not Recommended**	**Generally Feasible**	**Recommended**	**Not Recommended**	**Not Recommended**

Appendix F.

GSC Seismic Hazard Calculation

2015 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

January 16, 2017

Site: 48.3678 N, 80.254 W   User File Reference: Meloche Creek Culvert

Requested by: Thurber Engineering Ltd., Ottawa, Ontario

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)**
0.139	0.177	**0.154**	0.122	**0.091**	**0.051**	**0.025**	**0.0063**	**0.0027**	**0.097**	**0.074**

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)	0.011	0.040	0.071
Sa(0.1)	0.017	0.057	0.096
Sa(0.2)	0.018	0.055	0.089
Sa(0.3)	0.016	0.047	0.073
Sa(0.5)	0.013	0.037	0.056
Sa(1.0)	0.0063	0.021	0.032
Sa(2.0)	0.0027	0.0099	0.016
Sa(5.0)	0.0006	0.0021	0.0037
Sa(10.0)	0.0004	0.0010	0.0015
PGA	0.0093	0.032	0.053
PGV	0.0075	0.026	0.043

References

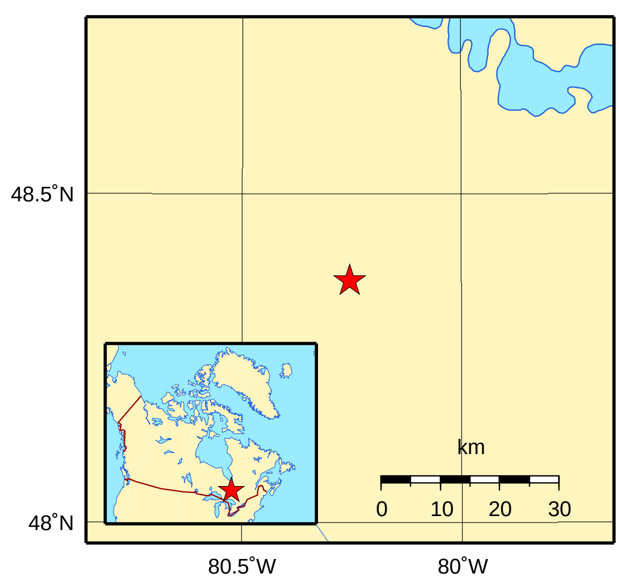
National Building Code of Canada 2015 NRCC no. 56190;
Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

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 G.

List of Special Provisions and OPSS Documents Referenced in this Report

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

OPSS.PROV 206	Construction Specifications for Grading
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts in Open Cut
OPSS.PROV 501	Construction Specification for Compacting
OPSS 511	Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS 805	Construction Specification for Temporary Erosion and Sediment Control Measures
OPSS 902	Construction Specification for Excavating and Backfilling – Structures
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material
OPSS.PROV 1205	Material Specification for Clay Seal
OPSD 208.010	Benching of Earth Slopes
OPSD 803.010	Backfill and Cover for Concrete Culverts with Spans Less Than or Equal to 3.0 m
OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
SP109S12	Amendment to OPSS 902 - QVE, Backfilling Compaction and Certification of Conformance
SP FOUN003	Dewatering Structure Excavations

2. Subsection 902.04.01 Design Requirements of SP FOUN0003 is amended by the addition of the following:

   The design Engineer and design-checking Engineer of the dewatering system shall have a minimum of 5 years of experience in designing systems of similar nature and scope to the required work.

3. Special Provision: Notice to Contractor - Existing Subsurface Conditions

   Meloche Creek Culvert (Site No. 39E-222/C)

   The Contractor is advised cobbles and/or boulders may be encountered in the existing highway embankments and native soils at the Meloche Creek Culvert (Site No. 39E-222/C) during excavation of the embankment. The Contractor shall select and use the appropriate methods and equipment to account for such possible obstructions.

   The Contractor is also advised that SPT refusal was encountered at elevations ranging from 308.6 m to 302.3 m in the boreholes drilled at the Meloche Creek Culvert site. The Contractor shall take into account the refusal for excavations and for any required dewatering measures.

<u>PIPE INSTALLATION BY TRENCHLESS METHOD</u> – Item No.

Special Provision

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1. SCOPE

This specification covers the general requirements for the installation of pipes by trenchless methods, including Jack & Bore, Pipe Ramming, Directional Drilling, and Tunnelling. The Contractor shall determine the most appropriate method of installation for each of the crossing locations.

This specification shall supersede OPSS 415 (Construction Specification for Pipeline Installation by Tunneling), OPSS 416 (Construction Specification for Pipeline and Utility Installation by Jacking and Boring) and OPSS 450 (Construction Specification for Pipeline and Utility Installation in Soil by Horizontal Directional Drilling).

2. REFERENCES

This specification refers to the following standards, specifications, or publications:

Ontario Provincial Standard Specifications, General

OPSS 180	Management and Disposal of Excess Materials

Ontario Provincial Standard Specifications, Construction

OPSS 401	Trenching, Backfilling, and Compacting
OPSS 404	Support Systems
OPSS 491	Preservation, Protection, and Reconstruction of Existing Facilities
OPSS 492	Site Restoration Following Installation of Pipelines, Utilities and Associated Structures
OPSS 517	Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS.PROV 539	Temporary Protection Systems

Ontario Provincial Standard Specifications, Material

OPSS.PROV 1004	Aggregates - Miscellaneous
OPSS.PROV 1350	Concrete - Materials and Production
OPSS.PROV 1440	Steel Reinforcement for Concrete
OPSS 1802	Smooth Walled Steel Pipe
OPSS.PROV 1820	Circular and Elliptical Concrete Pipe
OPSS 1840	Non-Pressure Polyethylene (PE) Plastic Pipe Products

American Society for Testing and Materials (ASTM) International Standards

ASTM A252-93	Welding and Seamless Steel Pipe Piles
ASTM D2657-03	Standard Practice for Heat Fusion Joining of Polyelofin Pipe and Fittings
ASTM D3350	Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
ASTM F894	Polyethylene Large Diameter Profile Wall Sewer and Drain Pipe

Canadian Standards Association Standards:

CSA B182.6	Profile Polyethylene Sewer Pipe and Fittings.
CAN/CSA A5-93	Portland Cement
CSA W59	Welded Steel Construction (Metal Arc Welding)

3. DEFINITIONS

For the purpose of this specification, the following definitions apply:

Auger Jack & Bore: a method of forming a horizontal bore in the subsurface by essentially simultaneously jacking ahead and rotating a cutter head, followed by removal of material from inside the bore by using an auger.

Backreamer: a cutting head suitably designed for the subsurface conditions that is attached to the end of a drill string to enlarge the pilot bore during a pullback operation.

Bore Path: a drilled path according to the grade and alignment tolerances specified in the Contract Documents.

Design Engineer: means the Engineer retained by the Contractor who produces the original design and working drawings. The design engineer shall be licensed to practice in the Province of Ontario.

Design Checking Engineer: means the Engineer retained by the Contractor who checks the original design and working drawings. The design checking engineer shall be licensed to practice in the Province of Ontario.

Digger Shield/Hand Mining: a method of forming a horizontal bore in the subsurface by essentially simultaneously jacking ahead while tunnelling advances using hand–mining (man-entry operation or "Jack and Mine) or a "digger" type shield with a hydraulic excavator arm to remove materials from inside the liner pipe.

Drilling Fluids: a mixture of water and additives, such as bentonite, polymers, surfactants, and soda ash, designed to block the pore space on a bore wall, reduce friction in the bore, and to suspend and carry cuttings to the surface.

Drilling Fluid Fracture or Frac Out: a condition where the drilling fluid's pressure in the bore is sufficient to overcome the in situ confining stress, thereby fracturing the soil and/or rock materials and allowing the drilling fluids to migrate to the surface at an unplanned location.

Engineer: a Professional Engineer licensed by the Professional Engineers of Ontario to practice in the Province of Ontario.

Excavation: includes all materials encountered regardless of type and extent. Excavation shall include removal of natural soil, large boulders, cobbles, wood and fill regardless of means necessary to break consolidated materials for removal.

Environmentally Sensitive Area (ESA): areas adjacent to construction that are off limits to the Contractor as specified elsewhere in the Contract.

Fill: man-made mixture of previously placed/handled materials such as sand, clay, silt, gravel, broken rock, sometimes containing organic and/or deleterious materials, placed in an excavation or other area to raise the surface elevation.

Grouting: injection of grout into voids.

Guidance System: an electronic system capable of locating the position, depth and orientation of the drill head during the directional drilling process.

Directional Drilling (DD): directional boring or guided boring.

HDPE: high density polyethylene.

Inadvertent Returns: the flow of unexpected fluids, saturated materials (or running soil) towards the drilling rig that typically originated from an artesian aquifer encountered during the drilling process.

Loss of Circulation: the discontinuation of the flow of drilling fluid in the bore back to the entry or exit point or other planned recovery points.

Pilot Bore: the initial bore to set directional controlled horizontal and vertical alignment between the connecting points.

Pipe Jacking: a method for installing steel casing or concrete pipe in the subsurface utilizing hydraulically operated jacks of adequate number and capacity to ensure smooth and uniform advancement without overstressing the liner/pipe.

Pipe Ramming: a method for installing steel casings utilizing the energy from a percussion hammer to advance a steel casing with a cutting shoe attached at the front end of the casing.

Primary Liner (Support): system installed prior to or concurrent with excavation, to maintain stability of an excavation and to support earth or rock and any structure utilities or other facilities in or on the supported earth or rock mass, until the excavation is completed.

Product: pipe culverts, pipe sewers, watermain pipe and sanitary pipe.

Pullback: that part of the DD method in which the drill string is pulled back through the bore path to the entry point.

Quality Verification Engineer (QVE): an Engineer who has a minimum of five (5) years experience in the field of pipe installation using trenchless methods or alternatively has demonstrated expertise by providing satisfactory quality verification services for the work at a minimum of two (2) projects of similar scope to the contract. The Quality Verification Engineer shall be retained by the Contractor to certify that the work is in general conformance with the contract documents and to issue Certificate(s) of Conformance.

Reaming: a process for pulling a tool attached to the end of the drill string through the bore path to enlarge the bore and mix the cuttings with the drilling fluid. This typically includes multiple passes.

Rock: natural beds or massive fragments, or the hard, stable, cemented part of the earth's crust, igneous, metamorphic, or sedimentary in origin, which may or may not be weathered and includes boulders having a size equivalent to 0.3 m in diameter or greater.

Secondary Liner: concrete pipe, HDPE pipe or un-reinforced cast-in-place concrete, installed subsequent to tunnel excavation.

Shaft: vertically sided excavation used as entry and/or exit points from which the trenchless method is initiated or directed for the installation of product.

Strike Alert: a system that is intended to alert and protect the operator in the case of inadvertent drilling into an electrical utility cable. The strike alert system consists of a sensor and an alarm connected to the drill rig and a grounding stake. The alarm may be audio or visual or both.

Slurry: a mixture of soil and/or rock cuttings, and drilling fluid.

Soil: all materials except those defined as rock, and excludes stone masonry, concrete, and other manufactured materials; includes rock fragments having an equivalent size less than 0.3 m in diameter.

Trenchless Installation: an underground method of constructing a passage open at both ends that involves installing a pipe. For the purpose of this specification, the pipe may be installed by any of the various methods defined herein such as Auger Jack & Boring, Pipe Jacking, Pipe Ramming, Directional Drilling, or using a tunnelling machine or hand mining methods.

Tunnelling: An underground method of constructing a passage using a tunnel boring machine (TBM), a microtunnel boring machine (MTBM) or hand mining using a shield to support the opening.

4. DESIGN AND SUBMISSION REQUIREMENTS

4.01 General

The Contractor's documentation, submission requirements and installation methods shall specifically consider and address the subsurface conditions at each pipe crossing as identified in the Foundation Investigation Report or elsewhere in the Contract Documents.

4.02 Working Drawings

Three copies of stamped working drawings for portal or shaft construction, primary liner, excavation, secondary lining, dewatering and groundwater control and grouting shall be submitted to the Contract Administrator (CA) at least one week prior to the commencement of the work for information purposes. All submissions shall bear the seal and signature of the Design Engineer and Design Checking Engineer. The Contractor shall have a copy of the stamped working drawings at the site during construction.

As a minimum, working drawings/details pertaining to the tunnel design and construction shall include the following (as appropriate):

a) Plans, Elevations and Details:

- A work plan outlining the materials, procedures, methods and schedule to be used to execute the work;
- A list of personnel, including backup personnel, and their qualifications and experience;
- A safety plan including the company safety manual and emergency procedures;
- The work area layout;
- An erosion and sediment control plan that includes a contingency plan in the event the erosion and sediment control measures fail;
- A drilling fluid management plan, if applicable, that addresses control of frac-out pressures, any potential environmental impacts and includes a contingency plan detailing emergency procedures in the event that the fluid management plan fails;

- Lighting, ventilation and fire safety details as may be required by applicable occupational health and safety regulations; and
- Excavated materials disposal plan.

b) Design Criteria:

- Primary liner design details, if applicable;
- Design assumption and material data when materials other than those specified are proposed for use; and
- Drill path design, details of alignment and alignment control, maximum curvature and reaming stages.

c) Materials:

- Certification from the manufacturer that the product furnished on the contract meets the specifications cited in the manufacturer's product specification and that the materials supplied are suitable for the application; and
- Material mixture for filling voids and installation procedures.

d) Upstream/Downstream Portal Installation Procedure:

- The access shaft or entry/exit pit details designed and stamped/signed by the Design Engineer, as applicable; and
- Face support and other temporary support details, if applicable.

e) Primary Liner/Secondary Liner Installation and Grouting Procedure:

- Excavation and pipe installation procedures, including methods to handle obstructions and prevent soil cave-in; and
- Details of tunnelling equipment/methods to be used for the works.

f) Excavation and Dewatering:

- Ground control/dewatering details, as applicable, describing the proposed method for control, handling, treatment, and disposal of water.

g) Monitoring Method:

- The methods to be employed to monitor and maintain the alignment of the installation.

4.03 Site Survey

Prior to commencing the work, the Contractor shall, at each pipe location, lay-out the alignment and install settlement monitoring points.

4.04 Certificate of Conformance

The Contractor shall submit details of the sequence and method of construction to the Quality Verification Engineer for review, prepared and stamped by the Design Engineer. The Contractor shall submit to the Contract Administrator a Certificate of Conformance sealed and signed by the Quality Verification Engineer a minimum of one week prior to commencement of work under this item. The Certificate shall state that the construction procedures are in conformance with the requirements and specifications of the contract documents.

The Contractor shall submit to the Contract Administrator a Certificate of Conformance sealed and signed by the Quality Verification Engineer upon completion of each of the following operations and prior to commencement of each subsequent operation for each pipe installation:

Site Surveying (as noted in Section 4.02)
Excavation for pits including dewatering of excavations
Jacking/Ramming/Directional Drilling of Casing/Liner
Installation of the Product
Grouting Operations

Each Certificate of Conformance shall state that the work has been carried out in general conformance with the contract documents, specifications and/or stamped working drawings.

In addition, upon completion of the installation of the pipe at each location, the Contractor shall submit to the Contract Administrator a final Certificate of Conformance sealed and signed by the Quality Verification Engineer. The Certificate shall state that the pipe has been installed in general conformance with the Contractor's Submission and Design Requirements, stamped working drawings and contract documents.

The Design Engineer will not be permitted to carry out the work of the Quality Verification Engineer.

5. MATERIALS

5.01 Product

The product shall be concrete pipe or high density polyethylene pipe as specified.

5.02 Concrete

Concrete shall be according to OPSS.PROV 1350. The concrete strength shall be as specified in the Contractor's design submission.

5.03 Concrete Reinforcement

Steel reinforcing for concrete work shall be according to OPSS.PROV 1440.

5.04 Timber

Timber shall be sound, straight, and free from cracks, shakes and large or loose knots.

5.05 Grout

The Contractor shall submit the proposed grout mix design for grouts to be used for lubricating jacking pipe and for filling of voids and annular spaces. Purging grout shall consist of a mixture of one part Portland cement conforming to the requirements of CAN/CSA A5-93 and two parts mortar sand conforming to OPSS.PROV 1004 wetted with only sufficient water to make the mixture plastic.

5.06 Auger Jack & Bore Materials

5.06.01 Pipe Materials

Steel pipe shall conform with ASTM A252-93 welded joints suitable for jacking operations. The Contractor shall select pipe class for pipe jacking.

Concrete pipe as per OPSS.PROV 1820.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

5.07 Pipe Ramming Materials

5.07.01 Pipe Materials

Steel pipe shall conform with ASTM A 252-93 welded joints.

New steel casing when specified shall be smooth wall carbon steel pipe according to ASTM A252-93 Grade 2.

Used steel casing can be used provided that the steel casing can resist the applicable static and dynamic loadings.

Pipe wall thickness shall be determined by the Contractor based on static and dynamic loads from traffic loading and anticipated ramming forces for selected pipe and driven pipe lengths. The wall thickness shall be increased as required to ensure the casing is not damaged during handling and installation. The pipe minimum wall thickness shall be as per Table 1 of OPSS 1802.

Pipe segments shall be determined by the Contractor.

Steel pipe joints shall be pressure fit type or welded.

All steel casing pipe shall be square cut.

Steel casing pipe shall have roundness such that the difference between the major and minor outside diameters shall not exceed 1% of the specified nominal outside diameter or 6 mm, whichever is less.

Steel casing pipe shall have a minimum allowable straightness of 1.5 mm maximum per metre of length.

5.07.02 Mill Certificates

For permanent casing, the Contractor shall submit to the Contract Administrator at the time of delivery one copy of the mill certificate, indicating that the steel meets the requirements for the appropriate standards for casings.

Where mill test certificates originate from a mill outside Canada or the United States of America the Contractor shall have the information on the mill certificate verified by testing by a Canadian laboratory. The laboratory shall be accredited by a Canadian National Accreditation Body to comply with the requirements of ISO/IEC Guide 25 for the specific tests or type of tests required by the material standard specified on the mill test certificate. The mill test certificates shall be stamped with the name of the Canadian testing laboratory and appropriate wording stating that the material conforms to the specified material requirements. The stamp shall include the appropriate material specification number, the date and the signature of an authorized officer of the Canadian testing laboratory.

5.08 Directional Drilling Materials

5.08.01 Drilling Fluids

The drilling fluids shall be mixed according to the manufacturer's recommendations and be appropriate for the anticipated subsurface conditions.

5.08.02 Pipe Materials

High Density Polyethylene (HDPE) pipe as per OPSS 1840 shall be used in accordance with ASTM D3350.

The requirements for fittings shall be suitable for and compatible with the class and type of pipe with which they will be used and in according to CAN/CSA-B182.6 or ASTM F894.

The Contractor shall determine the required dimensional ratio (DR) of the HDPE pipe to support all subsurface conditions and hydrostatic pressures, and to withstand the grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

The Contractor's submission shall demonstrate, in conjunction with the manufacturer's specifications, that the heat resistance of the pipe material is sufficient to tolerate without damage the heat of hydration generated by grout curing.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

Jointing of HDPE piping shall be completed by thermal butt fusion in accordance with manufacturer's recommended procedures and as outlined in the latest revision of ASTM D2657. All manufacturer's recommendations and procedures shall be followed during the jointing process.

Jointing of HDPE piping to other piping materials or appurtenances shall be completed using flanged connections.

5.09 Tunnelling Materials

5.09.01 Primary Liner

Tunnelling methods will require installation of a primary liner. The primary liner shall be designed by the Contractor and the design/drawings shall be stamped/signed by the Design Engineer. The design shall be submitted to the Contract Administrator as specified herein.

5.09.02 Secondary Liner

Concrete or High Density Polyethylene Pipe shall be used according to the following requirements.

5.09.02.01 Concrete Pipe

Concrete pipe as per OPSS.PROV 1820 shall be used. The Contractor shall select the pipe class to withstand grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

5.09.02.02 High Density Polyethylene (HDPE)

High Density Polyethylene (HDPE) pipe as per OPSS 1840 shall be used in accordance with ASTM D3350.

The requirements for fittings shall be according to CAN/CSA-B182.6 or ASTM F894.

The Contractor shall determine the required dimensional ratio (DR) to withstand the grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

Jointing of HDPE piping shall be completed by thermal butt fusion in accordance with manufacturer's recommended procedures and as outlined in the latest revision of ASTM D2657. All manufacturer's recommendations and procedures shall be followed during the jointing process.

Jointing of HDPE piping to other piping materials shall be completed using flanged connections.

6. EQUIPMENT

6.01 Auger Jack & Bore Equipment

Pipe auger jack & bore equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

Specific details of the manner in which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the liner shall be submitted to the Contract Administrator for information purposes prior to proceeding with the works.

6.02 Pipe Ramming Equipment

Pipe ramming equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

The pipe ramming hammer(s) shall be capable of driving the pipe casing from the drive pit through the existing subsurface conditions at the site.

Specific details of the manner in which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the pipe shall be submitted to the Contract Administrator for information purposes prior to proceeding with the works.

6.03 Directional Drilling Equipment

6.03.01 General

The directional drilling equipment shall consist of a directional drilling rig and a drilling fluid mixing and delivery system of sufficient capacity to successfully complete the product installation without exceeding the maximum tensile strength of the product being installed.

6.03.02 Drilling Rig

The directional drilling rig shall:

- consist of a leak free hydraulically powered boring system to rotate, push, and pull hollow drill pipe into the ground at a variable angle while delivering a pressurized fluid mixture to a guidable drill head;
- contain a guidance system to accurately guide boring operations;
- be anchored to the ground to withstand the rotating, pushing, and pulling forces required to complete the product installation; and
- be grounded during all operations unless otherwise specified by the drilling rig manufacturer.

6.03.03 Drill Head

The drill head shall be steerable by changing its rotation, be equipped with the necessary cutting surfaces and drilling fluid jets, and be of the type for the anticipated subsurface conditions,

6.03.04 Guidance System

The guidance system shall be setup, installed, and operated by trained and experienced personnel. The operator shall be aware of any magnetic or electromagnetic anomalies and shall consider such influences in the operation of the guidance system when a magnetic or electromagnetic system is used.

6.03.05 Drilling Fluid Mixing System

The drilling fluid mixing system shall be of sufficient size to thoroughly and uniformly mix the required drilling fluid.

6.03.06 Drilling Fluid Delivery System

The delivery system shall have a means of measuring and controlling fluid pressures and be of sufficient flow capacity to ensure that all slurry volumes are adequate for the length and diameter of the final bore and the anticipated subsurface conditions. Connections between the delivery pump and drill pipe shall be leak-free.

6.04 Tunnelling Equipment

Tunnelling equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

Specific details of the manner in which rock or boulders will be broken and removed from the tunnel face shall be submitted to the Contract Administrator information purposes. Use of rock fracturing chemicals shall only be considered subject to a field demonstration satisfactory to the Ministry prior to its use.
Use of explosives is prohibited.

7. CONSTRUCTION

7.01 General

The Contractor shall notify the Contract Administrator at least 48 hours in advance of starting work. The proposed method of pipe installation to be used by the Contractor shall be submitted to the Contract

Administrator for information purposes prior to commencing the work and shall be subject to the limitations presented in the following subsections.

7.01.01 Layout, Alignment and Depth Control

The location of the installation shall be established from the lines, elevations and tolerances specified in the Contract Documents. The pipe installation shall be to the horizontal and vertical alignments specified in the Contract Drawings. Deviations from location, alignment, grades and/or invert levels shall be corrected by the Contractor at no cost to the Ministry.

All reference points necessary to construct the pipe installation and appurtenances shall be laid out.

The Contractor shall calibrate tracking and locating equipment at the beginning of each work day, and shall monitor and record the alignment and depth readings provided by the tracking system at every 5 m in normal conditions and every 2 m where precise alignment control is necessary;

The Contract Administrator shall be provided with the assistance and access necessary to check the layout of the pipe installation and associated appurtenances.

All excavations shall be carried out in accordance with the Occupational Health and Safety Act (OHSA) of Ontario.

For directional drilling, the contractor shall ensure that during pilot hole drilling the maximum degree of deviation or "dog-leg" shall be 2.5 degrees per 9m drill pipe length. Any deviation exceeding 2.5 degrees will necessitate a pull-back and straightening of the alignment at the Contractor's sole expense. The pilot hole exit location shall be within 0.5m of the target location.

7.01.02 Construction Shafts

Construction shafts shall be specified in the Contractor's submission. The boundaries and protection of these shall be as required to contain all disturbances to areas outside of the ESA limits.

Shafts shall be maintained in a drained condition.

A minimum 2.4 m high secure fence shall be installed around the perimeter of the construction shaft area with gates and truck entrances. The fence shall be removed on completion of the work.

7.01.03 Protection Systems

The construction of all protection systems shall be according to OPSS.PROV 539. Where the stability, safety, or function of an existing roadway, watercourse, other works, proposed works or ESA's may be impaired due to the method of operation, protection shall be provided. Protection may include sheathing, shoring, and piles where necessary to prevent damage to such works or proposed works.

7.01.04 Settlement or Heave

Any disturbance to the ground surface (settlement or heave) as a result of the pipe installation shall be immediately corrected by the Contract, at no additional cost to the Ministry.

7.01.05 Stability of Excavation

The construction methods, plant, procedures, and precautions employed shall ensure that excavations are stable, free from disturbance, and maintained in a drained condition.

The construction methods, plant, and materials employed shall prevent the migration of soil and/or rock material into the excavation from adjacent ground.

7.01.06 Preservation and Protection of Existing Facilities

Preservation and protection of existing facilities shall be according to OPSS 491.

Minimum horizontal and vertical clearances to existing facilities as specified in the Contract Documents shall be maintained. Clearances shall be measured from the nearest edge of the largest cut diameter required to the nearest edge of the facility being paralleled or crossed.

Existing underground facilities shall be exposed to verify its horizontal and vertical locations when the outlet pipe path comes within 1.0 m horizontally or vertically of the existing facility. Existing facilities shall be exposed by non-destructive methods. The number of exposures required to monitor work progress shall be as specified in the Contract Documents.

7.01.07 Transporting, Unloading, Storing and Handling Materials

Manufacturer's handling and storage recommendations shall be followed.

7.01.08 Trenching, Backfilling and Compacting

Trenching, backfilling, and compacting for entry and exit points or other locations along the pipe path shall be according to OPSS 401.

7.01.09 Support Systems

Support systems shall be according to OPSS 404.

If any open excavation will encroach into the highway embankment the protection system shall satisfy the requirements for Performance Level 2 as specified in OPSS.PROV 539.

7.01.10 Dewatering

The work of this Section includes control, handling, treatment, and disposal of groundwater. The Contractor shall review the foundation investigation report for reference to soil and groundwater conditions on the project site and plan a dewatering scheme accordingly.

The Contractor shall control groundwater inflows to excavations to maintain stability of surrounding ground, to prevent erosion of soil, to prevent softening of ground exposed in the excavation, and to avoid interfering with execution of the work.

The Contractor shall maintain excavations free of standing water at all times during excavation, including while concrete is curing.

Should water enter the excavation in amounts that could adversely affect the performance of the work or could cause loss of ground, the Contractor shall take immediate steps to control the inflow.

The Contractor is alerted that seepage zones of perched water within the fill materials should be expected, particularly where granular materials are excavated.

Dewatering shall be according to OPSS 517.

7.01.11 Removal of Boulders

The Contractor is alerted that cobbles and boulders should be anticipated in the soil deposits at the site. Accordingly, the Contractor shall address the removal of cobbles and boulders in the proposed method of construction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered.

7.01.12 Record Keeping

Verification record requirements of the alignment and depth of the installation shall be as specified in the Contract Documents. A copy of the verification records shall be given to the Contract Administrator at the completion of the installation.

7.01.13 Testing

Testing of the product installation shall consist of verifying the specified grade between the two ends of the pipe and passing of water from the inlet end of the pipe to the outlet end to confirm gravity flow conditions.

7.01.14 Management and Disposal of Excess Material

Management and disposal of excess material shall be according to OPSS 180. Satisfactory re-usable excavated material required for backfill shall be separated from unsuitable excavated material.

7.01.15 Site Restoration

Site restoration shall be according to OPSS 492.

7.01.16 Supervision

A qualified individual, who is experienced in the pipe installation by trenchless methods shall supervise the work at all times.

7.02 Auger Jack & Bore Installation

7.02.01 Method of Installation Procedure

The installation procedure to be used shall be subject to the following limitations:

- Hydraulically operated jacks of adequate number and capacity shall be provided to ensure smooth and uniform advancement without over-stressing of the pipe.
- A suitably padded jacking head or collar shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.
- The jacking pipe shall be fully supported in the jacking pit at the specified line and grade.

- Selection of the excavation method and jacking equipment shall take into consideration the conditions at each pipe crossing.

7.02.02 Pipe Installation

Concrete pipe joints shall be water tight and according to OPSS.PROV 1820 and must withstand jacking forces, determined by the Contractor.

During the jacking of the liner the space between the liner and the wall of the excavation shall be kept filled with bentonite slurry. Upon completion of jacking, the space between the liner and the wall of the excavation shall be filled with grout.

The annular space between the liner and the product shall be fully grouted with a water tight, expandable and stable grout.

7.03 Pipe Ramming Installation

For pipe ramming installation the following requirements apply:

Only smooth walled steel pipe shall be used. But welding of pipe joints shall conform to CAS W59.

Ramming equipment of adequate capacity shall be provided to ensure smooth and uniform advancement without overstressing of the pipe. Delays shall be avoided between ramming operations.

A ramming head shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.

Two or more lubricated guide rails or sills shall be provided of sufficient length to fully support the pipe at the specified line and grade in the ramming pit. Pipe shall be installed to the line and grade specified.

Following installation of the liner pipe, all material shall be removed from the pipe to the satisfaction of the Contract Administrator. Any voids remaining between the pipe and the excavation wall shall be grouted as soon as the pipe is rammed. The annular space between the liner pipe and the product shall be fully grouted with a water tight, expandable and stable grout.

7.04 Directional Drilling Installation

7.04.01 General

When strike alerts are provided on a drilling rig, they shall be activated during drilling and maintained at all times.

7.04.02 Site Preparation

The work site shall be graded or filled to provide a level working area for the drilling rig. No alterations beyond what is required for DD operations are to be made. All activities shall be confined to designated work areas.

7.04.03 Pilot Bore

The pilot bore shall be drilled along the bore path in accordance with the grade, alignment, and tolerances as indicated on the Contractor’s submitted drilling plan to ensure that the product is installed to the line and grade shown on the Contract Drawings. The Contractor’s methods shall take into consideration the conditions at each crossing within the pipe alignment and shall be suitable to advance through such obstructions such as cobbles and boulders and address the potential for deflection off these obstruction and/or soil conditions.

In the event the pilot bore deviates from the submitted path, the Contract Administrator shall be notified. The Contract Administrator may require the Contractor to pullback and re-drill from the location along the bore path before the deviation.

In the event that a drilling fluid fracture, inadvertent returns, or loss of circulation occurs during pilot bore drilling operations, the Contract Administrator shall be advised of the event and action shall be taken in accordance with the Contractor’s submitted contingency plan.

At the entry and exit points, there is potential for ravelling of the existing soil, fill and or weathered rock areas along the alignment. This is conventionally addressed by the use of drilling fluid. However, casing may be required. The Contractor’s methods shall take into consideration the potential need to install sections of casing to manage ravelling at or near ground surface.

If a drill hole beneath the highway must be abandoned, the hole shall be backfilled with grout or bentonite to prevent future subsidence.

The Contractor shall maintain drilling fluid pressure and circulation throughout the DD process, including during the initial pilot bore and during the reaming process.

The Contractor shall at all times and for the entire length of the installation alignment be able to demonstrate the horizontal and vertical position of the alignment, the fluid volume used, return rates and pressures.

7.04.04 Drilling Fluid Fracture (Frac-Out)

In order to reduce the potential for hydraulic fracturing of the hole during directional drilling, a minimum depth of cover of 5m is normally maintained between the pipe and the ground surface. Sections of the pipe close to the exit pit with less than 5m cover shall be cased. The Contractor shall ensure that drilling fluid pressures are properly set and controlled to prevent frac-out, for the depth of cover available between the bottom of the pavement structure (bottom of the subbase material) and the top of the bore.

Since fluid loss normally occurs in fault zones, fracture zones, or seams of coarse material, fluid migration does not always gravitate to the surface, thus making detection difficult. Once a fluid loss is detected, the Contractor shall halt operations immediately and conduct a detailed examination of the drill path and implement measures to mitigate fluid loss. If no surface migration is evident, resume operation while paying particular attention to fluid monitoring.

In the event of a fluid migration to the surface occurring, the Contractor shall halt all operations immediately, isolate the migration site, and recover fluids. Once the fracture is controlled, continue drilling operations with the operator paying particular attention to the fracture points

7.04.05 Reaming

The bore shall be reamed using the appropriate tools to a diameter at least 50% greater than the outside diameter of the product.

7.04.06 Product Installation

7.04.06.0 General

The product shall be jointed according to manufacturer's recommendations. The length of the product to be pulled shall be jointed as one length before commencement of the continuous pulling operation.

The product shall be protected from damage during the pullback operation.

The minimum allowable bending radius for the product shall not be exceeded.

Product shall be allowed to recover before connections to new or existing facility are made. Product recovery time shall be according to manufacturers recommendations.

7.04.06.02 Pullback and Grouting

After successfully reaming the bore to the required diameter, the product shall be pulled through the bore path. Once the pullback operation has commenced, it shall continue without interruption until the product is completely pulled into bore unless otherwise approved by the Contract Administrator.

A swivel shall be used between the reamer and the product being installed to prevent rotational forces from being transferred to the product. When specified in the Contract Documents, a weak link or breakaway connector shall be used to prevent excess pulling force from damaging the product.

The product shall be inspected for damage where visible at excavation pits and where it exits the bore. Any damage noted shall be rectified to the satisfaction of the Contract Administrator,

The pull back and reaming operations shall not exceed the fluid circulation rate capabilities. Reaming and back pulling operations shall be planned to insure that, once started, all reaming and back pulling operations are completed without stopping and within the permitted work hours.

The space between the pipe and the excavation walls shall be filled with grout.

7. 05 Tunnelling Installation

7.05.01 General

The method of tunnelling shall be selected by the Contractor and shall be submitted to the Contract Administrator prior to commencement of the work for information purposes.

Excavation of native soil and fill shall be done in a manner to control groundwater inflow to the excavation and to prevent loss of ground into the excavation.

Methods of excavating the tunnel shall be capable of fully supporting the face and shall accommodate the removal of boulders and other oversize objects from the face. Continuous ground support shall be maintained during excavation.

As the excavation progresses, the Contractor shall continuously monitor (every 2 m) indications of support distress, such as cracking, deflection or failure of support system and subsidence of ground near the excavation.

The Contractor shall advance the ventilation system as a regular part of the normal excavation cycle.

The Contractor shall provide lighting in accordance with OHSA requirements for the entire length of the tunnel.

The tunnel is to be kept sufficiently dry at all times to permit work to be performed in a safe and satisfactory manner.

The Contractor shall maintain clean working conditions at all times in tunnels.

In the event that excavation threatens to endanger personnel, the Work, or adjacent property, the Contractor shall cease excavation. The Contractor shall then evaluate methods of construction and revise as necessary to ensure the safe continuation of the work.

The Contractor shall maintain tunnel excavation line and grade to provide for construction of final lining within specified tolerances.

7.05.01 Tunnelling Method

The tunnelling method shall be suitable to provide face support in changing ground conditions that may be encountered during the progress of the work. The selection of the tunnelling method should consider the soil conditions at each pipe crossing and the presence of obstructions, such as cobbles and boulders, with respect to the tunnel alignment.

7.05.02 Primary Liner (Support System)

Primary support systems shall prevent deterioration, loosening, or unravelling of ground surfaces exposed by excavation.

The primary liner support system shall be designed and installed to achieve the intended performance requirements.

Primary liner support system shall maintain the safety of personnel, minimize ground movement into the excavation, ensure stability and maintain strength of ground surrounding the excavation.

The primary liner shall be designed to support all subsurface conditions and hydrostatic pressures and to withstand any additional loads caused by installation and grouting, and shall ensure that no ground loading or other loading will be placed on the new work until after design strength has been reached.

The primary liner shall be installed so that the exterior is as tight as possible to the excavated surface of the tunnel and allows the placement of the full design thickness of the secondary lining.

Primary support systems shall be compatible with the encountered ground conditions, with the method of excavation, with methods for control of water, and with placement of the permanent lining.

All voids between the primary lining and the surface of the excavation shall be filled with cement grout. If an unexpanded liner is used, the space outside the liner plates shall be grouted at least daily.

7.05.03 Secondary Liner

7.05.03.01 Placing of Grout

The void outside the finished secondary liner shall be filled with cement grout according to the Contractor's submission.

Grout shall not be placed until the lining has achieved 85% of its specified strength or 30 MPa. Grouting shall be limited to such sequences and programs as are necessary to avoid damaging any part of the works or any other structure or property.

7.06 Instrumentation Monitoring

The work specified in this Section includes furnishing and installing instruments for monitoring of settlement and ground stability.

Surface settlement markers for monitoring ground stability shall be installed at the pavement/ground surface level on the shoulder, side slope and pavement at not greater than 5 m intervals along the tunnel alignment and as an array of three in-ground (1.5 m depth) measurement points on the shoulder of the highway perpendicular to the alignment. The equipment and procedures used for settlement monitoring during construction must be capable of surveying the settlement point elevations to within ± 1 mm of the actual elevation.

Surface settlement markers shall be hardened steel markers treated or coated to resist corrosion, with an exposed convex head having a minimum diameter of 12 mm and similar to surveyor's PK nails. Markers shall be rigidly affixed so as not to move relative to the surface to which it is attached. Traffic shall be managed by the contractor using short-term lane closures in accordance with the Ontario Traffic Manual (OTM).

In general, settlement monitoring points shall be 12-18 mm rebar encased in a 50-70 mm, SCH40 PVC pipe, set to a depth of 1.5 m below ground surface. The assembly shall be placed in a drill hole and backfilled with uniform sand.

The Contractor shall install all surface settlement instruments a minimum of one week prior to the start of works.

The surface settlement instruments shall be clearly labelled for easy identification.

The Contractor shall submit to the Contract Administrator a site plan showing the locations of the monitoring points, a geodetic survey of the settlement monitoring points including station, offset and elevation recorded at the following time intervals:

- Three consecutive readings at least one week prior to commencement of the work (Baseline Reading);
- Once per shift during tunnelling operations period; and
- Weekly after completion of the work for one month, or until such time at which all parties agree that further movement has stopped.

All readings shall be submitted to the Contract Administrative for information purposes on a weekly basis. Each report shall include all survey data collected in tabular and graphical format as plots of time versus settlement in comparison to survey data collected prior to commencement of the work.

7.07 Criteria for Assessment of Roadway Subsidence/Heave

Based on the monitoring of ground movement as specified in Subsections 4.02 and 7.06, the following represents trigger levels that define magnitude of movement and corresponding action:

- Review Level: If a maximum value of 10 mm relative to the baseline readings is reached, the Contractor shall review or modify the method, rate or sequence of construction or ground stabilization measures to mitigate further ground displacement. If this Review Level is exceeded, the Contractor shall immediately notify the CA and review and discuss response actions. The Contractor shall submit a plan of action to prevent Alert Levels from being reached. All construction work shall be continued such that the Alert Level is not reached.
- Alert Level: If a maximum value of 15 mm relative to the baseline readings is reached, the Contractor shall cease construction operations, inform the Contract Administrator and execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic. No construction shall take place until all of the following conditions are satisfied:
    - The cause of the settlement has been identified.
    - The Contractor submits a corrective/preventive plan.
    - Any corrective and/or preventive measure deemed necessary by the Contractor is implemented.
    - The CA deems it is safe to proceed.

The Contractor shall avoid damaging instrumentation during construction. Instrumentation that is damaged as a result of the Contractor's operation shall be repaired or replaced by the Contractor within one business day. The costs for replacement/repair shall be borne by the Contractor.

At the completion of the job, the Contractor shall abandon all instrumentations installed during the course of the Work.

9. MEASUREMENT FOR PAYMENT

Measurement shall be by Plan Quantity Payment as may be revised by Adjusted Plan Quantity Payment in metres, following along the centre line of the pipes from centre to centre of maintenance holes or chambers (catch basins) or from/to the end of the pipe where no maintenance hole or chamber is installed, of the actual length of pipe installed by trenchless methods.

10. BASIS OF PAYMENT

Payment at the contract price shall be full compensation for all labour, equipment and materials required for excavation (regardless of material encountered), dewatering, sheathing and shoring, supply and installation of pipe liners, settlement instrumentation and monitoring, site restoration, and all other work necessary to complete the installation as specified.

Payment for the rigid or flexible pipe conduits installed inside the pipe liners shall be paid separately under the appropriate tender items.

Where a protection system is made necessary because of the Contractor's operations (e.g. choice of trenchless installation method), the cost shall be included in this item and shall be full compensation for all labour, equipment and materials required to carry out the work including subsequently removing the temporary protection system and performing any necessary restoration work.

Payment for connecting intercepted drains and service connections shall be made on the following basis:

(a) Where such drains and service connections are shown on the contract drawings the cost of connections shall be included in the contract price for pipe installation.

(b) Where such drains and service connections are not shown on the contract drawings, the cost of connections will be considered an allowable extra to the contract.

Payment for removal of boulders/obstructions greater than an equivalent 0.3 m in diameter shall be on a time and materials basis. The Contractor shall inform the Contract Administrator when boulders/obstructions are encountered and prior to removal to allow for proper and accurate tracking of time and material charges.