



**THURBER** ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
SHAMROCK LAKE CENTRE CULVERT REPLACEMENT  
HIGHWAY 11  
THUNDER BAY DISTRICT, ONTARIO**

**G.W.P. No. 6910-12-00, W.P. No. 6910-12-00, SITE No. 48C-338/C**

**GEOCRES Number: 52H-39**

**Report**

**to**

**HATCH**

Date: August 25, 2016  
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**PART 1: FACTUAL INFORMATION**

**1. INTRODUCTION**

This report presents the factual data obtained from a foundation investigation carried out by Thurber Engineering Ltd. (Thurber) for the proposed replacement of the Shamrock Lake Centre Culvert on Highway 11, located north of Nipigon, Thunder Bay District, Ontario.

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

Thurber was retained by Hatch to carry out this foundation investigation under the Ministry of Transportation Ontario (MTO) Agreement Number 6015-E-0018-001.

A previous foundation investigation carried out at this site was documented in the report titled "Foundation Investigation Report, Shamrock Lake Culvert Centre, Highway 11, Unsurveyed Territory, Thunder Bay District", prepared by DST Consulting Engineers Inc. (DST), dated March 17, 2015; Geocres No. 52H-25. Reference should be made to the DST report for a written description of the subsurface conditions, borehole location plan, stratigraphic profile, record of borehole sheets and laboratory test results. It should be noted that DST is solely responsible for the subsurface information provided in the Foundation Investigation Report. The Record of Borehole sheets from the DST report have been enclosed in Appendix C of this report for reference, and the subsurface information presented in the DST report was incorporated in the current report, as appropriate.

**2. SITE DESCRIPTION**

The site is located on Highway 11, approximately 31.5 km north of Highway 11/17, in unsurveyed



territory north of Nipigon, Thunder Bay District, Ontario. The culvert allows an unnamed creek to flow from southeast to northwest under Highway 11 to Shamrock Lake. Highway 11 generally runs in a southwest-northeast direction at the culvert site.

The Terms of Reference indicates that the existing structure is a 76 m long, 4.9 m span by 2.0 m high, concrete rigid frame, open footing culvert, with a height of fill of 16 m. An Ontario Structure Inspection Manual (OSIM) report prepared in 2014 notes severe spalled concrete, exposed rebar, 19 vertical cracks on the culvert walls, large areas of delamination, and that the structure was considered to be in overall poor condition.

The grade level of Highway 11 at the existing culvert is at an approximate Elevation of 293 m.

Naturally low-lying areas are present near the inlet and outlet of the culvert, with vegetation consisting of grass, shrubs and frequent trees. The general area along Highway 11 is bounded by a bedrock plain on the southeast side at elevations greater than 400 m, and an outwash plain with lakes and swampy lowlands on the northeast side with an approximate Elevation of 274 m at Shamrock Lake.

Photographs in Appendix E show the general nature of the site and the existing culvert.

Based on published geological information, the culvert lies within an area of glaciofluvial outwash deposits of sand and gravel, and is bounded by bedrock plains to the northwest and southeast, and talus (rubble) immediately adjacent to the southeast side of the highway. The bedrock at the site consists of undifferentiated metasedimentary rocks, with igneous and metamorphic rock at the bedrock plains in the area.

### **3. INVESTIGATION PROCEDURES**

The borehole investigation and field testing program for this project was carried out from June 8 to 9, 2016, and consisted of drilling and sampling two (2) boreholes, designated as Boreholes 16-03 and 16-04. Borehole 16-03 was located near the culvert inlet and Borehole 16-04 was located near the culvert outlet. Both boreholes were advanced near the base of the highway embankment.

Utility clearances were obtained prior to the start of drilling. The coordinates and ground surface elevations for the boreholes were derived from topographic plans provided to Thurber by Hatch. The coordinate system MTM NAD 83, Zone 14 was used for the boreholes. The approximate locations of the boreholes are shown on the Borehole Locations and Soil Strata Drawing included



in Appendix D.

A portable tripod drill rig was used to advance Borehole 16-03 using NW casing and wash boring techniques, and a track-mounted CME 45 drill rig was used to advance Borehole 16-04 using hollow stem augers. The boreholes were advanced to depths of 8.5 m and 12.8 m respectively. Borehole 16-03 was extended beyond 8.5 m depth by conducting a Dynamic Cone Penetration Test (DCPT) to a depth of 11.0 m. In both boreholes, soil samples were obtained at selected intervals with a 50 mm outside diameter split spoon sampler driven in conjunction with the Standard Penetration Test (SPT).

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

Groundwater conditions were observed in the open boreholes throughout the drilling operations and in a temporary standpipe piezometer installed in Borehole 16-04. The standpipe piezometer consisted of a 19 mm diameter PVC pipe, with a slotted screen. The boreholes were backfilled on completion of drilling and the temporary standpipe piezometer was decommissioned in general accordance with Ontario Regulation 903 at the end of the field investigation.

Completion details of the boreholes and piezometers are summarized in Table 3.1.

**Table 3.1 – Borehole Completion Details**

<b>Borehole Number</b>	<b>Borehole Depth / Base Elevation (m)</b>	<b>Piezometer Tip Depth / Elevation (m)</b>	<b>Completion Details</b>
16-03	8.5 / 266.5	None installed	Bentonite holeplug from 8.5 m to ground surface.
16-04	12.8 / 262.7	12.2 / 263.3	Filter sand to 10.4 m, bentonite holeplug to 9.4 m, bentonite holeplug and cuttings to ground surface.

The previous investigation by DST included four (4) boreholes, numbered BH1 to BH4, which were each drilled through the existing highway embankment to depths of 25.0 m each. The borehole locations were referenced to the MTO station numbering system, and the ground surface elevations were established relative to a temporary local benchmark. Based on topographic information provided by Hatch, the ground surface elevations at the borehole locations have been



referenced to Geodetic Datum as shown in Table 3.2. The approximate locations of the DST boreholes are shown on the Borehole Locations and Soil Strata Drawing included in Appendix D.

**Table 3.2 – DST Borehole Elevations**

Borehole Number	Ground Surface Elevation	
	Assumed Local Datum (m)	Geodetic Datum (m)
BH1	99.9	292.5
BH2	100.0	292.6
BH3	99.8	292.4
BH4	99.9	292.5

#### **4. LABORATORY TESTING**

All recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected samples were also subjected to grain size distribution analyses (sieve and/or hydrometer) and plasticity testing (Atterberg Limits) where appropriate. The results of this laboratory testing program are shown on the Record of Borehole sheets included in Appendix A and on the figures included in Appendix B.

In order to assess the potential for sulphate attack on concrete foundations, as well as the potential for corrosion associated with the structure, a sample of the existing native soil, and a sample of the surface water from the creek upstream of the existing culvert were collected. The samples were submitted to SGS Canada Inc., a CALA accredited analytical laboratory in Lakefield, Ontario, for analytical testing of corrosivity parameters and sulphate content. The results of the analytical testing are summarized in Section 6 and are presented in Appendix B.

#### **5. DESCRIPTION OF SUBSURFACE CONDITIONS**

Reference is made to the Record of Borehole sheets included in Appendices A and C. Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets and on the “Borehole Locations and Soil Strata” drawing included in Appendix D. 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 and must be used for interpretation of the site conditions. It must be recognized and expected that soil conditions may vary between and beyond the borehole locations.



In general, the subsurface conditions encountered in the boreholes from the current and previous investigations consisted of asphalt pavement overlying granular fill and embankment fill, which was in turn underlain by native soil consisting of sand and silty sand. Topsoil and peat were also noted at the locations where there was no fill. Descriptions of the individual strata are presented below.

## 5.1 Asphalt

Boreholes BH1 and BH2 were drilled through the existing asphalt shoulder on Highway 11. The asphalt thickness measured in the boreholes ranged from 85 to 100 mm.

## 5.2 Fill

Underlying the asphalt in Boreholes BH1 and BH2, and at the ground surface of Boreholes BH3 and BH4, which were drilled through the highway shoulders, a 0.1 to 0.4 m thick layer of granular fill consisting of sand and crushed gravel was encountered.

A sand embankment fill containing trace to some gravel, trace to some silt, and trace cobbles was encountered below the granular fill in Boreholes BH1 to BH4. The sand fill ranged in thickness from 19.4 to 19.6 m, and extended to depths ranging from 19.8 to 19.9 m (Elev. 272.6 to 272.8 m). SPT 'N' values within the sand fill ranged from 4 to 33 blows per 0.3 m penetration, indicating a loose to dense relative density.

The measured moisture content of the fill generally ranged from 4% to 28%, with the exception of one sample in BH1, where the presence of organic material in the fill resulted in a moisture content of 41%. The results of grain size analyses conducted on samples of the fill are presented on the DST Record of Borehole sheets included in Appendix C, and are summarized in the following table:

Soil Particle	Percentage (%)
Gravel	0 to 25
Sand	39 to 95
Silt and Clay	4 to 61

## 5.3 Topsoil and Peat

A 150 mm thick layer of sandy topsoil with rootlets and wood fibres was encountered at the ground surface in Borehole 16-04.



A 0.6 m thick layer of peat with rootlets and wood fibres was encountered at the ground surface in Borehole 16-03. The base of the peat layer was at Elev. 274.4 m. An SPT 'N' value of 4 blows per 0.3 m penetration was recorded in the peat, indicating a soft state. A moisture content of 55% was measured in the peat.

The topsoil and peat thickness may vary in other areas of the site and this limited data should not be relied upon for estimating stripping quantities.

## 5.4 Sand

A native deposit of sand was encountered below the embankment fill, topsoil and peat layers in all of the boreholes at the site. Boreholes 16-04 and BH1 to BH4 were terminated in the sand at depths ranging from 12.8 to 25.0 m (Elev. 262.7 to 267.6 m). The thickness of the sand was 6.6 m in Borehole 16-03, with the base of the sand at a depth of 7.2 m (Elev. 267.8 m). The sand was brown to grey in colour and contained trace to some gravel and trace to some silt. Occasional wood fragments of 0.1 to 0.3 m in thickness were also encountered within the sand in Borehole 16-04, indicating the possible presence of alluvium. A silty sand layer was also encountered within the sand deposit in Borehole 16-04, as described in Section 5.5.

SPT 'N' values within the sand ranged from 4 to 33 blows per 0.3 m penetration, indicating a loose to dense relative density. The measured moisture content of the sand generally ranged from 8% to 30%, with the exception of zones where wood fragments were encountered. The moisture content in these zones ranged from 88% to 252%. The results of grain size distribution analyses conducted on selected samples of the sand are presented on the Record of Borehole sheets included in Appendices A and C and are summarized in the following table. The results from the Thurber boreholes are presented on Figure B1 in Appendix B.

Soil Particle	Percentage (%)
Gravel	0 to 17
Sand	75 to 97
Silt and Clay	1 to 18

## 5.5 Silty Sand

A 3.7 m thick silty sand layer containing trace clay was encountered within the sand deposit in Borehole 16-04. The base of the silty sand layer was encountered at a depth of 7.8 m (Elev. 267.7 m). Borehole 16-03 was terminated at 8.5 m depth (Elev. 266.5 m) in a silty sand layer underlying the sand deposit. A Dynamic Cone Penetration Test was conducted at the base of Borehole 16-



03, where cone refusal of greater than 100 blows per 0.3 m penetration was encountered at a depth of 11.0 m (Elev. 264.0 m).

SPT 'N' values within the silty sand ranged from 13 to 29 blows per 0.3 m of penetration, indicating a compact relative density. Measured moisture contents within the silty sand deposit ranged between 19% and 41%.

The results of grain size distribution analyses conducted on selected samples of the silty sand are presented on the Record of Borehole sheets included in Appendix A and on Figure B2 in Appendix B. The results are summarized in the following table:

Soil Particle	Percentage (%)
Gravel	0
Sand	63 to 74
Silt	23 to 34
Clay	3

## 5.6 Groundwater Conditions

Groundwater conditions were observed during drilling operations and groundwater levels were measured in the open boreholes and temporary standpipe piezometer upon completion of drilling. The groundwater levels measured in the open boreholes and in the piezometer are summarized in Table 5.1 below. Groundwater levels reported in the DST report are also included.

**Table 5.1 – Groundwater Measurements**

Borehole	Date	Water Level (m)		Remark
		Depth	Elevation	
16-03	June 9, 2016	0.5	274.5	Open borehole
16-04	June 9, 2016	1.5	274.0	Standpipe piezometer
	June 10, 2016	1.5	274.0	
	June 11, 2016	1.5	274.0	
	June 12, 2016	1.5	274.0	
BH1	October 20, 2014	19.8	272.7	Reported by DST
BH2	October 20, 2014	18.3	274.3	Reported by DST
BH3	October 20, 2014	18.3	274.2	Reported by DST
BH4	October 20, 2014	19.8	272.8	Reported by DST

A water level measurement near the outlet of the creek was reported on the drawings provided by Hatch, which indicate a creek level at Elevation 274.35 m on May 8, 2013. The groundwater level should be assumed to reflect the local creek water level. The groundwater levels above are



short-term readings and seasonal fluctuations of the groundwater levels are to be expected. In particular, the groundwater levels may be at a higher elevation after periods of significant or prolonged precipitation.

## 6. CORROSIVITY AND SULPHATE TEST RESULTS

A sample of the native sand from Borehole 16-04, and a sample of the surface water from the creek were submitted for analytical testing of corrosivity parameters and sulphate. The results of the analytical tests are shown in Table 6.1. The laboratory certificates of analysis are presented in Appendix B.

**Table 6.1 – Analytical Test Results**

Parameter	Units (Soil)	Units (Water)	Test Results	
			16-04, SS#2, 2.5'-4.5'	Shamrock Lake Centre
			(Sand)	(Creek Water)
Sulphide	%	mg/L	<0.02	<0.006
Chloride	µg/g	mg/L	10	0.39
Sulphate	µg/g	mg/L	2.0	1.6
pH	No unit	No unit	7.33 – 8.09	7.36
Electrical Conductivity	µS/cm	µS/cm	87	47
Resistivity	Ohms.cm	MOhms.cm	11500	21400
Redox Potential	mV	mV	273	197

## 7. MISCELLANEOUS

Thurber obtained subsurface utility clearances prior to drilling. Thurber obtained the northing and easting coordinates and ground surface elevations from measurements taken in the field relative to the topographic plans provided by Hatch.

RPM Drilling Inc. of Thunder Bay, Ontario supplied and operated the drilling, sampling and in-situ testing equipment for the field investigation. The field investigation was supervised on a full time basis by Mr. George Azzopardi of Thurber. Overall supervision of the field program was provided by Mr. Mark Farrant, P.Eng. of Thurber.

Geotechnical laboratory testing was carried out at Thurber's geotechnical laboratory. Analytical



laboratory testing was carried out by SGS Canada Inc. Interpretation of the field data and preparation of this report was carried out by Mr. Mark Farrant, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.



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**PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS**

**8. GENERAL**

This report provides an interpretation of the geotechnical data in the factual report, and presents foundation design recommendations for preliminary design of the proposed Shamrock Lake Centre Culvert replacement on Highway 11, located north of Nipigon, Thunder Bay District, Ontario.

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

Information on the existing culvert site was obtained from the MTO Terms of Reference and MTO Plan E-491880-11-2, titled "Crossing at Shamrock Lake Centre Culvert and Highway 11", dated May 2013, presenting survey data collected in May 2013. Based on the MTO Terms of Reference, the existing structure is a concrete rigid frame, open footing culvert with a span of 4.9 m, height of 2.0 m, and a total length of 76.0 m. The MTO survey plan shows the top of obvert at approximate Elevation 276.2 m at the inlet and 276.5 m at the outlet. The culvert invert is shown at approximate Elevation 274 m. The finished road grade at the culvert location is shown at approximate Elev. 292.6 m, which indicates approximately 19 m of fill above the culvert invert.

The General Arrangement drawing was not available at the time of preparation of this report. For

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the purpose of this report, it has been assumed that the invert and alignment of the replacement culvert will remain the same as for the existing culvert, and no grade raise and wingwalls/headwalls will be required at this culvert.

The discussions and recommendations presented in this report are based on information provided by Hatch and on the factual data obtained during the course of the current investigation. The existing subsurface information collected during the previous investigation by DST has also been reviewed and incorporated in this report, where appropriate.

Selected photographs of the culvert area are included in Appendix E for reference.

## **9. CULVERT FOUNDATIONS**

### **9.1 General**

The MTO Terms of Reference indicates that in light of the significant fill height above the culvert, trenchless methods for installation of the replacement culvert may be considered. The Terms of Reference also indicates that it is unknown whether this replacement culvert will be constructed using open cut methods utilizing a potential detour and roadway protection.

### **9.2 Culvert Alternatives**

This section presents discussions on alternate types of replacement culverts and foundation alternatives, and provides foundation recommendations on feasible and/or preferred foundation options. Several common culvert and foundation types are listed below along with comments on feasibility from a foundations perspective.

#### Circular Pipes (Concrete, Steel, HDPE)

From a foundation engineering standpoint, concrete, steel and HDPE pipes are technically feasible.

#### Concrete, Open Footing Culvert

Concrete open footing culverts are considered feasible but not geotechnically preferred due to the relatively deep excavation that will be required for footing construction and the associated need for dewatering.



### Concrete Box (Closed) Culvert

Concrete box (closed) culverts are considered feasible in an open cut construction at this site; specifically, a precast concrete culvert, which would allow for rapid installation. However, the open cut construction would require a very deep excavation through 19 m of fill and roadway protection design with tiebacks, strutting or a dead-man system.

### Precast Cap Panel on Sheet Piles

Another culvert replacement alternative that has been used in the past is precast cap panels supported on steel sheet piles; however, it is understood that MTO prefers not to use this alternative on major highways, such as Highway 11. Furthermore, the height of the unsupported sheet piles in a 19 m high fill would likely require bracing such as struts to reduce lateral deflection. Additional drilling to greater depths would also be required to enable sheet pile penetration design if this type of culvert were to be considered. Therefore, recommendations for this type of culvert have not been developed.

### Bridge Structure

An alternative approach would be to replace the culvert with a bridge structure founded on piles. Additional information on a proposed bridge layout including abutment locations as well as additional drilling to greater depths would be required to confirm foundation design parameters if this type of replacement approach were to be considered. Therefore, recommendations for bridge foundations have not been developed.

### Recommended Approach

A comparison of the culvert types and foundation alternatives based on their respective advantages and disadvantages is included in Appendix F.

Given the fact that the existing 4.9 m span by 2 m high concrete culvert is buried under 19 m of fill, the technically feasible option is to install multiple circular pipes by a trenchless method. A preferred alternative will be to line the existing culvert if it is structurally sound and has not sagged in the middle, and install a smaller diameter relief pipe adjacent to the existing culvert by a trenchless method.

## **10. TRENCHLESS RECOMMENDATIONS**

Trenchless installations should be carried out in accordance with the requirements of the Non-Standard Special Provision (NSSP) "Pipe Installation by Trenchless Methods". A copy of this NSSP is attached in Appendix G.



Trenchless methods that are typically considered to install pipes under highways include:

- Jack and bore
- Pipe ramming
- Microtunnelling (MTBM)
- Hand Mining
- Horizontal Directional Drilling

Selection of an appropriate trenchless method is the responsibility of the Contractor and will depend on the relative costs and risks associated with each method. The experience of the Contractor is of primary importance for trenchless installation. Amongst the important issues discussed in the NSSP are maintenance of alignment, handling of oversized obstructions and disposal of cuttings.

Due to the potential for flowing conditions at the face of the installation, due to the presence groundwater and cohesionless soils along the proposed pipe alignment, and the most likely need for a pipe with a diameter larger than 1.5 m, Pipe Ramming and Microtunnelling are considered feasible methods for this installation.

Jack and bore is considered not feasible due to the presence of non-plastic soils at the target depth, since this material could increase the risk under the presence of groundwater by creating unstable flowing conditions at the face of the installation.

Hand Mining is considered not feasible due to the presence of cohesionless soils and groundwater along the proposed pipe alignment, which will lead to unstable flowing conditions at the face of the excavation.

Horizontal Directional Drilling is considered not feasible since the pipe diameter will most likely need to be larger than 1.5 m, which is typically too large for this type of installation.

The recommended minimum distance between the existing and the new pipes is 1 to 2 pipe diameters.

Monitoring of the roadway surface should be carried out during trenchless installation. The settlement monitoring program and condition survey should follow MTO's Guidelines for Foundation Engineering – Tunnelling Specialty for Corridor Encroachment Permit Application. A copy of this document is attached in Appendix H.



## 10.1 Entry and Exit Pits

The design of safe and stable entry and exit pits for the trenchless installation is the responsibility of the contractor. Depending on the selected installation method, temporary protection systems may be required to support temporary excavations at the entry and exit pits.

Sheet-piles or soldier pile & lagging walls are considered appropriate for protection systems for the pits at this site. The fill and native material below the fill was noted to include occasional cobbles. Suggested wording for an NSSP on "Obstructions" is found in Appendix G.

The temporary excavation support system should be designed and constructed in accordance with OPSS 539, November 2009. The lateral movement of the temporary shoring system should meet Performance Level 2.

Earth pressures may be calculated using the parameters provided in the Table 10.1 for static conditions.

**Table 10.1 – Earth Pressure Design Parameters – Static Conditions**

Parameter	Soil Type			
	Silty Sandy Clay Fill $\Phi = 27^\circ$ $\gamma = 19 \text{ kN/m}^3$		Native Sand or Silty Sand $\Phi = 30^\circ$ $\gamma = 19 \text{ kN/m}^3$	
Surface Behind Wall	Horiz.	Sloping (2H:1V)	Horiz.	Sloping (2H:1V)
Active Earth Pressure Coefficient, $K_a$ (Unrestrained Wall)	0.38	0.71	0.33	0.54
At-rest Earth Pressure Coefficient, $K_o$ (Restrained Wall)	0.55	0.55	0.50	0.50
Passive Earth Pressure Coefficient, $K_p$ (Movement Towards Soil Mass)	2.6	-	3.0	-

Dewatering should be employed as necessary to keep the entry and exit pits dry.



## **11. BOX CULVERT**

### **11.1 Precast Concrete Box Culvert**

If a replacement box culvert will be constructed on the same alignment as the existing culvert with no grade raise, it is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading.

In order to provide a uniform foundation subgrade, a 300 mm thick layer of bedding material conforming to OPSS PROV 1010 Granular A or Granular B Type II requirements should be provided under the base of the box culvert, similar to as shown on OPSD 803.010. The bedding material must be placed on the prepared subgrade as soon as practicable following its inspection and approval. The subgrade preparation must be carried out in the dry. The surface prepared to support the box unit should have a 75 mm minimum thickness top levelling course consisting of uncompacted Granular A as per OPSS 422. Construction equipment should not be allowed to travel on the bedding or the prepared subgrade, which must be protected from disturbance during construction.

The invert level of the existing culvert is at approximate Elev. 274 m. Therefore, the underside of the bedding layer should be placed on the native sand deposit at or below an approximate elevation of 273.5 m. The native soils at that level consist of loose to compact sand. The presence of wood fragments within the sand at in Borehole 16-04 indicates that there is alluvium near the culvert outlet.

The following geotechnical capacities could be used for design of a box culvert of 4 to 5 m in width and founded at or below Elev. 273.5 m on the competent native sand subgrade:

- Factored Geotechnical Resistance at ULS of 450 kPa
- Geotechnical Resistance at SLS (less than 25 mm settlement) of 300 kPa.

The ULS resistance and settlement are dependent on the footing/culvert size, configuration and applied loads; the geotechnical resistances should therefore be reviewed if the culvert width or founding/invert elevation differs significantly from that given above.

The geotechnical resistances are for vertical, concentric loads. Where eccentric or inclined loads are applied, the resistance used in design must be reduced in accordance with the CHBDC 2014, Clause 6.10.3 and Clause 6.10.4.



Resistance to lateral forces / sliding resistance between the concrete slabs and the underlying Granular A or B Type II should be calculated assuming an ultimate coefficient of friction of 0.45.

The culvert should be designed to resist external loadings including frost forces, lateral earth pressures, hydrostatic pressure, weight of embankment fill, traffic loadings and surcharge due to construction equipment.

### **11.2 Frost Cover**

The depth of frost penetration at this site is approximately 2.4 m. The box culvert option does not require frost cover/protection.

Frost treatment/taper for a culvert should be in accordance with OPSD 803.010 for a box culvert.

### **11.3 Subgrade Preparation**

Performance of the replacement culvert will depend on the preparation of the subgrade. After the excavation reaches the design subgrade elevation, the exposed surface should be inspected to confirm that the subgrade is suitable and uniformly competent. Any remaining fill, topsoil, peat, creekbed deposits, disturbed soils and any deleterious materials within the replacement culvert footprint must be removed and replaced with well compacted bedding materials. Near the outlet of the culvert, alluvium with organic material was encountered in Borehole 16-04. Any alluvium with organics encountered during subgrade preparation near the outlet should be subexcavated by 1.5 m to an approximate Elev. of 272 m and replaced with granular material compacted as per OPSS.PROV 501.

In the event that subexcavation is required, the width of the subexcavation should be defined by a line extending from 0.3 m beyond the outside edge of the proposed culvert, outward and downward at 1H:1V. The subexcavated area should then be backfilled with granular material meeting OPSS.PROV 1010 Granular A or Granular B Type II requirements and compacted as per OPSS.PROV 501.

The work should be carried out in accordance with OPSS 902 and culvert construction and subgrade preparation must be carried out in the dry.

### **11.4 Settlement**

It is anticipated that a replacement box culvert will have approximately the same alignment and opening size as the existing culvert with no grade raise. Since there is no grade raise and the



foundation soils consist of compact to dense sand, very little post construction settlement is expected at this site.

### **11.5 Construction Considerations**

Detailed construction sequencing was not available at the time of preparation of this report. However, it is anticipated that one lane of traffic must be maintained, which requires staged construction.

Staged construction sequencing will likely require the following:

- Diversion of the creek will be required for construction. In addition, a suitable dewatering plan will be required to construct the culvert in the dry.
- Temporary roadway protection may be required during all stages of construction, including excavation and removal of the existing culvert, installation of the new culvert and backfilling.
- All culvert subgrade preparation and foundation preparation must be carried out in the dry.

## **12. EXCAVATION AND GROUNDWATER CONTROL**

All excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the embankment fill and native sand deposit at this site are classified as Type 3 soils above the water level and Type 4 soils below the water level. Peat and surficial alluvial deposits that are anticipated in the inlet and outlet areas should be classified as Type 4 soils.

Excavation and backfilling for culvert construction should be carried out in accordance with OPSS 902.

Excavations for culvert replacement will be carried out through the existing embankment fill and extended into the native sand, peat and alluvial deposit.

Installation of the culvert should be carried out in the dry. It is anticipated that excavation for culvert replacement will be carried out at or below the creek water level, and diversion of the creek flow will be required. The underlying native sand is relatively permeable, and seepage should be anticipated from the embankment fill and the foundation sand. Depending on the time of construction, a combination of cofferdam enclosures and creek diversion along with pumping from filtered sumps within the enclosure will be required to maintain dry excavations during the course of staged construction.



The design of an effective dewatering system that may be required is the responsibility of the Contractor and the Contract Documents must alert him to this responsibility and the need to engage a dewatering specialist. Dewatering must remain operational and effective until the culvert is installed and backfilled. Suggested wording for an NSSP in this regard is included in Appendix G.

### 13. CULVERT BACKFILL AND LATERAL EARTH PRESSURES

Backfill to the culvert should consist of free-draining, non-frost susceptible granular materials such as Granular A or B Type II conforming to the requirements of OPSS PROV 1010. Reference should be made to the backfill arrangements stipulated in OPSD 802.010, 803.010 or 802.034, as appropriate. Backfilling for the culvert should be in accordance with OPSS PROV 401 for a CSP or OPSS 902 for a box culvert. All fills should be placed in regular lifts and be compacted in accordance with OPSS PROV 501. The backfill should be placed and compacted in simultaneous lifts on both sides of the culvert, and the top of backfill elevation should not differ more than 400 mm on both sides of the culvert at all times. Heavy compaction equipment should not be used adjacent to the walls and on the roof of the culvert. Compaction equipment to be used adjacent to the culvert should be restricted in accordance with OPSS PROV 501.

Lateral earth pressures acting on the culvert walls may be assumed a triangular distribution. For a fully drained backfill, the pressures should be computed in accordance with the CHBDC 2014, but are generally given by the expression:

$$p_h = K (\gamma h + q)$$

where	$p_h$	=	horizontal pressure on the wall at depth h (kPa)
	K	=	earth pressure coefficient (see table below)
	$\gamma$	=	bulk unit weight of retained soil (see table below)
	h	=	depth below top of fill where pressure is computed (m)
	q	=	value of any surcharge (kPa)

Earth pressure coefficients for backfill to the culvert walls are dependent on the material used as backfill. Recommended unfactored values are shown in Table 13.1 below.

**Table 13.1 – Lateral Earth Pressure Coefficients (K)**

Loading Condition	OPSS Granular A or Granular B Type II $\phi = 35^\circ$ ; $\gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I (modified) $\phi = 32^\circ$ ; $\gamma = 21.2 \text{ kN/m}^3$		Existing Fill $\phi = 30^\circ$ ; $\gamma = 20 \text{ kN/m}^3$	
	Horizontal Backfill	Sloping Backfill (2H:1V)	Horizontal Backfill	Sloping Backfill (2H:1V)	Horizontal Backfill	Sloping Backfill (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48	0.33	0.54
At-rest (Restrained Wall)	0.43	0.62	0.47	0.70	0.50	0.76
Passive	3.7	-	3.3	-	3.0	-

Note: Submerged unit weight should be used below the groundwater level/high creek level.

For rigid structures such as concrete box culverts, at-rest horizontal earth pressures should be used for design. Active pressures should be used for any unrestrained wall.

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

In accordance with Clause 6.12.3 of the CHBDC 2014, a compaction surcharge should be added. The magnitude of the surcharge should be 12 kPa at the top of fill and decreasing to 0 kPa at a depth of 1.7 m for Granular B Type I, or at a depth of 2.0 m for Granular A or B Type II.

## 14. SEISMIC CONSIDERATIONS

The following seismic parameters should be used for design:

- Velocity Related Seismic Zone 0
- Zonal Velocity Ratio 0.0
- Acceleration Related Seismic Zone 0
- Zonal Acceleration Ratio 0.0

The site is underlain by a loose to dense sand. In view of the value of Velocity Related Seismic Zone of zero, liquefaction is not considered to be a concern at this site.



## **15. EMBANKMENT RESTORATION**

The existing Highway 11 embankment is approximately 19 m in height at the culvert location and the embankment slopes appear to be performing satisfactorily. Provided that the embankment is reconstructed at the same slope inclination as the existing embankment, but not steeper than 2H:1V, the restored embankment slope should remain stable.

It is anticipated that there will be no grade raise at this site for the culvert replacement, and therefore settlement of the embankment is not a concern. Furthermore, the foundation soils consist of loose to dense sand and any settlement is expected to be immediate in nature. Any settlement due to changes in the culvert configuration is expected to be less than 25 mm.

Embankment restoration after completion of the culvert replacement should be carried out in accordance with OPSS PROV 206 and OPSS PROV 209. The embankment material may consist of imported Granular A or B Type II material.

In general, surface vegetation, peat, topsoil, organic deposits, disturbed material or otherwise loose/soft soils should be stripped from the areas around the culvert inlets and outlets, and within the embankment footprints. Inspection and approval of the foundation surfaces by qualified geotechnical personnel should be conducted.

## **16. SCOUR AND EROSION PROTECTION**

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

Typically, rock protection should be provided over all surfaces with which creek water is likely to be in contact. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS PROV 804.

A concrete cut-off wall or clay seal should be used to minimize the potential for erosion or piping around the culvert. The clay seal should extend to approximately 0.3 m above the high water level and laterally for the width of the granular material, and have a minimum thickness of 0.5 m. The material requirements should be in accordance with OPSS PROV 1205. A geosynthetic clay liner may be used in place of a compacted clay seal.



## 17. TEMPORARY PROTECTION SYSTEM

Temporary roadway protection system should be implemented in accordance with OPSS PROV 539 and designed for Performance Level 2.

Options for roadway protection are a soldier pile-lagging system or interlocking sheet piles. The height of the roadway protection will be significant and may require intermediate support systems.

The following parameters may be applied for design of the temporary roadway protection system with horizontal backfill.

$\gamma$	=	21 kN/m <sup>3</sup>	- Bulk unit weight of fill and native soils
$\gamma_w$	=	10 kN/m <sup>3</sup>	- Submerged unit weight of fill
$K_a$	=	0.33	- Active earth pressure coefficient in fill
$K_a$	=	0.33	- Active earth pressure coefficient in native sand
$K_p$	=	3.0	- Passive earth pressure coefficient in fill
$K_p$	=	3.0	- Passive earth pressure coefficient in native sand

Full hydrostatic pressure should be considered assuming a water level at least equal to the design creek water level.

The design of temporary protection system is the responsibility of the Contractor. 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. All shoring systems should be designed by a Professional Engineer experienced in such designs, who will determine an appropriate support system.

## 18. CORROSION AND SULPHATE ATTACK POTENTIAL

The results of the corrosivity and sulphate analytical tests conducted on the native sand and the creek water indicates the following conditions at the locations tested:

- The potential for corrosion or sulphate attack on concrete foundations from the surrounding soil or surface water is considered to be negligible due to the low concentration of sulphate and chloride in the samples tested.
- The potential for soil or surface water corrosion on metal is considered to be mild.



- Appropriate protection measures are recommended if metal structural elements are used.

## **19. CONSTRUCTION CONCERNS**

The planned construction methodology includes trenchless methods or open cut construction in order to replace the culvert. Potential construction concerns include, but are not necessarily limited to, the following:

- Impact of trenchless operations on the existing pavement surface due to loss of material or heave. The Contractor's methodology selection must recognize and take into consideration these inherent risks. Contingency plans should be in place to manage any adverse impacts on the highway. The settlement of the pavement surface must be monitored during the trenchless operation.
- Implementation of an adequate and effective surface water management and dewatering plan. Surface runoff should be diverted away from excavations at all times. Box culvert construction must be carried out in the dry.
- The embankment fill and portions of the underlying soils were observed to contain occasional cobbles and the fill may contain other obstructions. The Contractor's equipment and methodology must be selected to handle such obstructions and successfully remove them without jeopardizing the highway. The impact of obstructions on the pipe alignment should be assessed.
- The Contractor must accurately establish, in three dimensions, the locations of all buried utilities crossing or closely paralleling the culvert alignment. Any discrepancies from the Contract Drawings must be reported to the Contract Administrator.

During construction, the Contract Administrator should employ experienced geotechnical staff to observe construction activities related to foundation construction.

The successful performance of the culvert will depend largely upon good workmanship and quality control during construction. Observation of the excavation and backfilling operations by the QVE will be required during construction to confirm that the foundation recommendations are correctly implemented and material specifications are met.



## 20. CLOSURE

Engineering analysis and preparation of this report was carried out by Mr. Mark Farrant P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.



Mark Farrant, P.Eng.

Project Manager, Geotechnical Engineer



P.K. Chatterji, P.Eng.

Review Principal, Designated MTO Contact

Client: Hatch

File No.: 13639

E file: H:\13000-13999\13639 MTO NWR Retainer Assignment 1 - Shamrock and Keemle Culverts\Reports & Memos\Shamrock Lake Centre Culvert\Shamrock Lake Centre Culvert - FIDR FINAL.docx

Date: August 25, 2016

Page: 23 of 23

## **Appendix A**

### **Record of Borehole Sheets**

## SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

### 1. TEXTURAL CLASSIFICATION OF SOILS

CLASSIFICATION	PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	Greater than 200mm	same
Cobbles	75 to 200mm	same
Gravel	4.75 to 75mm	5 to 75mm
Sand	0.075 to 4.75mm	Not visible particles to 5mm
Silt	0.002 to 0.075mm	Non-plastic particles, not visible to the naked eye
Clay	Less than 0.002mm	Plastic particles, not visible to the naked eye

### 2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

TERMINOLOGY	PROPORTION
Trace or Occasional	Less than 10%
Some	10 to 20%
Adjective (e.g. silty or sandy)	20 to 35%
And (e.g. sand and gravel)	35 to 50%

### 3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT <sup>(1)</sup> 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

- 1) Laboratory Triaxial Testing
- 2) Field Insitu Vane Testing
- 3) Laboratory Vane Testing
- 4) SPT value
- 5) Pocket Penetrometer



### 4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

DESCRIPTIVE TERM	SPT "N" VALUE
Very Loose	Less than 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	Greater than 50

### 5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE	SS Split Spoon Sample	WS Wash Sample	AS Auger (Grab) Sample
	TW Thin Wall Shelby Tube Sample	TP Thin Wall Piston Sample	
	PH Sampler Advanced by Hydraulic Pressure	PM Sampler Advanced by Manual Pressure	
	WH Sampler Advanced by Self Static Weight	RC Rock Core	SC Soil Core

$$\text{Sensitivity} = \frac{\text{Undisturbed Shear Strength}}{\text{Remoulded Shear Strength}}$$

 Water Level  
 Shear Strength Determination by Pocket Penetrometer

- (1) SPT 'N' Value      Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.
- (2) DCPT      Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

# UNIFIED SOILS CLASSIFICATION

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	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	SILTS AND CLAYS $W_L < 50\%$	ML	Inorganic silts and 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. ( $W_L < 30\%$ ).
		CI	Inorganic clays of medium plasticity, silty clays. ( $30\% < W_L < 50\%$ ).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

# RECORD OF BOREHOLE No 16-03

1 OF 2

METRIC

W.P. 6910-12-00 LOCATION Shamrock Lake Centre Culvert N 5 458 967.3 E 222 487.6 ORIGINATED BY GA  
 HWY 11 BOREHOLE TYPE Tripod/NW Casing/Dynamic Cone Penetration Test COMPILED BY AN  
 DATUM Geodetic DATE 2016.06.09 - 2016.06.09 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE							
275.0	GROUND SURFACE														
0.0	<b>PEAT</b> , some rootlets, occasional wood fibres Soft Brown Wet  <b>SAND</b> , trace gravel, trace silt Compact Brown Wet		1	SS	4										
274.4															
0.6															

Continued Next Page

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

# RECORD OF BOREHOLE No 16-03

2 OF 2

METRIC

W.P. 6910-12-00 LOCATION Shamrock Lake Centre Culvert N 5 458 967.3 E 222 487.6 ORIGINATED BY GA  
 HWY 11 BOREHOLE TYPE Tripod/NW Casing/Dynamic Cone Penetration Test COMPILED BY AN  
 DATUM Geodetic DATE 2016.06.09 - 2016.06.09 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	WATER CONTENT (%)					
	Continued From Previous Page							20 40 60 80 100						
264.0														
11.0	END OF BOREHOLE AT 11.0m UPON DCPT REFUSAL. BOREHOLE OPEN AND WATER LEVEL AT 0.5m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.													

# RECORD OF BOREHOLE No 16-04

1 OF 2

METRIC

W.P. 6910-12-00 LOCATION Shamrock Lake Centre Culvert N 5 459 024.7 E 222 435.8 ORIGINATED BY GA  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2016.06.08 - 2016.06.08 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
275.5	GROUND SURFACE							20	40	60	80	100		
0.0	TOPSOIL, sandy, some rootlets and wood fibres: (150mm)		1	SS	4		275							
0.2	SAND, trace silt, occasional rootlets and wood fibres Loose Brown Dry		2	SS	6									
	Wood fragments (log) from 1.5m to 1.8m Becoming Wet		3	SS	15		274							
			4	SS	4		273							
	Wood fragments (log) from 3.1m to 3.2m		5	SS	4		272							
271.4														
4.1	Silty SAND, trace clay Compact Brown Wet		6	SS	14		271							
							270							
			7	SS	13		269							
							268							
267.7														
7.8	SAND, trace to some gravel, trace to some silt Compact to Dense Brown Wet		8	SS	29		267							
			9	SS	31		266							

Continued Next Page

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

# RECORD OF BOREHOLE No 16-04

2 OF 2

METRIC

W.P. 6910-12-00 LOCATION Shamrock Lake Centre Culvert N 5 459 024.7 E 222 435.8 ORIGINATED BY GA  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2016.06.08 - 2016.06.08 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL																
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa																									
	Continued From Previous Page																																
			10	SS	26		265																										
							264																										
262.7			11	SS	30		263									14 80 6 (SI+CL)																	
12.8	END OF BOREHOLE AT 12.8m. BOREHOLE OPEN TO 12.2m AND WATER LEVEL AT 1.5m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.  WATER LEVEL READINGS: <table border="1"> <thead> <tr> <th>DATE</th> <th>DEPTH (m)</th> <th>ELEV. (m)</th> </tr> </thead> <tbody> <tr> <td>2016.06.09</td> <td>1.5</td> <td>274.0</td> </tr> <tr> <td>2016.06.10</td> <td>1.5</td> <td>274.0</td> </tr> <tr> <td>2016.06.11</td> <td>1.5</td> <td>274.0</td> </tr> <tr> <td>2016.06.12</td> <td>1.5</td> <td>274.0</td> </tr> <tr> <td>2016.06.12</td> <td colspan="2">Decommissioned</td> </tr> </tbody> </table>	DATE	DEPTH (m)	ELEV. (m)	2016.06.09	1.5	274.0	2016.06.10	1.5	274.0	2016.06.11	1.5	274.0	2016.06.12	1.5	274.0	2016.06.12	Decommissioned															
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2016.06.09	1.5	274.0																															
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2016.06.11	1.5	274.0																															
2016.06.12	1.5	274.0																															
2016.06.12	Decommissioned																																

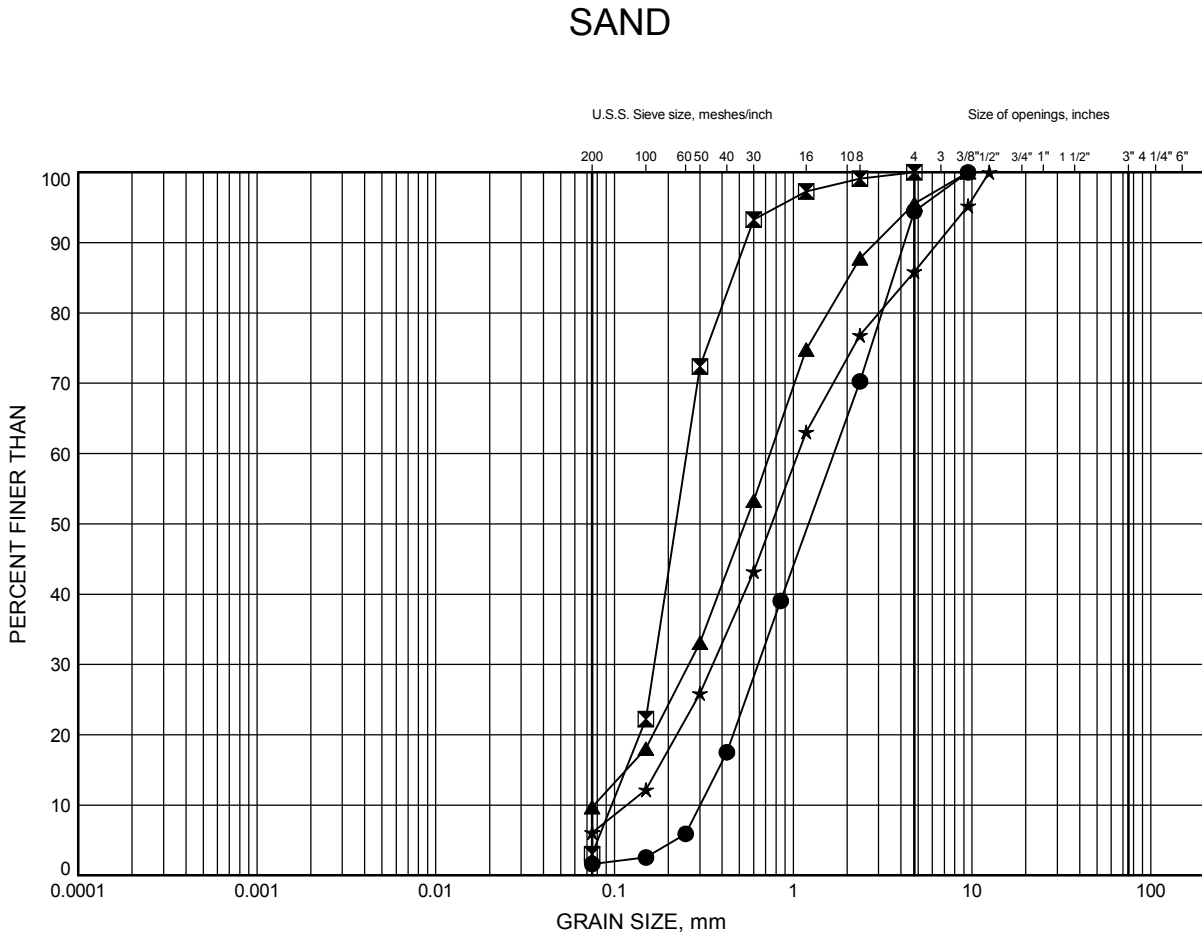
## **Appendix B**

### **Geotechnical and Analytical Laboratory Test Results**

# Shamrock Lake Centre Culvert Replacement

## GRAIN SIZE DISTRIBUTION

FIGURE B1



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-03	1.07	273.93
⊠	16-03	2.59	272.41
▲	16-04	9.45	266.05
★	16-04	12.50	263.00

Date July 2016  
W.P. 6910-12-00



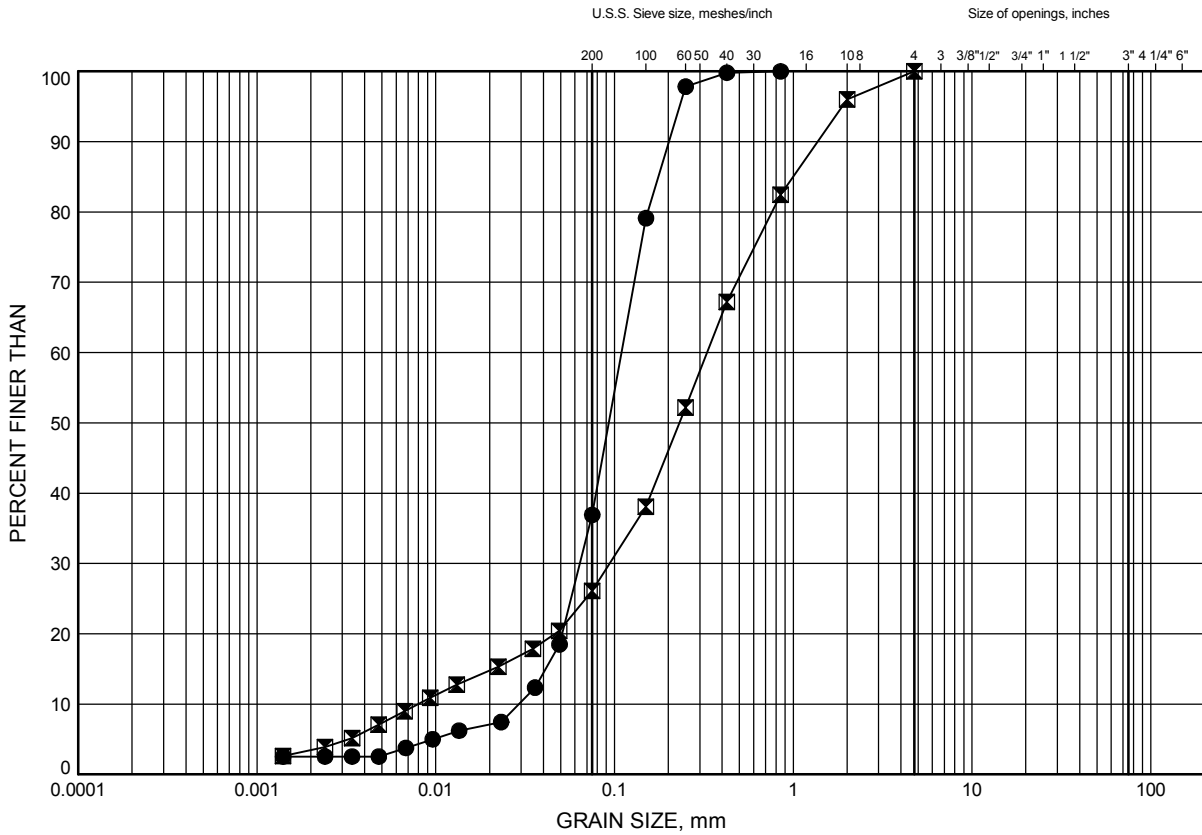
Prep'd MFA  
Chkd. MEF

# Shamrock Lake Centre Culvert Replacement

## GRAIN SIZE DISTRIBUTION

FIGURE B2

### Silty SAND



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-03	7.92	267.08
⊠	16-04	6.40	269.10

Date July 2016  
W.P. 6910-12-00



Prep'd MFA  
Chkd. MEF

**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.  
 Lakefield - Ontario - K0L 2H0  
 Phone: 705-652-2000 FAX: 705-652-6365

**Project : 13639****Thurber Engineering Ltd.****Attn : Mark Farrant**

103, 2010 Winston Park Drive  
 Oakville, ON  
 L6H 5R7,

Phone: 905-829-8666 x 228  
 Fax:

11-July-2016

**Date Rec. :** 30 June 2016  
**LR Report:** CA15745-JUN16  
**Reference:** 13639

**Copy:** #1

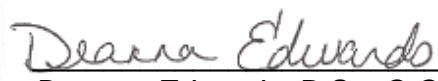
# CERTIFICATE OF ANALYSIS

## Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Approval Date	4: Analysis Approval Time	5: MDL	6: Shamrock Lake West	7: Shamrock Lake Centre	8: Keemle Lake
Sample Date & Time						27-Jun-16 07:35	27-Jun-16 07:50	27-Jun-16 08:05
Temperature Upon Receipt [°C]	---	---	--	--	---	14.0	14.0	14.0
Corrosivity Index [none]	07-Jul-16	15:20	07-Jul-16	15:20		< 1	< 1	< 1
pH [no unit]	30-Jun-16	14:14	04-Jul-16	12:17	0.05	7.44	7.36	6.43
Conductivity [µS/cm]	30-Jun-16	14:14	04-Jul-16	12:17	2	87	47	21
Resistivity (calculated) [MOhms.cm]	07-Jul-16	14:27	07-Jul-16	14:28	---	11500	21400	48100
Redox Potential [mV]	30-Jun-16	14:34	06-Jul-16	09:05	---	206	197	201
Chloride [mg/L]	06-Jul-16	06:58	07-Jul-16	11:30	0.04	1.3	0.39	0.09
Sulphate [mg/L]	06-Jul-16	06:58	07-Jul-16	11:30	0.04	1.6	1.6	0.81
Sulphide [mg/L]	01-Jul-16	10:00	04-Jul-16	12:51	0.006	< 0.006	< 0.006	0.006

**Method Descriptions**

Parameter	SGS Method Code	Reference Method Code
Anions by IC	ME-CA-[ENV]IC-LAK-AN-001	EPA300/MA300-Ions1.3
Conductivity	ME-CA-[ENV]EWL-LAK-AN-006	SM 2510
pH	ME-CA-[ENV]EWL-LAK-AN-006	SM 4500
Redox Potential		SM 2580
Sulphide by SFA	ME-CA-[ENV]SFA-LAK-AN-008	SM 4500

  
 Deanna Edwards, B.Sc, C.Chem  
 Project Specialist  
 Environmental Services, Analytical



**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.

Lakefield - Ontario - K0L 2H0

Phone: 705-652-2000 FAX: 705-652-6365

**Project :** 13639

**LR Report :** CA15745-JUN16

Temperature of Samples upon Receipt 14 degrees C  
Cooling Agent Present

Corrosivity Index is based on the American Water Works Corrosivity Scale according to AWWA C-105. An index greater than 10 indicates the soil matrix may be corrosive to cast iron alloys.



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Phone: 705-652-2000 FAX: 705-652-6365

**Project :** 13639

**LR Report :** CA15745-JUN16

## Quality Control Report

Inorganic Analysis												
Parameter	Reporting Limit	Unit	Method Blank				LCS / Spike Blank			Matrix Spike / Reference Material		
					RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
						%		Low	High		Low	High
Anions by IC - QCBatchID: DIO0054-JUL16												
Chloride	0.04	mg/L	<0.04		ND	20	103	80	120	105	75	125
Sulphate	0.04	mg/L	<0.04		ND	20	100	80	120	98	75	125
Conductivity - QCBatchID: EWL0498-JUN16												
Conductivity	2	µS/cm	< 2		0	10	97	90	110	NA		
pH - QCBatchID: EWL0498-JUN16												
pH	0.05	no unit	NA		1		97			NA		
Redox Potential - QCBatchID: EWL0500-JUN16												
Redox Potential	no	mV	NA		7	20	104	80	120	NA		
Sulphide by SFA - QCBatchID: SKA0002-JUL16												
Sulphide	0.006	mg/L	<0.006		ND	20	7	80	120	NV	75	125

**SGS Canada Inc.**

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 Lakefield - Ontario - KOL 2H0  
 Phone: 705-652-2000 FAX: 705-652-6365

**Project : 13639****28-June-2016****Thurber Engineering Ltd.****Attn : Mark Farrant**

103, 2010 Winston Park Drive  
 Oakville, ON  
 L6H 5R7,

Phone: 905-829-8666 x 228


Fax:

**Date Rec. : 21 June 2016****LR Report: CA14531-JUN16****Reference: 13639 Mark Farrant****CERTIFICATE OF ANALYSIS**

<b>Analysis</b>	<b>1: Analysis Start Date</b>	<b>2: Analysis Start Time</b>	<b>3: Analysis Approval Date</b>	<b>4: Analysis Approval Time</b>	<b>5: 16-01 SS #2, 2.5'-4.5'</b>	<b>6: 16-04 SS #2, 2.5'-4.5'</b>	<b>7: 16-05 SS #2, 2.5'-4.5'</b>
Sample Date & Time					07-Jun-16	08-Jun-16	12-Jun-16
Corrosivity Index [none]	27-Jun-16	17:00	27-Jun-16	17:00	3	3	3
pH [no unit]	22-Jun-16	10:19	22-Jun-16	11:34	7.28	7.33	5.96
Soil Redox Potential [mV]	27-Jun-16	14:03	27-Jun-16	16:53	284	273	363
Sulphide [%]	24-Jun-16	13:25	24-Jun-16	14:10	0.02	< 0.02	< 0.02
% Moisture (wet wt) [%]	24-Jun-16	07:20	24-Jun-16	14:10	73.2	82.0	88.3
pH [no unit]	42548	0.46	27-Jun-16	16:54	7.82	8.09	7.23
Chloride [µg/g]	25-Jun-16	11:33	27-Jun-16	14:22	49	10	11
Sulphate [µg/g]	25-Jun-16	11:33	27-Jun-16	14:22	61	2.0	8.8
Conductivity [uS/cm]	27-Jun-16	11:08	27-Jun-16	16:55	118	87	28
Resistivity (calculated) [Ohms.cm]	---	---	27-Jun-16	17:00	8500	11500	35700

Temperature of Samples upon receipt 12 degree C  
 Ice was added by SGS Courier

Corrosivity Index is based on the American Water Works Corrosivity Scale according to AWWA C-105. An index greater than 10 indicates the soil matrix may be corrosive to cast iron alloys.

  
**Deanna Edwards, B.Sc, C.Chem**  
**Project Specialist**  
**Environmental Services, Analytical**

**SGS Canada Inc.**

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Lakefield - Ontario - K0L 2H0

Phone: 705-652-2000 FAX: 705-652-6365

**Project :** 13639**LR Report :** CA14531-JUN16**Method Descriptions**

Parameter	SGS Method Code	Reference Method Code
Anions by IC	ME-CA-[ENV]IC-LAK-AN-001	EPA300/MA300-Ions1.3
Carbon/Sulphur	ME-CA-[ENV]ARD-LAK-AN-020	ASTM E1918
Conductivity	ME-CA-[ENV]EWL-LAK-AN-006	SM 2510
Metals Prep	ME-CA-[ENV]ARD-LAK-AN-013	
pH	ME-CA-[ENV]EWL-LAK-AN-001	SM 4500



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Phone: 705-652-2000 FAX: 705-652-6365

**Project :** 13639

**LR Report :** CA14531-JUN16

## Quality Control Report

Inorganic Analysis												
Parameter	Reporting Limit	Unit	Method Blank				LCS / Spike Blank			Matrix Spike / Reference Material		
					RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
						%		Low	High		Low	High
Anions by IC - QCBatchID: DIO0413-JUN16												
Chloride	0.4	µg/g	<0.4		1	20	101	80	120	103	75	125
Sulphate	0.4	µg/g	<0.4		2	20	96	80	120	95	75	125
Carbon/Sulphur - QCBatchID: ECS0031-JUN16												
Sulphide	0.02	%	<0.02		ND	20	100	80	120			
Conductivity - QCBatchID: EWL0419-JUN16												
Conductivity	2	uS/cm	< 2		0	10	97	90	110	NA		
pH - QCBatchID: ARD0070-JUN16												
pH	0.05	no unit			0	20	100	80	120			

## **Appendix C**

### **Factual Data from 2015 DST Foundation Investigation Report**

# RECORD OF BOREHOLE No BH1

1 OF 1

METRIC

W.P. 6013-E-0021 LOCATION Shamrock Lake Center STA 13+667, 4.5 RT ORIGINATED BY PR  
DIST Thunder Bay HWY 11 BOREHOLE TYPE Hollow Stem Auger 80 mm COMPILED BY DB  
DATUM Local DATE 2014 10 20 CHECKED BY DM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								20	40	60	80	100					
								20	40	60	80	100					
99.9	GROUND SURFACE																
98.9	ASPHALT		AS1	AS													16 74 (10)
98.2	FILL-SAND AND CRUSHED GRAVEL		SS2	SS	9												2 65 (33)
	FILL-SAND-trace to some gravel, trace to with silt, cobbles, BROWN, Loose to Dense		SS3	SS	9												
			SS4	SS	26		98										
			SS5	SS	20												2 91 (7)
			SS6	SS	22		96										
			SS7	SS	33												
			SS8	SS	16		94										
			SS9	SS	17		92										0 88 (12)
			SS10	SS	20												
							90										
			SS11	SS	33												
							88										
			SS12	SS	23												7 84 (9)
			SS13	SS	24		86										
	-roots		SS14	SS	9		84										
			SS15	SS	6												6 86 (8)
	-Black organics		SS16	SS	4		82										
80.1							80										
19.8	SAND-trace gravel, some silt, cobbles, GREY, Compact to Dense		SS17	SS	15												
			SS18	SS	18		78										
			SS19	SS	33												4 84 (12)
							76										
			SS20	SS	24												
74.9																	
25.0	END OF BOREHOLE																

NR = NO RECOVERY

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

○ 3% STRAIN AT FAILURE

ENCLOSURE 1

# RECORD OF BOREHOLE No BH2

1 OF 1

METRIC

W.P. 6013-E-0021 LOCATION Shamrock Lake Center STA 13+674, 4.5 RT ORIGINATED BY PR  
DIST Thunder Bay HWY 11 BOREHOLE TYPE Hollow Stem Auger 80 mm COMPILED BY DB  
DATUM Local DATE 2014 10 20 CHECKED BY DM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT  w <sub>p</sub>	NATURAL MOISTURE CONTENT  w	LIQUID LIMIT  w <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED      + FIELD VANE □ QUICK TRIAXIAL    × LAB VANE							
100.0	GROUND SURFACE														
98.9	ASPHALT		AS1	AS											
98.3	FILL-SAND AND CRUSHED GRAVEL		SS2	SS	8										
	FILL-SAND-trace to some gravel, trace to with silt, cobbles, BROWN, Loose to Compact		SS3	SS	12										0 65 (35)
			SS4	SS	21										
			SS5	SS	20										
			SS6	SS	18										
			SS7	SS	21										0 39 (61)
			SS8	SS	20										
			SS9	SS	16										
			SS10	SS	29										8 76 (16)
			SS11	SS	17										
			SS12	SS	19										
			SS13	SS	11										
			SS14	SS	9										6 80 (14)
			SS15	SS	8										
			SS16	SS	6										
80.2															
19.8	SAND-some gravel, trace to some silt, GREY, Loose to Compact		SS17	SS	12										17 75 (8)
			SS18	SS	9										
			SS19	SS	19										
			SS20	SS	23										0 82 (18)
75.0															
25.0	END OF BOREHOLE														

NR = NO RECOVERY

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

○ 3% STRAIN AT FAILURE

ENCLOSURE 2

# RECORD OF BOREHOLE No BH3

1 OF 1

METRIC

W.P. 6013-E-0021 LOCATION Shamrock Lake Center STA 13+655, 4.5 LT ORIGINATED BY PR  
DIST Thunder Bay HWY 11 BOREHOLE TYPE Hollow Stem Auger 80 mm COMPILED BY DB  
DATUM Local DATE 2014 10 20 CHECKED BY DM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								20	40	60	80	100					
99.8	GROUND SURFACE																
99.5	FILL-SAND AND CRUSHED GRAVEL			AS1	AS												25 64 (11)
0.3	FILL-SAND-trace to with gravel, trace to with silt, cobbles, BROWN, Loose to Compact			SS2	SS	7											3 71 (26)
				SS3	SS	10											
				SS4	SS	8											
				SS5	SS	5											
				SS6	SS	5											
				SS7	SS	11											
				SS8	SS	7											0 82 (18)
				SS9	SS	22											
				SS10	SS	21											
				SS11	SS	15											

NR = NO RECOVERY

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



○ 3% STRAIN AT FAILURE

# RECORD OF BOREHOLE No BH4

1 OF 1

METRIC

W.P. 6013-E-0021 LOCATION Shamrock Lake Center STA 13+662, 4.4 LT ORIGINATED BY PR  
DIST Thunder Bay HWY 11 BOREHOLE TYPE Hollow Stem Auger 80 mm COMPILED BY DB  
DATUM Local DATE 2014 10 20 CHECKED BY DM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										
								○ UNCONFINED	+ FIELD VANE	□ QUICK TRIAXIAL	× LAB VANE	WATER CONTENT (%)						
99.9	GROUND SURFACE						20	40	60	80	100						GR SA SI CL	
99.6	FILL-SAND AND CRUSHED GRAVEL		AS1	AS													16 71 (13)	
0.4	FILL-SAND-trace to some gravel, trace to some silt, cobbles, BROWN, Loose to Dense		SS2	SS	9													
			SS3	SS	10		98											
			SS4	SS	8													
			SS5	SS	21													
			SS6	SS	10		96											
			SS7	SS	29													
			SS8	SS	29		94											
			SS9	SS	30		92											
			SS10	SS	30		90											
			SS11	SS	32		88											
		SS12	SS	10	86													
		SS13	SS	6	84													
		SS14	SS	9	82													
		SS15	SS	10	80													
		SS16	SS	8	78													

NR = NO RECOVERY

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

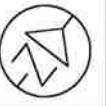
○ 3% STRAIN AT FAILURE

## **Appendix D**

### **Borehole Locations and Soil Strata Drawing**

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

CONT No  
WP No 6910-12-00



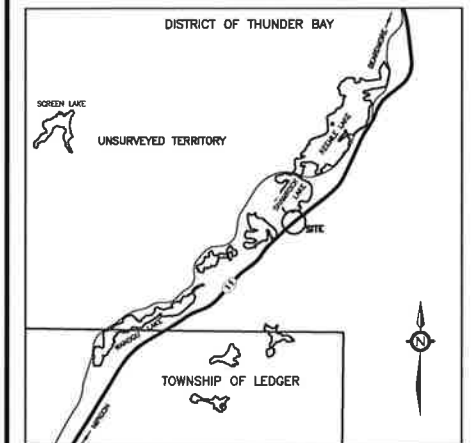
HIGHWAY 11  
SHAMROCK LAKE CENTRE  
CULVERT REPLACEMENT  
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

**HATCH**



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

- ◆ Borehole by Thurber (2016)
- ⊕ Borehole and Cone by Thurber (2016)
- ⊕ Borehole by DST (2014)
- N Blows /0.3m (Std Pen Test, 475J/blow)
- CONE Blows /0.3m (60° Cone, 475J/blow)
- PH Pressure, Hydraulic
- ▽ Water Level
- ⌋ Head Artesian Water
- ⌋ Piezometer
- 90% Rock Quality Designation (RQD)
- A/R Auger Refusal

NO	ELEVATION	NORTHING	EASTING
16-03	275.0	5 458 967.3	222 487.6
16-04	275.5	5 459 024.7	222 435.8
BH1	292.5	5 458 995.5	222 470.3
BH2	292.6	5 458 999.8	222 475.8
BH3	292.5	5 458 995.2	222 455.3
BH4	292.6	5 458 999.4	222 460.9

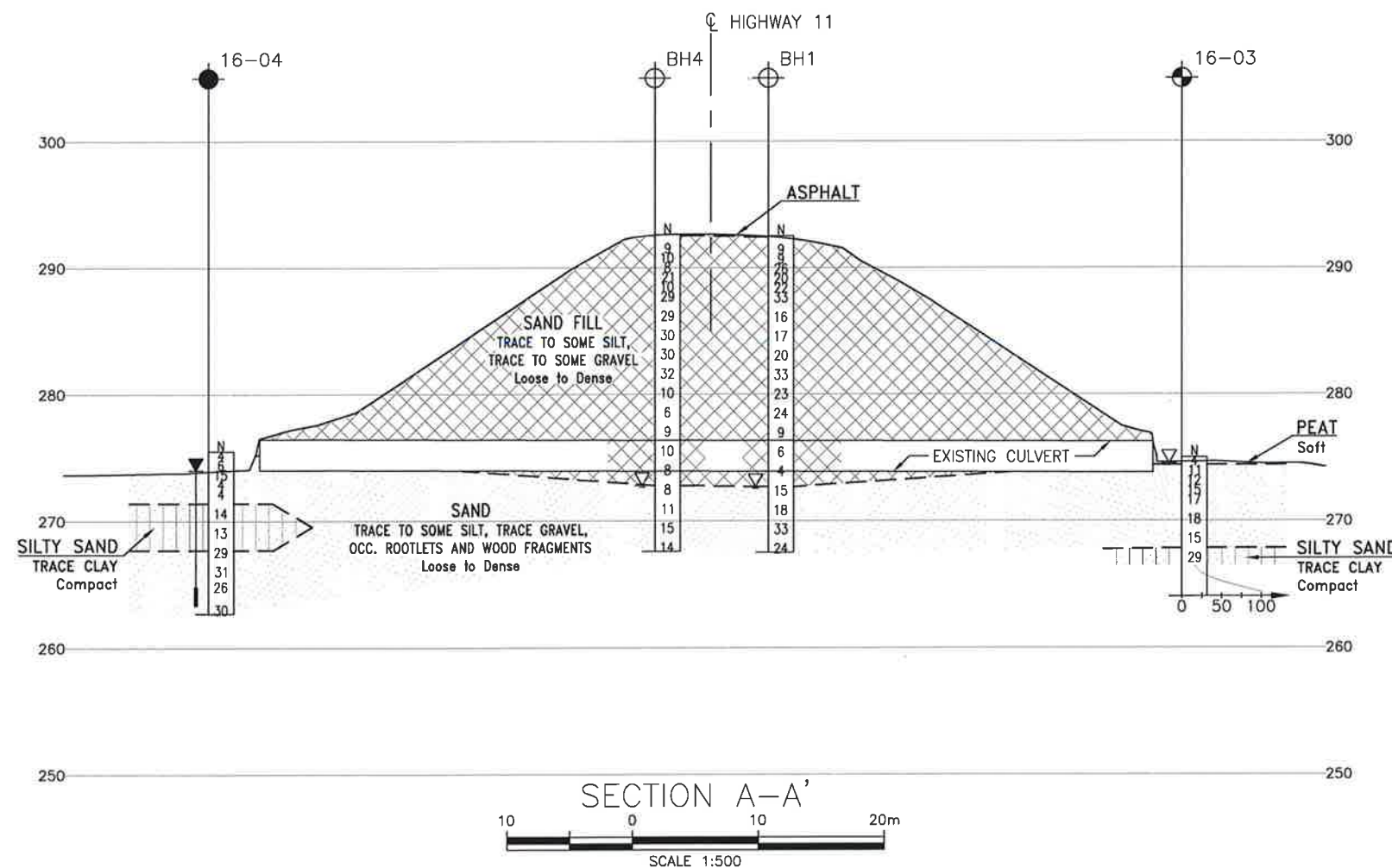
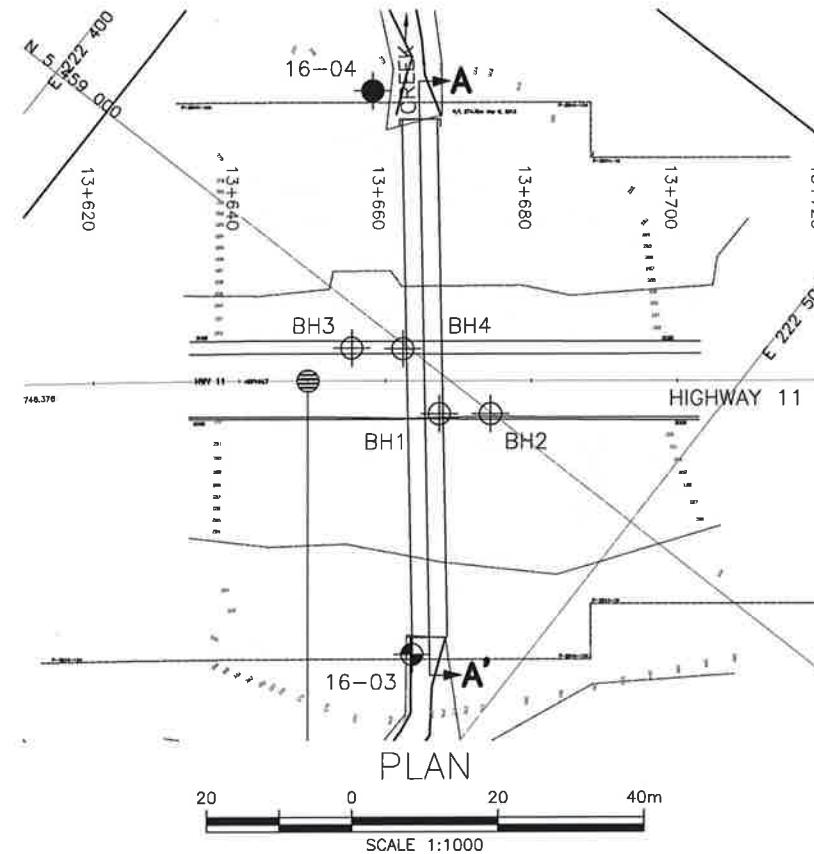
-NOTES-

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

GEOCRES No. 52H-39

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	MEF	CHK MRA	CODE
DRAWN	MFA	CHK MEF	SITE
			LOAD
			DATE
			AUG 2016
			STRUCT
			DWG 1

FILENAME: H:\Drafting\13000\13639\13639-PLPR-SC.dwg  
PLOTDATE: 8/24/2016 2:50 PM



## **Appendix E**

### **Site Photographs**



**Photo 1: Shamrock Lake Centre Culvert Inlet**



**Photo 2: Shamrock Lake Centre Culvert Outlet**



**Photo 3: Looking northeast along Highway 11 at Shamrock Lake Centre Culvert**



**Photo 4: Looking northeast along west side of Highway 11 embankment**



**Photo 5: Looking northeast along east side of Highway 11 embankment**

## **Appendix F**

### **Comparison of Construction Methodology Alternatives**

### COMPARISON OF FOUNDATION ALTERNATIVES

Precast Concrete Box Culvert	Concrete Open Footing Culvert	Trenchless Installation of Circular Pipes
<p><u>Advantages:</u></p> <ul style="list-style-type: none"> <li>i. Relatively rapid installation and less disturbance to subgrade soils if pre-cast segments are used.</li> <li>ii. Less stringent requirement for soil geotechnical resistances as loading is spread over a larger area.</li> </ul>	<p><u>Advantages:</u></p> <ul style="list-style-type: none"> <li>i. Conventional construction.</li> <li>ii. Possibly less disturbance of creek channel / less environmental issues such as those involving spawning fish species.</li> </ul>	<p><u>Advantages:</u></p> <ul style="list-style-type: none"> <li>i. Avoids deep excavation through highway.</li> <li>ii. Possibly allows two lanes of traffic to be maintained throughout.</li> </ul>
<p><u>Disadvantages:</u></p> <ul style="list-style-type: none"> <li>i. Requires deep excavation through 19 m of embankment fill and associated roadway protection.</li> </ul>	<p><u>Disadvantages:</u></p> <ul style="list-style-type: none"> <li>i. Requires deep excavation through 19 m of embankment fill and associated roadway protection.</li> <li>ii. Requires deeper excavation to achieve higher geotechnical resistances to support strip footings.</li> <li>iii. Potentially more difficult dewatering requirements.</li> </ul>	<p><u>Disadvantages:</u></p> <ul style="list-style-type: none"> <li>i. Requires construction of entry and exit pits and access to toe of slope.</li> <li>ii. Must maintain surface and groundwater control</li> </ul>
<b>FEASIBLE</b>	<b>NOT RECOMMENDED</b>	<b>PREFERRED</b>

## **Appendix G**

### **List of OPSS, OPSDs, and Suggested Text for Selected NSSP**

## **1. List of OPSS and OPSD Documents Relevant to this Project**

- OPSS PROV 206
- OPSS PROV 209
- OPSS 422
- OPSS PROV 501
- OPSS 517
- OPSS 518
- OPSS PROV 539
- OPSS PROV 804
- OPSS 902
- OPSS PROV 1010
- OPSS PROV 1205
- OPSD 802.010
- OPSD 802.034
- OPSD 803.010
- OPSD 803.031

## **2. Suggested Nssp Wording**

- Suggested Text for Nssp on “Obstructions”

“Excavations and installation of cofferdams and roadway protection systems could encounter obstructions such as cobbles and boulders embedded in the fill and native soils. Such obstructions may impede excavation progress and/or sheetpile installation. The Contractor shall be prepared to remove, drill through and/or penetrate these obstructions to achieve the design depths.”

- Suggested Text for Nssp on “Groundwater and Dewatering”

"The Contractor is notified that the site has high groundwater levels and that these levels may be higher than the water levels shown in the Foundation Investigation Report prepared for this site. While reference should be made to that report for a description of the encountered

conditions, the Contractor must satisfy himself regarding the groundwater levels likely to prevail at the time of construction and be prepared to implement dewatering procedures.

The Contractor is further notified that failure to implement dewatering in advance of excavating below the groundwater table may result in sloughing and boiling of the soil in the excavation and a loss in stability and bearing resistance.

Design and provision of an effective dewatering system is the responsibility of the Contractor. Subgrade preparation, culvert construction and backfilling must be carried out in the dry. "

## **PIPE INSTALLATION BY TRENCHLESS METHOD – Item No.**

---

Non Standard Special Provision

January 2012

---

### **1. SCOPE**

This specification covers the general requirements for the installation of pipes by trenchless methods.

The Contractor shall determine the most appropriate method of installation. Specifications for Jack and Bore, Pipe Ramming, Directional Drilling, and Tunnelling are provided herein, and shall be applied to the installation method considered feasible by the Contractor. It should be noted that in light of the stratigraphy at this site, Jack and Bore, Hand Mining and Horizontal Directional Drilling methods are not feasible and shall not be used.

OPSS 415 (Construction Specification for Pipeline and Utility Installation by Tunnelling), 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) shall not be used to do the work for the above tender item.

### **2. REFERENCES**

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

Foundation Investigation and Design Report, Shamrock Lake Centre Culvert Replacement, Highway 11, Thunder Bay District, Ontario, GWP No. 6910-12-00, WP No.6910-12-00, Site No. 48C-338/C, by Thurber Engineering Ltd., Reference No. 13639.

#### **Ontario Provincial Standard Specifications, General**

OPSS 180 Management and Disposal of Excess Material

#### **Ontario Provincial Standard Specifications, Construction**

OPSS 504 Preservation, Protection, and Reconstruction of Existing Facilities

OPSS 507 Site Restoration Following Installation of Pipelines, Utilities and Associated Structures in Open Cut

OPSS 514 Trenching, Backfilling, and Compaction

OPSS 517 Dewatering of Pipeline, Utility, and Associated Structure Excavation

OPSS 538 Support Systems

OPSS 539 Protection Schemes

#### **Ontario Provincial Standard Specifications, Material**

OPSS 1004 Aggregates - Miscellaneous

OPSS 1350 Concrete - Materials and Production

OPSS 1440 Steel Reinforcement for Concrete

OPSS 1802 Smooth Walled Steel Pipe

#### **MTO Specifications**

OPSS 1820 Material Specification for Circular Concrete Pipe

OPSS 1840 Material Specification for Non-Pressure Polyethylene 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:

**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.

**Jack and 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.

**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.

**Tunnelling:** an underground method of constructing a passage open at both ends that involves installing a pipe.

## **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.

### **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 (1) 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; and
- Design assumption and material data when materials other than those specified are proposed for use.
- 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 jacking procedures, including methodology to handle obstructions and preventing 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, layout 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 excavation
- Jacking/Ramming/Directional Drilling of Casing/Liner
- Excavation and Dewatering
- 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 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 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 1004 wetted with only sufficient water to make the mixture plastic.

## **5.06 Jack and Bore Materials**

### **5.06.01 Pipe Materials**

Steel pipe shall conform with ASTM A252-95 welded joints suitable for jacking operations. The Contractor shall select pipe class for pipe jacking.

Concrete pipe as per OPSS 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. A minimum wall thickness of 50 mm and minimum yield strength of 240 MPa is required.

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.

Joining 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 joining process.

Joining 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 to provide support and stability to the excavation.

### **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 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.

Joining 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 joining process.

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

### **6. EQUIPMENT**

#### **6.01 Jack & Bore Equipment**

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 explosives or rock fracturing chemicals shall only be considered subject to a field demonstration satisfactory to the Ministry prior to its use.

## **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 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 Shafts**

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 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 systems include primary liner and portal excavation support systems. 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 Contractor, 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 504.

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.

### **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 514.

### **7.01.09 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.

#### **7.01.10 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.

#### **7.01.11 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.

#### **7.01.12 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 median end of the pipe to the outlet end to confirm gravity flow conditions.

#### **7.01.13 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.

#### **7.01.14 Site Restoration**

Site restoration shall be according to OPSS 507.

#### **7.01.15 Supervision**

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

### **7.02 Jack and 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 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**

##### **7.04.06.01 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 2m) 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 OSHA 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  $\pm 1$  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 as shown on the Contract Drawings.

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 Subsection 4.02, 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 of sequence of construction or ground stabilization measures to mitigate further ground displacement.

If the 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 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 providing all labour, equipment and materials required for excavation (regardless of material encountered), dewatering, sheathing and shoring, supply and installation of pipe liners, settlement monitoring and instrumentations site restoration and for 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.

*Notes to Designer:*

*Under Section 7.01.06, minimum horizontal and vertical clearances to existing facilities shall be identified in the Contract Documents. 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. The number of exposures required to monitor work progress shall be specified in the Contract Documents.*

## **Appendix H**

### **Guidelines for Foundation Engineering – Tunnelling Specialty for Corridor Encroachment Permit Application**

**Guidelines For Foundation Engineering – Tunnelling Specialty  
For Corridor Encroachment Permit Application**

These guidelines specify MTO's minimum requirements for the Foundation Engineering – Tunnelling Specialty component of submissions from proponents of development within the Ministry of Transportation's (MTO) corridor permit control area. The Foundation Engineering – Tunnelling Specialty component of submissions is a requirement for the permit application only and do not cover all the design requirements.

The complexity ratings of Foundations Engineering services are defined in Table 1.

**Table 1: Complexity ratings for tunnelling specialty services**

Highway Classification	Tunnel Excavation Diameter ( $\phi$ )					
	$\leq 1$ m		$>1$ m & $\leq 2$ m		$>2$ m	
	Minimum Overburden Cover * (m)					
	$\geq 3 \phi$ (or 1.5 m whichever is greater)	$< 3 \phi$ (or 1.5 m whichever is greater)	$\geq 3 \phi$	$< 3 \phi$ (or 1.5 m whichever is greater)	$\geq 3 \phi$	$< 3 \phi$ (or 1.5 m whichever is greater)
Kings Highway	Low	Medium	Medium	High	High	High
400 Series Freeway	Medium	High	High	High	High	High

\*Minimum overburden cover is the vertical distance measured from the lowest ground elevation to the crown of the tunnel.

Foundations Engineering consultants that are registered in the MTO consultant acquisition system (RAQS) at complexity ratings identified in Table 1 are eligible to provide Foundations Engineering services for this project. Alternatively, the proponents may propose a Foundations Engineering consultant that is not registered in RAQS, in which case, the proponent must submit sufficient documentation to demonstrate that the consultant's qualifications meet or exceed the RAQS complexity requirements.

For Engineering Materials Testing and Evaluation, the consultant shall be qualified for Soil and Rock testing of complexity level at least equal to that identified for this project.

Consultant services shall be provided in accordance with the most recent editions of the Canadian Highway Bridge Design Code (CHBDC), and the 'Guideline for Professional Engineers Providing Geotechnical Engineering Services' published by the Professional Engineers of Ontario.

The designated principal contact identified for Foundations Engineering services by MTO shall sign, and where required, seal, all submissions and correspondence that are submitted to MTO.

Services include, but are not restricted to, conducting a site investigation that shall be of sufficient scope to verify design assumptions and to provide the contractor with adequate subsurface information for design and construction planning.

Sufficient subsurface (factual) information is required to determine the vertical and horizontal extent of subsurface materials (including both soil and rock) and their pertinent engineering properties and groundwater conditions.

Subsurface information is usually acquired by advancing boreholes, laboratory testing of soil samples and rock core samples, performing in-situ tests such as standard penetration tests, dynamic cone tests, and piezocone tests (CPTU) and test pits.

### **Minimum requirements for Subsurface Investigation and Recommendations**

A minimum of one borehole shall be advanced at each end of tunnel crossing. The boreholes shall be located outside but within 2 m of the tunnel's excavated footprint.

Spacing between the boreholes shall not exceed 50 m. In case of larger spacing between the boreholes, additional boreholes shall be advanced except where significant traffic disruptions might occur and where consistent conditions are evident.

Boreholes shall be advanced to 3 tunnel diameters (excavated diameters) below invert. If bedrock is encountered earlier, the borehole shall advance to at least 3 m below the invert of tunnel into the bedrock.

The investigations, if required, shall be supplemented with additional and deeper boreholes to verify consistent conditions and existence of boulders within critical foundation zones.

Sampling and testing, consisting of Standard Penetration Test, thin wall tube sample, rock cores, and MTO Field Vane Test where appropriate, shall be conducted to develop a comprehensive subsurface model. Semi-continuous sampling at 0.75m (2.5ft) intervals is required within overburden; whereas, sampling interval of 1.5m (5.0ft) is required below the tunnel invert.

Where encountered, the bedrock-soil interface shall be determined by geological definition and not the by the material properties.

All aspects of implementation of means of subsurface investigations including, but not limited to, planning, licensing, construction, maintenance, abandonment, and reporting, shall be in accordance with Ministry of the Environment Regulation 903 and its amendments (the water well regulation under the OWRA).

Boreholes and piezometer tubes shall be backfilled with a suitable bentonite/cement mixture. Test pits shall be backfilled with suitable material and either re-vegetated or otherwise protected from erosion. Temporary open holes shall be adequately covered.

Holes in roads shall be backfilled as required to prevent future settlement and acceptably patched where pavement surfaces have been damaged. Backfilling requirements shall be described in the Foundation Investigation and Design Report.

Where encountered, artesian groundwater conditions shall be sealed. Details of the artesian condition and the sealing operation shall be included in the Foundation Investigation Report.

Fieldwork shall be carried out in accordance with the Occupational Health and Safety Act.

Traffic protection in accordance with MTO requirements shall be provided during the course of any field investigations. However, where significant traffic disruptions might occur, boreholes may be relocated or numbers reduced with MTO's approval.

The locations and ground surface elevations of all boreholes, test pits and soundings shall be surveyed and referred to fixed reference points and data. Locations are to be identified by co-ordinates (Northing and Easting). The vertical accuracy of survey readings shall be within 0.1m; whereas, horizontal accuracy shall be within 0.5m.

#### **Minimum Laboratory Testing Requirements:**

Laboratory testing shall consist of routine testing of 25% of samples. One routine lab test is defined as natural water content plus Atterberg Limit plus grain size distribution tests. Complex laboratory testing is defined by all other tests including compressive strength, shear strength, consolidation, permeability and triaxial testing. Laboratory testing requirements shall be supplemented with additional routine and complex tests if required to verify strata boundaries and properties and behaviour of critical subsurface zones.

#### **Borehole Log Preparation and Foundation Drawing:**

Borehole log sheets, figures and drawings shall be prepared in accordance with MTO standards. The Foundation Drawing shall consist of a plan showing the locations of all borings, test pits and soundings and various stratigraphical longitudinal profiles and stratigraphical cross-sections at each tunnel structure foundation element and groundwater levels.

#### **Minimum Requirements for the Foundation Investigation and Design Report:**

A Foundation Investigation and Design Report shall consist of the factual subsurface information (including the field and laboratory test information) and the recommendations required for foundation design.

The report shall be signed and sealed by two professional engineers, registered with the Professional Engineers of Ontario, representing the consulting firm; one of them shall be the firm's designated principal contact for MTO's Foundations Engineering projects.

- The Foundation Investigation component of the report shall contain:
- Site Description - including topography, vegetation, drainage, existing land use, and structures.
- Investigation Procedures - including site investigation and lab testing procedures.
- Description of Subsurface Conditions - including soil, boulders, rock and groundwater conditions.
- Miscellaneous Section - that identifies the name of the drilling company, the laboratory where testing was performed, the persons who carried out the field supervision, and those who wrote and reviewed the report.

The Foundation Design component of the report shall present discussion and recommendations for design. The consultant shall analyse field data and test results and make comprehensive and practical recommendations pertaining to temporary, interim and permanent conditions at the Project.

The consultant shall identify and evaluate all reasonable and appropriate alternatives for the proposed tunnel crossing. Alternatives may include, but not limited to, jack & bore, pipe jacking using TBM, pipe ramming, micro-tunnelling (if economically feasible), utility tunnelling using TBM (two pass system), Horizontal Directional Drilling (HDD) and cut and cover methods.

The consultant shall identify and present overview assessments of the advantages, disadvantages, costs and risks/consequences of alternative tunnelling methods in a table. The report should conclude a preferred alternative from foundation engineering and cost effectiveness perspective.

In the development and design of the preferred alternative, the Consultant shall, as applicable, address:

- impacts on the land use and property, traffic and transportation, and environment,
- length and diameter constraints
- control of face stability
- capability of boulder excavation
- evaluation of temporary and permanent support
- alignment control
- estimated settlements and heave and management of these deformations
- special access and egress requirements for TBM's and other similar equipment such as those used for the Jack & Bore method including recommendations for vertical shafts and jacking pits;
- shored and un-shored alternatives for open-cut excavation;
- groundwater control & dewatering;
- the long-term stability of the tunnel;

- relative costs; and
- traffic management and contractor access for each alternative.

If borehole logs available from previous projects are included to meet the requirements of field investigations then the accuracy of subsurface information from these boreholes remains the responsibility of consultant except in situations where MTO specify the use of previous boreholes. Borehole logs from previous studies that are appended to the report shall be reformatted to meet the MTO's requirements.

The final foundation recommendations shall detail the geometric, material and strength properties of the new tunnel crossing plus the liner, bedding and backfill requirements, and slope and embankment restoration requirements. The invert elevation should be assessed in view of the subsurface conditions and the anticipated open face stability control.

The consultant is responsible for developing contract documents sufficient to implement the design. This typically includes:

- Contract specifications for materials and specialized construction activities, and
- Recommendations for methods of overcoming anticipated construction problems, in particular, those relating to dewatering, boulder excavation, alignment control and the stability of excavations and embankments.

The consultant shall develop a detailed instrumentation and monitoring program that meets the requirements of these guidelines. (see Appendix for typical settlement monitoring guidelines).

The consultant is responsible for preparing Traffic Control Plans and to obtain approvals and an Encroachment Permit from the Ministry, which are required for lane closures necessary to install the settlement monitoring points.

The tunnelling consultant shall ensure that the foundations engineering component of the project is adequately reflected in the design drawings, specifications and related contract documents.

Written confirmation is required from the Proponent and the tunnelling consultant that the design package submitted to MTO have been reviewed by the tunnelling consultant and that all recommendations have been satisfactorily incorporated in the contract package.

## **APPENDIX: SETTLEMENT MONITORING GUIDELINES - TUNNELING**

**The purpose of settlement monitoring is to prevent damage to existing utilities and highway structures along the tunnel alignment. Ground settlement include settlement due to lost ground and dewatering/drainage.**

### **Instrumentation Arrays**

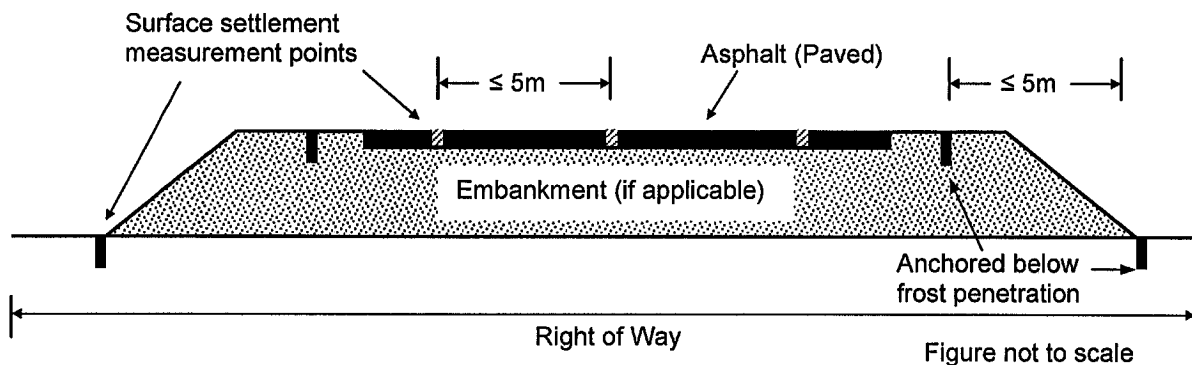
All measurement points shall be installed and surveyed before the start of excavation to establish benchmarks/baseline.

#### **Surface Monitoring Points**

Surface monitoring points will be installed to cover the whole length of the tunnel with in the right of way under the jurisdiction of MTO (Figure 1).

Surface monitoring points will be located at not greater than 5m intervals along the tunnel alignment. The surface monitoring will be identified using paint marks on the pavement. Surface monitoring points installed on the unpaved right of way shall be founded below frost penetration depths. The interval and/or marking of the points should be changed with MTO's approval where traffic disruptions might occur.

The final instrumentation plan should be finalised when Contractor's proposed construction method is available.



**Figure 1:** Typical configuration of surface settlement monitoring points along the tunnel alignment.

## **Condition Survey**

A condition survey for the pavement will be carried out prior to commencement of construction and documented for the purpose of requirement of restoration. The condition survey shall document visible flaws such as cracks, distortions and deviations, heaves, and depressions. This surface survey will be completed during the installation of the monitors and again once the tunnel has been completed.

## **Reading Frequency**

An average of at least two readings shall be taken to establish the initial conditions.

The reading and collection of data from the surface monitoring points shall be read and recorded by the Contractor during the construction period and after construction for period of at least 2 weeks provided that further settlement has stopped.

A minimum of three (3) sets of reading be taken daily, provided that movements are within anticipated limits. Otherwise, the frequencies should increase according to a pre-planned interval.

Monitoring of movements is required during work stoppages, such as during non-operation period (off-shifts) or weekends. A minimum of three (3) sets of readings should be taken daily.

Measurements of the monitoring points shall be reported promptly to MTO for review.

## **Data Collection and Data Transfer**

A procedure is required to be established in consultation with MTO so that the monitoring data and the interpreted data will reach all parties as soon as necessary. The contract administrator/consultant and the Contractor should interpret monitoring data as needed for the purpose of on-going construction. The Foundation Engineer should be contacted for technical support to the prime Consultant in the interpretation of ground movements and review of the Contractor's response when Review and Alert Levels are reached.

## **Criteria for Assessment**

The acceptable surface settlement (or heave) will be according to criteria as specified below.

**Baseline Reading** – A baseline reading of the instrumentation shall be taken prior to commencement of the work. An average of at least two initial readings shall be recorded as baseline reading.

Review Level – A maximum value of 10 mm relative to the baseline readings is suggested for this project. If this level is reached, the method, rate or sequence of construction, or ground stabilization measures should be reviewed or modified to mitigate further ground displacements.

Alert Level – A maximum value of 15mm relative to the baseline readings is suggested for this project. If this level is reached, the Contractor shall cease construction operations and to execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic.

### **Review of Contractor's Proposed Method**

MTO, the Proponent's prime consultant and Foundation Engineer should review the Contractor's proposed method of construction. The proposed method should include a description of the potential loss of ground, and calculation of the maximum settlement in relation to the Contractor's procedure and equipment, alternative/remedial measures when review level of measurement is reached; and contingency/remedial measures when alert level of measurement is reached.

### **Contractor's Responsibility For Restoration and Warranty Provision**

In addition to the monitoring program to assess the adequacy of the construction method to control potential ground movements and groundwater, the Contractor is responsible for reinstatement (such as surface paving) should movements or other surface distress occur, and provide a reasonable warranty period acceptable to MTO. Remedial measures shall be approved by MTO; however, MTO maintains the right to perform the maintenance at the proponent's expense.

### **Construction Monitoring**

The Proponent shall retain a qualified Geotechnical Consultant to supervise the installation of surface settlement points on site and to provide direction, technical input and field inspection on this project.