THURBER ENGINEERING LTD.

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

G.W.P. No. 6910-12-00, W.P. No. 6911-12-00, SITE No. 48C-186/C

GEOCRES Number: 52H-40

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 West 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 West, Highway 11, Unsurveyed Territory, Thunder Bay District”, prepared by DST Consulting Engineers Inc. (DST), dated March 17, 2015; Geocres No. 52H-26. 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 30.9 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 McKirdy 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 33.3 m long, 4.0 m span by 2.44 m high, concrete rigid frame, open footing culvert, with a height of fill of 5 m. An Ontario Structure Inspection Manual (OSIM) report prepared in 2014 notes the presence of multiple medium to wide cracks and other deterioration, but that the structure was considered to be in overall good condition. In 2004, repairs were made to spalled concrete at the inlet and outlet of the culvert.

The grade level of Highway 11 at the existing culvert is an approximate Elevation of 263.6 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 259 m at McKirdy 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 gravel and sand, 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 7 to 8, 2016, and consisted of drilling and sampling two (2) boreholes, designated as Boreholes 16-01 and 16-02. Borehole 16-01 was located near the culvert inlet and Borehole 16-02 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 track-mounted CME 55 drill rig was used to advance Borehole 16-01 using hollow stem augers, and a portable tripod drill rig was used to advance Borehole 16-02 using NW casing and wash boring techniques. Both drill rigs were supplied and operated by RPM Drilling Inc. of Thunder Bay, Ontario. The boreholes were advanced to depths of 14.3 m and 5.0 m respectively. Borehole 16-02 was extended beyond 5.0 m depth by conducting a Dynamic Cone Penetration Test (DCPT) to a depth of 5.9 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 16-01. 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

Borehole Number	Borehole Depth / Base Elevation (m)	Piezometer Tip Depth / Elevation (m)	Completion Details
16-01	14.3 / 243.3	13.7 / 243.9	Filter sand to 11.9 m, bentonite holeplug to 11.0 m, bentonite holeplug and cuttings to ground surface.
16-02	5.9 / 251.5	None installed	Bentonite holeplug from 5.9 m 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 14.3 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	263.5
BH2	99.6	263.3
BH3	99.6	263.3
BH4	100.1	263.7

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 with varying amounts of gravel and silt. Peat and silty sand were also noted at the locations where there was no fill. Descriptions of the individual strata are presented below.

5.1 Asphalt

Boreholes BH1 to BH4 were drilled through the existing asphalt pavement on Highway 11. The asphalt thickness measured in the boreholes ranged from 40 to 200 mm.

5.2 Fill

Underlying the asphalt, a 100 mm thick layer of granular fill consisting of sand and crushed gravel was encountered in Boreholes BH1 to BH4.

A sand embankment fill containing trace gravel and trace to some silt was encountered below the granular fill in Boreholes BH1 to BH4. The sand fill ranged in thickness from 5.9 to 7.4 m, and extended to depths from 6.1 to 7.6 m (Elev. 255.9 to 257.2 m). SPT ‘N’ values within the sand fill ranged from 2 to 30 blows per 0.3 m penetration, indicating a very loose to compact relative density.

The measured moisture content of the fill generally ranged from 4% to 17%, with the exception of one sample in BH1, where the presence of organic material in the fill resulted in a moisture content of 48%. 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 29
Sand	61 to 88
Silt and Clay	8 to 28

5.3 Peat

A layer of peat with some rootlets and occasional wood fibres was encountered at the ground surface in Borehole 16-02, which was drilled near the culvert outlet. The peat extended to a depth of 1.5 m (Elev. 255.9 m). SPT ‘N’ values of 3 and 10 blows per 0.3 m penetration were recorded in the peat, indicating a stiff to soft consistency. Moisture contents of 86% and 234% were measured in the peat.

5.4 Silty Sand

A deposit of silty sand with occasional rootlets was encountered at the ground surface in Borehole 16-01, which extended to a depth of 0.7 m (Elevation 256.9 m). The deposit was very loose, based on an SPT ‘N’ value of 2 blows per 0.3 m of penetration. A moisture content of 48% was measured on a sample of the silty sand.

5.5 Sand

A native deposit of sand was encountered below the embankment fill, peat and silty sand layers in all of the boreholes at the site. The boreholes were each terminated in the sand at depths ranging from 5.0 to 14.3 m (Elev. 243.3 to 252.4 m). A Dynamic Cone Penetration Test was conducted at the base of Borehole 16-02, where cone refusal of greater than 100 blows per 0.3 m penetration was encountered at a depth of 5.9 m (Elev. 251.5 m). The sand was grey in colour and contained trace to some gravel and trace to some silt.

SPT ‘N’ values within the sand generally ranged from 5 to 54 blows per 0.3 m penetration, indicating a loose to dense relative density, with occasional very loose (3 blows per 0.3 m penetration) and very dense (greater than 50 blows per 0.3 m penetration) zones. The measured moisture content of the sand ranged from 3% to 42%. 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 16
Sand	72 to 96
Silt and Clay	4 to 25

5.6 Groundwater Conditions

Groundwater conditions were observed during drilling operations and groundwater levels were measured in the open boreholes and in the 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	
16-01	June 8, 2016 June 9, 2016 June 10, 2016 June 11, 2016 June 12, 2016	0.0 0.0 0.0 0.1 0.1	257.6 257.6 257.6 257.5 257.5	Standpipe piezometer
16-02	June 8, 2016	0.0	257.4	Open borehole
BH1	October 14, 2014	6.1	257.4	Reported by DST
BH2	October 14, 2014	6.1	257.2	Reported by DST
BH3	October 14, 2014	6.1	257.2	Reported by DST
BH4	October 14, 2014	6.1	257.6	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 257.38 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 16-01, 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	
			16-01, SS#2, 2.5’-4.5’	Shamrock Lake West
			(Sand)	(Creek Water)
Sulphide	%	mg/L	0.02	<0.006
Chloride	µg/g	mg/L	49	1.3
Sulphate	µg/g	mg/L	61	1.6
pH	No unit	No unit	7.28 to 7.82	7.44

Parameter	Units (Soil)	Units (Water)	Test Results	
			16-01, SS#2, 2.5’-4.5’	Shamrock Lake West
			(Sand)	(Creek Water)
Electrical Conductivity	µS/cm	µS/cm	118	87
Resistivity	Ohms.cm	MOhms.cm	8500	11500
Redox Potential	mV	mV	284	206

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.

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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 West 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-491880-11-1, titled “Crossing at Shamrock Lake West 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 4.0 m, height of 2.44 m, and a total length of 33.3 m. The MTO survey plan shows the top of obvert at approximate Elevation 258.7 m at the inlet and 258.2 m at the outlet. The culvert invert is shown at approximate Elevation 256.8 m at the inlet and 256.4 m at the outlet. The finished road grade at the culvert location is shown at approximate Elev. 263.6 m, which indicates approximately 5 m of fill above the culvert. Small corrugated steel pipe (CSP) drains (approximately 300 mm diameter) are located in the highway embankment above the inlet and outlet of the concrete culvert.

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

9.1 Culvert Alternatives

This section presents discussions on available types of replacement culverts and foundation alternatives, and provides recommendations on preferred foundation options.

Several common culvert types that may be considered for the culvert replacement at this site are listed below:

- Concrete box (closed) culvert composed of pre-cast segments
- Concrete pipe or Corrugated steel pipe (CSP)
- Concrete, open footing culvert

A comparison of the culvert types and foundation alternatives based on their respective advantages and disadvantages is included in Appendix F. From a foundations and constructability perspective, use of a pre-cast box culvert, concrete pipe or CSP are preferred over the open footing option, based on the following considerations:

- Pre-cast box culvert or pipe culvert would require shallower depth of excavation compared with the open footing culvert;
- Pre-cast concrete box or pipe segments can often be installed more expeditiously than cast in place open footing culvert, resulting in shorter durations for dewatering and construction;

- A segmental box or pipe structure can accommodate some potential differential settlement along the culvert axis.

The open footing culvert is not recommended at this site due to the following concerns:

- Low geotechnical capacities in the shallow subgrade soils. The foundation soils consist of loose fine to medium sands under the water table and these soils are prone to boiling and disturbance if dewatering is not effective.
- Need for deeper excavation to reach competent founding level; the excavation base will be well below the river water level and will require significant dewatering effort.

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. Additional drilling to greater depths may also be required to confirm sheet pile design if this type of culvert were to be considered. Therefore, recommendations for this type of culvert are not included in this report.

Recommendations for the design and installation of a concrete box, concrete pipe or CSP culvert are presented below.

9.2 Foundation Design for Culverts

It is anticipated that the invert level of the replacement culvert will be similar to the invert of the existing culvert. There is approximately 5 m of fill above the existing culvert. Foundation design aspects for the replacement culvert includes subgrade conditions and preparation, geotechnical capacities, settlement of founding soils, lateral earth pressures, roadway protection system design, groundwater control, staged construction, and restoration of the roadway embankment.

9.2.1 Concrete Box Culvert

If the replacement 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 units 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 ranges from 256.4 to 256.8 m. Therefore, the underside of the bedding layer should be placed on the native sand deposit at or below an approximate elevation of 256 m. The native soils at that level consist of predominantly loose sand, with the exception of peat at 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. 256 m on the competent native sand subgrade:

- Factored Geotechnical Resistance at ULS of 300 kPa
- Geotechnical Resistance at SLS (less than 25 mm settlement) of 200 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.

9.2.2 Concrete Pipe or Corrugated Steel Pipe Culvert

Replacement of the culvert with a concrete pipe or CSP on the same alignment may be considered for this site. In order to accommodate the hydraulic requirements, multiple pipes may be required. It is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading.

If this alternative is selected, the concrete pipes or CSPs should be placed on a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A or Granular B Type II requirements as per OPSD 802.034 or 802.010. The bedding material should be placed on the prepared subgrade as soon as practical, following its inspection and approval. The subgrade preparation must be carried out in the dry. Construction equipment must not be allowed to travel on the bedding or the prepared subgrade, which must be protected from disturbance during construction.

The underside of the bedding layer should be placed at or below Elev. 256.0, which corresponds to loose sand subgrade.

9.2.3 Frost Cover

The depth of frost penetration at this site is approximately 2.4 m. The pipe and box culvert options do not require frost cover/protection.

Frost treatment/taper for a culvert should be in accordance with OPSD 803.031 for a pipe culvert and with OPSD 803.010 for a box culvert.

9.2.4 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 granular material compacted as per OPSS.PROV 501. The peat at the outlet of the culvert must be removed to expose the underlying native sand at or below Elev. 256 m.

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.

9.2.5 Settlement

It is anticipated that the replacement 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.

9.3 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.

10. 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 at this site are classified as Type 3 soils above the water level and Type 4 soils below the water level. 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 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 sand subgrade is relatively permeable, and seepage should be anticipated from the embankment fill and the foundation soils. Depending on the time of construction, a combination of cofferdam enclosures and creek diversion along with pumping from filtered sumps within an 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. Suggesting wording for an NSSP in this regard is included in Appendix G.

11. 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 and 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 200 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)
γ = 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 11.1 below.

Table 11.1 – Lateral Earth Pressure Coefficients (K)

Loading Condition	OPSS Granular A or Granular B Type II $\phi = 35°$; $\gamma = 22.8$ kN/m^3		OPSS Granular B Type I (modified) $\phi = 32°$; $\gamma = 21.2$ kN/m^3		Existing Fill $\phi = 30°$; $\gamma = 20$ 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.

12. 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 compact 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.

13. EMBANKMENT RESTORATION

The existing Highway 11 embankment is approximately 5 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 compact to dense sand and any settlements in these soils should be completed by the end of construction. 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.

14. 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.

15. 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 following parameters may apply for design of the temporary roadway protection system with horizontal backfill.

γ = 21 kN/m^3 - Bulk unit weight of fill and native soils
γ_w = 10 kN/m^3 - Submerged unit weight of fill
K_a = 0.33 - Active earth pressure coefficient in fill or native sand
K_p = 3.0 - Passive earth pressure coefficient in fill or 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.

16. CORROSION AND SULPHATE ATTACK POTENTIAL

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

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

17. CONSTRUCTION CONCERNS

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

- A suitable dewatering / unwatering system must be employed to enable culvert construction in the dry and prevent base boiling, sloughing and instability of the excavation walls.
- The water level in the river may fluctuate and be at higher elevation at the time of construction than indicated in the report.
- Cobbles or other buried obstructions may be encountered during excavation in the existing embankment fill and may interfere with installation of the temporary roadway protection system.
- The Contractor’s selection of construction equipment and methodology should include assessment of the capability of the existing embankment to support the proposed construction equipment and any temporary structures or fill (i.e., as a pad for crane support). Site conditions may limit the type of equipment suitable for use during construction. The design and safety of any temporary works is the responsibility of the Contractor.

18. 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

Thurber Engineering Ltd.

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Aug 25/16
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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(1) '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

C_{pen} 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			

Ministry of Transportation
Ontario

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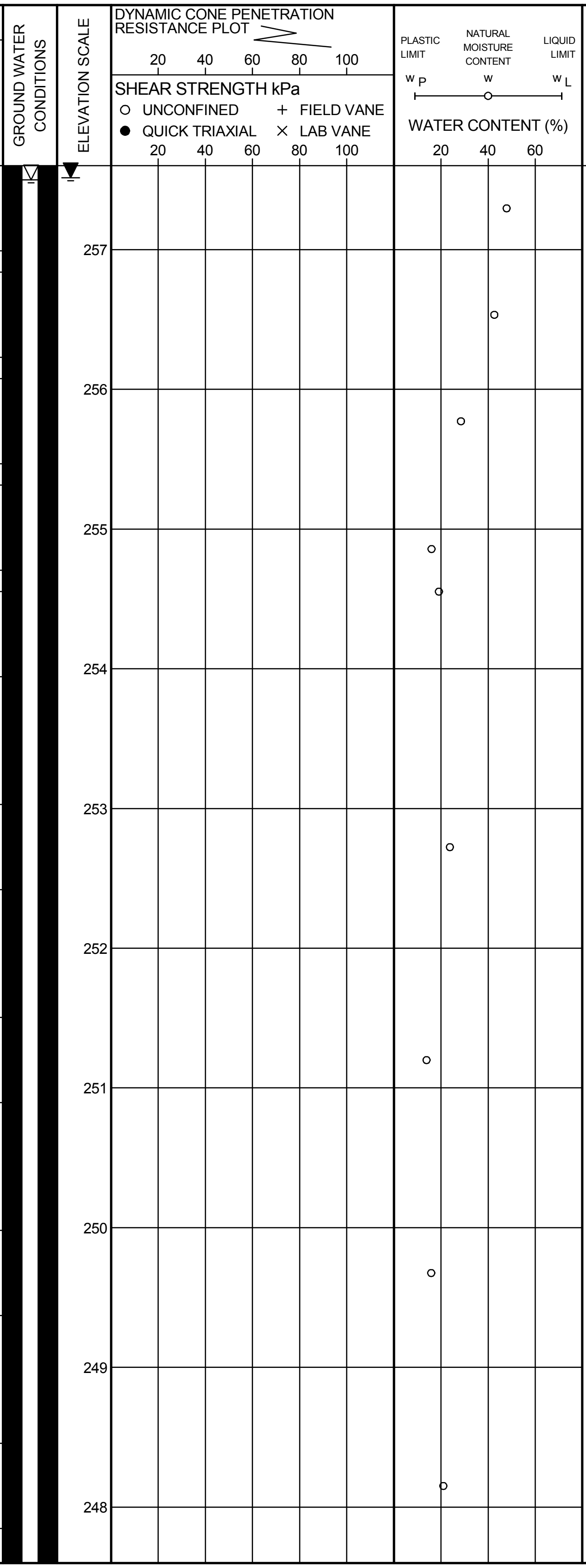
RECORD OF BOREHOLE No 16-01

1 OF 2

METRIC

W.P.	6911-12-00	LOCATION	Shamrock Lake West Culvert N 5 458 583.0 E 222 042.0	ORIGINATED BY	GA
HWY	11	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.06.07 - 2016.06.07	CHECKED BY	MEF

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
257.6	GROUND SURFACE							
0.0	Silty **SAND**, occasional rootlets, organic odour Very Loose Brown Wet	1	SS	2				
256.9 0.7	**SAND**, some gravel, trace silt, occasional wood fibres to 2.1m Very Loose to Compact Brown Wet	2	SS	3				
		3	SS	7				
	becoming Grey	4	SS	11	16	76	8 (SI+CL)	
254.6 3.0	**SAND**, trace silt Compact Grey Wet	5	SS	17				
		6	SS	14				
		7	SS	23	0	96	4 (SI+CL)	
		8	SS	16				
		9	SS	19	0	93	7 (SI+CL)	



UNIT WEIGHT γ kN/m3

Continued Next Page

+3, ×3: Numbers refer to Sensitivity

20 15 5 10 (%) STRAIN AT FAILURE

ONTMT4S 13639-MTO.GPJ 2015TEMPLATE(MTO).GDT 7/13/16

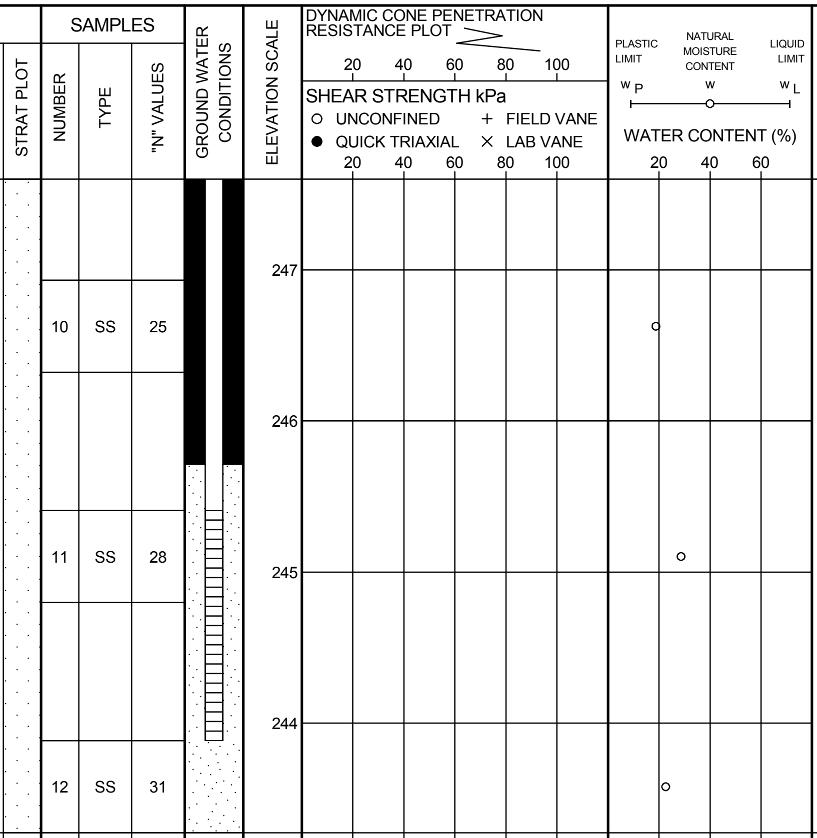
Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 16-01

2 OF 2 **METRIC**

W.P. 6911-12-00
LOCATION Shamrock Lake West Culvert N 5 458 583.0 E 222 042.0
ORIGINATED BY GA
HWY 11
BOREHOLE TYPE Hollow Stem Augers
COMPILED BY AN
DATUM Geodetic
DATE 2016.06.07 - 2016.06.07
CHECKED BY MEF



ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	UNIT WEIGHT γ kN/m 3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page					
		10	SS	25		
		11	SS	28		
243.3	becoming Dense	12	SS	31		1 94 5 (SI+CL)
14.3	END OF BOREHOLE AT 14.3m. BOREHOLE OPEN TO 14.3m AND WATER LEVEL AT 0.1m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.					

WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
2016.06.08	0.0	257.6
2016.06.09	0.0	257.6
2016.06.10	0.0	257.6
2016.06.11	0.1	257.5
2016.06.12	0.1	257.5
2016.06.12	Decommissioned	

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

$\overset{20}{15 \oplus 5}\ _{10}$ (%) STRAIN AT FAILURE

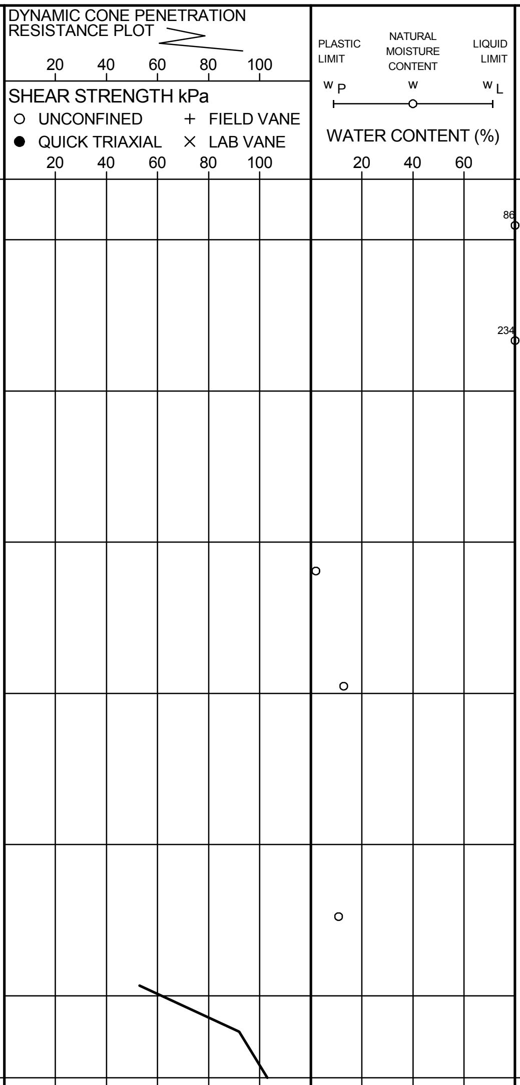
RECORD OF BOREHOLE No 16-02

1 OF 1

METRIC

W.P.	6911-12-00	LOCATION	Shamrock Lake West Culvert N 5 458 612.0 E 222 016.8	ORIGINATED BY	GA
HWY	11	BOREHOLE TYPE	Tripod/NW Casing/Dynamic Cone Penetration Test	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.06.07 - 2016.06.08	CHECKED BY	MEF

ELEV / DEPTH	SOIL PROFILE: DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
257.4	GROUND SURFACE								
0.0	**PEAT**, some rootlets, occasional wood fibres Stiff to Soft Brown Wet		1	SS	10		257		
			2	SS	3				
255.9 1.5	**SAND**, coarse grained, trace to some gravel, trace silt Compact Grey Wet		3	SS	20		256		
			4	SS	20		255		
			5	SS	24		254		
							253		
	becoming Very Dense		6	SS	50/ 0.150				
252.4 5.0	End of sampling at 5.0m and start DCPT						252		
251.5 5.9	END OF BOREHOLE AT 5.9m UPON DCPT REFUSAL. BOREHOLE OPEN AND WATER LEVEL AT GROUND SURFACE. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.								



+ 3, × 3: Numbers refer to Sensitivity

20
15 ⊕ 5
10
(%) STRAIN AT FAILURE

Appendix B

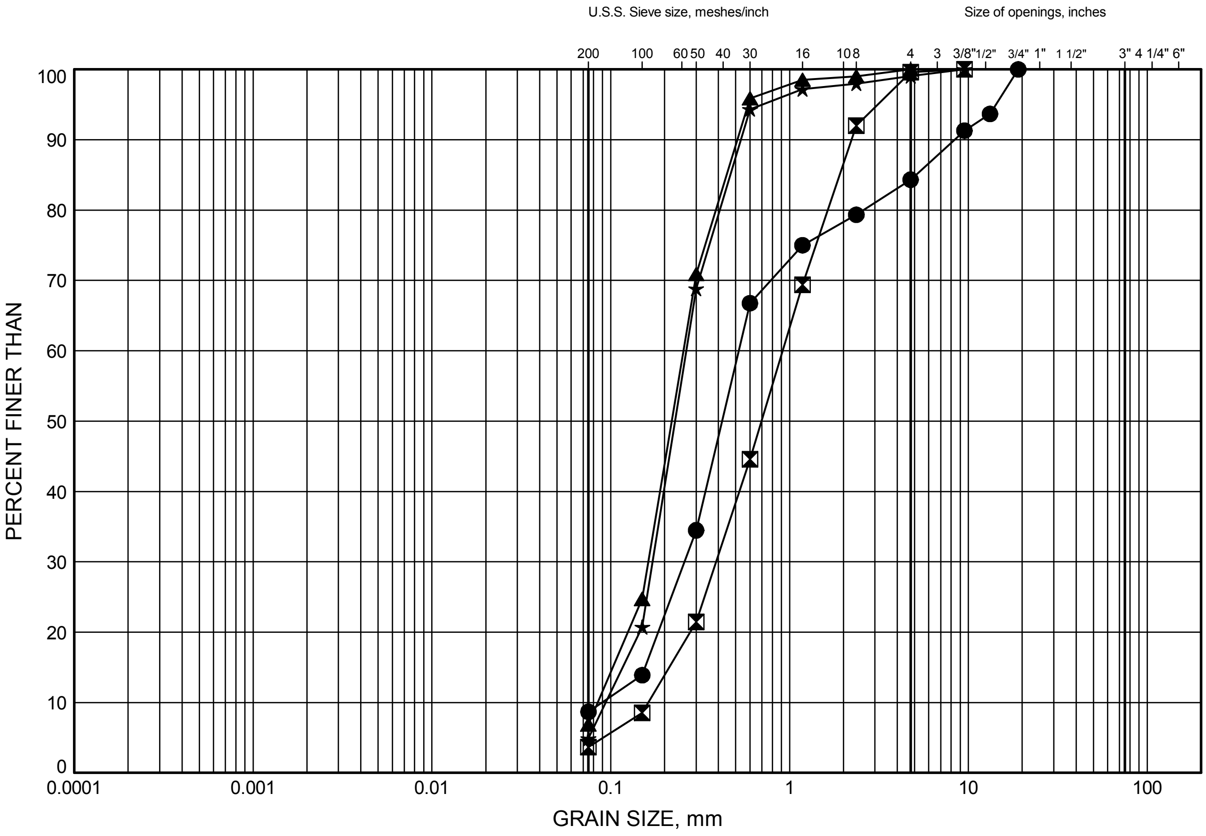
Geotechnical and Analytical Laboratory Test Results

Shamrock Lake West Culvert Replacement

GRAIN SIZE DISTRIBUTION

FIGURE B1

SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-01	2.59	255.01
☒	16-01	6.40	251.20
▲	16-01	9.45	248.15
★	16-01	14.02	243.58

Date July 2016

W.P. 6911-12-00

Prep'd MFA

Chkd. MEF

SGS Canada Inc.
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Lakefield - Ontario - KOL 2HO
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

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Approval Date	4: Analysis Approval Time	5: 16-01 SS #2, 2.5'-4.5'	6: 16-04 SS #2, 2.5'-4.5'	7: 16-05 SS #2, 2.5'-4.5'
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

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

Data reported represents the sample submitted to SGS. Reproduction of this analytical report in full or in part is prohibited without prior written approval. Please refer to SGS General Conditions of Services located at http://www.sgs.com/terms_and_conditions_service.htm. (Printed copies are available upon request.)
Test method information available upon request. “Temperature Upon Receipt” is representative of the whole shipment and may not reflect the temperature of individual samples.

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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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			

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Project : 13639

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Fax:

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

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

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Test method information available upon request. “Temperature Upon Receipt” is representative of the whole shipment and may not reflect the temperature of individual samples.

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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Test method information available upon request. “Temperature Upon Receipt” is representative of the whole shipment and may not reflect the temperature of individual samples.

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

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Test method information available upon request. “Temperature Upon Receipt” is representative of the whole shipment and may not reflect the temperature of individual samples.

Appendix C

Factual Data from 2015 DST Foundation Investigation Report

Ministry of
Transportation
Ontario

Foundation Design

RECORD OF BOREHOLE No BH1

1 OF 1

METRIC

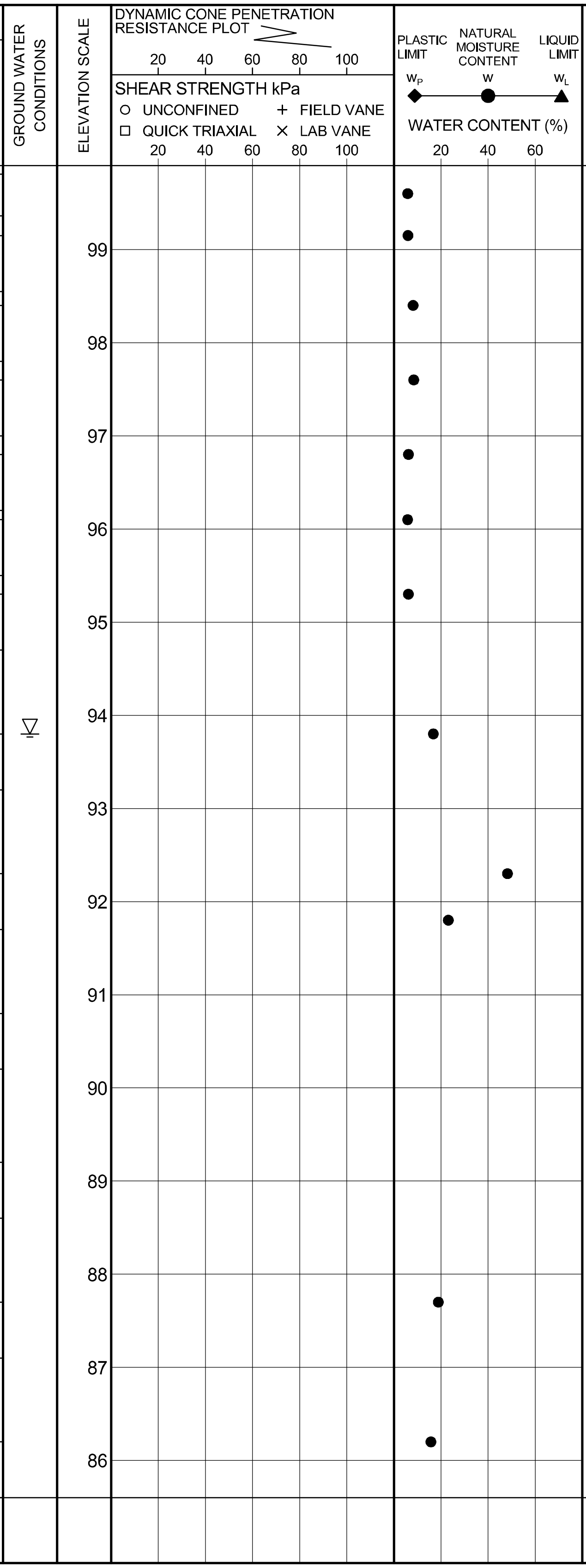
W.P.	6013-E-0021	LOCATION	Shamrock Lake West STA 13+081, 4.5 RT	ORIGINATED BY	PR
DIST	Thunder Bay HWY 11	BOREHOLE TYPE	Hollow Stem Auger 80 mm	COMPILED BY	DB
DATUM	Local	DATE	2014 10 14	CHECKED BY	DM

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
99.9	GROUND SURFACE
99.8 0.1	ASPHALT
99.7 0.2	FILL-SAND AND CRUSHED GRAVEL
	FILL-SAND-trace gravel, trace to with silt, BROWN, Very Loose to Compact
92.3	-black organics
7.6	SAND-trace to with silt, trace gravel, GREY, Loose to Dense
85.6 14.3	END OF BOREHOLE

SAMPLES

NUMBER	TYPE	"N" VALUES	GR	SA	SI CL
AS1	AS				
SS2	SS	8	17	68	(15)
SS3	SS	7			
SS4	SS	7			
SS5	SS	16	0	79	(21)
SS6	SS	8			
SS7	SS	3	1	75	(24)
SS8	SS	2			
SS9	SS	8	4	86	(10)
SS10	SS	20			
SS11	SS	9			
SS12	SS	33			
SS13	SS	26	7	73	(20)



UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)

NR = NO RECOVERY

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

$○^{3\%}$ STRAIN AT FAILURE

ON_MOT GS-TB-019794 SHAMROCK 30.8.GPJ DST_MIN.GDT 2/23/15

ENCLOSURE 1

RECORD OF BOREHOLE No BH2

1 OF 1 **METRIC**

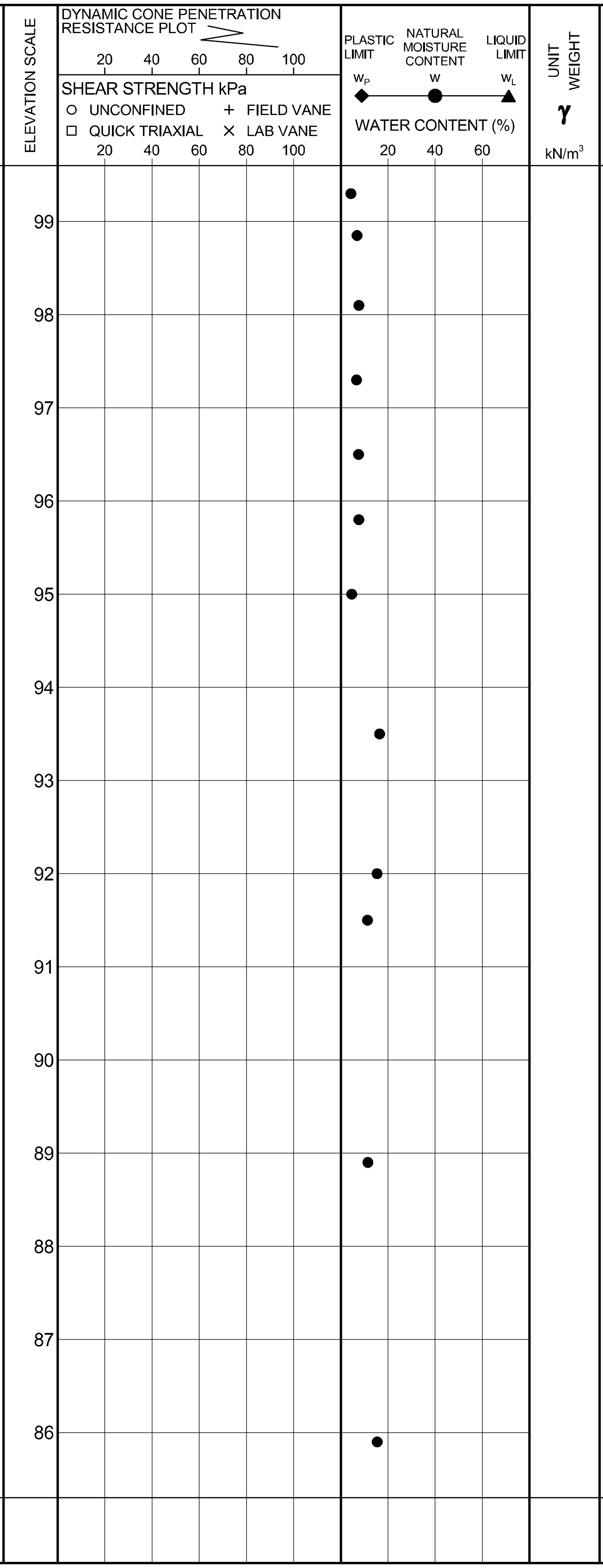
W.P. 6013-E-0021
LOCATION Shamrock Lake West STA 13+071, 4.5 RT
ORIGINATED BY PR
DIST Thunder Bay HWY 11
BOREHOLE TYPE Hollow Stem Auger 80 mm
COMPILED BY DB
DATUM Local
DATE 2014 10 14
CHECKED BY DM

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
99.6	GROUND SURFACE
99.5 0.1	ASPHALT
99.4 0.2	FILL-SAND AND CRUSHED GRAVEL
	FILL-SAND-trace gravel, trace to with silt, BROWN, Very Loose to Compact
93.5 6.1	SAND-trace to some gravel, trace to some silt, GREY, Loose to Dense
85.3 14.3	END OF BOREHOLE

SAMPLES

NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
AS1	AS			25	63	(12)	
SS2	SS	9					
SS3	SS	4					
SS4	SS	3		1	77	(22)	
SS5	SS	12					
SS6	SS	17					
SS7	SS	14					
			∇				
SS8	SS	9		4	88	(8)	
SS9	SS	44					
SS10	SS	23					
SS11	SS	25		7	81	(12)	
SS12	SS	15					
SS13	SS	20		15	79	(6)	



NR = NO RECOVERY

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

$\bigcirc^{3\%}$ STRAIN AT FAILURE

ON_MOT GS-TB-019794 SHAMROCK 30.8.GPJ DST_MIN.GDT 2/23/15

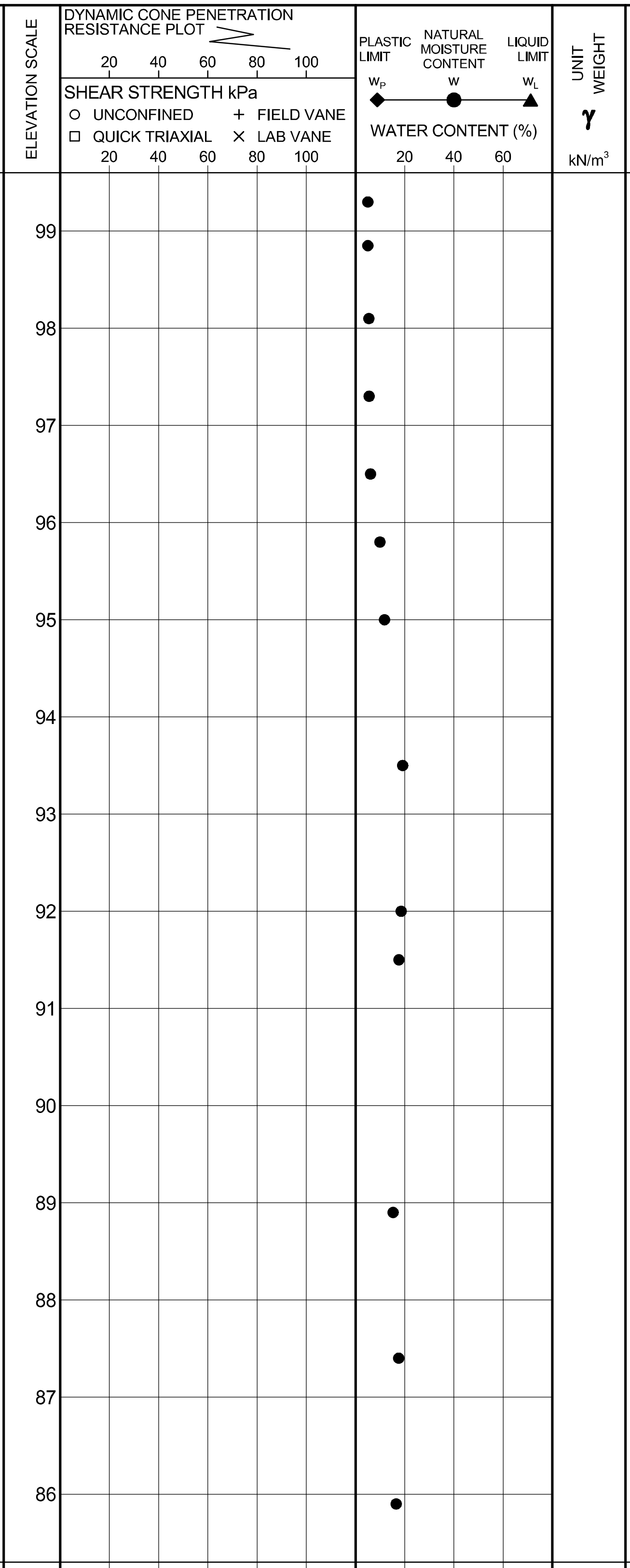
Ministry of
Transportation
Ontario

RECORD OF BOREHOLE No BH3

1 OF 1 **METRIC**

W.P. 6013-E-0021 LOCATION Shamrock Lake West STA 13+074, 4.6 LT ORIGINATED BY PR
DIST Thunder Bay HWY 11 BOREHOLE TYPE Hollow Stem Auger 80 mm COMPILED BY DB
DATUM Local DATE 2014 10 14 CHECKED BY DM

SOIL PROFILE		SAMPLES				REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	GR	SA	SI	CL
99.6	GROUND SURFACE								
99.5 0.1	ASPHALT								
99.4 0.2	FILL-SAND AND CRUSHED GRAVEL	AS1	AS						
	FILL-SAND-trace gravel, trace to some silt, BROWN, Very Loose to Compact	SS2	SS	16		29	61	(10)	
		SS3	SS	9					
		SS4	SS	7		1	85	(14)	
		SS5	SS	6					
		SS6	SS	2					
		SS7	SS	6		9	75	(16)	
93.5 6.1	SAND-trace to some gravel, trace to some silt, GREY, Loose to Compact	SS8	SS	5	▽				
		SS9	SS	9		13	78	(9)	
		SS10	SS	12					
		SS11	SS	29		4	80	(16)	
		SS12	SS	14					
		SS13	SS	9		3	87	(11)	
85.3 14.3	END OF BOREHOLE								

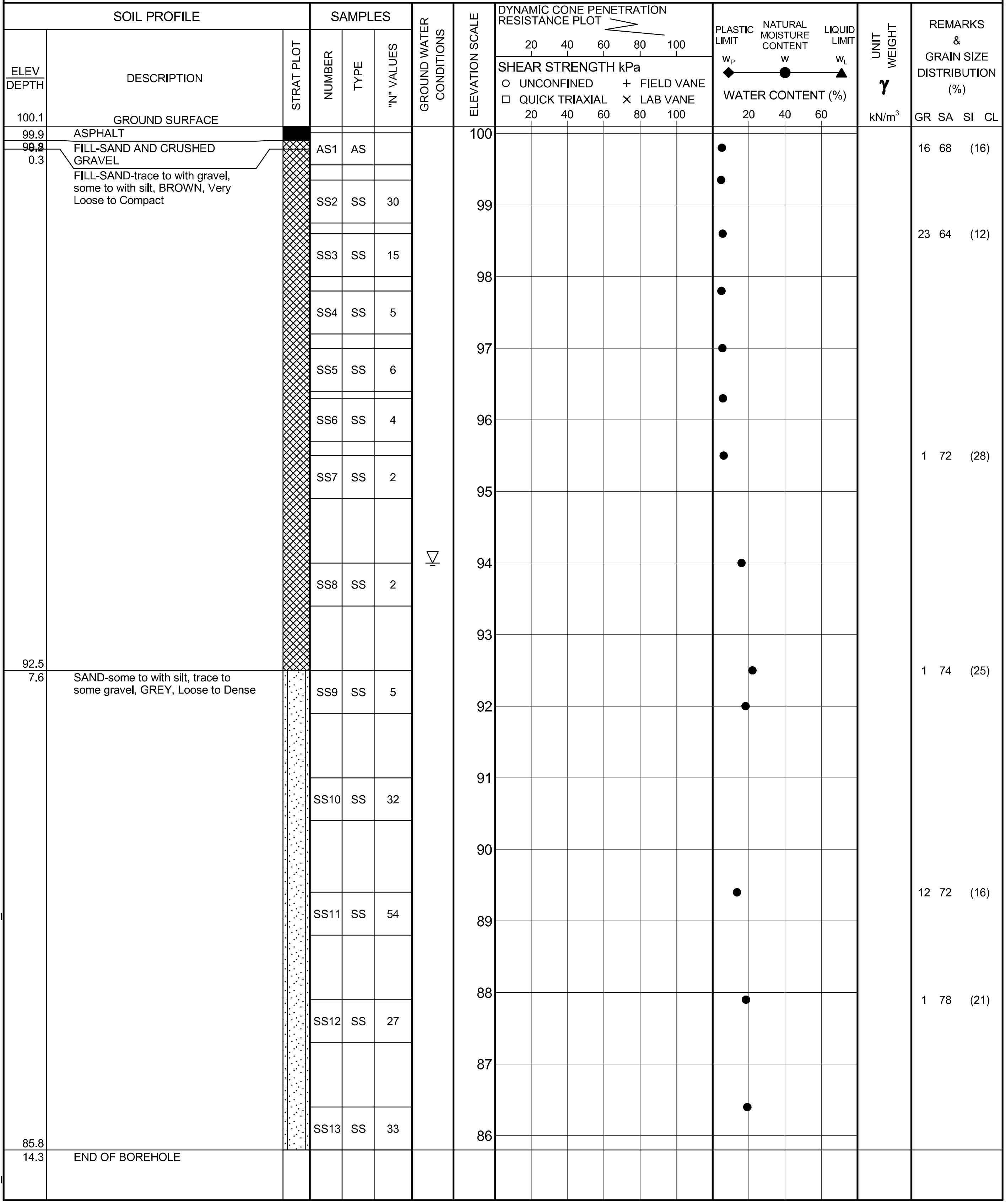


NR = NO RECOVERY $+^3, \times^3$: Numbers refer to Sensitivity $○^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No BH4

1 OF 1 **METRIC**

W.P. 6013-E-0021 LOCATION Shamrock Lake West STA 13+087, 4.6 LT ORIGINATED BY PR
DIST Thunder Bay HWY 11 BOREHOLE TYPE Hollow Stem Auger 80 mm COMPILED BY DB
DATUM Local DATE 2014 10 14 CHECKED BY DM



ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
100.1	GROUND SURFACE									
99.9	ASPHALT									
99.8 0.2 0.3	FILL-SAND AND CRUSHED GRAVEL	AS1	AS				16	68	(16)	
	FILL-SAND-trace to with gravel, some to with silt, BROWN, Very Loose to Compact	SS2	SS	30						
		SS3	SS	15			23	64	(12)	
		SS4	SS	5						
		SS5	SS	6						
		SS6	SS	4						
		SS7	SS	2			1	72	(28)	
					∇					
		SS8	SS	2						
92.5 7.6	SAND-some to with silt, trace to some gravel, GREY, Loose to Dense	SS9	SS	5			1	74	(25)	
		SS10	SS	32						
		SS11	SS	54			12	72	(16)	
		SS12	SS	27			1	78	(21)	
		SS13	SS	33						
85.8 14.3	END OF BOREHOLE									

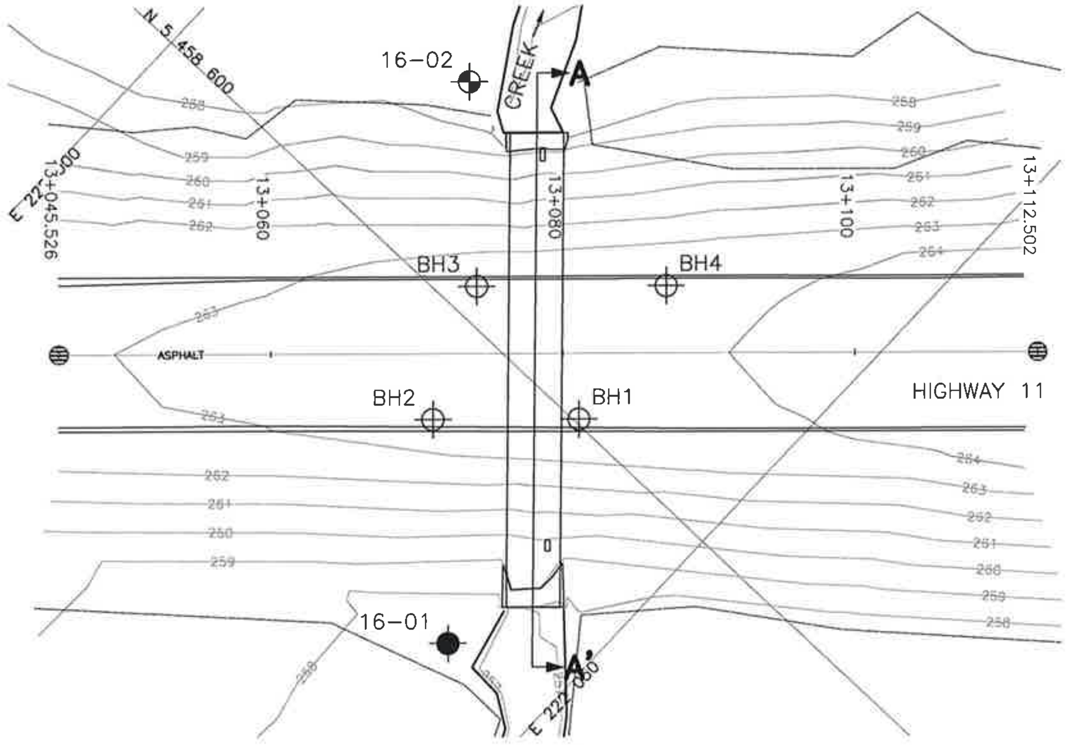
NR = NO RECOVERY $+^3, \times^3$: Numbers refer to Sensitivity $\circ^{3\%}$ STRAIN AT FAILURE

ENCLOSURE 4

Appendix D

Borehole Locations and Soil Strata Drawing

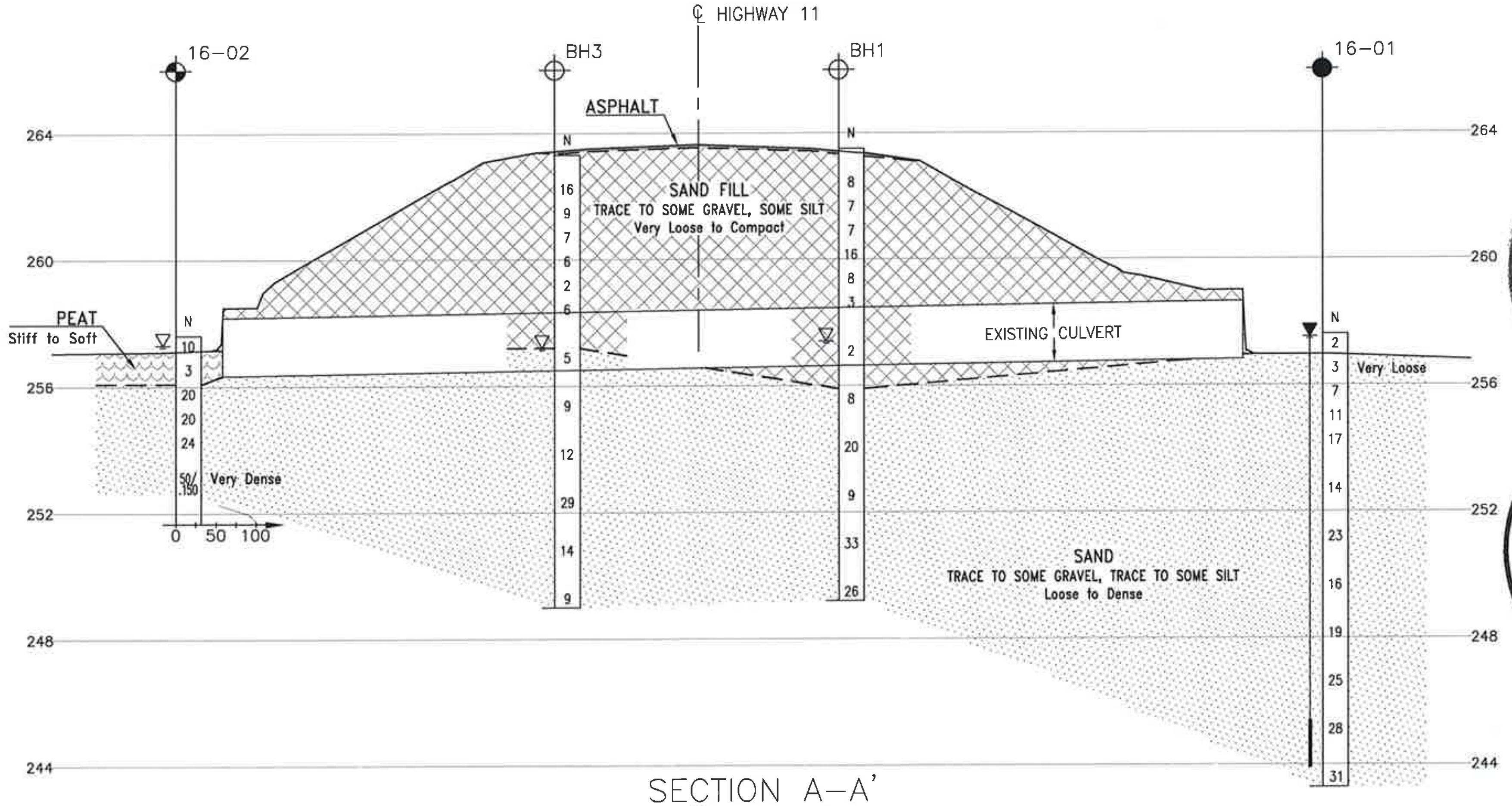
MINISTRY OF TRANSPORTATION, ONTARIO



PLAN

10 0 10 20m

SCALE 1:500



SECTION A–A'

4 0 4 8m

SCALE 1:200

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

P. K. CHATTERJI
Aug 25/16

M.E. FARRANT
100053767
Aug. 23/16

LICENSED PROFESSIONAL ENGINEER
PROVINCE OF ONTARIO

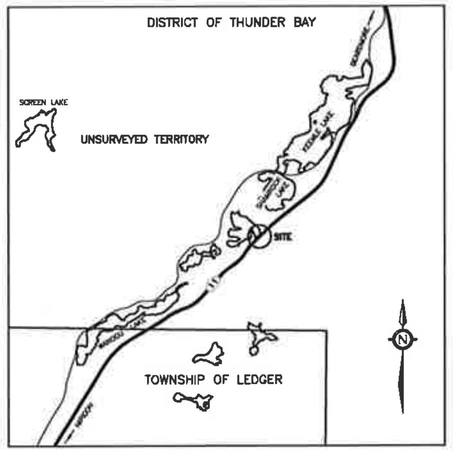
CONT No
WP No 6911–12–00

SHEET

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

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
16–01	257.6	5 458 583.0	222 042.0
16–02	257.4	5 458 612.0	222 016.8
BH1	263.5	5 458 600.3	222 038.1
BH2	263.3	5 458 593.4	222 030.8
BH3	263.3	5 458 602.1	222 026.7
BH4	263.7	5 458 611.0	222 036.2

-NOTES-

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

GEOCRES No. 52H-40

REVISIONS	DATE	BY	DESCRIPTION

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

FILENAME: H:\Drafting\13000\13639\TED–13639–PLPR–SW.dwg
PLOTDATE: 8/24/2016 2:51 PM

Appendix E

Site Photographs

Photo 1: Shamrock Lake West Culvert Inlet

Photo 2: Shamrock Lake West Culvert Outlet

Photo 3: Looking northeast along Highway 11 at Shamrock Lake West 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

Foundation Comparison

COMPARISON OF FOUNDATION ALTERNATIVES

Concrete Box Culvert	**Concrete or Corrugated Steel Pipe (CSP) Culvert**	**Concrete Open Footing Culvert**
Advantages: i. Relatively rapid installation and less disturbance to subgrade soils if pre-cast segments are used. ii. Shallower excavation depths and shorter duration for dewatering. iii. Less stringent requirement for soil geotechnical resistances as loading is spread over a larger area. iv. Segmental option can accommodate potential differential settlement along culvert axis.	Advantages: i. Ease of construction. ii. Shallower excavation depths and shorter duration for dewatering. iii. Less stringent requirement for soil geotechnical resistances iv. Segmented pipes can accommodate potential differential settlement along culvert axis v. Concrete or steel pipes may be more cost effective than concrete box or open footing culverts.	Advantages: i. Conventional construction. ii. Possibly less disturbance of creek channel / less environmental issues such as those involving spawning fish species.
Disadvantages: i. Likely more expensive than a concrete pipe or CSP culvert.	Disadvantages: i. Steel pipes may have shorter design life than concrete culverts. ii. Multiple pipes may be needed to meet hydraulic requirements.	Disadvantages: i. Requires deeper excavation to achieve higher geotechnical resistances to support strip footings. ii. Potentially more difficult dewatering requirements.
RECOMMENDED	**RECOMMENDED**	**NOT RECOMMENDED**

Appendix G

List of OPSSs and OPSDs and Suggested Wording for NSSP

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

- OPSS PROV 206
- OPSS PROV 209
- OPSS 422
- OPSS PROV 401
- 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 Wording for NSSP on Dewatering

Effective dewatering shall be designed and provided by the Contractor during structure excavation, bedding placement and backfilling to allow the work to proceed in the dry. Excavation below the creek and groundwater level may lead to instability and sloughing of the cohesionless embankment fill and the native sands. The dewatering system must be effective to maintain the water level below the final subgrade level throughout construction. The dewatering system must remain operational and effective until the culvert is installed and backfilled.