THURBER ENGINEERING LTD.

celebrating 60 YEARS

FINAL
FOUNDATION INVESTIGATION AND DESIGN REPORT
AUBREY CREEK CULVERT REPLACEMENT
HWY 642, 17.9 KM EAST OF HWY 516, DRAYTON TOWNSHIP
SITE NO.: 41S-256/C

6015-E-0033
WP 6847-14-01

Geocres No.: 52J-16

Report to:

Planmac Engineering Inc.

Location:
Latitude: 50.058493
Longitude: -91.735147

April 2017
File: 12356

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

TABLE OF CONTENTS

APPENDICES

**FOUNDATION INVESTIGATION AND DESIGN REPORT
AUBREY CREEK CULVERT REPLACEMENT
HWY 642, 17.9 KM EAST OF HWY 516, DRAYTON TOWNSHIP
SITE NO.: 41S-256/C**

6015-E-0033
Geocres No.: 52J-16

PART 1. FACTUAL INFORMATION

1 INTRODUCTION

This section of the report presents the factual findings obtained from a foundation investigation completed for the proposed replacement of the existing Aubrey Creek Culvert crossing Highway 642, approximately 17.9 km east of the Highway 516 and Highway 642 intersection in Drayton Township, District of Kenora. Thurber Engineering Limited (Thurber) carried out the current investigation as a sub-consultant to Planmac Engineering Inc. (Planmac) under Contract No. 6015-E-0033.

The purpose of this investigation was to explore the subsurface conditions at this site and, based on the data obtained, to present a borehole location plan, record of boreholes, stratigraphic profile, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions was developed of the anticipated geotechnical conditions influencing design and construction of the culvert replacement.

2 SITE DESCRIPTION

The existing culvert is located near Station 16+600 on Highway 642 in Drayton Township. The culvert consists of a steel plate corrugated steel pipe culvert (SPCSP) with approximate dimensions for diameter and length of 3.0 and 13.4 m, respectively. The flow through the culvert is from south to north. The culvert invert is at an elevation of approximately 372.5 m. At the location of the culvert, Highway 642 is a rural local undivided two-lane highway with no gravel shoulders beyond the surface treated platform. The road surface of the Highway 642 embankment is approximately 0.5 m above the top of the culvert at an elevation of 376.0 m. The embankment side slopes are at 2H:1V in general but as steep as approximately 1H:1V in the immediate vicinity of the culvert.

The terrain in the area of the culvert is generally level and consists of wide, grass covered creek banks with treed areas bordering both sides of the highway and creek. Select photographs showing the existing conditions of the culvert area are included in Appendix D for reference.

3 SITE INVESTIGATION AND FIELD TESTING

Thurber carried out the current site investigation and field testing as outlined in Section 17.8 of the proposal. The site investigation and field testing program was carried out between August 24th and October 22nd, 2016 and consisted of drilling and sampling five boreholes identified as AB16-1b and AB16-1 through AB16-4.

Prior to commencement of drilling, utility clearances were obtained in the vicinity of the borehole locations. Drilling for the on-road boreholes was carried out using a CME-750 drill rig equipped with hollow stem augers. AB16-1 was drilled with portable tri-pod equipment and AB16-1b and AB16-4 were drilled with portable tri-pod equipment from a raft. Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). Borehole AB16-1, which was advanced with the tri-pod equipment, utilized a half weight hammer for the SPT testing. A correction for the use of a half-weight hammer has been applied to the reported values. The boreholes were sampled to depths ranging from 2.9 m to 15.8 m below the existing ground surface and Borehole AB16-3 was extended to a depth of 28.3 m with a Dynamic Cone Penetration Test (DCPT). The boreholes were decommissioned following the field investigation in general accordance with MOEE requirements.

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

The approximate borehole locations are shown on the Borehole Locations and Soil Strata Drawing included in Appendix A. The coordinates and elevations of the boreholes are also provided on the drawing and the Borehole Records in Appendix B.

3.1 Laboratory Testing

The recovered soil samples were subjected to visual identification and to natural moisture content determination. Selected samples were also subjected to Atterberg Limit testing and gradation analysis (hydrometer and/or sieve). The results of these tests are summarized on the Record of Borehole sheets included in Appendix B. Surface water and soil samples were submitted for analytical testing. The laboratory results are included in Appendix C.

4 DESCRIPTION OF SUBSURFACE CONDITIONS

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

In general terms, the site stratigraphy was found to consist of pavement structure and embankment fill underlain by peat and organic material over a deposit of clay over silt and silty sand. SPT refusal or bedrock was not encountered with the sampled depth of investigation.

4.1 Embankment Fill

Granular embankment fill was observed in all holes except Borehole AB16-1b and consisted of sand with gravel and silt to silty sand and varied in thickness from 0.4 to 3.0 m (underside elevation of 371.8 m to 373.7 m). Frequent cobbles and boulders were noted in AB16-4. Refusal at 2.9 m depth was observed in AB 16-1. SPT tests carried out in the granular fill gave N-values ranging from 3 to 53 blows per 300 mm of penetration indicating a very loose to dense relative density. The measured moisture contents were recorded between 4 and 47%.

Gradation analyses were completed on three samples of the fill. The results are summarized on the Record of Borehole sheets in Appendix B and the grain size distribution curves are included in Figure C1 of Appendix C. The results of the laboratory tests are summarized as follows:

Soil Particle	Percentage (%)
Gravel	5 - 29
Sand	63 - 72
Silt & Clay	8 - 23

4.2 Peat / Organics

A layer consisting predominantly of organics such as decayed wood, rootlets and peat was encountered in Boreholes AB16-1b, AB16-2, AB16-3 and AB16-4; the layer varied in thickness from 1.5 to 2.5 m (underside elevation of 370.4 m to 371.7 m). SPT tests carried out in the peat/organics gave N-values ranging from 1 to 13 blows per 300 mm of penetration indicating a very loose to compact consistency, but typically very loose. The measured moisture contents were recorded between 35 and 189%.

4.3 Clay

The peat/organics were underlain by a native deposit of clay in Boreholes AB16-1b, AB16-2, AB16-3 and AB16-4 and varied in thickness from 1.4 to 3.3 m (underside elevation of 368.4 m to 369.2 m). It is noted that the lower 0.8 m of the clay layer in Borehole AB16-1b was classified as a silty clay.

SPT tests gave N-values typically ranging from weight of hammer to 8 blows per 300 mm of penetration. Field vane test were performed within the deposit and recorded undrained shear strengths ranging from 22 to 54 kPa indicating a soft to stiff consistency. The measured moisture content of the clay ranged from 21 to 53%.

Gradation analysis were completed on four samples of the clay. The results are summarized on the Record of Borehole sheets in Appendix B and the grain size distribution curves for these samples are included in Figures C2 of Appendix C. The results of the laboratory tests are summarized as follows:

Soil Particle	Percentage (%)
Gravel	0
Sand	0 - 5
Silt	47 - 77
Clay	18 - 50

Atterberg limit testing was carried out on four samples. The results are shown on Figure C5 in Appendix C and are summarized as follows:

Test	Percentage (%)
Liquid Limit	22 - 40
Plasticity Index	7 - 23

The clay soil ranges from low to intermediate plasticity but can generally be classified as a clay of low plasticity (CL).

4.4 Silt

A silt layer was encountered in Boreholes AB16-1b, AB16-2, AB16-3 and AB16-4 below the clay layer. The thickness of the silt layer ranged from 1.1 to 2.6 m (underside elevation of 366.0 m to 367.3 m).

SPT tests gave N-values typically ranging from weight of hammer to 11 blows per 300 mm of penetration. The measured moisture content of the silt ranged from 21 to 47%.

Gradation analysis were completed on four samples of the silt. The results are summarized on the Record of Borehole sheets in Appendix B and the grain size distribution curves for these samples are included in Figures C3 of Appendix C. The results of the laboratory tests are summarized as follows:

Soil Particle	Percentage (%)
Gravel	0
Sand	0 - 4
Silt	80 - 90
Clay	9 - 20

4.5 Sandy Silt to Silty Sand

Immediately below the silt layer in Boreholes AB16-1b, AB16-2, AB16-3 and AB16-4, a layer consisting of a mixture of silt and sand ranging from sandy silt to silty sand was found. All above listed boreholes were terminated within this layer.

SPT tests gave N-values ranging from weight of hammer to 16 blows per 300 mm of penetration. The measured moisture content of the silt ranged from 14 to 21%.

Gradation analysis were completed on five samples of the silt and sand. The results are summarized on the Record of Borehole sheets in Appendix B and the grain size distribution curves for these samples are included in Figures C4 of Appendix C. The results of the laboratory tests are summarized as follows:

Soil Particle	Percentage (%)
Gravel	0
Sand	22 - 51
Silt	45 - 75
Clay	2 - 6

4.6 Groundwater

No artesian pressures were encountered during drilling.

The water level within the creek was reported to be at elevation 373.96 m at the inlet in April 2016. It is expected that the groundwater level will largely be controlled by the water level in Aubrey Creek. It should be noted seasonal fluctuations of the groundwater level are to be expected and that the groundwater level at the time of construction may vary. In particular, the groundwater level may be at a higher elevation after periods of significant and/or prolonged precipitation events.

5 MISCELLANEOUS

The borehole locations were selected relative to existing site features and proposed foundation location. After completion of drilling, the borehole locations were surveyed by Thurber personnel relative to the existing culvert and ground surface elevations were obtained from topographic information provided by Planmac.

RPM Drilling Limited from Thunder Bay, Ontario supplied the drilling equipment and conducted the drilling, sampling and in-situ testing for the on-land field program. OGS Drilling Inc. of Almonte, Ontario supplied the raft, drilling equipment and conducted the drilling, sampling and in-situ testing for the over-water portion of the field program. The field investigation was supervised on a full time basis by Mr. Troy Mackinnon and Mr. Nicholas Weil of Thurber. Overall supervision of the investigation program was conducted by Mr. Stephen Peters, P.Eng.

Routine geotechnical laboratory testing was carried out by Thurber's laboratory in Oakville, Ontario. Analytical testing was completed by SGS Canada Inc and AGAT Laboratories on the water and soil samples respectively. Interpretation of the data and preparation of this report were carried out by Mr. Christopher Murray, E.I.T. and Dr. Fred Griffiths, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng, a Designated Principal Contact for MTO Foundation Projects.

Thurber Engineering Ltd.
Report Prepared By:

Christopher Murray, E.I.T.
Geotechnical Engineer in Training

LICENSED PROFESSIONAL ENGINEER
F. J. GRIFFITHS
April 12/17
PROVINCE OF ONTARIO

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

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
April 12/17
PROVINCE OF ONTARIO

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

FOUNDATION INVESTIGATION AND DESIGN REPORT
AUBREY CREEK CULVERT REPLACEMENT
HWY 642, 17.9 KM EAST OF HWY 516, DRAYTON TOWNSHIP
SITE NO.: 41S-256/C

6015-E-0033
Geocres No.: 52J-16

PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS

6 GENERAL

This section of the report provides an interpretation of the factual data and geotechnical recommendations for the replacement of the existing Aubrey Creek Culvert. The culvert crosses Highway 642, approximately 17.9 km east of Highway 516 in Drayton Township, District of Kenora. Geotechnical assessment and recommendations are provided to assist the design team in designing a suitable foundation for the proposed replacement culvert. The plans and profiles used for preparation of this report were provided by Planmac Engineering Inc (Planmac).

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

The existing culvert, conveying Aubrey Creek under Highway 642, is a steel plate corrugated steel pipe culvert (SPCSP) with approximate dimensions for diameter and length of 3.0 and 13.4 m, respectively. The top of the culvert is reported to be at elevation 375.52 m and 375.46 m at the inlet and outlet, respectively. The embankment fill height above the culvert is in the order of 0.5 m. The creek flows from south to north at this site.

Thurber Engineering Limited (Thurber) carried out the current investigation as a sub-consultant to Planmac under Contract No. 6015-E-0033.

6.1 Proposed Structure

A General Arrangement (GA) drawing dated November 2016 indicates that the proposed culvert replacement structure is a 3.0 m diameter corrugates steel pipe (CSP). The replacement culvert is proposed to be constructed near the same alignment as the existing culvert with invert elevations at approximately 372.4 m. Email correspondence with Planmac dated April 4, 2017 indicates that the proposed culvert length is 20.12 m and not 16.12 m as is indicated on the GA. A temporary flow passage will be required during construction and is shown on the 60% design drawings to be located some 27 m west of the existing culvert alignment.

6.2 Applicable Codes and Design Considerations

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

It is understood that the culvert structure has a consequence classification of *Typical Consequence*, in accordance with Section 6.5.1 of the CHBDC. Accordingly, a consequence factor (Ψ) of 1.0, as per Table 6.1 of the CHBDC, has been used in assessing factored geotechnical resistances. If the consequence classification changes, the geotechnical assessment will need to be reviewed and revised.

7 SEISMIC CONSIDERATIONS

7.1 Spectral and Peak Acceleration Hazard Values

The seismic hazard data for the CHBDC is based on the fifth generation seismic model developed by the Geological Survey of Canada (GSC). Seismic hazard data for this site has been obtained from the GSC's seismic hazard calculator. The data includes peak ground acceleration (PGA), peak ground velocity (PGV), and the 5% damped spectral response acceleration values (Sa(T)) for the reference ground condition (Site Class C) for a range of periods (T) and for a range of return periods including the 475-year, 975-year and 2475-year events. The GSC seismic hazard calculation data sheet for this site is presented in Appendix F.

The site coefficients used to determine the design spectral acceleration and displacement values are a function of the Site Class and the reference peak ground acceleration (PGA_{ref}).

7.2 CHBDC Seismic Site Classification

In accordance with the CHBDC, the selection of the seismic site classification is based on the soil conditions encountered in the upper 30 m of the stratigraphy. The Seismic Site Class for this culvert is a Site Class E in accordance with Table 4.1 of the CHBDC.

7.3 Seismic Liquefaction

The potential for liquefaction of the foundation soils has been assessed comparing Cyclic Stress Ratio to Cyclic Resistance Ratio generated from the SPT N-values. Using this method, the results indicate that an adequate Factor of Safety against liquefaction under earthquake loading exists for this site using the site-specific PGA value factored for Site Class E and a magnitude 6.1 earthquake event.

8 DESIGN OPTIONS

Based on the soil stratigraphy and the existing stream bed elevation, it is expected that the subgrade for the culvert replacement will be in the peat. Since a culvert that is longer than the existing will be installed and the embankment will be widened to flatten the side slopes, the peat deposit outside of the current embankment footprint will be loaded above existing stress conditions. Therefore, to reduce the potential for differential settlements, all peat encountered in the footprint of the embankment and founding area of the new culvert must be excavated and removed in accordance with OPSS 209 and replaced with compacted granular fill founded on the native undisturbed firm to stiff clay. From 1 m to more than 2 m of peat may have to be subexcavated from the culvert footprint area. Selection of the culvert type must consider the proposed construction procedures, staging requirement, geotechnical resistance available in the foundation soils, the depth to suitable bearing stratum and post-construction settlement criteria.

8.1 Culvert Type and Foundation Alternatives

Culvert types are discussed below from a geotechnical perspective and a comparison, based on their respective advantages and disadvantages, is included in Appendix E.

- Open Bottom Culvert (Box, Arch)
  Concrete, open footing culverts are not recommended for this site from a foundation engineering perspective since the available geotechnical resistance will be low, the post construction settlement would be greater than alternative options and greater dewatering efforts would be required during construction to place the foundations in the dry.
- Steel Sheet Pile Walls with Precast Concrete Slab
  A sheet pile wall supporting precast concrete slabs is not recommended at this site due to the limited lateral capacity available from the foundation soils and the depth to a suitable end bearing stratum.
- Closed Bottom Culvert
  Given the subsurface conditions, a rigid frame, close bottom (RFCB), concrete culvert is technically feasible at this site. Precast sections, rather than cast-in-place construction, can be installed expediently with less potential for disturbance of the founding soils during installation.
- Pipe Culvert (Concrete, HDPE, Steel)
  From a foundation engineering perspective, pipe culverts are considered feasible, provided that other design issues including flow capacity, hydraulic properties and durability can be satisfied.

8.2 Construction Methodology Alternatives

For the proposed culvert replacement options listed in Section 8.1, the following construction methods have been considered.

8.2.1 Trenchless Techniques

Trenchless techniques would have the advantage of minimum disruption to traffic and would avoid an excavation through the existing highway embankment. However, considering the size of the replacement culvert, the limited cover over the existing culvert and limited area for entry/exit pits, trenchless replacement is not considered suitable at this site.

8.2.2 Open Cut with Full Road Closure

Installation of a new culvert using open cut techniques with a full road closure would allow for an expedited construction schedule and reduced costs associated with requiring roadway protection and creek diversion. However, this method would induce significant traffic disruptions which makes this alternative not feasible.

8.2.3 Open Cut with Staged Temporary Widening (or Lowering)

Widening of the existing highway and/or construction of a detour embankment to accommodate a temporary traffic passage has been considered. However, placement of additional fill will cause an increase in the loading on the subgrade peat and clay soils and will induce time-dependent settlement for both the temporary detour and existing embankment. Additionally, property acquisition may be required for this option. Temporary embankment lowering is not feasible at this site due to the limited cover over the culvert.

8.2.4 Open Cut with Staged Construction and Temporary Protection System

The preferred construction option is open cut in conjunction with staged culvert replacement. This option will require roadway protection, as discussed in Section 10.2, installed along the embankment centerline to maintain a single lane of traffic along the current highway alignment.

8.3 Recommended Approach for the Culvert Replacement

From a foundation engineering perspective, replacement of the culvert with a corrugated steel pipe (CSP) culvert using open cut techniques and temporary traffic protection to maintain traffic flow is the recommended approach.

It is noted that a box culvert installed with a similar approach is also viewed as a feasible alternative. The recommended geotechnical resistance for a pre-cast box culvert installed along the existing alignment at the proposed founding elevation with a 1 to 2 m granular pad are as follows:

- Factored Geotechnical Resistance at ULS of 200 kPa
- Factored Geotechnical Resistance at SLS of 65 kPa

The factored geotechnical resistances include the following factors:

- Consequence Factor of 1.0
- Geotechnical resistance factors (CHBDC Table 6.2):
  - ϕ_{gu} = 0.5 (static analysis; typical degree of understanding)
  - ϕ_{gs} = 0.8 (static analysis; typical degree of understanding)

The bearing resistance values are for vertical concentric loading. In the case of eccentric or inclined loading, the bearing resistance must be reduced in accordance with CHBDC Clause 6.10.3 and Clause 6.10.4.

Resistance to lateral forces/sliding resistance between the precast concrete and the underlying Granular 'A' bedding (Section 9.2) should be evaluated in accordance with the CHBDC assuming an unfactored coefficient of friction of 0.45.

If a box culvert is selected it should be designed and constructed in accordance with OPSS 422 and OPSD 803.010 (with Granular A used as bedding and embedment material). The recommendations of Sections 9.2, 9.3, 9.4, 9.5, 9.6, 9.7 and 10 should all be applied.

9 FOUNDATION DESIGN RECOMMENDATIONS

The recommended replacement is a CSP which will have a diameter of approximately 3.0 m. The culvert should be designed and constructed in accordance with OPSS.PROV 421. Geotechnical foundation bearing resistance values are not required for design of CSP culverts.

9.1 Foundation Bearing Resistances

9.1.1 Wingwalls

If wingwalls are required as part of the culvert design, the footing should be founded on a leveling pad with a minimum thickness of 0.5 m consisting of Granular ‘A” material at or below the depth of frost. The engineered pad should be placed on a geotextile separation (Class II non-woven FOS 50 to 150 μm) on the native subgrade provided that it is undisturbed, uniformly competent and free of any soft and deleterious materials including peat and organics. The top of the Granular ‘A’ pad must extend to 0.5 m beyond the outside edge of all sides of the footing and sloped at 1H:1V, or flatter. The following geotechnical resistance values are recommended for wingwalls at this site:

- Factored Geotechnical Resistance at ULS of 125 kPa
- Factored Geotechnical Resistance at SLS of 50 kPa

The recommended values presented above are for an assumed vertical concentric loading only. Effects of load eccentricity and inclination need to be taken into account.

9.1.2 Frost Depth

The depth of frost penetration at this site is 2.5 m, as per OPSD 3090.100, and all footings must be protected from frost with a minimum of 2.5 m of earth cover or thermal equivalent. It is not necessary to found a pipe culvert at a depth below frost penetration however, frost treatment for a pipe culvert should be as per OPSD 803.031.

9.2 Subgrade Preparation

Performance of the replacement culvert will depend on the preparation of the subgrade. The borehole information indicates a variable thickness of peat/organic deposit within the culvert footprint area. The peat was observed to extend to as deep as elevation 370.5m which is approximately 2 m below the stream bed.

All peat, organics, soft or loose creek bed deposits, disturbed soils and deleterious materials must be removed from the footprint of the culvert and wingwall foundations to expose competent native firm to stiff clay subgrade material at or below the design founding elevations. The width of the subexcavation should be defined by a line extending from 0.5 m beyond the outside edge of the proposed culvert footprint, outward and downward at 1H:1V.

The excavation should be carried out in accordance with OPSS 209. The subexcavated area should be backfilled as described in the following sections.

9.2.1 Peat Removal with Full Dewatering

Prior to peat excavation, the following dewatering measures must be in place:

- Creek diversion
- Sheet pile cofferdam enclosure
- Pumping from inside the cofferdam

Additional information on surface water and groundwater control can be found in Section 10.3 below. If this full dewatering option is employed the peat/organics/unsuitable soils may be removed to the top of native clay and replaced with Granular A and compacted as per OPSS.PROV 501.

Given the firm conditions anticipated at the subexcavation level of the replacement culvert, construction equipment should not be permitted to travel on the exposed subgrade. The exposed subgrade must be inspected to confirm that the subgrade is suitable and uniformly competent. In addition, the compaction of granular bedding directly above the subgrade is likely to result in disturbance of the material with pumping of fines into the granular bedding and difficulty achieving the specified degree of compaction. Protection of the subgrade should include placement of a mud slab 100 mm thick beneath the Granular A material.

9.2.2 Peat Removal without Full Dewatering

Given the anticipated depth of the peat/unsuitable soil excavation and replacement and potential for groundwater flow and seepage of surface water through the embankment fill, backfilling in wet conditions (below water level) could be considered. When backfilling is conducted in the wet, select rock fill material should be used.

Following peat removal, a separation layer consisting of a non-woven geotextile should be placed between the native soils and rock fill. The geotextile should meet the specifications for OPSS 1860 Class II, and have a fabric opening size (FOS) not greater than 212 µm.

Rock fill used to backfill subexcavated areas below the water table may be placed by end dumping. Granular fill must not be used to backfill excavations below the water table. The rock fill placement below the water level should follow OPSS.PROV 209.

The rock fill material should be well graded and should consist of sound rock with a maximum particle size of 300 mm. Rock fill placed above the water level should be placed in a controlled manner (not end dumped) including blading, dozing and chinking of the rock to minimize voids and bridging. Rock fill above the water level must be compacted as per OPSS.PROV 206. Alternatively a geotextile should be placed as a separator between the rockfill and overlying granulars (nonwoven Class II FOS 50 to 150 µm) Where granular fill or bedding material is to be placed over rock fill, the rock fill subgrade must be blinded with spall material and rock fill chinking shall be in accordance with OPSS.PROV 206. All granular fill must be compacted as per OPSS 501.

For this backfilling option under water, if the peat is not completely removed, there is a risk of additional settlement of the culvert.

9.3 Bedding

The bedding material should be placed on the prepared subgrade as soon as is practical following inspection and approval. Placement of the bedding material should be carried out in the dry.

In order to provide a uniform foundation subgrade, a minimum 150 mm thick layer of bedding material conforming to OPSS PROV 1010 Granular A requirements should be provided under the base of the CSP culvert.

Bedding placement should follow OPSD 802.010 for flexible pipe culverts. In addition, OPSD 803.031 with a frost depth of 2.5 m should be used for frost treatment.

The bedding should be compacted in thin lifts as specified in OPSS.PROV 501.

Construction equipment should not be allowed to travel on the bedding or the prepared subgrade, which must be protected from disturbance during construction.

9.4 Temporary Flow Diversion Culvert

No boreholes were advanced along the alignment of the proposed temporary flow diversion culvert located approximately 27 m west of the existing culvert. It is expected that since the foundation soils under the diversion culvert will experience a net unloading, the foundation soils will not undergo a further increase in loading stresses. If loose, soft or peat soils are encountered within the depth of the temporary culvert, the foundation should be subexcavated 500 mm and backfilled with Granular ‘A’. To help distribute surface loadings and prevent loss of backfill material, a non-woven geotextile should be placed along the exposed subgrade and extend up the sides of the excavation a minimum of 1.0 m. The culvert bedding can be placed directly above the geotextile.

Consideration can be given to decommissioning the temporary flow diversion culvert in place. In this case, a frost taper should be included as per OPSD 803.030 or 803.031. Provided a flowable grout with a unit weight of less than 21 kN/m^3 is used to fill the diversion pipe, it is anticipated that settlement will be limited. It may be necessary to return to the site three years later to address localized settlement in the vicinity of the diversion culvert with a lift of asphalt.

Scour and erosion protection, as per Section 9.7, should also be implemented.

9.5 Embedment and Earth Pressure

It is recommended that culvert embedment consist of free-draining, non-frost susceptible granular materials such as Granular A material meeting the requirements of OPSS.PROV 1010 and placed in accordance with OPSS.PROV 401. The backfill for wing walls must be in accordance with OPSS 902 and placed to the extent shown on OPSD 3101.150. The backfill should be compacted in regular lifts in accordance with OPSS.PROV 401 and 501. Heavy compaction equipment, used adjacent to and above the structure, must be restricted in accordance with OPSS.PROV 501.

9.5.1 Static Lateral Earth Pressure Coefficients

Earth pressures may be assumed to be triangular and to be governed by the characteristics of the backfill. For a fully drained condition, the pressures should be computed in accordance with the CHBDC but generally are given by the following expression:

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

where:

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

A lateral earth pressure due to backfill compaction should be added to the calculated lateral earth pressure in accordance with CHBDC Clause 6.12.3. Earth pressure coefficients are dependent on the material used as backfill and the inclination of the ground surface behind the wall. Typical values are shown in Table 9-1.

Table 9-1. Earth Pressure Coefficients

Condition	Earth Pressure Coefficient (K)					
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^o$, $\gamma = 22.8$ kN/m^3		OPSS Granular B Type I $\phi = 32^o$, $\gamma = 20.0$ kN/m^3		Existing Sand Fill $\phi = 30^o$, $\gamma = 20.0$ kN/m^3	
	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)
Active, K_A (Yielding Wall)	0.27	0.40	0.31	0.48	0.33	0.54
At Rest, K_O (Non-Yielding Wall)	0.43	-	0.47	-	0.5	-
Passive, K_P (Movement towards Soil Mass)	3.7	-	3.3	-	3.0	-
Soil Group(*)	"medium dense sand"		"loose to medium dense sand"		"loose sand"	

Note: (*) Figure C6.16 of the Commentary to the CHBDC.

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

The parameters in the table correspond to full mobilization of active and passive earth pressures and require certain relative movements between the wall and adjacent soil to produce these conditions. The values to be used in design can be assessed from Figure C6.16 of the Commentary to the CHBDC using the soil group designation as outlined in Table 9-1. Active pressures should be used for wing walls or unrestrained walls. For rigid structures such as a concrete box culvert, it is recommended that at-rest earth pressures be used in design. Where ground surfaces are sloped behind the walls, the corresponding coefficients provided in Table 9-1 should be used.

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

9.5.2 Combined Static and Seismic Lateral Earth Pressure Parameters

The following recommendations are per Section C4.6.5 of the Commentary to the CHBDC which states that seismically induced lateral soil pressures may be calculated using the Mononobe-Okabe Method with:

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

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

The recommended seismic lateral earth pressure parameters for seismic loading are provided in Table 9-2. The provided earth pressure coefficients are based on a PGA with a 2% probability of exceedance in 50 years of 0.044g (Geological Survey of Canada – Fifth Generation) and a F(PGA) of 1.81 as per Table 4.8 of the CHBDC (S6-14 update No. 1, April 2016)

Table 9-2. Earth Pressure Coefficients (Under Seismic Loads)

Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^o$, $\gamma = 22.8$ kN/m^3		OPSS Granular B Type I $\phi = 32^o$, $\gamma = 20.0$ kN/m^3	
	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)
Yielding Wall, K_{AE}	0.29	0.43	0.33	0.51
Non-Yielding Wall, K_{AE}	0.32	0.49	0.35	0.56

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

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

where:

σ_h = horizontal pressure at depth d (kPa)
d = depth below top of the wall (m)
K = static earth pressure coefficient
(K_A for yielding walls, K_O for non-yielding walls)
K_{AE} = combined static and seismic earth pressure coefficient
H = total height of wall (m)

9.6 Embankment Design and Construction

Embankment reconstruction after culvert replacement should be carried out in accordance with OPSS.PROV 206. The embankment should be reinstated with side slopes of 2H:1V (or flatter) if constructed using Select Subgrade Material (SSM) or Granular B Type I. No material or stockpiling should be allowed above the existing grades without further analysis.

Granular fill should be placed and compacted in accordance with OPSS.PROV 501. Where new embankment fill is placed against existing embankment slopes or on a sloping ground surface steeper than 3H:1V, benching of the existing slope should be carried out in accordance with OPSD 208.010.

Provided no grade raise is required, embankment widening is limited to flattening of the side slopes in the vicinity of the new culvert and the peat is fully removed in conjunction with proper construction methods, no long term or global stability issues are anticipated for embankments built at this site. If embankment widening is required as part of the slope flattening adjacent to the culvert alignment where peat soil have not removed, settlement under the flattened slope is to be expected. The magnitude of the embankment compression in embankments constructed with granular materials due to compression of the compacted fill is in the order of 0.5% of the embankment height and is expected to be completed after completion of fill placement.

9.7 Scour Protection and Erosion Control

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

Typically, rock protection should be provided over all earth surfaces which could be contacted by flowing water. Treatment at the outlet should be in accordance with OPSD 810.010. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS.PROV 804.

It is recommended that a clay seal and a concrete cut-off wall be used to minimize the potential for piping and erosion around the inlet of the culvert. The clay seal must extend to approximately 300 mm above the high water level and laterally for the width of the granular material, and have a minimum thickness of 500 mm. The material requirements should be in accordance with OPSS.PROV 1205. A geosynthetic clay liner may be used as a clay seal.

9.8 Cement Type and Corrosion Potential

One soil sample was submitted to AGAT Laboratories in Mississauga, Ontario for analysis of pH, water soluble sulphate and chloride concentrations, and resistivity. The analysis was completed to determine the potential for degradation of the concrete in the presence of soluble sulphates and the potential for corrosion of exposed steel. The analysis results are summarized in the Table 9-3. A copy of the test results are provided in Appendix C.

Table 9-3: Results of Chemical Analysis

Borehole	Sample	Depth (m)	pH	Resistivity (Ohm-m)	Chloride (µg/g)	Sulphate (µg/g)
AB16-2	SS3	1.8	9.36	70.9	15	4

The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with soil and groundwater at the site. Soluble sulphate concentrations less than 1000 µg/g generally indicate that a low degree of sulphate attack is expected for concrete in contact with soil and groundwater.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The soil pH measured was slightly outside what is considered the normal range for soil pH of 5.5 to 9.0. The test results provided may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects.

10 CONSTRUCTION CONSIDERATIONS

10.1 Excavations

All excavation must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of OHSA, the fill and native soils above the water table may be classified as Type 3 soil. The organics soils, alluvial deposits as well as the native silt below the water table are classified as Type 4 soils.

Excavation for the culvert replacement must be carried out in accordance with OPSS 902 and will be carried out through the existing embankment fill and extend into the underlying peat and native deposits. The sides of temporary excavations must be sloped in accordance with the requirement of the OHSA. At locations where there are space restrictions or where a slope has to be retained, the excavations will need to be carried out within a protection system, further discussion is presented in Section 10.2.

10.2 Temporary Protection System

Roadway protection will be required during various stages of construction. Roadway protection must be implemented in accordance with OPSS.PROV 539 and designed for Performance Level 2 (maximum 25 mm horizontal deflection). The actual pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall and these factors must be considered when designing the shoring system. The protection system should be installed at a suitable distance away from the new culvert to limit the disturbance to subgrade associated with removal of the protection system following completion of construction. Alternatively, the sheet piles could be left in place and cut off at or below 2.5 m beneath the finished pavement grade. Vibratory equipment is not permitted at this site for installation or removal of the temporary protection system. Suggested wording for an NSSP is provided in Appendix G.

Lateral earth pressure coefficients, under fully mobilized conditions, that can be used in design for the embankment fill and culvert backfill are provided in Table 9-1. The lateral earth pressure coefficients for the underlying native clays and silt soils are given below:

γ_w	=	10	(kN/m^3, unit weight of water)
γ	=	19	(kN/m^3, bulk unit weight of soil)
K_A	=	0.39	
K_P	=	2.6	

The design of the roadway protection is the responsibility of the Contractor. The designer of the roadway protection system should ensure the penetration depth is sufficient to provide base fixity and incorporate traffic loading and surcharge loading due to construction equipment and operations. All shoring should be designed by a licensed Professional Engineer experienced in such designs. The Contractors design should include an assessment of the foundation soils ability to support the weight of the crane used during installation of the protection system.

10.3 Surface and Groundwater Control

A temporary flow passage will be required to convey creek flow around the construction site.

Given the anticipated depth of excavation required to remove unsuitable soils, it is recommended that the culvert replacement be carried out within a sheet pile enclosure for both the full and partial dewatering options for subgrade preparation described in Sections 9.2.1 and 9.2.2.

The groundwater control system required for subgrade improvement work in the dry must be capable of lowering the groundwater level to a minimum of 0.5 m below the base of the peat excavation and not create basal instability in the native firm to stiff clay. Where subgrade improvement work is carried out in the wet, the dewatering system should lower groundwater to 0.5 m below the base of the bedding.

Temporary groundwater and surface water control measures will be required to remain operational during construction until the culvert is installed on a dry, sound base and backfilled. Dewatering systems must be designed by a dewatering specialist.

Based on the groundwater and soil conditions, special attention must be paid to construction dewatering and not to create basal instability in the native firm to stiff clay. Further assessment of dewatering requirements and the need for a PTTW should be carried out by specialists experienced in this field.

11 CONSTRUCTION CONCERNS

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

- The thickness and extent of peat, organic and soft streambed deposits may vary at locations away from the boreholes.
- Disturbance of the soil subgrade within the culvert foundation footprint. Where fine-grained soils are exposed, these areas will be soft and moisture sensitive and may become disturbed when subjected to construction traffic. Site and subgrade drainage will be critical to maintain subgrade conditions. The contractor must be aware of the issue so that he may adjust his operation to suit the subgrade conditions.
- Buried obstructions may be encountered during excavation in the existing embankment fill or interfere with driving of sheet piles. Obstructions within the fill could also interfere during excavation activities
- Water levels may fluctuate. Excavation will involve lowering the groundwater level below the excavation base to maintain a reasonably dry excavation within a sheet pile enclosure. The dewatering scheme will be critical for culvert construction at this site.
- The Contractor’s selection of construction equipment and methodology must include assessment of the capability of the existing embankment to support the proposed construction equipment and any temporary structure fill (i.e., as a pad for crane support). An NSSP should be included in the contract alerting the Contractor to these conditions.

The successful performance of the culvert will depend largely upon good workmanship and quality control during construction. Subgrade examination and field density testing should be carried out by qualified geotechnical personal during construction to confirm that foundation recommendations are correctly implemented and material specifications are met.

12 CLOSURE

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

Thurber Engineering Ltd.
Report Prepared By:

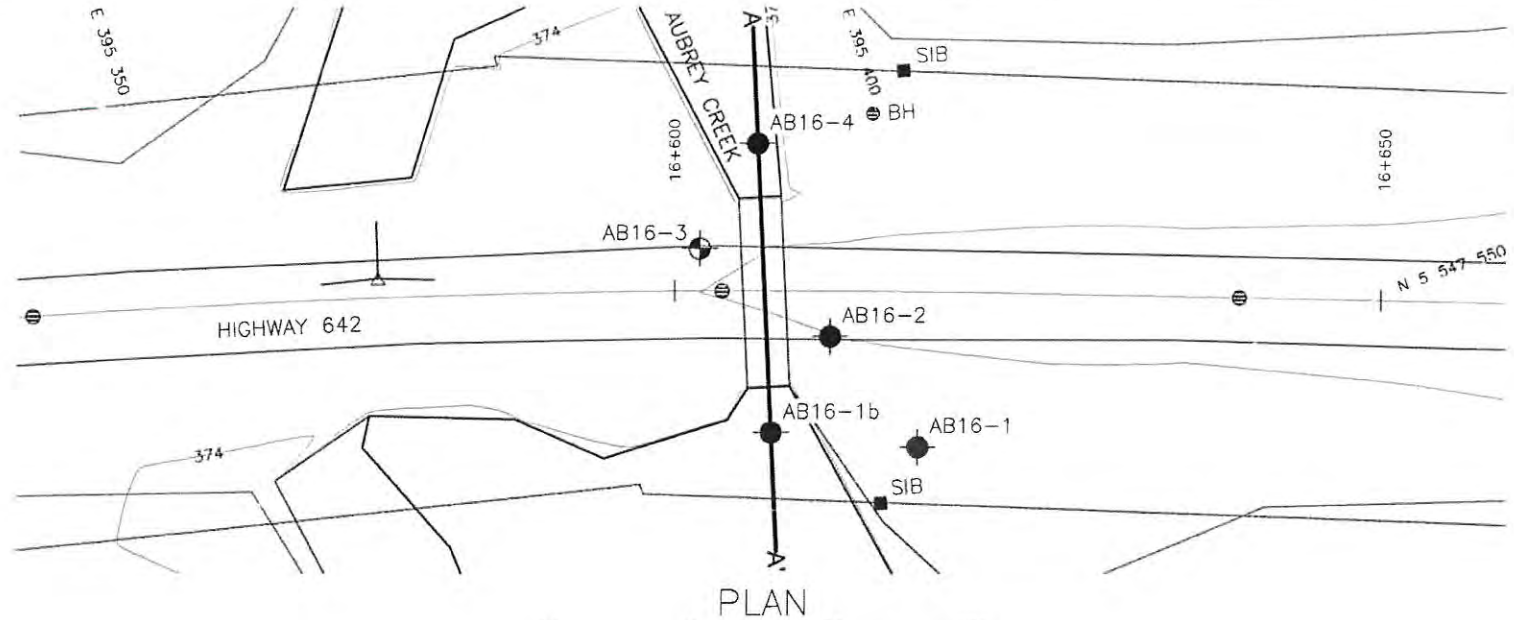
Christopher Murray, E.I.T.
Geotechnical Engineer in Training

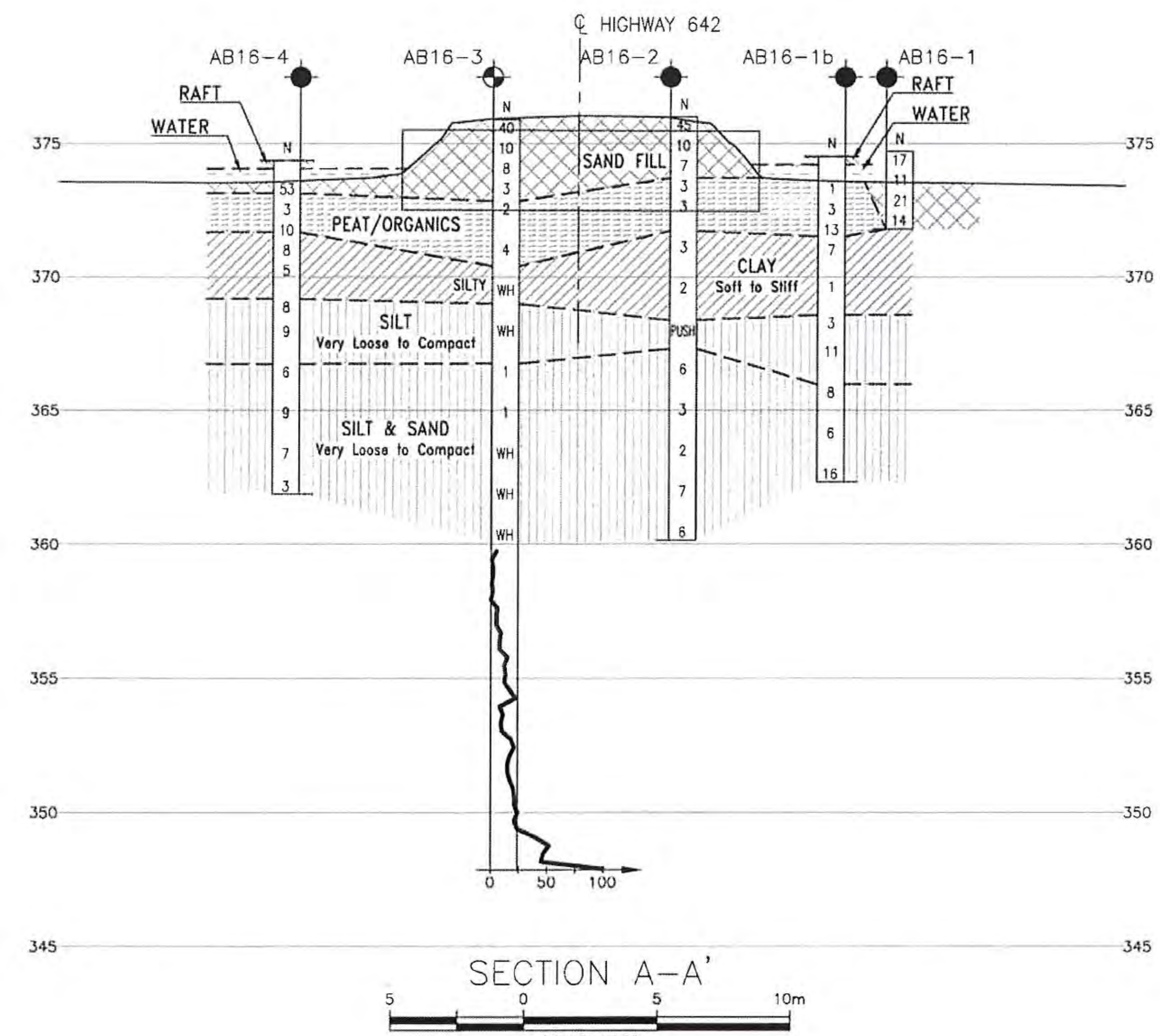
Fred Griffiths, P.Eng, Ph.D.
Senior Associate
Senior Geotechnical Engineer

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

Appendix A.

Borehole Location Plan and Stratigraphic Drawings





METRIC

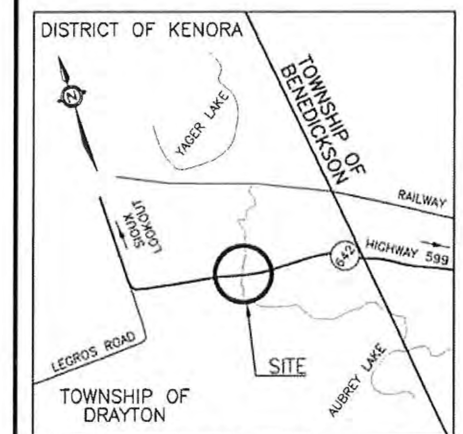
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

CONT No
GWP No 6359-14-00

HIGHWAY 642
AUBREY CREEK
CULVERT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

(symbol)	Borehole
(symbol)	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
(symbol)	Water Level
(symbol)	Head Artesian Water
(symbol)	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
AB16-1	374.7	5 547 550.9	395 395.1
AB16-1b	374.5	5 547 555.2	395 385.6
AB16-2	376.0	5 547 560.3	395 391.8
AB16-3	375.9	5 547 569.2	395 385.1
AB16-4	374.4	5 547 574.8	395 391.3

LICENSED PROFESSIONAL ENGINEER P. R. CHATTERJI PROVINCE OF ONTARIO — Apr 12/17

LICENSED PROFESSIONAL ENGINEER F. J. GRIFFITHS PROVINCE OF ONTARIO — April 12/17

-NOTES-

1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
3) Borehole locations are shown in MTM Zone 16 coordinates.

GEOCRES No. 52J-16

REVISIONS	DATE	BY	DESCRIPTION

DESIGN CM | CHK – | CODE | LOAD | DATE APR 2017
DRAWN MFA | CHK CM | SITE | STRUCT | DWG 1

FILENAME: H:\Drafting\12000\12356\TED-12356-PLSC-AC.dwg
PLOTDATE: 4/10/2017 2:28 PM

Appendix B.

Record of Borehole Sheets

THURBER

60 YEARS

SYMBOLS, ABBREVIATIONS AND TERMS USED ON TEST HOLE RECORDS

TERMINOLOGY DESCRIBING COMMON SOIL GENESIS

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

TERMINOLOGY DESCRIBING SOIL STRUCTURE:

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

RECOVERY:

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

N-VALUE:

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

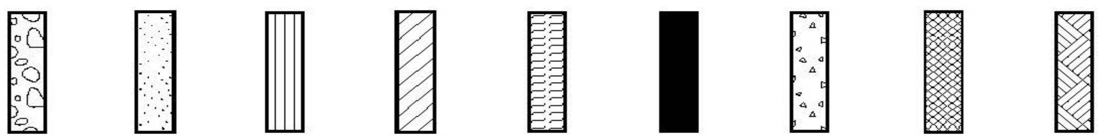
DYNAMIC CONE PENETRATION TEST (DCPT):

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

THURBER

60 YEARS

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



Boulders Cobbles Gravel	Sand	Silt	Clay	Organics	Asphalt	Concrete	Fill	Bedrock

TEXTURING CLASSIFICATION OF SOILS

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

SAMPLE TYPES

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

TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

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

TERMS DESCRIBING CONSISTENCY (COHESIONLESS SOILS ONLY)

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

MODIFIED UNIFIED SOIL CLASSIFICATION

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

Note - W_L= Liquid Limit

EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

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

TERMS

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

DISCONTINUITY SPACING

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

STRENGTH CLASSIFICATION

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No AB16-1

METRIC

GWP# 6359-14-00 | LOCATION Hwy 642 - Aubrey Creek Culvert N 5 547 550.9 E 395 395.1 | ORIGINATED BY TM

HWY 642 | BOREHOLE TYPE Tripod | COMPILED BY JM

DATUM Geodetic | DATE 2016.09.12 - 2016.09.12 | CHECKED BY SP

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m3	GR	SA	SI	CL
374.7													
0.0	SAND with Gravel and Silt, trace Organics Compact to Dense Brown **FILL**		1	SS	17			○					
							374						
			2	SS	11			○		29	63	8 (SI+CL)	
373.2 1.5	SILTY SAND, trace Gravel and Organics Compact to Dense Grey **FILL**		3	SS	21		373	○					
			4	SS	14		372	○		5	72	19	4
371.8 2.9	End of borehole at 2.9 m (casing and spoon refusal) Moved 3 m East and encountered refusal at 1.8 m Groundwater level at 1.8 m												

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

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

REMARKS & GRAIN SIZE DISTRIBUTION (%)

+3, ×3: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No AB16-1b

METRIC

GWP# 6359-14-00 | LOCATION Hwy 642 - Aubrey Creek Culvert N 5 547 555.2 E 395 385.6 | ORIGINATED BY NW

HWY 642 | BOREHOLE TYPE Portable Raft / B Casing | COMPILED BY JM

DATUM Geodetic | DATE 2016.10.21 - 2016.10.21 | CHECKED BY SP

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	SHEAR STRENGTH (FIELD VANE, kPa / sensitivity)	WATER CONTENT (%)	GR	SA	SI	CL
374.5											
0.0	**RAFT**										
374.2 / 0.3	**WATER**				374						
373.6 / 0.9	**FINE FIBROUS to AMORPHOUS PEAT** Very Loose to Compact Brown	1	SS	1			121				
		2	SS	3	373		97				
		3	SS	13	372		85				
371.5 / 3.0	**CLAY (CL)** Stiff to Firm Grey	4	SS	7	371	8.5; 2.4		0	5	63	32
	- becoming silty at 5.1 m	5	SS	1	370 / 369	2.5; 2.2					
368.6 / 5.9	**SILT (ML)** Very Loose to Compact Grey	6	SS	3	368			0	1	90	9
		7	SS	11	367						
366.0 / 8.5	**SILT (ML)** with Sand to **SANDY SILT (ML)** Loose to Compact Grey	8	SS	8	366 / 365			0	22	75	3

Continued Next Page

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

RECORD OF BOREHOLE No AB16-1b

METRIC

GWP#	6359-14-00	LOCATION	Hwy 642 - Aubrey Creek Culvert N 5 547 555.2 E 395 385.6	ORIGINATED BY	NW
HWY	642	BOREHOLE TYPE	Portable Raft / B Casing	COMPILED BY	JM
DATUM	Geodetic	DATE	2016.10.21 - 2016.10.21	CHECKED BY	SP

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
	SILT (ML) with Sand to **SANDY SILT (ML)** Loose to Compact Grey	9	SS	6		○ (~19)				
					364					
					363					
		10	SS	16		○ (~19)	0	44	54	2
362.3 / 12.2	- End of borehole at 12.2 m									

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

+ 3, × 3: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No AB16-2

METRIC

GWP#	6359-14-00	LOCATION	Hwy 642 - Aubrey Creek Culvert N 5 547 560.3 E 395 391.8
HWY	642	BOREHOLE TYPE	HSA / CME 750
DATUM	Geodetic	DATE	2016.08.25 - 2016.08.25

ORIGINATED BY TM
COMPILED BY JM
CHECKED BY SP

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
376.0											
0.0	SAND with Gravel and Silt Loose to Dense Brown **FILL**		1	SS	45						
			2	SS	10		375				24 68 8 (SI+CL)
			3	SS	7		374				
373.7 2.3	**Organics**, Decayed Wood, Rootlets and Amorphous Peat Very Loose Black		4	SS	3				189		
			5	SS	3		373				
371.7 4.3	**CLAY (CL)** Stiff to Firm Grey						372				
			6	SS	3		371				
			7	SS	2		370				0 0 69 31
							369	3.0 (field vane) 1.7 (field vane)			
368.4 7.6	**SILT (ML)** Very Loose Grey - Shelby Tube taken at 7.6 m, 1.2 m of blowback		1	TW	PUSH		368	2.1 (field vane) >>			0 1 86 13
367.3 8.7	**SANDY SILT (ML)** Very Loose to Loose Grey						367				
			8	SS	6						

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100
PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

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

RECORD OF BOREHOLE No AB16-2

METRIC

GWP# 6359-14-00	LOCATION Hwy 642 - Aubrey Creek Culvert N 5 547 560.3 E 395 391.8		ORIGINATED BY TM
HWY 642	BOREHOLE TYPE HSA / CME 750		COMPILED BY JM
DATUM Geodetic	DATE 2016.08.25 - 2016.08.25		CHECKED BY SP

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
		9	SS	3	365	~14	0	30	64	6
					364					
		10	SS	2		~14				
					363					
		11	SS	7	362	~16				
					361					
		12	SS	6		~16				
360.2 / 15.8	- End of borehole - Hole open and dry - Hole backfilled with bentonite and cuttings									

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

+ ³, × ³: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No AB16-3

METRIC

GWP# 6359-14-00	LOCATION Hwy 642 - Aubrey Creek Culvert N 5 547 569.2 E 395 385.1	ORIGINATED BY TM	
HWY 642	BOREHOLE TYPE HSA / CME 750	COMPILED BY JM	
DATUM Geodetic	DATE 2016.08.24 - 2016.08.24	CHECKED BY SP	

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

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
375.9								
0.0	SAND some Gravel, trace Silt, Loose to Dense, Brown, **FILL**	1	SS	40				
		2	SS	10				
		3	SS	8				
		4	SS	3				
372.9 / 3.0	**ORGANICS**, Rootlets, Amorphous Peat, trace Gravel, Very Loose, Black	5	SS	2				
		6	SS	4				
370.4 / 5.5	**SILTY CLAY (CL)**, Firm, Grey	7	SS	WH				
369.0 / 6.9	**SILT (ML)**, Very Loose, Grey	8	SS	WH	0	0	80	20
	- 0.9 m of blowback at 8.8 m depth - Pumped water down hole, continued augering							
366.8 / 9.1	**SANDY SILT (ML)** to **SILTY SAND (SM)**, Very Loose	9	SS	1				

ELEVATION SCALE: 375, 374, 373, 372, 371, 370, 369, 368, 367, 366

Water content annotation at sample 5: 115

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

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

ONTMT4S 12356 AUBREY CULVERT.GPJ 2012TEMPLATE(MTO).GDT 12/4/17

RECORD OF BOREHOLE No AB16-3

METRIC

GWP# 6359-14-00 | LOCATION Hwy 642 - Aubrey Creek Culvert N 5 547 569.2 E 395 385.1 | ORIGINATED BY TM

HWY 642 | BOREHOLE TYPE HSA / CME 750 | COMPILED BY JM

DATUM Geodetic | DATE 2016.08.24 - 2016.08.24 | CHECKED BY SP

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
	Grey									
		10	SS	1	365	~15				
					364					
		11	SS	WH	363	~18				
		12	SS	WH	362	~18				
					361					
		13	SS	WH		~18	0	51	45	4
360.1 / 15.8	- End of SPT sampling at 15.6 m, continued with DCPT				360					
					359					
					358					
					357					
					356					

DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100)

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

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

UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No AB16-3

METRIC

GWP# 6359-14-00	LOCATION	Hwy 642 - Aubrey Creek Culvert N 5 547 569.2 E 395 385.1	ORIGINATED BY TM
HWY 642	BOREHOLE TYPE	HSA / CME 750	COMPILED BY JM
DATUM Geodetic	DATE	2016.08.24 - 2016.08.24	CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Continued From Previous Page										
							355				
							354				
							353				
							352				
							351				
							350				
							349				
							348				
	- End of DCPT at 28.3 m										

+ 3, × 3: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No AB16-4

METRIC

GWP# 6359-14-00 | LOCATION Hwy 642 - Aubrey Creek Culvert N 5 547 574.8 E 395 391.3 | ORIGINATED BY NW

HWY 642 | BOREHOLE TYPE Portable Raft / B Casing | COMPILED BY JM

DATUM Geodetic | DATE 2016.10.22 - 2016.10.22 | CHECKED BY SP

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	SHEAR STRENGTH kPa	WATER CONTENT (%)	GR	SA	SI	CL
374.4 / 0.0	**RAFT**										
374.1 / 0.3	**WATER**				374						
373.6 / 0.8	**SAND** with Gravel, Frequent Cobbles and Boulders, Dense, Brown, **FILL**	1	SS	53							
373.2 / 1.2	**FINE FIBROUS to AMORPHOUS PEAT**, Very Loose, Brown	2	SS	3	373						
		3	SS	10	372						
371.7 / 2.7	**CLAY (CI to CL)**, Firm to Soft, Grey	4	SS	8	371			0	3	47	50
		5	SS	5	370	1.3 (field vane)		0	5	77	18
						2.0 (field vane)					
369.2 / 5.2	**SILT (ML)**, Loose, Grey	6	SS	8	369						
		7	SS	9	368			0	4	81	15
					367						
366.8 / 7.6	**SANDY SILT (ML)** to **SILTY SAND (SM)**, Loose, Grey	8	SS	6	366						
		9	SS	9	365			0	47	50	3

Continued Next Page

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

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No AB16-4

METRIC

GWP# 6359-14-00 | LOCATION Hwy 642 - Aubrey Creek Culvert N 5 547 574.8 E 395 391.3 | ORIGINATED BY NW

HWY 642 | BOREHOLE TYPE Portable Raft / B Casing | COMPILED BY JM

DATUM Geodetic | DATE 2016.10.22 - 2016.10.22 | CHECKED BY SP

ELEV DEPTH	DESCRIPTION (Continued From Previous Page)	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE) 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
							364				
			10	SS	7				○ (~19)		
							363				
			11	SS	3				○ (~17)		
361.9							362				
12.5	- End of borehole at 12.5 m										

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

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

Appendix C.

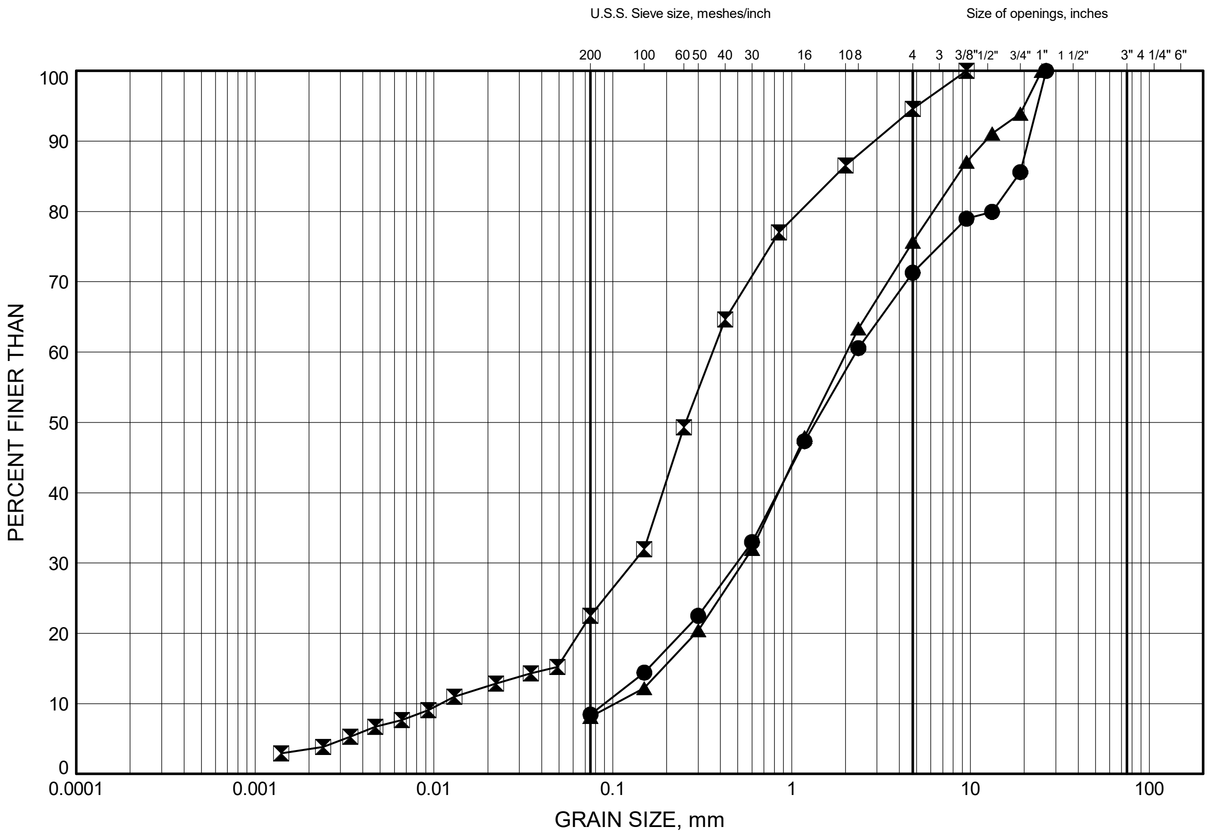
Laboratory Testing

Aubrey Creek Culvert

GRAIN SIZE DISTRIBUTION

FIGURE C1

FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	AB16-1	1.14	373.56
⧗	AB16-1	2.67	372.03
▲	AB16-2	1.07	374.93

Date November 2016

GWP# 6359-14-00

THURBER

Prep'd ....

Chkd. ....

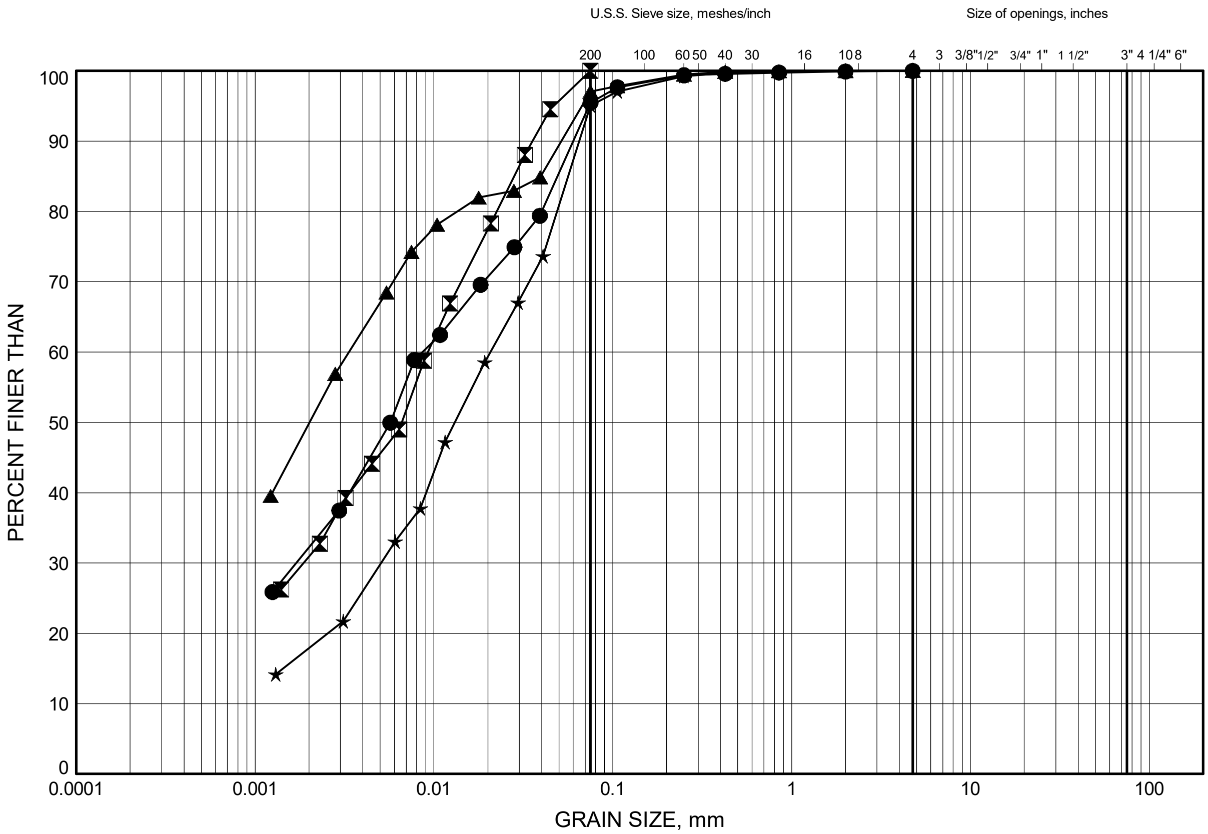
GRAIN SIZE DISTRIBUTION - THURBER 12356 AUBREY CULVERT.GPJ 25/11/16

Aubrey Creek Culvert

GRAIN SIZE DISTRIBUTION

FIGURE C2

CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	AB16-1b	3.51	370.99
⧗	AB16-2	6.40	369.60
▲	AB16-4	3.35	371.05
★	AB16-4	4.11	370.29

GRAIN SIZE DISTRIBUTION - THURBER 12356 AUBREY CULVERT.GPJ 25/11/16

Date November 2016

GWP# 6359-14-00

THURBER

Prep'd ....

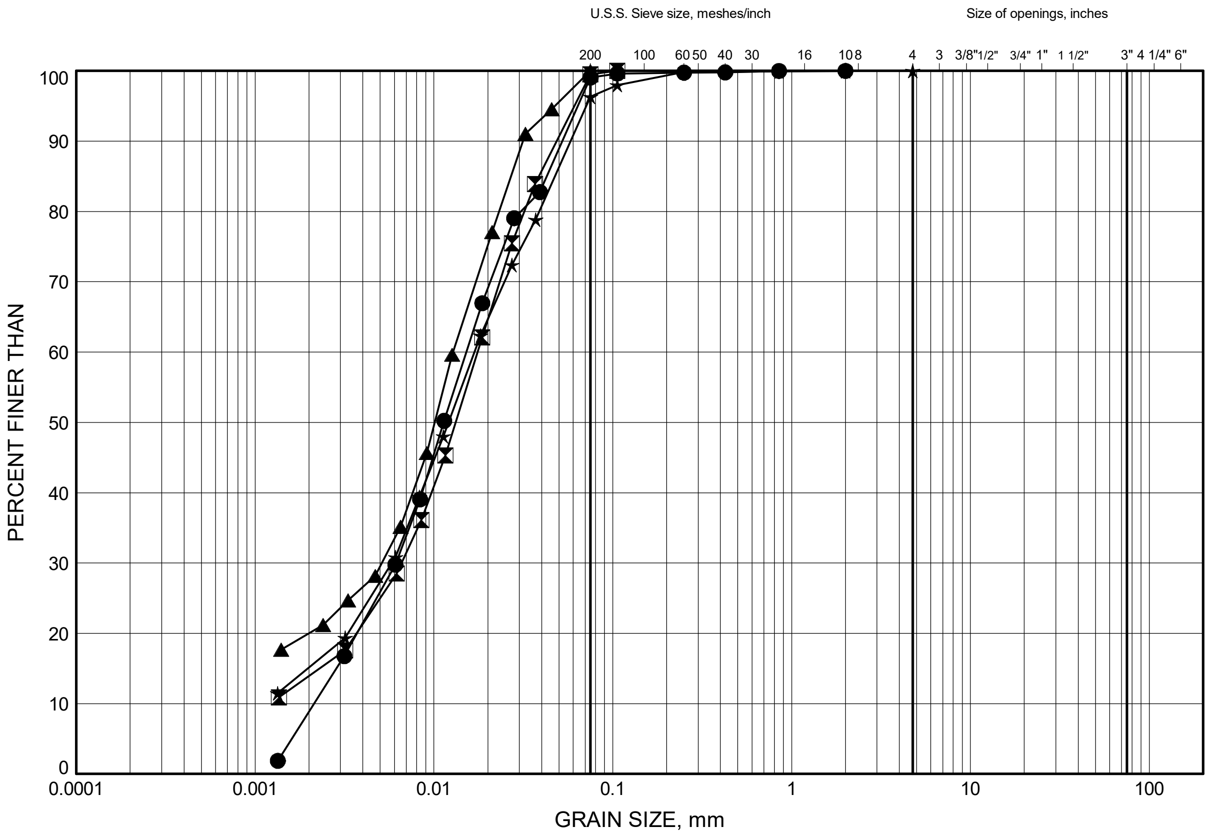
Chkd. ....

Aubrey Creek Culvert

GRAIN SIZE DISTRIBUTION

FIGURE C3

SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	AB16-1b	6.25	368.25
⧗	AB16-2	7.92	368.08
▲	AB16-3	7.92	367.98
★	AB16-4	6.40	368.00

Date November 2016

GWP# 6359-14-00

THURBER

Prep'd ....

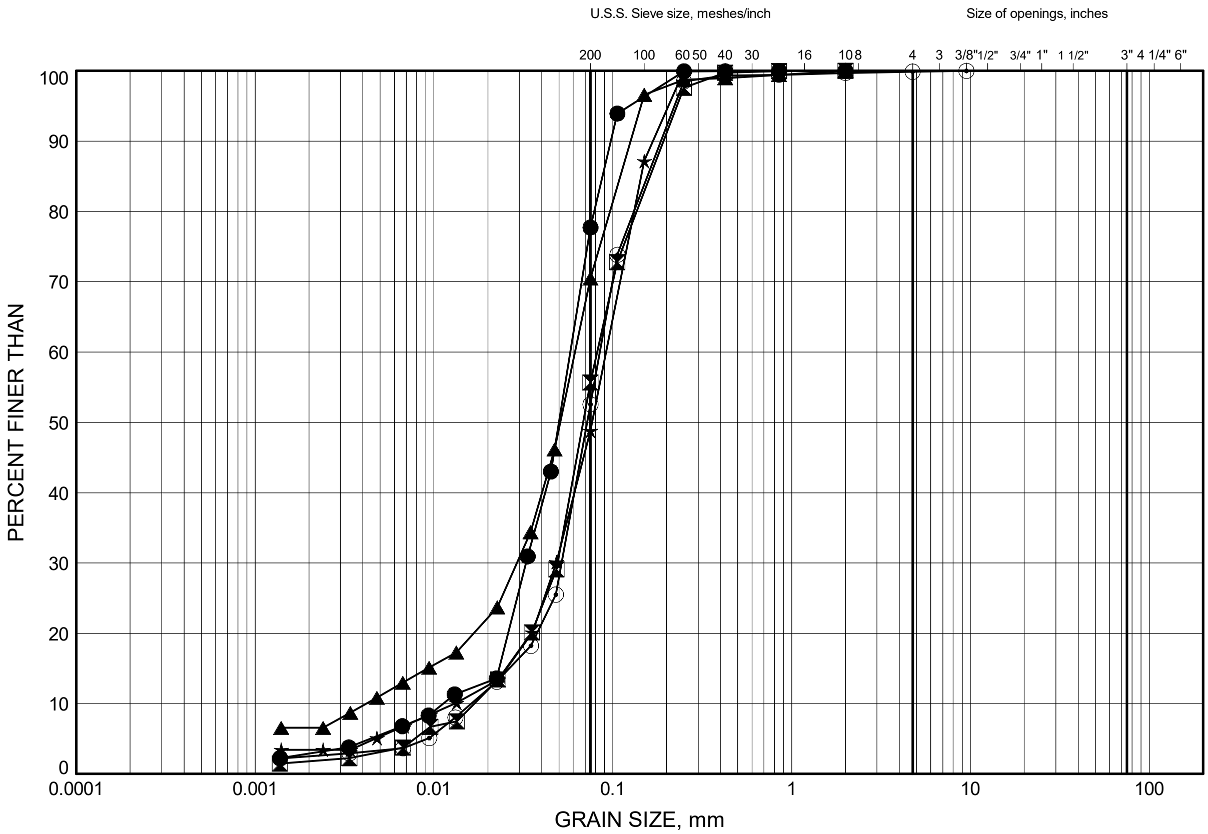
Chkd. ....

Aubrey Creek Culvert

GRAIN SIZE DISTRIBUTION

FIGURE C4

SANDY SILT to SILTY SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	AB16-1b	8.84	365.66
⧗	AB16-1b	11.89	362.61
▲	AB16-2	10.97	365.03
★	AB16-3	15.54	360.36
⊙	AB16-4	9.45	364.95

Date November 2016

GWP# 6359-14-00

THURBER

Prep'd ....

Chkd. ....

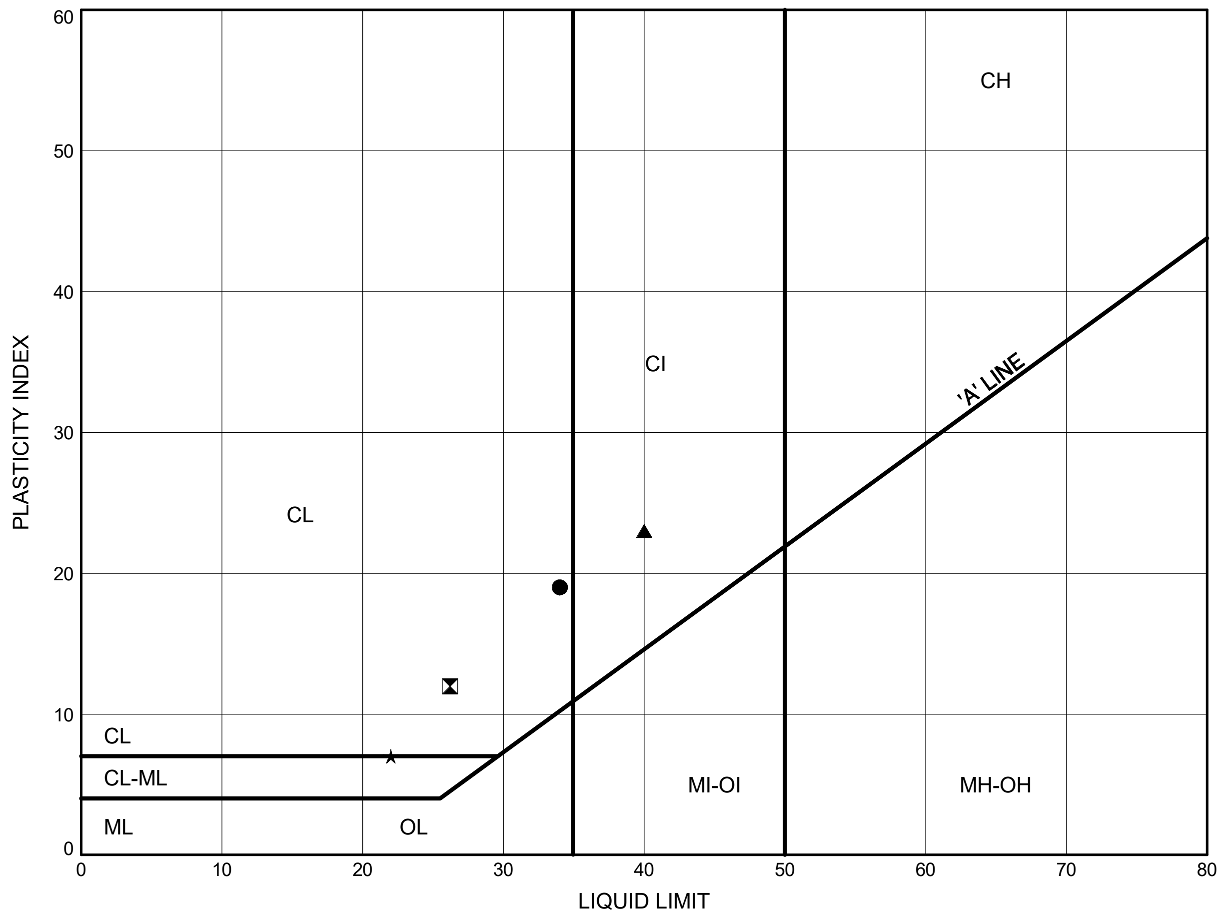
GRAIN SIZE DISTRIBUTION - THURBER 12356 AUBREY CULVERT.GPJ 25/11/16

Aubrey Creek Culvert

ATTERBERG LIMITS TEST RESULTS

FIGURE C5

CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	AB16-1b	3.51	370.99
⧗	AB16-2	6.40	369.60
▲	AB16-4	3.35	371.05
★	AB16-4	4.11	370.29

THURBALT 12356 AUBREY CULVERT.GPJ 25/11/16

Date November 2016

GWP# 6359-14-00

THURBER

Prep'd ....

Chkd. ....

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
http://www.agatlabs.com

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

ATTENTION TO: WEISS MEHDAWI

PROJECT: 12356

AGAT WORK ORDER: 16T139310

SOIL ANALYSIS REVIEWED BY: Amanjot Bhela, Inorganic Coordinator

DATE REPORTED: Sep 27, 2016

PAGES (INCLUDING COVER): 5

VERSION*: 1

Should you require any information regarding this analysis please contact your client services representative at (905) 712-5100

*NOTES

All samples will be disposed of within 30 days following analysis. Please contact the lab if you require additional sample storage time.

AGAT Laboratories

Certificate of Analysis

AGAT WORK ORDER: 16T139310

PROJECT: 12356

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
http://www.agatlabs.com

CLIENT NAME: THURBER ENGINEERING LTD

ATTENTION TO: WEISS MEHDAWI

SAMPLING SITE:

SAMPLED BY:

Corrosivity Package

DATE RECEIVED: 2016-09-20

DATE REPORTED: 2016-09-27

		SAMPLE DESCRIPTION:		FL-1/SS2 (2. 5-4.5')		FL-3/SS4 (7. 5-8.5')		AB-2/SS3 (5-7')
		SAMPLE TYPE:		Soil		Soil		Soil
		DATE SAMPLED:		8/22/2016		8/22/2016		8/22/2016
Parameter	**Unit**	**G / S**	**RDL**	**7861502**	**RDL**	**7861508**	**RDL**	**7861509**
Sulphide	%		0.05	<0.05	0.05	0.06	0.05	<0.05
Chloride (2:1)	µg/g		2	264	4	383	2	15
Sulphate (2:1)	µg/g		2	17	4	65	2	4
pH (2:1)	pH Units		NA	8.44	NA	11.4	NA	9.36
Electrical Conductivity (2:1)	mS/cm		0.005	0.633	0.005	1.32	0.005	0.141
Resistivity (2:1)	ohm.cm		1	1580	1	758	1	7090
Redox Potential (2:1)	mV		5	232	5	88	5	211

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

7861502 EC/Resistivity, pH, Chloride, Sulphate and Redox Potential were determined on the extract obtained from the 2:1 leaching procedure (2 parts DI water: 1 part soil).
Please note that samples were analyzed past hold time.

7861508 EC/Resistivity, pH, Chloride, Sulphate and Redox Potential were determined on the extract obtained from the 2:1 leaching procedure (2 parts DI water: 1 part soil).
Please note that samples were analyzed past hold time.
Elevated RDL indicates the degree of sample dilution prior to the analysis for Anions in order to keep analytes within the calibration range of the instrument and to reduce matrix interference.

7861509 EC/Resistivity, pH, Chloride, Sulphate and Redox Potential were determined on the extract obtained from the 2:1 leaching procedure (2 parts DI water: 1 part soil).
Please note that samples were analyzed past hold time.

Certified By: Amanjot Bhela

AGAT Laboratories
5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
http://www.agatlabs.com

Quality Assurance

CLIENT NAME: THURBER ENGINEERING LTD | **AGAT WORK ORDER: 16T139310**
PROJECT: 12356 | **ATTENTION TO: WEISS MEHDAWI**
SAMPLING SITE: | **SAMPLED BY:**

Soil Analysis

RPT Date: Sep 27, 2016			DUPLICATE			Method Blank	REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits Lower	Acceptable Limits Upper	Recovery	Acceptable Limits Lower	Acceptable Limits Upper	Recovery	Acceptable Limits Lower	Acceptable Limits Upper
Corrosivity Package															
Sulphide	7861502	7861502	< 0.05	< 0.05	NA	< 0.05	100%	80%	120%	NA			NA		
Chloride (2:1)	7862971		<2	<2	NA	< 2	93%	80%	120%	98%	80%	120%	99%	70%	130%
Sulphate (2:1)	7862971		23	24	4.3%	< 2	92%	80%	120%	96%	80%	120%	98%	70%	130%
pH (2:1)	7861508	7861508	11.4	11.4	0.0%	NA	100%	90%	110%	NA			NA		
Electrical Conductivity (2:1)	7861508	7861508	1.32	1.32	0.0%	< 0.005	99%	90%	110%	NA			NA		
Redox Potential (2:1)	7861508	7861508	88	88	0.0%	< 5	102%	70%	130%	NA			NA		

Comments: NA signifies Not Applicable.
Duplicate Qualifier: As the measured result approaches the RL, the uncertainty associated with the value increases dramatically, thus duplicate acceptance limits apply only where the average of the two duplicates is greater than five times the RL.

Certified By: Amanjot Bhela

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
http://www.agatlabs.com

Method Summary

CLIENT NAME: THURBER ENGINEERING LTD **AGAT WORK ORDER: 16T139310**

PROJECT: 12356 **ATTENTION TO: WEISS MEHDAWI**

SAMPLING SITE: **SAMPLED BY:**

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Soil Analysis			
Sulphide	MIN-200-12025	ASTM E1915-09	GRAVIMETRIC
Chloride (2:1)	INOR-93-6004	McKeague 4.12 & SM 4110 B	ION CHROMATOGRAPH
Sulphate (2:1)	INOR-93-6004	McKeague 4.12 & SM 4110 B	ION CHROMATOGRAPH
pH (2:1)	INOR 93-6031	MSA part 3 & SM 4500-H+ B	PH METER
Electrical Conductivity (2:1)	INOR-93-6036	McKeague 4.12, SM 2510 B	EC METER
Resistivity (2:1)	INOR-93-6036	McKeague 4.12, SM 2510 B,SSA #5 Part 3	CALCULATION
Redox Potential (2:1)		McKeague 4.12 & SM 2510 B	REDOX POTENTIAL ELECTRODE

AGAT Laboratories

5835 Coopers Avenue
Mississauga, Ontario L4Z 1Y2
Ph: 905.712.5100 Fax: 905.712.5122
webearth.agatlabs.com

Chain of Custody Record

If this is a Drinking Water sample, please use Drinking Water Chain of Custody Form (potable water intended for human consumption)

Laboratory Use Only

Work Order #: 16T139310

Cooler Quantity:

Arrival Temperatures: 7.9 | 8.1 | 8.1 / 6.9 | 7.1 | 7.1

Custody Seal Intact: ☐Yes ☐No ☐N/A

Notes:

Report Information:

Company: Thurber Engineering Ltd.
Contact: Weiss Mehdawi
Address: 103, 2010 Winston Park Dr. Oakville, ON.
Phone: 905-829-8666 Fax:
Reports to be sent to:
1. Email: wmehdawi@Thurber.ca
2. Email:

Regulatory Requirements: ☐ No Regulatory Requirement

(Please check all applicable boxes)

☐ Regulation 153/04 — Table (Indicate One): ☐Ind/Com ☐Res/Park ☐Agriculture; Soil Texture (Check One): ☐Coarse ☐Fine

☐ Sewer Use: ☐Sanitary ☐Storm; Region (Indicate One)

☐ Regulation 558 ☐ CCME ☐ Prov. Water Quality Objectives (PWQO) ☐ Other (Indicate One)

Is this submission for a Record of Site Condition? ☐ Yes ☐ No

Report Guideline on Certificate of Analysis ☐ Yes ☐ No

Turnaround Time (TAT) Required:

Regular TAT ☑ 5 to 7 Business Days

Rush TAT (Rush Surcharges Apply)

☐ 3 Business Days ☐ 2 Business Days ☐ 1 Business Day

OR Date Required (Rush Surcharges May Apply):

Please provide prior notification for rush TAT
**TAT is exclusive of weekends and statutory holidays*

Project Information:

Project: 12356
Site Location:
Sampled By:
AGAT Quote #: 13202 PO:
Please note: If quotation number is not provided, client will be billed full price for analysis

Invoice Information:

Bill To Same: Yes ☑ No ☐
Company:
Contact:
Address:
Email:

Sample Matrix Legend

B	Biota
GW	Ground Water
O	Oil
P	Paint
S	Soil
SD	Sediment
SW	Surface Water

Analysis columns: Field Filtered - Metals, Hg, CrVI (Please Circle) Y / N; Metals and Inorganics; Metal Scan; Hydride Forming Metals; Client Custom Metals; ORPs: ☐ B-HWS ☐ Cl ☐ CN ☐ Cr^{6+} ☐ EC ☐ FOC ☐ NO_3/NO_2 ☐ Total N ☐ Hg ☐ pH ☐ SAR (Check Applicable); Nutrients: ☐ TP ☐ NH_3 ☐ TKN ☐ NO_3 ☐ NO_2 ☐ NO_3/NO_2; Volatiles: ☐ VOC ☐ BTEX ☐ THM; CCME Fractions 1 to 4; ABNs; PAHs; Chlorophenols; PCBs; Organochlorine Pesticides; TCLP Metals/Inorganics; Sewer Use; Corrosivity Package

Sample Identification	Date Sampled	Time Sampled	# of Containers	Sample Matrix	Comments/ Special Instructions	Corrosivity Package
FL-1/SS2 (2.5-4.5')	Aug 22/16			Soil		✓
FL-3/SS4 (7.5'-8.5')	Aug 22/16			Sand		✓
AB-2/SS3 (5-7')	Aug 22/16			Sand		✓

Samples Relinquished By (Print Name and Sign):	Date	Time	Samples Received By (Print Name and Sign):	Date	Time
Rizwan [signature]	2016/09/20	10:20	[signature]	2016/09/20	9:05

Page ___ of ___

Nº: T 024761

Appendix D.

Site Photographs

Photo 1. Culvert Inlet

Photo 2. Raft Drilling Setup at Culvert Inlet

Photo 3. Culvert Outlet looking Downstream

Photo 4. Raft Drilling Setup at Culvert Outlet

Photo 5. Roadway Platform Over Culvert Looking East

Photo 6. South Culvert Embankment Looking East

Appendix E.

Foundation Comparison

COMPARISON OF ALTERNATIVE FOUNDATION TYPES

Open Bottom Culvert	***Steel Sheet Pile Walls with Precast Concrete Slab***	***Closed Bottom Culvert***	***Pipe Culvert***
Advantages: *i.* Relatively expedient installation if precast units are used.	*Advantages:* i. Ease of construction. ii. Potentially minimized volume of excavation and roadway protection required. iii. Maintains water flow throughout construction. iv. Minimizes potential for disturbance of streambed.	*Advantages:* i. Relatively expedient installation if precast units are used. ii. Smaller magnitude of settlement than open footing culvert due to lower bearing stress on subgrade.	*Advantages:* *i.* Can tolerate larger magnitude of settlement than concrete (rigid frame) culverts. *ii.* Lower cost than concrete (rigid frame) culverts.
Disadvantages: i. Foundation subgrade will provide low geotechnical resistances. *ii.* Potential for post construction settlement. *iii.* Requires deeper excavation increasing volume and dewatering concern	*Disadvantages:* i. Foundation subgrade will provide low geotechnical resistances. ii. High cost of sheet piles	*Disadvantages:* *i.* Requires compacted granular pad on subgrade. *ii.* Requirement for temporary by-pass culvert or pumped diversion to maintain water flow	*Disadvantages:* *i.* CSP and HDPE pipes not as durable as concrete culverts. *ii.* Requirement for temporary by-pass culvert or pumped diversion to maintain water flow
Not Recommended	**Not Recommended**	**Feasible**	**Recommended**

Appendix F.

GSC Seismic Hazard Calculation

2015 National Building Code Seismic Hazard Calculation

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

November 17, 2016

Site: 50.0584 N, 91.7351 W   User File Reference: Aubrey Creek Culvert

Requested by: Christopher Murray, Thurber Engineering

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

Sa(0.05)	Sa(0.1)	**Sa(0.2)**	Sa(0.3)	**Sa(0.5)**	**Sa(1.0)**	**Sa(2.0)**	**Sa(5.0)**	**Sa(10.0)**	**PGA (g)**	**PGV (m/s)**
0.061	0.082	**0.073**	0.057	**0.040**	**0.020**	**0.0079**	**0.0016**	**0.0007**	**0.044**	**0.028**

Notes. Spectral (Sa(T), where T is the period in seconds) and peak ground acceleration (PGA) values are given in units of g (9.81 m/s²). Peak ground velocity is given in m/s. Values are for "firm ground" (NBCC 2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are specified in **bold** font. Three additional periods are provided - their use is discussed in the NBCC2015 Commentary. Only 2 significant figures are to be used. ***These values have been interpolated from a 10-km-spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the directly calculated values.***

Ground motions for other probabilities:

Probability of exceedance per annum	0.010	0.0021	0.001
Probability of exceedance in 50 years	40%	10%	5%
Sa(0.05)	0.0023	0.015	0.030
Sa(0.1)	0.0039	0.023	0.042
Sa(0.2)	0.0044	0.022	0.039
Sa(0.3)	0.0039	0.018	0.032
Sa(0.5)	0.0028	0.013	0.023
Sa(1.0)	0.0011	0.0058	0.011
Sa(2.0)	0.0005	0.0022	0.0042
Sa(5.0)	0.0002	0.0005	0.0008
Sa(10.0)	0.0002	0.0003	0.0005
PGA	0.0021	0.012	0.023
PGV	0.0014	0.0078	0.015

References

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

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

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

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

Aussi disponible en français

Appendix G.

List of Special Provisions and OPSS Documents Referenced in this Report

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

   - OPSS.PROV 206
   - OPSS 209
   - OPSS.PROV 401
   - OPSS 421
   - OPSS 422
   - OPSS.PROV 501
   - OPSS.PROV.539
   - OPSS.PROV 804
   - OPSS 902
   - OPSS.PROV 1010
   - OPSS.PROV 1205
   - OPSS 1860

   - OPSD 208.010
   - OPSD 802.010
   - OPSD 803.010
   - OPSD 803.031
   - OPSD 810.010
   - OPSD 3090.100
   - OPSD 3101.150

2. Suggested text for a NSSP on “Foundation Support”

   The site is underlain by peat, clay and saturated silts. Any additional embankment loading or foundation loading due to embankment widening to support a crane pad is expected to be difficult at this site. The Contractor must retain an experienced geotechnical consultant to design their temporary works such as crane pads.

3. Suggested text for NSSP on “Installation of Temporary Protection System:

   Vibratory equipment is not permitted for installation or removal of temporary protection systems.