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FOUNDATION INVESTIGATION AND DESIGN REPORT
KITCHEN CREEK CULVERT REPLACEMENT
HIGHWAY 11
DISTRICT OF RAINY RIVER, ONTARIO

G.W.P. No. 6324-14-00, W.P. No. 6324-14-01, SITE No. 45-277C

GEOCRES Number: 52C-51

Report

to

HATCH

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103, 2010 Winston Park Drive, Oakville, ON L6H 5R7 T: 905 829 8666 F: 905 829 1166
thurber.ca

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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 Kitchen Creek Culvert on Highway 11, located west of Fort Francis, within the Township of Crozier, in the District of Rainy River, 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 Ltd. (Hatch) to carry out this foundation investigation under the Ministry of Transportation Ontario (MTO) Agreement Number 6015-E-0018-003.

In the preparation of this report and in addition to the borehole drilled under the current assignment, reference has been made to information on subsurface conditions contained in an earlier preliminary foundation report and a structural design report. The titles of these reports are listed as follows:

- Preliminary Foundation Investigation and Design Report, Kitchen Creek Culvert, Highway 11, District of Rainy River, Township of Crozier, prepared by Golder Associates (Golder), dated September 8, 2015; Geocres No. 52C-41. The information presented in the above report was reviewed and incorporated in the current report, as appropriate. (Reference 1).

- Structural Design Report, Kitchen Creek Culvert, Site No. 45-277C, Highway 11, prepared by Hatch Mott MacDonald and dated December 2015. (Reference 2).

Reference should be made to the Golder report for a written description of the subsurface conditions, borehole location plan, stratigraphic profile and laboratory test results. It should be noted that Golder is solely responsible for the subsurface information provided in the preliminary Foundation Investigation and Design Report (FIDR). The borehole logs from the Golder report are attached in Appendix E.

2. SITE DESCRIPTION

The site is located on Highway 11, approximately 10.5 km west of the junction of Highway 11 and Highway 602 near Fort Francis, within the Township of Crozier, in the District of Rainy River, Ontario. Highway 11 generally runs in an approximate east-west direction at the culvert site. The culvert allows Kitchen creek to flow in a southerly direction under Highway 11.

The Structural Design Report (Reference 2) provided to Thurber by Hatch indicates that the existing structure consists of an open footing concrete culvert covered by approximately 2.3 m of fill. The culvert is 21 m long, 5 m wide. A Biennial Inspection on July 26 2013 notes areas of cracking, exposed rusting rebar, and scaling. The structure components were considered to be in good to poor condition.

The grade level of Highway 11 at the existing culvert is at an approximate Elevation of 354.5 m. The culvert invert is at approximately Elevation 348.8 m at the inlet (north end). The creek water level was measured at Elevation 349.5 m by others in November, 2012 and at an Elevation 349.8 m by Golder in February, 2015. The highest groundwater level measured was at Elevation 350.73.

Kitchen Creek runs through a golf course to the south of the existing culvert and the lands to the north of the culvert contain a mix of forested areas and agricultural lands. The lands surrounding the site are relatively flat.

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

Based on published geological information, the culvert lies within modern alluvium deposits of fine sand, silt, clay and organics associated with Kitchen Creek, underlain by deposits of silty clay. Several areas of glaciolacustrine fine-grained deposits of silt and clay, and swamp and organic deposits of peat and muck were identified on geological maps within the area of the site. The bedrock at the site is identified as mafic to intermediate metavolcanic rock.

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3. INVESTIGATION PROCEDURES

The borehole investigation and field testing program for this project was carried out on July 24, 2016, and consisted of drilling and sampling one (1) borehole, designated as Borehole 16-05. Borehole 16-05 was located on Highway 11, approximately 10 m east of the existing culvert on the paved shoulder of the east bound lane. The borehole was located near the alignment of the proposed stream diversion pipe.

Utility clearances were obtained prior to the start of drilling. The ground surface elevation for the borehole was derived from cross sections and topographic plans provided to Thurber by Hatch. The approximate location of the borehole is shown on the Borehole Locations and Soil Strata Drawing included in Appendix D.

A rubber track mounted CME 55 drill rig was used to advance Borehole 16-05 using hollow stem augers. The borehole was advanced to a depth of 15.8 m (Elevation 338.7) below the existing road surface. A Dynamic Cone Penetration Test (DCPT) was carried out below the sampled portion of the borehole to a cone refusal depth of 27.4 m (Elevation 327.1) below the existing grade.

Samples of the overburden soils were obtained from the borehole at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). Field vane shear testing using an MTO "N" size vane was carried out in soft to firm cohesive soils.

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

Groundwater conditions were observed in the open borehole throughout the drilling operations and in the open borehole upon completion of drilling. The borehole was backfilled in general accordance with Ontario Regulation 903.

Completion details of the borehole 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
16-05	15.8 / 338.7	None installed	Borehole backfilled with cuttings and asphalt reinstated at surface.

The previous investigation conducted by Golder (Reference 1) included four (4) boreholes, numbered KT-1 to KT-4. Boreholes KT-1 and KT-4 were advanced at the toe of the slope near the culvert outlet and inlet to depths of 9.8 m, and Boreholes KT-2 and KT-3 were advanced from the existing highway platform to depths of approximately 14.9 m and 10.1 m, respectively. The approximate locations of the Golder boreholes are shown on the Borehole Locations and Soil Strata Drawing included in Appendix D, and on the 2015 Golder report's Borehole Locations and Soil Strata Drawing included in Appendix E. The subsurface information, including the Record of Borehole sheets and the Borehole Locations and Soil Strata drawings, from both the current and preliminary investigations should be included in the contract documents.

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 E. Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets and on the "Borehole Locations and Soil Strata" drawings included in Appendices D and E. 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.

The borehole logs from the previous Golder investigation are presented in Appendix E and are generally consistent with the results of the current investigation.

In general, the subsurface conditions encountered in the borehole from the current investigation consisted of embankment fill consisting of silty clay and silty sand underlain by a deposit of native silty clay. Trace to some organics were noted within the fill and within the upper 2.0 m of the native silty clay.

Descriptions of the individual strata are presented below.

5.1 Pavement Structure

Borehole 16-05 was drilled in the paved shoulder of Highway 11. The pavement structure consisted of approximately 100 mm of asphalt over approximately 600 mm of granular base.

In Boreholes KT-2 and KT-3, the pavement structure consists of 170 mm of asphalt over sand to gravelly sand fill.

5.2 Fill

Embankment fill was encountered beneath the road structure. The fill consisted of layers of cohesionless and cohesive soils. Each layer is described below:

- A layer of brown sand to gravelly sand containing some silt was encountered in Boreholes KT-2 and KT-3 below the asphalt. The thickness of this sand to gravelly sand fill layer was 1.0 m and 2.8 m. Auger grinding was noted within this layer in the upper 0.8 to 1.2 m, inferring the presence of cobbles.

- Cohesive fill was contacted below the sand to gravelly sand fill, at 1.2 m and 3.0 m depth, in Boreholes KT-2 and KT-3, and below the pavement structure, at 0.7 m depth, in Borehole 16-05. The cohesive fill consisted of brown to grey clay and silty clay containing some sand to sandy, trace gravel and trace of organics. A lower layer of silty clay fill was encountered at 3.0 m depth in Borehole 16-05. The clay/silty clay fill thickness ranged from 1.8 m to 3.4 m. Auger grinding was also noted within the clay fill between 1.5 and 3 m depth in Borehole KT-2, inferring the presence of cobbles.

- Below the cohesive fill, a layer of brown to grey silty sand and sand fill was contacted at depths of 3.0 m and 5.3 m in Boreholes KT-2 and KT-3, respectively. A layer of sandy silt fill was contacted within the silty clay fill, at 2.2 m depth, in Borehole 16-05. The thickness of the sand, silty sand and sandy silt fill ranged from 0.7 m to 2.3 m.

The depths to the base of the fill varied from 4.9 m to 6.0 m (Elevations 348.5 to 349.6), below the existing road surface.

SPT 'N' values in the cohesionless fill ranged from 9 to 14 blows per 0.3 m of penetration, indicating a loose to compact state. Higher SPT 'N' values, ranging from 89 blows per 0.3 m of penetration to 50 blows per 0.15 m of penetration were noted in the upper frozen gravelly sand fill in Boreholes KT-2 and KT-3.

Within the silty clay fill, the SPT 'N' values ranged from 3 to 14, indicating a soft to stiff consistency, in Boreholes 16-05 and KT-2. In Borehole KT-3, the SPT 'N' values in the frozen silty clay fill ranged from 26 to 66 blows per 0.3 m of penetration. It must be noted that the high SPT 'N' values in the upper sand / clay fill might not be representative, as the sand/silty clay fill was frozen.

The measured moisture content of the fill ranged from 5% to 33%.

The results of grain size distribution analyses conducted on selected samples of the fill are presented on the Record of Borehole sheets included in Appendices A and E and are summarized in the following table. The results from the grain size distribution analyses from Thurber (Borehole 16-05) are presented on Figure B1 in Appendix B.

Soil Particle	**Percentage (%)**	
	Cohesionless Fill	**Cohesive Fill**
Gravel %	1 to 21	0 to 1
Sand %	61 to 82	18 to 46
Silt %	-	24 to 34
Clay %	-	30 to 50
Silt and Clay %	17 to 18	-

Soil Property	Percentage (%)
Liquid Limit	48 - 53
Plasticity Limit	21 - 25

The results of the Atterberg Limits testing indicate the silty clay is medium to high plastic with group symbols CI to CH.

5.3 Peat

A 700-mm thick layer of dark brown peat was contacted surficially in Borehole KT-1, which extended to Elevation 349.5. The peat was described as amorphous containing trace to some sand.

5.4 Silty Clay

Native silty clay was encountered beneath the fill in Boreholes 16-05, KT-2 and KT-3 and below the peat in Borehole KT-1. In Borehole KT-4, the silty clay was contacted surficially. The silty clay contains trace to some sand and trace gravel. Occasional organics were noted within the upper 2.0 m of the silty clay. A clayey silt zone was noted in Borehole KT-1 from 4.1 m to 7.0 m depth (Elevations 346.1 to 343.2).

All the boreholes were terminated within the silty clay at depths ranging from 9.8 m to 15.8 m (Elevations 338.7 to 344.4). A Dynamic Cone Penetration Test was conducted in the inferred silty clay, from the bottom of Borehole 16-05, until reaching refusal of 100 blows per 0.3 m of penetration at a depth of 27.4 m (Elevation 327.1).

SPT ‘N’ values recorded in the native silty clay varied between 3 and 15 blows for 0.3 m penetration. The vane shear test (VST) measured in-situ undrained shear strength was greater than 100 kPa. Based on the SPT and VST data, the consistency of the lower silty clay is typically stiff to very stiff.

Natural moisture contents ranged from 19% to 39%.

The results of grain size distribution analyses and Atterberg Limit tests conducted on selected samples of the silty clay, are presented on the Record of Borehole sheets included in Appendices A and E and are summarized in the following table. The results from the grain size distribution analyses from Thurber (Borehole 16-05) are presented on Figures B2 and B3 in Appendix B.

Soil Particle	Percentage (%)
Gravel	0 to 2
Sand	10 to 18
Silt	25 to 48
Clay	32 to 65
Soil Property	**Percentage (%)**
Liquid Limit	15 to 28
Plasticity Limit	32 to 64

The results of the Atterberg Limits testing indicate the silty clay is medium to high plastic with group symbols CI to CH, with the exception of the low plasticity clayey silt zone (CL) in Borehole KT-1.

5.5 Groundwater Conditions

Groundwater conditions were observed during drilling operations and groundwater levels were measured in the open boreholes upon completion of drilling. The groundwater levels measured in the open borehole are summarized in Table 5.1 below. Groundwater levels reported in the Golder report (Reference 1) are also included.

Table 5.1 – Groundwater Measurements

Borehole	Date	Water Level (m)		Remark
		Depth	Elevation	
16-05	July 24, 2016	10.1	344.4	Open borehole
KT-1	March 21, 2015	0.0	350.2	Reported by Golder
KT-2	February 12, 2015	Dry	-	Reported by Golder
KT-3	February 15, 2015	Dry	-	Reported by Golder
KT-4	March 21, 2015	Dry	-	Reported by Golder

A water level measurement near the inlet of the creek was reported on the drawings provided by Hatch, which indicate a creek water level at Elevation 349.5 m from November 2012. The creek level when frozen, was reported by Golder at Elevation 349.8 in February 2015. The high water level is reported to be at Elev. 350.73 m. 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 silty clay from Borehole 16-05, 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	
			16-05, SS#4, 3.0 m - 3.7 m (Silty Clay)	Kitchen Creek Culvert (Creek Water)
Sulphide	%	mg/L	<0.02	0.04
Chloride	µg/g	mg/L	300	4
Sulphate	µg/g	mg/L	110	<10
pH	No unit	No unit	7.70 to 8.29	7.51
Electrical Conductivity	µS/cm	µS/cm	384	104
Resistivity	Ohms.cm	MOhms.cm	2600	957
Redox Potential	mV	mV	211	370

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. Omar Ali 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. Cory Zanatta, EIT and Ms. R. Palomeque Reyna, P.Eng. The report was reviewed by Mr. Keli Shi, P.Eng., and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.

Cory Zanatta
Geotechnical Engineer-In-Training

Keli Shi, P.Eng.
Geotechnical Engineer

P.K. Chatterji, P.Eng.
Review Principal, Designated MTO Contact

FOUNDATION INVESTIGATION AND DESIGN REPORT
KITCHEN CREEK CULVERT REPLACEMENT
HIGHWAY 11
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G.W.P. No. 6324-14-00 W.P. No. 6324-14-01, SITE No. 45-277C

GEOCRES Number: 52C-51

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 detailed design of the proposed Kitchen Creek 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 contractor. The 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 Structural Design Report, (SDR) (Reference 2). The Structural Design Report provided discussion on the existing structure, discussion of alternatives for the proposed culvert replacement, and recommendations for the preferred alternative.

The existing culvert consists of a 21.0 m long, 5.0 m wide, open footing concrete culvert. The SDR indicates the inlet and outlet invert elevations are 348.78 and 348.76, respectively. The finished road grade at the culvert location is shown at approximate Elev. 354.5 m, which indicates approximately 2.0 m to 2.3 m of fill above the culvert.

In the process of the preliminary design the following options for the replacement structure were considered:

Option 1 – Precast Concrete Closed Box
Option 2 – Precast Open Footing Culvert
Option 3 – Round Corrugated Steel Pipe (CSP) Culvert

As described in the SDR, the preferred structure alternative is Option 3, which is reported to satisfy all of the design criteria and results in a favorable aquatic environment while providing a lightweight, cost effective replacement option. For Option 3 (CSP), the structure would consist of two 25.0 m long, 4.0 m diameter round aluminized or polymer laminated corrugated steel pipes. Option 1 (Concrete Closed Box), also satisfies the design requirements, but it is more expensive. The proposed structure would consist of a single cell precast concrete closed box culvert being 5.4 m wide and 3.0 m high.

The culvert replacement is proposed to be constructed utilizing a traffic staging, which would require installation of a temporary roadway protection system and a temporary stream diversion pipe (CSP).

Preliminary General Arrangement (GA) drawings for both the CSP and concrete closed box options were included in the SDR, which show the proposed replacement culvert and the temporary diversion pipe arrangement. The invert and alignment of the replacement culvert and the finished road grade level will remain largely the same as for the existing culvert. Headwalls are proposed at the north and south ends of the culvert (inlet and outlet).

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. In addition, the existing subsurface information collected during the preliminary investigation and documented in the Geocres Report No. 52C-41 (Reference 1) has been reviewed and incorporated in this report, where appropriate.

The subsurface information, including the Record of Borehole sheets and the Borehole Locations and Soil Strata drawings, from both the current and preliminary investigations should be included in the contract documents.

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 both feasible options, 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.

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 penetration design if this type of culvert were to be considered. Furthermore, it may be difficult to drive sheet piles at this site through the fill, which might contain cobbles and boulders. Therefore, recommendations for this type of culvert have not been developed.

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

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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 and no grade raise is proposed. There is approximately 2.0 m to 2.3 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

Replacement of the culvert with a concrete box culvert on the same alignment is identified in the SDR as a viable alternative for this site. If the replacement culvert will be constructed on the same alignment as the existing culvert with no grade raise and no embankment widening, 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 is approximately 348.8 m. Therefore, the underside of the bedding layer should be placed at or below Elevation 348.5 m. The native soils at that level consist of predominantly firm to stiff silty clay.

The following geotechnical capacities could be used for design of a box culvert of 4 to 5 m in width founded at or below Elev. 348.5 m on the firm to stiff silty clay subgrade:

- Factored Geotechnical Resistance at ULS of 200 kPa
- Geotechnical Resistance at SLS (for up to than 25 mm of settlement) of 125 kPa.

The consequence factor of 1 was utilized in this design adopting the typical consequence level. The geotechnical resistance factor of 0.5 for bearing, and 0.8 for settlement, both adopted for typical degree of understanding, were used to obtain the above values, as per CHBDC 2014, Sec. 6.9.

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.

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 Open Footing Concrete Culvert

Strip footings supporting an open footing concrete culvert should be founded on the firm to stiff silty clay below the frost depth at or below Elev. 346.5 m. The footings should extend below any existing embankment fill and surficial organic materials, where encountered.

The recommended geotechnical resistances at the Ultimate Limit State (ULS) and the geotechnical reaction at Serviceability Limit State (SLS) for the above noted founding elevation, are given below for footing widths of 1 to 2 m:

- Factored Geotechnical Resistance at ULS of 200 kPa
- Geotechnical Resistance at SLS (for up to 25 mm of settlement) of 125 kPa

The above assumes that there is no grade raise. The consequence factor of 1 was utilized in this design adopting the typical consequence level. The geotechnical resistance factor of 0.5 for bearing, and 0.8 for settlement, both adopted for typical degree of understanding, were used to obtain the above values, as per CHBDC 2014, Sec. 6.9.

The resistance values provided 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 Clause 6.10.3 and Clause 6.10.4.

Resistance to lateral forces / sliding resistance between precast concrete and the underlying silty clay should be evaluated in accordance with the CHBDC (2014) assuming an ultimate coefficient of friction of 0.35.

All organic soil and excessively loose/soft material should be removed from the footing subgrade. The founding surface should be protected from softening during construction by placement of a 75 mm mud slab on the prepared bearing surface as soon as practical following inspection and approval.

Scour and erosion protection must be provided for the footings.

9.2.3 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. 348.5, which corresponds to firm to stiff silty clay subgrade.

9.2.4 Culvert Headwall / Wingwalls

The GA drawings in the SDR show a proposed headwall and wingwalls at the inlet and outlet of the replacement culvert. If headwalls and wingwalls are required, consideration may be given to using Retained Soil Systems (RSS) walls or cantilevered concrete walls. RSS walls are more tolerant to settlement.

The borehole information indicates that the founding conditions at the wall locations generally consist of the firm to stiff silty clay deposit.

9.2.4.1 RSS Walls

For RSS walls, the contract drawings should include information on the longitudinal alignment of the wall in plan, the top and base elevations of the wall in profile, cross-sectional space constraints and an NSSP for the RSS wall.

The performance of a RSS is dependent on, among other factors, the characteristics of its foundation. Failure to provide an adequate foundation may lead to settlement and distortion of the RSS and, in severe cases, to possible failure of the system. The foundation of the entire RSS mass must be considered, i.e. from the face of the wall to the furthest extent of the reinforcement.

To provide an acceptable foundation performance, the RSS mass should be founded on a 500 mm thick engineered fill pad resting on the native firm to stiff silty clay subgrade at or below an approximate elevation of 348.3 m or lower. An RSS wall founded on this material may be designed using a factored geotechnical resistance at ULS of 200 kPa and a geotechnical reaction at SLS of 100 kPa (for up to 25 mm of settlement). Engineered fill pads placed under the RSS mass must consist of OPSS PROV Granular A or Granular B Type II compacted to 100% of its SPMDD at a moisture content within 2% of optimum. The engineered pad must be at least 300 mm beyond the limits of the RSS mass and levelling strip.

If these geotechnical resistances are not adequate to support the proposed RSS walls, the bearing capacity may be improved by subexcavation of 1 m of silty clay and replacement with well compacted granular material. In this case, the bearing capacity can be increased to a factored geotechnical resistance at ULS of 200 kPa and a geotechnical reaction at SLS of 125 kPa.

The geotechnical resistances provided above are for concentric, vertical loading. The effects of load inclination and eccentricity need to be taken into account according to the CHBDC (2014) Clauses 6.10.3 and 6.10.4.

The entire block of reinforced earth must be designed against various modes of failure including sliding and overturning. Sliding resistance along the base of the wall may be estimated using an ultimate friction coefficient of 0.45 for an engineered granular fill subgrade.

Topsoil, organics, loose fill, and any soft/wet material must be stripped from the footprint of the RSS. The subgrade under the RSS foundation should be inspected and any soft spots sub-excavated and replaced with compacted granular materials prior to placing fill. The subgrade preparation for the RSS wall must be carried out in the dry.

The proprietary RSS system must meet the Ministry's specifications for performance and appearance. The RSS supplier/designer may specify more stringent criteria or other requirements related to the particular design. The internal stability of the RSS wall must be analyzed by the supplier/designer of the proprietary product selected for this site.

A stability analysis was conducted for the global stability of the proposed approximately 5 m high RSS walls shown on the 100% design drawings provided by Hatch. Figures 1 and 2 in Appendix H show that both the short and long term cases will be stable, with Factors of Safety of 2.07 and 1.67 respectively.

9.2.4.2 Foundation for Concrete Retaining Walls

From a foundation standpoint, concrete retaining walls may be supported on spread footings founded on the firm to stiff silty clay subgrade. The walls should be provided with sufficient frost cover (minimum 2.2 m) and founded at Elevation 346.6 m or lower. A factored geotechnical resistance at ULS of 200 kPa and a geotechnical reaction at SLS of 100 kPa (for up to 25 mm of settlement) may be used for design. A 300 mm thick granular levelling pad should be provided below the footing. Load inclination and eccentricity should also be taken into account as outlined above.

Resistance to lateral forces / sliding resistance between precast concrete and the underlying clay should be evaluated in accordance with the CHBDC (2014) assuming an ultimate coefficient of friction of 0.3 for firm to stiff silty clay.

9.2.5 Frost Cover

The depth of frost penetration at this site is approximately 2.2 m. The pipe and box culvert options do not require frost cover/protection. Frost cover is required for concrete retaining walls if used.

If required at this site, frost treatment/taper for the culvert should be in accordance with OPSD 803.031 for a pipe culvert and with OPSD 803.010 for a box culvert.

9.2.6 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 silty clay.

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.

9.2.7 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 or embankment widening. Since there is no grade raise or widening, minimal post construction settlement is expected at this site. It must be noted that any additional load imposed on the culvert replacement will induce immediate settlement and consolidation settlement of the cohesive soils (firm to stiff silty clay) at this site.

9.3 Construction Considerations

As indicated in the SDR, construction staging will be required to maintain one lane of traffic.

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 silty clay 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 silty clay deposit. It must be noted that during the previous investigation (Reference 1), auger grinding was noted within the fill during the field investigation, which may indicate the presence of cobbles or any obstruction in the fill.

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. Seepage should be anticipated from the embankment fill. 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. STREAM DIVERSION PIPE

The Preliminary General Arrangement drawing indicates a CSP stream diversion pipe located approximately 11.0 m to the north of the centreline of the new culvert. The invert of the diversion pipe is indicated at approximately Elev. 348.8, which corresponds to a firm to stiff silty clay.

Temporary shoring may be required to install the diversion pipe at the proposed depth of approximately 6.0 m.

The CSP 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 802.010. The bedding material should be placed on the prepared subgrade as soon as practical, following its inspection and approval. The subgrade preparation should be carried out in the dry. The prepared subgrade should be protected from disturbance during construction.

12. CULVERT BACKFILL AND LATERAL EARTH PRESSURES

Backfill to the culvert should consist of free-draining, non-frost susceptible granular materials such as Granular A or B Type II conforming to the requirements of OPSS PROV 1010. Reference should be made to the backfill arrangements stipulated in OPSD 802.010, 803.010 or 802.034, as appropriate. Backfilling for the culvert should be in accordance with OPSS PROV 401 for a CSP or OPSS 902 for a box culvert. All fills should be placed in regular lifts and be compacted in accordance with OPSS PROV 501. The backfill should be placed and compacted in simultaneous lifts on both sides of the culvert, and the top of backfill elevation should not differ more than 500 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 12.1 below.

Table 12.1 – Lateral Earth Pressure Coefficients (K)

Loading Condition	OPSS Granular A or Granular B Type II ϕ = 35°; γ = 22.8 kN/m^3		OPSS Granular B Type I (modified) ϕ = 32°; γ = 21.2 kN/m^3	
	Horizontal Backfill	Sloping Backfill (2H:1V)	Horizontal Backfill	Sloping Backfill (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48
At-rest (Restrained Wall)	0.43	0.62	0.47	0.70
Passive	3.7	-	3.3	-

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.

13. SEISMIC CONSIDERATIONS

The seismic site classification for this is site is based on the N_{60} criteria. The harmonic mean of the typical N_{60} values provided above is 15 blows, which corresponds to a Seismic Site Class D in accordance with Table 4.1, Clause 4.4.3.2 of the CHBDC. The peak ground acceleration, PGA, for a 2% in 50 years probability of exceedance at this site is 0.038 g as per the National Building Code of Canada (NBCC).

In accordance with Clause 4.6.5 of the CHBDC 2014, retaining structures should be designed using active (K_{AE}) and passive (K_{PE}) earth pressure coefficients that incorporate the effects of earthquake loading. The coefficients of horizontal earth pressure for seismic loading presented in Table 13.1 may be used:

Table 13.1 – Earth Pressure Coefficients for Earthquake Loading

Condition	Earth Pressure Coefficient (K)	
	OPSS Granular A or Granular B Type II ϕ = 35°, γ = 22.8 kN/m^3	OPSS Granular B Type I (modified) ϕ = 32°, γ = 21.2 kN/m^3
Active (K_{AE})*	0.29	0.33
Passive (K_{PE})	3.6	3.2
At Rest (K_{OE})**	0.51	0.55

* After Mononobe and Okabe, passive case assumes a horizontal surface in front of the wall.
** After Woods

Although the site is underlain by firm to stiff silty clay, in view of the low potential for seismic activity in the area, liquefaction is not considered to be a concern at this site

14. 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 sheet piles, although the sheet piles may be difficult to drive in the fill, which contains possible cobbles and boulders. Suggested wording for an NSSP on obstructions is included in Appendix G.

The soil parameters in Table 14.1 may apply for design of the temporary roadway protection system with horizontal backfill.

Table 14.1 –Soil Parameters for Temporary Protection System Design

Soil Parameter	Existing Fill	Native Silty Sand to Sandy Silt	Native Silty Clay
γ	20 kN/m^3	20 kN/m^3	19 kN/m^3
γ_w	10 kN/m^3	10 kN/m^3	9 kN/m^3
K_a	0.4	0.33	0.4
K_p	2.5	3.0	2.5

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 protection/shoring system is a function of the construction sequence and the relative flexibility of the wall, and these factors have to be considered when designing the shoring system. All protection systems should be designed by a Professional Engineer experienced in such designs, who will determine an appropriate support system.

15. EMBANKMENT RESTORATION

The existing Highway 11 embankment is approximately 3.5 m to 4.0 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 or embankment widening at this site for the culvert replacement, and therefore settlement of the embankment is not a concern. 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, Granular B Type II, or Granular B Type III material. Alternatively, the existing embankment fill may be used above the culvert cover and below the roadbase granular fill, provided it is free of organics, and at a moisture content that is suitable for compaction.

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

16. SCOUR AND EROSION PROTECTION

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

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

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

17. CORROSION AND SULPHATE ATTACK POTENTIAL

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

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

- The potential for soil or surface water corrosion on metal is considered to be mild to moderate.

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

18. 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 creek 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. Suggested wording for an NSSP on obstructions is included in Appendix G.
- 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.

19. CLOSURE

Engineering analysis and preparation of this report was carried out by Ms. R. Palomeque Reyna, P.Eng. and Mr. Keli Shi, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.

Rocío Palomeque Reyna, P.Eng.
Geotechnical Engineer

Keli Shi, P.Eng.
Geotechnical Engineer

P.K. Chatterji, P.Eng.
Review Principal, Designated MTO Contact

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 Sample	GS 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.

<u>UNIFIED SOILS CLASSIFICATION</u>

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILTS AND CLAYS $W_L < 50\%$	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. ($W_L < 30\%$).
		CI	Inorganic clays of medium plasticity, silty clays. ($30\% < W_L < 50\%$).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

RECORD OF BOREHOLE No 16-05

METRIC

W.P. 6324-14-01 | LOCATION Kitchen Creek Culvert Replacement N 5 386 901.4 E 263 794.5 | ORIGINATED BY OA

HWY 11 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY AN

DATUM Geodetic | DATE 2016.07.24 - 2016.07.24 | CHECKED BY MEF

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
354.5	GROUND SURFACE					
0.0	**ASPHALT:** (100mm)					
0.1	**SAND** and **GRAVEL**, Grey, Moist (FILL)	1	GS		○	
353.8 / 0.7	Silty **CLAY**, some sand to sandy, trace gravel, Firm to Stiff, Grey, Moist (FILL)	1	SS	7	○	
		2	SS	14	○	0 46 24 30
352.3 / 2.2	Sandy **SILT**, trace gravel, pieces of wood, Compact, Grey, Wet (FILL)	3	SS	11	○	
351.5 / 3.0	Silty **CLAY**, trace sand, trace gravel, trace to some organics, Soft, Grey, Wet	4	SS	3	○	
349.6 / 4.9	Silty **CLAY**, some sand, trace gravel, Firm to Stiff, Brown to Grey, Moist	5	SS	7	○	
		6	SS	6	├○┤	0 11 38 51
		7	SS	14	○	
		8	SS	7	○	

Elevation scale: 354, 353, 352, 351, 350, 349, 348, 347, 346, 345

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

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 16-05

METRIC

W.P. 6324-14-01	LOCATION Kitchen Creek Culvert Replacement N 5 386 901.4 E 263 794.5	ORIGINATED BY OA
HWY 11	BOREHOLE TYPE Hollow Stem Augers	COMPILED BY AN
DATUM Geodetic	DATE 2016.07.24 - 2016.07.24	CHECKED BY MEF

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

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
	Silty **CLAY**, some sand Firm to Soft Grey Moist							
		9	SS	8	0	13	25	62
	Wet	10	SS	5				
		11	SS	3				
		12	SS	5	0	10	25	65
338.7 15.8	End of sampling at 15.8m and start DCPT							

Elevation scale: 344, 343, 342, 341, 340, 339, 338, 337, 336, 335

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 16-05

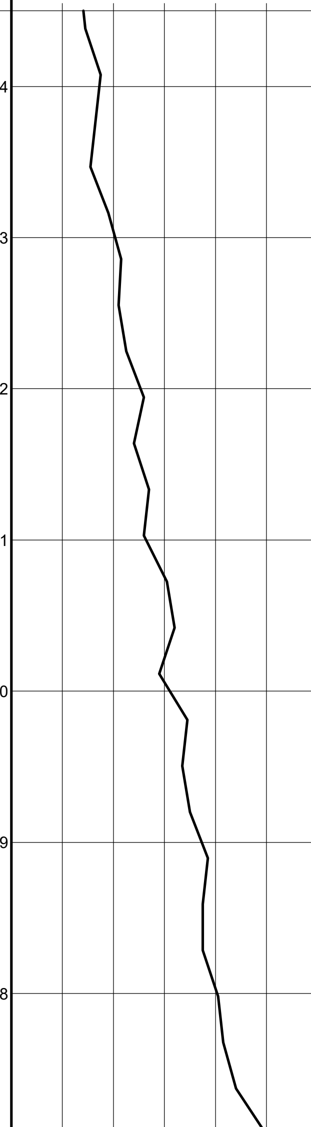
METRIC

W.P. 6324-14-01 | LOCATION Kitchen Creek Culvert Replacement N 5 386 901.4 E 263 794.5 | ORIGINATED BY OA

HWY 11 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY AN

DATUM Geodetic | DATE 2016.07.24 - 2016.07.24 | CHECKED BY MEF

ELEV / DEPTH	SOIL PROFILE – 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
	Continued From Previous Page										
							334				
							333				
							332				
							331				
							330				
							329				
							328				
327.1 / 27.4	END OF BOREHOLE AT 27.4m UPON DYNAMIC CONE PENETRATION REFUSAL. WATER LEVEL AT 10.1m UPON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO 0.1m, THEN ASPHALT TO SURFACE.										



+ ³, × ³: Numbers refer to Sensitivity

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

Appendix B

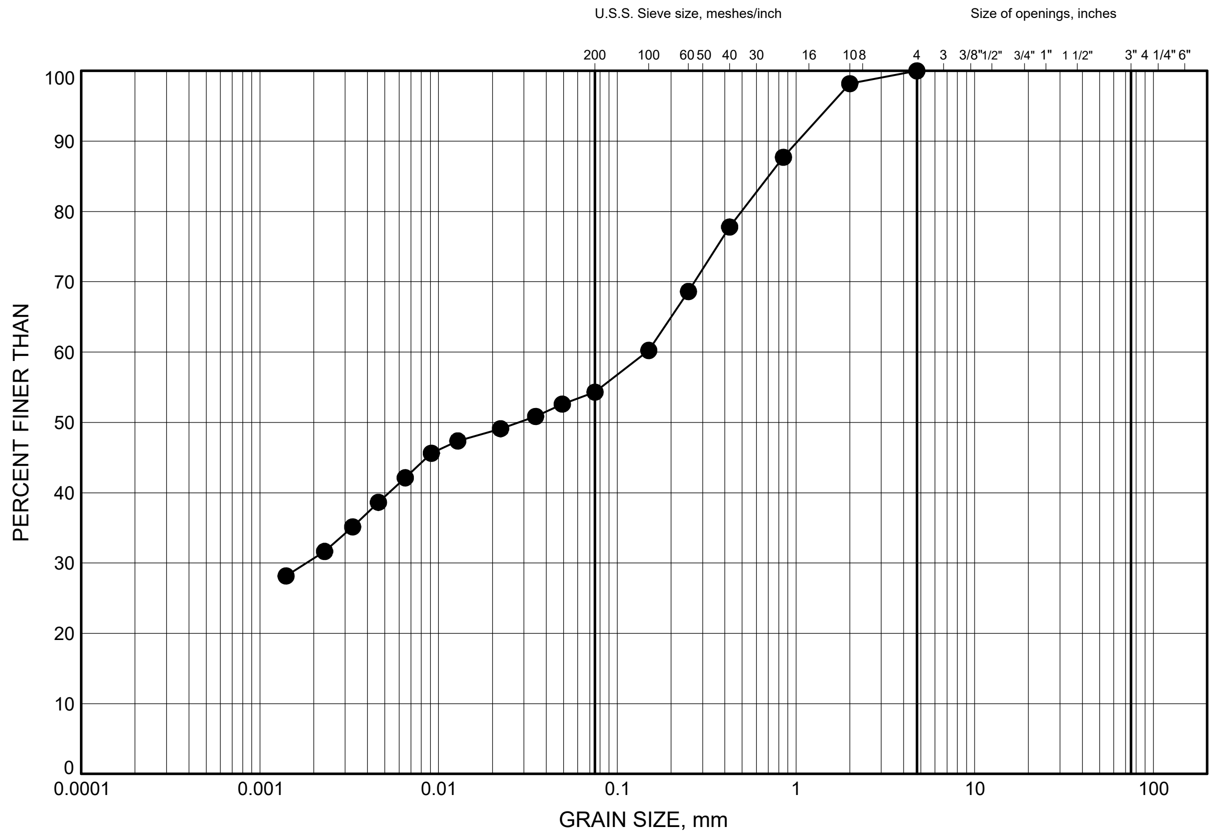
Geotechnical and Analytical Laboratory Test Results

Kitchen Creek Culvert Replacement

GRAIN SIZE DISTRIBUTION

FIGURE B1

Silty CLAY FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-05	1.83	352.67

GRAIN SIZE DISTRIBUTION - THURBER 13004-MTO.GPJ 9/28/16

Date September 2016

W.P. 6324-14-01

THURBER

Prep'd AN

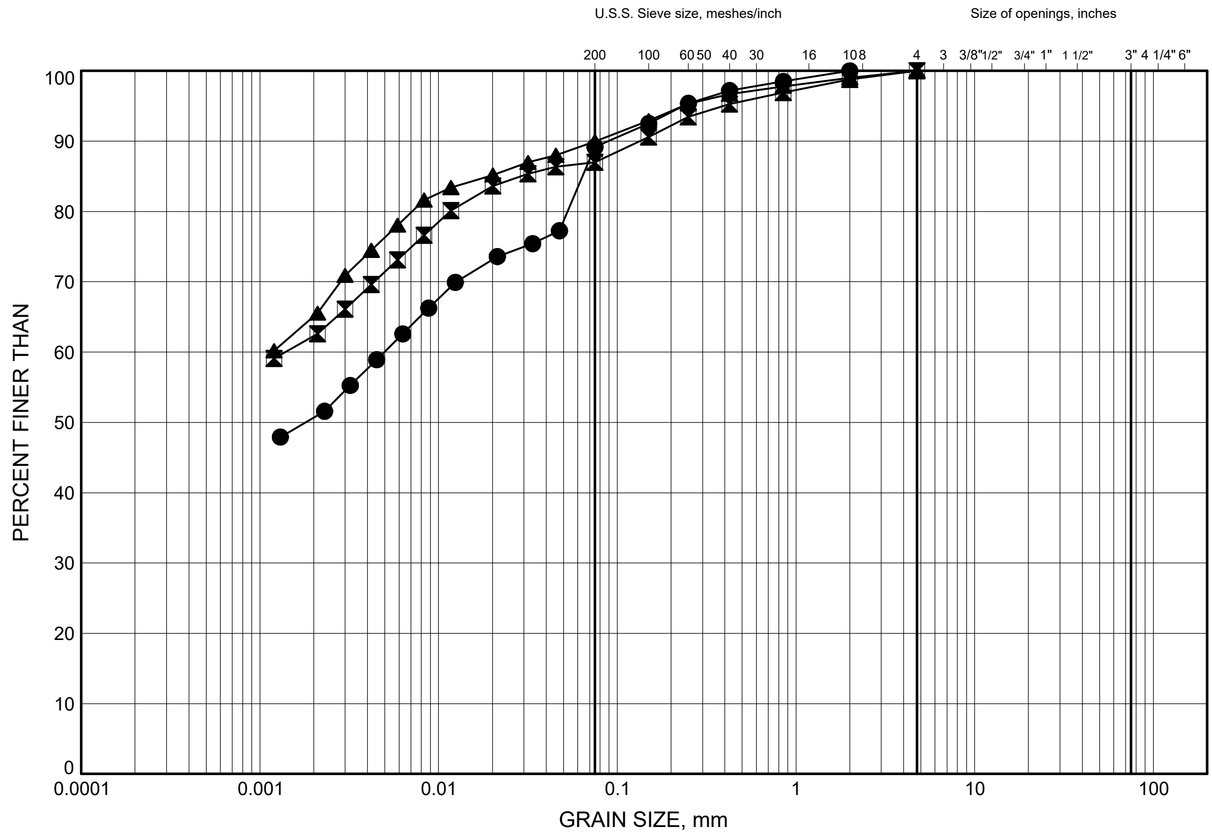
Chkd. RPR

Kitchen Creek Culvert Replacement

GRAIN SIZE DISTRIBUTION

FIGURE B2

Silty CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-05	6.40	348.10
⧗	16-05	10.97	343.53
▲	16-05	15.54	338.96

GRAIN SIZE DISTRIBUTION - THURBER 13004-MTO.GPJ 9/28/16

Date September 2016

W.P. 6324-14-01

THURBER

Prep'd AN

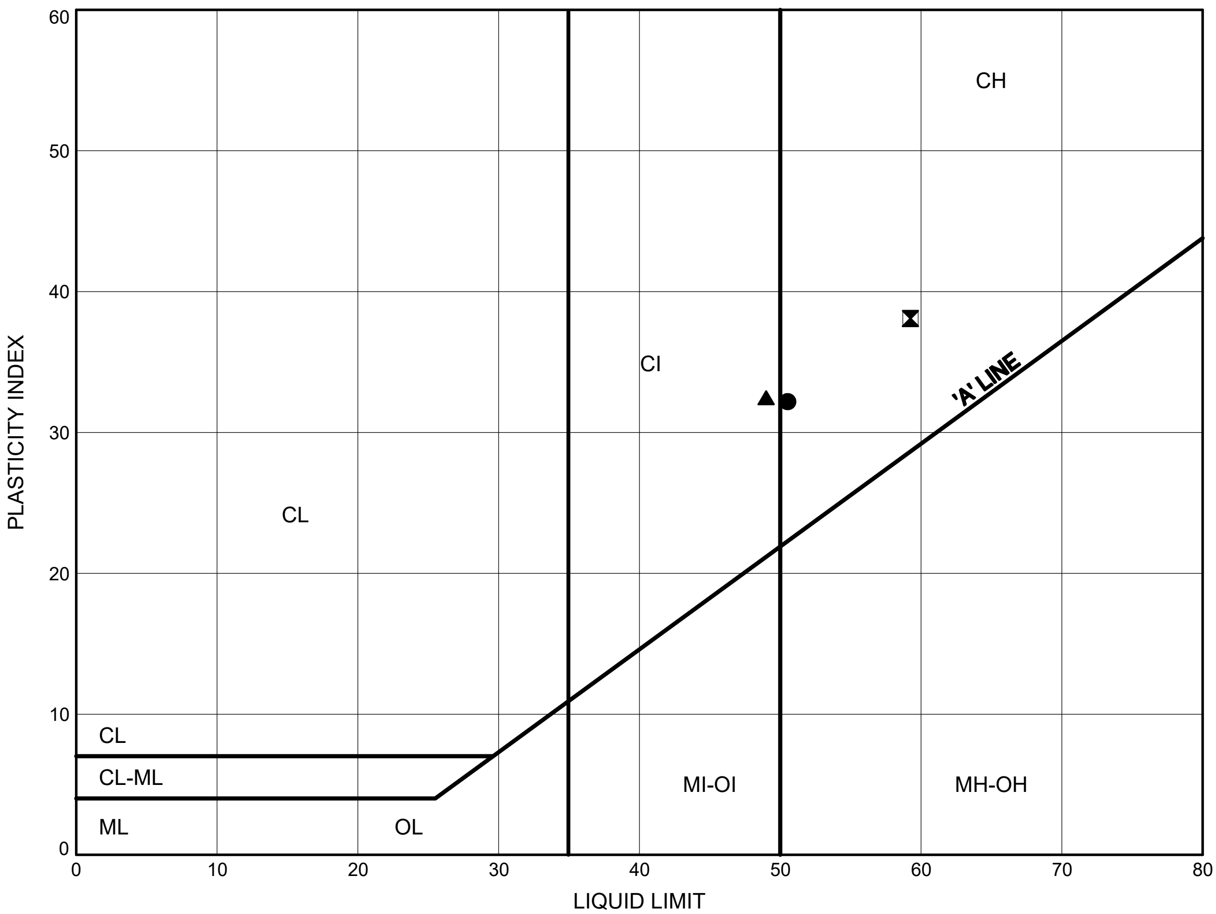
Chkd. RPR

Kitchen Creek Culvert Replacement

ATTERBERG LIMITS TEST RESULTS

FIGURE B3

Silty CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-05	6.40	348.10
⧗	16-05	10.97	343.53
▲	16-05	15.54	338.96

THURBALT 13004-MTO.GPJ 9/28/16

Date September 2016

W.P. 6324-14-01

THURBER

Prep'd AN

Chkd. RPR

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

Project : 13004

09-August-2016

Thurber Engineering Ltd.
Attn : Mark Farrant

103, 2010 Winston Park Drive, Oakville
, L6H 5R7
Phone: 905-829-8666 x 228, Fax:

Date Rec. : 03 August 2016
LR Report: **CA14113-AUG16**
Reference: 13004

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: BH-16-05 SS4 10'-12'**
Sample Date & Time					24-Jul-16
Temperature Upon Receipt [°C]	---	---	---	---	24.2
Corrosivity Index [none]	09-Aug-16	13:32	09-Aug-16	14:29	2
pH [no unit]	08-Aug-16	11:40	09-Aug-16	09:32	7.70
Soil Redox Potential [mV]	08-Aug-16	18:47	09-Aug-16	08:27	211
Sulphide [%]	08-Aug-16	10:07	09-Aug-16	09:35	< 0.02
% Moisture (wet wt) [%]	05-Aug-16	07:02	05-Aug-16	09:08	25.3
pH [no unit]	04-Aug-16	09:56	04-Aug-16	15:49	8.29
Chloride [µg/g]	05-Aug-16	18:51	09-Aug-16	09:15	300
Sulphate [µg/g]	05-Aug-16	18:51	09-Aug-16	09:15	110
Conductivity [uS/cm]	04-Aug-16	09:56	04-Aug-16	15:49	384
Resistivity (calculated) [Ohms.cm]	09-Aug-16	13:31	09-Aug-16	14:29	2600

Deanna Edwards

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

OnLine LIMS

0000751588

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

Temperature of Samples upon receipt 24 degrees C
No 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.

OnLine LIMS

0000751588

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

Project : 13004
LR Report : **CA14113-AUG16**

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
pH	ME-CA-[ENV]EWL-LAK-AN-001	SM 4500

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

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: DIO0053-AUG16												
Chloride	0.4	µg/g	<0.4		0	20	109	80	120	111	75	125
Sulphate	0.4	µg/g	<0.4		3	20	101	80	120	101	75	125
Carbon/Sulphur - QCBatchID: ECS0007-AUG16												
Sulphide	0.02	%	<0.02		NV	20	113	80	120			
Conductivity - QCBatchID: EWL0045-AUG16												
Conductivity	2	uS/cm	2		1	10	99	90	110	NA		
pH - QCBatchID: EWL0045-AUG16												
pH	0.05	no unit	NA		0		100			NA		

OnLine LIMS

0000751588

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

Project : 13004

02-August-2016

Thurber Engineering Ltd.
Attn : Mark Farrant

103, 2010 Winston Park Drive, Oakville
, L6H 5R7
Phone: 905-829-8666 x 228, Fax:

Date Rec. : 27 July 2016
LR Report: **CA15442-JUL16**
Reference: 13004

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: Kitchen Creek Culvert
Sample Date & Time					N/A
Temperature Upon Receipt [°C]	---	---	---	---	21.0
Corrosivity Index [none]	02-Aug-16	13:33	02-Aug-16	13:33	16
pH [no unit]	27-Jul-16	06:49	28-Jul-16	15:17	7.51
Redox Potential [mV]	27-Jul-16	13:39	02-Aug-16	10:54	370
Sulphide [mg/L]	29-Jul-16	13:00	29-Jul-16	12:19	0.04
Chloride [mg/L]	27-Jul-16	11:45	28-Jul-16	10:10	4
Sulphate [mg/L]	27-Jul-16	12:42	29-Jul-16	14:35	< 10
Conductivity [uS/cm]	27-Jul-16	06:49	28-Jul-16	15:17	104
Resistivity (calculated) [MOhms.cm]	02-Aug-16	13:27	02-Aug-16	13:27	957

Temperature of Samples upon receipt 15 degrees C
No 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.

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

OnLine LIMS

0000746055

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

Method Descriptions

Parameter	SGS Method Code	Reference Method Code
Anions by discrete analyzer	ME-CA-[ENV]EWL-LAK-AN-026	US EPA 325.2
Anions by discrete analyzer	ME-CA-[ENV]EWL-LAK-AN-026	US EPA 375.4
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

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

Project : 13004
LR Report : **CA15442-JUL16**

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 discrete analyzer - QCBatchID: DIO0458-JUL16												
Chloride	1	mg/L	<1		1	20	96	80	120	91	75	125
Sulphate	1	mg/L	1		1	20	93	80	120	109	75	125
Conductivity - QCBatchID: EWL0410-JUL16												
Conductivity	2	uS/cm	< 2		0	10	98	90	110	NA		
pH - QCBatchID: EWL0385-JUL16												
pH	0.05	no unit	NA		0		100			NA		
Redox Potential - QCBatchID: EWL0394-JUL16												
Redox Potential	no	mV	NA		1	20	107	80	120	NA		
Sulphide by SFA - QCBatchID: SKA0211-JUL16												
Sulphide	0.02	mg/L	<0.02		0	20	92	80	120	NV	75	125

Appendix C

Site Photographs

Photo 1: Kitchen Creek Culvert, looking west

Photo 2: Kitchen Creek Culvert, north side of the culvert (inlet)

Photo 3: Kitchen Creek Culvert, looking east

Photo 4: Kitchen Creek Culvert, outlet (south side)

Photo 5: Kitchen Creek Culvert, inlet (north side)

Appendix D

Borehole Locations and Soil Strata Drawing

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

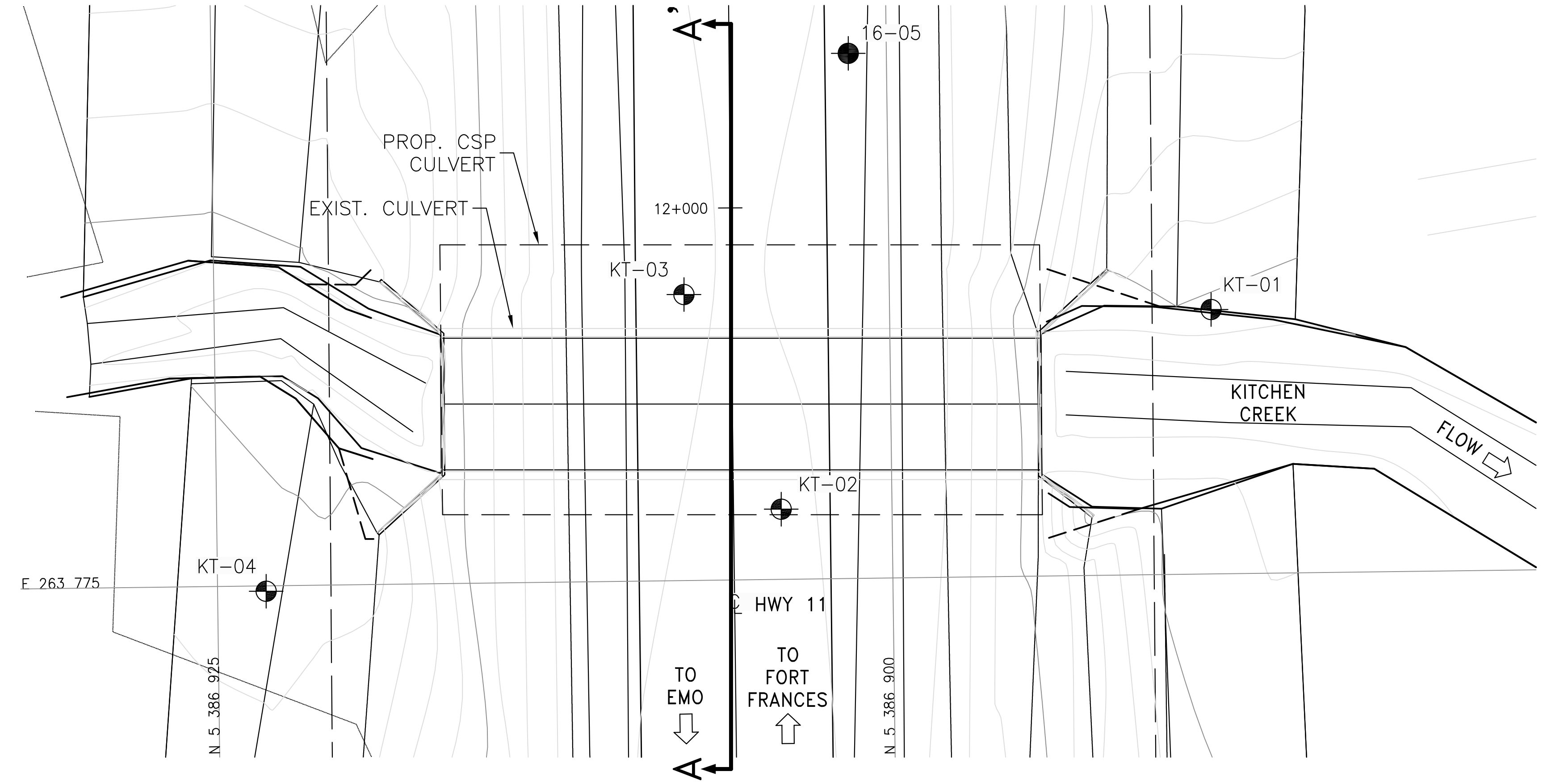
CONT No 2016-6035
WP No 6324-14-01

KITCHEN CREEK CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET 9

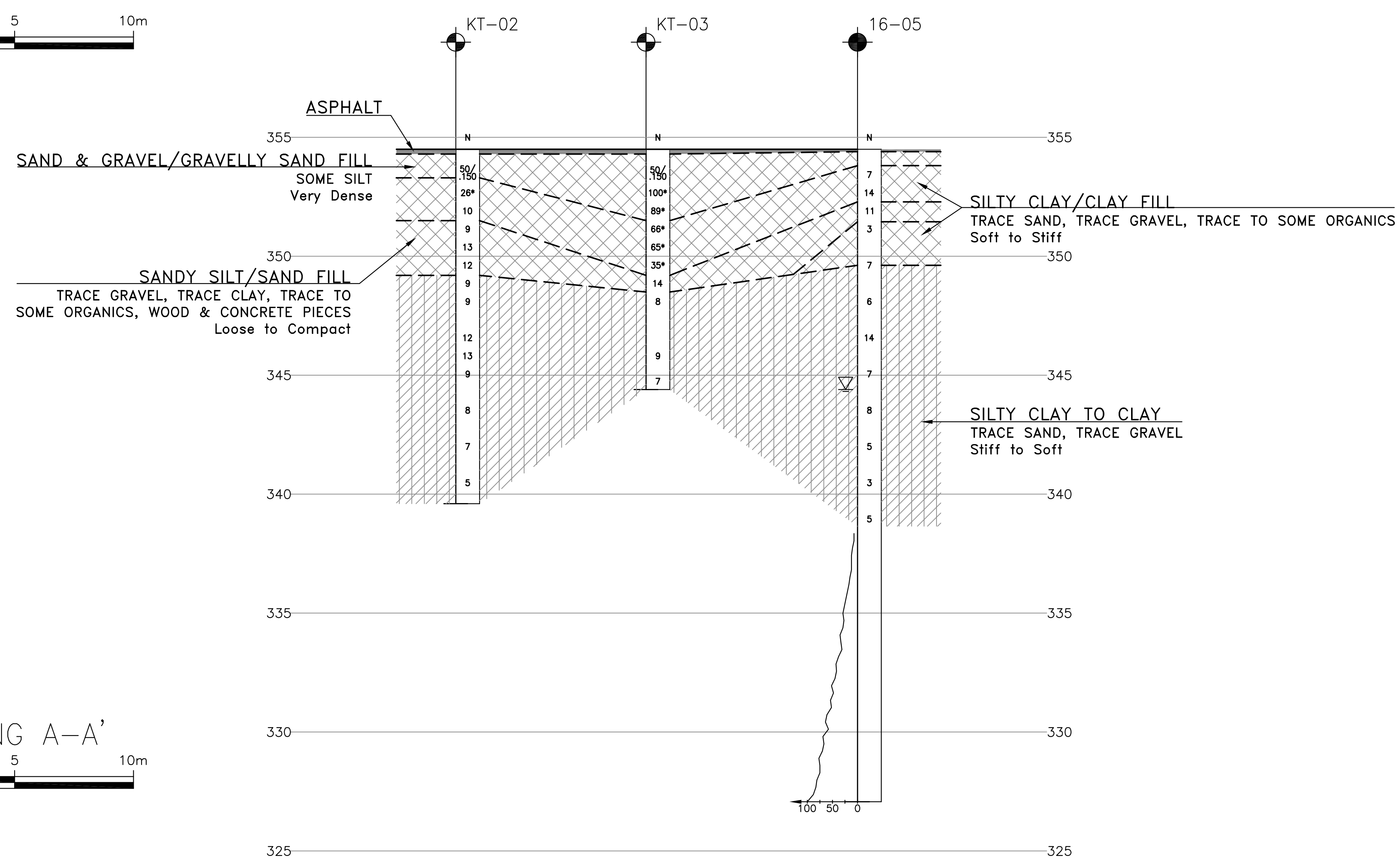
HATCH

THURBER ENGINEERING LTD.



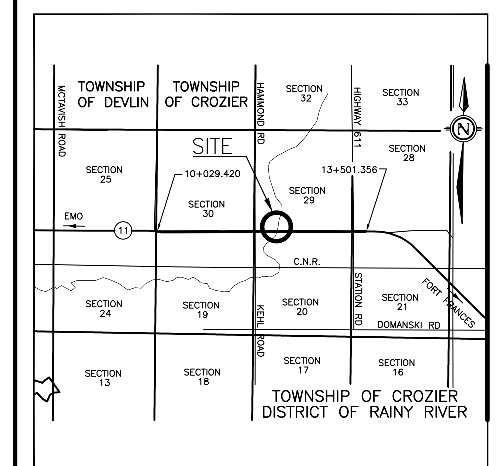
PLAN

SCALE 1:250 (5 0 5 10m)



PROFILE ALONG A-A'

SCALE 1:250 (5 0 5 10m)



KEYPLAN

LEGEND

(symbol)	Borehole (Current Investigation)
(symbol)	Borehole (Previous Investigation)
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
16-05	354.5	5 386 901.4	263 794.5
KT-01	350.2	5 386 888.1	263 784.8
KT-02	354.5	5 386 904.1	263 777.6
KT-03	354.5	5 386 907.6	263 785.6
KT-04	350.9	5 386 923.2	263 774.8

-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) * Values are not representative as soil was frozen

GEOCRES No. 52C-51

REVISIONS	DATE	BY	DESCRIPTION
DESIGN RPR	CHK RPR	CODE	LOAD	DATE JAN 2017
DRAWN AN	CHK	SITE	STRUCT	DWG 2

FILENAME: H:\Drafting\13000\13004\Ted13004-PLPR-KitchenCreekCulvert.dwg
PLOTDATE: 1/13/2017 10:45 AM

Appendix E

Factual Data from Golder Foundation Investigation Report

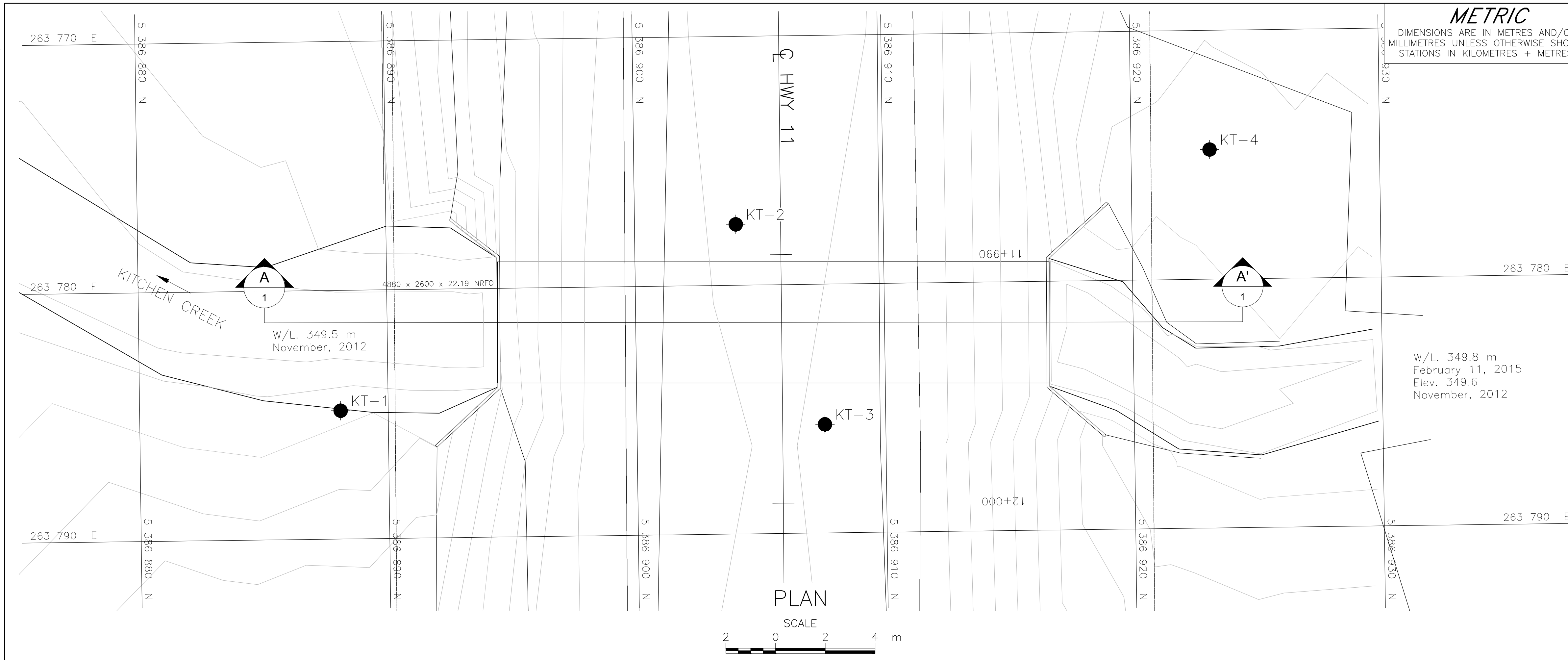
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

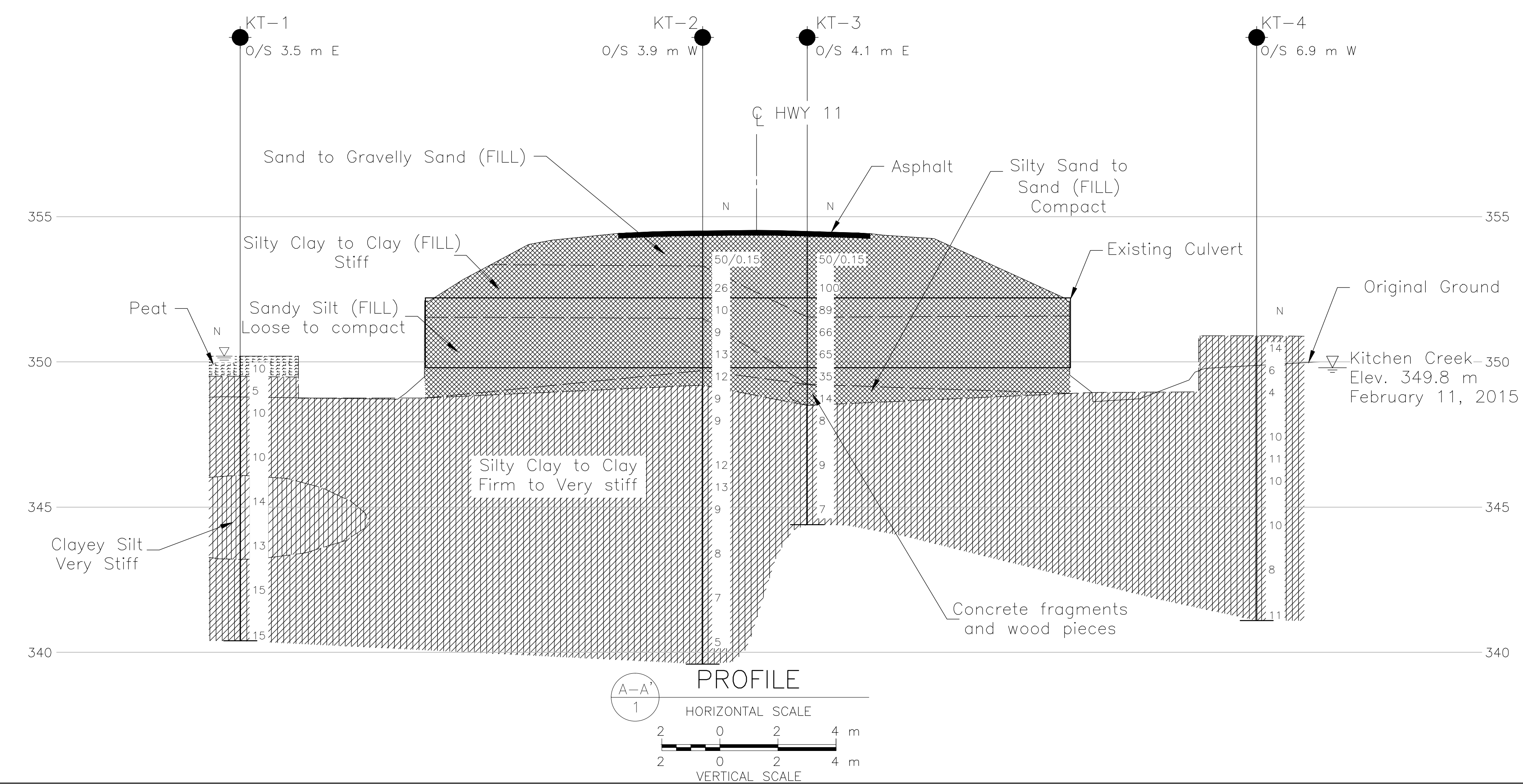
CONT No.
GWP No. 6324-14-00

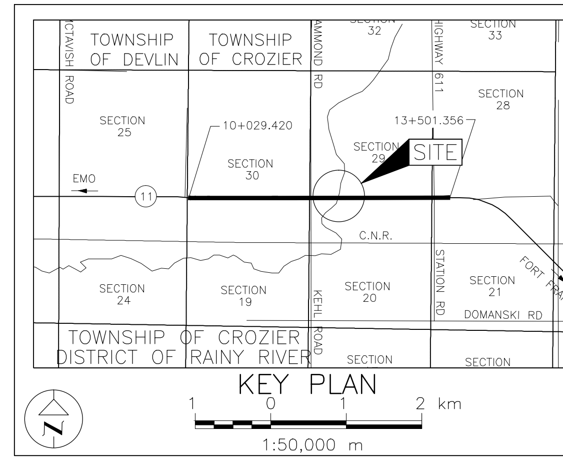
SHEET

HIGHWAY 11
KITCHEN CREEK CULVERT STA 11+993
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates







KEY PLAN
1 0 1 2 km
1:50,000 m

LEGEND

- ● Borehole
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- ▽ WL upon completion of drilling

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
KT-1	350.2	5386888.1	263784.8
KT-2	354.5	5386904.1	263777.6
KT-3	354.5	5386907.6	263785.6
KT-4	350.9	5386923.2	263774.8

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by MTO, drawing file no. BC301111, received FEB 20, 2015.

LICENSED PROFESSIONAL ENGINEER S.E.M. POOT 90471921 SEP 08, 2015 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER J.M.A.COSTA SEP 08, 2015 PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

Geocres No. 52C-41

HWY. 11		PROJECT NO. 1411523	DIST.
SUBM'D. AC	CHKD.	DATE: 8/25/2015	SITE: 45-277/C
DRAWN: JJL	CHKD. SEMP	APPD. JMAC	DWG. 1

MINISTRY OF TRANSPORTATION, ONTARIO

PLOT DATE: September 3, 2015

RECORD OF BOREHOLE No KT-1

 METRIC

PROJECT 1411523
G.W.P. 6324-14-00
LOCATION N 5386888.1; E 263784.8
ORIGINATED BY MR
DIST HWY 11
BOREHOLE TYPE Portable equipment - NW Casing and Wash Boring
COMPILED BY AC
DATUM GEODETIC
DATE March 20 and 21, 2015
CHECKED BY SEMP

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
350.2	GROUND SURFACE
0.0	PEAT, Amorphous, trace to some sand Dark brown Frozen
349.5 / 0.7	SILTY CLAY to CLAY, trace to some sand, trace gravel Firm to very stiff Grey Wet Trace organics above 1.5 m depth. Clayey silt zone encountered from 4.1 m to 7.0 m depth. Very stiff
340.4 / 9.8	END OF BOREHOLE Note: 1. Water level at ground surface (Elev. 350.2 m) upon completion of drilling.

SAMPLES

NUMBER	TYPE	"N" VALUES	Water Content (%)	Remarks & Grain Size Distribution (%) GR SA SI CL
1	SS	10		
2	SS	5	Plotted (plastic limit – natural moisture – liquid limit)	OC=3.3%
3	SS	10		
4	SS	10		
5	SS	14	Plotted	2 18 48 32
6	SS	13		
7	SS	15	Plotted	
8	SS	15		

Shear strength: >100 (at approx. elev. 347.6 and 346.1)

Ground water conditions: water level at ground surface.

Elevation scale: 350, 349, 348, 347, 346, 345, 344, 343, 342, 341

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED; 20 40 60 80 100
PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60
UNIT WEIGHT γ kN/m³

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

Golder Associates

RECORD OF BOREHOLE No KT-2

 METRIC

PROJECT 1411523

G.W.P. 6324-14-00 LOCATION N 5386904.1; E 263777.6 ORIGINATED BY DM

DIST ___ HWY 11 BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers COMPILED BY AC

DATUM GEODETIC DATE February 12, 2015 CHECKED BY SEMP

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, × REMOULDED (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
354.5	GROUND SURFACE
0.0	ASPHALT (170 mm)
0.2	Sand to gravelly, some silt (FILL) Brown Frozen Augers Grinding from surface to 1.2 m depth on inferred cobbles.
353.3 1.2	Clay, some sand, trace gravel (FILL) Stiff Brown to grey Frozen* to moist Augers grinding between 1.5 m and 3.0 m depth on inferred cobbles.
351.5 3.0	Sandy silt, trace clay, trace organics (FILL) Loose to compact Brown to grey Moist
349.7 4.8	Sand, some silt (FILL) Compact Brown to grey Moist
349.2 5.3	CLAY, trace to some sand, trace gravel Stiff to very stiff Grey Wet
339.6	

NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
1	SS	50/0.15				
2	SS	26*	1	18	31	50
3	SS	10				
4	SS	9				
5	SS	13				
6 A/B	SS	12	1	82	(17)	
7	SS	9				
8	SS	9				
9	SS	12	2	13	34	51
10	SS	13				
11	SS	9				
12	SS	8	1	11	34	54
13	SS	7				
14	SS	5				

Elevation scale: 354, 353, 352, 351, 350, 349, 348, 347, 346, 345, 344, 343, 342, 341, 340

>100

>100

Continued Next Page

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

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 03/09/15 DATA INPUT:

Golder Associates

RECORD OF BOREHOLE No KT-2

 METRIC

PROJECT 1411523
G.W.P. 6324-14-00 LOCATION N 5386904.1; E 263777.6 ORIGINATED BY DM
DIST HWY 11 BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers COMPILED BY AC
DATUM GEODETIC DATE February 12, 2015 CHECKED BY SEMP

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 × REMOULDED (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 ---										
14.9	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling.										

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

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 31/08/15 DATA INPUT:

RECORD OF BOREHOLE No KT-3

 METRIC

PROJECT 1411523
G.W.P. 6324-14-00
LOCATION N 5386907.6; E 263785.6
ORIGINATED BY DM
DIST HWY 11
BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers
COMPILED BY AC
DATUM GEODETIC
DATE February 15, 2015
CHECKED BY SEMP

ELEV / DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
354.5	GROUND SURFACE									
0.0	ASPHALT (170 mm)									
0.2	Sand to gravelly sand, some silt (FILL) Brown to grey Frozen* Augers grinding in the upper 0.8 m on inferred cobbles.	1	SS	50/0.15*		354				
		2	SS	100*		353				
		3	SS	89*		352				21 61 (18)
351.5 / 3.0	Silty clay with sand, trace organics (FILL) Grey Frozen	4	SS	66*		351				
		5	SS	65*						0 34 34 32
		6	SS	35*		350				
349.2 / 5.3	Silty sand, trace to some clay, trace organics, trace concrete fragments, decomposed wood pieces (FILL) Compact Black Wet	7	SS	14		349				
348.5 / 6.0	CLAY, trace to some sand Stiff to very stiff Grey Wet Sand interlayers in Sample 8.	8	SS	8		348				0 10 33 57
		9	SS	9		347				
						346	>100			
		10	SS	7		345				
344.4 / 10.1	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling.						>100			

Legend: ○ UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; × REMOULDED. Water content: PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L.

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

Golder Associates

RECORD OF BOREHOLE No KT-4

 METRIC

PROJECT 1411523
G.W.P. 6324-14-00
LOCATION N 5386923.2; E 263774.8
ORIGINATED BY MR
DIST HWY 11
BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers
COMPILED BY AC
DATUM GEODETIC
DATE March 21, 2015
CHECKED BY SEMP

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
350.9	GROUND SURFACE
0.0	CLAY, trace to some sand Stiff to very stiff Grey Frozen* to wet Brown, trace to some organics noted from ground surface to 2.1 m depth.
341.1 9.8	END OF BOREHOLE Note: 1. Borehole dry upon completion of drilling.

SAMPLES

NUMBER	TYPE	"N" VALUES
1	SS	14*
2	SS	6*
3	SS	4
4	SS	10
5	SS	11
6	SS	10
7	SS	10
8	SS	8
9	SS	11

STRAT PLOT | GROUND WATER CONDITIONS | ELEVATION SCALE: 350, 349, 348, 347, 346, 345, 344, 343, 342

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100 — >100 (at approx. elev. 348.2)

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

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60

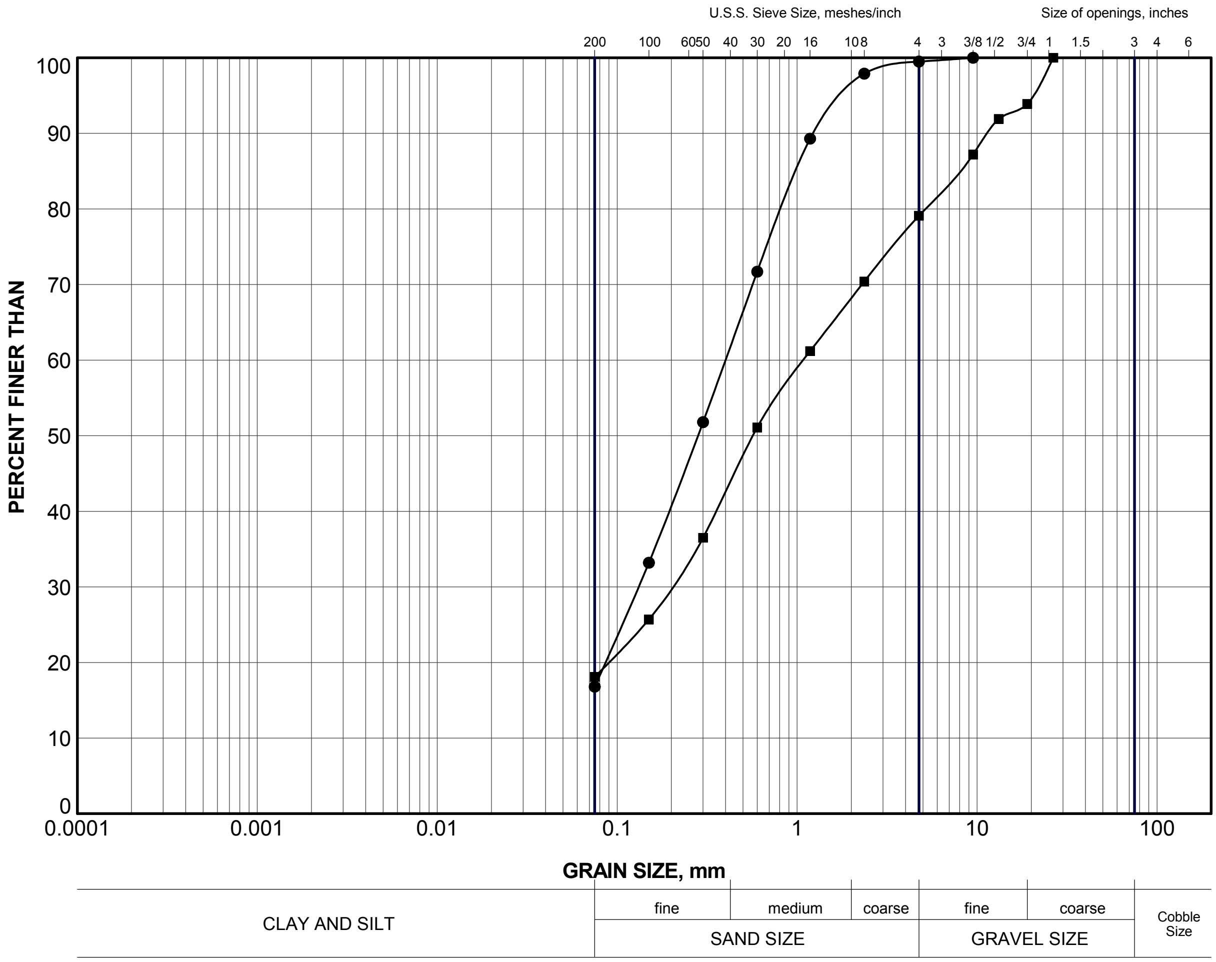
UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)

GR	SA	SI	CL
0	10	35	55

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

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 31/08/15 DATA INPUT:



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	KT-2	6B	349.5
■	KT-3	3	351.9

PROJECT

HIGHWAY 11
KITCHEN CREEK CULVERT STA 11+993

TITLE

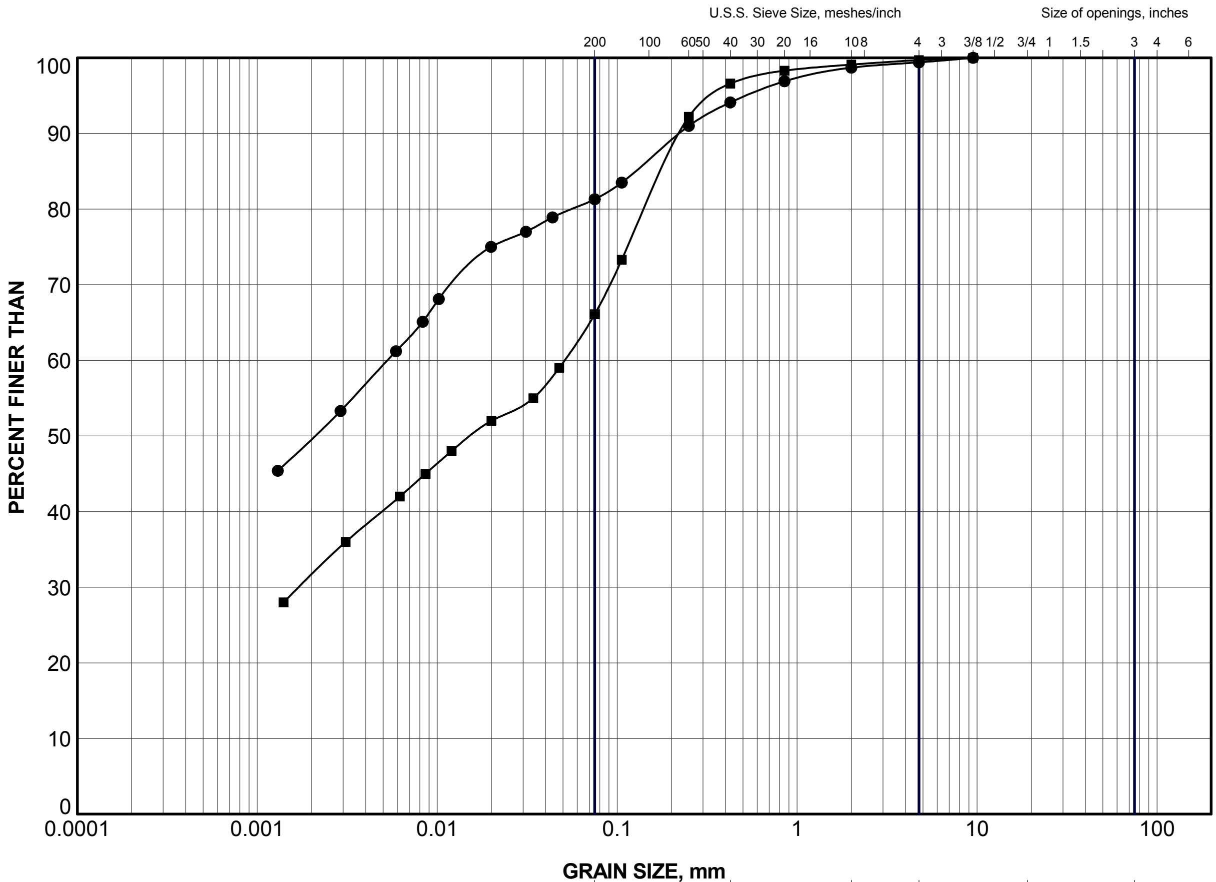
GRAIN SIZE DISTRIBUTION

SAND to GRAVELLY SAND (FILL)

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		1411523	FILE No.	1411523.GPJ
DRAWN	TB	Jun 2015	SCALE N/A	REV.
CHECK	SEMP	Jun 2015	FIGURE B1	
APPR	JMAC	Jun 2015		

SUD-MTO GSD (NEW) GLDR_LDN.GDT



CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	KT-2	2	352.7
■	KT-3	5	350.4

PROJECT

HIGHWAY 11
KITCHEN CREEK CULVERT STA 11+993

TITLE

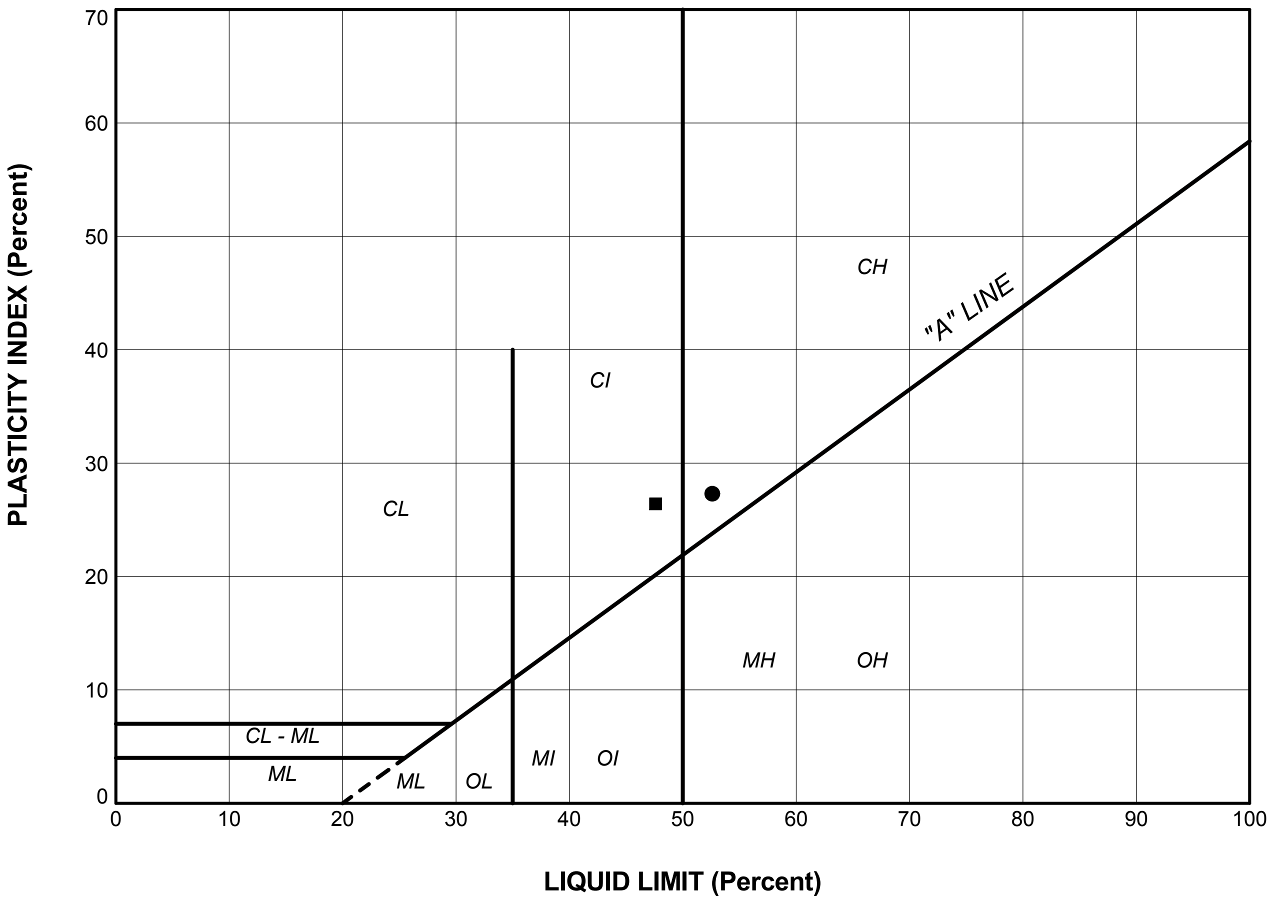
GRAIN SIZE DISTRIBUTION

SILTY CLAY with SAND to CLAY (FILL)

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		1411523	FILE No. 1411523.GPJ
DRAWN	TB	Jun 2015	SCALE N/A REV.
CHECK	SEMP	Jun 2015	
APPR	JMAC	Jun 2015	FIGURE B2

SUD-MTO GSD (NEW) GLDR_LDN.GDT



SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	KT-2	2	52.6	25.3	27.3
■	KT-3	5	47.6	21.2	26.4

PROJECT

HIGHWAY 11
KITCHEN CREEK CULVERT STA 11+993

TITLE

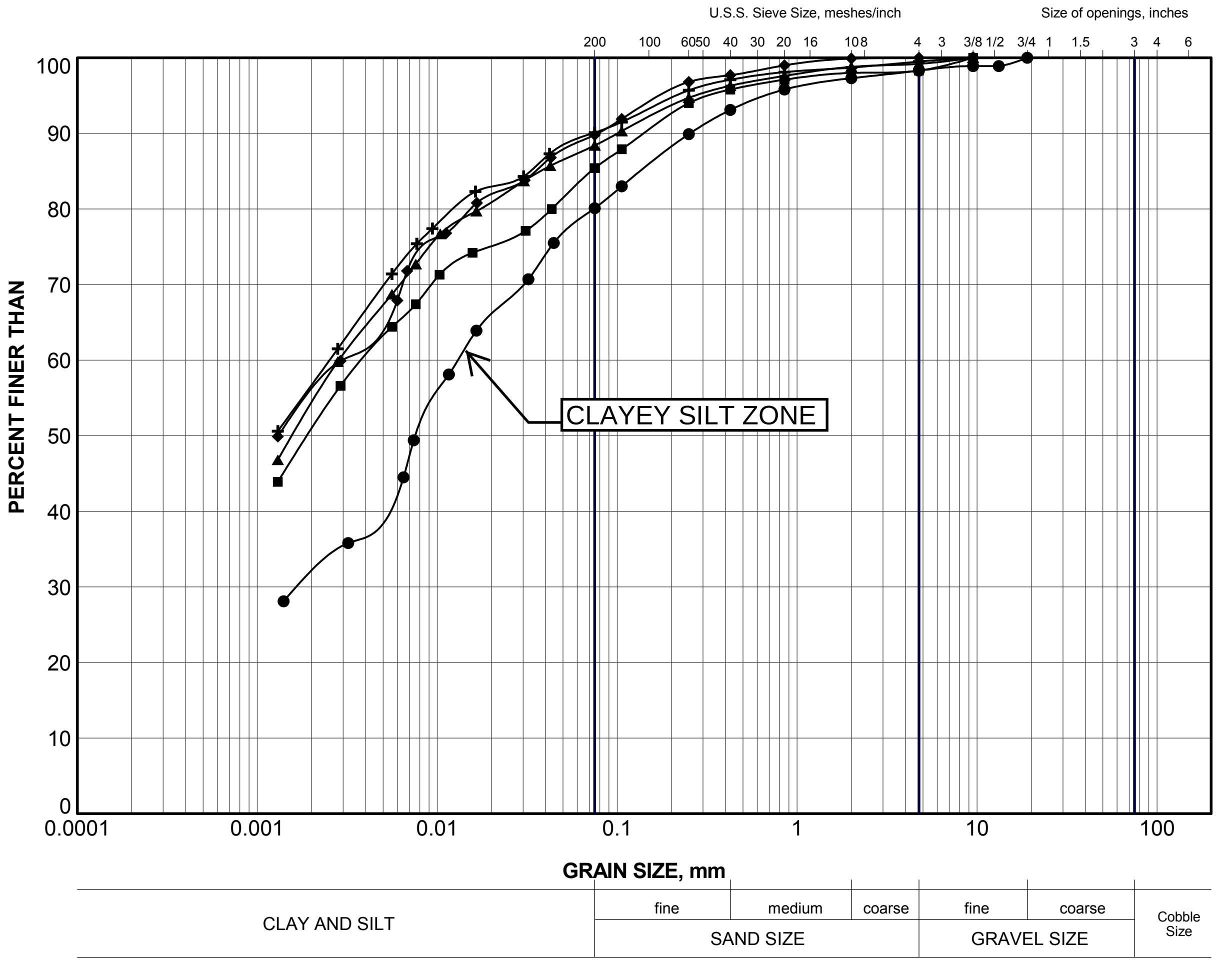
PLASTICITY CHART

SILTY CLAY with SAND to CLAY (FILL)

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		1411523	FILE No.	1411523.GPJ
DRAWN	TB	Jun 2015	SCALE N/A	REV.
CHECK	SEMP	Jun 2015		
APPR	JMAC	Jun 2015	**FIGURE B3**	

SUD-MTO PL (NEW) GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	KT-1	5	345.3
■	KT-2	9	346.6
▲	KT-2	12	343.5
+	KT-3	8	348.1
◆	KT-4	4	347.6

PROJECT

HIGHWAY 11
KITCHEN CREEK CULVERT STA 11+993

TITLE

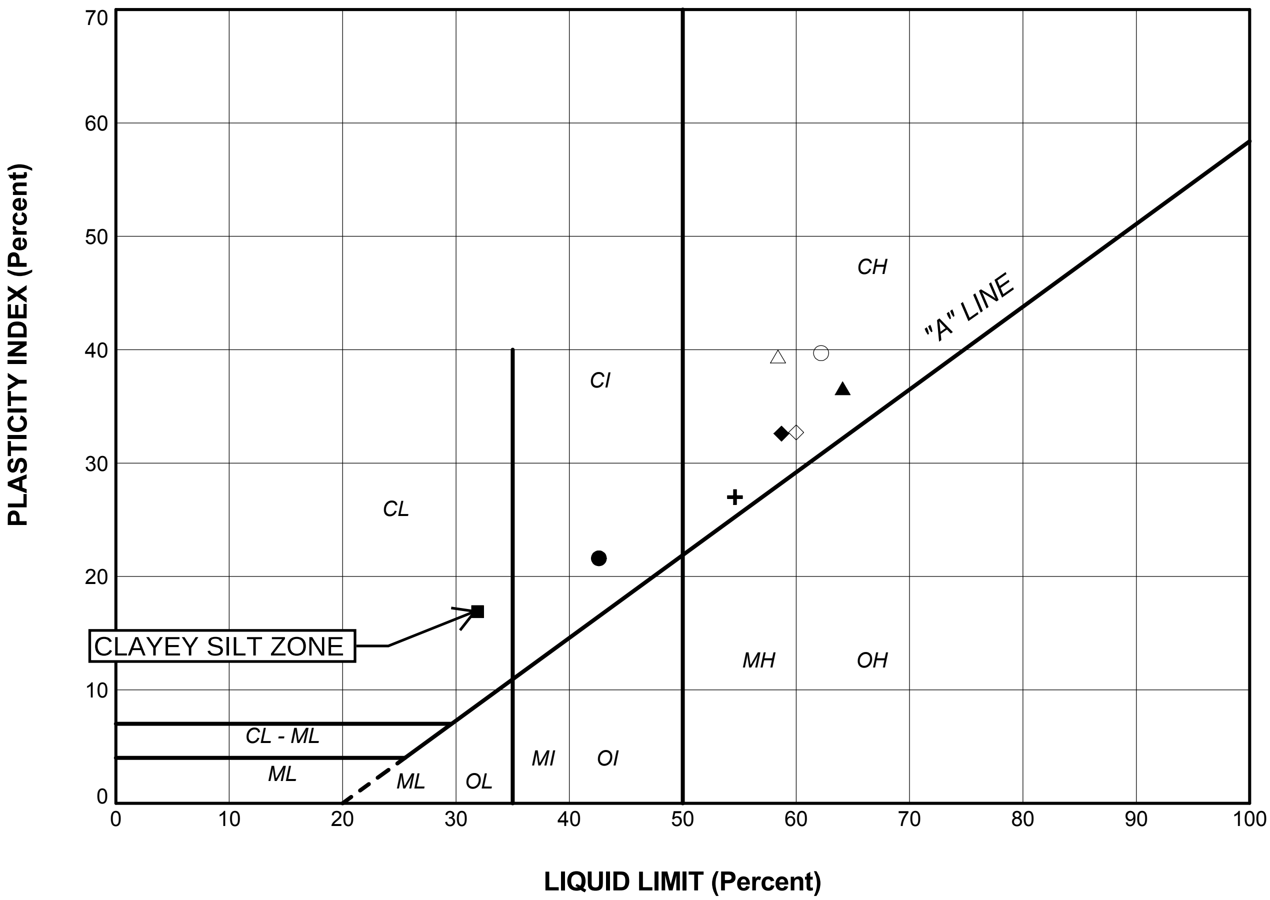
GRAIN SIZE DISTRIBUTION

CLAY

PROJECT No.		1411523	FILE No.	1411523.GPJ
DRAWN	TB	Jun 2015	SCALE N/A	REV.
CHECK	SEMP	Jun 2015	FIGURE B4	
APPR	JMAC	Jun 2015		

Golder Associates
SUDBURY, ONTARIO

SUD-MTO GSD (NEW) GLDR_LDN.GDT



SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	KT-1	2	42.6	21.0	21.6
■	KT-1	5	31.9	15.0	16.9
▲	KT-1	7	64.1	27.5	36.6
+	KT-2	9	54.6	27.6	27.0
◆	KT-2	12	58.7	26.1	32.6
◇	KT-3	8	60.0	27.3	32.7
○	KT-4	4	62.2	22.5	39.7
△	KT-4	6	58.4	19.0	39.4

PROJECT
HIGHWAY 11
KITCHEN CREEK CULVERT STA 11+993

TITLE
PLASTICITY CHART
SILTY CLAY to CLAY

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		1411523	FILE No.	1411523.GPJ
DRAWN	TB	Jun 2015	SCALE N/A	REV.
CHECK	SEMP	Jun 2015	FIGURE B5	
APPR	JMAC	Jun 2015		

SUD-MTO PL (NEW) GLDR_LDN.GDT

Appendix F

Foundation Comparison

COMPARISON OF FOUNDATION ALTERNATIVES

<table>
<tr><th>Concrete Box Culvert</th><th>Concrete or Corrugated
Steel Pipe (CSP) Culvert</th><th>Concrete
Open Footing Culvert</th></tr>
<tr><td>Advantages:

i. Relatively rapid installation and less disturbance to subgrade soils if pre-cast segments are used.

ii. Less stringent requirement for soil geotechnical resistances as loading is spread over a larger area.

iii. Segmental option can accommodate potential differential settlement along culvert axis.</td><td>Advantages:

i. Ease of construction.

ii. Less stringent requirement for soil geotechnical resistances.

iii. Segmented pipes can accommodate potential differential settlement along culvert axis

iv. Concrete or steel pipes may be more cost effective than concrete box or open footing culverts.</td><td>Advantages:

i. Conventional construction.

ii. Possibly less disturbance of creek channel / less environmental issues such as those involving spawning fish species.</td></tr>
<tr><td>Disadvantages:

i. More expensive than a concrete pipe or CSP culvert.

ii. Large excavation through approx. 5 m of fill required to install culvert.

iii. Relatively high roadway protection system required.</td><td>Disadvantages:

i. Steel pipes may have shorter design life than concrete culverts.

ii. Multiple pipes needed to meet hydraulic requirements.

iii. Large excavation through approx. 5 m of fill required to install pipes.

iv. Relatively high roadway protection system required.</td><td>Disadvantages:

i. Requires deeper excavation and potentially longer dewatering requirements.

ii. Cannot tolerate differential settlement.</td></tr>
<tr><td>FEASIBLE</td><td>FEASIBLE</td><td>NOT RECOMMENDED</td></tr>
</table>

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 PROV 539
- OPSS PROV 804
- OPSS 902
- OPSS PROV 1010
- OPSS PROV 1205
- OPSS 1860
- 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 will lead to subgrade softening. The dewatering system must be effective to maintain the water level at a minimum depth of 0.5 m below the final subgrade level throughout construction. The dewatering system must remain operational and effective until the culvert is installed and backfilled.

3. Suggested Wording for NSSP on Obstructions

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

Appendix H

Figures

Name: RSS Wall Model: Mohr-Coulomb Unit Weight: 22 kN/m³ Cohesion: 200 kPa Phi: 35 °
Name: Granular Fill Material Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 32 °
Name: Native Silty Clay-Undrained Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion: 75 kPa Phi: 0 °
Name: Bedding Material Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 35 °

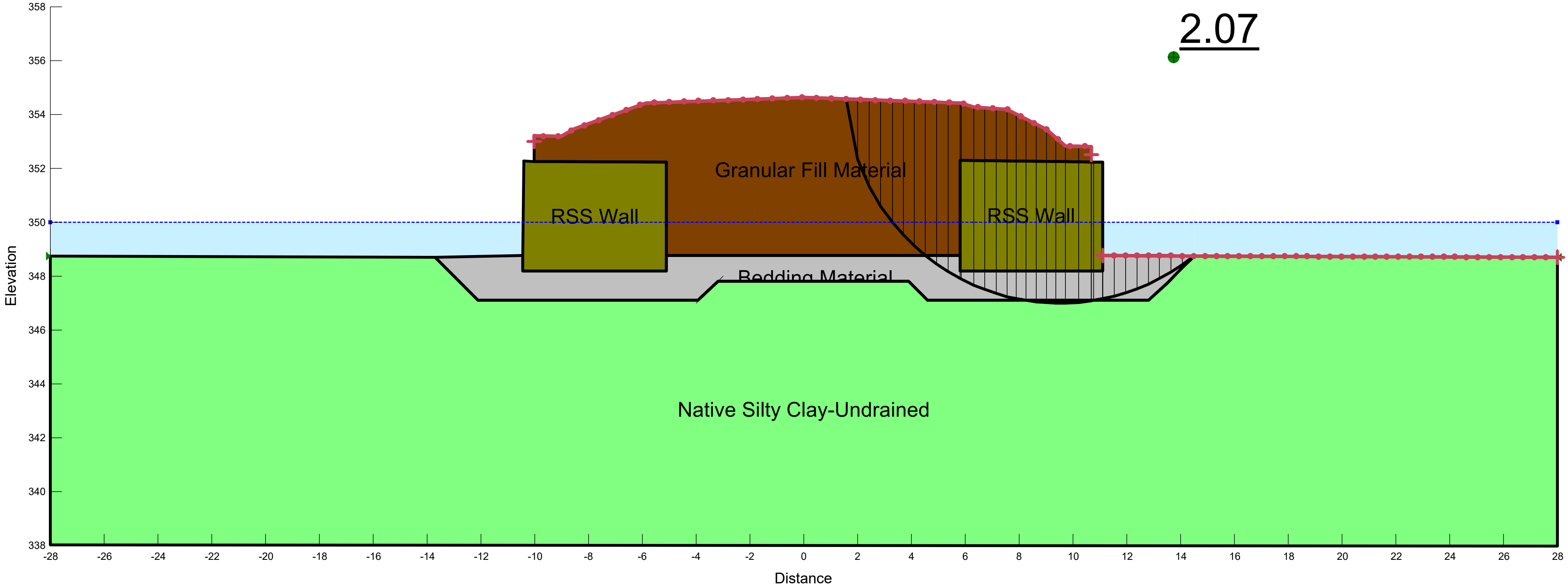


Figure 1: Kitchen Creek Culvert - Slope Stability Analysis
Short Term Condition

Name: RSS Wall Model: Mohr-Coulomb Unit Weight: 22 kN/m³ Cohesion: 200 kPa Phi: 35 °
Name: Granular Fill Material Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 32 °
Name: Native Silty Clay-Drained Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion: 5 kPa Phi: 27 °
Name: Bedding Material Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 35 °

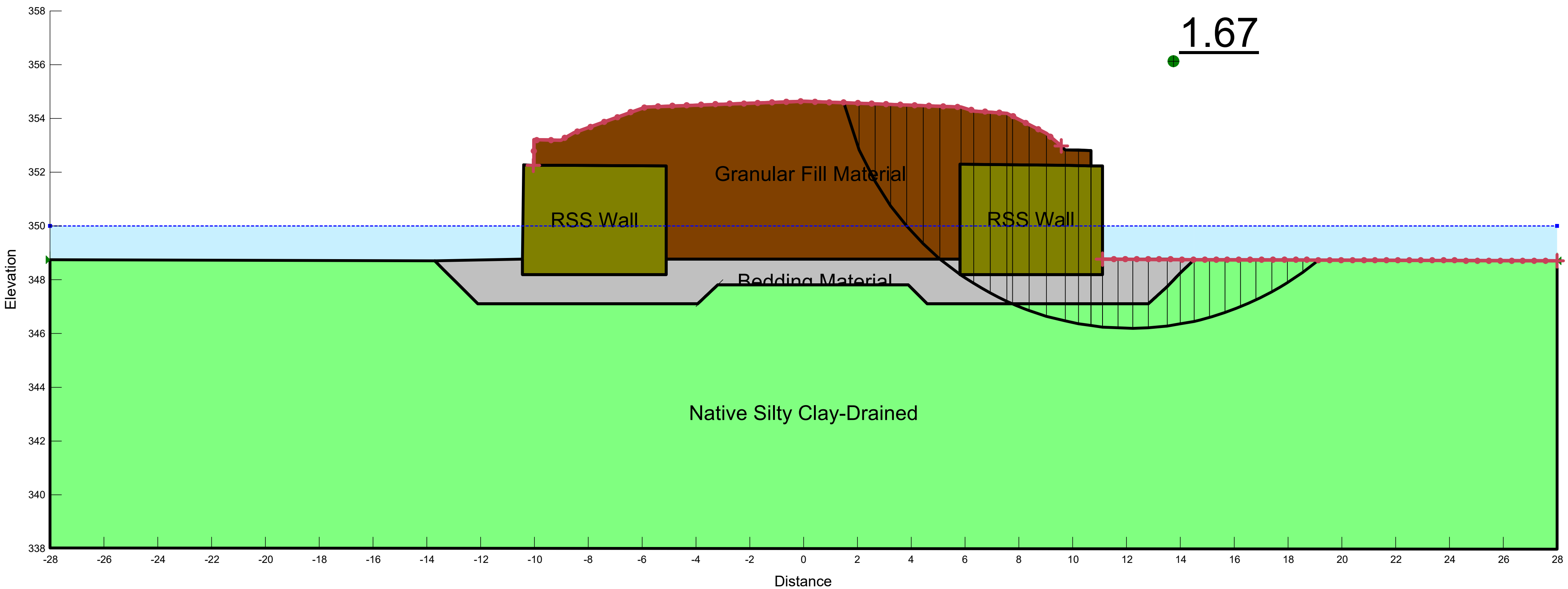


Figure 2: Kitchen Creek Culvert - Slope Stability Analysis
Long Term Condition