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FOUNDATION INVESTIGATION AND DESIGN REPORT
TURNER CREEK CULVERT REPLACEMENT
HIGHWAY 602
DISTRICT OF RAINY RIVER
TOWNSHIP OF AYLSWORTH, ONTARIO

G.W.P. No. 6324-14-00, W.P. No. 6341-14-01, SITE No. 45-279/C

GEOCRES Number: 52C-53

Report

to

HATCH

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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 Turner Creek Culvert on Highway 602, located west of Fort Francis, in the Township of Aylsworth, in the District of Rainy River, Ontario.

The purpose of this investigation was to explore the subsurface conditions at the culvert location to supplement the existing information obtained during the preliminary design of the project 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, Turner Creek Culvert, Highway 602, District of Rainy River, Township of Aylsworth", prepared by Golder Associates (Golder), dated September 25, 2015; G.W.P. 6341-14-00. (Reference 1). The information presented in this report was reviewed and incorporated in the current report, as appropriate.

- Structural Design Report, Turner Creek Culvert, Site No. 45-279C, Highway 602, 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. The Record of Borehole sheets from the Golder report are attached in Appendix E. The subsurface information, including the Record of Borehole sheets and the Borehole Locations and Soil Strata drawings, from both the current investigation and the Golder preliminary Foundation Investigation and Design Report (FIDR) should be included in the contract documents. It should be noted that Golder is solely responsible for the subsurface information provided in the preliminary FIDR.

2. SITE DESCRIPTION

The site is located on Highway 602, approximately 5.7 km west of the junction of Highway 613 and Highway 602 near Fort Francis, within the Township of Aylsworth, in the District of Rainy River, Ontario. The culvert allows Turner Creek to flow in a southerly direction under Highway 602. Highway 602 generally runs in an approximate east-west direction at the culvert site.

The Structural Design Report (SDR) provided to Thurber by Hatch indicates that the existing structure is a 28.0 m long, 3.0 m wide, open footing concrete culvert. The highway embankment is approximately 7 m high, and there is 3.2 m of fill above the culvert. A Biennial Inspection on November 27, 2013 indicated that the components of the structure were in generally good to poor condition, with a wide crack at the centre of the culvert barrel, wide cracking at the footing, and horizontal cracking on the east wall. The inlet and outlet were noted to be in fair to poor condition with some spalling, scaling, delamination, efflorescence, and concrete disintegration. A 2015 Ontario Structure Inspection Manual (OSIM) report, subsequently reported the culvert structure to be in overall poor condition, with undermining of the foundation at the inlet, and erosion at all four corners of the approach embankments.

The grade level of Highway 602 at the existing culvert is at an approximate Elevation of 335.6 m. The culvert invert is approximate at Elevation 328.8 m at the inlet (north end) and 328.7 m at the outlet (south end). The creek water level was measured at Elevations 331.5 m and 329.6 m by others in June, 2014 and November, 2014, respectively. The creek ice elevation was at Elevation 330.4 m as measured by Golder in March, 2015.

The lands surrounding Turner Creek and the culvert at the site predominantly consist of agricultural lands with a few forested areas. Turner Creek discharges into Rainy River approximately 450 m south of the culvert. Rainy River runs in a generally east-west direction near the site. The lands surrounding the site are relatively flat with elevations between 334 m and 336 m.

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

Based on published geological information, the culvert lies in an area of fine-grained, undifferentiated till, predominantly silty clay to silt matrix, bordering on glaciolacustrine plain deposits of silt and clay. Bedrock at the site is identified as consisting of various metasedimentary rock types.

3. INVESTIGATION PROCEDURES

The borehole investigation and field testing program for this project was carried out on July 20 and 21, 2016, and consisted of drilling and sampling one (1) borehole, designated as Borehole 16-06. Borehole 16-06 was located on the westbound lane of Highway 602, approximately 10 m west of the centreline of the existing culvert, near the alignment of the proposed creek diversion pipe.

Borehole 16-06 was advanced to a depth of approximately 18.9 m (Elevation 316.6 m) below the existing road surface elevation. A Dynamic Cone Penetration Test (DCPT) was carried out below the sampled portion of the borehole to a cone refusal depth of 28.3 m (Elevation 307.2 m) below the existing grade.

The approximate location of the borehole is shown on the Borehole Locations and Soil Strata Drawing included in Appendix D.

Utility clearances were obtained prior to the start of drilling. The ground surface elevations for the boreholes were derived from cross sections and topographic drawings provided to Thurber by Hatch. The coordinate system MTM NAD 83, Zone 16 was used for the borehole.

A rubber track mounted CME 55 drill rig was used to advance Borehole 16-06 using hollow stem augers. Samples of the overburden soils were obtained from the boreholes 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 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 boreholes and processed the recovered soil samples for transport to Thurber's laboratory for further examination and testing.

Groundwater conditions were observed in the open borehole throughout the drilling operations and 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	Sampled Borehole Depth / Base Elevation (m)	Piezometer Tip Depth / Elevation (m)	Completion Details
16-06	18.9/316.6	None installed	Borehole backfilled with bentonite holeplug and auger cuttings to 0.1 m, then asphalt to surface.

The previous investigation by Golder included four (4) boreholes, numbered TR-1 to TR-4. Boreholes TR-1 and TR-4 were advanced at the toe of the embankment slope near the culvert inlet and outlet to depths of approximately 6.7 m (Elevations 324.8 and 325.5 m), and Boreholes TR-2 and TR-3 were advanced from the existing highway platform to depths of approximately 23.9 m and 23.5 m (Elevations 311.7 and 312.0 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.

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 boreholes from the current and previous investigations consisted of asphalt pavement overlying granular fill and silty clay embankment fill, underlain by native sandy silty clay till. Descriptions of the individual strata are presented below.

5.1 Pavement Structure

Boreholes 16-06, TR-2 and TR-3 were drilled from the paved platform of Highway 602 and the pavement structure consisted of approximately 25 mm to 40 mm of asphalt over approximately 0.7 to 0.8 m of granular base material, consisting of sand and gravel to sand with some gravel.

5.2 Silty Clay Fill

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

- A layer of brown to grey silty clay fill containing trace sand to sandy, trace gravel, and trace wood and organics, was contacted below the road base granular fill, at depths ranging from 0.7 m to 0.8 m (Elev. 334.7 to 334.9 m) in Boreholes 16-06, TR-2 and TR-3. In Borehole TR-1, the silty clay fill was encountered surficially. The silty clay fill ranged in thickness from 1.4 m to 4.2 m.

- A 300 mm thick layer of sand and gravel fill was encountered below the silty clay fill at 2.3 m depth (Elev. 333.2 m) in Borehole 16-06.

The depth to the base of the fill varied from 1.4 m to 4.9 m (Elev. 330.1 to 332.9 m).

SPT 'N' values recorded in the silty clay fill typically ranged from 3 to 8 blows for 0.3 m of penetration. Higher SPT 'N' values ranging from 11 to 76 blows per 0.3 m of penetration were noted in the upper frozen fill in Boreholes TR-1 to TR-3. An SPT 'N' value of 48 blows per 0.3 m of penetration was also measured at the base of the silty clay fill in Borehole 16-06. Vane shear tests (VST) conducted in the silty clay fill in Borehole TR-2 measured in-situ undrained shear strength in the range of 91 to greater than 100 kPa. Based on the SPT and VST data, the consistency of the silty clay fill ranges from soft to hard.

The underlying sand and gravel fill was compact, with an SPT 'N' value of 21 blows for 0.3 m of penetration.

The measured moisture content of the ranged from 21% to 38% in the silty clay fill, and was 6% in the sand and gravel fill.

The results of a grain size distribution analysis and Atterberg Limits tests conducted on selected samples of the silty clay 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 Borehole 16-16 are presented on Figure B1 in Appendix B.

Soil Particle	**Percentage (%)**
Gravel	5
Sand	33
Silt	38
Clay	24
Soil Property	**Percentage (%)**
Liquid Limit	85 to 88
Plasticity Limit	27 to 29

The results of the Atterberg Limits testing indicate the silty clay fill is highly plastic with a group symbol of CH.

5.3 Sandy Silty Clay Till

A deposit of brown to grey sandy silty clay till containing trace gravel was encountered in all boreholes beneath the fill layers, and at the ground surface in Borehole TR-4. Till formations are known to contain cobbles and boulders. The sandy silty clay till ranged in thickness from 15.2 m to 17.6 m in Boreholes TR-2 and TR-3, and extended to depths of 20.1 to 21.3 m (Elev. 314.2 to 315.5 m).

Boreholes TR-1 and TR-4 were terminated within the silty clay till at 6.7 m depth (Elev. 324.8 and 325.5 m). The sampled portion of Borehole 16-06 was terminated within the silty clay till at 18.9 m depth (Elev. 316.6 m).

SPT 'N' values recorded in the cohesive till ranged from 4 to 16 blows for 0.3 m of penetration. VST in-situ undrained shear strength measurements ranging from 72 kPa to greater than 100 kPa. Based on the SPT and VST data, the consistency of the silty clay till is typically stiff to very stiff. Natural moisture contents ranged from 19% to 23%.

The results of grain size distribution analyses and Atterberg Limit tests conducted on selected samples of the silty clay till 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 and Atterberg Limits from Borehole 16-06 are presented on Figures B2 and B3 in Appendix B.

Soil Particle	**Percentage (%)**
Gravel	0 to 4
Sand	26 to 34
Silt	27 to 40
Clay	26 to 44
Soil Property	**Percentage (%)**
Liquid Limit	30 to 41
Plasticity Limit	14 to 25

The results of the Atterberg Limits tests indicate that the silty clay till has low to medium plasticity with group symbols of CL to CI.

5.4 Silty Clay

A deposit of silty clay was encountered below the till in Boreholes TR-2 and TR-3 at depths of 20.1 m to 21.3 m (Elev. 315.5 and 314.2 m), respectively. The silty clay generally contains trace sand and is grey in colour. Boreholes TR-2 and TR-3 were terminated within the silty clay layer at depths of 23.9 m and 23.5 m depth (Elev. 311.7 and 312.0 m).

SPT 'N' values recorded in the silty clay were 6 blows for 0.3 m of penetration. VST values of measured in-situ undrained shear strength ranged from 89 kPa to 96 kPa. Based on the SPT and VST data, the consistency of the clay is typically stiff. The natural moisture content was measured as 57%.

The results of grain size distribution analyses and Atterberg Limit tests conducted on a sample of the silty clay, are presented on the Record of Borehole sheets included in Appendix E and are summarized in the following table.

Soil Particle	Percentage (%)
Gravel	0
Sand	2
Silt	21
Clay	77
Soil Property	**Percentage (%)**
Liquid Limit	81
Plasticity Limit	29

The results of the Atterberg Limits test indicates that the silty clay layer is highly plastic with a group symbol of CH.

5.5 Groundwater Conditions

Groundwater conditions were observed during drilling operations and in the open boreholes upon completion of drilling. The groundwater levels reported in the Golder report are summarized in Table 5.1 below.

Table 5.1 – Groundwater Measurements

Borehole	Date	Water Level (m)		Remark
		Depth	Elevation	
TR-1	March 15, 2015	Dry	-	Reported by Golder
TR-2	March 13, 2015	4.8	330.8	Reported by Golder
TR-3	March 14, 2015	5.0	330.5	Reported by Golder
TR-4	March 22, 2015	0.0	332.2 [(1)]	Reported by Golder

[(1)] Borehole TR-4 was advanced using NW casing and wash boring techniques. As such, the water level may not be representative of in situ groundwater conditions.

A water level measurement near the inlet of the creek was reported on the drawings provided by Hatch, which indicate a creek level at Elevation 331.5 m on June 18, 2014 and 329.6 m on November 9, 2014. The creek level when frozen, was reported by Golder at Elevation 330.4 in March 2015.

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 16-06, 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	
			16-06, SS#5, 4.6 m – 5.2 m (Silty Clay Till)	Turner Creek Culvert (Creek Water)
Sulphide	%	mg/L	<0.02	0.03
Chloride	µg/g	mg/L	11	4
Sulphate	µg/g	mg/L	150	<10
pH	No unit	No unit	7.85 to 8.58	7.14
Electrical Conductivity	µS/cm	µS/cm	187	98
Resistivity	Ohms.cm	MOhms.cm	5350	1020
Redox Potential	mV	mV	240	252

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.

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

8. GENERAL

This report provides an interpretation of the geotechnical data in the factual report, and presents foundation design recommendations for detailed design of the proposed Turner Creek Culvert replacement on Highway 602, located west of Fort Frances, in the Township of Aylsworth, Rainy River 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 28.0 m long, 3.0 m wide, open footing concrete culvert. The SDR indicates that the inlet and outlet invert elevations are 328.8 and 328.7, respectively. The top of obvert is at approximate Elev. 332.4 m. The finished road grade at the culvert location is shown at approximate Elev. 335.6 m, which results in approximately 3.2 m of fill above the culvert.

The height of the highway embankment is approximately 7 m.

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

Option 1 – Precast Concrete Closed Box Culvert
Option 2 – Precast Open Footing Metal Box 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 a 32.8 m long, 4.0 m diameter round aluminized or polymer laminated corrugated steel pipe. The SDR also identifies Option 1 (Concrete Closed Box), as a viable culvert replacement alternative, with some advantages over Option 3, although it is more expensive. Both of the CSP and concrete closed box options are discussed in Section 9 below, as well as other potential replacement alternatives.

The culvert replacement is proposed to be constructed utilizing a detour route and a temporary stream diversion pipe (CSP). Recommendations for a traffic staging option, with a temporary roadway protection system, are also included in this report.

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. Wingwalls are proposed at the south end of the culvert (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 Draft Preliminary Foundation Investigation and Design Report prepared by Golder (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
- 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 the CSP or pre-cast box culverts are both feasible options, based on the following considerations:

- Pre-cast box culvert or pipe culverts 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 culverts, resulting in shorter durations for dewatering and construction;
- A segmental box or pipe structure can accommodate some potential differential settlement along the culvert axis.

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

9.2 Foundation Design for Culverts

Based on the SDR, the invert level of the replacement culvert will be similar to the invert of the existing culvert, and no grade raise or significant embankment widening is proposed. There is approximately 3.2 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 Corrugated Steel Pipe Culvert

Replacement of the culvert with a CSP on the same alignment is identified in the SDR as the preferred option for this site. The proposed invert level of the CSP is Elev. 328.4 to 328.5 m. It is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading due to the replacement culvert.

If this alternative is selected, 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 and placement and compaction of the bedding material 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. 328.5, which corresponds to stiff silty clay till subgrade.

9.2.2 Concrete Box Culvert

Replacement of the culvert with a concrete box culvert on the same alignment is identified as a viable alternative for this site. The proposed invert level of the concrete box is Elev. 328.7 to 328.8 m. It is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading due to the replacement culvert.

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 and placement and compaction of the bedding material 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 underside of the bedding layer should be placed at or below Elev. 328.5 m, which corresponds to stiff silty clay till subgrade.

The following geotechnical capacities could be used for design of a box culvert of 4 to 5 m in width founded at or below Elevation 328.5 m on the stiff silty clay till subgrade:

- Factored Geotechnical Resistance at ULS of 250 kPa
- Geotechnical Resistance at SLS (less than 25 mm settlement) of 180 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 and the underlying Granular A or B Type II should be calculated assuming an ultimate coefficient of friction of 0.45.

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

9.2.3 Open Footing Concrete Culvert

Strip footings supporting an open footing concrete culvert should be founded on the stiff silty clay till below the frost depth (2.3 m) at or below Elev. 326.5 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 225 kPa
- Geotechnical Resistance at SLS (less than 25 mm settlement) of 150 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 till 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.

9.2.4 Culvert Wingwalls / Headwall

The GA drawings in the SDR show proposed wingwalls at the outlet of the replacement culvert. If wingwalls or headwalls 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 stiff silty clay till 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 stiff silty clay till subgrade at or below an approximate elevation of 328.3 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 125 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.

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 and placement and compaction of the granular fill 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 4 m high RSS wall at the outlet, which was shown on the 60% 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 1.84 and 1.53 respectively. The 100% design drawings do not show the presence of an RSS wall.

A geotextile filter fabric must be incorporated in the RSS design to prevent loss of fines from the granular material behind the wall subject to fluctuating water levels.

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 stiff silty clay till subgrade. The walls should be provided with sufficient frost cover (minimum 2.3 m) and founded at Elev. 326.5 m or lower. A factored geotechnical resistance at ULS of 200 kPa and a geotechnical reaction at SLS of 125 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 silty clay till should be evaluated in accordance with the CHBDC (2014) assuming an ultimate coefficient of friction of 0.35 for stiff silty clay till.

9.2.5 Frost Cover

The depth of frost penetration at this site is approximately 2.3 m. The base of open footing concrete culvert or retaining wall footings, if employed, should be provided with a minimum of 2.3 m of earth cover as protection against frost action. The frost cover requirement does not apply to the base of a CSP or box culvert.

As the top of the culvert will be well below the depth of frost penetration, a frost taper will not be required provided the excavation backfill above the culvert cover consists of similar material as the existing embankment fill (silty clay). A frost taper should be considered if the existing embankment fill and the excavation backfill are not similar materials.

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 bedding materials compacted as per OPSS.PROV 501.

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

The work should be carried out in accordance with OPSS 902 and culvert construction, subgrade preparation and placement and compaction of granular material must be carried out in the dry.

9.2.7 Settlement

Based on the GA drawings in the SDR, the replacement culvert will have approximately the same alignment and opening size as the existing culvert with no grade raise. Since there is no grade raise or widening, minimal post construction settlement is expected at this site. It must be noted that any additional load imposed on the culvert replacement, including fill to widen the embankment or fill placed behind wingwalls will induce immediate settlement and consolidation settlement of the stiff cohesive soils (silty clay till) at this site.

9.3 Construction Considerations

As indicated in the SDR, a detour route may be available for replacement of the culvert. However, if one lane of traffic is required to be maintained, a construction staging approach could be utilized.

Staged construction sequencing would 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. 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 till deposit. Obstructions such as cobbles or debris might be encountered within 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 GA drawings in the SDR show a temporary CSP stream diversion pipe located approximately 8.0 m west of the centreline of the new culvert. The invert of the diversion pipe is indicated at approximately Elev. 328.6 m, where the soil consists of stiff silty clay till. Temporary shoring may be required to install the diversion pipe at the proposed depth of approximately 7.0 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 or 803.010, 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 $\phi = 35°$; $\gamma = 22.8$ kN/m^3		OPSS Granular B Type I (modified) $\phi = 32°$; $\gamma = 21.2$ 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

In accordance with the CHBDC 2014, the selection of the seismic site classification is based on the soil conditions encountered in the upper 30 m of the stratigraphy. The stratigraphy of the site is typically a stiff silty clay till with an average undrained shear strength between 50 and 100 kPa. This 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% probability of exceedance in 50 years at this site is 0.037 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 $\phi = 35°$, $\gamma = 22.8$ kN/m^3	OPSS Granular B Type I (modified) $\phi = 32°$, $\gamma = 21.2$ kN/m^3
Active (K_{AE})*	0.29	0.33
Passive (K_{PE})	3.6	3.2
At Rest (K_{OE})**	0.49	0.53

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

The site is underlain by stiff silty clay till and liquefaction is not considered to be a concern at this site.

14. TEMPORARY PROTECTION SYSTEM

The 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 till which might contain cobbles and boulders.

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 Clay Till
γ	20 kN/m^3	20 kN/m^3
γ_w	10 kN/m^3	10 kN/m^3
K_a	0.39	0.33
K_p	2.6	3.0

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 602 embankment is approximately 7 m in height (3.2 m above the culvert) 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. Additional settlement would be induced if the final configuration includes additional fill to raise or widen the embankment, including placement of fill behind wingwalls.

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 till and creek water indicates the following conditions at the locations tested:

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

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

- Appropriate protection measures are recommended if concrete or 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.

- 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 Mr. Mark Farrant, P.Eng., 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.

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Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction

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

4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE		
SS Split Spoon Sample	WS Wash Sample	AS Auger 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			

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 16-06

METRIC

W.P.	6341-14-01	LOCATION	Turner Creek Culvert N 5 376 164.4 E 249 393.1	ORIGINATED BY	OA
HWY	602	BOREHOLE TYPE	Solid Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.07.20 - 2016.07.21	CHECKED BY	MEF

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	GR	SA	SI	CL
335.5	GROUND SURFACE								
0.0	**ASPHALT:** (40mm)								
	SAND and **GRAVEL** Brown Moist (FILL)	1	GS		335				
334.7 / 0.8	Silty **CLAY**, some sand to sandy, trace gravel Firm Grey Moist (FILL)	1	SS	8	334				
	Hard	2	SS	48		5	33	38	24
333.2 / 2.3	**SAND** and **GRAVEL** Compact Grey Moist (FILL)	3	SS	21	333				
332.9 / 2.6	Sandy, Silty **CLAY**, trace gravel Stiff Grey Moist (TILL)	4	SS	7	332				
		5	SS	12	331	0	34	35	31
		6	SS	10	330, 329				
		7	SS	8	328, 327				
		8	SS	8	326				

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

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Continued Next Page

+³, ×³: Numbers refer to Sensitivity

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

Ministry of Transportation
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THURBER

RECORD OF BOREHOLE No 16-06

METRIC

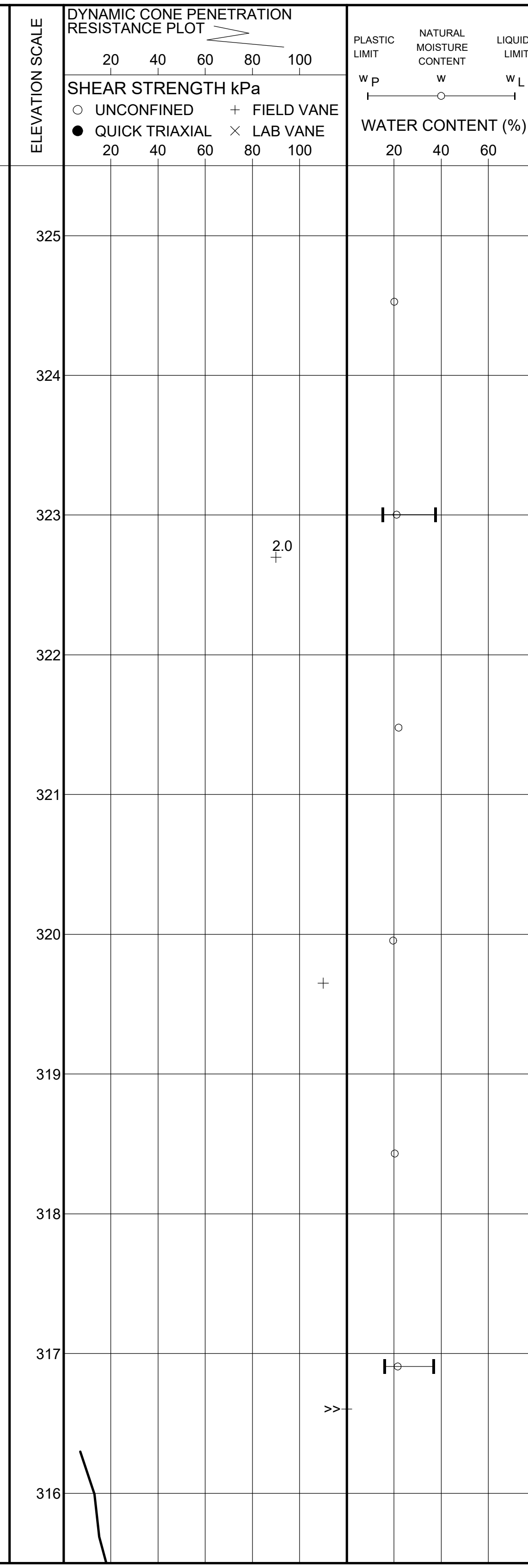
W.P. 6341-14-01 | LOCATION Turner Creek Culvert N 5 376 164.4 E 249 393.1 | ORIGINATED BY OA

HWY 602 | BOREHOLE TYPE Solid Stem Augers | COMPILED BY AN

DATUM Geodetic | DATE 2016.07.20 - 2016.07.21 | CHECKED BY MEF

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Sandy, Silty **CLAY**, trace gravel Firm to Stiff Grey Moist (TILL)				
		9	SS	8	
		10	SS	9	0 29 27 44
		11	SS	7	
		12	SS	6	
		13	SS	8	
		14	SS	7	0 31 28 41
316.6 18.9	End of sampling at 18.9m and start DCPT				



UNIT WEIGHT γ kN/m³

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+ 3, × 3: Numbers refer to Sensitivity

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

Ministry of Transportation
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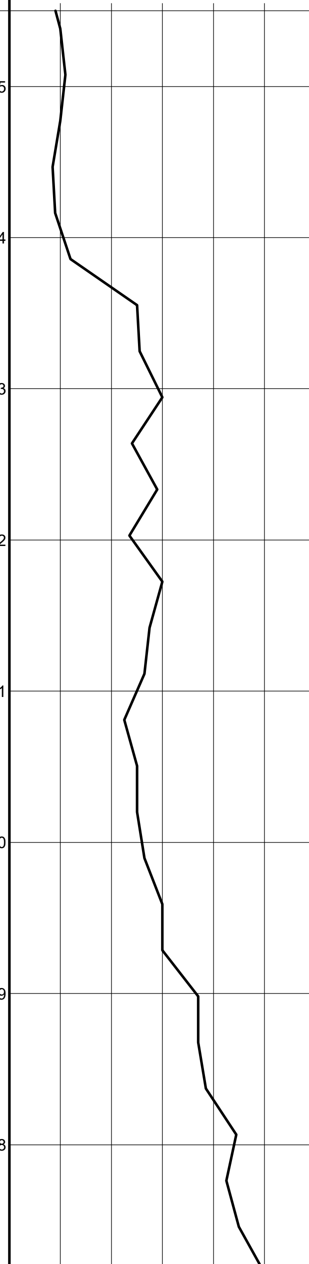
THURBER

RECORD OF BOREHOLE No 16-06

METRIC

W.P. 6341-14-01	LOCATION Turner Creek Culvert N 5 376 164.4 E 249 393.1		ORIGINATED BY OA
HWY 602	BOREHOLE TYPE Solid Stem Augers		COMPILED BY AN
DATUM Geodetic	DATE 2016.07.20 - 2016.07.21		CHECKED BY MEF

SOIL PROFILE: ELEV / DEPTH	SOIL PROFILE: DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "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										
							315				
							314				
							313				
							312				
							311				
							310				
							309				
							308				
307.2 / 28.3	END OF BOREHOLE AT 28.3m UPON DYNAMIC CONE REFUSAL. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND AUGER CUTTINGS TO 0.1m, THEN ASPHALT TO SURFACE.										



+³, ×³: Numbers refer to Sensitivity

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

Appendix B

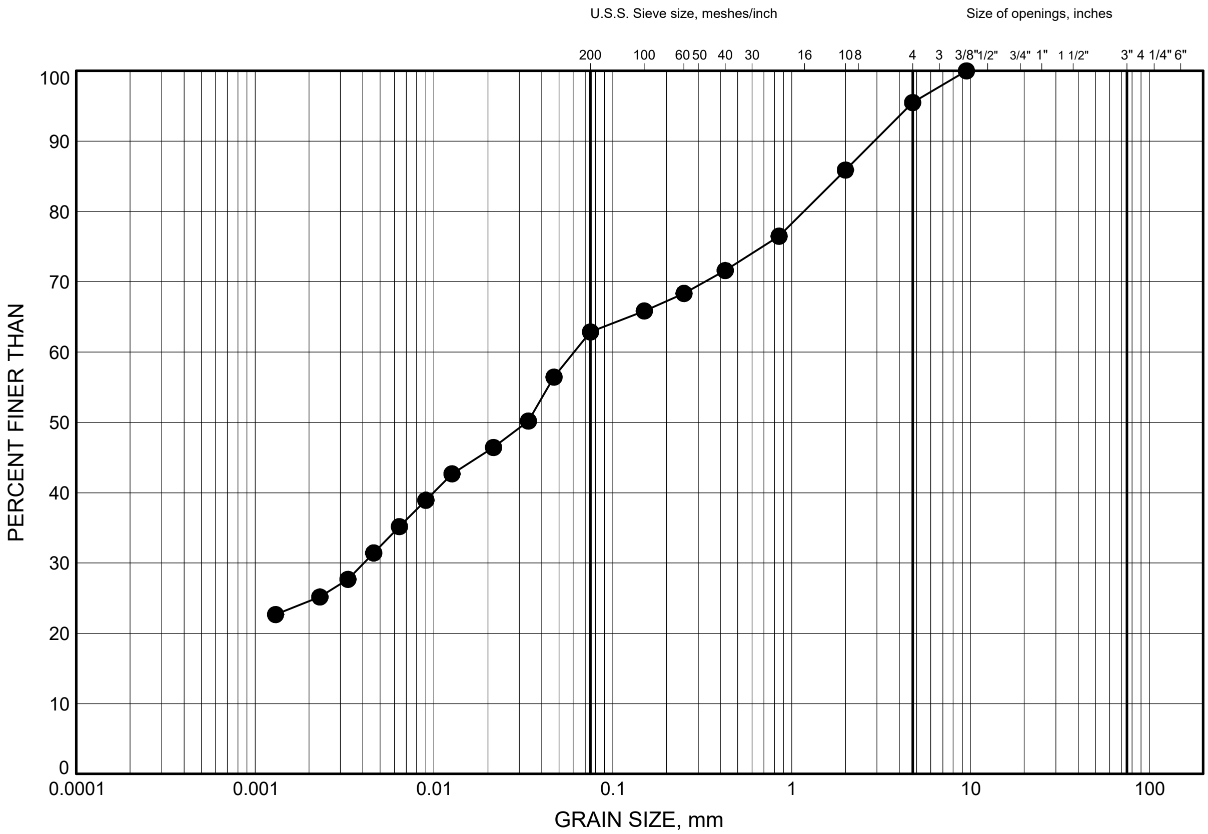
Geotechnical and Analytical Laboratory Test Results

Turner Creek Culvert

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)
●	16-06	1.83	333.67

Date October 2016

W.P. 6341-14-01

THURBER

Prep'd AN

Chkd. MEF

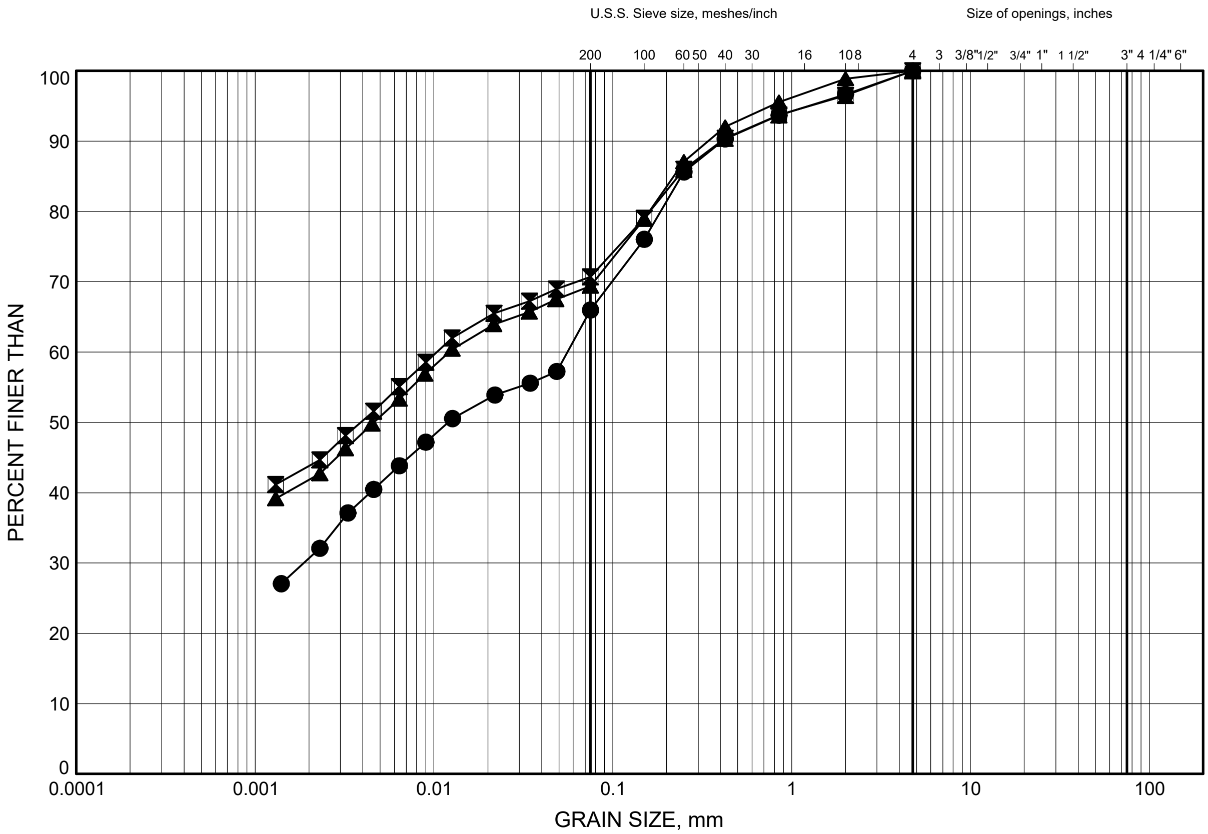
GRAIN SIZE DISTRIBUTION - THURBER 13004-MTO.GPJ 10/6/16

Turner Creek Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B2

Sandy, Silty CLAY TILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-06	4.88	330.62
⧗	16-06	12.50	323.00
▲	16-06	18.59	316.91

Date October 2016

W.P. 6341-14-01

THURBER

Prep'd AN

Chkd. MEF

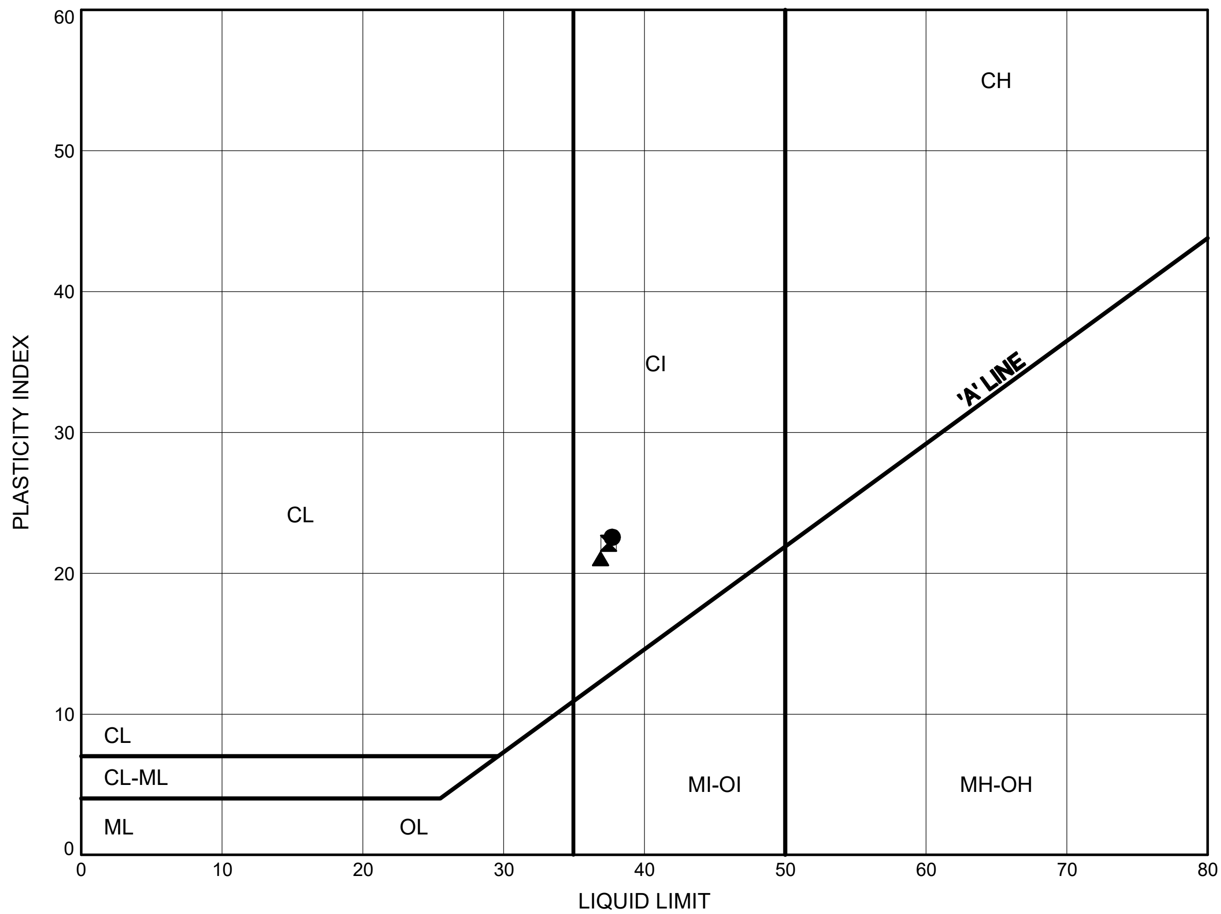
GRAIN SIZE DISTRIBUTION - THURBER 13004-MTO.GPJ 10/6/16

Turner Creek Culvert

ATTERBERG LIMITS TEST RESULTS

FIGURE B3

Sandy, Silty CLAY TILL



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-06	4.88	330.62
⧗	16-06	12.50	323.00
▲	16-06	18.59	316.91

THURBALT 13004-MTO.GPJ 10/6/16

Date October 2016

W.P. 6341-14-01

THURBER

Prep'd AN

Chkd. MEF

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	6: BH-16-06 SS5, 15'-17'
Sample Date & Time					21-Jul-16
Temperature Upon Receipt [°C]	---	---	---	---	24.2
Corrosivity Index [none]	09-Aug-16	13:32	09-Aug-16	14:29	1
pH [no unit]	08-Aug-16	11:40	09-Aug-16	09:32	7.85
Soil Redox Potential [mV]	08-Aug-16	18:47	09-Aug-16	08:27	240
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	15.5
pH [no unit]	04-Aug-16	09:56	04-Aug-16	15:49	8.58
Chloride [µg/g]	05-Aug-16	18:51	09-Aug-16	09:15	11
Sulphate [µg/g]	05-Aug-16	18:51	09-Aug-16	09:15	150
Conductivity [uS/cm]	04-Aug-16	09:56	04-Aug-16	15:49	187
Resistivity (calculated) [Ohms.cm]	09-Aug-16	13:31	09-Aug-16	14:29	5350

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

OnLine LIMS

0000751588

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
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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.

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

Project : 13004

LR Report : **CA14113-AUG16**

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		

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	7: Turner 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	7.14
Redox Potential [mV]	27-Jul-16	13:39	02-Aug-16	10:54	252
Sulphide [mg/L]	29-Jul-16	13:00	29-Jul-16	12:19	0.03
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	98
Resistivity (calculated) [MOhms.cm]	02-Aug-16	13:27	02-Aug-16	13:27	1020

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: Highway 602 embankment over Turner Creek Culvert, looking east

Photo 2: Turner Creek Culvert Outlet, south side

Photo 3: Turner Creek Culvert, south embankment, looking west

Photo 4: Turner Creek Culvert, north embankment, looking east

Appendix D

Borehole Locations and Soil Strata Drawing

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

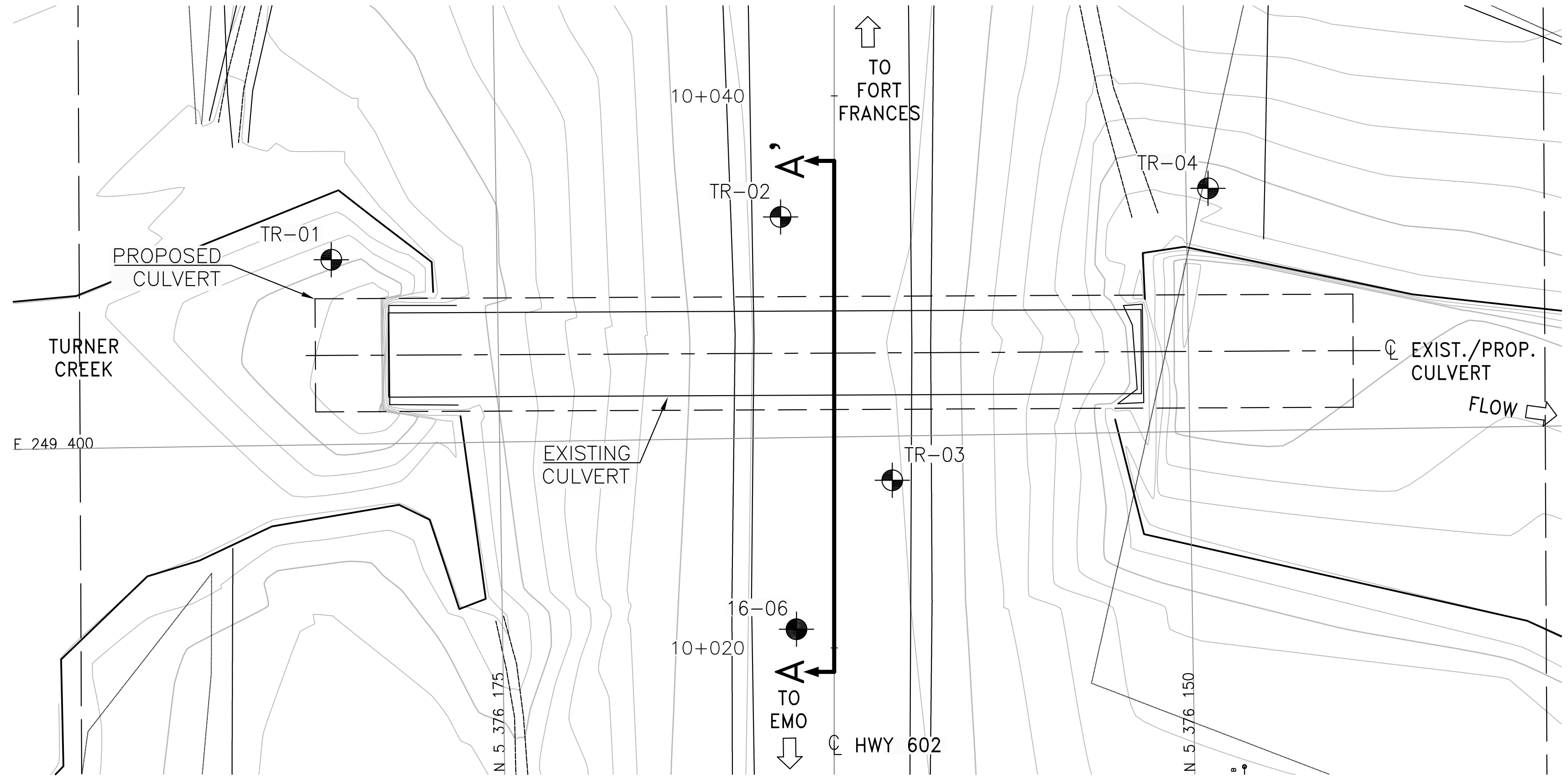
CONT No 2016–6035
WP No 6341–14–01

TURNER CREEK CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET 19

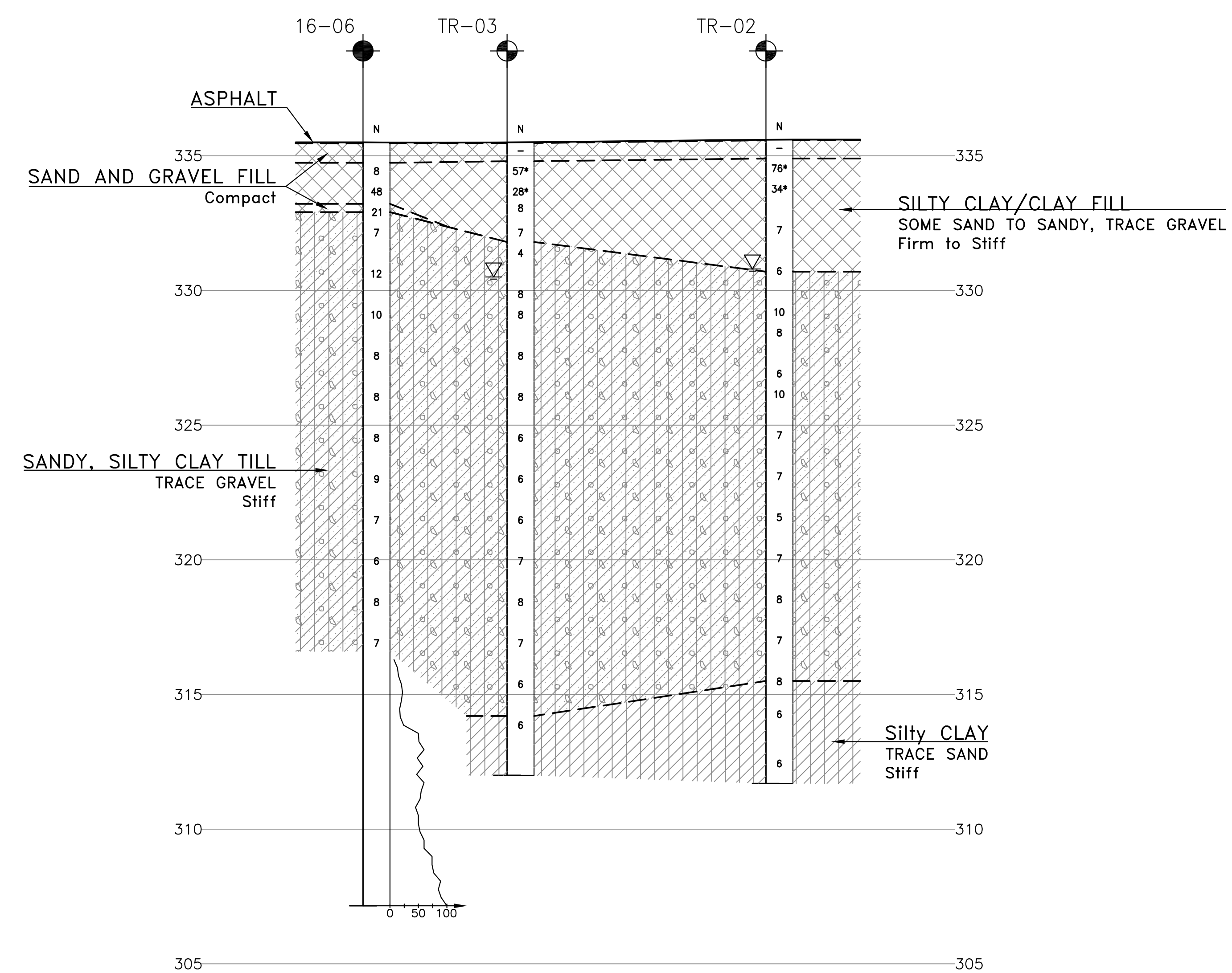
HATCH

THURBER ENGINEERING LTD.



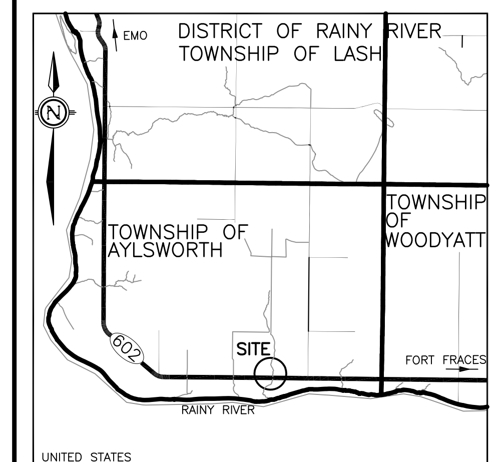
PLAN

5 0 5 10m
SCALE 1:250



PROFILE ALONG ℄ A–A'

5 0 5 10m
SCALE 1:250



KEYPLAN

LEGEND

Symbol	Description
⯐	Borehole (Current Investigation)
⯐	Borehole (Previous Investigation)
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
▽	Water Level
▼	Head Artesian Water
ǀ	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
16–06	335.5	5 376 164.4	249 393.1
TR–01	331.5	5 376 181.0	249 406.7
TR–02	335.6	5 376 164.7	249 408.0
TR–03	335.5	5 376 160.8	249 398.4
TR–04	332.2	5 376 149.2	249 408.8

-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 conceptual illustration.

GEOCRES No. 52C-53

REVISIONS

DATE	BY	DESCRIPTION

DESIGN MEF	CHK MEF	CODE	LOAD	DATE JAN 2017
DRAWN AN	CHK	SITE	STRUCT	DWG 2

Appendix E

Factual Data from 2015 Golder Foundation Investigation Report

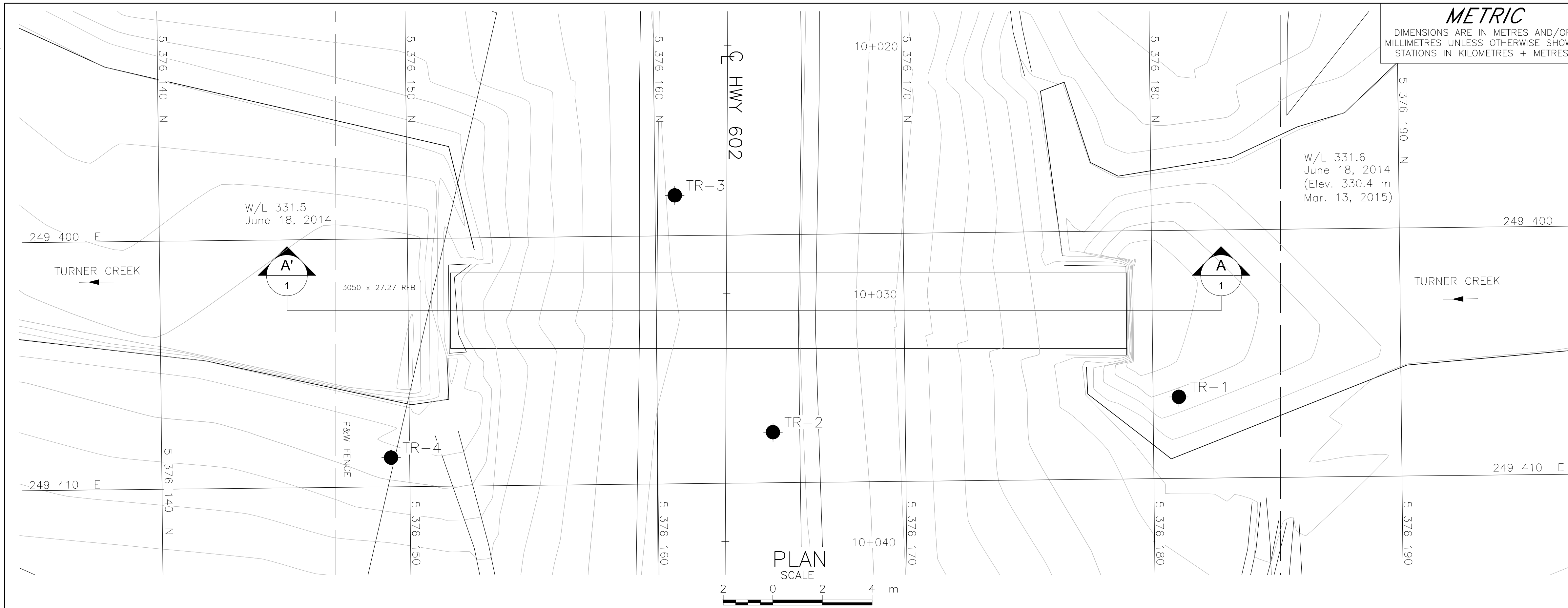
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

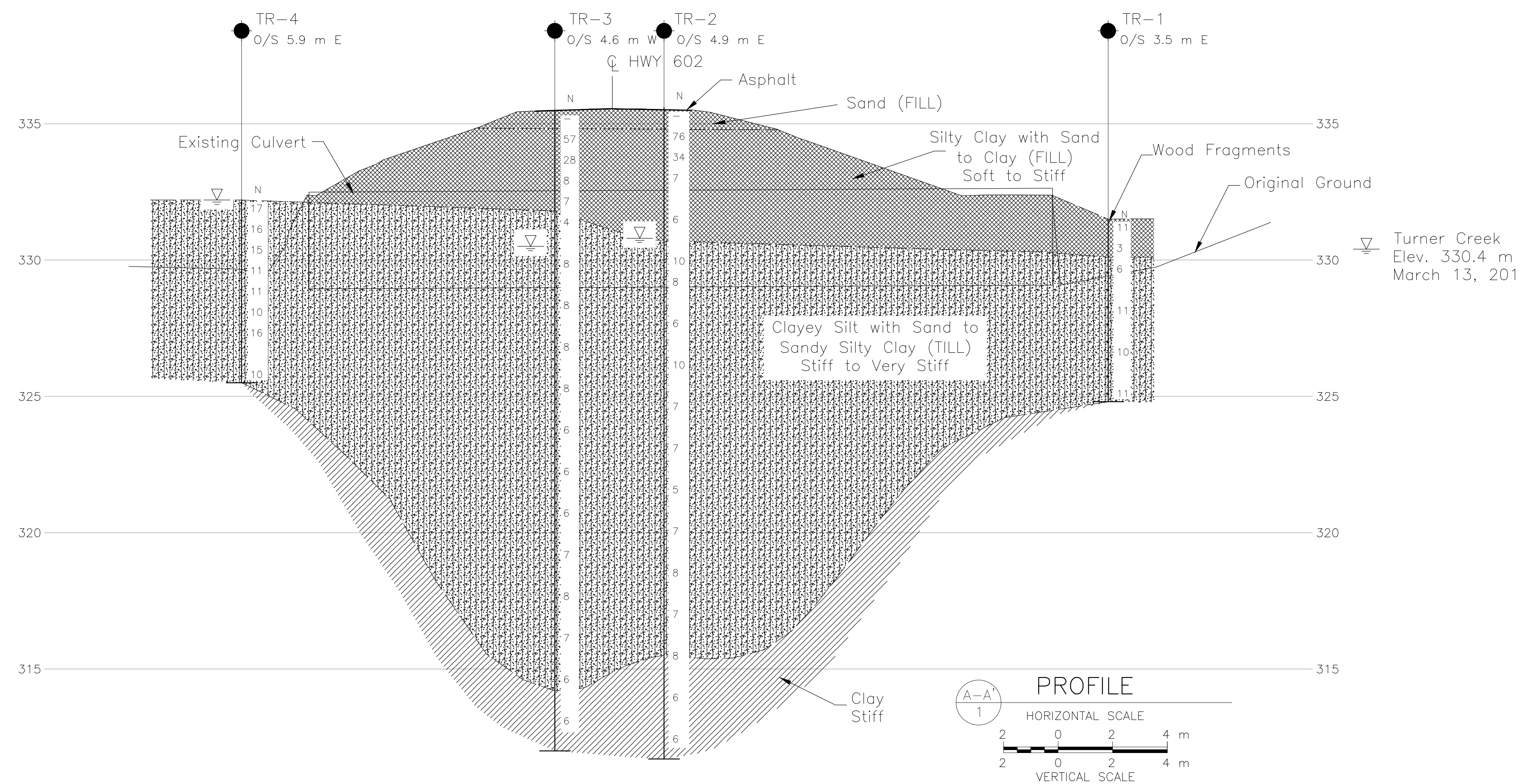
CONT No.
GWP No. 6341-14-00

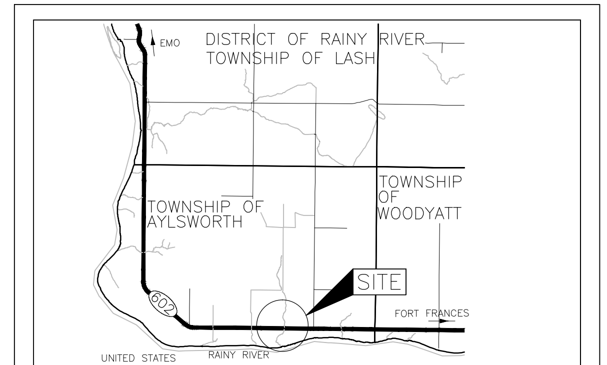
SHEET

HIGHWAY 602
TURNER CREEK CULVERT STA 10+031
BOREHOLE LOCATION PLAN 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
TR-1	331.5	5376181.0	249406.7
TR-2	335.6	5376164.7	249408.0
TR-3	335.5	5376160.8	249398.4
TR-4	332.2	5376149.2	249408.8

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. E14876021, dated JUN 2014, received JAN 27, 2015.

LICENSED PROFESSIONAL ENGINEER S.E.M. POOT 90471921 SEP 28, 2015 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER J.M.A.COSTA SEP 28, 2015 PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

Geocres No. 52C-42

HWY. 602	PROJECT NO. 1411526		DIST.
SUBM'D. AC	CHKD.	DATE: 9/28/2015	SITE: 45-279/C
DRAWN: JJL/TB	CHKD. SEMP	APPD. JMAC	DWG. 1

RECORD OF BOREHOLE No TR-1

 METRIC

PROJECT 1411523			
G.W.P. 6341-14-00	LOCATION N 5376181.0; E 249406.7	ORIGINATED BY MR
DIST ___ HWY 602	BOREHOLE TYPE 108 mm I. D. Continuous Flight Hollow Stem Augers	COMPILED BY AC
DATUM GEODETIC	DATE March 15, 2015	CHECKED BY SEMP

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	DYNAMIC CONE PENETRATION	WATER CONTENT (%) (Wp / w / WL)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
331.5	GROUND SURFACE						
0.0	Silty clay with sand, trace gravel, trace wood and organics (FILL) Soft Brown to grey Frozen* to wet	1	SS	11*			
		2	SS	3			
330.1 / 1.4	Sandy SILTY CLAY, trace gravel (TILL) Very stiff Brown to grey Wet	3	SS	6		plotted	2 26 35 37
					>100		
		4	SS	11			
					>100		
		5	SS	10			
					>100		
324.8		6	SS	11		plotted	3 28 35 34
6.7	END OF BOREHOLE						

Note:

1. Borehole dry upon completion of drilling.

Legend: SHEAR STRENGTH kPa — ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED; UNIT WEIGHT γ kN/m³

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

Golder Associates

RECORD OF BOREHOLE No TR-2

 METRIC

PROJECT 1411523
G.W.P. 6341-14-00
DIST ___ HWY 602
DATUM GEODETIC
LOCATION N 5376164.7; E 249408.0
BOREHOLE TYPE 108 mm I. D. Continuous Flight Hollow Stem Augers
DATE March 13, 2015
ORIGINATED BY MR
COMPILED BY AC
CHECKED BY SEMP

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
335.6	GROUND SURFACE					
0.0	ASPHALT (25 mm)					
	Sand, some gravel (FILL) Brown Frozen	1	AS	-		
334.9 / 0.7	Clay, trace sand (FILL) Firm Brown to grey Frozen* to wet	2	SS	76*		
		3	SS	34*		0 3 32 65
	Trace organics encountered at 2.3 m depth.	4	SS	7		
		5	SS	6		
					∇ (approx. 330.9)	
330.7 / 4.9	Sandy SILTY CLAY, trace gravel (TILL) Very stiff Grey Wet	6	SS	10		
		7	SS	8		2 28 35 35
		8	SS	6		
		9	SS	10		
		10	SS	7		
		11	SS	7		
		12	SS	5		0 30 36 34

Plotted data: Field vane shear strength (+) ~ 88 kPa at elev. ~332.2 (sensitivity 1), ~ 73 kPa at elev. ~330.7 (sensitivity 1); remoulded values >100 at elev. ~331.9, 330.4, 328.4, 326.9, 325.4, 323.9, 322.3, 320.8. Water content: sample 1 ~5%; sample 3 ~33%; sample 4 w ~37%, w_P ~27%, w_L 88; sample 7 w ~20%, w_P ~18%, w_L ~40%; sample 12 w ~23%, w_L ~40%.

Elevation scale: 335, 334, 333, 332, 331, 330, 329, 328, 327, 326, 325, 324, 323, 322, 321

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

Continued Next Page

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

Golder Associates

RECORD OF BOREHOLE No TR-2

 METRIC

PROJECT 1411523			
G.W.P. 6341-14-00	LOCATION N 5376164.7; E 249408.0		ORIGINATED BY MR
DIST	HWY 602	BOREHOLE TYPE 108 mm I. D. Continuous Flight Hollow Stem Augers	COMPILED BY AC
DATUM GEODETIC	DATE March 13, 2015		CHECKED BY SEMP

--- CONTINUED FROM PREVIOUS PAGE ---

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	DYNAMIC CONE PENETRATION / SHEAR STRENGTH kPa	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L (WATER CONTENT %)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Sandy SILTY CLAY, trace gravel (TILL) Very stiff Grey Wet	13	SS	7	320				
					319	>100			
		14	SS	8			plotted		7 25 33 35
					318	>100			
		15	SS	7	317				
					316	>100			
315.5 20.1	CLAY, trace sand Stiff Grey Wet	16	SS	8	315	+ 2, + 2			
		17	SS	6	314		plotted (81)		0 2 21 77
					313	+ 2, + 1			
		18	SS	6	312	+ 1			
311.7 23.9	END OF BOREHOLE Note: 1. Water level at a depth of 4.8 m below ground surface (Elev. 330.8 m) upon completion of drilling.								

Shear strength legend: ○ UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; × REMOULDED

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

RECORD OF BOREHOLE No TR-3

 METRIC

PROJECT 1411523
G.W.P. 6341-14-00
LOCATION N 5376160.8; E 249398.4
ORIGINATED BY MR
DIST
HWY 602
BOREHOLE TYPE 108 mm I. D. Continuous Flight Hollow Stem Augers
COMPILED BY AC
DATUM GEODETIC
DATE March 14, 2015
CHECKED BY SEMP

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
335.5	GROUND SURFACE											
0.0	ASPHALT (25 mm)											
	Sand, some gravel (FILL) Brown Frozen	1	AS	-								
334.8 / 0.7	Clay, trace sand (FILL) Firm to stiff Brown to grey Frozen* to wet	2	SS	57*								
		3	SS	28*			85		0	4	30	66
	Trace organics noted from 2.3 m to 3.7 m depth.	4	SS	8								
		5	SS	7								
331.8 / 3.7	CLAYEY SILT with sand to Sandy SILTY CLAY, trace gravel (TILL) Stiff to very stiff Grey Wet	6	SS	4								
					▽	>100						
		7	SS	8					4	26	37	33
						>100						
		8	SS	8								
						>100						
		9	SS	8					4	27	35	34
						>100						
		10	SS	8								
						>100						
		11	SS	6								
						>100						
		12	SS	6								
						>100						
		13	SS	6								

Elevation scale: 335, 334, 333, 332, 331, 330, 329, 328, 327, 326, 325, 324, 323, 322, 321

Legend: ○ UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; × REMOULDED. PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L. REMARKS & GRAIN SIZE DISTRIBUTION (%).

Continued Next Page

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

RECORD OF BOREHOLE No TR-3

 METRIC

PROJECT 1411523
G.W.P. 6341-14-00
LOCATION N 5376160.8; E 249398.4
ORIGINATED BY MR
DIST ___ HWY 602
BOREHOLE TYPE 108 mm I. D. Continuous Flight Hollow Stem Augers
COMPILED BY AC
DATUM GEODETIC
DATE March 14, 2015
CHECKED BY SEMP

--- CONTINUED FROM PREVIOUS PAGE ---

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	CLAYEY SILT with sand to Sandy SILTY CLAY, trace gravel (TILL) Stiff to very stiff Grey Wet				
		14	SS	7	
		15	SS	8	1 33 40 26
		16	SS	7	
		17	SS	6	
314.2 / 21.3	CLAY Stiff Grey Wet				
		18	SS	6	
312.0 / 23.5	END OF BOREHOLE				

Elevation scale: 320, 319, 318, 317, 316, 315, 314, 313, 312

Dynamic cone penetration: >100 (approx. elev. 319.6), >100 (approx. elev. 316.9), >100 (approx. elev. 315.1)

Field vane (sensitivity) results plotted near 100 kPa: 1 (approx. 320.0), 1, 1 (approx. 318.4, 318.1), 1 (approx. 315.4), 2, 2 (approx. 314.0, 313.7), 1, 1 (approx. 312.3, 312.0)

Note:

1. Water level at a depth of 5.0 m below ground surface (Elev. 330.5 m) upon completion of drilling.

Legend: 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 TR-4

 METRIC

PROJECT 1411523
G.W.P. 6341-14-00
LOCATION N 5376149.2; E 249408.8
ORIGINATED BY MR
DIST ___ HWY 602
BOREHOLE TYPE Portable Equipment - NW Casing and Wash Boring
COMPILED BY AC
DATUM GEODETIC
DATE March 22, 2015
CHECKED BY SEMP

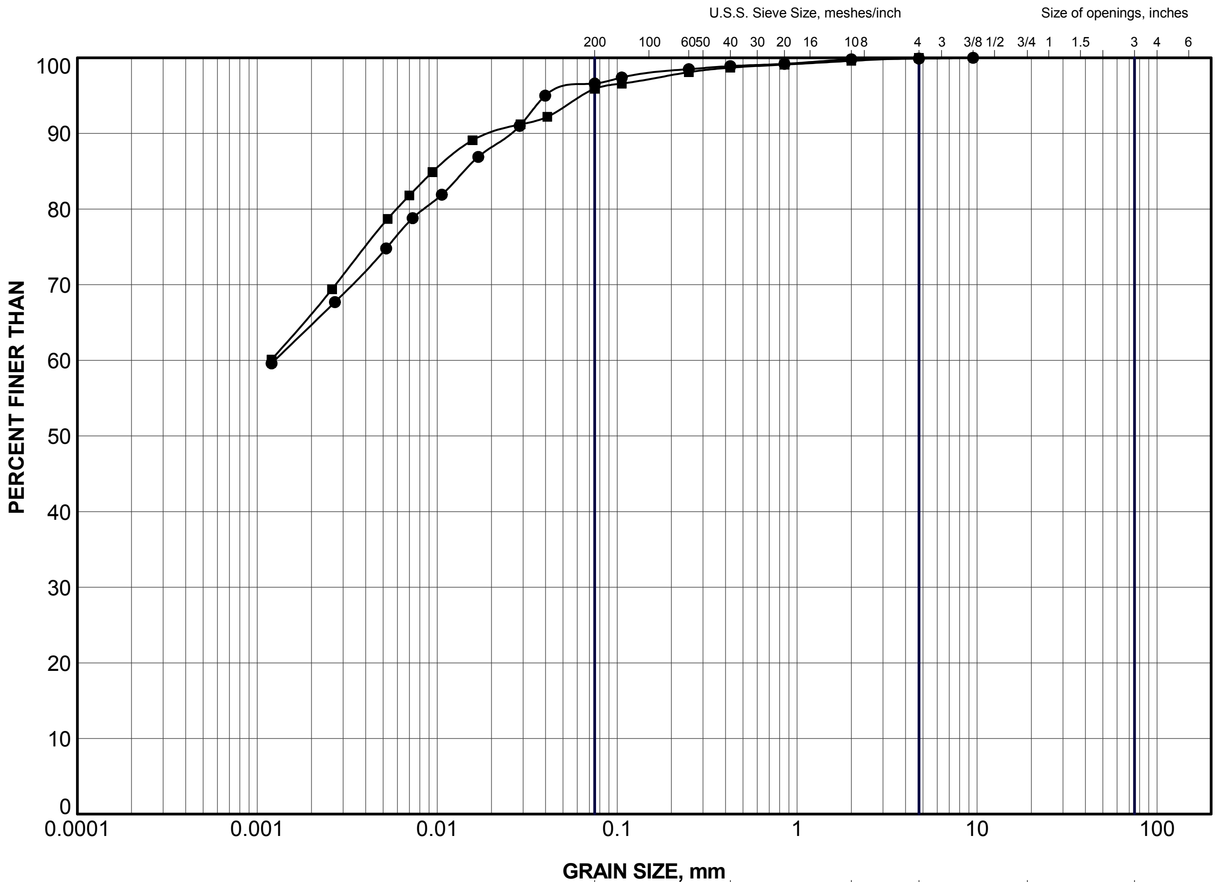
ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	GR	SA	SI	CL
332.2	GROUND SURFACE								
0.0	Sandy SILTY CLAY, trace gravel (TILL) Stiff to very stiff Grey Frozen* to wet	1	SS	17*					
		2	SS	16*					
	Trace organics encountered in upper 1.5 m.	3	SS	15					
		4	SS	11	~21				
		5	SS	11					
		6	SS	10	~22 (Wp ~20, WL ~42)	2	28	36	34
		7	SS	16					
		8	SS	10					
325.5 / 6.7	END OF BOREHOLE								

Note:

1. Water level at ground surface (Elev. 332.2 m) upon completion of drilling.

Column headings: SOIL PROFILE; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (332 to 326); 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

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



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	TR-2	3	333.8
■	TR-3	3	333.7

PROJECT

HIGHWAY 602
TURNER CREEK CULVERT STA 10+031

TITLE

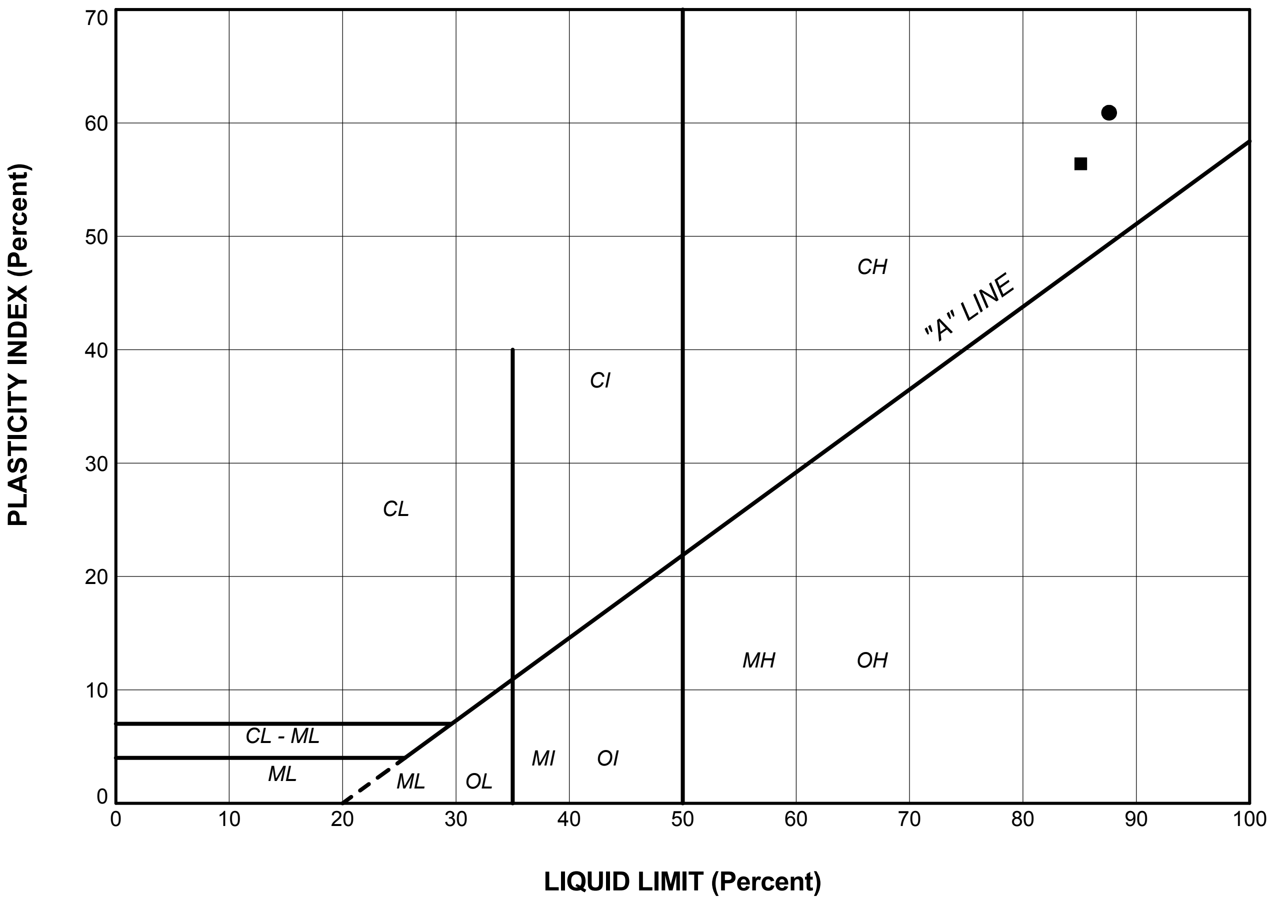
GRAIN SIZE DISTRIBUTION

CLAY (FILL)

Golder Associates
SUDBURY, ONTARIO

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

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
●	TR-2	4	87.6	26.7	60.9
■	TR-3	3	85.1	28.7	56.4

PROJECT

HIGHWAY 602
TURNER CREEK CULVERT STA 10+031

TITLE

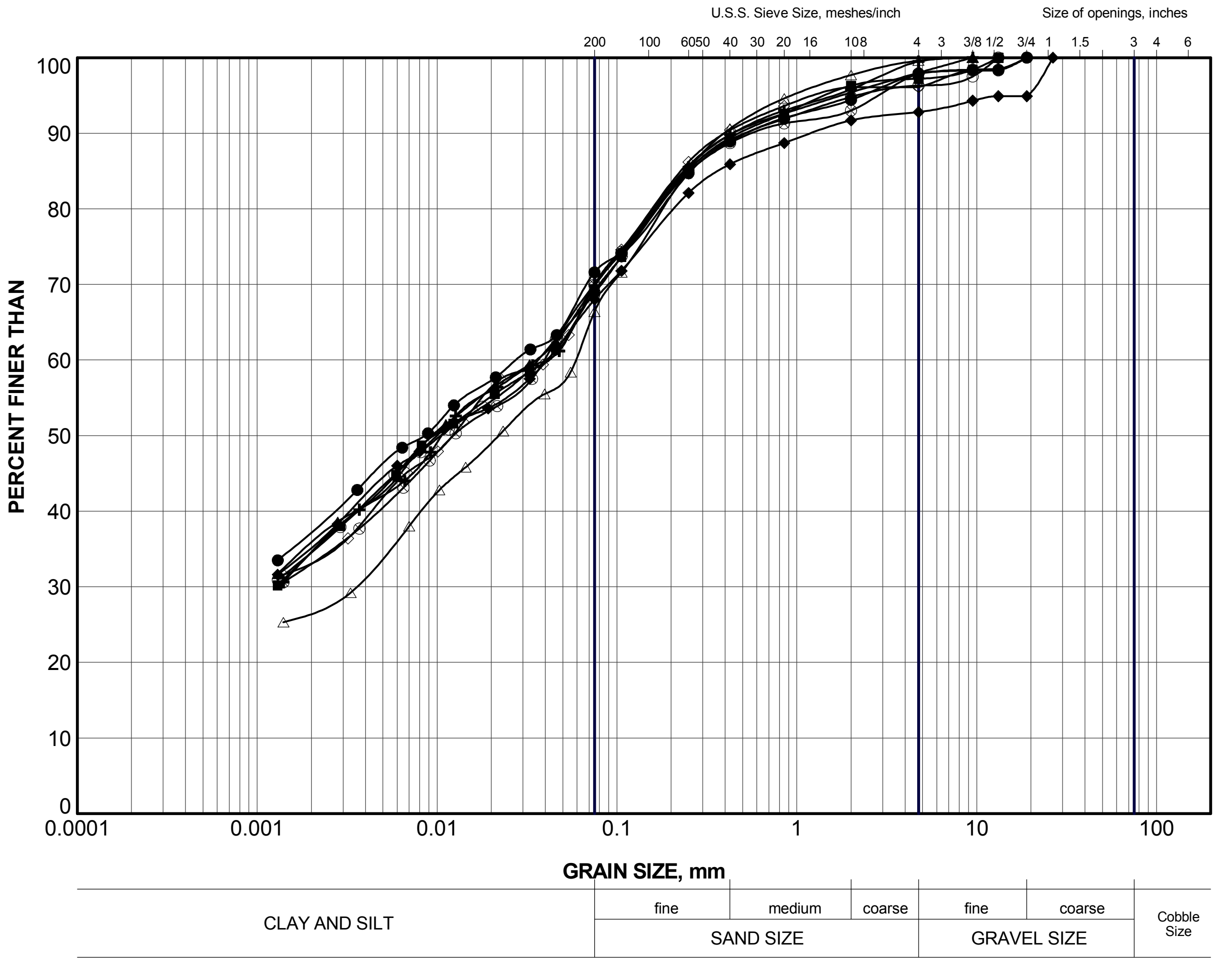
PLASTICITY CHART

CLAY (FILL)

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		1411523	FILE No.	1411523.GPJ
DRAWN	JJL	Sep 2015	SCALE N/A	REV.
CHECK	SEMP	Sep 2015	**FIGURE B2**	
APPR	JMAC	Sep 2015		

SUD-MTO PL (NEW) GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	TR-1	3	329.7
■	TR-1	6	325.1
▲	TR-2	7	329.2
✚	TR-2	12	321.6
◆	TR-2	14	318.5
◇	TR-3	7	329.9
○	TR-3	9	326.8
△	TR-3	15	317.7
⊗	TR-4	6	328.1

PROJECT

HIGHWAY 602
TURNER CREEK CULVERT STA 10+031

TITLE

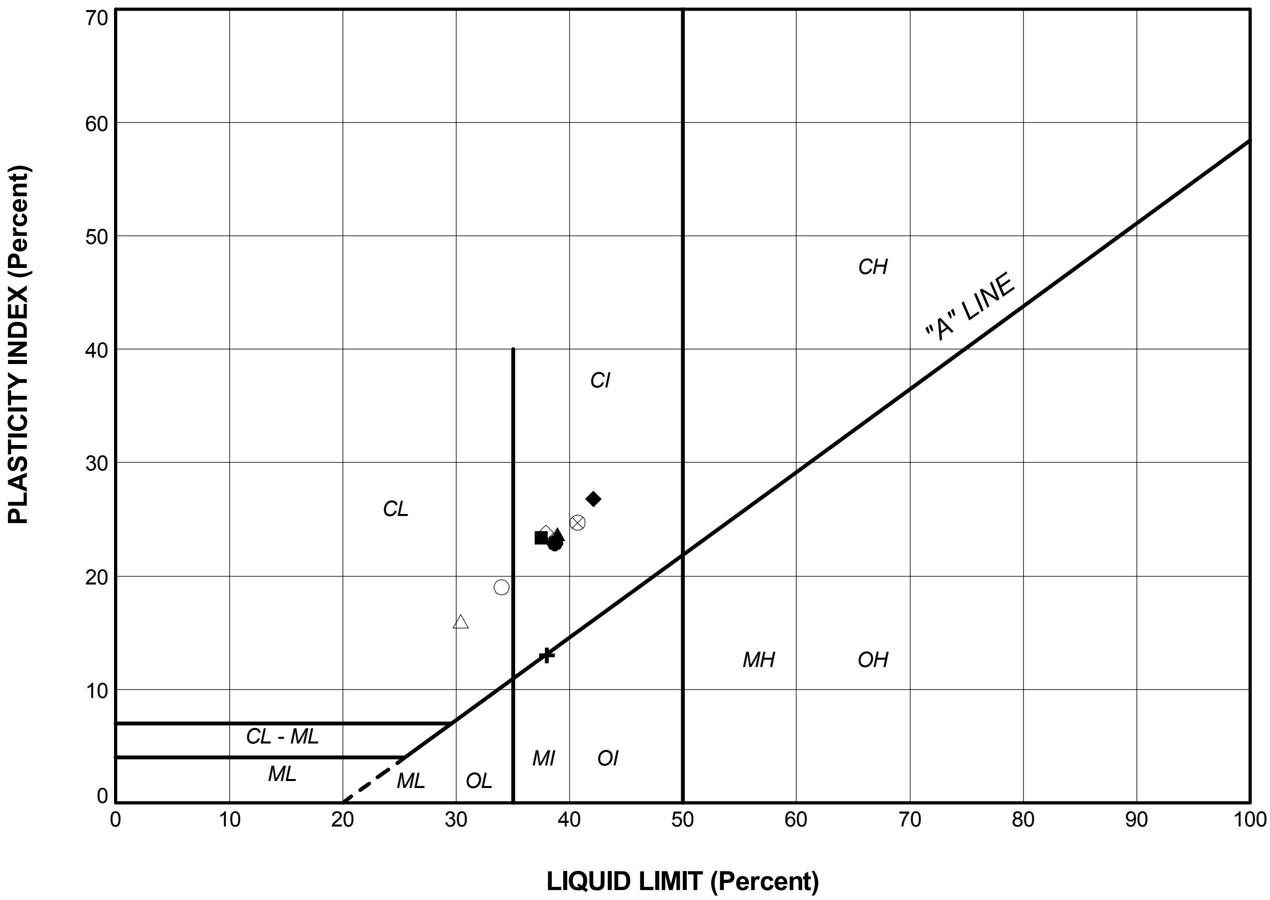
GRAIN SIZE DISTRIBUTION

CLAYEY SILT with SAND to SANDY SILTY CLAY (TILL)

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		1411523	FILE No.	1411523.GPJ
DRAWN	JJL	Sep 2015	SCALE N/A	REV.
CHECK	SEMP	Sep 2015		
APPR	JMAC	Sep 2015	FIGURE B3	

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
●	TR-1	3	38.7	15.8	22.9
■	TR-1	6	37.5	14.1	23.4
▲	TR-2	7	38.9	15.2	23.7
✚	TR-2	12	38.0	25.0	13.0
◆	TR-2	14	42.1	15.3	26.8
◇	TR-3	7	37.9	14.1	23.8
○	TR-3	9	34.0	15.0	19.0
△	TR-3	15	30.4	14.4	16.0
⊗	TR-4	6	40.7	16.0	24.7

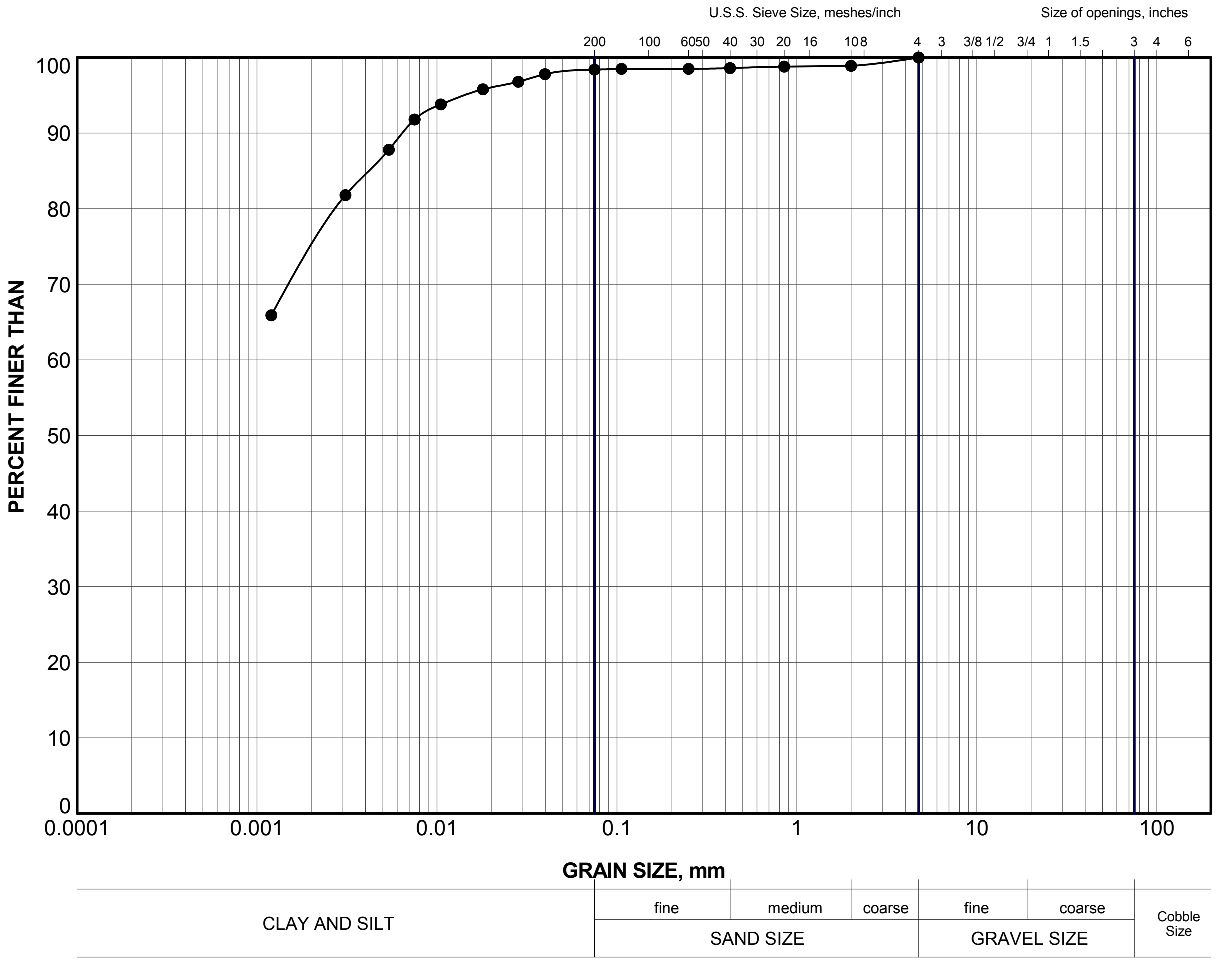
PROJECT
HIGHWAY 602
TURNER CREEK CULVERT STA 10+031

TITLE
PLASTICITY CHART
CLAYEY SILT with SAND to SANDY SILTY CLAY (TILL)

PROJECT No.		1411523	FILE No.	1411523.GPJ
DRAWN	JJL	Sep 2015	SCALE N/A	REV.
CHECK	SEMP	Sep 2015		
APPR	JMAC	Sep 2015	**FIGURE B4**	

Golder Associates
SUDBURY, ONTARIO

SUD-MTO PL (NEW) GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	TR-2	17	314.0

PROJECT

HIGHWAY 602
TURNER CREEK CULVERT STA 10+031

TITLE

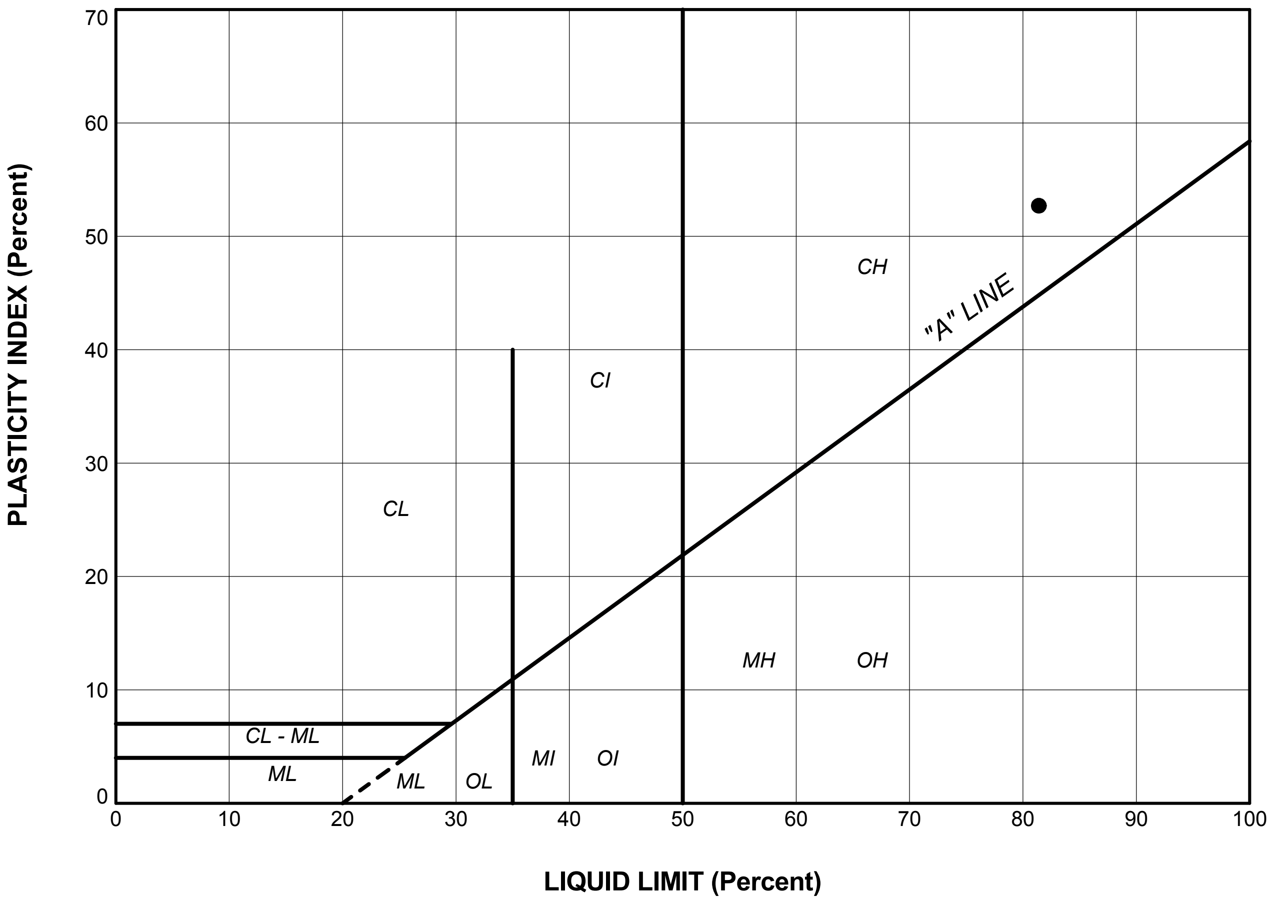
GRAIN SIZE DISTRIBUTION

CLAY

PROJECT No.		1411523	FILE No.	1411523.GPJ
DRAWN	JJL	Sep 2015	SCALE N/A	REV.
CHECK	SEMP	Sep 2015	**FIGURE B5**	
APPR	JMAC	Sep 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
●	TR-2	17	81.4	28.7	52.7

PROJECT

HIGHWAY 602
TURNER CREEK CULVERT STA 10+031

TITLE

PLASTICITY CHART

CLAY

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		1411523	FILE No. 1411523.GPJ
DRAWN	JJL	Sep 2015	SCALE N/A REV.
CHECK	SEMP	Sep 2015	
APPR	JMAC	Sep 2015	FIGURE B6

SUD-MTO PL (NEW) GLDR_LDN.GDT

Appendix F

Foundation Comparison

COMPARISON OF FOUNDATION ALTERNATIVES

Corrugated Steel Pipe (CSP) Culvert	Concrete Box Culvert	Concrete Open Footing Culvert
<u>Advantages:</u> 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.	<u>Advantages:</u> 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.	<u>Advantages:</u> i. Conventional construction. ii. Possibly less disturbance of creek channel / less environmental issues such as those involving spawning fish species.
<u>Disadvantages:</u> i. Steel pipes may have shorter design life than concrete culverts. ii. Multiple pipes needed to meet hydraulic requirements. iii. Large excavation through approx. 7 m of fill required to install pipe. iv. Relatively high roadway protection system required.	<u>Disadvantages:</u> i. More expensive than a concrete pipe or CSP culvert. ii. Large excavation through approx. 7 m of fill required to install culvert. iii. Relatively high roadway protection system required.	<u>Disadvantages:</u> i. Requires deeper excavation and potentially longer dewatering requirements. ii. Cannot tolerate differential settlement.
FEASIBLE	**FEASIBLE**	**NOT RECOMMENDED**

Appendix G

List of OPSSs and OPSDs and Suggested Wording for NSSP

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

- OPSS PROV 206
- OPSS PROV 209
- OPSS 422
- OPSS PROV 401
- OPSS PROV 501
- OPSS PROV 539
- OPSS PROV 804
- OPSS 902
- OPSS PROV 1010
- OPSS PROV 1205
- OPSD 802.010
- 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 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 °

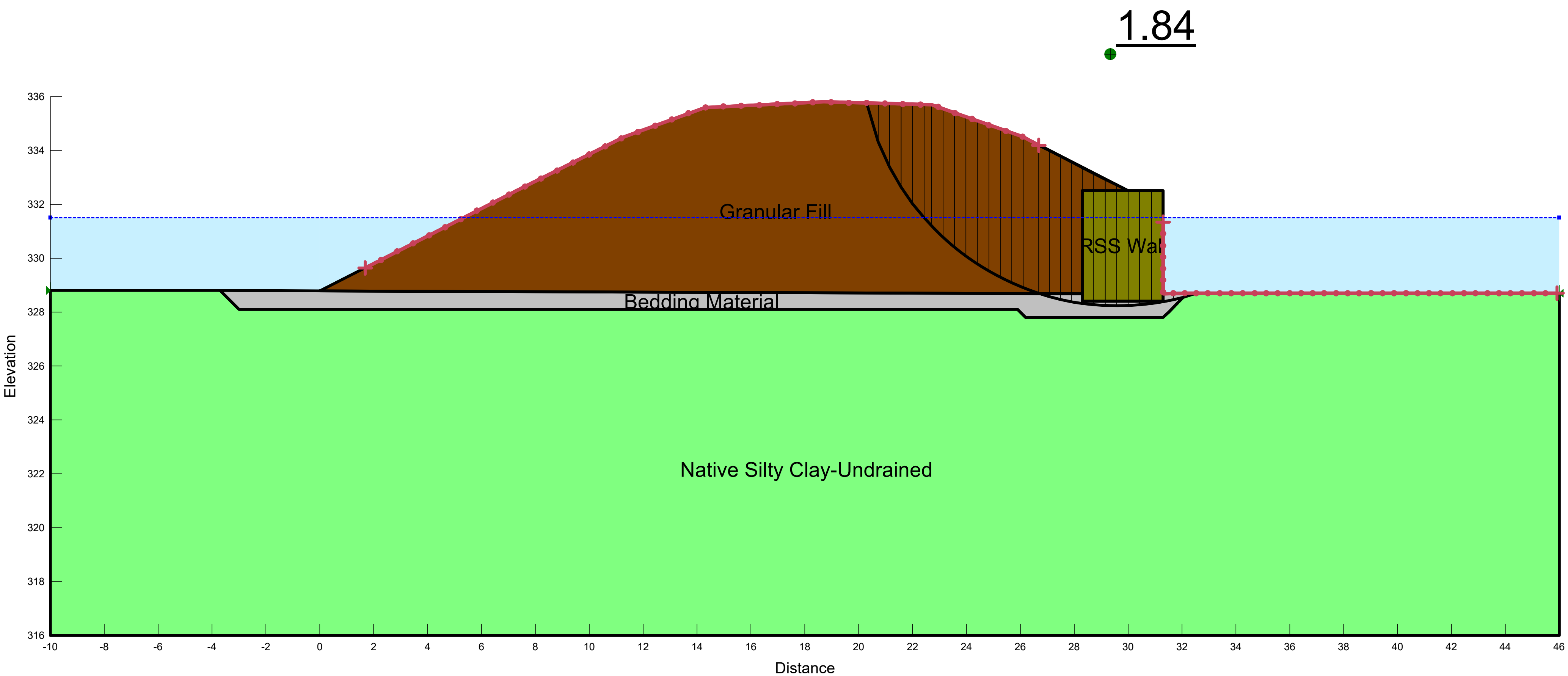


Figure 1: Turner Creek Culvert - Slope Stability Analysis
Short Term Condition

Name: RSS Wall Model: Mohr-Coulomb Unit Weight: 22 kN/m³ Cohesion: 200 kPa Phi: 35 °
Name: Granular Fill 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: 10 kPa Phi: 27 °
Name: Bedding Material Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 35 °

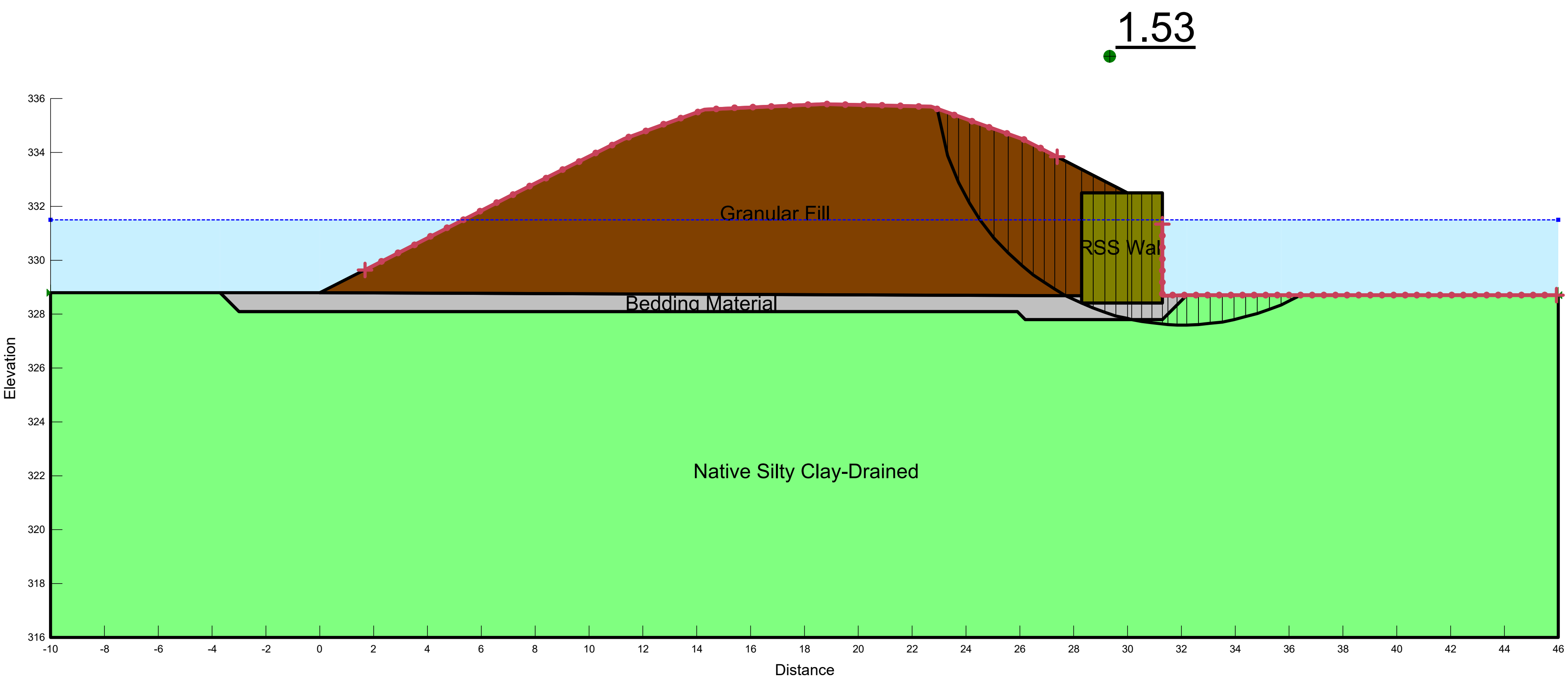


Figure 2: Turner Creek Culvert - Slope Stability Analysis
Long Term Condition