



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT
REPLACEMENT OF STRUCTURAL CULVERT No. 29-250/C
FORESTERS FALLS CULVERT CROSSING OF HIGHWAY 17
RENFREW COUNTY, ON
W.P. 4113-01-01
AGREEMENT NUMBER: 4014-E-0014**

GEOCRES NUMBER: 31F-193

**SUBMITTED TO
WSP CANADA**

LOCATION:

**LATITUDE: 45.62172°
LONGITUDE: -76.87045°**

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual data obtained from a foundation investigation conducted by Thurber Engineering Ltd. (Thurber) for the replacement of the Foresters Falls culvert located on Highway 17, within Renfrew County. Thurber carried out the investigation as a subconsultant to WSP Canada (WSP) as part of Agreement No. 4014-E-0014.

No previous foundation investigation information for the subject culvert was available. General Arrangement (GA) drawings and base plan mapping were provided by WSP for the preparation of this report.

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

2 SITE DESCRIPTION

Culvert 29-250/C is located on Highway 17, approximately 30 m west of the intersection with Foresters Falls Road and approximately 1.0 km east of Cobden, Ontario. The location of the culvert is shown on the inset Key Plan on Drawing No. 1 in Appendix A.

It is noted that for project orientation purposes, Highway 17 within the project limits, will be assumed to run west-east.

The existing culvert is an open bottom, rigid frame, cast-in-place concrete structure with an internal span of 5.5 m, height of 1.8 m and length of 33 m that carries creek flow from south to north below the highway. The GA drawing indicates that the of the top of stream bed elevation ranges from 123.68 m to 123.39 m at the inlet and outlet respectively.

At this location, Highway 17 is an undivided highway with one through lane in each direction with gravel shoulders. At the intersection with Foresters Falls Road, Highway 17 has a left hand turning lane in the eastbound direction and a right turn taper in the westbound direction. A steel cable guide rail is located along the south side of the highway and a combination of steel beam and steel cable guide rails is present along the north side. Based on the GA drawing, the roadway cross-section at the culvert location consists of a 3.92 m wide eastbound lane, a 3.75 m left turning lane and a 3.47 m wide westbound lane and 2.3 m wide gravel shoulders.

The site is located within a physiographic region known as the Muskrat Lake Ridges which is characterized as a steep scarp composed of Precambrian rocks overlain by a thin overburden deposit of sand and gravel.

The highway embankment slopes beside the inlet and outlet are graded at approximately 2H:1V (Horizontal:Vertical) and 3H:1V, respectively, and are grass and brush covered; no signs of erosion or instability were noted. Based on the GA drawing, the elevation of Highway 17 at the culvert is approximately 128.3 m and the elevation of the top of the existing culvert at the inlet and outlet ends is approximately 126.1 m and 125.9 m, respectively.

The lands south of Highway 17 near the project limits are generally agricultural with some brush cover. A residential property is located on the south side of the highway immediately adjacent to the culvert inlet. There is a concrete block retaining wall along the west creek bank adjacent to the private property. The creek channel appeared to be narrower on the south/upstream side than on the north/downstream side where brush and swampy terrain is present. The storm water drainage in the area is to existing culverts and ditches.

Site photographs showing the general conditions at the site, along the highway embankment and at the inlet and outlet are presented in Appendix D.

3 SITE INVESTIGATION

3.1 Field Investigation

A field investigation was carried out between October 23rd and November 4th, 2015, based on initial plans for replacement of the culvert along the existing alignment. The investigation included advancing four boreholes (Boreholes 701 through 704). Due to obstructions in the fill material in Borehole 703 at a depth of approximately 1.4 m, an additional borehole (Borehole 703A) was advanced approximately 2 m to the north of the original borehole location. The approximate locations and elevations of the boreholes are illustrated on Drawing No. 1 provided in Appendix A and are summarized in Table 3-1.

Based on the December 2016 GA drawing provided by WSP, the replacement culvert is to be installed east of the existing culvert on a new skewed alignment offset approximately 7.5 m and 12.6 m from the existing centerline at the outlet and inlet, respectively.

A supplemental investigation was carried out on June 29th and 30th, 2017 and included advancing two additional boreholes (Boreholes 705 and 706). The approximate locations and elevations of the boreholes are illustrated on Drawing No. 1 provided in Appendix A and are summarized in Table 3-1.

Table 3-1: Borehole Summary

Borehole	Location	Latitude (degrees)	Longitude (degrees)	Ground Surface Elevation (m)	Depth (m)
701	Existing Culvert Inlet	45.62173	-76.87070	127.0	4.7
702	Highway 17	45.62170	-76.87050	128.2	9.0
703A	Highway 17	45.62186	-76.87060	128.1	4.5
704	Existing Culvert Outlet	45.62192	-76.87053	125.1	6.4
705	Proposed Culvert Inlet	45.62162	-76.87061	127.8	10.9
706	Proposed Culvert Outlet	45.62183	-76.87035	125.1	9.8

As a component of our standard procedures and due diligence, Thurber contacted Ontario One Call to provide utility locates/clearances for the intended borehole locations. Thurber also contacted USL-1 Underground Service Locaters Inc. of Ottawa, Ontario to provide private utility locate clearances for the boreholes located adjacent to the private property.

The boreholes completed during the 2015 field investigation were advanced using a CME75 truck mounted drill rig with NW casing for the roadway embankment boreholes, and portable drilling equipment for the inlet and outlet boreholes. The boreholes completed during the 2017 field investigation were advanced using a track mounted drill rig with NW casing at the inlet, and portable drilling equipment at the outlet.

The subsurface stratigraphy encountered in the boreholes was recorded in the field by Thurber personnel. Split spoon samples were collected at regular depth intervals in all boreholes during the completion of Standard Penetration Tests (SPT), following the methods described in ASTM Standard D1586-11. In-situ shear vane testing was carried out within cohesive strata. All soil samples recovered from the boreholes were placed in moisture-proof containers and the samples were transported to Thurber's Ottawa laboratory for further examination and testing. Bedrock was cored in Borehole 702 and 705 using NQ size coring equipment following ASTM Standard D6032-08. Bedrock core samples were stored in core boxes for transport.

A 25 mm inside diameter PVC piezometer was installed in Borehole 704 to allow for measurement of the groundwater level at the site. The piezometer construction details are illustrated on the Record of Borehole sheet for Borehole 704, provided in Appendix B. The piezometer was decommissioned on December 16, 2015, after the water level was read.

The boreholes without a piezometer installation were backfilled with a low-permeability mixture of auger cuttings and bentonite pellets in general accordance with the intent of Ontario MOE Regulation 903. Boreholes advanced within paved areas were capped with 150 mm of cold patch asphalt.

The as-drilled locations of the boreholes and ground surface elevations at the borehole locations were surveyed by Thurber on December 16, 2015 (Boreholes 701 through 704) and on July 4, 2017 (Boreholes 705 and 706). The vertical datum used was a horizontal control monument (HCM) located on the culvert outlet. The HCM was identified on base plans provided by WSP as having a geodetic elevation of 125.974 m. The location of the HCM is indicated on Drawing No. 1 in Appendix A.

3.2 LABORATORY TESTING

Natural moisture content determination and visual identification of all soil samples was completed in accordance with the current MTO standards. In addition, grain size distribution analyses, and Atterberg Limits testing were carried out on selected samples to MTO and ASTM standards. Point load Strength Index testing was carried out on select bedrock core samples in accordance with ASTM Standard D5731-16.

The geotechnical laboratory test results are presented on the Record of Borehole sheets in Appendix B and are illustrated on the figures in Appendix C.

Chemical analysis for determination of pH, resistivity, soluble sulphate and chloride concentrations was carried out on three soil samples. A copy of the chemical analysis results is provided in Appendix C.

4 DESCRIPTION OF SUBSURFACE CONDITIONS

4.1 Overview / General

Reference is made to the Record of Borehole sheets in Appendix B for details of the soil stratigraphy encountered in the boreholes. A stratigraphic profile for the culvert area is presented on Drawing No. 1 in Appendix A for illustrative purposes. An overall description of the stratigraphy is given in the following paragraphs; however, the factual data presented in the Record of Boreholes governs any interpretation of the site conditions.

In general, the stratigraphy in the area of the of the boreholes is characterized by an asphalt pavement structure, overlying granular embankment fill overlying layers of silt, sand and clay, overlying a glacial till deposit, underlain by bedrock. It should be noted that cobbles and boulders were encountered in the embankment fill in Borehole 703A and within the glacial till deposit.

More detailed descriptions of the individual strata are presented below.

4.2 Asphalt

Two boreholes were advanced through the Highway 17 pavement structure. The thickness of the asphalt at the borehole locations was 175 mm and 190 mm.

4.3 Fill – Silty Sand with Gravel

In all boreholes, a fill layer consisting predominantly of sand with varying amounts of silt and gravel was encountered at surface or below the surficial layers. The top of this layer ranges from Elevation 128.1 m to 125.1 m. The thickness of the layer ranged from 1.0 m to 4.5 m. The SPT 'N' values ranged from 1 to 54 blows; indicating a very loose to very dense condition; but typically loose to compact. Frequent cobbles and boulders were encountered in Borehole 703 and 703A; coring techniques were required to advance the borehole.

The moisture content of the samples tested ranged from 3% to 22%. The results of grain size analysis conducted on samples of this material are summarized in Table 4-1 and are illustrated on Figures 1 and 2 in Appendix C.

Table 4-1: Gradation Results for Fill

Soil Particles	%
Gravel	2 to 36
Sand	47 to 79
Silt and Clay	10 to 27

4.4 Silt / Sandy Silt (ML)

A stratum of silt with varying amounts of sand was encountered beneath the fill layer in Boreholes 701 and 704 and below the silty sand layer in Boreholes 705 and 706. The top of this layer ranges from Elevation 122.7 m to 124.5 m. The thickness of the layer ranged from 1.0 m to 1.8 m. The SPT 'N' values ranged from 3 to 18 blows; indicating a very loose to compact condition.

The moisture content of the samples tested ranged from 21% to 59%. The results of grain size analysis conducted on samples of this material are summarized in Table 4-2 and are illustrated on Figure 3 in Appendix C.

Table 4-2: Gradation Results for Silt

Soil Particles	%
Gravel	0 to 1
Sand	24 to 42
Silt	44 to 70
Clay	5 to 14

Based on the results of Atterberg Limits testing the material is a non-plastic silt.

4.5 Silty Sand (SM) with Gravel

A stratum of silty sand with gravel was encountered beneath the fill layer in Boreholes 702, 705 and 706. The silty sand with gravel contained trace amounts of organic matter in all three boreholes. The top of this layer ranges from Elevation 124.8 m and 124.1 m. The thickness of the layer ranged from 1.3 m to 2.3 m. The SPT 'N' values ranged from 5 to 26 blows; indicating a loose to compact condition.

The moisture content of the samples tested ranged from 19% to 31%. The results of grain size analysis conducted on samples of this material are summarized in Table 4-3 and are illustrated on Figure 4 in Appendix C.

Table 4-3: Gradation Results for Silty Sand

Soil Particles	%
Gravel	14 to 24
Sand	52 to 66
Silt and Clay	15 to 30

Based on the results of Atterberg Limits testing the fines of this material are non-plastic.

4.6 Clay (CL to CI)

A clay deposit was encountered beneath the silt/sandy silt in Boreholes 704 and 706. The top of clay layer (where present) ranges from Elevation 121.8 m to 122.7 m. The thickness of the layer ranged from 4.0 m to 5.3 m. In-situ shear vane test results indicated undrained shear strengths ranging from 85 kPa to greater than 100 kPa; indicating a stiff to very stiff consistency.

The moisture content of the samples tested ranged from 17% to 42%. The results of grain size analysis conducted on samples of this material are summarized in Table 4-4 and are illustrated on Figure 5 in Appendix C.

Table 4-4: Gradation Results for Clay

Soil Particles	%
Gravel	0 to 1
Sand	4 to 7
Silt	50 to 65
Clay	30 to 46

The results of Atterberg Limits testing completed on samples of this material are summarized in Table 4-5 and are illustrated on Figure 6 in Appendix C. The results indicate a clay of low to intermediate plasticity.

Table 4-5: Atterberg Limits Test Results

Liquid Limit	28 to 39
Plastic Limit	15 to 18
Plasticity Index	13 to 21

4.7 Silty Sand with Gravel Till

A glacial till layer consisting predominantly of silty sand with gravel was encountered below the silty sand layer in Borehole 702, below the sandy silt layer in Borehole 701 and below the clay layer in Borehole 706. This stratum has a top elevation of 116.4 m to 122.1 m and has a thickness of 1.1 to 1.7 m where completely penetrated. Boreholes 701 and 706 were terminated in this layer. The SPT 'N' values ranged from 13 to 110 blows; indicating a compact to very dense condition.

The moisture content of the samples tested ranged from 8% to 20%. The results of a grain size analysis test on samples of this material are summarized in Table 4-6 and are illustrated on Figure 7 in Appendix C.

Table 4-6: Gradation Results for Glacial Till

Soil Particles	%
Gravel	28 to 40
Sand	44 to 59
Silt and Clay	13 to 19

4.8 Bedrock

Granite bedrock was encountered beneath the glacial till stratum in Boreholes 702 and 705. The bedrock surface was encountered at Elevation 120.4 m in both boreholes. Both boreholes were advanced into bedrock by coring with NQ size coring equipment. Photographs of the bedrock core are provided in Appendix B. The total core recovery (TCR) ranged from 83% to 100%, the solid core recovery (SCR) ranged from 74% to 86% and the Rock Quality Designation (RQD) ranged from 44% to 97%. Based on the RQD value the bedrock is classified as fair to excellent quality.

The results of point load index testing indicate that the intact rock ranges from strong to very strong.

4.9 Groundwater Conditions

The groundwater level in the piezometer installed in Borehole 704 was measured on December 16, 2015, at a depth of 0.78 m; corresponding to Elevation 124.3 m. The groundwater level was measured in Borehole 701 in the open borehole prior to backfilling at Elevation 125.6 m.

The water level in the creek was measured at the time of Thurber's field investigations at Elevation 124.3 m.

These observations are short-term readings to seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after the spring snowmelt or after periods of heavy rainfall. The groundwater level in the area of the culvert is expected to be heavily influenced by the water level in the creek.

5 MISCELLANEOUS

Thurber staked and/or marked the borehole locations in the field and obtained utility clearances prior to drilling. Thurber surveyed the borehole locations, and determined the ground surface elevations based on contract drawings provided by WSP Canada. Ohlmann Geotechnical Services (OGS) Inc. of Almonte, Ontario and Forage M3 Drilling Services Inc. of Hawkesbury, Ontario supplied and operated the drilling equipment to carry out the drilling, sampling, and in-situ testing. The drilling, and sampling operations in the field were supervised on a full-time basis by Mr. Simon Paxton, and Justin Gray of Thurber. Laboratory testing was carried out by Thurber in its MTO-approved laboratory in Ottawa.

Overall project management and direction of the field program was provided by Paul Carnaffan, P.Eng. Interpretation of the field data and preparation of this report was completed by Kenton Power, P.Eng. The report was reviewed by Paul Carnaffan, P.Eng. and Dr. P.K. Chatterji, P.Eng., the Designated Principal Contact for MTO Foundations Projects.



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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

6 GENERAL

This report presents the interpretation of the factual data obtained from a foundation investigations conducted by Thurber for the replacement of structural Culvert No. 29-250/C located on Highway 17, in Renfrew County, Ontario. Geotechnical assessment and recommendations are provided to assist the design team in designing a suitable foundation for the proposed replacement culvert and associated retaining walls.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation, and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. Contractors 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.

No previous foundation investigation information for the subject culvert was available. A Preliminary General Arrangement (GA) drawing and base plan mapping were provided by WSP for the preparation of this report. A copy of the Preliminary GA is provided in Appendix B.

The following sections address geotechnical recommendations for the replacement of the existing Foresters Falls Culvert. The discussions and recommendations presented in this report are based on the information provided by WSP and on the factual data obtained during the course of this investigation.

6.1 Proposed Structure

Based on the Preliminary GA, the culvert replacement is to take place on a new skewed alignment to the east of the existing culvert. The proposed culvert is to have a 5.0 m span, soffit elevation ranging from 124.95 to 125.05 m and streambed elevation ranging from 123.40 to 123.50 m. The Preliminary GA drawing identifies wingwalls at the culvert outlet and east side of the inlet, and a new armour stone retaining wall extending in-line with the west side of the culvert across the existing creek bed at the culvert inlet. The armour stone retaining wall in part replaces the concrete block wall that supports the residential driveway.

The centreline of the new culvert alignment is to be offset from the centreline of the existing culvert by approximately 7.6 m and 12.1 m at the outlet and inlet, respectively. The edge to edge spacing between the culverts will be about 1.4 m at the outlet and 5.9 m at the inlet.

The existing culvert is an open bottom, rigid frame, cast-in-place concrete structure with an internal span of 5.5 m, height of 1.8 m and length of 33 m. It has up to 2.2 m of cover above it. The width of the footings has been identified as 750 mm but the depth of the footings has not been confirmed. If the existing footings are founded at frost depth below the streambed, they should be just outside of the zone of influence of the new box culvert. The final design will need to ensure that there is no negative influence between the existing and proposed structures.

It is understood that the new culvert is to be constructed in stages and that all existing lanes must be maintained throughout the construction.

It is also understood that creek flow may be maintained through the existing culvert during construction of the new culvert. The creek would then be realigned to flow through the new culvert. Consideration may be given to abandoning parts of the existing culvert in place by filling the culvert with grout or concrete.

6.2 Applicable Codes and Design Considerations

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

In accordance with CHBDC, the analysis and design of the structures takes into consideration the importance of the structures and the consequence associated with exceeding limit states. The importance category and consequence classification are defined by the Regulatory Authority, which in this case is the Ministry of Transportation, Ontario (MTO).

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

It is also understood that the culvert is being designed to the Major Route seismic importance category.

The frost penetration depth at this site is 1.9 m as per OPSD 3090.101.

6.3 Geotechnical Assessment

Based on the results of the field and laboratory investigation and the information provided by WSP with regards to the proposed project requirements, the geotechnical foundation design considerations include:

- The native stiff to very stiff clay and compact to dense glacial till deposit offer moderate bearing resistance for culvert and retaining wall foundations. These deposits are overlain by silt and silty sand deposits that range from very loose to compact, and contain trace to some organic matter at some locations. The very loose to loose silt and sand deposits are not suitable for the support of foundations and must be removed and replaced with engineered fill during the subgrade preparation;
- The depth to bedrock is highly variable. Bedrock was encountered at Elevation 120.4 m in Boreholes 702 and 705, but was not encountered within the

- depth of drilling at the culvert outlet. Limited embedment may be available for the installation of protection systems near the inlet where shallow bedrock was encountered.
- Cobbles and boulders were encountered within the glacial till and within the embankment fill at some locations (e.g. Borehole 703 and 703A). Obstructions may be encountered during excavation or during the installation or temporary protection systems.
 - A temporary flow passage system and dewatering of work excavations will be required. The proximity of the new culvert to the existing culvert must be considered to ensure that the excavations and loads from the culverts do not adversely impact the other structure. A temporary protection system may be required. If the existing culvert is to be used as a component of a temporary flow passage system or temporary protection system, it must be confirmed that the structure can support unbalanced earth pressures and/or hydrostatic pressures that may develop.
 - Excavation for replacement of the culvert will extend through cohesionless soils below the groundwater level and the water level in the creek. The management of surface water flow and dewatering must consider both dewatering volumes as well as control of hydrostatic pressures to prevent boiling of the base of the excavation or sloughing of the side slopes. An adequate and effective surface water management and dewatering plan must be implemented to construct the replacement culvert and walls in the dry.
 - The preliminary dewatering and staging plans include abandoning and decommissioning the existing culvert in place by filling it with concrete/grout. Not removing the existing culvert during construction offers the advantage of reducing the extent of cofferdams required which could reduce the cost and overall construction days. The disadvantages in this case is that due to the proximity between the existing and proposed culverts the mutual influence of one on the other must be considered in the design both during construction and long term. The potential for unbalanced pressures on the existing culvert must be considered, and partial removal of the existing culvert at the outlet end may be required to avoid conflict with the new culvert or wingwalls.

7 SEISMIC CONSIDERATIONS

7.1 Spectral and Peak Acceleration Hazard Values

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

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

7.2 CHBDC Seismic Site Classification

In accordance with the CHBDC, the selection of the seismic site classification is based on the soil conditions encountered in the upper 30 m of the stratigraphy. Based on the SPT N-values of the soil (and assigning an N-value of 100 to the bedrock) beneath the culvert foundation elevation, the site is classified as a Seismic Site Class D in accordance with Table 4.1 in Section 4.4.3.2 of the CHBDC.

7.3 Seismic Liquefaction Assessment

The soils beneath the anticipated founding elevation consist of stiff to very stiff clay and compact to very dense glacial till deposits. The glacial till is not considered susceptible to liquefaction under earthquake loading associated with the seismic hazard data for this site.

Some of the clay is susceptible to cyclic mobility based on the results of moisture content and plasticity testing and the criteria presented by Bray et. al. (2004).

8 DESIGN OPTIONS

Culvert/foundation alternatives and construction approaches are presented and evaluated in the following sections and a preferred replacement alternative from a foundation engineering perspective is recommended.

8.1 Culvert Type/Foundation Alternatives

Common culvert and foundation types are listed below and a comparison of these alternatives from a foundation perspective, based on their respective advantages and disadvantages are outlined below, and are summarized in the tables provided in Appendix E.

8.1.1 Circular Pipes

From a foundation engineering perspective, circular pipes installed with appropriate granular bedding over the glacial till and/or clay subgrade are feasible. However, it is understood that numerous circular pipes on new alignments would be required to provide the required hydraulic opening.

8.1.2 Open Bottom Culvert

An open bottom concrete culvert founded at or below elevation 121.5 m (1.9 m below the top of stream bed elevation), is considered feasible at this site from a foundation standpoint. At this elevation, it is expected that the replacement culvert will be founded on the compact to very dense till at the culvert inlet and the stiff to very stiff clay at the culvert outlet. Localized removal of loose sandy silt with organic matter may be required.

8.1.3 Closed Bottom (Box) Culvert

Based on the stream bed elevation of approximately 123.5 m indicated on the Preliminary GA and allowing for a 450 mm thick layer of interior substrate and a 400 mm thick concrete base, the founding elevation is expected to be around Elevation 122.6 m. A minimum of 300 mm of bedding material is recommended, however, deeper excavation (as deep as 121.4 m) will be required in

some areas to remove very loose sandy silt and/or silt and sand with organic matter. The grades would then be raised with engineered fill, placed and compacted in lifts.

8.1.4 Pre-cast vs Cast-in-Place Concrete Culverts

From a foundation engineering perspective, both pre-cast and cast-in-place culverts are considered feasible for this site. Pre-cast units are manufactured in a controlled casting environment eliminating the drawbacks imposed by varying weather and site conditions. The use of pre-cast units will generally allow for quicker installation, possibly reducing dewatering requirements and the overall construction schedule. Larger cranes are likely required for installation of large span pre-cast units which may impact the required construction staging zone. Cast-in-place culverts are less prone to disturbance during removal of temporary protection systems.

Fabrication and installation of concrete structural culverts under a design build project should be in accordance with Special Provision DBSP3271.

8.2 Construction Methodology Alternatives

This section presents discussions from a foundation perspective on alternative construction methods for the replacement of Culvert 29-250/C. Further comparison of these construction methodologies is summarized in the tables provided in Appendix E.

In preparation of these recommendations the following options have been considered:

1. Trenchless techniques
2. Open cut with staged construction and roadway protection
3. Open cut with staged construction with platform widening

8.2.1 Trenchless Techniques

Trenchless techniques have the advantage of minimum disruption to traffic and would avoid an excavation through the existing highway embankment. However, obstructions in embankment fill, a mixed clay and granular interface, and a very loose to compact saturated silt to silty sand present along the alignment are not conducive to trenchless methods. In addition, there is limited area to construct entry/exits pits on the south side of the highway due to the existing residential property. Trenchless techniques are not recommended for this site.

8.2.2 Open Cut using Staged Construction and Temporary Protection Systems

The culvert could be replaced using open cut techniques with staged construction (half and half). It is noted that operational requirements require that all existing traffic lanes (through lanes and turn lanes) be kept open throughout construction, therefore the use of temporary protection systems does not allow for staged construction unless used in conjunction with temporary detour widenings.

Increased difficulty with the installation of protection systems should be anticipated due to the presence of obstructions within the embankment fill and the relatively shallow depth to bedrock. Sheet piles systems may encounter obstructions in the fill at this site. Protection systems would likely consist of H-piles with timber lagging installed by pre-drilling holes for installation of H-piles; rock anchors would likely be required.

8.2.3 Open Cut using Staged Construction and Temporary Widening

The culvert could be replaced using open cut techniques with staged construction and temporary platform widening. It is understood that there are potential constraints with widening due to the residential property on the south side of the highway and the intersection with Foresters Falls Road on the north side. If implemented, it is understood that widening would likely be limited to the north side. In addition to embankment widening, this option may require a temporary culvert extension and utility relocation. Loose silt and stiff to very stiff clay deposits were identified in the boreholes on the north side of the highway. In addition, the vegetation on the north side includes cattails suggesting that muskeg deposits may be present.

8.3 Recommended Approach for the Culvert Replacement

Based on the soil stratigraphy and traffic operation requirements, the recommended replacement methodology from a foundation perspective would be to replace the culvert using open cut techniques with staged construction carried out with temporary protection systems in conjunction with temporary detour widenings to the north side. A closed box culvert is the preferred culvert foundation option.

9 FOUNDATION DESIGN RECOMMENDATIONS

9.1 Culvert Foundation Bearing Resistances

The factored geotechnical resistances of a closed bottom culvert between 5 and 6 m wide, founded at or below Elevation 122.3 m on undisturbed stiff to very stiff clay, compact to very dense glacial till, or engineered fill above these subgrade soils are as follows:

- Factored geotechnical resistance at ULS 220 kPa
- Factored geotechnical resistance at SLS 150kPa

The factored geotechnical resistances for the foundations of an open bottom culvert with a width between 1.0 and 2.0 m, founded at or below elevation 121.5 m, on undisturbed stiff to very stiff clay, compact to very dense glacial till, or engineered fill above these subgrade soils are as follows:

- Factored geotechnical resistance at ULS 220 kPa
- Factored geotechnical resistance at SLS 150 kPa

The factored geotechnical resistances include the following factors:

- The factored geotechnical resistance values at SLS provided above correspond to the stress increase relative to current site conditions that will result in 25 mm of total settlement.
- Consequence factor (Ψ) of 1.0
- Geotechnical resistance factors (CHBDC Table 6.2):
 - Bearing (ULS), $\phi_{gu} = 0.5$ (static analysis; typical degree of understanding)
 - Settlement (SLS), $\phi_{gs} = 0.8$ (static analysis; typical degree of understanding)

The geotechnical resistances provided in Section 9.1 are for vertical concentric loading and will need to be adjusted for the effects of inclined or eccentric loading, if applicable, as illustrated in the CHBDC Clause 6.10.3 and Clause 6.10.4.

The structural design of the culvert should consider differential settlement beneath the culvert. Based on the SLS bearing resistance provided above, a maximum of 25 mm of differential settlement should be anticipated along the culvert alignment.

Resistance to lateral forces through sliding resistance between concrete foundations and the underlying soils should be evaluated using the unfactored coefficients of friction provided in Table 9-1.

Table 9-1: Design Parameters for Sliding Resistance

Founding Material	Unfactored Coefficients of Friction	
	Cast-in-place	Pre-cast
Clay	0.35	N/A
Glacial Till	0.50	N/A
OPSS Granular A or B II	0.55	0.45

9.2 Subgrade Preparation, Culvert Bedding and Backfilling

Excavation and backfilling for installation of the new culvert should be carried out in accordance OPSS 902 and MTO Special Provision (SP) No. 109S12, Amendment to OPSS 902, March 2018.

Subgrade preparation beneath the culvert and wall foundations should include excavation and removal of the existing fill and any loose, soft or organic materials. The grades should then be raised as required using compacted Granular B Type II.

Where boulders are encountered at the subgrade elevation, the boulders should be removed and replaced with Granular B Type II.

The creek water level was observed at Elevation 124.3 m during the course of Thurber's field investigations, as such the base of the excavation would range from 2.0 m to 3.2 m below the measured creek level. Therefore, creek diversion and dewatering will be required for the preparation of the subgrade, placing and compacting the bedding layer and to construct the culvert in the dry.

The native subgrade materials will be easily disturbed when saturated subjected to construction or personal traffic, freeze thaw actions, ingress or ponding water. One option to protect the exposed subgrade would be to cover it with a 100 mm thick concrete working slab. After the concrete for the working slab has set, the culvert could then be constructed directly on the working slab without the need for a granular pad or bedding material. Suggested wording for an NSSP to alert the Contractor to the requirement for a working slab has been provided in Appendix H.

If a closed box structure is to be constructed without a working slab a bedding layer with a minimum thickness of 300 mm will be required.

Backfill for the culvert must consist of free draining granular material conforming to OPSS Granular A or B Type II material specifications.

Leaving the existing culvert in place and filling it with concrete or grout after construction of the new culvert offers several advantages including:

- Could help manage creek flow during construction of the new culvert
- Reduces the overall footprint of excavation required, thereby reducing requirements for protection systems and dewatering. This likely results in lower cost, fewer working days, and reduced impact to Highway 17 traffic.

The primary disadvantage of abandoning the existing culvert in place is that it will be more difficult to remove in the future.

If the existing culvert is removed, backfill following removal of the existing culvert may consist of approved excavated material or material meeting OPSS.PROV 1010 specifications for Select Subgrade Material (SSM), Granular A or Granular B. Where backfill material within the frost depth differs from the adjacent embankment fill, a frost taper should be provided.

Compaction of bedding and backfill materials should be carried out in accordance with OPSS.PROV 501.

It is recommended that the backfill detailing of OPSD 803.010 be utilized with a frost penetration line below the top of the culvert. The frost treatment depth, k , should be set at 1.9 m. The depth of road bed granulars, d , should be set at 0.770 m.

9.3 Retaining Wall Design

The Preliminary GA drawing identifies wingwalls at the culvert outlet and east side of the inlet, and a new armour stone retaining wall extending in-line with the west side of the culvert across the existing creek bed at the culvert inlet. The armour stone retaining wall in part replaces the concrete block wall that supports the residential driveway.

The geometry of the walls may change during detailed design, however, for preliminary design, it is anticipated that the top of the walls is expected to be approximately equal to the top of the culvert and the base of the walls is likely to be founded at the same elevation as the culvert. The maximum exposed wall height is expected to be about 2 m. The backfill behind the walls is expected to range from horizontal to 2H:1V, depending on the location.

The following retaining wall options have been evaluated from a foundations engineering perspective:

- Inverted T
- Concrete Gravity wall
- Armour stone
- Gabions
- RSS

The assessment is summarized in a table presented in Appendix E.

A flexible wall system such as armour stone or concrete block wall that can be founded at the same elevation as the closed box culvert is recommended.

The use of concrete gravity walls at this site is not recommended as they would require full depth frost protection and hence would require a deeper excavation than what is currently proposed for the culvert which could undermine the culvert base and would increase dewatering requirements.

The use of RSS walls below the water level requires project specific design, review and approval rather than specification of an RSS wall from the designated sourced list.

From a geotechnical engineering perspective, the use of armour stone or gabion walls is considered feasible at this site and are recommended. Typically, such systems are often founded above the design frost depth as they are able to tolerate some movement due to frost heave.

From a practical point of view, unless considered necessary beyond the Foundation Engineering purview, the use of a single wall design across the whole site would simplify the project.

The subgrade preparation and bearing resistance values provided in Sections 9.1 and 9.2 are applicable for the retaining walls.

The lateral earth pressure parameters of Section 9.4 should be used in design of the walls.

Resistance to lateral forces through sliding between the gabion baskets and the bedding material should be evaluated using an unfactored coefficient of friction of 0.65.

Slope stability analyses have been carried out for walls at both the inlet and outlet for both static and seismic cases (including the case of residual clay strength due to cyclic mobility), assuming a base or footing width of 1.5 m. Acceptable Factors of Safety have been determined. Copies of the slope stability results are provided in Appendix F. The global stability should be checked as part of the detailed design of the walls once the geometry and founding elevation has been confirmed.

9.4 Lateral Earth Pressures

The lateral earth pressure parameters provided in Table 9-2 and 9-3 in the following sections are based on the assumption that the backfill is fully drained so that there are no unbalanced hydrostatic pressures. If adequate drainage cannot be confirmed, the potential for buildup of hydrostatic pressures should be considered in the design.

9.4.1 Static Lateral Earth Pressure Coefficients

Lateral earth pressures acting on structures should be computed in accordance with the CHBDC but generally are given by the expression:

$$P_h = K^*(\gamma h + q)$$

where:

P_h = horizontal pressure on the wall (kPa)

K = earth pressure coefficient

γ = unit weight of retained soil (kN/m³)

h = depth below top of fill where pressure is computed (m)

q = value of any surcharge (kPa)

The recommended lateral earth pressure parameters for use in the design for both a horizontal backslope and a 2H:1V backslope are provided in Table 9-2.

Table 9-2: Static Lateral Earth Pressure Coefficient

Parameter	OPSS Granular A & B Type II	Native Till	Existing Fill & Native Silty Sand / Silt	Native Clay
Soil Unit Weight, kN/m^3 , γ	21	21	19	18
Angle of Internal Friction, ϕ	35°	32°	30°	27°
Coefficient of at Rest Earth Pressure, K_o	0.43	0.47	0.50	0.55
Horizontal Backslope				
Coefficient of Active Earth Pressure, K_a (Unrestrained Wall)	0.27	0.31	0.33	0.38
2H:1V Backslope				
Coefficient of Active Earth Pressure, K_a (Unrestrained Wall)	0.39	0.47	0.54	0.71

For rigid structures, it is recommended that at-rest horizontal lateral earth pressures be used for design. Active pressures should be used for the design of unrestrained walls.

A lateral pressure due to backfill compaction equal to should be added to the calculated lateral earth pressure in accordance with Section 6.12.3 of the CHBDC.

If the sloped embankment or backfill above the retaining wall or temporary protection systems differs from that presented in Table 9-2 the lateral earth pressure parameters must be adjusted accordingly.

9.4.2 Combined Static and Seismic Lateral Earth Pressure Parameters

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

- $k_h = \frac{1}{2} F(\text{PGA}) \cdot \text{PGA}$ for structures that allow for 25 mm to 50 mm of movement, and
- $k_h = F(\text{PGA}) \cdot \text{PGA}$ for non-yielding walls

For the 2H:1V backfill, the parameters are beyond the limitations for the Mononobe-Okabe method and the general limit equilibrium method has been used to calculate the seismic lateral earth pressures.

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

Table 9-3: Lateral Earth Pressure (Under Seismic Loads)

Parameter	OPSS Granular A & B Type II
Soil Unit Weight, kN/m^3 , γ	21
Angle of Internal Friction, ϕ	35°
Horizontal Backslope	
Dynamic Active Earth Pressure Coefficient, K_{AE} (Restrained Wall)	0.45
Dynamic Active Earth Pressure Coefficient, K_{AE} (Unrestrained Wall)	0.35
2H:1V Backslope	
Dynamic Active Earth Pressure Coefficient, K_{AE} (Restrained Wall)	0.89
Dynamic Active Earth Pressure Coefficient, K_{AE} (Unrestrained Wall)	0.66

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

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

where:

σ_h = lateral earth pressure at depth, d (kPa)

d = depth below the top of the wall (m)

K = static earth pressure coefficient

(K_o for non-yielding and K_a for yielding walls)

γ = unit weight of the backfill soil (kN/m^3)

K_{AE} = combined static and seismic earth pressure coefficient

H = total height of the wall (m)

9.5 Erosion Protection

Slope protection and drainage measures will be required to ensure the long-term surficial stability of the embankment slopes.

Erosion protection should be provided at the culvert inlet and outlet areas. Details on the erosion control/protection measures proposed for this project are illustrated on the Preliminary GA drawing. Further reference should be made to WSP's Hydrology and Hydraulic Assessment Report, dated March 2018. If the Contractor proposes design changes to erosion protection measures they must consider hydrologic and hydraulic factors presented in WSP's report and should be carried out by specialists experienced in this field. The results of the final erosion control analyse should be reviewed by the foundation engineer to ensure that the foundation design and related earthworks are in accordance with the recommendations provided.

Typically, rock protection should be provided over all surfaces with which culvert water is likely to be in contact. Treatment at the outlets should be in accordance with OPSD 810.010. A vegetation cover should be established on all other exposed earth surfaces as soon as practical to protect against surficial erosion in general accordance with OPSS.PROV 804.

Consideration should be given to including cut-off walls at the culvert inlet and outlet areas.

It is recommended that a clay seal be used to minimize the potential for erosion near the inlet and outlet areas. The clay seal should extend a minimum of 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 as a clay seal.

9.6 Cement Type and Corrosion Potential

Three samples of the native soils encountered at the site were submitted to Paracel Laboratories in Ottawa, Ontario for analysis of pH, water soluble sulphate and chloride concentrations, and resistivity. The analysis results are summarized in the Table 9-4 and a copy of the test results is provided in Appendix C.

Table 9-4: Results of Chemical Analysis

Borehole	Sample	Depth (m)	pH	Resistivity (Ohm-cm)	Chloride (µg/g)	Sulphate (µg/g)
704	SS4	2.1	7.6	2530	129	27
705	SS6	3.8	7.3	1540	298	75
706	SS3	1.5	7.3	1470	297	131

The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with soil and groundwater at the site. The soluble sulphate results in Table 9-4 were compared with the parameters in Table 3 of the Canadian Standards Association Standards A23.1-14 (CSA A23.1) and indicate a low degree of sulphate attack potential on concrete structures at this site.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The test results provided in Table 9-4 were compared with Table 3.2 of the MTO Gravity Pipe Design Guideline and generally indicate a moderately to severely corrosive environment. The test results provided in Table 9-4 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects.

10 CONSTRUCTION CONSIDERATIONS

10.1 Excavations

It is anticipated that temporary excavations in the order of 7 m below Highway 17 will be required for the construction of the new culvert. These excavations will extend below the groundwater level and the water level observed in the creek.

All excavations must be conducted in accordance with the requirements of the Occupational Health & Safety Act & Regulations (OHSA) for Construction Projects. The fills at the site should be classified as Type 3 above the groundwater level and Type 4 below the groundwater level in accordance with OHSA.. Any alluvium or cohesionless silts and sands below the groundwater level would be classified as Type 4. However, as indicated in OHSA, if an excavation contains more than one type of soil, the soil type for the excavation shall be classified as the type with the highest number among the soil types present within the excavation. In accordance with OHSA unsupported excavations made in Type 4 soils must have side slopes no steeper than 3H:1V from the base of the excavation.

At locations where there are space restrictions or where the excavation could impact an existing structure (e.g. existing culvert) or existing roadway (e.g. Highway 17 or existing Foresters Falls Road embankment), the excavations will need to be supported by a protection system. Further discussion regarding temporary protection systems is presented in Section 10.2.

It is noted that unbalanced earth pressures and/or hydrostatic pressures on the existing culvert could result in sliding or unacceptable bending moments in the culvert walls. Using the existing culvert to support the excavation for the new foundations or to support components of a temporary flow passage system means that the existing culvert is being used as a temporary protection system. Where the Contractor is using parts of the existing structure as part of their temporary protection system or dewatering system, this must be addressed as part of OPSS.PROV 539 and/or OPSS.PROV 517 and SP 517F01

Selection of the equipment and methodology to excavate and prepare the founding surface is the responsibility of the Contractor.

Excavation below the groundwater level to construct the culvert foundation will be required and excavation below the groundwater level without prior dewatering is not recommended since the inflow of groundwater will cause base heave/boiling and sloughing of the foundation soil below the water level, making it difficult to maintain a dry, sound base on which to work. One option would be to construct a sheet pile wall enclosure designed with sufficient depth in the clay layer or till layer to achieve base fixity. As cobbles and boulders were observed in the boreholes a NSSP alerting bidders to their presence has been provided in Appendix F.

10.2 Temporary Protection Systems

If required, temporary protection systems should be provided in accordance with OPSS.PROV 539 and designed for Performance Level 2. All protection systems should be designed by a Professional Engineer experienced in such designs. Typical lateral earth pressure coefficients are provided in Table 9-2.

The design of temporary protection systems is the responsibility of the Contractor. All shoring should be designed by a licensed professional engineer experienced in such designs. The designer of the protection systems must ensure the penetration depth is sufficient to provide base fixity and incorporate traffic loading and surcharge loading due to construction equipment and operations and shall consider the slope of temporary embankments above the top of the protection system.

It is noted that cobbles and boulders were encountered within the existing embankment fill and within the glacial till. Increased difficulty with the installation of protection system should be anticipated due to the presence of these potential obstructions. One option is to use soldier piles and timber lagging with the piles installed in holes predrilled through the embankment and set in the till and/or bedrock. Rock anchors may be used to resist lateral loads. Recommended wording for an NSSP alerting the Contractor to this condition and the requirement to use appropriate equipment and installation techniques is provided in Appendix F.

10.3 Dewatering

The Contractor must be prepared to control the groundwater and surface water flow at the site to permit the proposed culvert replacement to be constructed in a dry and stable excavation. It is

recommended that the replacement be conducted during a drier season such as after the spring freshet or prior to the fall season.

Temporary water course diversion will be required to replace the culvert in the dry. It is understood that the preliminary design allows for creek flow to be maintained through the existing culvert during construction of the new culvert, followed by realignment of the creek. After construction of the new culvert is complete the existing culvert would be abandoned in place and decommissioned by filling with grout/concrete. It is noted that partial removal of the ends of the culvert may be required for construction of wing walls.

Cofferdams may be required to prevent the creek from spilling into the adjacent excavation for the new culvert and during creek realignment.

Reference should be made to WSP's Draft Hydrogeological Assessment in Support of an Environmental Activity and Sector Registry (EASR) for Culvert Replacement Work at Replacement Work at the Foresters Falls Road Culvert (Site 29-250C) dated February 2018, with regards to volume of water expected to be withdrawn for the excavations for the culvert replacement, and the need for a PTTW.

The design of any dewatering system that may be required is the responsibility of the Contractor. The Contract Documents must alert them to this responsibility and to design the system in accordance with SP No. FOUN0003.

The Dewatering Systems Designer Fill-in information for SP No. FOUN0003 are provided in the following table.

Design Storm Return Period	Preconstruction Survey Distance
*	**
Where required, fill-in information will be provided in the WSP's Draft Hydrogeological Assessment in Support of an Environmental Activity and Sector Registry (EASR) for Culvert Replacement Work at the Foresters Falls Road Culvert (Site 29-250C) dated February 2018	Within a 250 m radius around the Highway 17 Foresters Falls Culvert site

In accordance with Section 902.04 of SP FOUN0003, the dewatering system is to be designed in accordance with OPSS.PROV 517 and SP 517F01; Amendment to OPSS 517, July 2017.

The Table A Fill-ins for SP 517F01 are as provided below.

IDF Curve Location	Latitude: 45.62172°		Longitude: -76.87045°			
Temporary Flow Passage Systems						
Site Name / Station Reference	Minimum Return Period (Years)	Return Period Flow Estimates (m³/s)				Design Engineer Requirements (Note 1)
		2 Year	5 Year	10 Year	25 Year	
**	***	****	****	****	****	*****
Site 29-250/C Foresters Falls Culvert Crossing of Highway 17 Approximate Station 14+000	Where required, fill-in information will be provided in the WSP's Draft Hydrogeological Assessment in Support of an Environmental Activity and Sector Registry (EASR) for Culvert Replacement Work at the Foresters Falls Road Culvert (Site 29-250C) dated February 2018.					

Dewatering Systems		
Site Name / Station Reference	Preconstruction Survey Distance (Note 2) (m)	Design Engineer Requirements (Note 1)
**	*****	*****
Site 29-250/C Foresters Falls Culvert Crossing of Highway 17 Approximate Station 14+000	Yes Within a 250 m radius around the Highway 17 Foresters Falls Culvert site	Yes
<p>Note:</p> <ol style="list-style-type: none"> 1. "Yes" means the design Engineer and design-checking Engineer shall have a minimum of 5 years of experience in designing systems of similar nature and scope to the required work. "No" means a minimum experience level is not required for the design Engineer and design-checking Engineer. 2. "N/A" indicates a preconstruction survey is not required. 		

The groundwater level will fluctuate and the minimum groundwater elevation for the site at the time of the proposed culvert replacement should be taken as the water level in the creek at the time of construction as defined by SP 517F01.

Excavation below the groundwater level to construct the culvert foundation will be required and excavation below the groundwater level without prior dewatering is not recommended since the inflow of groundwater will cause base heave/boiling and sloughing of the foundation soil below the water level, making it difficult to maintain a dry, sound base on which to work.

Excavation below the groundwater level is anticipated to extend to a depth of approximately 2.5 m during construction to replace the culvert. The ground settlement due to dewatering is estimated to be less than 15 mm near the edge of beyond the footprint of the excavation and quickly decrease with increasing distance from the culvert.

10.4 Erosion Control

The contractor should provide silt fences and erosion control blankets, as required, throughout the duration of the construction to prevent silt/sediments from running off the site as per OPSS 805.

11 CONSTRUCTION CONCERNS

The planned construction methodology includes an open cut excavation for the installation of a new culvert.

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

- Construction will extend below the water level in the creek. An adequate and effective surface water management and dewatering plan must be implemented to construct the replacement culvert and subgrade in the dry.
- Confirmation that the backfill is adequately placed and compacted to specifications.

- Boulders may be encountered in the glacial till subgrade surface at the founding elevation and may require localized sub-excavation and replacement.
- Increased difficulty with the installation of protection systems should be anticipated due to the presence of obstructions within the embankment fill and the relatively shallow depth to bedrock near the inlet.

The successful performance of the construction of this structure will depend largely upon good workmanship and quality control during construction. Observation of the excavation and backfilling operations will be required as per MTO SP No. 109S12, amendment to OPSS 902 during construction to confirm that the foundation recommendations are correctly implemented and material specifications are met.

12 CLOSURE

Overall project management and direction of the field program was provided by Paul Carnaffan, P.Eng. Interpretation of the field data and preparation of this report was completed by Kenton Power, P.Eng. The report was reviewed by Paul Carnaffan, P.Eng. and Dr. P.K. Chatterji, P.Eng., the Designated Principal Contact for MTO Foundations Projects.



Kenton C. Power, P.Eng.
Geotechnical Engineer



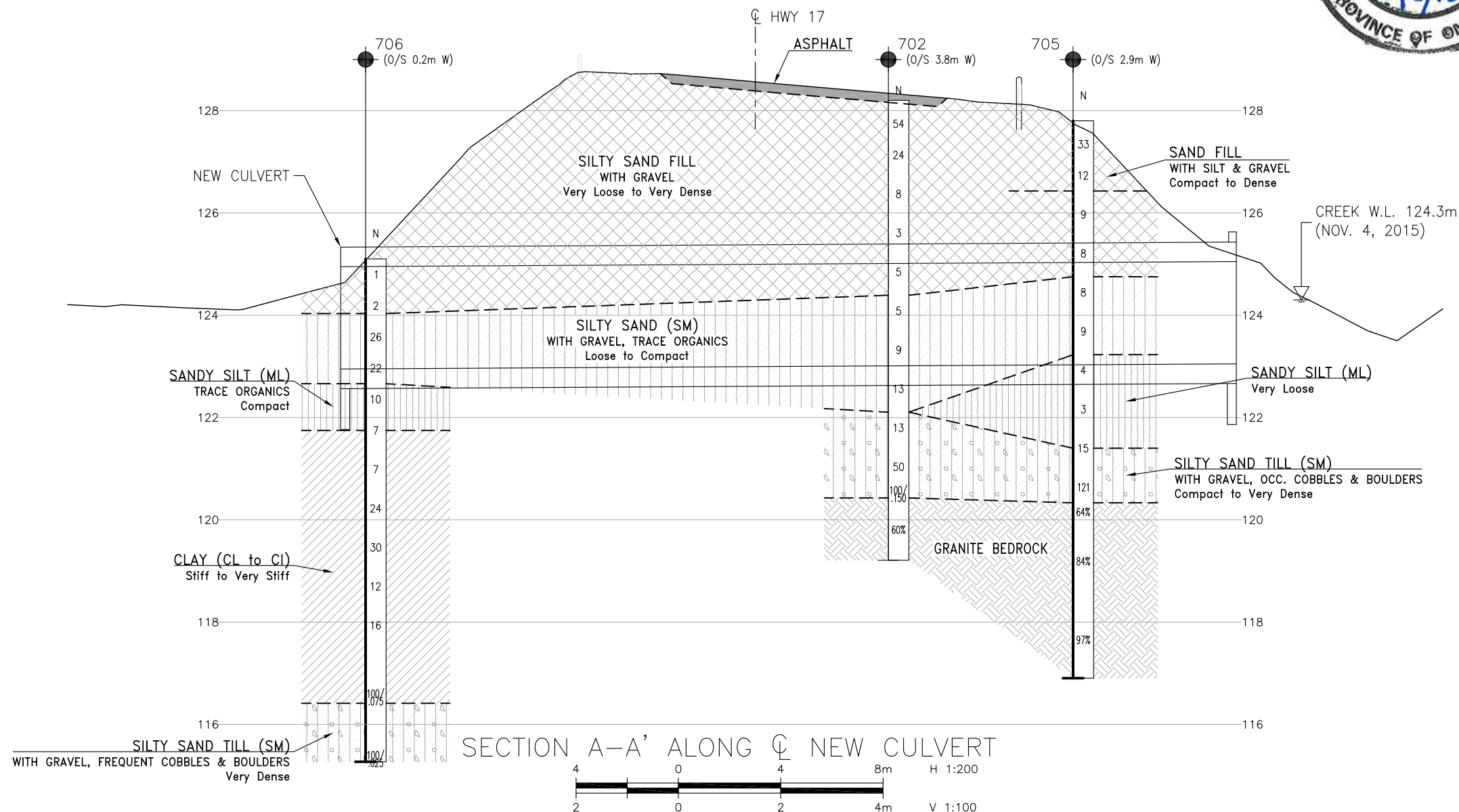
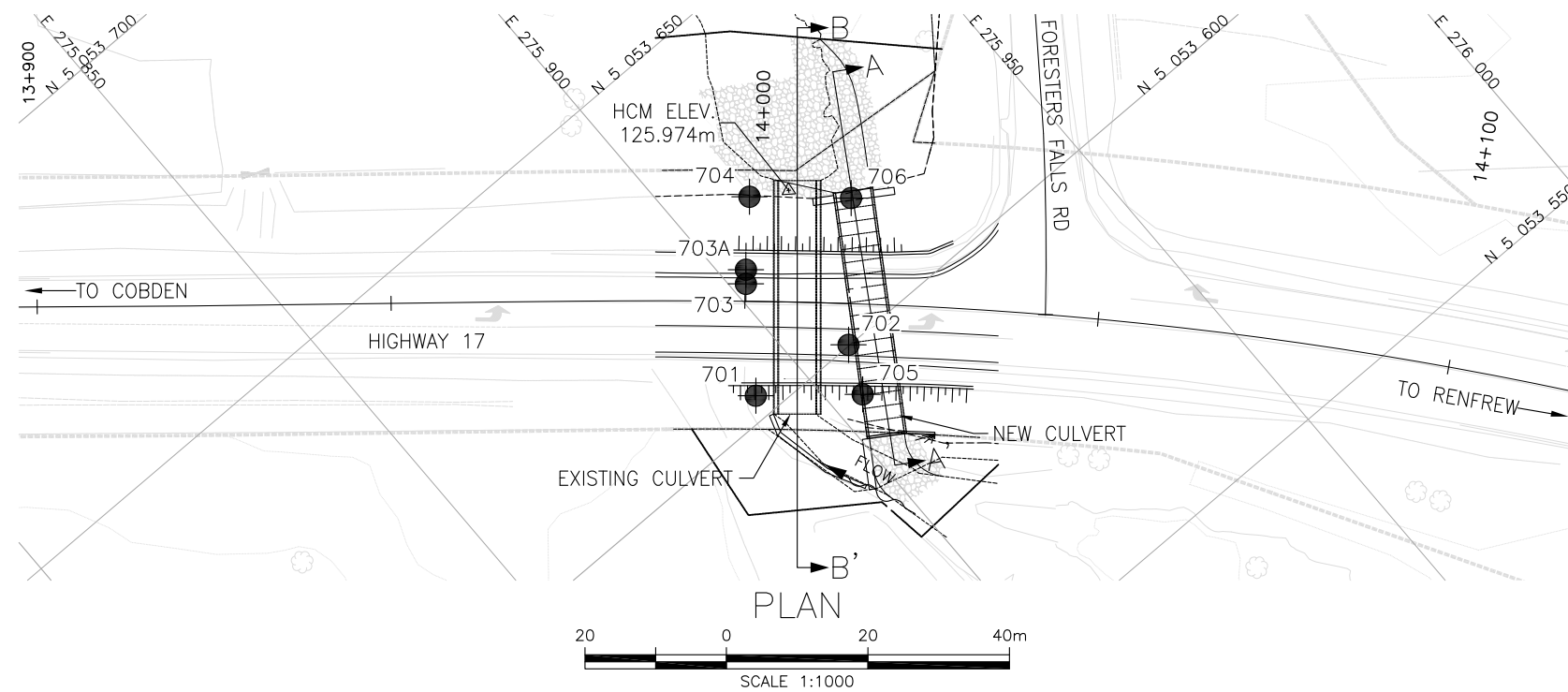
Paul Carnaffan, P.Eng.
Principal, Senior Geotechnical Engineer



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

APPENDIX A

BOREHOLE LOCATIONS AND SOIL STRATA DRAWINGS PRELIMINARY GENERAL ARRANGEMENT DRAWING

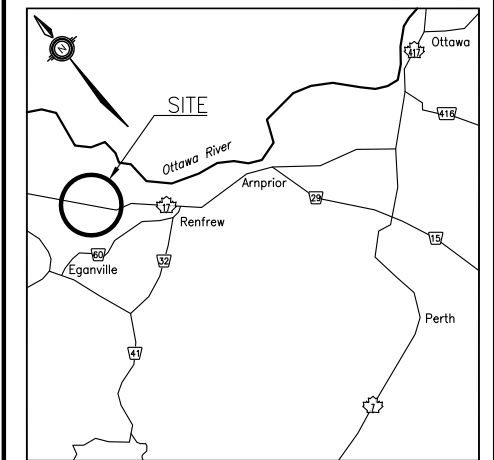


METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN








CONT No
WP No 4114-13-01

HIGHWAY 17
FORESTERS FALLS ROAD
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA



KEYPLAN

LEGEND

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

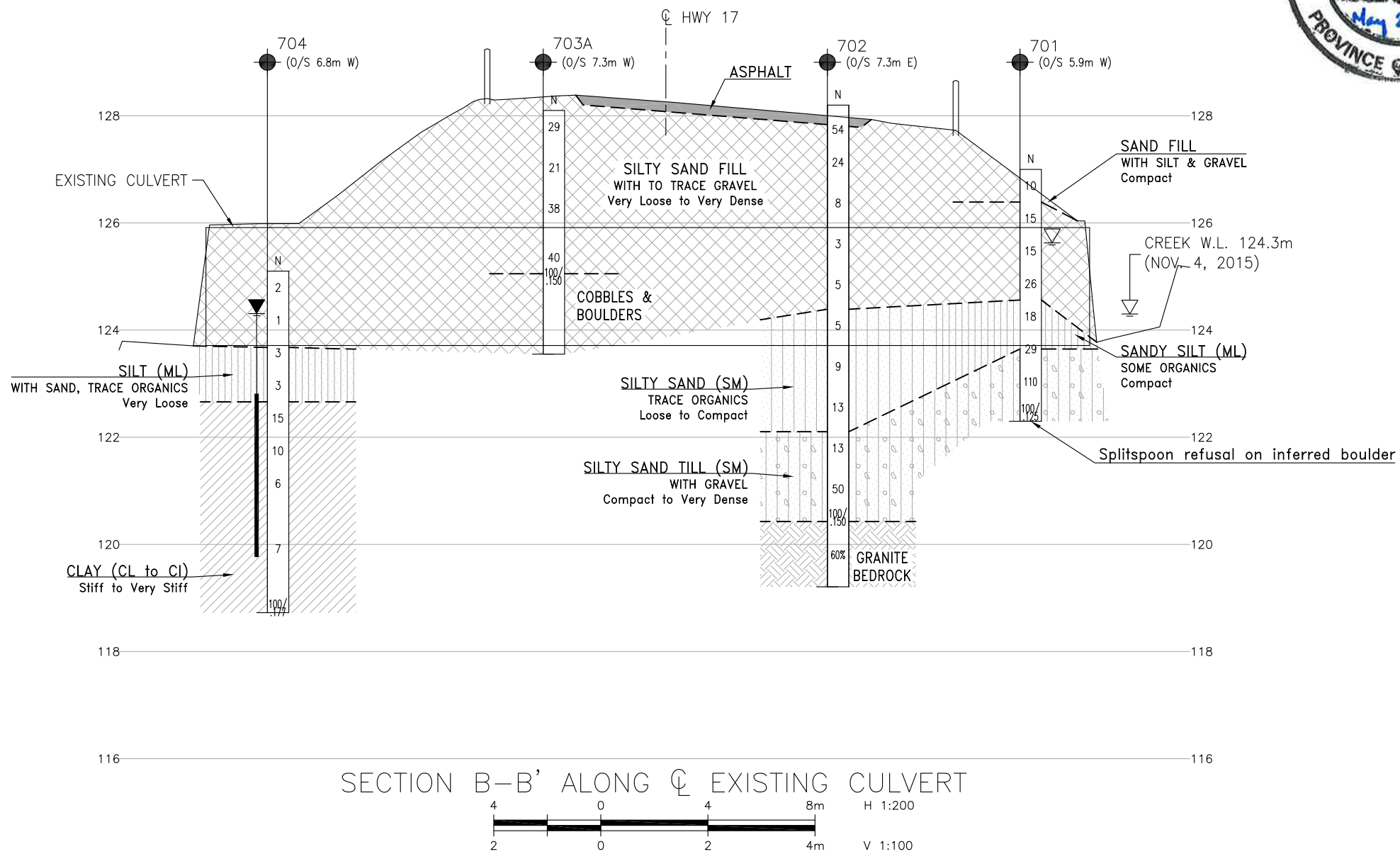
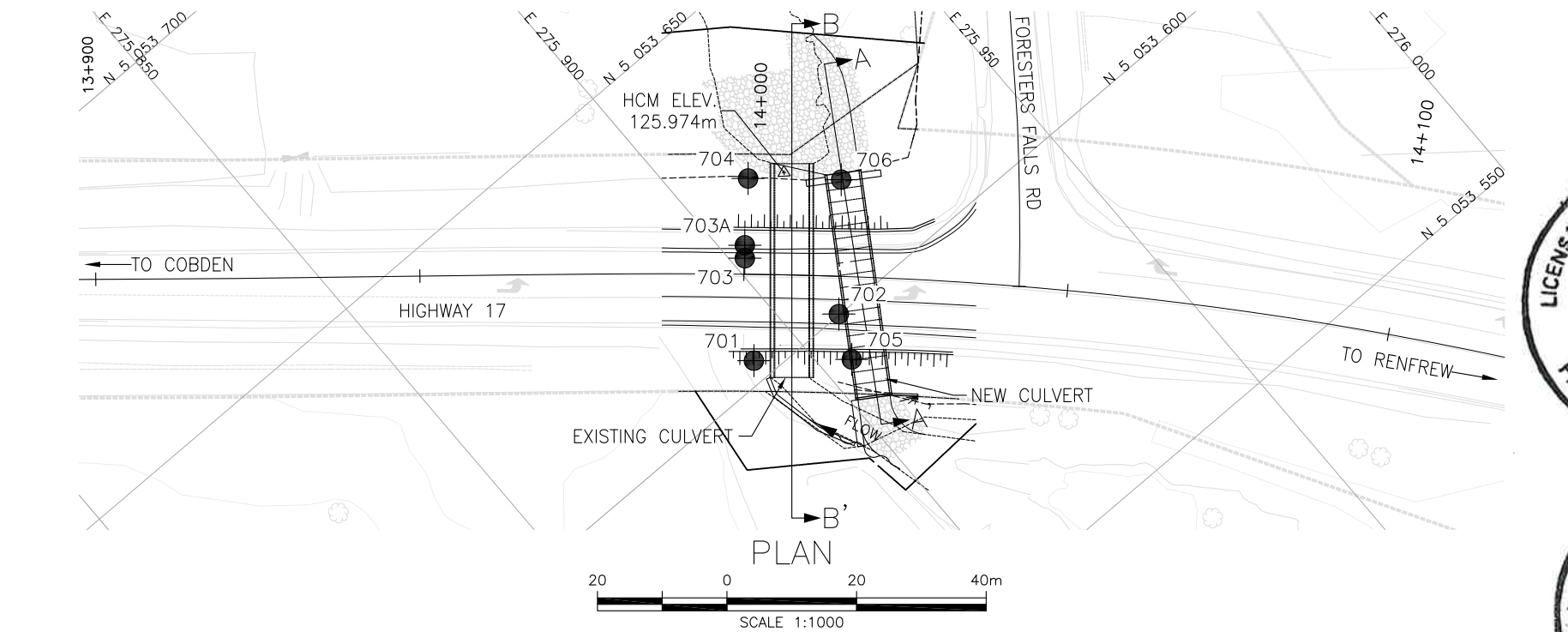
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701	127.0	5 053 603.1	275 892.7
702	128.2	5 053 600.1	275 907.4
703	128.1	5 053 616.1	275 901.9
703A	128.1	5 053 617.6	275 903.2
704	125.1	5 053 625.1	275 910.3
705	127.8	5 053 590.9	275 900.2
706	125.1	5 053 614.3	275 919.5

-NOTES-

- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- 3) Borehole locations are shown in MTM Zone 9 coordinates.

GEOCRES No. 31F-193

REVISIONS							
	DATE	BY	DESCRIPTION				
DESIGN	KP	CHK -	CODE	LOAD	DATE	FEB 2018	
DRAWN	MFA	CHK KP	SITE 29-250/C1STRUCT		DWG	1	



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

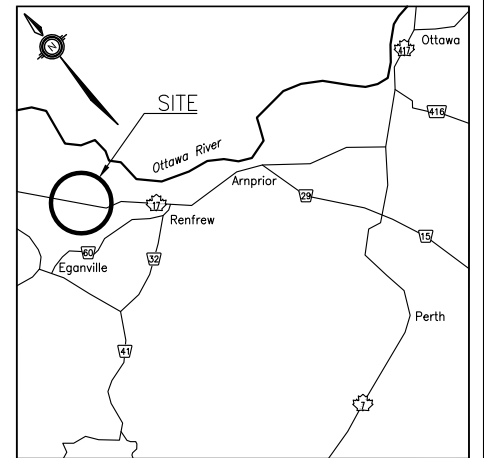


CONT No
WP No 4114-13-01

HIGHWAY 17
FORESTERS FALLS ROAD
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

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

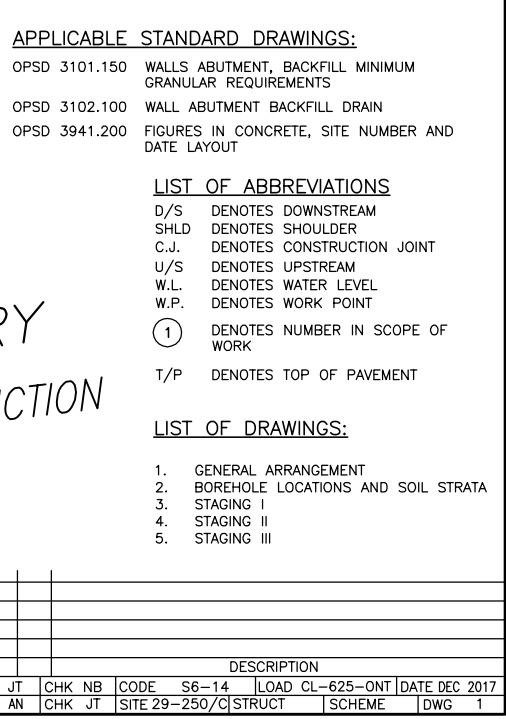
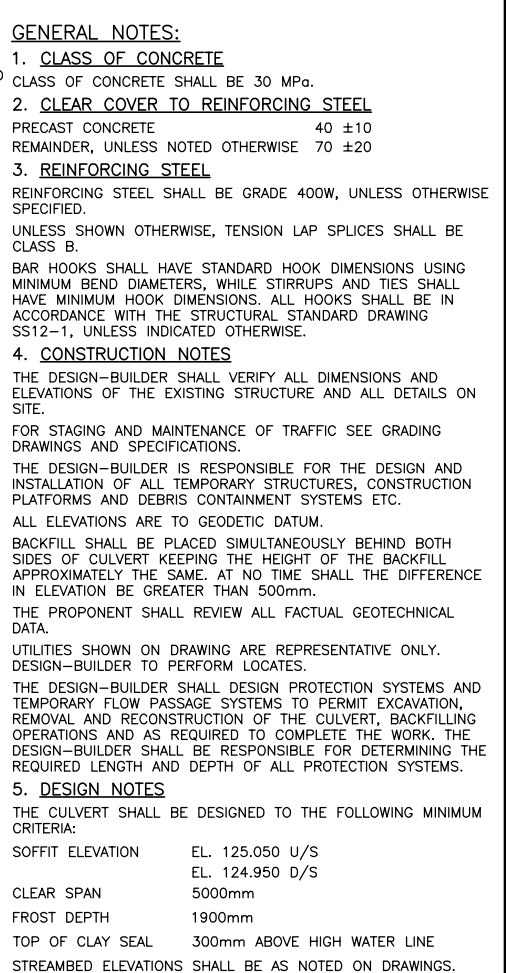
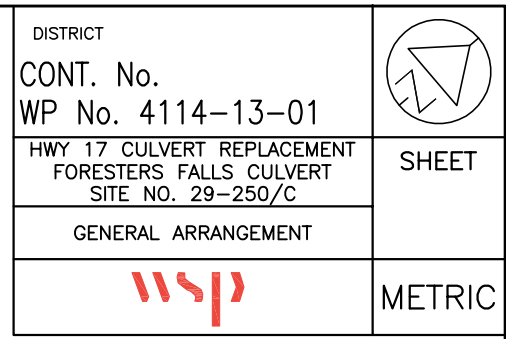
NO	ELEVATION	NORTHING	EASTING
701	127.0	5 053 603.1	275 892.7
702	128.2	5 053 600.1	275 907.4
703	128.1	5 053 616.1	275 901.9
703A	128.1	5 053 617.6	275 903.2
704	125.1	5 053 625.1	275 910.3
705	127.8	5 053 590.9	275 900.2
706	125.1	5 053 614.3	275 919.5

-NOTES-

- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- 3) Borehole locations are shown in MTM Zone 9 coordinates.

GEOCRES No. 31F-193

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	KP	CHK -	CODE
DRAWN	MFA	CHK KP	SITE 29-250/C/STRUCT
DATE	FEB 2018	DATE	FEB 2018
DWG	2	DWG	2



APPENDIX B

RECORD OF BOREHOLE SHEETS BEDROCK CORE PHOTOGRAPHS



SYMBOLS, ABBREVIATIONS AND TERMS USED ON TEST HOLE RECORDS

TERMINOLOGY DESCRIBING COMMON SOIL GENESIS

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

TERMINOLOGY DESCRIBING SOIL STRUCTURE:

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

RECOVERY:

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

N-VALUE:

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

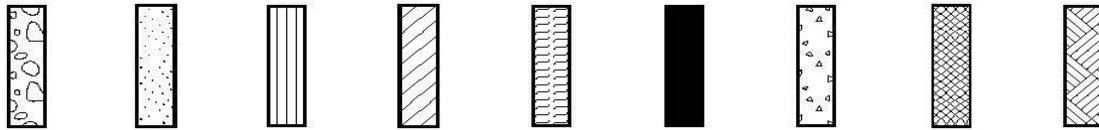
DYNAMIC CONE PENETRATION TEST (DCPT):

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



STRATA PLOT:

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



Boulders
Cobbles
Gravel Sand Silt Clay Organics Asphalt Concrete Fill Bedrock

TEXTURING CLASSIFICATION OF SOILS

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

TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

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

SAMPLE TYPES

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

TERMS DESCRIBING CONSISTENCY (COHESIONLESS SOILS ONLY)

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

MODIFIED UNIFIED SOIL CLASSIFICATION

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

Note - W_L = Liquid Limit



EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

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

TERMS

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

DISCONTINUITY SPACING

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

STRENGTH CLASSIFICATION

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

RECORD OF BOREHOLE No 701

1 OF 1

METRIC

W.P. 4114-13-01 LOCATION Site 29-250/C Foresters Falls Rd. Culvert N 5 053 603.1 E 275 892.7 ORIGINATED BY SMP
 HWY 17 BOREHOLE TYPE NQ Casing COMPILED BY SMP
 DATUM Geodetic DATE 2015.10.28 - 2015.10.28 CHECKED BY KP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)		
								20 40 60 80 100							20 40 60		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE							W P W L		
127.0																	
0.0	Sand with silt and gravel Compact Brown to grey FILL		1	SS	10										29 61 10 (SI+CL)		
126.4																	
0.6	Silty sand with gravel Compact Brown to grey FILL		2	SS	15		126										
			3	SS	15										36 47 17 (SI+CL)		
			4	SS	26		125										
124.5																	
2.4	Sandy SILT (ML) Compact Grey		5	SS	18		124								0 30 57 13		
	- Some organics at 3 m		6	SS	29												
123.6																	
3.4	Silty SAND (SM) with gravel TILL Compact to Very Dense Grey		7	SS	110		123								40 44 16 (SI+CL)		
122.3			8	SS	100/												
4.7	End of Borehole Splitspoon refusal on inferred boulder Groundwater measured in open borehole at 1.4 m BGS (elev. 125.6 m)				125mm												

RECORD OF BOREHOLE No 702

1 OF 1

METRIC

W.P. 4114-13-01 LOCATION Site 29-250/C Foresters Falls Rd. Culvert N 5 053 600.1 E 275 907.4 ORIGINATED BY SMP
 HWY 17 BOREHOLE TYPE HSA COMPILED BY SMP
 DATUM Geodetic DATE 2015.11.04 - 2015.11.04 CHECKED BY KP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)					
								20 40 60 80 100				20 40 60					
						○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE											
128.2																	
0.0	175 mm ASPHALT																
0.2	Silty sand with gravel		1	SS	54		128									25 62 13 (SI+CL)	
127.6	Very dense Brown and Grey FILL																
0.6	Silty sand with gravel Very loose to compact Brown to grey FILL		2	SS	24		127										
			3	SS	8		126									24 56 20 (SI+CL)	
			4	SS	3		125										
			5	SS	5		124										
124.4																	
3.8	Silty SAND (SM), some gravel, trace organics Loose to compact Grey		6	SS	5		123										
			7	SS	9		122									14 56 23 7	
			8	SS	13		121										
122.1																	
6.1	Silty SAND (SM) with gravel TILL Compact to dense Grey		9	SS	13		120										
			10	SS	50											30 51 19 (SI+CL)	
120.4			11	SS	100/												
7.8	GRANITE BEDROCK Slightly weathered Fair quality Strong to very strong Grey		1	NW	150mm		119.2									RUN #1 TCR=83% SCR=74% RQD=60%	
119.2																	
9.0	End of Borehole																

ONTMT4S 19-5161-263 FORRESTER'S FALL RD.GPJ 2012TEMPLATE(MTO).GDT 26/2/18

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 703A

1 OF 1

METRIC

W.P. 4114-13-01 LOCATION Site 29-250/C Foresters Falls Rd. Culvert N 5 053 617.6 E 275 903.2 ORIGINATED BY SMP
 HWY 17 BOREHOLE TYPE HSA COMPILED BY SMP
 DATUM Geodetic DATE 2015.11.03 - 2015.11.03 CHECKED BY KP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
128.1								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					
0.0								WATER CONTENT (%)					
							20 40 60 80 100		20 40 60				

ONTMT4S 19-5161-263 FORRESTER'S FALL RD.GPJ 2012TEMPLATE(MTO).GDT 26/2/18

RECORD OF BOREHOLE No 704

1 OF 1

METRIC

W.P. 4114-13-01 LOCATION Site 29-250/C Foresters Falls Rd. Culvert N 5 053 625.1 E 275 910.3 ORIGINATED BY SMP
HWY 17 BOREHOLE TYPE NQ Casing COMPILED BY SMP
DATUM Geodetic DATE 2015.10.23 - 2015.10.23 CHECKED BY KP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
								○ UNCONFINED + FIELD VANE					
								● QUICK TRIAXIAL × LAB VANE					
				WATER CONTENT (%)				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT					
				20 40 60 80 100				W P W W L					
125.1													
0.0	Silty sand trace gravel Very Loose Brown FILL		1	SS	2								
			2	SS	1								2 77 21 (SI+CL)
123.7													
1.4	Silt (ML) with sand trace organics Very loose Grey		3	SS	3								
			4	SS	3								1 24 70 5
122.7													
2.4	CLAY (CL to CI) Stiff to very stiff Grey		5	SS	15								
			6	SS	10								1 4 65 30
			7	SS	6								
	- Undrained shear greater than 100 kPa												
			10	SS	7								0 4 50 46

+³ ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 705

1 OF 2

METRIC

W.P. 4114-13-01 LOCATION Site 29-250/C Foresters Falls Rd. Culvert N 5 053 590.9 E 275 900.2 ORIGINATED BY JAG
 HWY 17 BOREHOLE TYPE NW Casing COMPILED BY JAG
 DATUM Geodetic DATE 2017.06.29 - 2017.06.29 CHECKED BY KP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
								20 40 60 80 100					
127.8													
0.0	Sand with silt and gravel Compact to dense Brown FILL		1	SS	33		127						
			2	SS	12								
126.5							126						
1.4	Silty sand with gravel Loose Brown to grey FILL		3	SS	9								
			4	SS	8		125						
124.8													
3.0	Silty SAND (SM) with gravel, trace wood and organic matter Loose Grey/brown		5	SS	8		124						24 52 24 (SI+CL)
			6	SS	9								
123.3	- wood pieces at 4.6m						123						0 42 44 14
4.6	Sandy SILT (ML) Very loose to loose Grey		7	SS	4								
			8	SS	3		122						
121.4			9	SS	15								
6.4	Silty SAND (SM) with gravel TILL, occasional cobbles and boulders Compact to very dense Grey						121						28 59 13 (SI+CL)
			10	SS	121								
120.4							120						RUN #1 TCR=100% SCR=100% RQD=64%
7.5	GRANITE BEDROCK Slightly weathered Fair to excellent quality Strong to very strong Grey		1	NW									RUN #2 TCR=100% SCR=100% RQD=84%
			2	NW			119						
							118						

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

ONTMT4S 19-5161-263 FORRESTER'S FALL RD GPJ 2012TEMPLATE(MTO)GDT 26/2/18

RECORD OF BOREHOLE No 705

2 OF 2

METRIC

W.P. 4114-13-01 LOCATION Site 29-250/C Foresters Falls Rd. Culvert N 5 053 590.9 E 275 900.2 ORIGINATED BY JAG
 HWY 17 BOREHOLE TYPE NW Casing COMPILED BY JAG
 DATUM Geodetic DATE 2017.06.29 - 2017.06.29 CHECKED BY KP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W P	W	W L		
	Continued From Previous Page																
116.9	GRANITE BEDROCK Slightly weathered Fair to excellent quality Strong to very strong Grey		3	NW												RUN #3 TCR=100% SCR=100% RQD=97%	
10.9	End of Borehole																

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

RECORD OF BOREHOLE No 706

1 OF 1

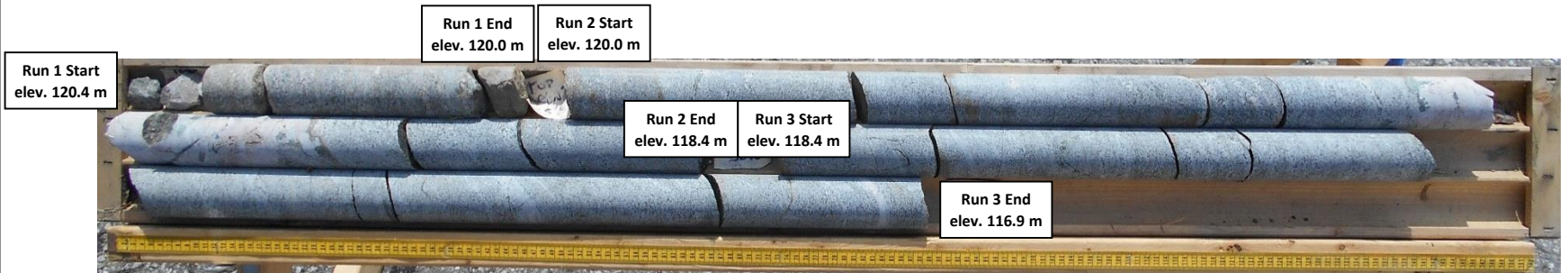
METRIC

W.P. 4114-13-01 LOCATION Site 29-250/C Foresters Falls Rd. Culvert N 5 053 614.3 E 275 919.5 ORIGINATED BY JAG
HWY 17 BOREHOLE TYPE NW Casing COMPILED BY JAG
DATUM Geodetic DATE 2017.06.30 - 2017.06.30 CHECKED BY KP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						WATER CONTENT (%)					
125.1																			
0.0																			
0.1	100mm TOPSOIL		1	SS	1		125												
	Silty sand with gravel Very loose Brown FILL		2	SS	2														18 55 27 (SI+CL)
124.1							124												
1.1	Silty SAND (SM) with gravel, trace wood and organic matter Compact Brown to grey		3	SS	26														
			4	SS	22		123												19 66 15 (SI+CL)
122.7																			
2.4	Sandy SILT (ML), trace organic matter Compact Grey		5	SS	10		122												
121.8			6	SS	7														
3.4	CLAY (CL to CI) Stiff to very stiff Grey						121												
			7	SS	7														
			8	SS	24		120												
			9	SS	30		119												0 7 63 30
			10	SS	12														
			11	SS	16		118												0 6 54 40
							117												
116.4			12	SS	100/ 75mm														
8.7	Silty SAND (SM) with gravel TILL - frequent cobbles and boulders Very dense Grey						116												
115.3			13	SS	100/ 25mm														
9.8	End of Borehole																		

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

Borehole 705
Run 1 to 3 (of 3)
Elevation 120.4 m to 116.9 m

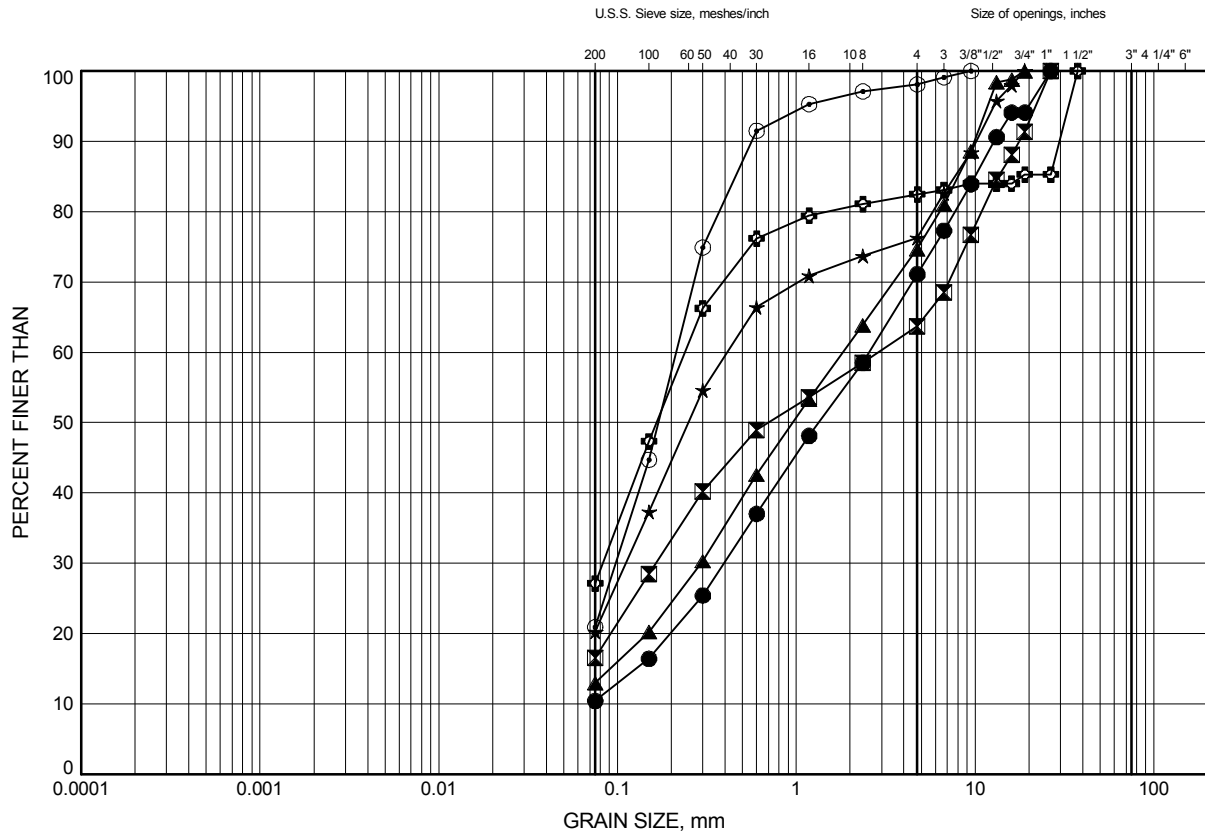


APPENDIX C
LABORATORY TEST RESULTS

29-250/C Foresters Falls Rd. Culvert
GRAIN SIZE DISTRIBUTION

FIGURE 1

Fill - Silty Sand with Gravel



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	701	0.30	126.68
⊠	701	1.60	125.38
▲	702	0.34	127.87
★	702	1.80	126.41
⊙	704	0.91	124.23
⊕	706	0.84	124.28

Date February 2018
W.P. 4114-13-01

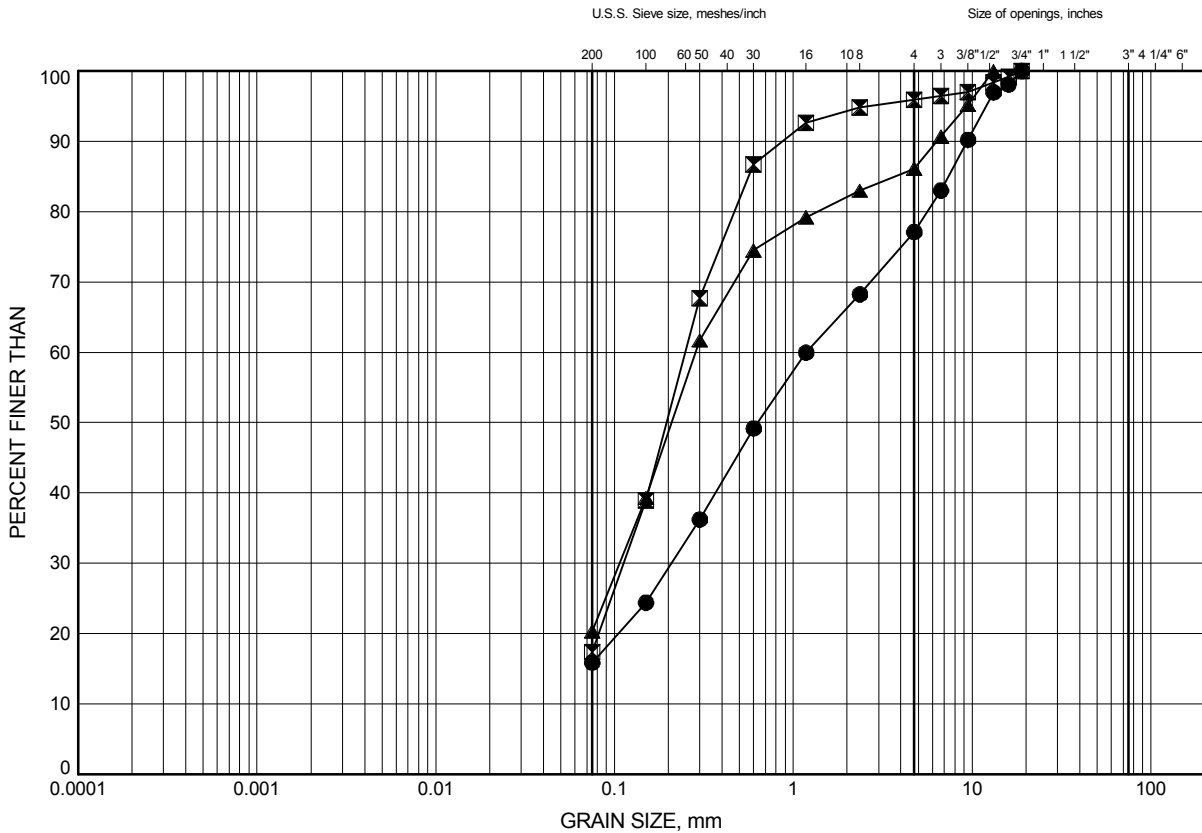


Prep'd KCP
Chkd. PC

29-250/C Foresters Falls Rd. Culvert
GRAIN SIZE DISTRIBUTION

FIGURE 2

Fill - Silty Sand with Gravel



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	703A	0.30	127.78
⊠	703A	1.07	127.02
▲	703A	2.47	125.62

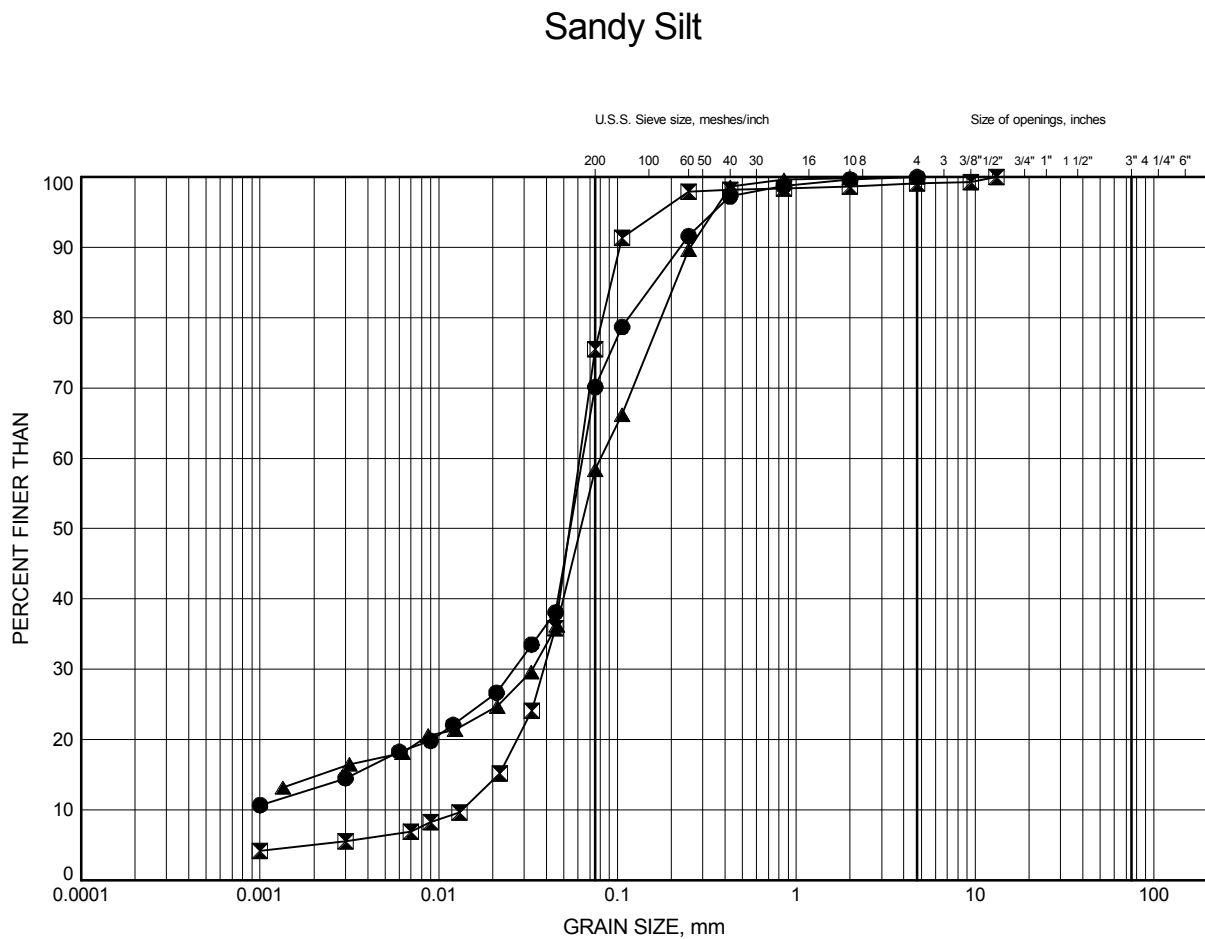
Date February 2018
W.P. 4114-13-01



Prep'd KCP
Chkd. PC

29-250/C Foresters Falls Rd. Culvert
GRAIN SIZE DISTRIBUTION

FIGURE 3



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	701	3.17	123.81
⊠	704	2.13	123.01
▲	705	4.88	122.96

Date February 2018
W.P. 4114-13-01

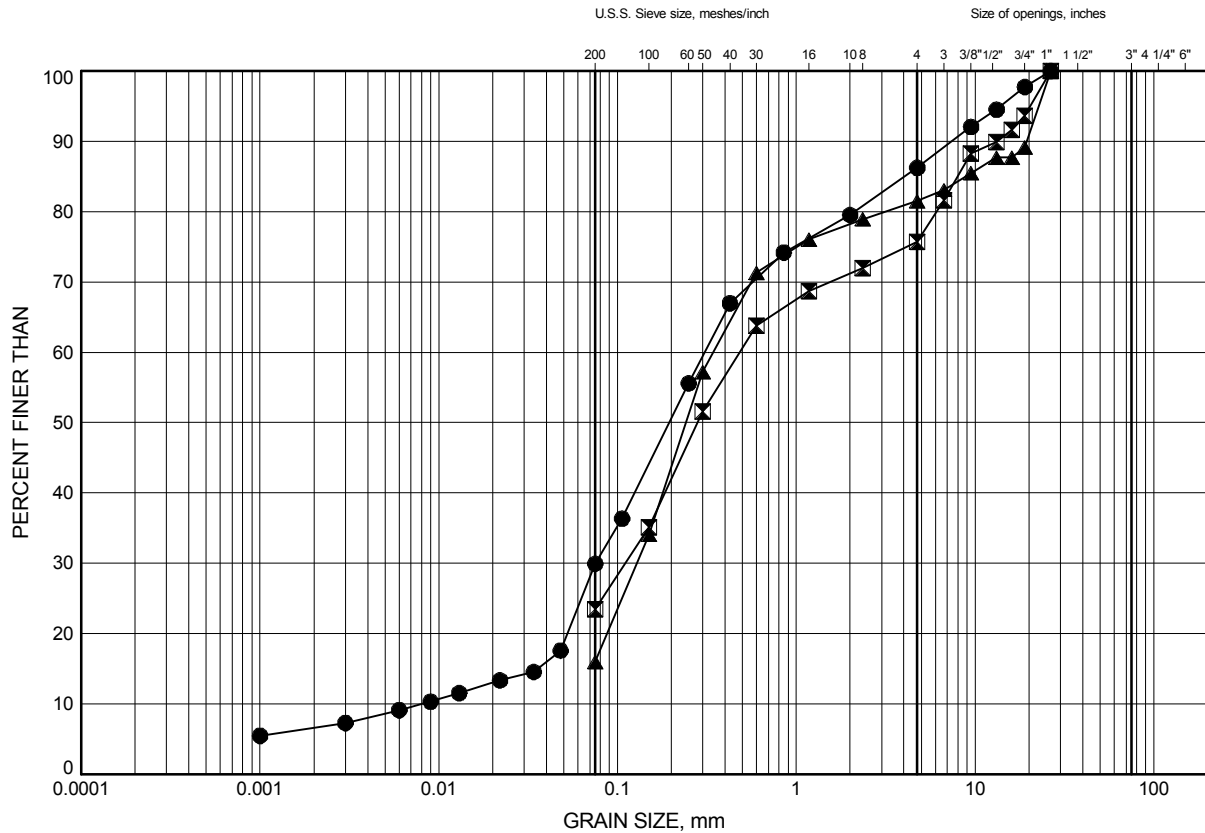


Prep'd KCP
Chkd. PC

29-250/C Foresters Falls Rd. Culvert
GRAIN SIZE DISTRIBUTION

FIGURE 4

Silty Sand with Gravel



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	702	4.88	123.33
⊠	705	3.35	124.48
▲	706	2.13	122.99

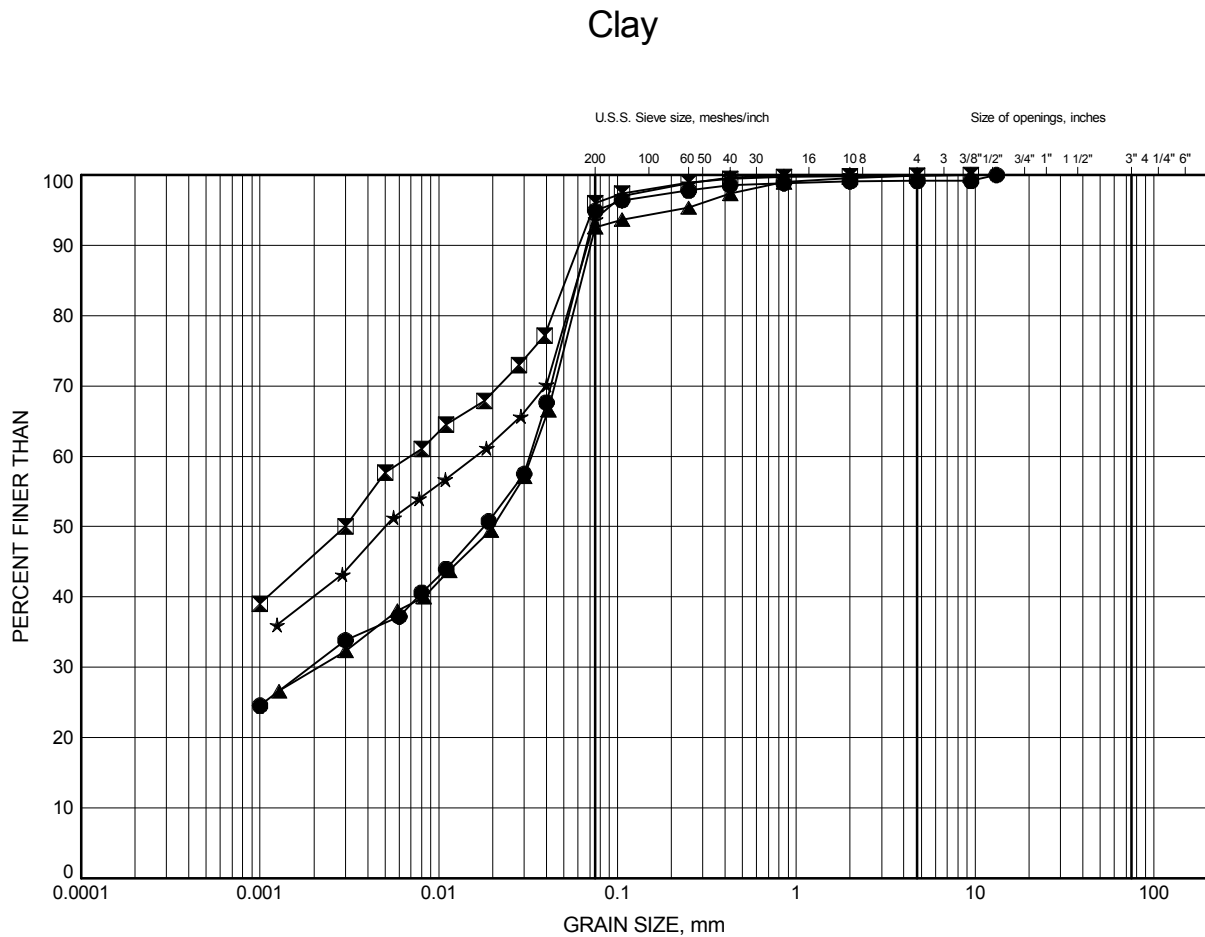
Date February 2018
W.P. 4114-13-01



Prep'd KCP
Chkd. PC

29-250/C Foresters Falls Rd. Culvert
GRAIN SIZE DISTRIBUTION

FIGURE 5



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	704	3.35	121.79
⊠	704	5.18	119.96
▲	706	5.64	119.48
★	706	7.16	117.96

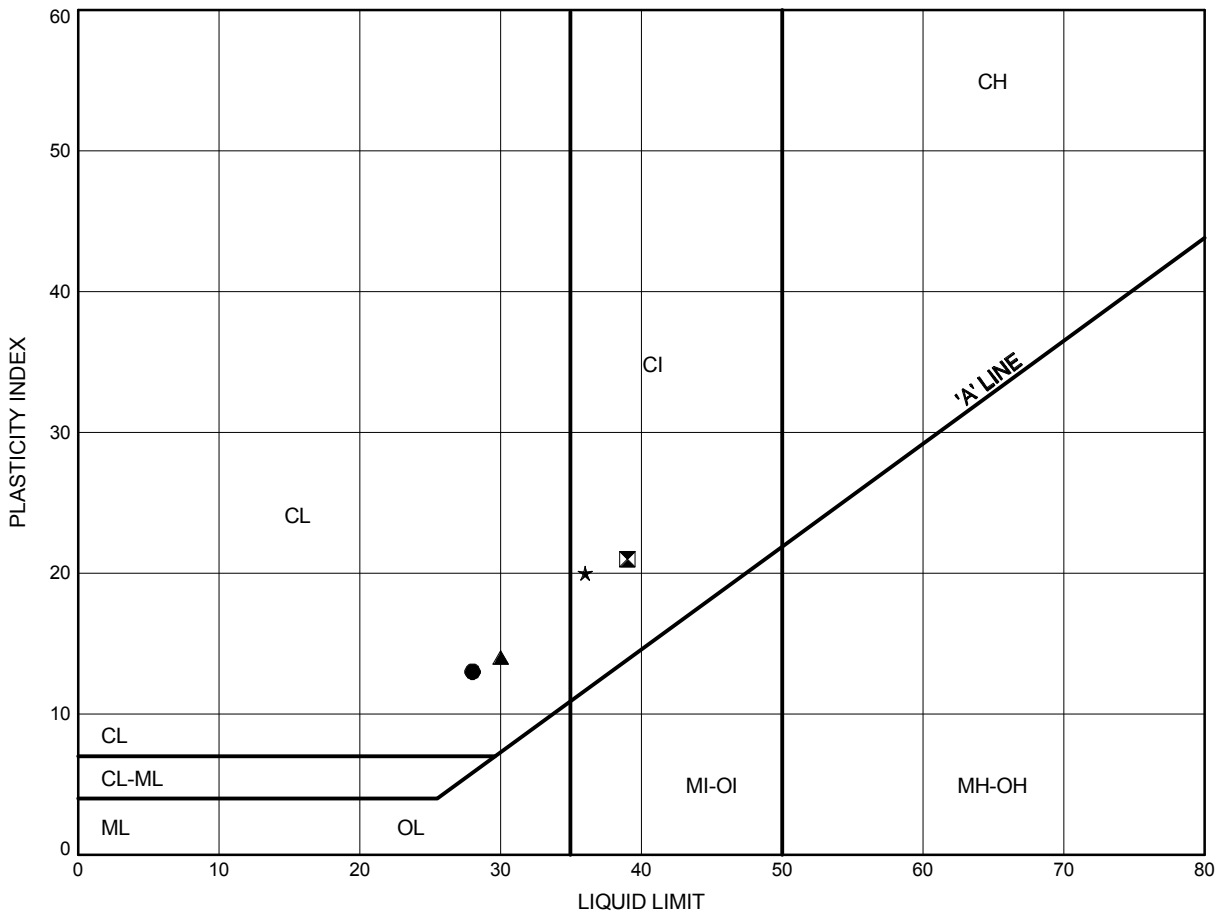
Date February 2018
W.P. 4114-13-01



Prep'd KCP
Chkd. PC

29-250/C Foresters Falls Rd. Culvert
ATTERBERG LIMITS TEST RESULTS

FIGURE 6



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	704	3.35	121.79
⊠	704	5.18	119.96
▲	706	5.64	119.48
★	706	7.16	117.96

Date February 2018
W.P. 4114-13-01

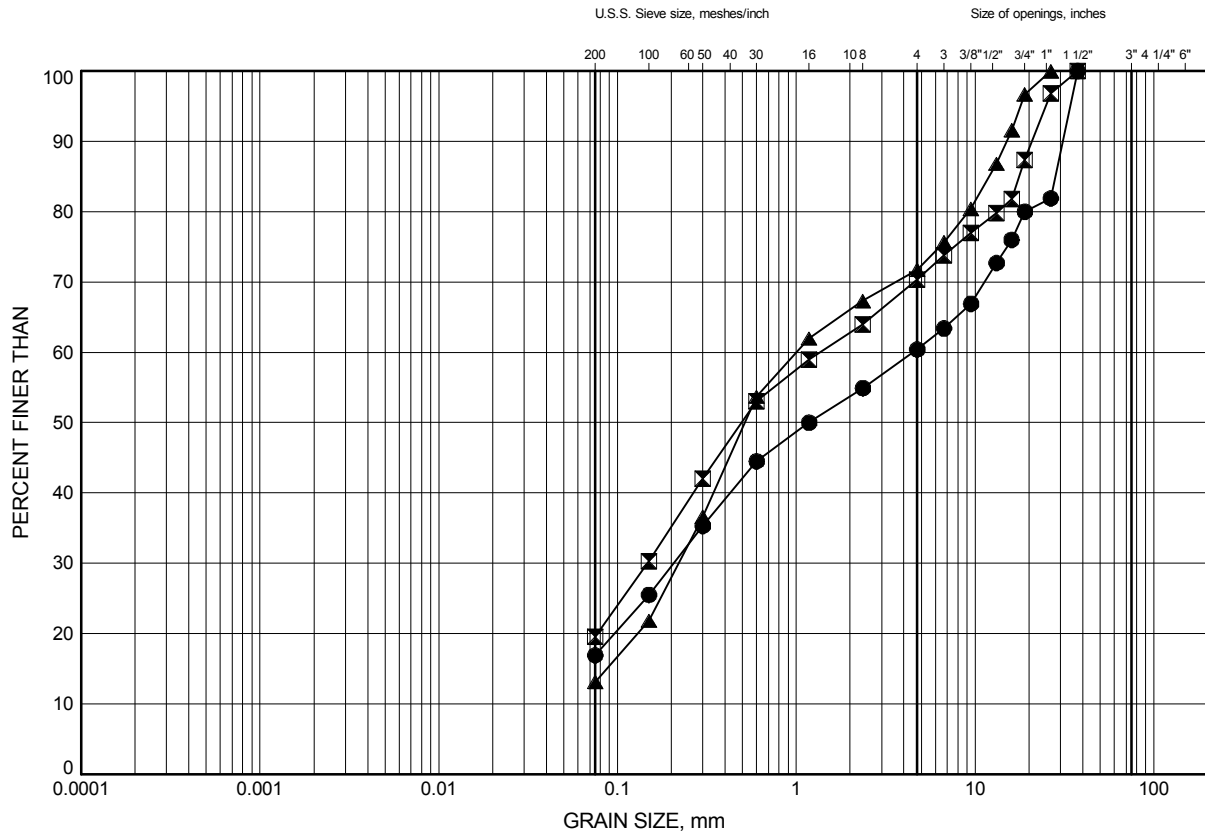


Prep'd KCP
Chkd. PC

29-250/C Foresters Falls Rd. Culvert
GRAIN SIZE DISTRIBUTION

FIGURE 7

Silty Sand with Gravel - Till



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	701	3.96	123.02
⊠	702	7.16	121.04
▲	705	7.16	120.67

Date February 2018
W.P. 4114-13-01



Prep'd KCP
Chkd. PC

Certificate of Analysis

Thurber Engineering Ltd.

2460 Lancaster Rd, Unit 107
Ottawa, ON K1B4S5
Attn: Kenton Power

Client PO: 19-5161-263 Task 60
Project: Forester Falls
Custody: 14059

Report Date: 14-Jul-2017
Order Date: 10-Jul-2017

Order #: 1728119

This Certificate of Analysis contains analytical data applicable to the following samples as submitted:

Paracel ID	Client ID
1728119-01	705, SS6, 12'6"-14'6"
1728119-02	706, SS3, 4'-6'

Approved By:



Dale Robertson, BSc
Laboratory Director

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 19-5161-263 Task 60

Report Date: 14-Jul-2017

Order Date: 10-Jul-2017

Project Description: Forester Falls

Analysis Summary Table

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	12-Jul-17	12-Jul-17
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	11-Jul-17	12-Jul-17
Resistivity	EPA 120.1 - probe, water extraction	13-Jul-17	13-Jul-17
Solids, %	Gravimetric, calculation	12-Jul-17	12-Jul-17

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 19-5161-263 Task 60

Report Date: 14-Jul-2017

Order Date: 10-Jul-2017

Project Description: Forester Falls

Client ID:	705, SS6, 12'6"-14'6"	706, SS3, 4'-6'	-	-
Sample Date:	29-Jun-17	30-Jun-17	-	-
Sample ID:	1728119-01	1728119-02	-	-
MDL/Units	Soil	Soil	-	-

Physical Characteristics

% Solids	0.1 % by Wt.	76.0	80.1	-	-
----------	--------------	------	------	---	---

General Inorganics

pH	0.05 pH Units	7.34	7.26	-	-
Resistivity	0.10 Ohm.m	15.4	14.7	-	-

Anions

Chloride	5 ug/g dry	298	297	-	-
Sulphate	5 ug/g dry	75	131	-	-

Certificate of Analysis
 Client: Thurber Engineering Ltd.
 Client PO: 19-5161-263 Task 60

Report Date: 14-Jul-2017

Order Date: 10-Jul-2017

Project Description: Forester Falls

Method Quality Control: Blank

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	ND	5	ug/g						
Sulphate	ND	5	ug/g						
General Inorganics									
Resistivity	ND	0.10	Ohm.m						

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 19-5161-263 Task 60

Report Date: 14-Jul-2017

Order Date: 10-Jul-2017

Project Description: Forester Falls

Method Quality Control: Duplicate

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	304	5	ug/g dry	298			2.0	20	
Sulphate	76.2	5	ug/g dry	74.7			2.0	20	
General Inorganics									
pH	7.57	0.05	pH Units	7.60			0.4	10	
Resistivity	27.8	0.10	Ohm.m	28.1			1.1	20	
Physical Characteristics									
% Solids	80.8	0.1	% by Wt.	80.9			0.1	25	

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 19-5161-263 Task 60

Report Date: 14-Jul-2017

Order Date: 10-Jul-2017

Project Description: Forester Falls

Method Quality Control: Spike

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	402	5	ug/g	298	104	78-113			
Sulphate	178	5	ug/g	74.7	103	78-111			

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 19-5161-263 Task 60

Report Date: 14-Jul-2017

Order Date: 10-Jul-2017

Project Description: Forester Falls

Qualifier Notes:

None

Sample Data Revisions

None

Work Order Revisions / Comments:

None

Other Report Notes:

n/a: not applicable

ND: Not Detected

MDL: Method Detection Limit

Source Result: Data used as source for matrix and duplicate samples

%REC: Percent recovery.

RPD: Relative percent difference.

Soil results are reported on a dry weight basis when the units are denoted with 'dry'.

Where %Solids is reported, moisture loss includes the loss of volatile hydrocarbons.

Certificate of Analysis

Thurber Engineering Ltd.

2460 Lancaster Rd, Unit 107
Ottawa, ON K1B4S5
Attn: Kenton Power

Client PO:
Project: 19-5161-263
Custody:

Report Date: 13-Nov-2015
Order Date: 10-Nov-2015

Order #: 1546148

This Certificate of Analysis contains analytical data applicable to the following samples as submitted:

Paracel ID	Client ID
1546148-01	BH704 SS4 6' to 8'
1546148-02	BH601 SS4 6' to 8'
1546148-03	BH501 SS6 10.5' to 12.5'

Approved By:

Mark Foto

~~Mark~~ Foto, M.Sc.
Lab Supervisor

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 13-Nov-2015

Order Date: 10-Nov-2015

Project Description: **19-5161-263****Analysis Summary Table**

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	12-Nov-15	12-Nov-15
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	11-Nov-15	11-Nov-15
Resistivity	EPA 120.1 - probe, water extraction	12-Nov-15	12-Nov-15
Solids, %	Gravimetric, calculation	12-Nov-15	12-Nov-15

Certificate of Analysis
Client: Thurber Engineering Ltd.

Report Date: 13-Nov-2015

Order Date: 10-Nov-2015

Client PO:
Project Description: 19-5161-263

Client ID:		BH704 SS4 6' to 8'	BH601 SS4 6' to 8'	BH501 SS6 10.5' to 12.5'	-
Sample Date:		22-Oct-15	19-Oct-15	27-Oct-15	-
Sample ID:		1546148-01	1546148-02	1546148-03	-
MDL/Units		Soil	Soil	Soil	-
Physical Characteristics					
% Solids	0.1 % by Wt.	81.9	76.3	91.8	-
General Inorganics					
pH	0.05 pH Units	7.56	7.73	7.99	-
Resistivity	0.10 Ohm.m	25.3	31.2	157	-
Anions					
Chloride	5 ug/g dry	129	70	6	-
Sulphate	5 ug/g dry	27	112	7	-

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 13-Nov-2015

Order Date: 10-Nov-2015

Project Description: **19-5161-263**

Method Quality Control: Blank

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	ND	5	ug/g						
Sulphate	ND	5	ug/g						
General Inorganics									
Resistivity	ND	0.10	Ohm.m						

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 13-Nov-2015

Order Date: 10-Nov-2015

Project Description: **19-5161-263**

Method Quality Control: Duplicate

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	7.0	5	ug/g dry	7.1			0.5	20	
Sulphate	24.3	5	ug/g dry	25.1			3.6	20	
General Inorganics									
pH	8.11	0.05	pH Units	7.99			1.5	10	
Resistivity	24.8	0.10	Ohm.m	25.3			1.9	20	
Physical Characteristics									
% Solids	78.2	0.1	% by Wt.	77.6			0.7	25	

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 13-Nov-2015

Order Date: 10-Nov-2015

Project Description: **19-5161-263****Method Quality Control: Spike**

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	100	5	ug/g	7.1	93.3	78-113			
Sulphate	104	5	ug/g	25.1	79.1	78-111			

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 13-Nov-2015

Order Date: 10-Nov-2015

Project Description: **19-5161-263**

Qualifier Notes:

None

Sample Data Revisions

None

Work Order Revisions / Comments:

None

Other Report Notes:

n/a: not applicable

ND: Not Detected

MDL: Method Detection Limit

Source Result: Data used as source for matrix and duplicate samples

%REC: Percent recovery.

RPD: Relative percent difference.

Soil results are reported on a dry weight basis when the units are denoted with 'dry'.

Where %Solids is reported, moisture loss includes the loss of volatile hydrocarbons.

APPENDIX D
SITE PHOTOGRAPHS



Figure 1: Roadway platform looking east towards Foresters Falls Road



Figure 2: Looking north towards existing culvert inlet and the proposed location to the right



Figure 3: Looking upstream from Culvert 29-250/C



Figure 4: Culvert 29-250/C outlet looking east



Figure 5: Looking downstream from Culvert outlet



Figure 6: South embankment looking east from existing culvert towards proposed inlet



Figure 7: North embankment looking east from existing culvert towards proposed outlet

APPENDIX E

COMPARISON OF CULVERT TYPE/FOUNDATION ALTERNATIVES COMPARISON OF CONSTRUCTION METHODOLOGY OPTIONS COMPARISON OF RETAINING WALL TYPES

Comparison of Culvert Type/Foundation Alternatives

Comment	Circular Pipes	Open Footing Culvert	Closed Box Culvert
<i>Advantages</i>	Readily available materials and simple installation methods		Wide base spreads out load, reducing risk of differential settlement due to variable subgrade conditions Less prone to effects of scour and erosion
<i>Disadvantages</i>	Numerous parallel pipes required to provide hydraulic opening equivalent to existing culvert.	More susceptible to effects of scour and erosion Higher foundation loads than closed box	
<i>Risks / Consequences</i>	Potential for base disturbance if groundwater not controlled / added cost and schedule delays	Potential for base disturbance if groundwater not controlled / added cost and schedule delays	Potential for base disturbance if groundwater not controlled / added cost and schedule delays
<i>Relative Cost</i>	Moderate	Moderate	Moderate
	NOT RECOMMENDED	RECOMMENDED	RECOMMENDED

Comparison of Construction Methodology Options

Comment	Trenchless: Horizontal Directional Drilling	Staged Construction with Platform Widening	Staged Construction, with Roadway Protection
Advantages	<p>Avoids open cut.</p> <p>Does not require staging – minimal traffic impact</p> <p>Relatively well-known technology and readily available.</p>	<p>Avoids need for installation of protection system</p>	<p>Limits volume of earthwork compared to platform widening</p> <p>Wider roadway platform with existing turning lane</p>
Disadvantages	<p>High mobilization costs</p> <p>Mixed face condition with clay and till and bedrock</p>	<p>Potentially large volumes of earthwork required</p>	<p>Traffic impacts</p> <p>Roadway protection requires soldier piles socketed into bedrock / till</p> <p>Requires water/groundwater control</p>
Risks/Consequences	<p>Variation in rock elevation/ major cost increase for bedrock excavation</p> <p>Obstructions/delays</p>	<p>Settlement of widened portion of embankment/ increased maintenance</p> <p>Utility relocation/increase construction cost and schedule</p>	<p>Variation in rock elevation / cost increase for rock sockets</p> <p>Difficulty installing protection system/delays</p> <p>Removal of oversized particles during installation of protection system leads to settlement of adjacent highway/increased maintenance</p>
Relative Cost	High	Moderate	Moderate
	NOT FEASIBLE	FEASIBLE	RECOMMENDED

Comparison of Retaining Wall Types

Comment	Inverted T	Concrete Gravity Wall	Armour Stone	Gabions	Retained Soil System (RSS)
Advantages	Can be designed for both horizontal and sloped backslopes Can be founded above the design frost depth, limiting excavation requirements Pre-cast modular units installed without mechanical connections	Can be designed for both horizontal and sloped backslopes Can be used in water ways	Can be founded above the design frost depth, limiting excavation requirements Come to site ready to install	Can be founded above the design frost depth Can be designed for both horizontal and sloped backslopes Ease of installation Can be used in water ways	Can be founded above the design frost depth, limiting excavation requirements Can tolerate some movement due to frost heave Can be designed for both horizontal and sloped backslopes
Disadvantages	Proprietary product Larger cranes likely required for installation of the pre-cast units which may impact the required construction staging zone	Cast-in-place units Requires full frost depth protection Increased dewatering requirements	Quarried stone Best suited for horizontal backslopes Friction fit stones do not interlock Limited wall height	Corrosion protection systems required	Proprietary product RSS walls below the water level requires project specific design, review and approval rather than specification of an RSS wall from the designated sourced list Corrosion protection systems required
Relative Cost	Moderate	Moderate	Moderate	Low	Moderate
	FEASIBLE	FEASIBLE – NOT RECOMMENDED	FEASIBLE – AT SOME LOCATIONS	FEASIBLE	FEASIBLE – NOT RECOMMENDED

APPENDIX F

**GSC SEISMIC HAZARD CALCULATION
SLOPE STABILITY ANALYSE RESULTS
LIST OF REFERENCED SPECIFICATIONS
NON-STANDARD SPECIAL PROVISION**

2015 National Building Code Seismic Hazard Calculation

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

February 26, 2018

Site: 45.6216 N, 76.8704 W User File Reference: Foresters Falls Culvert

Requested by: , Thurber Engineering Ltd.

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

Sa(0.05)	Sa(0.1)	Sa(0.2)	Sa(0.3)	Sa(0.5)	Sa(1.0)	Sa(2.0)	Sa(5.0)	Sa(10.0)	PGA (g)	PGV (m/s)
0.372	0.440	0.366	0.277	0.197	0.099	0.048	0.013	0.0048	0.235	0.164

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

Ground motions for other probabilities:

Probability of exceedance per annum	0.010	0.0021	0.001
Probability of exceedance in 50 years	40%	10%	5%
Sa(0.05)	0.031	0.108	0.191
Sa(0.1)	0.045	0.141	0.236
Sa(0.2)	0.043	0.125	0.203
Sa(0.3)	0.035	0.099	0.157
Sa(0.5)	0.026	0.073	0.114
Sa(1.0)	0.013	0.038	0.059
Sa(2.0)	0.0053	0.018	0.028
Sa(5.0)	0.0011	0.0042	0.0070
Sa(10.0)	0.0006	0.0017	0.0028
PGA	0.025	0.077	0.129
PGV	0.017	0.056	0.091

References

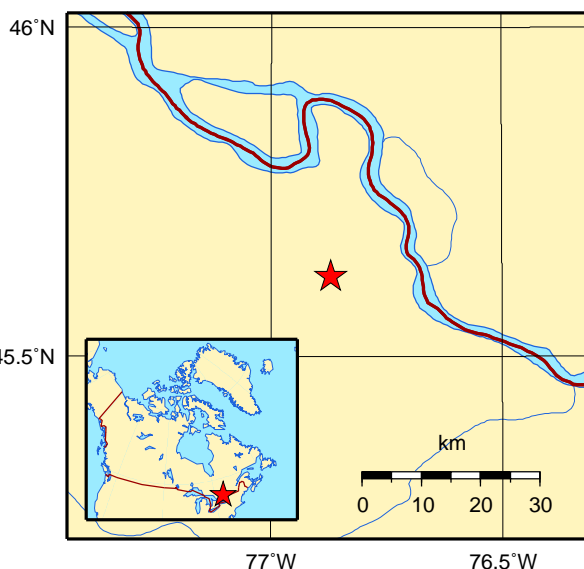
National Building Code of Canada 2015 NRCC no. 56190;
Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

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

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

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

Aussi disponible en français



Natural Resources
Canada

Ressources naturelles
Canada

Canada

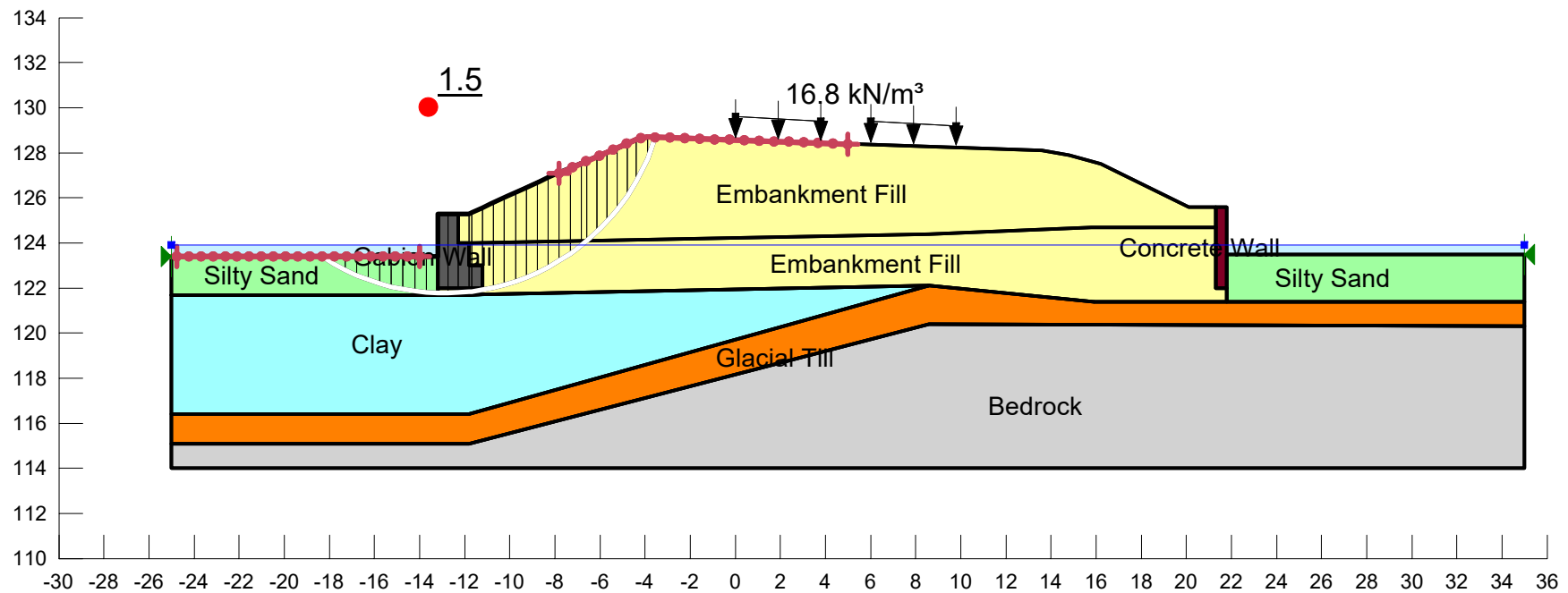
Title: Foresters Falls Culvert Crossing

Comments: Global Stability Assessment

Name: Outlet Gabion Wall

Method: Morgenstern-Price, Half-Sine
 Minimum Slip Surface Depth: 1.52 m
 PWP Conditions Source: Piezometric Line
 Seismic, H: 0 V: 0
 Slip Surface Center: (-12.91142, 131.58311) w/ Radius: 9.8039656 m

Silty Sand	19 kN/m ³	0 kPa	27 °
Clay	18 kN/m ³	85 kPa	0 °
Gabion Wall	21 kN/m ³		
Embankment Fill	19 kN/m ³	0 kPa	30 °
Glacial Till	21 kN/m ³	0 kPa	35 °
Concrete Wall	24.5 kN/m ³		
Bedrock			



Reviewed By: _____
 Tool Version: 8.15.6.13446
 Last Solved Date: 2018-05-03, 12:24:18 PM
 Directory: \\ott-pserver1\Project Data\Projects\19\5161\263 - ER Mega 5\Culverts\Site 29-250C-Renfrew Rd 21\Foundations\Analysis\SlopeW\Retaining Wall.gsz

Figure 1

Title: Foresters Falls Culvert Crossing
Comments: Global Stability Assessment
Name: Outlet Gabion Wall Seismic

Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1.52 m
PWP Conditions Source: Piezometric Line
Seismic, H: 0.125 V: 0
Slip Surface Center: (-13.572024, 135.68193) w/ Radius: 13.902372 m

Silty Sand	19 kN/m ³	0 kPa	27 °
Clay	18 kN/m ³	85 kPa	0 °
Gabion Wall	21 kN/m ³		
Embankment Fill	19 kN/m ³	0 kPa	30 °
Glacial Till	21 kN/m ³	0 kPa	35 °
Concrete Wall	24.5 kN/m ³		
Bedrock			

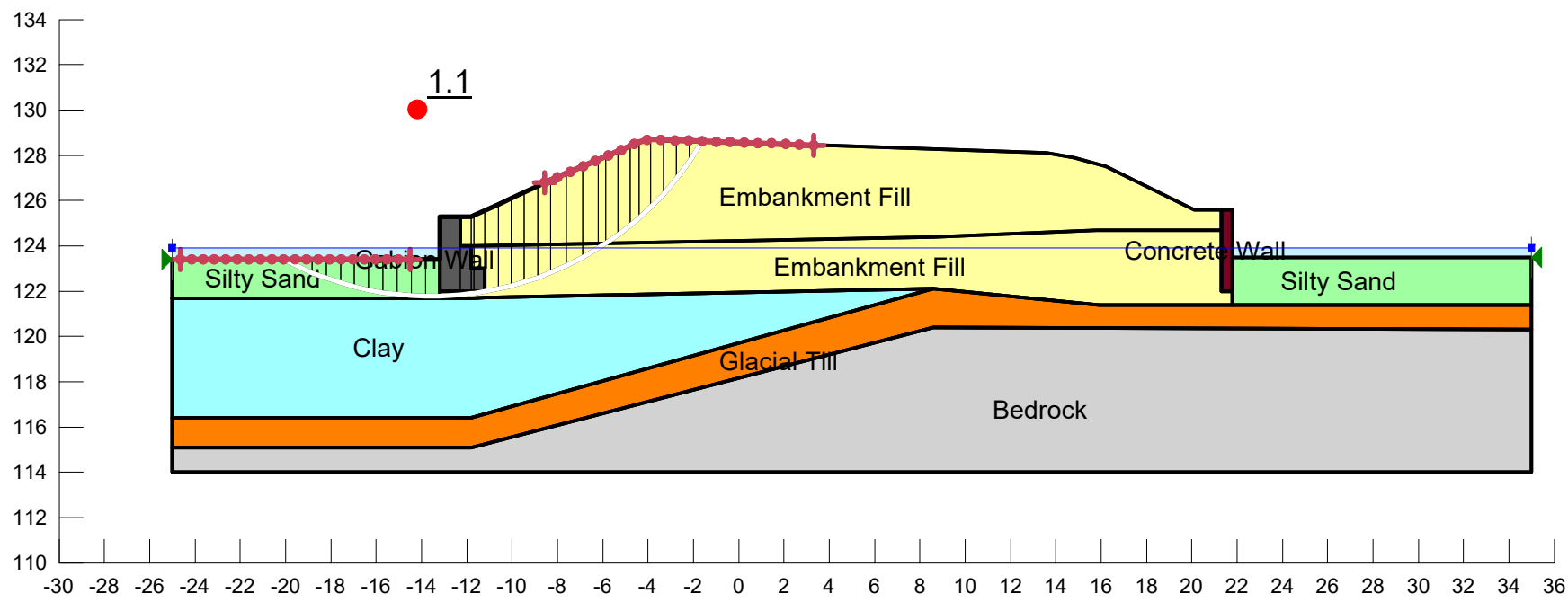


Figure 2

Title: Foresters Falls Culvert Crossing
Comments: Global Stability Assessment
Name: Outlet Gabion Wall (Post Seismic)

Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1.52 m
PWP Conditions Source: Piezometric Line
Seismic, H: 0 V: 0
Slip Surface Center: (-12.91142, 131.58311) w/ Radius: 9.8039656 m

Silty Sand	19 kN/m ³	0 kPa	27 °
Gabion Wall	21 kN/m ³		
Embankment Fill	19 kN/m ³	0 kPa	30 °
Glacial Till	21 kN/m ³	0 kPa	35 °
Concrete Wall	24.5 kN/m ³		
Bedrock			
Clay (Residual-0.85*Su)	18 kN/m ³	72 kPa	0 °

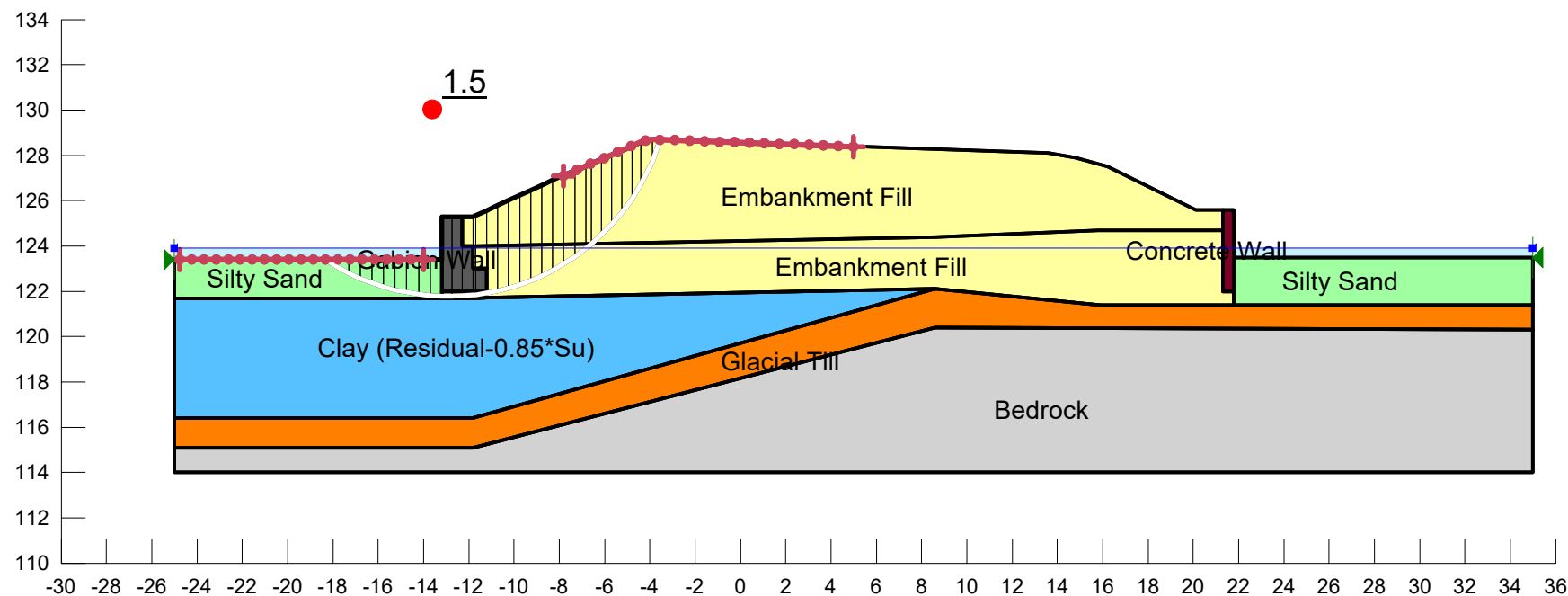


Figure 3

Title: Foresters Falls Culvert Crossing

Comments: Global Stability Assessment

Name: Inlet Concrete Wall

Method: Morgenstern-Price, Half-Sine

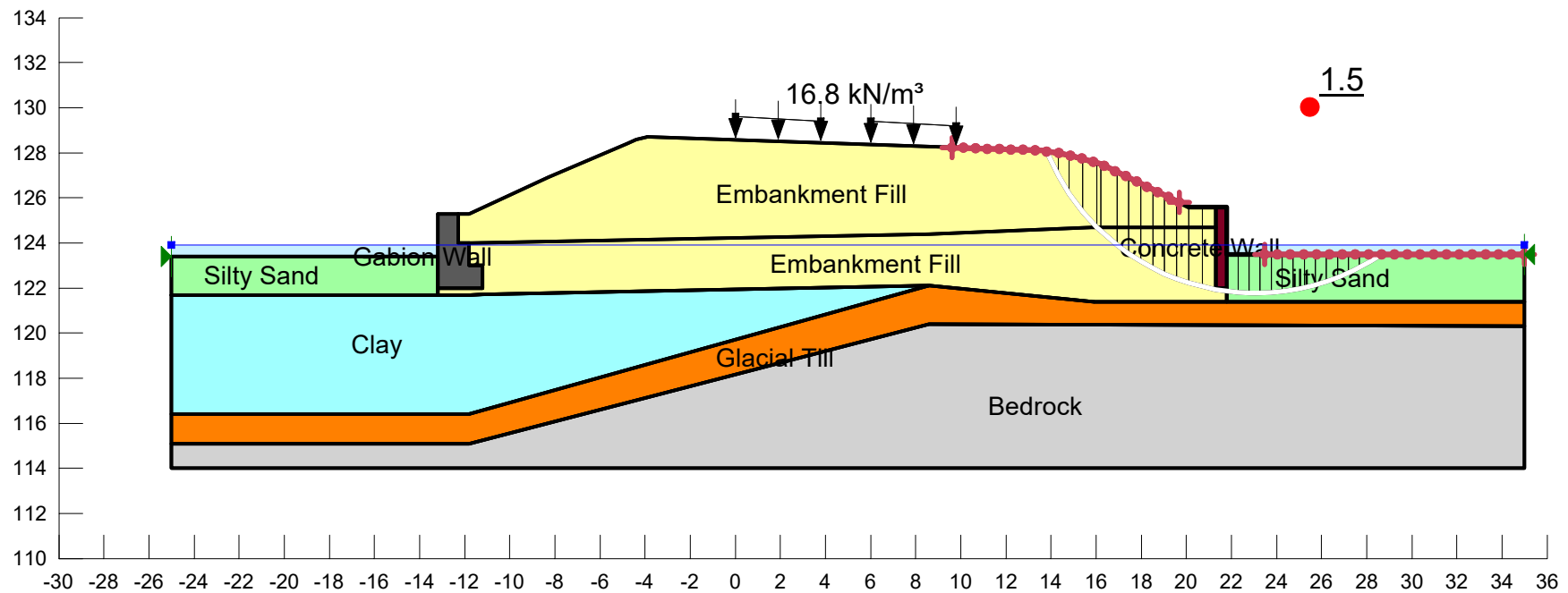
Minimum Slip Surface Depth: 1.52 m

PWP Conditions Source: Piezometric Line

Seismic, H: 0 V: 0

Slip Surface Center: (23.065928, 131.72748) w/ Radius: 9.9479045 m

Silty Sand	19 kN/m ³	0 kPa	27 °
Clay	18 kN/m ³	85 kPa	0 °
Gabion Wall	21 kN/m ³		
Embankment Fill	19 kN/m ³	0 kPa	30 °
Glacial Till	21 kN/m ³	0 kPa	35 °
Concrete Wall	24.5 kN/m ³		
Bedrock			



Reviewed By: _____

Tool Version: 8.15.6.13446

Last Solved Date: 2018-05-03, 12:29:03 PM

Directory: \\ott-pserver1\Project Data\Projects\19\5161\263 - ER Mega 5\Culverts\Site 29-250C-Renfrew Rd 21\Foundations\Analysis\SlopeW\Retaining Wall.gsz

Figure 4

Title: Foresters Falls Culvert Crossing

Comments: Global Stability Assessment

Name: Inlet Concrete Wall Seismic

Method: Morgenstern-Price, Half-Sine

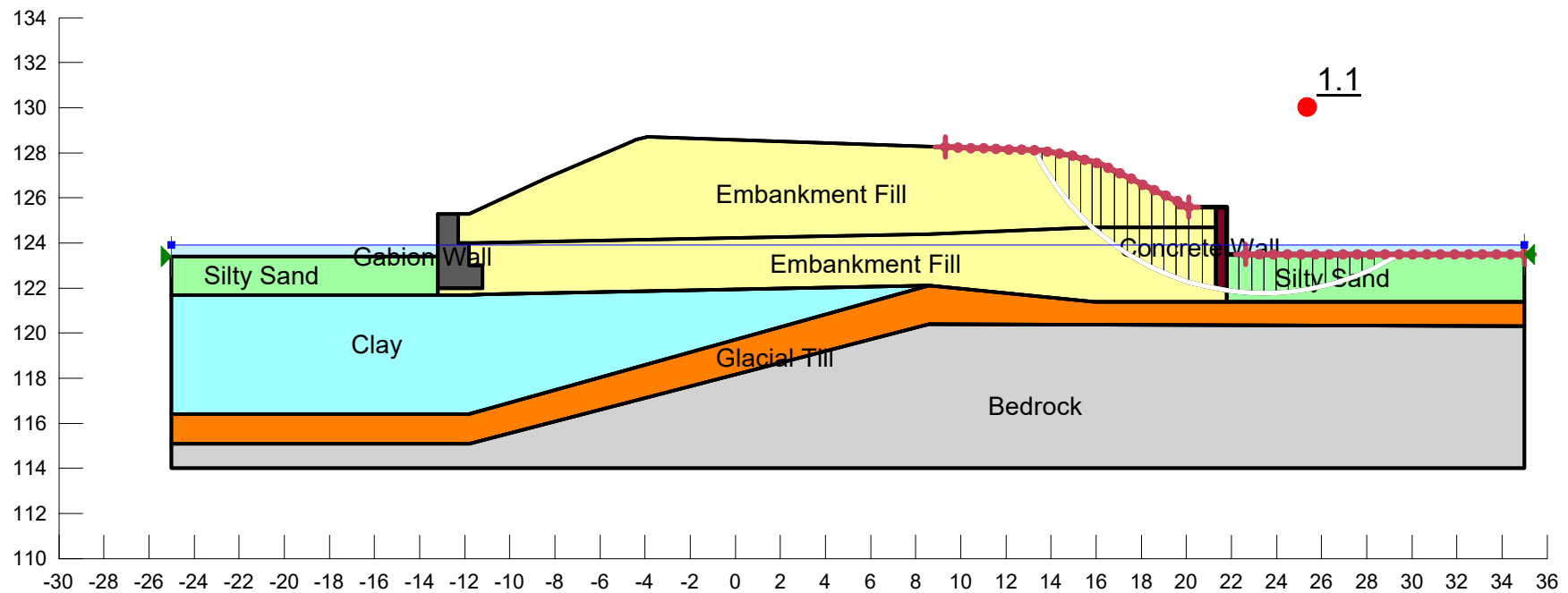
Minimum Slip Surface Depth: 1.52 m

PWP Conditions Source: Piezometric Line

Seismic, H: 0.125 V: 0

Slip Surface Center: (23.426607, 133.08239) w/ Radius: 11.30843 m

Silty Sand	19 kN/m ³	0 kPa	27 °
Clay	18 kN/m ³	85 kPa	0 °
Gabion Wall	21 kN/m ³		
Embankment Fill	19 kN/m ³	0 kPa	30 °
Glacial Till	21 kN/m ³	0 kPa	35 °
Concrete Wall	24.5 kN/m ³		
Bedrock			



Reviewed By: _____

Tool Version: 8.15.6.13446

Last Solved Date: 2018-05-03, 12:29:06 PM

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Figure 5

LIST OF REFERENCED SPECIFICATIONS

OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
OPSD 3090.101	Foundation, Frost Penetration Depths for Southern Ontario
OPSS.PROV 404	Construction Specification for Support Systems
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 517	Construction Specification for Dewatering
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS 805	Construction Specification for Temporary Erosion and Sediment Control Measures
OPSS 902	Construction Specification for Excavating and Backfilling-Structures
OPSS.PROV 1010	Material Specification for Aggregates-Base, Subbase, Select Subgrade, and Backfill Material
OPSS.PROV 1205	Material Specification for Clay Seal
Special Provision 109S12	Amendment to OPSS 902, March 2018
Special Provision 517F01	Amendment to OPSS 517, July 2017
Special Provision Foun0003	Dewatering Structure Excavations, March 2018
Design Build Special Provision 3271	Performance-Based Specification for Design and Construction of Structural Culverts

NON-STANDARD SPECIAL PROVISIONS

RECOMMENDED WORDING FOR “NSSP – A CONCRETE WORKING SLAB”

This Non-standard Special Provision covers the requirements for the supply and placement of a concrete working slab to protect the sand and silt subgrade of the entry/exits pits and provide a proper working surface for the tunnelling equipment.

Excavation for the working slab shall be according to OPSS.PROV 902. Within four hours following inspection and approval of the prepared subgrade, a working slab with a minimum thickness of 100 mm shall be placed on the foundation subgrade as specified in the Contract Documents. Concrete for working slabs shall have a minimum 28 day strength of 20 MPa.

RECOMMENDED WORDING FOR “NSSP – 902.07.05 EXCAVATION”

Subsection 902.07.05 of OPSS 902 is amended by the addition of the following:

Excavations at the site may be impeded by obstructions within the existing fill and glacial till. The contractor shall be prepared to dislodge and remove these obstructions and extend the excavations to the design depths.

Reference can be made to the Foundation Investigation Report for the Replacement of Structural Culvert No. 29-250/C Foresters Falls Culvert Crossing of Highway 17, prepared by Thurber Engineering Ltd., 2018, for further details on likely subsurface conditions at the culvert location.

RECOMMENDED WORDING FOR “NSSP – TEMPORARY PROTECTION SYSTEM”

Temporary protection system will be installed in ground conditions that include, cobbles and boulders. The Contractor's installation method and temporary protection system must be penetrating obstructions such as cobbles, boulders or other obstructions within the fill and glacial till.

Reference can be made to the Foundation Investigation Report for the Replacement of Structural Culvert No. 29-250/C Foresters Falls Culvert Crossing of Highway 17, prepared by Thurber Engineering Ltd., 2018, for further details on likely subsurface conditions at the foundation locations.