



THURBER ENGINEERING LTD.

**FINAL
FOUNDATION INVESTIGATION AND DESIGN REPORT
CULVERT SITE 27-252/C
HIGHWAY 417, CASSELMAN ON**

G.W.P. 451-98-00

Geocres No.: 31G-269

Report to:

Ainley Group

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PART 1. FACTUAL INFORMATION

1 INTRODUCTION

This section of the report presents the factual findings obtained from a foundation investigation completed for Culvert 27-252/C beneath the eastbound and westbound lanes of Highway 417. The culvert is located approximately 125 m east of County Road 7 within the Township of Cambridge. Thurber Engineering Limited (Thurber) carried out the current investigation as a sub-consultant to Ainley Graham & Associates Limited (Ainley) under Assignment No. 4016-E-0036.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide a borehole location plan, records of boreholes, stratigraphic profile, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions influencing design and construction was developed in the course of the current investigation. No previous foundation investigation information was available for the subject culvert site within the Geocres Library.

2 SITE DESCRIPTION

The existing culvert is a corrugated steel sectional plate arch culvert servicing the Leo Denis Municipal Drain and is understood to have been constructed in 1971. The culvert is reported to be 3.4 m wide by 2.2 m high and approximately 88 m long with a generally north to south alignment. The flow through the culvert is to the south.

At the location of the culvert, Highway 417 is a four-lane rural divided freeway with two 3.75m wide driving lanes in each direction. The embankment fill heights are approximately 1.8 m and 1.6 m over the culvert with the road surface at approximate elevations of 65.7 m and 65.4 m for the westbound and eastbound lanes, respectively. The existing embankment side slopes are inclined at approximately 3H:1V. No signs of erosion or slope instability were noted on the existing highway embankment during the field investigation. The roadway surface over the culvert was generally in good condition with no dips or bumps noted during the field investigation. The existing culvert, however, did show minimal signs of corrosion. The land adjacent to the highway is mainly agricultural with occasional commercial properties present. Traffic volumes are understood to be 24,500 AADT (2016).

Photographs showing the existing conditions in the area of the culvert are included in Appendix D for reference.

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3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing program was carried out on September 25th, 2017 for the on-road investigation and between June 20th and 22nd, 2018 for the off-road investigation. Drilling consisted of advancing four boreholes identified as 17-5 through 17-8. The drilling was carried out using a track mounted CME 55 drill rig for both off-road and on-road boreholes. Prior to commencement of drilling, utility clearances were obtained in the vicinity of the borehole locations.

The northing, easting and elevation of the boreholes from the current investigation are shown on the Borehole Location and Soil Strata Drawing No. 1 in Appendix A, the individual Record of Borehole sheets in Appendix B and are summarized in Table 3-1. The termination depth of each of the boreholes is also provided, below. The borehole elevations were surveyed using geodetic benchmark GBM 00819758419 (elev. 71.241 m) and a Trimble Catalyst with centimetre precision in conjunction with a Nikon-AP-8 with an accuracy of +/- 1.5 mm. Borehole locations were measured off existing site features and translated to northings and eastings based on the available base plans. The site is within MTM Zone 8.

Table 3-1: Borehole Summary

Borehole No.	Drilled Location	Northing (m)	Easting (m)	Ground Surface Elevation (m)	Termination Depth (m)
17-5	Near Culvert inlet	5 019 386.5	181 019.9	64.2	11.9
17-6	Westbound inside shoulder	5 019 362.5	181 026.2	65.7	13.5
17-7	Eastbound inside shoulder	5 019 332.7	181 003.1	65.4	13.5
17-8	Near Culvert outlet	5 019 304.4	181 015.1	64.0	11.7

The boreholes were advanced through soil using hollow stem augers. Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). In-situ shear vane testing was carried out within the cohesive strata using an N-vane. Bedrock was cored with NQ size coring equipment.

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

A 19 mm diameter standpipe piezometer was installed in Borehole 17-8 to allow for measurements of the groundwater level after completion of drilling. The piezometer installation details are illustrated on the Record of Borehole sheet for Borehole 17-8, provided in Appendix B. Following completion of the field investigation the remaining boreholes were backfilled in accordance with MOE requirements (O.Reg. 903, as amended).

4 LABORATORY TESTING

The recovered soil samples were subjected to visual identification and to natural moisture content determination. Selected samples were also subjected to gradation analysis (hydrometer and/or sieve) and Atterberg Limit testing. The results of these tests are summarized on the Record of Borehole sheets included in Appendix B. One sample of soil recovered from within Borehole 17-8 was selected and submitted for analytical testing of corrosivity parameters and sulphate content. All laboratory test results from the field investigation are provided in Appendix C.

5 GENERAL DESCRIPTION OF SUBSURFACE CONDITIONS

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

In general terms, the site was found to be underlain by a granular embankment fill overlying native deposits of clay and glacial till over bedrock. A veneer of topsoil was present at the surface of the off-road boreholes.

5.1 Surficial Materials

5.1.1 Silt to Silty Sand with Organics

A layer consisting of silt to silty sand ranging in thickness from 100 to 150 mm was encountered at surface in Boreholes 17-5 and 17-8. Wood fragments and organics were encountered in this layer. The moisture content was measured to be 12% on one sample.

5.1.2 Fill: Silty Sand with Gravel

A layer of silty sand with varying amounts of gravel was encountered below the topsoil in Boreholes 17-5 and 17-8, and at surface in Boreholes 17-6 and 17-7. The underside of this fill ranged from 2.9 to 3.1 m below ground surface in Boreholes 17-5 and 17-8 (elev. 61.1 m). The underside depth of this fill was 0.5 m below the gravel shoulder in Boreholes 17-7 and 17-6 (elev. 64.9 to 65.2 m).

The SPT tests conducted in this layer gave N-values ranging from 10 to 39 blows, indicating a relative density of compact to dense. Recorded moisture contents ranged from 2 to 16%.

Gradation analyses were completed on three samples of the silty sand with gravel fill. The grain size distribution curves for these samples are included in Figure C1 of Appendix C. The results of the tests are summarized in Table 5-1 below and are presented on the corresponding Record of Borehole sheets in Appendix B.

Table 5-1 Gradation Results for Silty Sand with Gravel Fill

Soil Particle	Percentage (%)
Gravel	30 – 44
Sand	44 – 52
Silt	12 – 18
Clay	

5.1.3 Fill: Silty Sand

A layer of silty sand was encountered below the silty sand with gravel fill in Boreholes 17-6 and 17-7. The underside of this fill ranged from 1.2 to 1.6 m below the existing gravel shoulder (elev. 63.8 to 64.5 m).

The SPT tests conducted in this layer gave an N-value of 15, indicating a compact relative density. Recorded moisture contents for the sample tested ranged from 11 to 17%.

Gradation analysis was completed on one sample of the silty sand fill layer. The grain size distribution curve for this sample is included in Figure C1 of Appendix C. The results of the test indicated the material to consist of 1% gravel, 67% sand and 32% fines and are presented on the corresponding Record of Borehole sheet in Appendix B.

5.2 Silt

A layer of silt was encountered below the silty sand fill in Borehole 17-6. The silt layer has a thickness of 0.5 m with an underside elevation of 64.0 m. An SPT test gave an N-value of 11 blows, indicating a compact relative density. A single moisture content of 30% was measured.

5.3 Clay (CH)

A deposit of native clay was encountered beneath the embankment fill in Boreholes 17-5, 17-7, and 17-8 and below the silt layer in Borehole 17-6. The thickness of this layer was found to range from 2.7 to 5.3 m with underside elevations ranging from 55.9 to 58.8 m. The upper portion in Boreholes 17-6 and 17-7 was noted to be a firm to stiff weathered crust, ranging in thickness from 1.0 to 1.3 m.

In-situ shear vane test results throughout the layer indicated undrained shear strengths ranging from 17 to 64 kPa, indicating a soft to stiff consistency. The results of the in-situ shear vane tests indicated that the clay exhibits moderate to high sensitivity. SPT tests below the crust gave N-values ranging from Weight of Hammer (WH) to 3 blows. Recorded moisture contents ranged from 23 to 86%.

The results of grain size analyses conducted on six samples of the clay are summarized in Table 5-2 and illustrated on Figure C2 of Appendix C.

Table 5-2 Gradation Results for Clay

Soil Particle	Percentage (%)
Gravel	0
Sand	0 – 2
Silt	21 – 49
Clay	51 – 77

The results of Atterberg Limits testing completed on six samples of this material are summarized in Table 5-3 and are summarized on the Record of Borehole sheets in Appendix B and the Atterberg Limits graph is included in Figure C4 of Appendix C.

Table 5-3 Atterberg Limits Results for Clay

Parameter	Value
Liquid Limit	54 – 72
Plastic Limit	20 – 30
Plasticity Index	30 – 45

The laboratory results indicate that the clay has high plasticity (CH).

Near the base of the clay layer in Boreholes 17-7 and 17-8 a silt layer was observed. This layer has a thickness of 0.2 to 0.8 m with an underside elevation of 55.9 to 58.8 m.

5.4 Silty Sand with Gravel (Glacial Till)

A native deposit of glacial till consisting of varying amounts of sand, silt, and gravel was encountered underlying the clay in all boreholes. The glacial till extended to a depth of 8.1 to 10.1 m (elev. 55.3 to 55.9 m).

SPT tests gave N-values ranging from 12 to 100 blows for 125 mm, indicating a relative density of compact to very dense. Occasional to frequent cobbles and boulders were encountered within this deposit at Boreholes 17-5 through 17-7. A 1 m boulder was observed at a depth of 6.8 m below ground surface in Borehole 17-5 (elev. 57.4 m). The recorded moisture contents ranged from 6 to 21%.

Gradation analysis was completed on one sample of the glacial till. The grain size distribution curve is included in Figure C3 of Appendix C. The results of the test indicated the material to consist of 29% gravel, 50% sand and 21% fines and are presented on the corresponding Record of Borehole sheet in Appendix B. Test results indicate an SM material.

5.5 Bedrock

Bedrock was proven by coring in all four boreholes. Information on the bedrock surface is summarized in Table 5-4.

Table 5-4 Summary of Bedrock Elevations

Borehole No.	Depth to Bedrock (m)	Bedrock Elevation (m)
17-5	8.9	55.3
17-6	10.1	55.6
17-7	9.6	55.8
17-8	8.1	55.9

The bedrock encountered within Boreholes 17-5 through 17-8 consisted of slightly weathered to fresh limestone with shale partings. The Total Core Recovery (TCR) measured on the bedrock core ranged from 67 to 100%, the Solid Core Recovery (SCR) ranged from 67 to 100%, and the Rock Quality Designation (RQD) ranged from 63 to 100%, with one value of 43%. Based on the measured RQD values, the bedrock is classified as fair to excellent, but predominantly excellent.

Unconfined Compressive Strength (UCS) testing was carried out on the bedrock. The results of UCS testing carried out on three samples of the rock core ranged from 105 to 153 MPa, indicating the intact limestone bedrock to be very strong. Photographs of the bedrock core are provided in Appendix C.

5.6 Groundwater

The groundwater level measured in the standpipe piezometer in Borehole 17-8 was recorded at a depth of 0.3 m on June 26, 2018 (elev. 63.7 m). The water level of the Leo Denis Municipal Drain was measured to be at an elevation of 62.2 m on June 22, 2018. It is expected that the groundwater level will likely reflect the water level in the municipal drain ditch. These observations are considered short term and it should be noted that the groundwater level at the time of construction may be different and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant and/or prolonged precipitation events.

5.7 Analytical Testing

One sample of the native soil was submitted to Paracel Laboratories in Ottawa, Ontario for analysis of pH, water soluble sulphate and chloride concentrations, sulphide content, resistivity and conductivity. Results of the analysis are summarized in Table 5-5.

Table 5-5 Summary of Analytical Testing

Borehole (Sample)	Depth (mbgs)	Sulphate (µg/g)	pH (-)	Resistivity (Ohm-cm)	Conductivity (uS/cm)	Chloride (µg/g)	Sulphide (%)
17-8 (SS4)	2.3 – 2.9	89	7.89	2,750	363	105	0.14

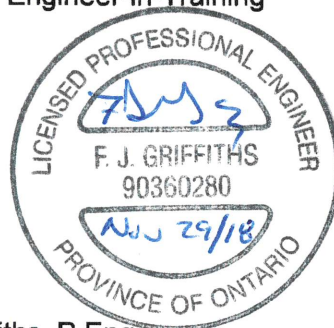
6 MISCELLANEOUS

Borehole locations were selected by Thurber relative to existing site features. The as-drilled locations and ground surface elevations were surveyed by Thurber following completion of the field program.

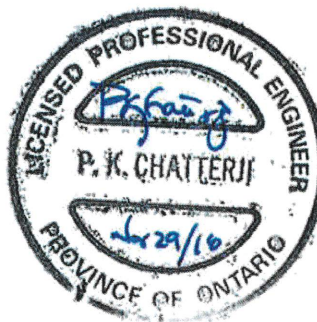
George Downing Estate Drilling Ltd. of Hawkesbury, Ontario supplied and operated the drilling equipment to conduct the drilling, soil sampling, in-situ testing and borehole decommissioning. Beaconlite of Ottawa, Ontario supplied the traffic control equipment and personnel for TL-29 lane closures required for the on-road boreholes and TL-12 shoulder closures for the off-road boreholes in conformance with Ontario Book 7 requirements. The field investigation was supervised on a full-time basis by either Mr. Justin Gray, E.I.T. or Miss Katya Edney, P.Eng. of Thurber. Overall supervision of the investigation program was conducted by Dr. Fred Griffiths, P.Eng.

Routine geotechnical laboratory testing was completed by Thurber's laboratory in Ottawa, Ontario. Analytical testing was completed by Paracel Laboratories in Ottawa, Ontario. Interpretation of the factual data and preparation of this report were carried out by Miss Allison Chow, E.I.T. and Dr. Fred Griffiths, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng. a Designated Principal Contact for MTO Foundation Projects.

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PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 INTRODUCTION

This section of the report provides an interpretation of the factual data from Part 1 of this report and presents geotechnical recommendations to assist the project team in designing the proposed replacement of Culvert 27-252/C crossing under the west bound and east bound lanes of Highway 417 near the County Road 7 Interchange in Casselman, Ontario. The discussion and recommendations presented in this report are based on the information provided by Ainley and on the factual data obtained during the course of the investigation.

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

The existing culvert is a corrugated steel sectional plate arch culvert servicing the Leo Denis Municipal Drain and is reported to be 3.4 m wide by 2.2 m high and approximately 88 m long with a generally north to south alignment. The flow through the culvert is to the south. The water level of the Leo Denis Municipal Drain was measured to be at an elevation of 62.2 m on June 22, 2018.

The embankment fill heights are approximately 1.8 m and 1.6 m above the culvert with the road surface at approximate elevations of 65.7 m and 65.4 m for the westbound and eastbound lanes, respectively. The existing embankment side slopes are inclined at approximately 3H:1V.

No previous foundation investigation information for the subject culvert was available in the Geocres Library.

Thurber Engineering Limited (Thurber) carried out the current investigation as a sub-consultant to Ainley Consulting Engineers Planners (Ainley) under Assignment No. 4016-E-0036.

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7.1 Proposed Structure

At the time of preparation of the final Foundation Investigation and Design Report, based on information provided by Ainley and on the General Arrangement (GA) drawing (copy provided in Appendix A), it is understood that the existing culvert will be replaced with a concrete culvert with a width of 4.0 m, height of 3.0 m and a length of approximately 88.5 m. Cut-off walls are proposed for the new culvert. The culvert inverts are expected to be at approximately elevation 61.3 and 61.2 m at the inlet and outlet, respectively.

7.2 Applicable Codes and Design Considerations

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

It is understood that the culvert structure has a consequence classification of *Typical Consequence*, in accordance with Section 6.5.1 of the CHBDC. Accordingly, a consequence factor (Ψ) of 1.0, as per Table 6.1 of the CHBDC, has been used in assessing factored geotechnical resistances.

The frost penetration depth and associated recommendations are provided in Section 10.3.

8 SEISMIC CONSIDERATIONS

8.1 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). The seismic hazard for this site has been obtained from the GSC calculator. The data includes a peak ground acceleration (PGA), peak ground velocity (PGV) and the 5% spectral response acceleration values ($S_a(T)$) for the reference ground condition (Site Class C) for a range of periods (T) and for a range of return periods including 475-year, 975-year and 2475-year events. The GSC seismic hazard calculated data sheet for this site is included 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), which at this site for a reference Site Class C and a 2475 year event is 0.372g.

8.2 CHBDC Seismic Site Classification

In accordance with the CHBDC, the selection of the seismic site classification is based on the energy-corrected average penetration resistance for the upper 30 m of the stratigraphy.

Based on the soil conditions encountered below the anticipated culvert foundation elevation, the site has been classified as a Site Class E in accordance with Section 4.4.3.2 of the CHBDC (S6-14).

8.3 Seismic Liquefaction

A liquefaction triggering analysis for the non-cohesive soils at the site was completed using the Idriss and Boulanger simplified procedure outlined in Section C4.6 of the CHBDC Commentary (S6-14). Based on the factored PGA, the non-cohesive foundation soils

encountered at the drilled locations are not considered susceptible to liquefaction during a 1 in 2475 year seismic event.

The susceptibility of the cohesive soils at the site to experience cyclic mobility or cyclic softening was assessed using the Bray et al. (2004) criteria using samples collected from the investigation and index property testing. Based on Bray's chart for assessing liquefaction susceptibility, the material is classified as non-susceptible to cyclic mobility or cyclic softening.

9 DESIGN OPTIONS

9.1 Culvert Type and Foundation Alternatives

Selection of the culvert type must consider the proposed construction procedures, staging requirement, geotechnical resistance available in the foundation soils, the depth to suitable bearing stratum and post-construction settlement criteria. From a geotechnical perspective, the following culvert types were considered:

- Circular Pipes (Concrete, HDPE, Steel)
From a foundation engineering perspective, pipe culverts are a feasible alternative.
- Open Bottom Culvert (Box, Arch)
Open bottom culverts are not recommended at this site from a foundation engineering perspective since the foundation clay would offer low bearing resistance and would require greater excavation and dewatering efforts during construction to place the foundation in the dry. Differential settlement may also occur if footings are founded in the soft foundation clay.
- Closed Bottom Culvert (Box)
Precast segmental box culvert in an open cut construction is considered a feasible option from a foundation engineering perspective. Precast sections, rather than cast-in-place construction, can be installed expediently with less potential for disturbance of the founding soils during installation.
- Steel Sheet Pile Walls with Precast Concrete Slab
A steel sheet pile culvert is not recommended under Highway 417.

A comparison of these alternatives, based on their respective advantages and disadvantages, is included in Appendix E. It is not considered to be economical or practical to support a culvert on deep foundations at this site and therefore this option is not presented in this report.

9.2 Construction Methodology Alternative

For the proposed culvert replacement, the following construction methods were considered.

- Open Cut with Full Road Closure and Detour
Installation of a new culvert using open cut techniques and separate full road closure for the east bound and west bound lanes would allow for an expedited construction schedule and could reduce costs associated with roadway protection. It is

understood that the culvert location is beyond the limits of the lane closures proposed for the highway pavement reconstruction. A full closure of either the east bound or west bound lanes is not considered feasible due to the proximity of the site to the County Road 7 Interchange.

- Open Cut with Staged Temporary Protection System

The use of open cut techniques in conjunction with staged culvert replacement is a feasible construction option from a geotechnical perspective. This option will require roadway protection, installed along the embankment centerline to maintain a single lane of traffic flow along the current highway alignment.

- Open Cut with Temporary Modular Bridge

It is considered feasible at this site to complete a culvert replacement within a full width open cut excavation with a single lane temporary modular bridge spanning the excavation to allow for movement of traffic across the site. This approach does not provide significant advantages over the more economical temporary protection system approach and is therefore not recommended, particularly for Highway 417. Furthermore, the borehole investigation to confirm the design of the modular bridge foundation was not included within the scope of the current investigation and further field investigations would be required,

- Open Cut with Staged Temporary Widening

Widening of the existing highway and/or construction of a temporary detour embankment to accommodate a traffic passage during construction has been considered. However, placement of new fill where clay soils are present in the foundation could generate settlement under the footprint of the embankment widening as well as the existing embankment. Furthermore, due to the depth of excavation, the width of widening would be excessive without a temporary protection system or grade lowering. This option is not recommended.

- Trenchless Techniques

Trenchless techniques would have the advantage of minimum disruption to traffic and would avoid a large excavation through the existing highway embankment. However, this site will involve installation of a relatively large diameter pipe by trenchless method and there is insufficient cover above the replacement culvert and therefore a trenchless culvert installation is not recommended at this site.

9.3 Recommended Approach for the Culvert Replacement

From a foundation engineering perspective, the alternative of replacing the existing culvert with a closed precast segregated box culvert using staged open cut techniques is the recommended culvert replacement option. Temporary protection systems (TPS) would be needed to facilitate construction.

10 FOUNDATION DESIGN RECOMMENDATIONS

Foundation design aspects for the replacement culvert include subgrade conditions, geotechnical resistances, settlement of the founding soils, imposed loading pressures, erosion control, protection system design, groundwater control and stability of stage

construction. The culvert must be designed to resist loading including lateral earth pressures, hydrostatic pressure, weight of embankment fill, traffic loading and any surcharge due to construction equipment and activities under static and seismic conditions.

10.1 Culvert Foundation Bearing Resistances

A closed box culvert may be founded on the native, undisturbed clay and can be designed based on the factored geotechnical resistance values provided below.

The recommended geotechnical resistances for a pre-cast box culvert installed on a bedding layer (see Section 10.2) overlying undisturbed native soft to firm clay subgrade is provided below. A closed box culvert would not need to be founded below the depth of frost. For a 4 m wide box culvert with an invert at approximate elevation 61.2 m and a 300 mm thick base slab or 200 mm granular bedding, the geotechnical resistance is as follows.

- Factored Geotechnical Resistance at ULS 120 kPa
- Factored Geotechnical Resistance at SLS or 60 kPa

The factored geotechnical resistances include the following factors:

- Consequence factor (Ψ) of 1.0 (as per CHBDC Table 6.1)
- Geotechnical resistance factors (as per CHBDC Table 6.2):
 - $\phi_{gu} = 0.5$ (static analysis; typical degree of understanding)
 - $\phi_{gs} = 0.8$ (static analysis; typical degree of understanding)

The bearing resistance values are for vertical, concentric loading. In the case of eccentric or inclined loading, the bearing resistance must be reduced in accordance with CHBDC Clause 6.10.3 and Clause 6.10.4. Foundation settlement, based on the supplied SLS resistance, is expected to be less than 25 mm.

Resistance to lateral forces/sliding resistance between concrete and the underlying Granular 'A' bedding (Section 10.2) should be evaluated in accordance with the CHBDC assuming an unfactored coefficient of 0.45 for precast concrete and 0.5 for cast-in-place concrete.

It is noted that construction will extend below the groundwater level. Water diversion and dewatering (Section 11.3) will be required to place the bedding material and install the culvert in the dry.

10.2 Subgrade Preparation, Bedding and Backfilling

Subgrade preparation for the culvert replacement should include excavation and removal of the existing culvert and backfill materials. All organics, existing fill, soft or loose drain base deposits, disturbed soils, alluvial deposits and deleterious materials must be stripped from the footprint of the foundation to expose competent native firm clay subgrade at or below the desired founding elevations. The exposed subgrade must be inspected to confirm that the subgrade is suitable and uniformly competent. Any soft or organic materials at the subgrade level should be sub-excavated and backfilled with granular fill consisting of OPSS.PROV 1010 Granular A or Granular B Type II material as soon as possible after

reaching the subgrade level and following receipt of written notice to proceed in accordance with SP 109S12. The granular fill should be compacted as per OPPS.PROV 501.

In order to provide a more uniform foundation subgrade condition for the closed box culvert, a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A or Granular B Type II requirements must be provided under the base of the culvert as per OPSS 422 and OPSD 803.010.

The subgrade may be easily disturbed when saturated and should be protected from disturbance from both construction traffic and weather. Construction equipment should not travel on the exposed subgrade. Protection of the subgrade should include installation of Class II non-woven geotextile with a maximum FOS of 150 μ m (OPSS 1860) installed beneath the Granular bedding layer. Suggested wording for an NSSP identifying the sensitive foundation soils is present in Appendix G.

Dewatering will be required to prepare the subgrade in the dry. Please refer to Section 11.3 for additional comments on groundwater and surface water control.

It is recommended that culvert cover consist of free-draining, non-frost susceptible granular materials such as Granular A material meeting the requirements of OPSS.PROV 1010. The cover must be in accordance with OPSS 902.

Culvert backfill above the granular cover should be in accordance with OPSS 902 and consist of material meeting the requirements of Granular A or Granular B Type II. It should be compacted in regular lifts as per OPSS.PROV 501. Heavy compaction equipment, used adjacent to the structure, must be restricted in accordance with OPSS.PROV 501. Care must be exercised when compacting the fill adjacent to and above the culvert in order not to damage the culvert.

10.3 Frost Depth

The depth of frost penetration at this site is estimated to be 1.8 m, as per OPSD 3090.101. It is not necessary to found a closed box culvert below the depth of frost penetration.

10.4 Backfill and Earth Pressure

Lateral earth pressures parameters provided in Table 10-1 and Table 10-2 in the sections below 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 design.

If the backfill geometry and/or material is different than those indicated in Tables 10.1 and 10.2, the lateral earth pressure parameters provided are not applicable and recalculation of the parameters will be required.

10.4.1 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 following expression:

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

where:

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

A lateral earth pressure due to backfill compaction should be added to the calculated lateral earth pressure in accordance with Clause 6.12.3 of the CHBDC. Typical earth pressure coefficients for backfill are shown in Table 10-1.

Table 10-1. Earth Pressure Coefficients for Vertical Walls

Condition	Earth Pressure Coefficient (K)					
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$		OPSS SSM and Existing Silty Sand Fill $\phi = 30^\circ, \gamma = 21.0 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active, K_A (Yielding Wall)	0.27	0.39	0.31	0.47	0.33	0.54
At Rest, K_O (Non-Yielding Wall)	0.43	-	0.47	-	0.50	-
Passive, K_P (Movement towards Soil Mass)	3.7	-	3.3	-	3.0	-
Soil Group(*)	"medium dense sand"		"loose to medium dense sand"		"loose sand"	

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

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

The parameters in the table correspond to full mobilization of active and passive earth pressures and require certain relative movements between the wall and adjacent soil to produce these conditions. The values to be used in design can be assessed from Figure C6.16 of the Commentary to the CHBDC using the soil group designation as outlined in Table 10-1. Active earth pressures should be used for any head walls or unrestrained walls. For rigid structures such as a concrete box culvert, it is recommended that at-rest

horizontal earth pressures be used for design. Where ground surfaces are sloped at 2H:1V behind the walls, the corresponding coefficients provided in the Table 10-1 should be used.

10.4.2 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 Mononobe-Okabe Method with:

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

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

The coefficients of horizontal earth pressure for seismic loading presented in Table 10-2 may be used. The provided earth pressure coefficients are based on a Seismic Site Class E and a PGA_{ref} with a 2% probability of exceedance in 50 years (2475-year event) of 0.298g equal to $0.8 \times PGA$ in accordance with CHBDC Clause 4.4.3.3. An $F(PGA)$ of 0.99 has been interpolated from Table 4.8 of the CHBDC (S6-14 update No. 1, April 2016).

Table 10-2. Dynamic Earth Pressure Coefficients for Vertical Walls

Condition	Earth Pressure Coefficient (K)	
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$	OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$
	Horizontal Surface Behind Wall	Horizontal Surface Behind Wall
Active, K_{AE} Yielding Wall	0.38	0.43
Active, K_{AE} Non-Yielding Wall	0.55	0.61

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 soils 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_a for yielding walls, K_o for non-yielding walls)
γ	=	unit weight of retained soil, (use submerged unit weight for soil below groundwater level)
K_{AE}	=	combined static and seismic earth pressure coefficient
H	=	total height of the wall (m)

10.5 Embankment Design and Reinstatement

Embankment reconstruction after culvert replacement should be carried out in accordance with OPSS.PROV 206. The embankment should be reinstated with side slopes of 2H:1V (or flatter) if constructed using Granular A or Granular B Type II. The fill should be placed and compacted in accordance with OPSS.PROV 501. The existing silty sand with gravel fill from the existing embankment should not be reused.

Frost taper treatment, if required, should be as per OPSD 803.010 and as directed within a Pavement Report or Pavement Design Memo.

Provided the subgrade is prepared as outlined above and construction of the embankment is carried out in accordance with recommendations provided within this report, the embankment side slopes should remain stable.

It is understood that no grade raise or embankment widening is anticipated along the alignment of Highway 417 and therefore negligible foundation settlement is expected to occur.

The magnitude of the embankment compression constructed with granular materials is in the order of 0.5% of the embankment height and is expected to occur during fill placement.

10.6 Cement Type and Corrosion Potential

Analytical tests were completed to determine the potential for degradation of the concrete in the presence of soluble sulphates and the potential for corrosion of exposed steel. The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with soil and groundwater at the site. Soluble sulphate concentrations less than 1000 µg/g generally indicate a low degree of sulphate attack is expected for concrete in contact with soil and groundwater. The class of concrete selected should consider the effects of road de-icing salts.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The test results provided in Section 5.7 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects. The corrosion effects of road de-icing salts should also be considered.

11 CONSTRUCTION CONSIDERATIONS

11.1 Excavation

All excavation must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of OHSA, the fills and native soils above the water table may be classified as Type 3 soil. Cohesionless fill or soils below the groundwater level are classified as Type 4 soils.

Excavation for the culvert replacement must be carried out in accordance with OPSS 902 and will be carried out through the existing embankment fill and extend into the underlying native clay deposits. The sides of temporary excavations must be sloped in accordance with the requirement of the OHSA. Selection of the equipment and methodology to excavate and prepare the founding surface is the responsibility of the Contractor. Stockpiling or surface surcharge should not be allowed on the embankment or side slopes.

At locations where there are space restrictions or where a slope has to be retained, the excavations will need to be carried out within a protection system. Further discussion on temporary protection systems (TPS) is presented in Section 11.2.

11.2 Temporary Protection Systems

Temporary Protection Systems may be required during various stages of construction and must be implemented in accordance with OPSS.PROV 539 and designed for Performance Level 2 (maximum 25 mm horizontal deflection). The actual pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall and these factors must be considered when designing the shoring system.

The design of roadway protection is the responsibility of the Contractor. All protection systems should be designed by a licensed Professional Engineer experienced in such designs and retained by the Contractor. The design of the roadway protection system must incorporate traffic loading and surcharge loading due to construction equipment and operations.

It is recommended that an NSSP be included in the tender documents to alert the Contractor to the potential for cobbles and boulders and obstructions within the glacial till and the potential need for deadman tie-backs, struts and/or raker supports to achieve the specified performance level due to the shallow depth of refusal noted during the field investigation.

The protection system should be installed at a sufficient distance away from the new culvert to limit the disturbance to subgrade associated with removal of the protection system following complete of construction. Alternatively, the protection system near the culvert could be left in place and cut off in accordance with OPSS 539.

Lateral earth pressure coefficient, under fully mobilized conditions, that can be used in design of the protection system installed through the embankment fill and culvert backfill are provided in Table 10-1 and Table 10-2. The lateral earth pressure coefficients for the existing native clay and glacial till soils are given below for a vertical wall with a horizontal backslope:

CLAY

γ	=	19 kN/m ³	(use submerged unit weight for soil below groundwater level)
K_A	=	0.39	
K_P	=	2.6	

GLACIAL TILL

γ	=	19.5 kN/m ³	(use submerged unit weight for soil below groundwater level)
K_A	=	0.31	
K_P	=	3.2	

Given the potential presence of cobbles and boulders in the till, it may be difficult to drive sheet piles. Given the presence of shallow bedrock, lateral support may need to be enhanced using bracing or rakers. The installation of soldier piles with lagging may be the preferred alternative. The soldier piles may have to be drilled in and socketed into bedrock if required. Suggested wording for an NSSP for obstructions is included in Appendix G.

11.3 Dewatering

Creek diversion controlled by coffer dams will be required.

The depth of excavation for culvert replacement will extend below the groundwater level and ditch water level observed at the time of the investigation. The Contractor must be prepared to control the groundwater and surface water flow at the site to permit construction in a dry and stable excavation. Water from surface flow and/or groundwater must be diverted away from any excavation at all times. Groundwater perched within the embankment fill and, surface runoff will tend to seep into, and accumulate in excavations.

The design of dewatering systems is the responsibility of the Contractor. The Contract Documents must alert the Contractor to this responsibility and to design the system in accordance with NSSP FOUN0003 which amends OPSS 902. A preconstruction survey is recommended, thus Designer Fill-In ** in the SP should be "200 m". Recommended wording for an NSSP amending NSSP FOUN0003 to include the requirement that the design Engineer and design-checking Engineer of the dewatering system have a minimum of 5 years of experience in designing systems of similar nature and scope to the required work has been provided in Appendix G.

The groundwater level will fluctuate and the minimum groundwater elevation for the site at the time of the proposed work should be taken as the water level of the design storm return period defined by the contract documents for the dewatering system.

Temporary groundwater and surface water control measures will be required to remain operational during construction until the culvert is installed and backfilled. It is anticipated that the culvert replacement work will be isolated within a water tight enclosure. Sheet Pile cofferdams can be designed following the recommendations provided in Section 11.2. The comments on installation and extraction of Temporary Protection Systems are also relevant for Sheet Pile Cofferdams.

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. The groundwater level within the culvert footprint should be lowered by pumping from sumps prior to excavation to at least 500 mm below the underside of the target depth of each excavation stage prior to initiating excavation.

Further assessment of dewatering requirements and the need for a PTTW should be carried out by specialists experienced in this field.

11.4 Scour Protection and Erosion Control

Based on the subsurface conditions encountered at the drilled locations through the embankment at this site the embankment soils are considered to have moderate susceptibility to erosion as per the Wischmeier Nomograph. The native soils at the inlet and outlet are considered to have low susceptibility to erosion.

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

Typically, rock protection should be provided over all earth surfaces subjected to flowing water in accordance with OPSS 511. Treatment at the outlet should be in accordance with OPSD 810.010. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS.PROV 804.

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

12 CONSTRUCTION CONCERNS

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

- Disturbance of the soil subgrade. The foundation will be placed on firm clay soil, which may become disturbed if subjected to construction traffic. Construction methodology and drainage will be critical to maintain subgrade conditions.
- Cobbles and boulders may be encountered in the existing glacial till and could interfere with roadway protection installation.
- Shallow depth of refusal may interfere with installation of roadway protection installation
- Groundwater levels may fluctuate. Excavation will involve lowering the groundwater level below the excavation base to maintain a reasonably dry excavation and stable side slopes. There is a risk of basal instability. The dewatering scheme will be important for culvert construction at this site.
- The Contractor's selection of construction equipment and methodology must include assessment of the capability of the existing embankment to support the proposed

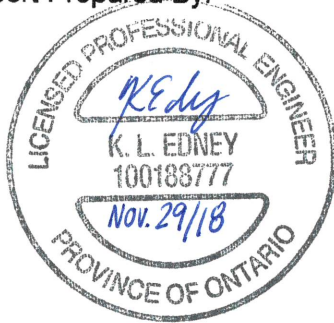
construction equipment and any temporary structure fill (i.e., as a pad for crane support).

The successful performance of the culvert will depend largely upon good workmanship and quality control during construction. Subgrade examination should be carried out by qualified geotechnical personal during construction in accordance with SP 109S12 to confirm that foundation recommendations are correctly implemented, and material specifications are met.

13 CLOSURE

Engineering analysis and preparation of this report were carried out by Dr Fred Griffiths, P.Eng and Miss Katya Edney, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng a Designated Principal Contact for MTO Foundation Projects.

Thurber Engineering Ltd.
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Senior Associate
Senior Geotechnical Engineer

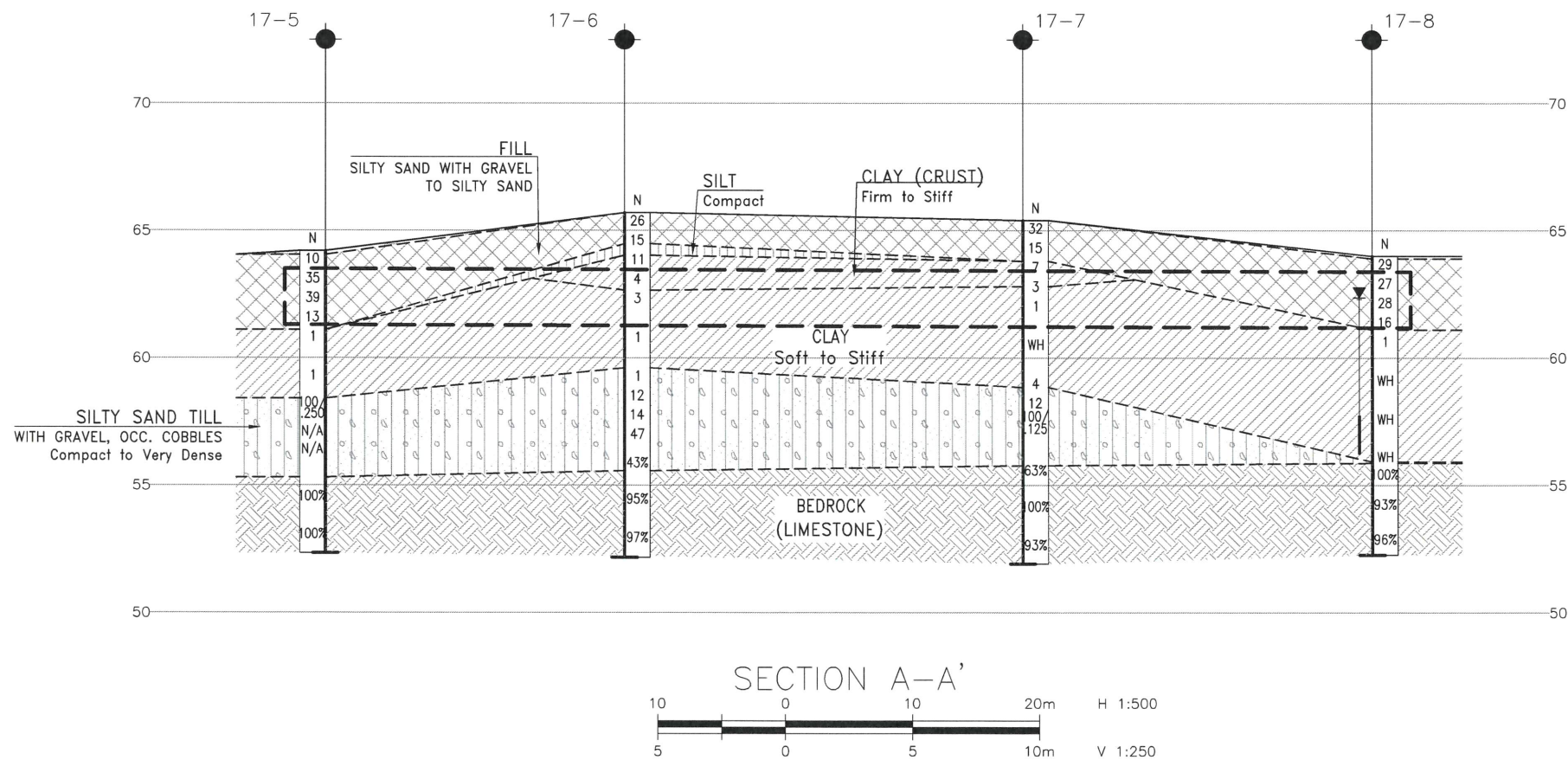
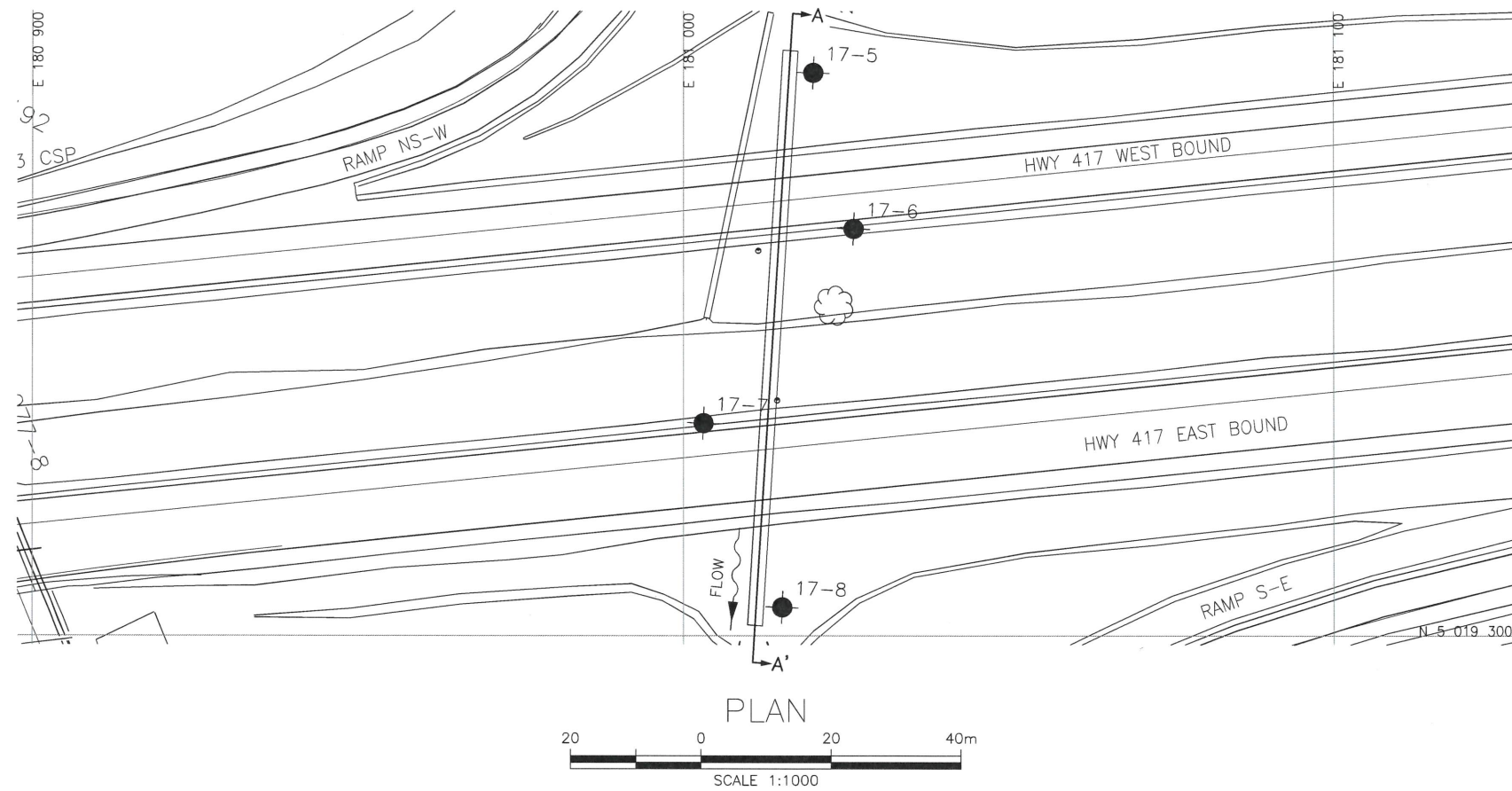


Dr. P.K. Chatterji, P.Eng.
Review Principal,
Senior Geotechnical Engineer

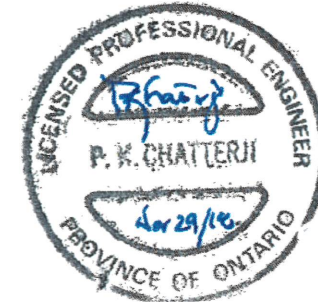
FINAL

Appendix A.

Borehole Location Plan and Stratigraphic Drawings



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



CONT No
GWP No 451-98-00

HIGHWAY 417
CULVERT 27-252/C
REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET



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
17-5	64.2	5 019 386.5	181 019.9
17-6	65.7	5 019 362.5	181 026.2
17-7	65.4	5 019 332.7	181 003.1
17-8	64.0	5 019 304.4	181 015.1

NOTES

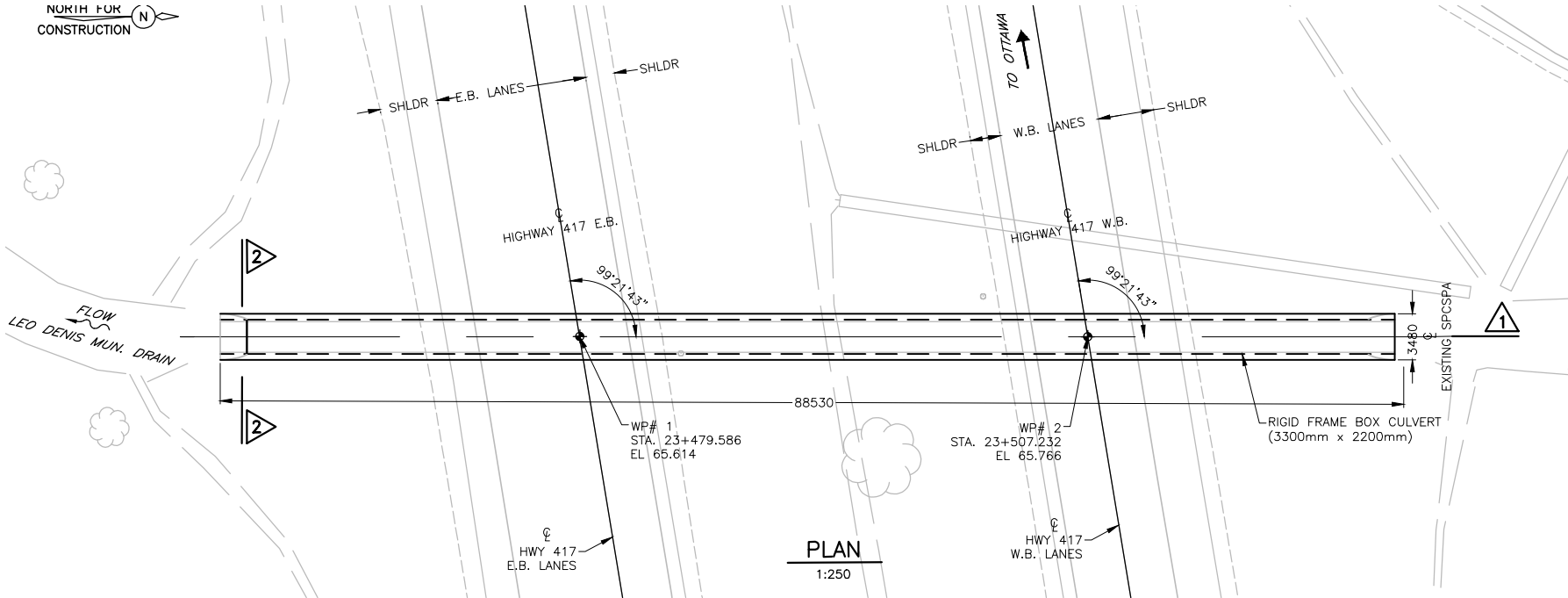
- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Coordinate system is MTM NAD 83 Zone 8.

GEOCRES No. 31G-269

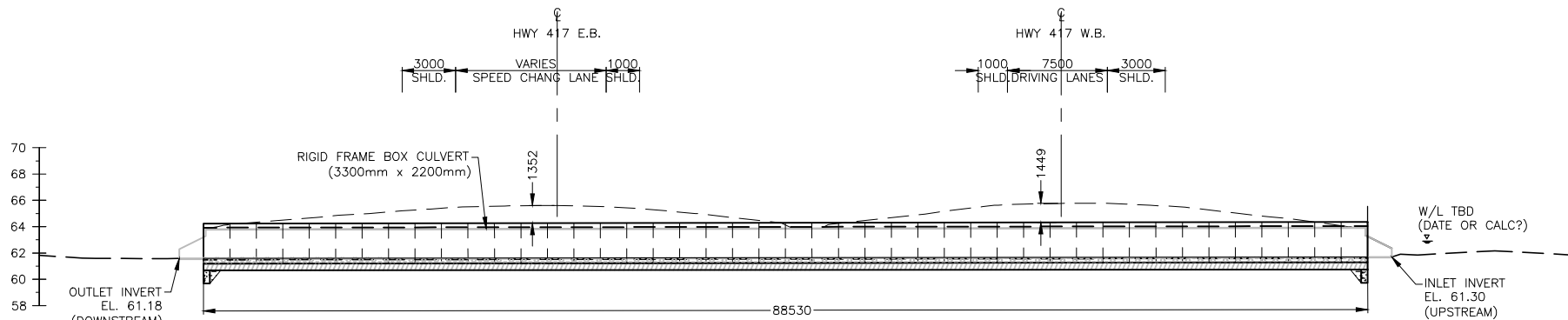
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			STRUCT
			DWG 1
			DATE NOV 2018

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MODIFIED: 2018-07-13
MINISTRY OF TRANSPORTATION, ONTARIO
PR-D-707 88-05

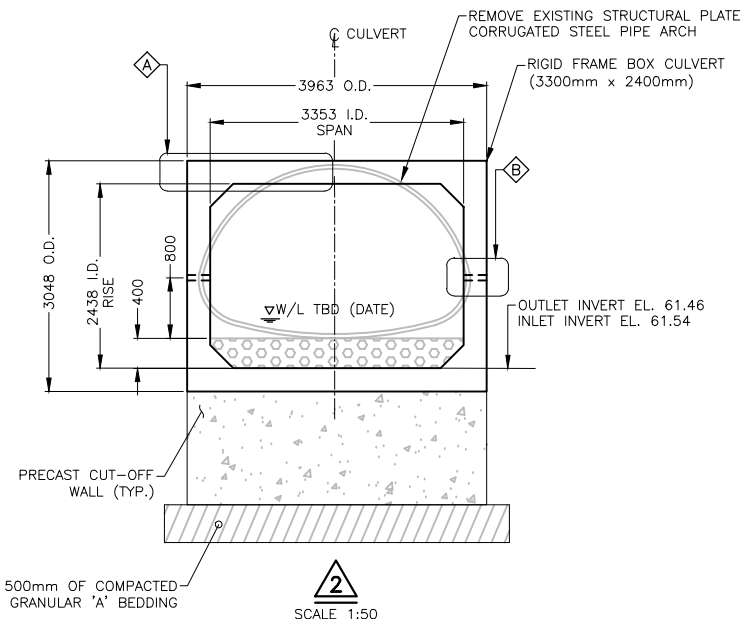
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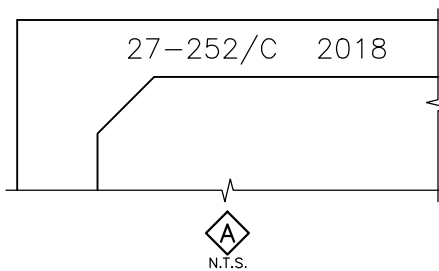
PLAN
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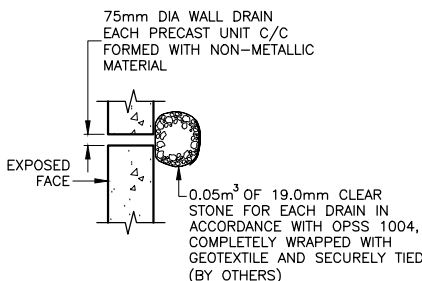
1
SCALE 1:250



2
SCALE 1:50



N.T.S.



B
SCALE 1:25

LEGEND:

- BEDDING MATERIAL
NEW CONCRETE
SUBSTRATE

METRIC

DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES UNLESS
OTHERWISE SHOWN

CONT
WP

451-98-00



SITE No. 27-252/C

SHEET

PRELIMINARY GENERAL
ARRANGEMENT

1

Anley
CONSULTING
ENGINEERS
PLANNERS

FLOW DATA: EXISTING CULVERT

DURATION	PEAK FLOW "Q" (m3/S)	WATER LEVEL (m)
2 YR.	1.361	-
5 YR.	2.297	-

GENERAL NOTES

- CLASS OF CONCRETE
35MPa UNLESS OTHERWISE NOTED.
- CLEAR COVER TO REINFORCING STEEL
PRECAST CONCRETE 50±10
ALL EXPOSED CORNERS TO BE CHAMFERED 20mm.
- REINFORCING STEEL
REINFORCING STEEL SHALL BE GRADE 400W UNLESS OTHERWISE SPECIFIED.
UNLESS SHOWN OTHERWISE, TENSION LAP SPLICES SHALL BE CLASS B.
BAR HOOKS SHALL HAVE STANDARD HOOK DIMENSIONS USING MINIMUM BEND DIAMETERS WHILE STIRRUPS AND TIES SHALL HAVE MINIMUM HOOK DIMENSIONS. ALL HOOKS SHALL BE IN ACCORDANCE WITH THE STRUCTURAL STANDARD DRAWINGS SS12-1, UNLESS INDICATED OTHERWISE.

CONSTRUCTION NOTES

- PRECAST END UNITS SHALL BE EQUAL LENGTH. ALL INTERNAL UNITS SHALL BE EQUAL LENGTH.
- BACKFILL SHALL BE PLACED SIMULTANEOUSLY BEHIND BOTH SIDES OF STRUCTURE KEEPING THE HEIGHT OF THE BACKFILL APPROXIMATELY THE SAME. AT NO TIME SHALL THE DIFFERENCE IN ELEVATION BE GREATER THAN 500mm.
- NO PRECAST UNIT SHALL BE PLACED UNTIL THE DEPTH OF THE EXCAVATION AND THE CHARACTER OF THE FOUNDATION HAVE BEEN APPROVED BY THE QUALITY VERIFICATION ENGINEER. CARE SHALL BE TAKEN NOT TO DISTURB THE FOUNDING SOILS.
- DESIGN SOILS BEARING CAPACITIES MUST BE VERIFIED BY THE QUALITY VERIFICATION ENGINEER ON SITE:
AT SLS = ____ kPa (TBD)
AT ULS = ____ kPa (ALONG THE JOINTS) (TBD)

SCOPE OF WORK *

- INSTALL AND CONTINUOUSLY MONITOR TEMPORARY FLOW PASSAGE SYSTEM AND MANAGE FLOW OF WATER FOR DURATION OF THE WORK.
- COMPLETE PRECONSTRUCTION SURVEY.
- REMOVE DEBRIS AND CLEAN CULVERT SURFACES.
- SUPPLY AND INSTALL RIGID BOX CULVERT AND CUT-OFF WALLS.

* NOT INTENDED TO SHOW SEQUENCE OF WORK

LIST OF ABBREVIATIONS

WP#	WORKING POINT NUMBER
EL.	ELEVATION
TYP.	TYPICAL
SHLD.	SHOULDER
DIA.	DIAMETER
STA.	STATION
W/L	WATER LEVEL
I.D.	INNER DIAMETER
O.D.	OUTTER DIAMETER

LIST OF DRAWINGS

- GENERAL ARRANGEMENT

DRAWING NOT TO BE SCALED
100mm ON ORIGINAL DRAWING

DATE	BY	DESCRIPTION	DATE
DESIGN ###	CHK ###	CODE ###	LOAD ###
DRAWN ###	CHK ###	SITE ###	DWG ##

Appendix B.

Record of Borehole Sheets



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).

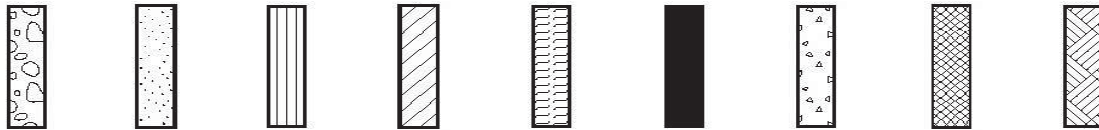
DYNAMIC CONE PENETRATION TEST (DCPT):

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 17-5

1 OF 2

METRIC

GWP# 451-98-00 LOCATION Lat: 45.303522°, Long: -75.078395° Culvert Site 27-252/C MTM z8: N 5 019 386.5 E 181 019.9 ORIGINATED BY AC
 HWY 417 BOREHOLE TYPE HSA/NQ coring COMPILED BY AC
 DATUM Geodetic DATE 22.06.2018 - 22.06.2018 CHECKED BY FG

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			
64.2											
0.0											
0.2	SILTY SAND with organics and wood fragments compact brown FILL		1	SS	10		64				
	SILTY SAND with gravel compact to dense grey-brown FILL		2	SS	35		63				
			3	SS	39		62				40 46 14 (SI+CL)
			4	SS	13						
61.1											
3.1	CLAY (CH) firm to stiff grey		5	SS	1		61				0 2 39 59
							60	3.3			
			6	SS	1			5.0			
							59	3.3			
58.4											
5.8	SILTY SAND (SM) with gravel TILL very frequent cobbles and boulders very dense grey		7	SS	100/250 mm		58				
	1 m boulder at 6.8 m		8	NQ	N/A		57				
			9	NQ	N/A		56				
55.3											
8.9	BEDROCK LIMESTONE with shale partings and silt seams fine grained fresh thinly bedded very strong		1	NQ			55				RUN #1 TCR=100% SCR=100% RQD=100%

Continued Next Page

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

DOUBLE LINE SITE 27-252C.GPJ 2012TEMPLATE(MTO).GDT 28/11/18

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 17-6

1 OF 2

METRIC

GWP# 451-98-00 LOCATION Lat: 45.303308°, Long: -75.078309° Culvert Site 27-252/C MTM z8: N 5 019 362.5 E 181 026.2 ORIGINATED BY JG
 HWY 417 BOREHOLE TYPE HSA/NQ coring COMPILED BY JG
 DATUM Geodetic DATE 25.09.2017 - 25.09.2017 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W P W W L				GR SA SI CL
								20 40 60 80 100	20 40 60					
						○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE		WATER CONTENT (%)						
65.7	WB Gravel Shoulder													
0.0	SILTY SAND with gravel dense grey		1	SS	26									
65.2	FILL													
0.5	SILTY SAND compact brown		2	SS	15									
64.5	FILL													
1.2	SILT compact grey													
64.0														
1.7	CLAY (CH) (crust) stiff brown		3	SS	11									
			4	SS	4									
62.7														
3.0	CLAY (CH) firm grey		5	SS	3									
			6	SS	1									
			7	SS	1									
58.7														
7.0	SILTY SAND (SM) with gravel TILL occasional cobbles compact to very dense grey		8	SS	12									
			9	SS	14									
			10	SS	47									
			1	NQ										

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DOUBLE LINE SITE 27-252C.GPJ 2012TEMPLATE(MTO).GDT 28/11/18

Continued Next Page

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 (%) STRAIN AT FAILURE

RUN #1
TCR=87%

RECORD OF BOREHOLE No 17-6

2 OF 2

METRIC

GWP# 451-98-00 LOCATION Lat: 45.303308°, Long: -75.078309° Culvert Site 27-252/C MTM z8: N 5 019 362.5 E 181 026.2 ORIGINATED BY JG
 HWY 417 BOREHOLE TYPE HSA/NQ coring COMPILED BY JG
 DATUM Geodetic DATE 25.09.2017 - 25.09.2017 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	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									
							20	40	60	80	100	20	40	60			
55.6	Continued From Previous Page																
10.1	BEDROCK LIMESTONE fresh very strong grey		2	NQ													
			3	NQ													
52.2																	
13.5	End of Borehole																

RUN #2
TCR=100%
SCR=100%
RQD=95%
UCS=104.5MPa

RUN #3
TCR=100%
SCR=100%
RQD=97%

RECORD OF BOREHOLE No 17-7

1 OF 2

METRIC

GWP# 451-98-00 LOCATION Lat: 45.303035°, Long: -75.078596° Culvert Site 27-252/C MTM z8: N 5 019 332.7 E 181 003.1 ORIGINATED BY JG
HWY 417 BOREHOLE TYPE HSA/NQ coring COMPILED BY JG
DATUM Geodetic DATE 25.09.2017 - 25.09.2017 CHECKED BY FG

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					
								20 40 60 80 100					
65.4	EB Gravel Shoulder												
0.0	SILTY SAND with gravel dense grey		1	SS	32								30 52 18 (SI+CL)
64.9	FILL												
0.5	SILTY SAND compact brown FILL		2	SS	15								
63.8													
1.6	CLAY (CH) (crust) firm brown		3	SS	7								0 0 44 56
62.8													
2.6	CLAY (CH) firm grey		4	SS	3								
			5	SS	1								
			6	SS	WH								0 1 28 71

DOUBLE LINE SITE 27-252C.GPJ 2012TEMPLATE(MTO).GDT 28/11/18

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

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(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 17-7

2 OF 2

METRIC

GWP# 451-98-00 LOCATION Lat: 45.303035°, Long: -75.078596° Culvert Site 27-252/C MTM z8: N 5 019 332.7 E 181 003.1 ORIGINATED BY JG
 HWY 417 BOREHOLE TYPE HSA/NQ coring COMPILED BY JG
 DATUM Geodetic DATE 25.09.2017 - 25.09.2017 CHECKED BY FG

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										W _P	W	W _L	WATER CONTENT (%)	GR	SA	SI	CL																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
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DOUBLE LINE SITE 27-252C.GPJ 2012TEMPLATE(MTO).GDT 28/11/18

RECORD OF BOREHOLE No 17-8

1 OF 2

METRIC

GWP# 451-98-00 LOCATION Lat: 45.302783°, Long: -75.078436° Culvert Site 27-252/C MTM z8: N 5 019 304.4 E 181 015.1 ORIGINATED BY KE
HWY 417 BOREHOLE TYPE HSA/NQ coring COMPILED BY AC
DATUM Geodetic DATE 20.06.2018 - 21.06.2018 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
64.0								20 40 60 80 100		W _P	W	W _L	kN/m ³	GR SA SI CL
0.0								20 40 60 80 100						
0.1	SILT some sand with organics compact brown FILL		1	SS	29									
	SILTY SAND with gravel compact grey FILL		2	SS	27									
			3	SS	28									44 44 12 (SI+CL)
			4	SS	16									
61.1														
2.9	CLAY (CH) soft to firm grey		5	SS	1									
			6	SS	WH									0 2 21 77
			7	SS	WH									
	silt layer from 7.3 m to 8.1 m													
			8	SS	WH									
55.9														
58.9	SILTY SAND (SM) with gravel TILL very loose, grey												FI	
8.1	BEDROCK LIMESTONE with shale partings fine grained with calcite nodules slightly weathered to fresh thinly bedded very strong grey		1	NQ									0	RUN #1 TCR=100% SCR=100% RQD=100%
													1	
													2	RUN #2 TCR=100% SCR=97% RQD=93%
													0	
			2	NQ									1	
													1	

Continued Next Page

+ 3, × 3: Numbers refer to
Sensitivity

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(%) STRAIN AT FAILURE



DOUBLE LINE SITE 27-252C.GPJ 2012TEMPLATE(MTO).GDT 28/11/18

RECORD OF BOREHOLE No 17-8

2 OF 2

METRIC

GWP# 451-98-00 LOCATION Lat: 45.302783°, Long: -75.078436° Culvert Site 27-252/C MTM z8: N 5 019 304.4 E 181 015.1 ORIGINATED BY KE
 HWY 417 BOREHOLE TYPE HSA/NQ coring COMPILED BY AC
 DATUM Geodetic DATE 20.06.2018 - 21.06.2018 CHECKED BY FG

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			SHEAR STRENGTH kPa					WATER CONTENT (%)					
								20 40 60 80 100	W P W W L									
	Continued From Previous Page																	
	BEDROCK LIMESTONE with shale partings fine grained with calcite nodules slightly weathered to fresh thinly bedded very strong grey						53									2	RUN #3 TCR=100% SCR=100% RQD=96%	
																		0
																		2
																		1
																		0
52.3																0		
11.7	End of Borehole Water level in well at 0.3 mbgs (elev. 63.7 m) on June 26, 2018																	

DOUBLE LINE SITE 27-252C.GPJ 2012TEMPLATE(MTO).GDT 28/11/18

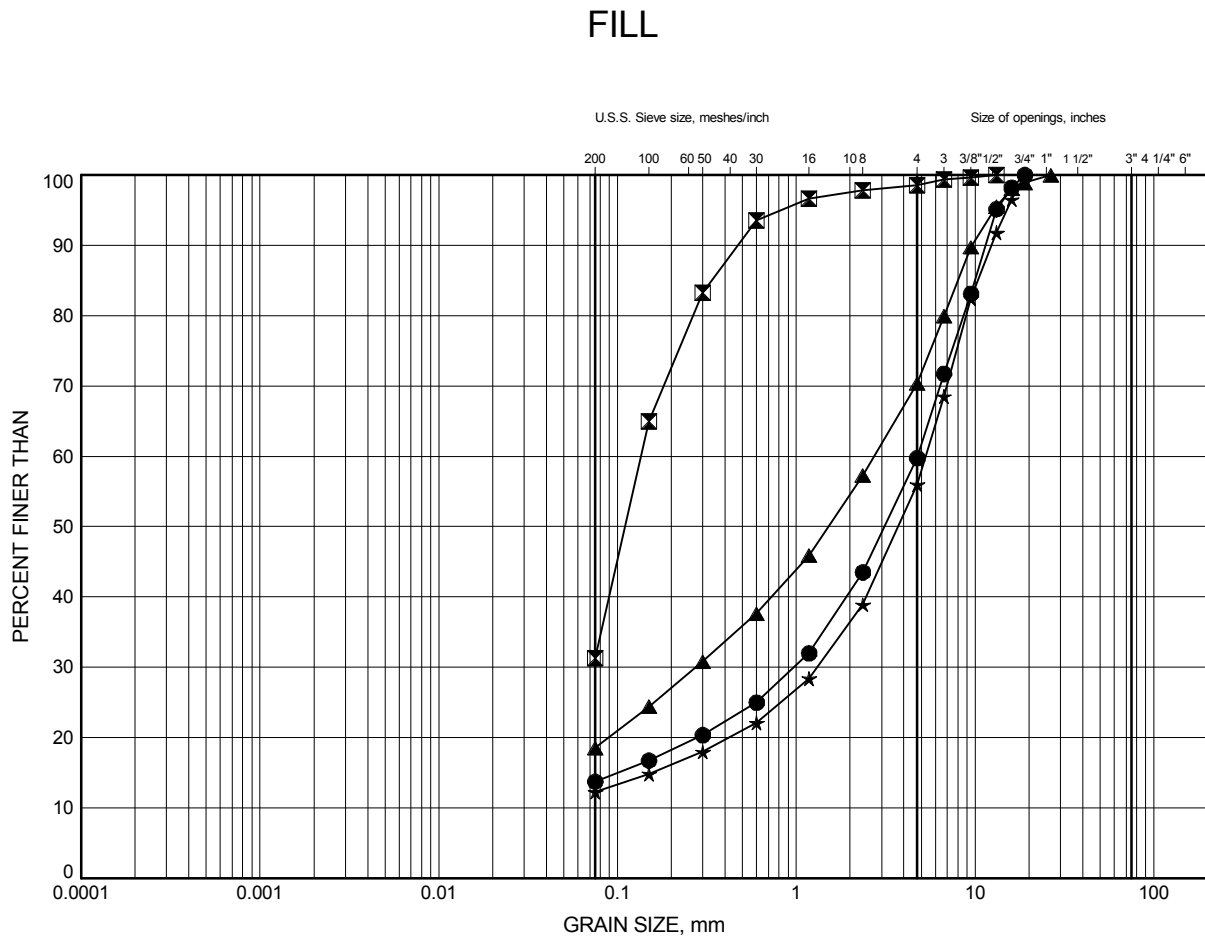
Appendix C.
Laboratory Testing

Appendix C.1
Particle Size Analysis Figures

Site 27-252/C

GRAIN SIZE DISTRIBUTION

FIGURE C1



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-5	1.8	62.4
☒	17-6	1.1	64.6
▲	17-7	0.3	65.1
★	17-8	1.8	62.2

Date November 2018
GWP# 451-98-00

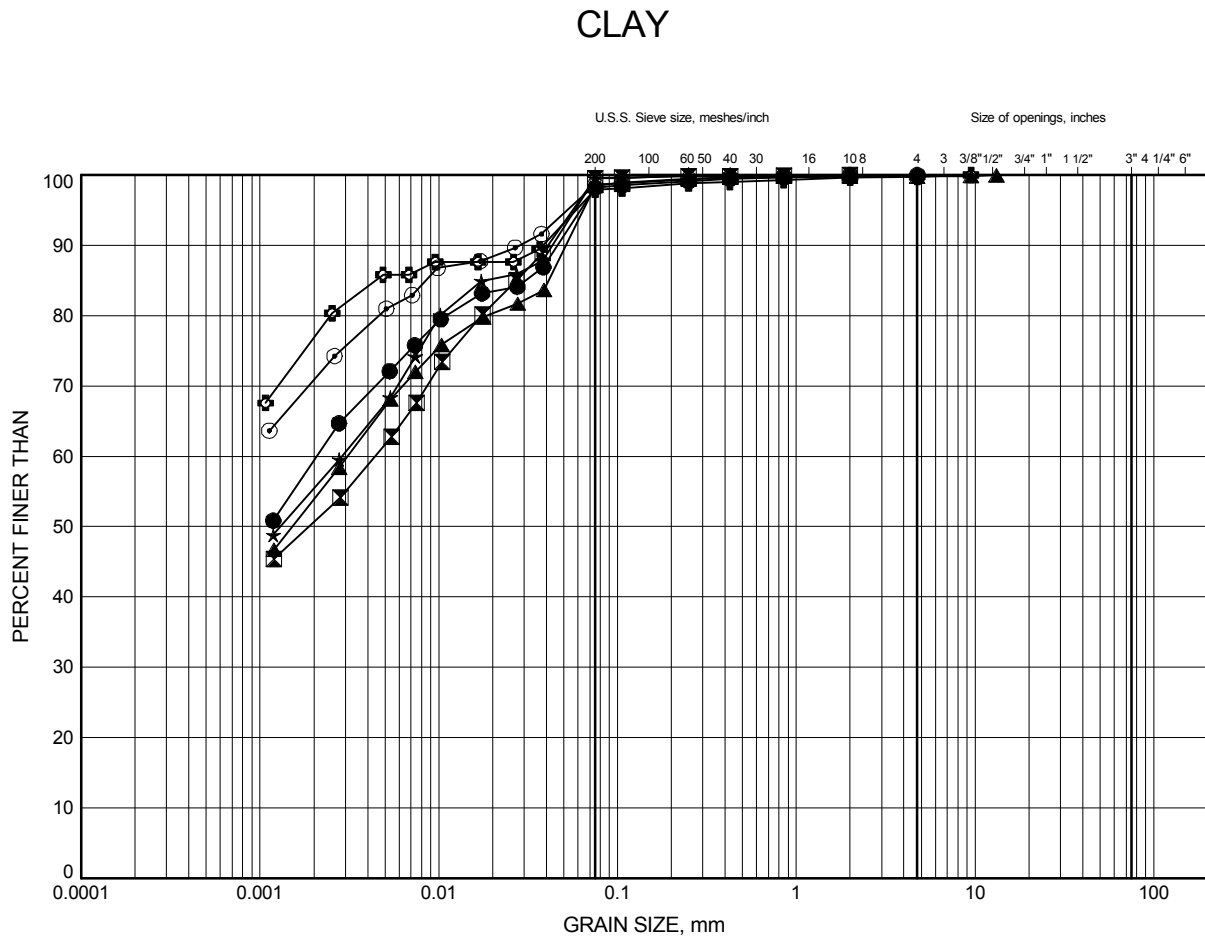


Prep'd KE
Chkd. FG

Site 27-252/C

GRAIN SIZE DISTRIBUTION

FIGURE C2



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-5	3.4	60.8
⊠	17-6	2.6	63.1
▲	17-6	4.9	60.8
★	17-7	1.8	63.6
⊙	17-7	4.9	60.5
⊕	17-8	4.9	59.1

Date November 2018

GWP# 451-98-00



Prep'd KE

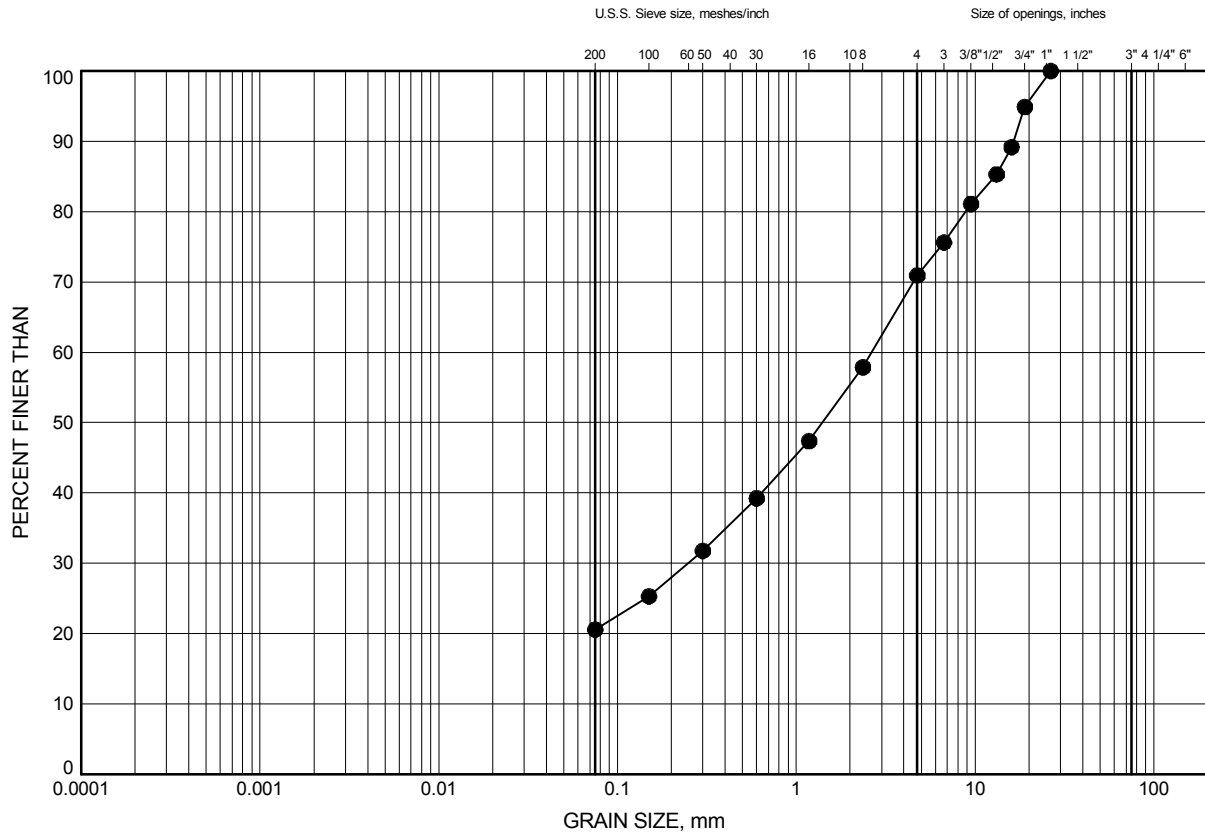
Chkd. FG

Site 27-252/C

GRAIN SIZE DISTRIBUTION

FIGURE C3

SILTY SAND WITH GRAVEL (GLACIAL TILL)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-6	8.7	57.0

Date November 2018
GWP# 451-98-00



Prep'd KE
Chkd. FG

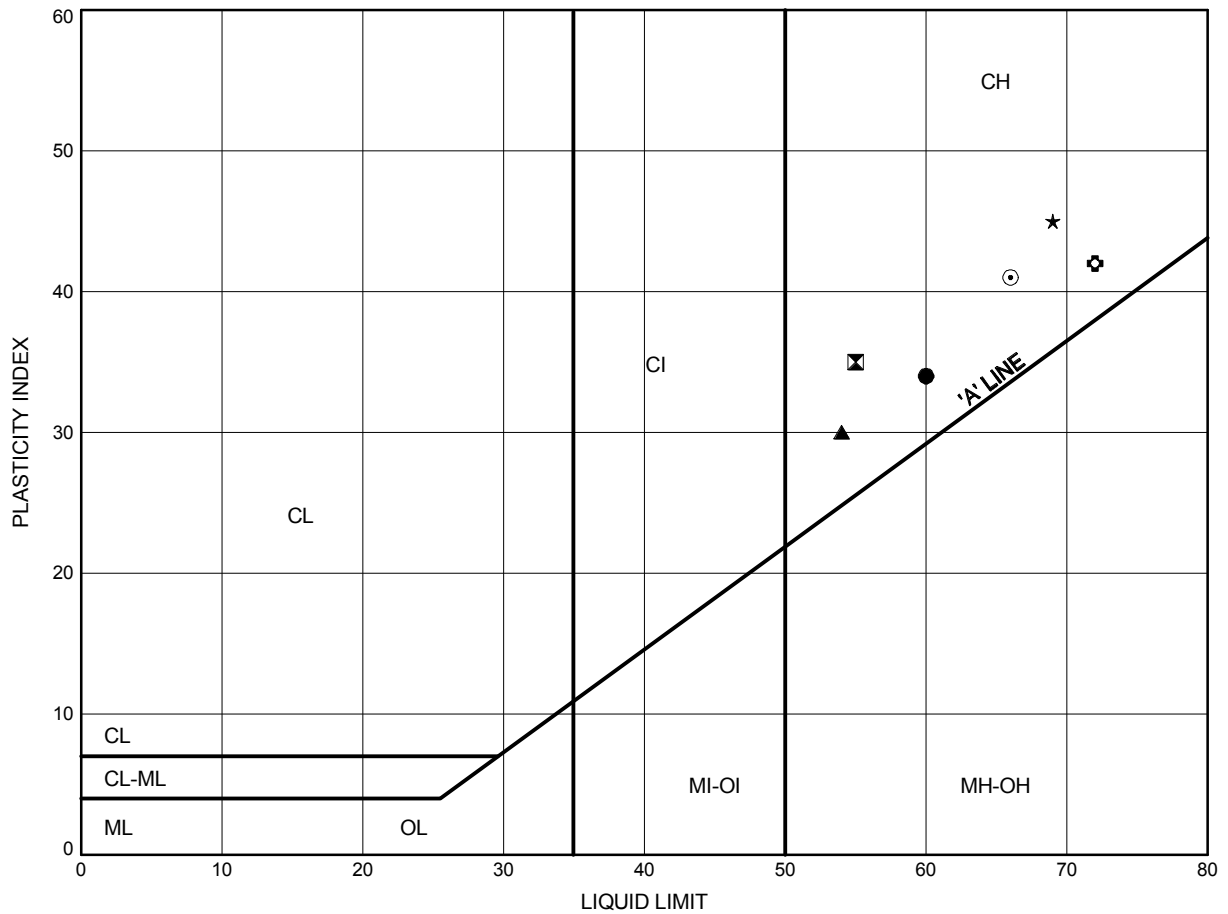
Appendix C.2
Atterberg Limits Figures

Site 27-252/C

ATTERBERG LIMITS TEST RESULTS

FIGURE C4

CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-5	3.4	60.8
⊠	17-6	2.6	63.1
▲	17-6	4.9	60.8
★	17-7	1.8	63.6
⊙	17-7	4.9	60.5
⊕	17-8	4.9	59.1

Date November 2018
GWP# 451-98-00



Prep'd KE
Chkd. FG

Appendix C.3

Rock Core Photos and Testing Results

Borehole 17-5
Run 1 to 2 (of 2)
Elevation 55.3 m to 52.3 m



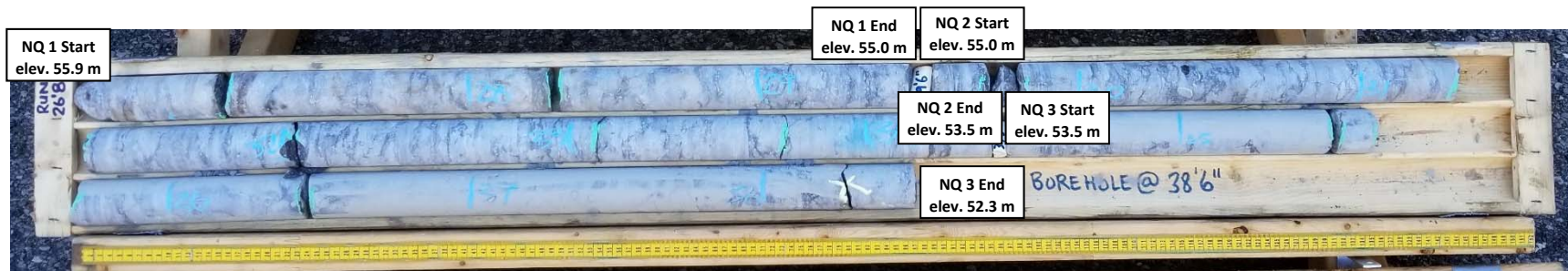
Borehole 17-6
Run 1 to 3 (of 3)
Elevation 56.5 m to 52.2 m



Borehole 17-7
Run 1 to 4 (of 4)
Elevation 57.5 m to 51.9 m



Borehole 17-8
Run 1 to 3 (of 3)
Elevation 55.9 m to 52.3 m





Stantec

Stantec Consulting Ltd
2781 Lancaster Rd, Suite 100 A&B
Ottawa, ON K1B 1A7
Tel: (613) 738-6075
Fax: (613) 722-2799

July 11, 2018
File: 122410864

Attention: Thurber Engineering Ltd., File #18310

Reference: ASTM D7012, Method C, Unconfined Compressive Strength of Intact Rock Core

The table below summarizes five (5) rock core unconfined compressive strength results.

Location	Sample Depth	Compressive Strength (MPa)	Description of Break
17-1	Run 2 @ 22'4"	143.6	Well-formed cone on one end
17-5	Run 2 @ 36'4"	138.0	Well-formed cone on one end
17-10	Run 2 @ 53'7"	98.0	Reasonably well-formed cones on both ends
17-11	Run 3 @ 51'10"	127.4	Vertical cracking through both ends
17-13	Run 2 @ 23'10"	140.4	Specimen shattered

Sincerely,

Stantec Consulting Ltd

Denis Rodriguez
Laboratory Technician
Tel: 613-738-6075
denis.rodriquez@stantec.com



Stantec

Stantec Consulting Ltd
2781 Lancaster Rd, Suite 100 A&B
Ottawa, ON K1B 1A7
Tel: (613) 738-6075
Fax: (613) 722-2799

November 6, 2017
File: 122410864

Attention: Thurber Engineering Ltd., File #18310

Reference: ASTM D7012, Method C, Unconfined Compressive Strength of Intact Rock Core

The table below summarizes six rock core unconfined compressive strength results.

Location	Sample Depth	Compressive Strength (MPa)	Description of Break
BH17-2 Run-2	35'9"	134.1	Two well-formed cones on either end
BH17-3 Run-2	33'6"	133.5	Two well-formed cones on either end
BH17-6 Run-3	41'2"	104.5	Well-formed cone on bottom, vertical cracks through top
BH17-7 Run-2	32'8"	152.7	Well-formed cone on bottom, vertical cracks through top
Bh17-14 Run-3	36'10"	105.2	Two well-formed cones on either end
BH17-15 Run-2	32'5"	107.5	No well-formed cones, cracks throughout core

Sincerely,

Stantec Consulting Ltd

Brian Prevost

Brian Prevost
Laboratory Supervisor
Tel: 613-738-6075
brian.prevost@stantec.com

Appendix C.4
Analytical Testing Results

Certificate of Analysis

Thurber Engineering Ltd.

2460 Lancaster Rd, Suite 104
Ottawa, ON K1B 4S5
Attn: Justin Gray

Client PO: 18310
Project: Site 27-252/C
Custody: 39857

Report Date: 29-Jun-2018
Order Date: 25-Jun-2018

Order #: 1826165

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

Paracel ID	Client ID
1826165-01	17-8, SS4, 7'6"-9'6"

Approved By:



Dale Robertson, BSc
Laboratory Director

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 18310

Report Date: 29-Jun-2018
Order Date: 25-Jun-2018
Project Description: Site 27-252/C

Analysis Summary Table

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	27-Jun-18	27-Jun-18
Conductivity	MOE E3138 - probe @25 °C, water ext	27-Jun-18	29-Jun-18
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	26-Jun-18	27-Jun-18
Resistivity	EPA 120.1 - probe, water extraction	27-Jun-18	27-Jun-18
Solids, %	Gravimetric, calculation	27-Jun-18	27-Jun-18

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 18310

Report Date: 29-Jun-2018

Order Date: 25-Jun-2018

Project Description: Site 27-252/C

Client ID:	17-8, SS4, 7'6"-9'6"	-	-	-
Sample Date:	06/20/2018 09:00	-	-	-
Sample ID:	1826165-01	-	-	-
MDL/Units	Soil	-	-	-

Physical Characteristics

% Solids	0.1 % by Wt.	92.2	-	-	-
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General Inorganics

Conductivity	5 uS/cm	363	-	-	-
pH	0.05 pH Units	7.89	-	-	-
Resistivity	0.10 Ohm.m	27.5	-	-	-

Anions

Chloride	5 ug/g dry	105	-	-	-
Sulphate	5 ug/g dry	89	-	-	-

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 18310

Report Date: 29-Jun-2018
Order Date: 25-Jun-2018
Project Description: Site 27-252/C

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									
Conductivity	ND	5	uS/cm						
Resistivity	ND	0.10	Ohm.m						

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 18310

Report Date: 29-Jun-2018
Order Date: 25-Jun-2018
Project Description: Site 27-252/C

Method Quality Control: Duplicate

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	265	5	ug/g dry	282			6.1	20	
Sulphate	146	5	ug/g dry	151			3.0	20	
General Inorganics									
Conductivity	293	5	uS/cm	290			1.1	6.2	
pH	7.89	0.05	pH Units	7.83			0.8	10	
Resistivity	34.1	0.10	Ohm.m	34.5			1.1	20	
Physical Characteristics									
% Solids	84.4	0.1	% by Wt.	85.3			1.0	25	

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 18310

Report Date: 29-Jun-2018
Order Date: 25-Jun-2018
Project Description: Site 27-252/C

Method Quality Control: Spike

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	374	5	ug/g	282	92.2	78-113			
Sulphate	254	5	ug/g	151	104	78-111			

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 18310

Report Date: 29-Jun-2018
Order Date: 25-Jun-2018
Project Description: Site 27-252/C

Qualifier Notes:

Login Qualifiers :

Received at temperature > 25C
Applies to samples: 17-8, SS4, 7'6"-9'6"

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.

Subcontracted Analysis

Thurber Engineering Ltd.
2460 Lancaster Rd, Suite 104
Ottawa, ON K1B 4S5
Attn: Justin Gray

Tel: (613) 408-6795
Fax: (613) 247-2185

Paracel Report No **1826165**
Client Project(s): **Site 27-252/C**
Client PO: **18310**
Reference: **Standing Offer**
CoC Number: **39857**

Order Date: 25-Jun-18
Report Date: 05-Jul-18

Sample(s) from this project were subcontracted for the listed parameters. A copy of the subcontractor's report is attached

Paracel ID	Client ID	Analysis
1826165-01	17-8, SS4, 7'6"-9'6"	Sulphide, solid

**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - K0L 2H0
Phone: 705-652-2000 FAX: 705-652-6365

Paracel Laboratories

Attn : Dale Robertson

300-2319 St.Laurent Blvd.
Ottawa, ON
K1G 4K6,

Phone: 613-731-9577
Fax:613-731-9064

05-July-2018

Date Rec. : 27 June 2018
LR Report: CA12932-JUN18
Reference: Project#:1826165

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

Sample ID	Sample Date & Time	Sulphide %
1: Analysis Start Date		05-Jul-18
2: Analysis Start Time		10:43
3: Analysis Completed Date		05-Jul-18
4: Analysis Completed Time		13:06
5: QC - Blank		<0.02
6: QC - STD % Recovery		85%
7: QC - DUP % RPD		11%
8: RL		0.02
9: 17-8, SS4, 7'6"-9'6"	20-Jun-18	0.14

RL - SGS Reporting Limit

Kimberley Didsbury
Project Specialist
Environmental Services, Analytical

Appendix D.

Site Photographs



Photo 1. Looking north upstream at culvert inlet



Photo 2. Looking south along Highway 11.



Photo 3. Looking south downstream at culvert outlet



Photo 4. Looking west on eastbound Highway 417

Appendix E.

Foundation Comparison

COMPARISON OF ALTERNATIVE FOUNDATION TYPES

Type	Closed Box Culvert	Circular Pipe Culvert (Trenchless Installation)	Open Bottom Culvert	Precast Concrete Slab on Sheet Pile Culvert
Advantages	<p>Relatively expedient installation if precast units are used.</p> <p>Smaller magnitude of settlement than open footing culvert due to lower bearing stress on subgrade.</p> <p>Minimized differential settlement between culvert and approach fills.</p>	<p>Can tolerate larger magnitude of settlement than concrete (rigid frame) culverts.</p> <p>Avoids open cut.</p> <p>Allows traffic to be maintained throughout construction.</p>	<p>Relatively expedient installation if precast units are used.</p> <p>Possibility to maintain work zone outside of existing waterway.</p>	<p>Potentially minimized volume of excavation and roadway protection.</p> <p>Maintains water flow throughout construction and minimizes potential for disturbance of streambed.</p> <p>Allows for winter construction.</p>
Disadvantages	<p>Requires large excavation and roadway protection.</p> <p>Requires compacted granular pad on subgrade.</p> <p>Requires installation of a temporary by-pass culvert to maintain existing creek alignment.</p>	<p>Requires construction of entry and exit pits and access to toes of slope.</p> <p>Requires specialised construction equipment.</p> <p>Feasibility also depends on flow capacity and other hydraulic properties. May need a second pipe.</p>	<p>Requires deeper excavation increasing excavation volume and dewatering efforts.</p> <p>Founding subgrade could provide lower geotechnical resistances.</p> <p>Potential for post construction settlement.</p>	<p>Quantity and cost of sheet piles.</p> <p>Unconventional design for under Highway 417.</p> <p>Differential settlement will occur between non-yielding culvert and approach fills.</p>
Risks/ Consequences	<p>Groundwater control requires enclosed excavation.</p>	<p>Groundwater control may require enclosed excavation.</p> <p>Feasibility limited due to available cover.</p>	<p>Increased risk of basal instability of footing excavation due to depth of excavation below water table.</p>	<p>Possibility of encountering obstructions and inadequate lateral support due to shallow refusal.</p>
Relative Cost	Low	High	Medium	Medium to High
Recommendation	Recommended	Not Feasible	Generally Feasible	High Risk / Not Feasible

Appendix F.

GSC Seismic Hazard Calculation

2015 National Building Code Seismic Hazard Calculation

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

July 31, 2018

Site: 45.3031 N, 75.0784 W User File Reference: HWY 417 Casselman Interchange, ON

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)
0.622	0.711	0.584	0.438	0.304	0.144	0.066	0.017	0.0059	0.372	0.250

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)	0.054	0.200	0.342
Sa(0.1)	0.073	0.244	0.403
Sa(0.2)	0.064	0.205	0.334
Sa(0.3)	0.050	0.154	0.250
Sa(0.5)	0.035	0.106	0.172
Sa(1.0)	0.017	0.051	0.082
Sa(2.0)	0.0067	0.023	0.037
Sa(5.0)	0.0014	0.0052	0.0092
Sa(10.0)	0.0006	0.0020	0.0034
PGA	0.039	0.131	0.215
PGV	0.024	0.082	0.137

References

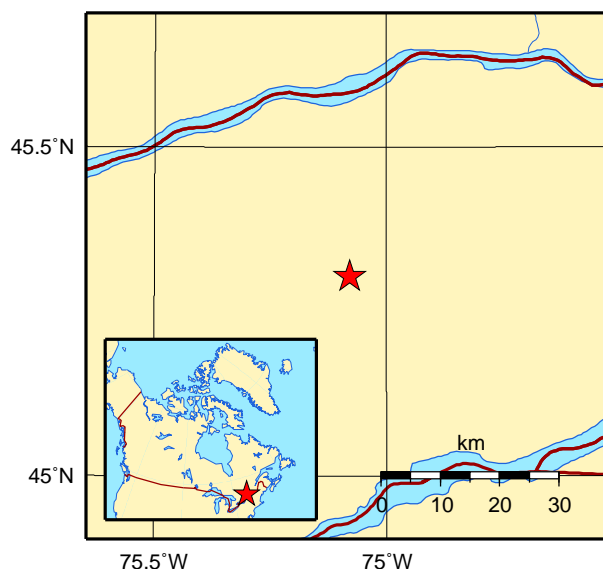
National Building Code of Canada 2015 NRCC no. 56190;
Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

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

Appendix G.

**List of Special Provisions and OPSS Documents Referenced in this Report
Suggested Wording for NSSPs**

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

OPSS.PROV 206	Construction Specification for Grading
OPSS.PROV 501	Construction Specification for Compacting
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts in Open Cuts
NSSP FOUN0003	Dewatering Structure Excavations
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 1205	Material Specification for Clay Seal
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS 902	Construction Specification for Excavating and Backfilling Structures
OPSS.PROV 1010	Material Specification for Aggregates Base, Subbase, Select Subgrade, and Backfill Material
OPSS 1860	Material Specification for Geotextile
OPSD 208.010	Benching of Earth Slopes
OPSD 3090.101	Foundation Frost Penetration Depths for Southern Ontario
OPSD 803.010	Backfill and Cover for Concrete Culverts with Span Less than or Equal to 3.0 m
OPSS.PROV 517	Construction Specification for Dewatering
OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
SP 517F01	Design Storm Return Period and Preconstruction Survey
SP 109S12	QVE, Backfilling, Compaction, and Certificate of Conformance

2. Suggested text for an NSSP on “Vibration”

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

3. Suggested text for an NSSP on “Protection of Sensitive Foundation Soils”

The Contractor is advised that the native clay that will be exposed at the subgrade following removal of existing culvert is moisture sensitive and may become disturbed or otherwise negatively impacted if subjected to construction or personnel traffic, freeze-thaw actions, ingress or ponding water. The Contractor shall be responsible for implementing adequate groundwater control measures and to minimize construction and personnel traffic on the founding subgrade.

4. Suggested text for an NSSP on “Obstructions”

Installation of roadway protection system and coffer dams will encounter obstructions such as cobbles and boulders in the native soils. Such obstructions may impede the work from reaching bedrock. The Contractor shall be prepared to remove, drill through and/or penetrate these obstructions.

5. Suggested text for an NSSP on “Dewatering”

The excavation will extend below the groundwater level and could lead to instability and sloughing of the sides of the excavation and heaving of the base, accompanied by loss in geotechnical resistance of the soils. Appropriate means of dewatering must be implemented to depress the groundwater level sufficiently far below the base of the excavation to prevent any instability, sloughing, or heaving and so as to preserve the stability of the excavation and to allow the culvert subgrade preparation work to proceed in the dry. Temporary dewatering measures will be required to remain operational during construction until the culvert is installed and backfilled.

6. Recommended Wording for an NSSP on “Dewatering Structure Excavations”

Subsection 902.04.01 Design Requirements of NSSP FOUN0003 is amended by the addition of the following:

The design Engineer and design-checking Engineer of the dewatering system shall have a minimum of 5 years of experience in designing systems of similar nature and scope to the required work.