



**THURBER** ENGINEERING LTD.

**FINAL  
FOUNDATION INVESTIGATION AND DESIGN REPORT  
CULVERT SITE 27-363/C  
HIGHWAY 417, CASSELMAN ON**

**G.W.P. 451-98-00**

Geocres No.: 31G-272

Report to:

**Ainley Group**

Latitude: 45.301524  
Longitude: -75.081411

November 2018  
Thurber File: 18310

## TABLE OF CONTENTS

### PART 1. FACTUAL INFORMATION

1	INTRODUCTION .....	1
2	SITE DESCRIPTION .....	1
3	SITE INVESTIGATION AND FIELD TESTING.....	2
4	LABORATORY TESTING.....	3
5	GENERAL DESCRIPTION OF SUBSURFACE CONDITIONS.....	3
5.1	Embankment Fill .....	3
5.1.1	Asphalt .....	3
5.1.2	Fill: Gravel with Silt and Sand to Silty Gravel with Sand .....	3
5.1.3	Fill: Silty Sand with Gravel.....	4
5.2	Silty Sand to Sandy Silt (Glacial Till).....	4
5.3	Bedrock.....	5
5.4	Groundwater .....	5
5.5	Analytical Testing .....	6
6	MISCELLANEOUS .....	7

### PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS

7	INTRODUCTION .....	8
7.1	Proposed Structure .....	9
7.2	Applicable Codes and Design Considerations.....	9
8	SEISMIC CONSIDERATIONS.....	9
8.1	Spectral and Peak Acceleration Hazard Values .....	9
8.2	CHBDC Seismic Site Classification .....	9
8.3	Seismic Liquefaction .....	9
9	DESIGN OPTIONS.....	10
9.1	Culvert Type and Foundation Alternatives.....	10
9.2	Construction Methodology Alternative .....	10
9.3	Recommended Approach for the Culvert Replacement .....	11
10	FOUNDATIONS DESIGN RECOMMENDATIONS .....	11
10.1	Culvert Foundation Bearing Resistances.....	12
10.2	Subgrade Preparation, Bedding and Backfilling .....	12

10.3	Frost Depth .....	13
10.4	Backfill and Earth Pressure.....	13
10.4.1	Static Lateral Earth Pressure Coefficients.....	13
10.4.2	Combined Static and Seismic Lateral Earth Pressure Parameters .....	15
10.5	Embankment Design and Reinstatement .....	16
10.5.1	Temporary Embankment Widening .....	16
10.5.2	Embankment Reconstruction .....	17
10.6	Cement Type and Corrosion Potential.....	17
11	CONSTRUCTION CONSIDERATIONS .....	17
11.1	Excavation .....	17
11.2	Temporary Protection Systems.....	18
11.3	Dewatering.....	18
11.4	Scour Protection and Erosion Control.....	19
12	CONSTRUCTION CONCERNS .....	20
13	CLOSURE .....	20

## **APPENDICES**

Appendix A.	Borehole Location Plan and Stratigraphic Drawings
Appendix B.	Record of Borehole Sheets
Appendix C.	Laboratory Testing
Appendix D.	Site Photographs
Appendix E.	Foundation Comparison
Appendix F.	GeoStudio Slope Stability Output GSC Seismic Hazard Calculation
Appendix G.	List of Special Provisions and OPSS Documents Referenced in this Report Suggested Wording for NSSPs

**FINAL  
FOUNDATION INVESTIGATION AND DESIGN REPORT  
CULVERT SITE 27-363/C  
HIGHWAY 417, CASSELMAN ON**

**G.W.P. 451-98-00  
Geocres No.: 31G-272**

**PART 1. FACTUAL INFORMATION**

**1 INTRODUCTION**

This section of the report presents the factual findings obtained from a foundation investigation completed for Culvert 27-363/C beneath at the W-N/S and N-E ramps of the Highway 417/County Road 7 Interchange. The culvert is located approximately 150 m west of County Road 7 within the Township of Cambridge. Thurber Engineering Limited (Thurber) carried out the investigation as a sub-consultant to Ainley Graham & Associates Limited (Ainley) under Agreement 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 throughout the 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 59 m long with a generally northeast to southwest alignment. The flow through the culvert is to the southwest.

At the location of the culvert, the W-N/S ramp is a 4.8 m wide single-lane ramp with a 3.0 m wide paved outside shoulder and the N-E ramp is a 4.8 m wide single-lane ramp with a 3.0 m wide paved inside shoulder. The ramp embankment fill heights are approximately 2.2 m and 1.8 m above the culvert with the road surface at approximate elevations of 65.8 m and 66.3 m for the N -E and W-N/S ramps, respectively. The existing embankment side slopes are inclined flatter than 2H:1V. The land adjacent to the ramp is mainly undeveloped fields of grass. No signs of erosion or slope instability were noted on the existing highway embankments 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 some signs of corrosion. Traffic volumes are understood to be 3029 AADT (2014) and 1306 AADT (2014) for the W-N/S and N -E ramps, respectively.

Select photographs of the existing conditions near the culvert are included in Appendix D for reference.

**FINAL**

### 3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing program was carried out on September 14<sup>th</sup>, 2017 for the on-road investigation and between June 19<sup>th</sup> and 27<sup>th</sup>, 2018 for the off-road investigation. Drilling consisted of advancing four boreholes identified as 17-13 through 17-16. The drilling was performed using a track mounted CME 55 drill rig for off-road Boreholes 17-13 and 17-16 and a truck mounted CME 55 drill rig for on-road Boreholes 17-14 and 17-15. 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 are provided in Appendix B and 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**

<b>Borehole No.</b>	<b>Drilled Location</b>	<b>Northing (m)</b>	<b>Easting (m)</b>	<b>Ground Surface Elevation (m)</b>	<b>Termination Depth (m)</b>
17-13	Near Culvert inlet	5 019 182.7	180 806.4	63.1	8.8
17-14	N-E ramp shoulder	5 019 174.2	180 793.5	65.8	12.9
17-15	W-N/S ramp shoulder	5 019 163.1	180 763.3	66.3	12.9
17-16	Near Culvert outlet	5 019 145.6	180 761.0	63.0	6.3

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). 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 17-13 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 17-13, 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 determination of natural moisture content. 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 the Boreholes 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 provided 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 glacial till. Bedrock was encountered within the depth of investigation in Boreholes 17-13, 17-14, and 17-15.

##### **5.1 Embankment Fill**

###### **5.1.1 Asphalt**

Boreholes 17-14 and 17-15 were drilled through the existing W-N/S and N-E ramps, respectively and encountered a layer of asphalt at the surface with a thickness of 100 mm.

###### **5.1.2 Fill: Gravel with Silt and Sand to Silty Gravel with Sand**

Below the surficial asphalt in Boreholes 17-14 and 17-15 and at surface in Borehole 17-13 was a layer of fill consisting of gravel with varying amounts of silt and sand. Occasional to frequent cobbles and boulders were observed in the fill in Borehole 17-13. The underside of this fill ranged from 0.6 to 1.4 m below the existing roadway surface (elev. 64.9 to 65.2 m) in Boreholes 17-14 and 17-15, and 2.1 m below ground surface (elev. 61.0 m) in Borehole 17-13.

The SPT 'N' values ranged from 8 to 37 in the layer, indicating a relative density of loose to dense. The moisture content for the samples tested ranged from 3% to 15%.

The results of grain size analyses conducted on two samples of the gravel fill are summarized in Table 5-1 and illustrated on Figure C1 in Appendix C.

**Table 5-1 Gradation Results for Gravel Fill**

Soil Particle	Percentage (%)
Gravel	39 – 45
Sand	28 – 43
Silt	12 – 33
Clay	

### 5.1.3 Fill: Silty Sand with Gravel

A layer of silty sand with varying amounts of gravel was encountered below the gravel fill in Boreholes 17-14 and 17-15 and at surface in Borehole 17-16. The layer has a thickness ranging from 1.5 to 4.3 m, extending to elevations ranging from 60.9 to 61.5 m.

The SPT 'N' values ranged from 11 to 27, indicating a compact relative density. The moisture content for the samples ranged from 3% to 15%. The results of grain size analyses conducted on four samples from this layer are summarized in Table 5-2 and illustrated on Figure C1 in Appendix C.

**Table 5-2 Gradation Results for Silty Sand to Silty Sand with Gravel Fill**

Soil Particle	Percentage (%)
Gravel	0 – 33
Sand	44 – 77
Silt	18 – 26
Clay	

## 5.2 Silty Sand to Sandy Silt (Glacial Till)

Below the fill materials in all boreholes was a deposit of glacial till consisting of a heterogenous mixture of silty sand to sandy silt with varying amounts of gravel. It should be noted that the lower 1.2 m of the glacial till in Borehole 17-15 consisted of primarily gravel with some sand and silt. Frequent cobbles and boulders were encountered in Borehole 17-13. Borehole 17-16 was terminated within the glacial till at a final depth of 6.3 m below the existing ground surface (elev. 56.7 m). The thickness of this layer in Boreholes 17-13 to 17-15 ranged from 3.2 to 4.2 m with base elevations ranging from 56.7 to 57.8 m.

The SPT 'N' values ranged from 6 blows per 300 mm of penetration to 100 blows for 125 mm of penetration, indicating a relative density of loose to very dense.

The moisture content for the samples tested ranged from 5% to 16%. The results of grain size analyses conducted on six samples of the glacial till are summarized in Table 5-3 and illustrated in Figure C2 in Appendix C.

**Table 5-3 Gradation Results for Glacial Till**

Soil Particle	Percentage (%)	
Gravel	15 – 35	
Sand	31 – 46	
Silt	35 – 40	24 – 33
Clay	7 – 10	

Atterberg Limits testing conducted on three samples of this material indicated a non-plastic silt (ML) material.

Glacial till inherently contains cobbles and boulders.

### 5.3 Bedrock

Bedrock was proven by coring in Boreholes 17-13 to 17-15, inclusive. 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)
17-13	5.3	57.8
17-14	9.1	56.7
17-15	9.0	57.3

The bedrock encountered within Boreholes 17-13 through 17-15 consisted of slightly weathered to fresh limestone with black shale partings. The total core recovery (TCR) ranged from 81% to 100%, the solid core recovery (SCR) ranged from 77% to 100% with one value of 29%, and the rock quality designation (RQD) ranged from 62% to 100% with one value of 0%. Based on the RQD values, the bedrock is classified as very poor to excellent quality but is 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 140 MPa, indicating the intact limestone bedrock to be very strong. Photographs of the bedrock core are provided in Appendix C.

### 5.4 Groundwater

The groundwater level measured in the standpipe piezometer in Borehole 17-13 was recorded at a depth of 0.8 m (elev. 62.3 m) on August 3, 2018.

The water level in Borehole 17-16 was observed at 5.5 m below ground surface (elev. 57.5 m) during drilling. It is likely that this groundwater level has been affected by drilling operations.



The water level of the Leo Denis Municipal Drain was measured to be at an elevation of 61.6 m on June 20, 2018. It is expected that the groundwater level will likely reflect the water level in the creek.

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.

## **5.5 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 analyses 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 (%)
17-13 (SS3)	1.5 – 2.1	87	7.9	1,710	583	227	0.19

## 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-12 shoulder closures for the 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 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.

Allison Chow, B.A.Sc.  
Geotechnical Engineer-in-Training



Dr. Fred Griffiths, P.Eng.  
Senior Associate  
Senior Geotechnical Engineer



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

FINAL

**FINAL**  
**FOUNDATION INVESTIGATION AND DESIGN REPORT**  
**CULVERT SITE 27-363/C**  
**HIGHWAY 417, CASSELMAN ON**

**G.W.P. 451-98-00**  
**Geocres No.: 31G-272**

**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 Site 27-363/C crossing the W-N/S and N-E Ramps of Highway 417 and 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 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 noted to have been constructed in 1971. The culvert is reported to be 3.4 m wide by 2.2 m high and approximately 59 m long with a generally northeast to southwest alignment. The flow through the culvert is to the southwest. The water level of the Leo Denis Municipal Drain was measured to be at an elevation of 61.6 m on June 20, 2018.

The ramp embankment fill heights are approximately 2.2 m and 1.8 m above the culvert with the road surface at approximate elevations of 65.8 m and 66.3 m for the N-E and W-N/S ramps, respectively. The existing embankment side slopes are inclined flatter than 2H: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.

**FINAL**

## **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 58.6 m long concrete culvert with an external width of 4.0 m and height of 3.0 m. Cut-off walls are proposed for the new culvert. The culvert invert is expected to be at approximately elevation 61.0 m and will be covered with approximately 0.4 m of substrate.

## **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 ( $\Psi$ ) 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 D in accordance with Section 4.4.3.2 of the CHBDC (S6-14).

## **8.3 Seismic Liquefaction**

A liquefaction assessment for the non-cohesive soils at the site was completed using Table C4.4 of the CHBDC Commentary (S6-14). Given the presence of glacial till beneath

the proposed culvert, there is a very low potential for the founding soils to liquefy during a 1 in 2475 year seismic event.

## **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.
- Closed Bottom Culvert (Box)  
A precast segmental box culvert placed with 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.
- Open Bottom Culvert (Box, Arch)  
Open bottom culverts are considered feasible for this site from a foundation engineering perspective but would require greater excavation and dewatering efforts during construction to place the foundation in the dry.
- Steel Sheet Pile Walls with Precast Concrete Slab  
A sheet pile wall supporting precast concrete slabs is not recommended at this site due to the shallow depth to refusal and the resulting low lateral resistance that would be available.

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 Ramp Closure  
Installation of a new culvert using open cut techniques and a full closure for the W-N/S and N-E ramps 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 of the contract, thus the ramp closures would be separate set-ups.
- Open Cut with Staged Temporary Protection System  
The width of the existing W-N/S ramp is a 4.8 m with a 3.0 m wide paved outside shoulder and the N-E ramp is a 4.8 m wide single-lane ramp with a 3.0 m wide paved

inside shoulder. The existing side slopes are relatively flat. A three-stage construction scenario allowing one lane of traffic on each ramp throughout would require widening the top of the embankment by approximately 6.2 m at the crest on the inlet side (Ramp N-E) with a grade raise of as much as 0.8 m and approximately 4.1 m at the crest on the outlet side (Ramp W-N/S) with a grade raise of as much as 1.0 m. The grade raise would taper down to intersect the existing embankment slope. The site is underlain by a glacial till, thus the widening would generate less than 10 mm of settlement beneath the new crest of the slope. The temporary widening should be removed upon completion of the culvert replacement. It is noted that a temporary protection system will be required to separate the three stages of construction.

- 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 single lane temporary modular bridges 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. 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.

- Trenchless Techniques

Tunneling would have the advantage of minimum disruption to traffic and would avoid a large excavation through the existing highway embankments. However this site will involve installation of a relatively large diameter pipe by trenchless method and there is insufficient cover above the replacement culvert (less than one culvert diameter) and therefore a trenchless culvert installation is not recommended for 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 box culvert using ramp closures is recommended. If traffic flow must be maintained a staged open cut technique is recommended for a new closed box culvert. Temporary protection systems (TPS) and a temporary embankment widening would be needed to facilitate construction.

## **10 FOUNDATIONS 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 glacial till 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 loose to compact glacial till 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 61.0 m and a 300 mm thick base slab, the geotechnical resistance is as follows.

- Factored Geotechnical Resistance at ULS 230 kPa
- Factored Geotechnical Resistance at SLS or 125 kPa

The factored geotechnical resistances include the following factors:

- Consequence factor ( $\Psi$ ) 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 observed creek water 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 till 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 OPSS.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 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  $\mu\text{m}$  (OPSS 1860) installed beneath the Granular layer.

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 OPSS Select Subgrade Material or better and 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. However, frost taper treatment, if required, should be as per OPSD 803.010 and as directed within the Pavement Design Memo.

### **10.4 Backfill and Earth Pressure**

Lateral earth pressures parameters provided in Table 10-1 and 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)  
 $\gamma$  = 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 D 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.

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

where:

$\sigma_h$	=	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)
$\gamma$	=	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

### 10.5.1 Temporary Embankment Widening

As described in Section 9.2 above, a temporary embankment widening is being considered to allow traffic flow during a staged approach to culvert replacement. The top of the embankment would be widened by approximately 6.2 m at the crest on the inlet side (Ramp N-E) with a grade raise of as much as 1.0 m and approximately 4.1 m at the crest on the outlet side (Ramp W-N/S) with a grade raise of as much as 1.0 m. Given the limited thickness, it is recommended that OPSS Granular B Type I be utilized as the temporary fill to present a more uniform surface to the pavement subbase. The grade raise would taper down no steeper than 2H:1V to intersect the existing embankment slope. The existing slope should be regraded as needed to be no steeper than 2H:1V.

The site is underlain by a glacial till, thus the proposed widening would generate less than 10 mm settlement beneath the new fill placed for temporary embankment widening.

The slope stability of the temporary embankment has been assessed using GeoStudio 2018 Slope/W software for limit equilibrium analysis. A traffic surcharge load as per Section 6.12.5 of the CHBDC was used in the analysis.

The GeoStudio 2018 Slope/W results for the stability assessment of the temporary embankment widening are shown in Appendix F. The factor of safety meets the target value of 1.5 under static conditions for both the inlet and outlet sides. The factor of safety for the temporary embankment widening meets the target value of 1.1 under seismic conditions on the outlet side. The factor of safety for the temporary condition on the inlet side is marginally deficient at 1.0 however it is noted that should the design seismic event occur during the limited duration of the temporary embankment, the embankment deformation that may occur on the inlet side would be readily repairable. The existing inlet embankment regraded to be no steeper than 2H:1V meets the target value of 1.1 under seismic conditions.

The temporary widening should be removed upon completion of the culvert replacement.

### 10.5.2 Embankment Reconstruction

Embankment reconstruction after culvert replacement should be carried out in accordance with OPSS.PROV 206. The embankment should be reinstated with side slopes of 2H:1V (or flatter) if constructed using Select Subgrade Material (SSM) or Granular B Type I. The fill should be placed and compacted in accordance with OPSS.PROV 501

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

Provided 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 permanent grade raise is anticipated along the ramps and therefore negligible settlement of the underlying soils 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 5.5 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. The native soils below the groundwater level are also classified as Type 3 soils provided dewatering is implemented.

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 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 fill and glacial till.

The protection system should be installed at a sufficient distance away from the new culvert to limit the disturbance to esubgrade 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 coefficient for the existing native till foundation soils are given below for a vertical wall with a horizontal backslope:

### GLACIAL TILL - Silty Sand / Sandy Silt

$\gamma$	=	19.5 kN/m <sup>3</sup>	(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 "250 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 at the time of the proposed work should be taken as the drain 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. It is anticipated that Sheet Pile cofferdams will be difficult to install and may not be water tight. Therefore, it is recommended to pump from within sand bag 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 low 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:

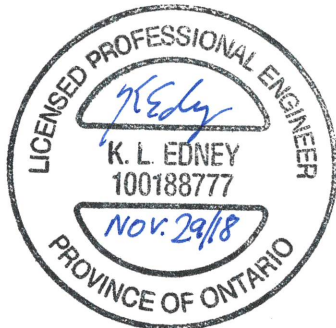
- Disturbance of the soil subgrade. The foundation will consist of silty soils. The moisture sensitive subgrade conditions may become disturbed if subjected to construction traffic. Site and subgrade drainage will be critical to maintain subgrade conditions.
- Cobbles and Boulders may be encountered in the existing glacial till and 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. The dewatering scheme will be critical for culvert construction at this site.
- The Contractor's selection of construction equipment and methodology must include assessment of the capability of the existing embankment to support the proposed construction equipment and any temporary structure fill (i.e., as a pad for crane support).

The successful performance of the culvert will depend largely upon good workmanship and quality control during construction. Subgrade examination and field density testing should be carried out by qualified geotechnical personal during construction 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.

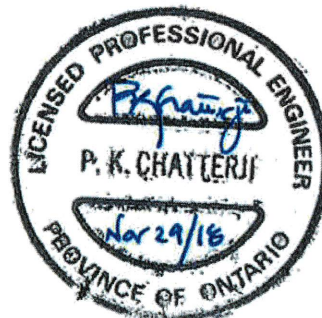
Thurber Engineering Ltd.  
Report Prepared By:



Katya Edney, P.Eng.  
Geotechnical Engineer



Dr. Fred Griffiths, P.Eng.  
Senior Associate  
Senior Geotechnical Engineer



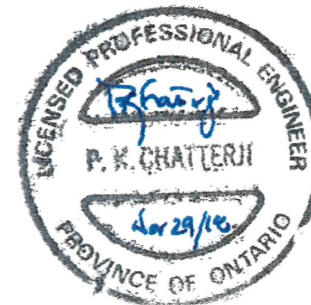
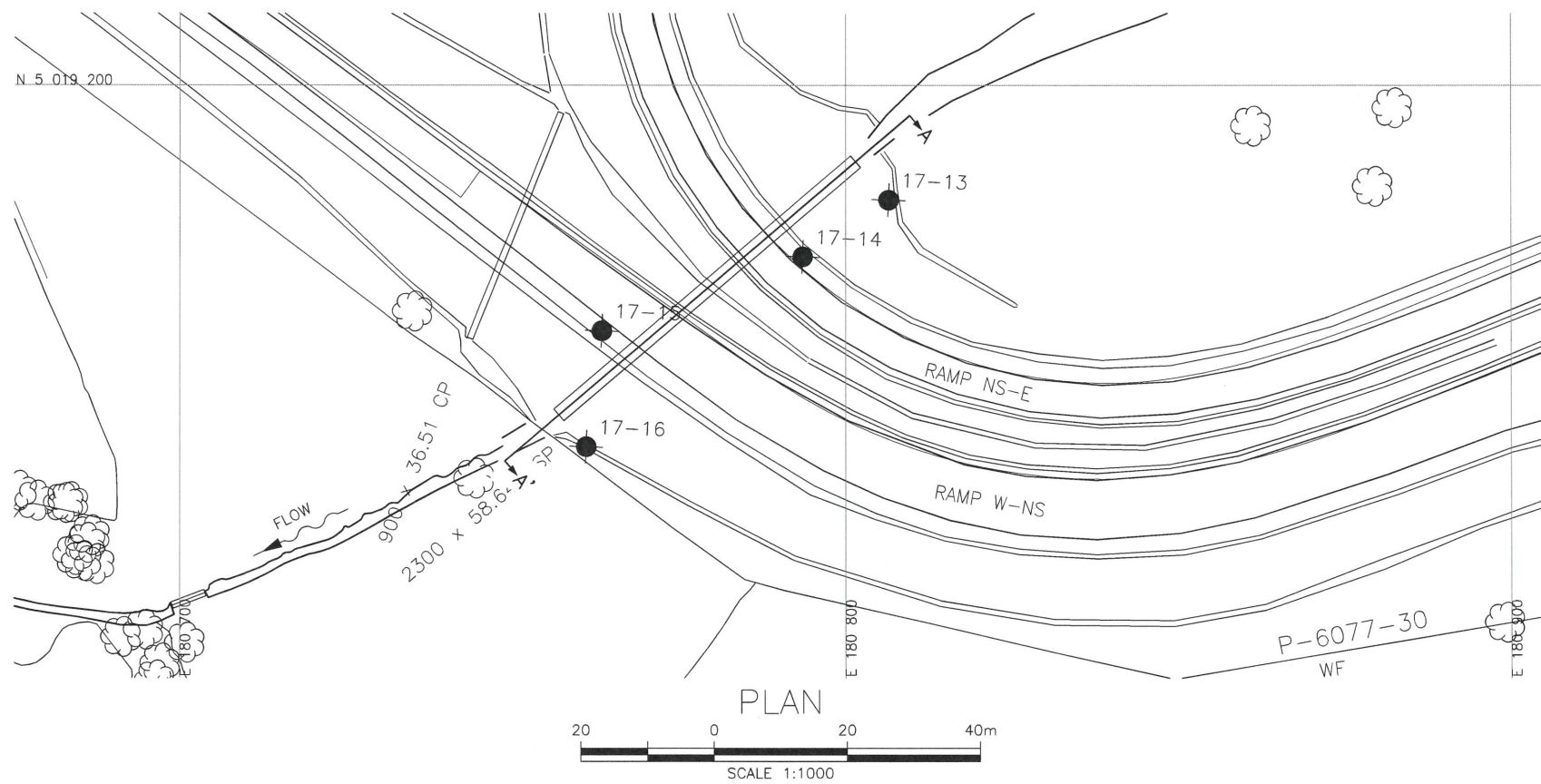
Dr. P.K. Chatterji, P.Eng.  
Review Principal,  
Senior Geotechnical Engineer

FINAL



**Appendix A.**

**Borehole Location Plan and Stratigraphic Drawings**



CONT No  
GWP No 451-98-00

HIGHWAY 417  
CULVERT 27-363/C  
REPLACEMENT  
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET



KEYPLAN

LEGEND

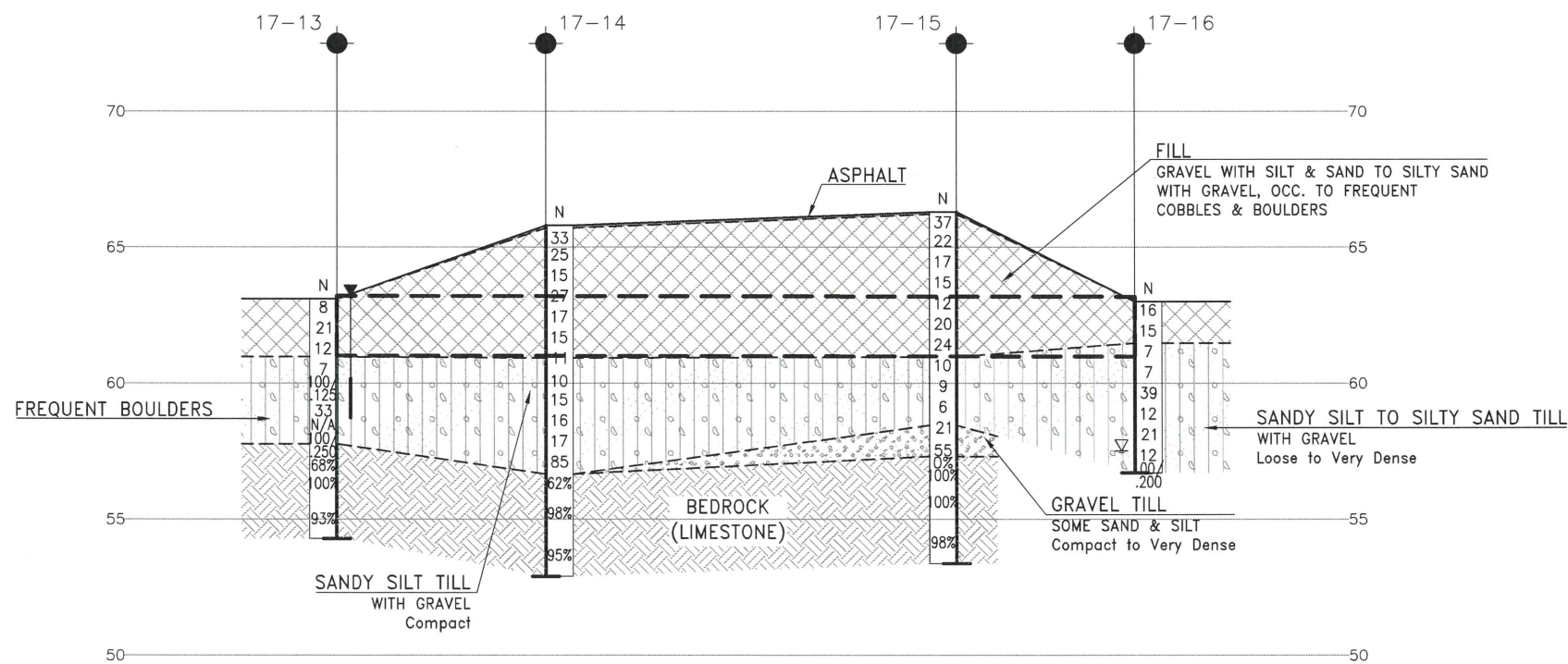
●	Borehole
⊙	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
W	Water Level
⊥	Head Artesian Water
⊥	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
17-13	63.1	5 019 182.7	180 806.4
17-14	65.8	5 019 174.2	180 793.5
17-15	66.3	5 019 163.1	180 763.3
17-16	63.0	5 019 145.6	180 761.0

NOTES

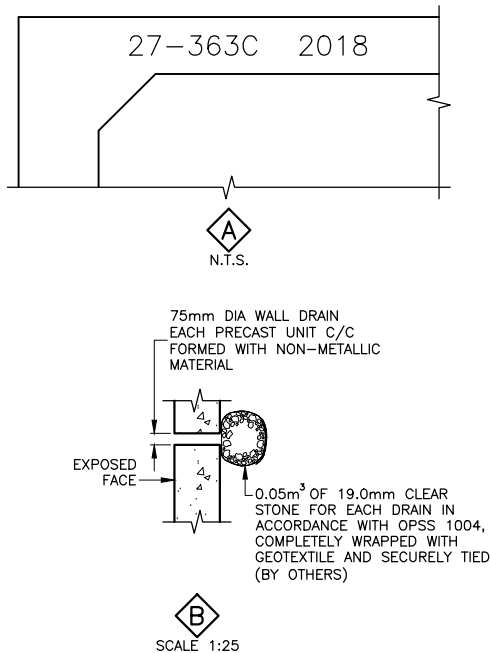
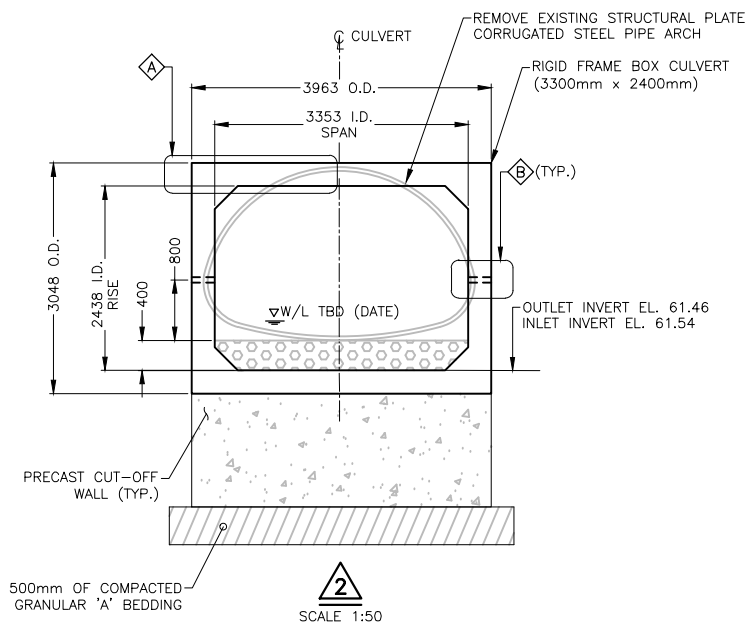
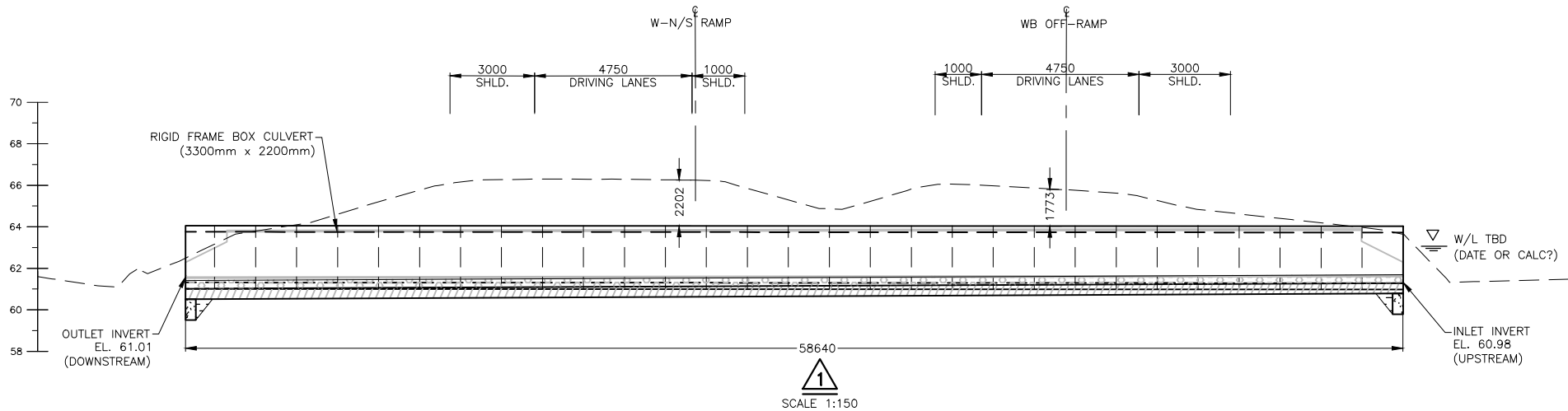
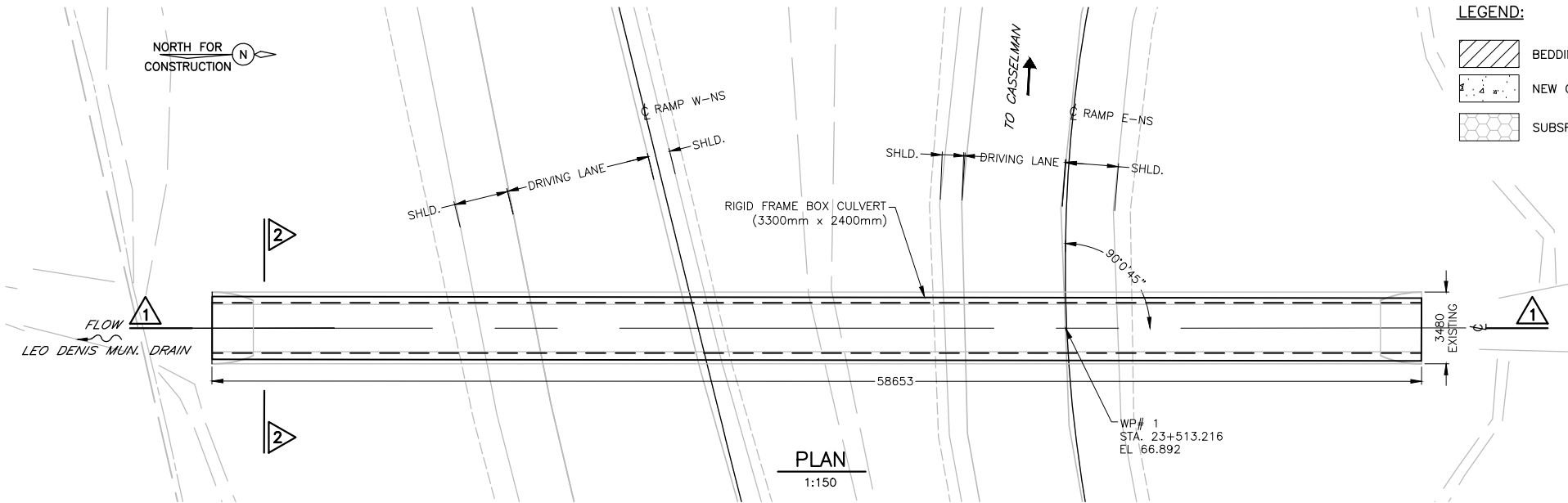
- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Coordinate system is MTM NAD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

GEOCRES No. 31G-272



REVISIONS	DATE	BY	DESCRIPTION
DESIGN	KE	CHK	PC
DRAWN	MFA	CHK	KE
CODE	LOAD	DATE	NOV 2018
SITE	STRUCT	DWG	1

DRAWING NAME: K:\MTO\17804 - Highway 417 Reconstruction\451-98-00 Working CT\Structural\17804-1 - Site No.27-363C - General Arrangement.dwg  
CREATED: 2018-07-13 4:18 PM  
MODIFIED: 2018-07-13  
MINISTRY OF TRANSPORTATION, ONTARIO  
PR-D-707 88-05



FLOW DATA: EXISTING CULVERT

DURATION	PEAK FLOW "Q" (m³/s)	WATER LEVEL (m)
2 YR.	1.394	-
5 YR.	2.341	-

- 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.  | OUTER DIAMETER       |

- LIST OF DRAWINGS**
- GENERAL ARRANGEMENT

DRAWING NOT TO BE SCALED  
100mm ON ORIGINAL DRAWING

REVISIONS																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				</
-----------	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	----

**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).

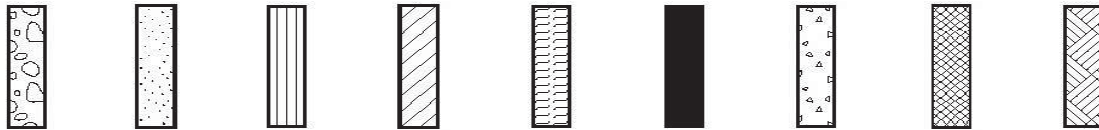
### DYNAMIC CONE PENETRATION TEST (DCPT):

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 17-13

1 OF 1

METRIC

GWP# 451-98-00 LOCATION Lat: 45.301652°, Long: -75.081065° Culvert Site 27-363/C MTM z8: N 5 019 182.7 E 180 806.4 ORIGINATED BY KE  
 HWY 417 BOREHOLE TYPE HSA, NQ Coring COMPILED BY AC  
 DATUM Geodetic DATE 19.06.2018 - 19.06.2018 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  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)						
63.1								20	40	60	80	100						
0.0	SILTY GRAVEL with sand trace organics at surface occasional to frequent boulders and cobbles loose to compact grey-brown FILL		1	SS	8		63											
			2	SS	21		62											39 28 33 (SH+CL)
			3	SS	12		61											
61.0			4	SS	7		60											
2.1	SILTY SAND (SM) with gravel TILL frequent boulders loose to very dense grey		5	SS	100/ 125 mm		59											30 46 24 (SH+CL)
			6	SS	33		58											
			7	NQ	N/A		57											
			8	SS	100/ 250 mm		56											
57.8			1	NQ			55											
5.3	BEDROCK LIMESTONE with shale partings fresh to slightly weathered grey thinly bedded fine to medium grained very strong		2	NQ														
			3	NQ														
54.3																		
8.8	End of Borehole Water level in well at 0.8 mbgs (elev. 62.3 m) on 03/08/2018																	

DOUBLE LINE SITE 27-363C.GPJ 2012TEMPLATE(MTO).GDT 8/11/18

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 17-14

1 OF 2

METRIC

GWP# 451-98-00 LOCATION Lat: 45.301573°, Long: -75.081228° Culvert Site 27-363/C MTM z8: N 5 019 174.2 E 180 793.5 ORIGINATED BY JG  
HWY 417 BOREHOLE TYPE HSA, NQ Coring COMPILED BY JG  
DATUM Geodetic DATE 14.09.2017 - 14.09.2017 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT  γ  kN/m <sup>3</sup>	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 <sub>p</sub> w      w <sub>L</sub>					
65.8	Paved Shoulder												
0.0	ASPHALT (100 mm)												
0.1	GRAVEL with silt and sand dense grey FILL		1	SS	33								
65.2	SILTY SAND compact brown FILL		2	SS	25								
0.6			3	SS	15								
63.7	SILTY SAND with gravel compact grey FILL		4	SS	27								
2.1			5	SS	17								
			6	SS	15								
60.9	SANDY SILT (ML) with gravel TILL compact grey		7	SS	11								
4.9			8	SS	10								
			9	SS	15								
58.5	SILTY SAND (SM) with gravel TILL compact to very dense grey		10	SS	16								
7.3			11	SS	17								
			12	SS	85								
56.7	BEDROCK LIMESTONE grey fresh very strong		1	NQ									
9.1													

0 77 23  
(SI+CL)

33 49 18  
(SI+CL)

18 35 40 7  
Non-plastic

31 36 33  
(SI+CL)

RUN #1  
TCR=81%  
SCR=77%  
RQD=62%

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE


DOUBLE LINE SITE 27-363C.GPJ 2012TEMPLATE(MTO).GDT 8/11/18

# RECORD OF BOREHOLE No 17-14

2 OF 2

METRIC

GWP# 451-98-00 LOCATION Lat: 45.301573°, Long: -75.081228° Culvert Site 27-363/C MTM z8: N 5 019 174.2 E 180 793.5 ORIGINATED BY JG  
 HWY 417 BOREHOLE TYPE HSA, NQ Coring COMPILED BY JG  
 DATUM Geodetic DATE 14.09.2017 - 14.09.2017 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  $\gamma$  kN/m <sup>3</sup>	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										
	Continued From Previous Page							20	40	60	80	100						
	BEDROCK LIMESTONE grey fresh very strong		2	NQ			55										RUN #2 TCR=100% SCR=100% RQD=98%	
								54										RUN #3 TCR=100% SCR=100% RQD=95% UCS=105.2MPa
52.9					3	NQ			53									
12.9	End of Borehole																	

DOUBLE LINE SITE 27-363C.GPJ 2012TEMPLATE(MTO).GDT 8/11/18

# RECORD OF BOREHOLE No 17-15

1 OF 2

METRIC

GWP# 451-98-00 LOCATION Lat: 45.301468°, Long: -75.081611° Culvert Site 27-363/C MTM z8: N 5 019 163.1 E 180 763.3 ORIGINATED BY JG  
HWY 417 BOREHOLE TYPE HSA, NQ Coring COMPILED BY JG  
DATUM Geodetic DATE 14.09.2017 - 14.09.2017 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
66.3	Paved Shoulder												
0.0	ASPHALT (100 mm)												
0.1	GRAVEL with silt and sand dense grey FILL		1	SS	37		66						45 43 12 (SH+CL)
64.9			2	SS	22		65						
1.4	SILTY SAND compact brown FILL		3	SS	17		64						1 75 24 (SH+CL)
62.8			4	SS	15		63						
3.5	SILTY SAND with gravel compact grey to brown FILL		5	SS	12		62						
61.0			6	SS	20		61						30 44 26 (SH+CL)
5.3	SANDY SILT (ML) with gravel TILL compact grey		7	SS	24		60						
58.5			8	SS	10		59						26 31 35 8 Non-plastic
7.8	GRAVEL some sand and silt TILL compact to very dense grey		9	SS	9		58						
57.3			10	SS	6		57						
9.0	BEDROCK LIMESTONE grey fresh very strong		11	SS	21								
			12	SS	55								
			1	NQ									RUN #1 TCR=94% SCR=29% RQD=0% RUN #2 TCR=100% SCR=100% RQD=100%
			2	NQ									

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE

DOUBLE LINE SITE 27-363C.GPJ 2012TEMPLATE(MTO).GDT 8/11/18

# RECORD OF BOREHOLE No 17-15

2 OF 2

METRIC

GWP# 451-98-00 LOCATION Lat: 45.301468°, Long: -75.081611° Culvert Site 27-363/C MTM z8: N 5 019 163.1 E 180 763.3 ORIGINATED BY JG  
 HWY 417 BOREHOLE TYPE HSA, NQ Coring COMPILED BY JG  
 DATUM Geodetic DATE 14.09.2017 - 14.09.2017 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
	Continued From Previous Page							20 40 60 80 100						
								○ UNCONFINED + FIELD VANE						
								● QUICK TRIAXIAL × LAB VANE						
								20 40 60 80 100						
								PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT						
								W P W W L						
								WATER CONTENT (%)						
								20 40 60						
</														



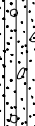
DOUBLE LINE SITE 27-363C.GPJ 2012TEMPLATE(MTO).GDT 8/11/18

# RECORD OF BOREHOLE No 17-16

1 OF 1

METRIC

GWP# 451-98-00 LOCATION Lat: 45.301311°, Long: -75.081635° Culvert Site 27-363/C MTM z8: N 5 019 145.6 E 180 761.0 ORIGINATED BY SOB  
 HWY 417 BOREHOLE TYPE HSA COMPILED BY AC  
 DATUM Geodetic DATE 27.06.2018 - 27.06.2018 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)			
63.0								○ UNCONFINED	+	FIELD VANE										
								● QUICK TRIAXIAL	×	LAB VANE										
0.0	SILTY SAND some gravel compact grey-brown FILL		1	SS	16															
			2	SS	15															
61.5																				
1.5	SANDY SILT (ML) with gravel TILL loose to dense grey		3	SS	7															
			4	SS	7															
			5	SS	39															
			6	SS	12															
			7	SS	21															
57.7																				
5.3	SILTY SAND (SM) with gravel TILL trace clay compact to very dense grey		8	SS	12															
			9	SS	100/															
56.7																				
6.3	End of Borehole Water level during drilling operations at 5.5 mbgs (elev. 57.5 m)				200 mm															

DOUBLE LINE SITE 27-363C.GPJ 2012TEMPLATE(MTO).GDT 8/11/18

**Appendix C.**  
**Laboratory Testing**

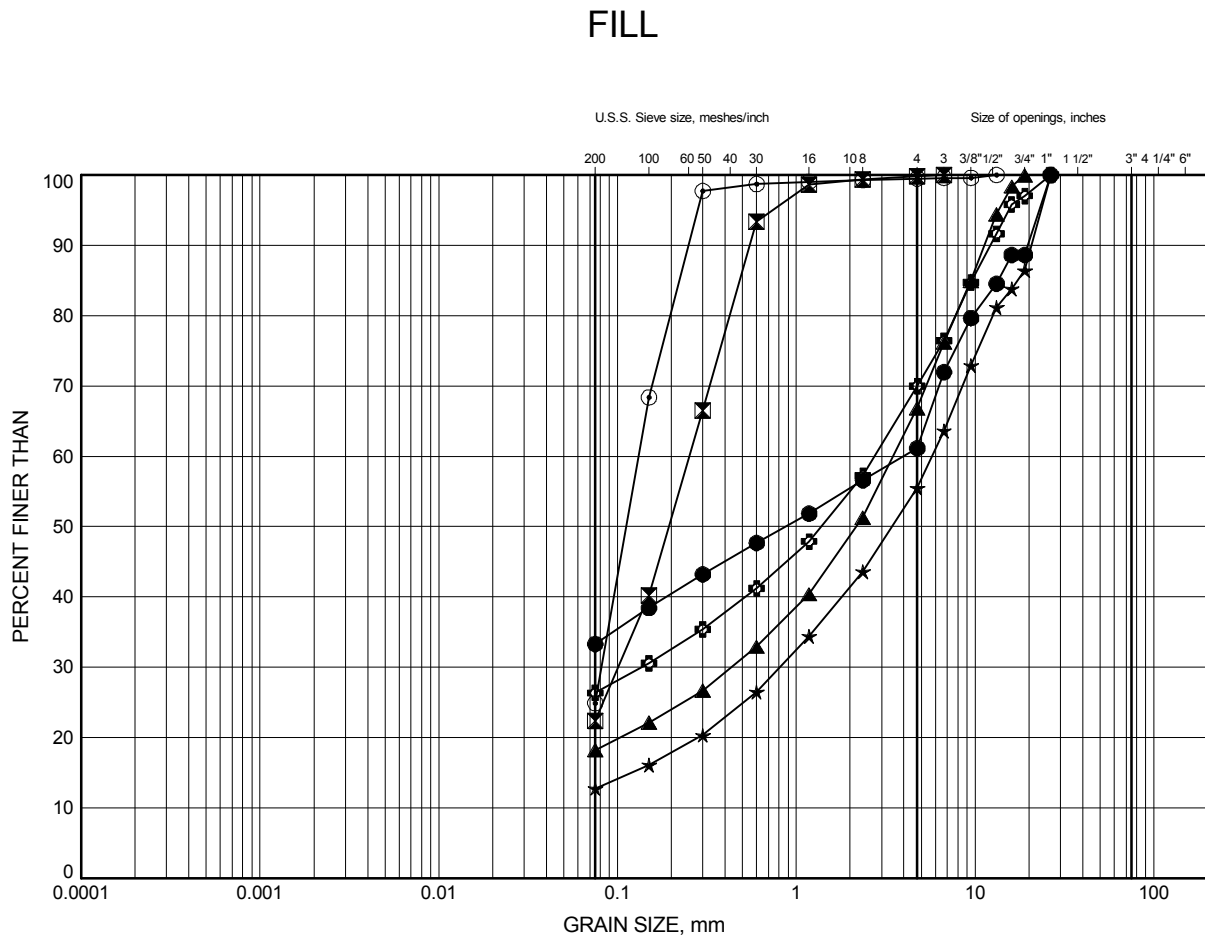
**Appendix C.1**  
**Particle Size Analysis Figures**



# Site 27-363/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)
●	17-13	1.1	62.1
⊠	17-14	1.1	64.7
▲	17-14	3.4	62.4
★	17-15	1.1	65.2
⊙	17-15	2.6	63.7
⊞	17-15	4.9	61.4

Date November 2018

GWP# 451-98-00



Prep'd KE

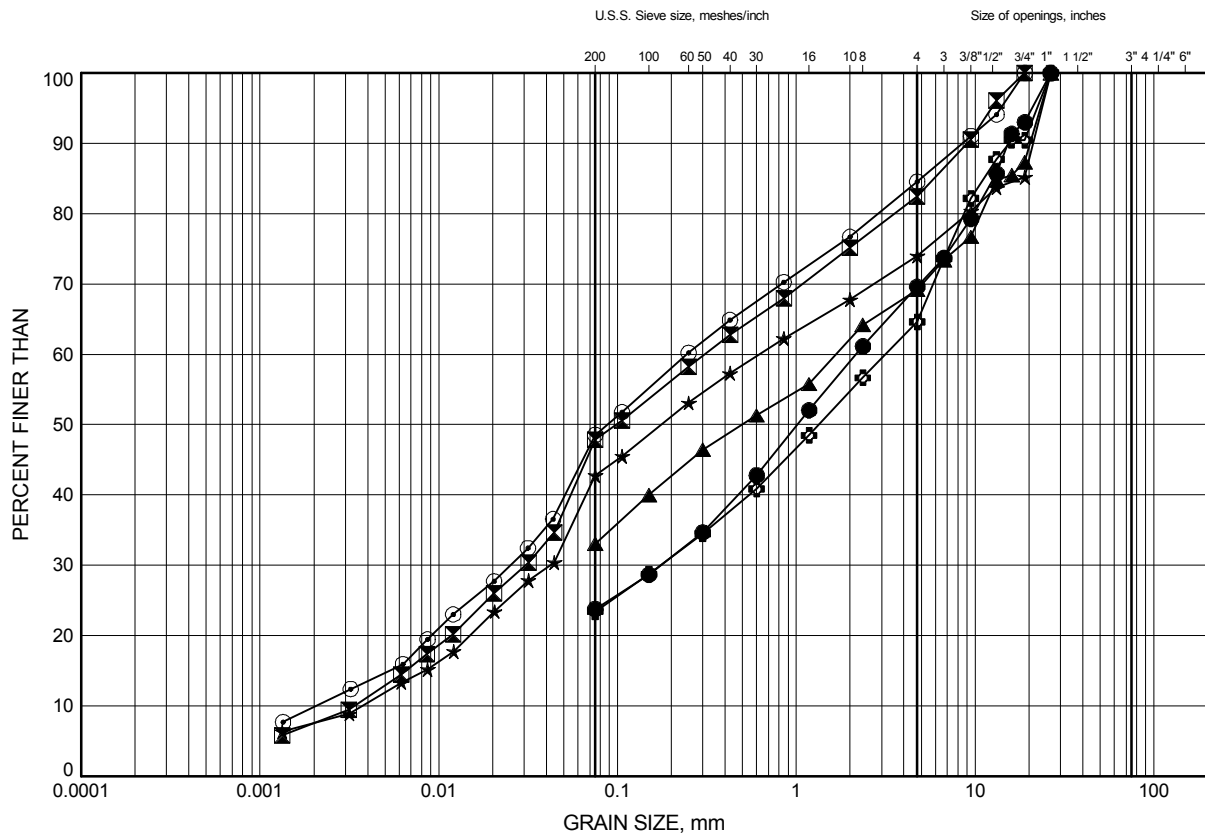
Chkd. FG

Site 27-363/C

# GRAIN SIZE DISTRIBUTION

FIGURE C2

## Silty Sand to Sandy Silt (GLACIAL TILL)



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-13	4.1	59.0
⊠	17-14	6.4	59.4
▲	17-14	8.7	57.1
★	17-15	7.2	59.1
⊙	17-16	3.4	59.7
⊕	17-16	5.6	57.4

Date November 2018

GWP# 451-98-00



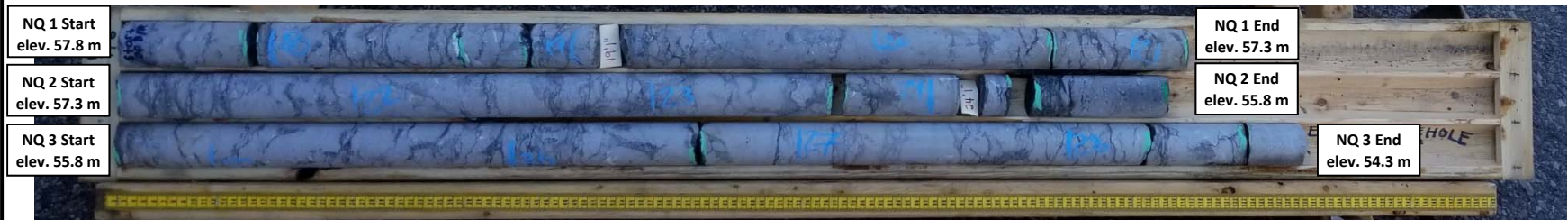
Prep'd KE

Chkd. FG

## **Appendix C.2**

### **Rock Core Photos and Testing Results**

**Borehole 17-13**  
**Run 1 to 3 (of 3)**  
**Elevation 57.8 m to 54.3 m**



**THURBER** ENGINEERING LTD.

**Foundation Investigation**  
**Highway 417 Interchange 27-363/C**  
**Foundations**

**GWP: 451-98-00**

**Project No.: 18310**

**Borehole 17-14**  
**Run 1 to 3 (of 3)**  
**Elevation 56.7 m to 52.9 m**



**THURBER** ENGINEERING LTD.

**Foundation Investigation**  
**Highway 417 Interchange 27-363/C**  
**Foundations**

**GWP: 451-98-00**

**Project No.: 18310**

**Borehole 17-15**  
**Run 1 to 4 (of 4)**  
**Elevation 57.3 m to 53.4 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](mailto: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](mailto:brian.prevost@stantec.com)



**Appendix C.3**  
**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 27-363/C  
Custody: 39853

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

**Order #: 1826163**

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

Paracel ID	Client ID
1826163-01	17-13, SS3, 5'-7'

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 27-363/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 27-363/C**

<b>Client ID:</b>	17-13, SS3, 5'-7'	-	-	-
<b>Sample Date:</b>	06/19/2018 09:00	-	-	-
<b>Sample ID:</b>	1826163-01	-	-	-
<b>MDL/Units</b>	Soil	-	-	-

**Physical Characteristics**

% Solids	0.1 % by Wt.	91.3	-	-	-
----------	--------------	------	---	---	---

**General Inorganics**

Conductivity	5 uS/cm	583	-	-	-
pH	0.05 pH Units	7.90	-	-	-
Resistivity	0.10 Ohm.m	17.1	-	-	-

**Anions**

Chloride	5 ug/g dry	227	-	-	-
Sulphate	5 ug/g dry	87	-	-	-

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

Report Date: 29-Jun-2018  
 Order Date: 25-Jun-2018  
**Project Description: Site 27-363/C**

**Method Quality Control: Blank**

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
<b>Anions</b>									
Chloride	ND	5	ug/g						
Sulphate	ND	5	ug/g						
<b>General Inorganics</b>									
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 27-363/C

**Method Quality Control: Duplicate**

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
<b>Anions</b>									
Chloride	265	5	ug/g dry	282			6.1	20	
Sulphate	146	5	ug/g dry	151			3.0	20	
<b>General Inorganics</b>									
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	
<b>Physical Characteristics</b>									
% 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 27-363/C

**Method Quality Control: Spike**

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
<b>Anions</b>									
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 27-363/C

**Qualifier Notes:**

***Login Qualifiers :***

Asbestos - Limited quantity  
*Applies to samples: 17-13, SS3, 5'-7'*

**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 **1826163**  
Client Project(s): **Site 27-363/C**  
Client PO: **18310**  
Reference: **Standing Offer**  
CoC Number: **39853**

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
1826163-01	17-13, SS3, 5'-7'	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:** CA12934-JUN18  
**Reference:** Project#:1826163

**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		13:07
5: QC - Blank		<0.02
6: QC - STD % Recovery		85%
7: QC - DUP % RPD		11%
8: RL		0.02
9: 17-13, SS3, 5'-7'	19-Jun-18	0.19

RL - SGS Reporting Limit

Kimberley Didsbury  
Project Specialist  
Environmental Services, Analytical

## **Appendix D.**

### **Site Photographs**



**Photo 1. Looking east towards inlet.**



**Photo 2. Looking west from N/S-E ramp along culvert alignment**





**Photo 3. Looking south on W-N/S ramp towards culvert crossing**



**Photo 4. Looking west at culvert outlet**

## **Appendix E.**

### **Foundation Comparison**






### COMPARISON OF ALTERNATIVE FOUNDATION TYPES

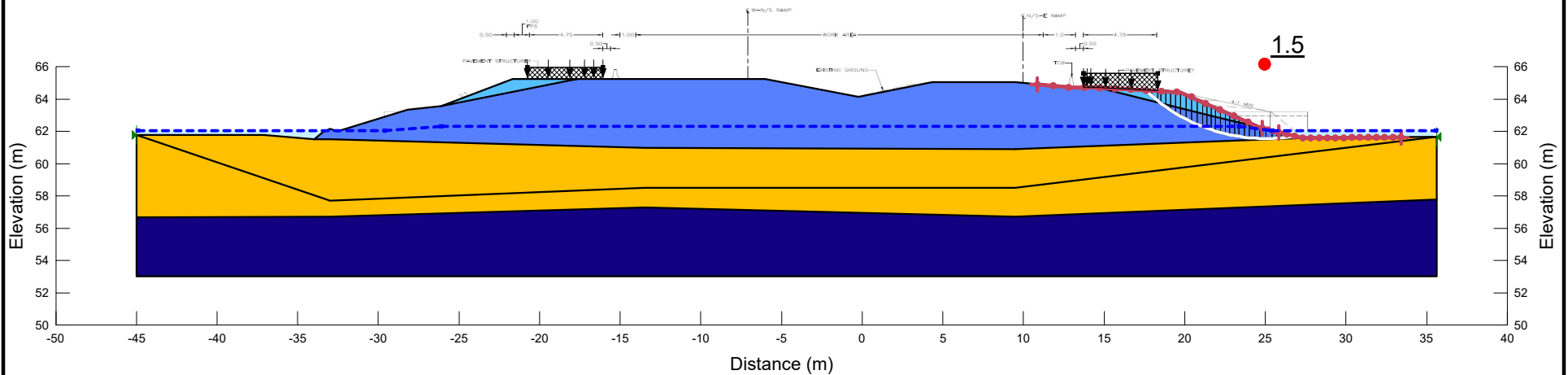
Type	Closed Box Culvert	Circular Pipe Culvert (Trenchless Installation)	Open Bottom Culvert	Precast Concrete Slab on Sheet Pile Culvert
<b>Advantages</b>	<p>Relatively expedient installation if precast units are used.</p> <p>Smaller magnitude of settlement than open footing culvert due to lower bearing 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>
<b>Disadvantages</b>	<p>Requires large excavation and roadway protection or ramp closure.</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>Requires roadway protection or ramp closure.</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.</p> <p>Differential settlement will occur between non-yielding culvert and approach fills.</p>
<b>Risks/ Consequences</b>	<p>Groundwater control may require enclosed excavation.</p>	<p>Limited cover available over pipe increases risk of roadway heave or settlement</p> <p>Groundwater control may require enclosed excavation.</p>	<p>Groundwater control may require sheet pile enclosed excavation.</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>
<b>Relative Cost</b>	Low	High	Medium	Medium to High
<b>Recommendation</b>	<b>Recommended</b>	<b>Not Feasible</b>	<b>Generally Feasible</b>	<b>High Risk / Not Feasible</b>

**Appendix F.**

**GeoStudio Slope Stability Output  
GSC Seismic Hazard Calculation**



Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Phi-B (°)	Piezometric Line
	Bedrock	Bedrock (Impenetrable)					1
	Soil #1 FILL - Silty Sand	Mohr-Coulomb	21	0	30	0	1
	Soil #2 FILL - Gran B Type I	Mohr-Coulomb	21	0	32	0	1
	Soil #3 TILL - Sandy Silt	Mohr-Coulomb	19.5	0	32	0	1
	Soil #4 TILL - Silty Sand	Mohr-Coulomb	19.5	0	32	0	1



Project Name:  
Casselman Culvert 27-363/C with 2H:1V Reinstatement

Analysis Title:  
1.0 Static Temporary Widening Inlet

Project No.:  
18310

Date: August 2018

Seismic Coeff.:  
H: 0g, V: 0g

Scale:  
1:381






Prepared by: KE

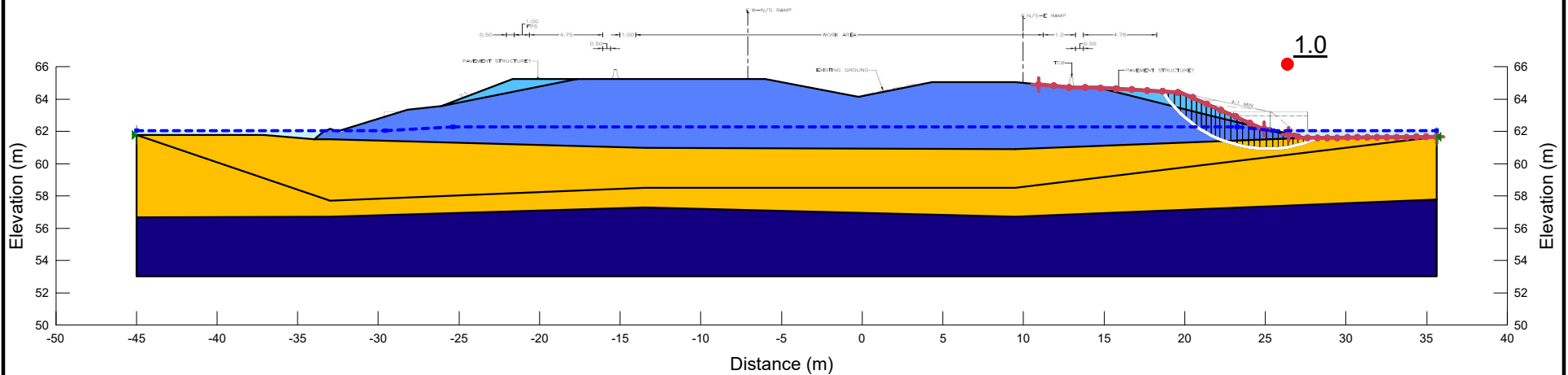
Reviewed by: FG

Analysis Details:

Method: Morgenstern-Price, Half-Sine  
Minimum Slip Surface Depth: 1.52 m  
Center: (25.033558, 72.329473) m w/ Radius: 10.76956 m  
Surcharge (Unit Weight): 18 kN/m³

Figure F1

Color	Name	Model	Unit Weight (kN/m³)	Cohesion* (kPa)	Phi* (°)	Phi-B (°)	Piezometric Line
	Bedrock	Bedrock (Impenetrable)					1
	Soil #1 FILL - Silty Sand	Mohr-Coulomb	21	0	30	0	1
	Soil #2 FILL - Gran B Type I	Mohr-Coulomb	21	0	32	0	1
	Soil #3 TILL - Sandy Silt	Mohr-Coulomb	19.5	0	32	0	1
	Soil #4 TILL - Silty Sand	Mohr-Coulomb	19.5	0	32	0	1



Project Name:  
Casselman Culvert 27-363/C with 2H:1V Reinstatement

Analysis Title:  
2.0 Seismic Temporary Widening Inlet

Project No.:  
18310

Date:  
August 2018

Seismic Coeff.:  
H: 0.185g, V: 0g

Scale:  
1:381

Prepared by:  
KE

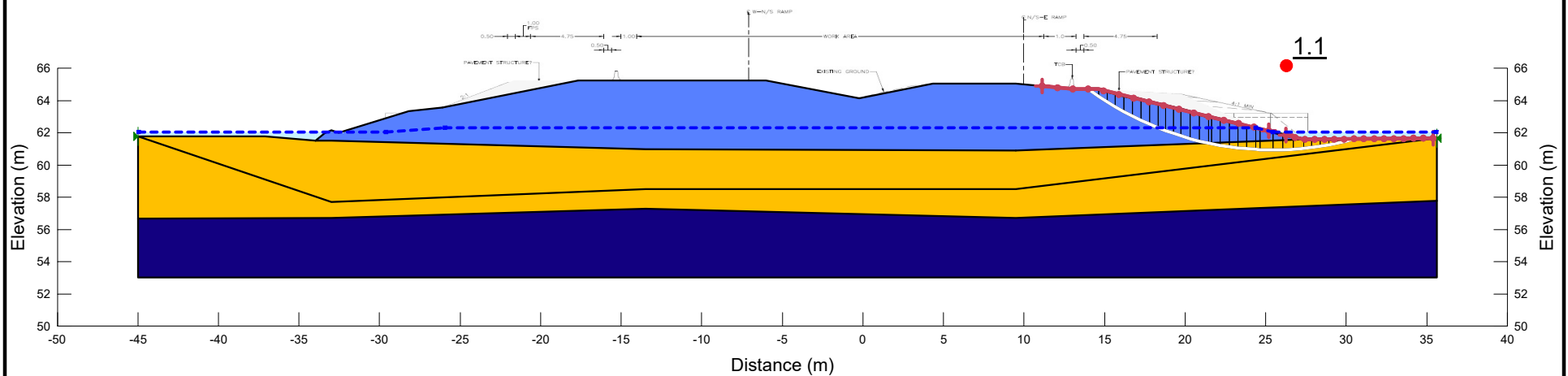
Reviewed by:  
FG

Analysis Details:

Method: Morgenstern-Price, Half-Sine  
Minimum Slip Surface Depth: 1.52 m  
Center: (25.118423, 68.60462) m w/ Radius: 7.6774042 m

Figure F2

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Phi-B (°)	Piezometric Line
■	Bedrock	Bedrock (Impenetrable)					1
■	Soil #1 FILL - Silty Sand	Mohr-Coulomb	21	0	30	0	1
■	Soil #3 TILL - Sandy Silt	Mohr-Coulomb	19.5	0	32	0	1
■	Soil #4 TILL - Silty Sand	Mohr-Coulomb	19.5	0	32	0	1



Project Name:  
Casselman Culvert 27-363/C with 2H:1V Reinstatement

Analysis Title:  
3.0 Seismic LongTerm Inlet

Project No.:  
18310

Seismic Coeff.:  
H: 0.185g, V: 0g

Prepared by: KE

Date: August 2018






Scale:  
1:381

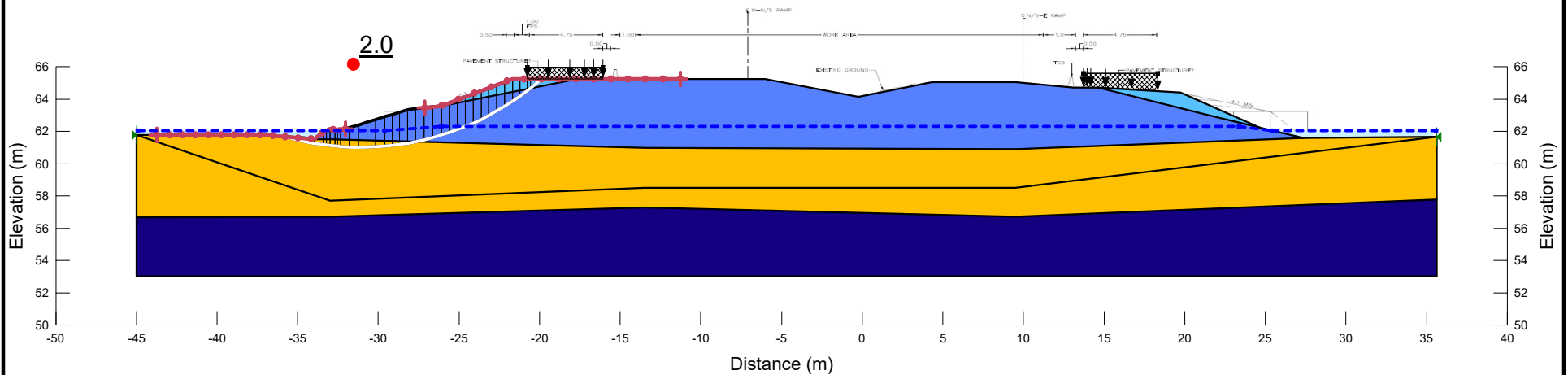
Reviewed by: FG

Analysis Details:

Method: Morgenstern-Price, Half-Sine  
Minimum Slip Surface Depth: 1.52 m  
Center: (25.45038, 80.275131) m w/ Radius: 19.330193 m

Figure F3

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Phi-B (°)	Piezometric Line
	Bedrock	Bedrock (Impenetrable)					1
	Soil #1 FILL - Silty Sand	Mohr-Coulomb	21	0	30	0	1
	Soil #2 FILL - Gran B Type I	Mohr-Coulomb	21	0	32	0	1
	Soil #3 TILL - Sandy Silt	Mohr-Coulomb	19.5	0	32	0	1
	Soil #4 TILL - Silty Sand	Mohr-Coulomb	19.5	0	32	0	1



Project Name:  
Casselman Culvert 27-363/C with 2H:1V Reinstatement

Analysis Title:  
4.0 Static Temporary Widening Outlet

Project No.:  
18310

Date: August 2018

Seismic Coeff.:  
H: 0g, V: 0g

Scale:  
1:381

Prepared by: KE

Reviewed by: FG

Analysis Details:

Method: Morgenstern-Price, Half-Sine  
Minimum Slip Surface Depth: 1.52 m  
Center: (-31.079482, 77.946094) m w/ Radius: 16.926263 m  
Surcharge (Unit Weight): 18 kN/m³

Figure F4



# 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)	<b>Sa(0.2)</b>	Sa(0.3)	<b>Sa(0.5)</b>	<b>Sa(1.0)</b>	<b>Sa(2.0)</b>	<b>Sa(5.0)</b>	<b>Sa(10.0)</b>	<b>PGA (g)</b>	<b>PGV (m/s)</b>
0.622	0.711	<b>0.584</b>	0.438	<b>0.304</b>	<b>0.144</b>	<b>0.066</b>	<b>0.017</b>	<b>0.0059</b>	<b>0.372</b>	<b>0.250</b>

**Notes.** Spectral ( $S_a(T)$ , where  $T$  is the period in seconds) and peak ground acceleration (PGA) values are given in units of  $g$  ( $9.81 \text{ m/s}^2$ ). Peak ground velocity is given in  $\text{m/s}$ . Values are for "firm ground" (NBCC 2015 Site Class C, average shear wave velocity  $450 \text{ m/s}$ ). 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

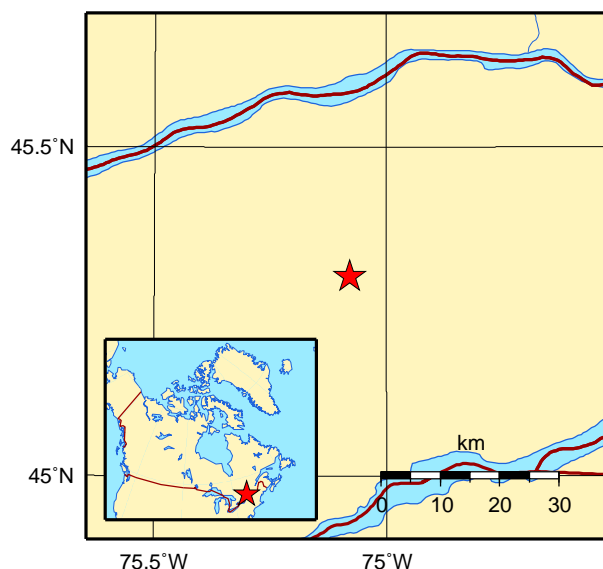
**National Building Code of Canada 2015 NRCC no. 56190;**  
**Appendix C:** Table C-3, Seismic Design Data for Selected Locations in Canada

**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](http://www.EarthquakesCanada.ca) and [www.nationalcodes.ca](http://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 a 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.

3. 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.