



THURBER ENGINEERING LTD.

**PRELIMINARY
FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 17 TWINNING, RENFREW AREA
LITTLE HALLIDAY CREEK CULVERTS
STA.17+893 EBL AND WBL, HORTON TOWNSHIP
SITE NO. 29X-0405/C0
WP 4068-09-00 / ASSIGNMENT NO. 4018-E-0009**

Geocres No.: 31F-228

Report to:

Ministry of Transportation Ontario

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PART 1. FACTUAL INFORMATION

1 INTRODUCTION

Thurber Engineering Ltd. (Thurber) has been engaged by the Ministry of Transportation Ontario (MTO) to carry out Foundation Investigations to support the design of the Highway 17 Twinning Project which extends from Scheel Drive westerly to 3 km west of Bruce Street in the Renfrew area.

This report addresses the Highway 17/Halliday Creek crossing located near Station 17+893 in Horton Township just west of Renfrew, Ontario. The existing Highway 17 alignment at this site will become the future Highway 17 westbound lanes and new eastbound lanes will be constructed to the west of the existing alignment at this location. The culvert currently present under the existing Highway 17 lanes will require replacement while a new culvert will be required under the proposed eastbound lanes.

This section of the report presents the factual findings obtained from foundation investigations completed for both the new and replacement culverts near Station 17+893.

Thurber carried out the investigation under Ministry of Transportation (MTO) Assignment No. 4018-E-0009.

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.

It should be noted that the use of and reliance on Part 1 of the Report is governed by and limited to the terms and conditions set out in the Report and a reliance letter. The Preferred Proponent remains responsible to assess the need for additional investigations and to complete that work.



2 SITE DESCRIPTION

2.1 General

The site is located on Highway 17 approximately 675 m north of the existing intersection with Bruce Street. For project purposes, Highway 17 is herein described as oriented north-south and Halliday Creek, east-west.

The existing Highway 17 in the vicinity of the site is an undivided highway with a westbound passing lane, gravel shoulders and a posted speed limit of 90 km/hr. Three-cable guiderails are present on both sides. The AADT for this existing section of Highway 17 near the site had a reported AADT of 12,300 in 2016.

The land adjacent to the site generally consists of agricultural fields with residential homes located approximately 100 m south of the existing highway. The terrain is relatively flat with slight downward slope towards the creek. Occasional trees and shrubs are present along the existing highway right-of-way and the creek.

The existing culvert is a 2.4 m diameter, 41.1 m long corrugated steel pipe (CSP) culvert. The cover above the existing culvert is approximately 2.5 m. The culvert facilitates the flow of Little Halliday Creek under the highway embankment from west to east and has an invert elevation of approximately 144.2 m. It is noted that the creek runs in a small incised valley which was noted to be approximately 2.5 m wide. There was approximately 0.35 m depth of water in the creek on April 27, 2021.

The existing highway embankment side slopes did not show any visible signs of distress at the time of the investigation. The embankment sides are sloped at approximately 2.5H:1V.

Photographs showing the existing conditions in the area of the site at the time of the field investigation are included in Appendix D for reference.

2.2 Site Geology

Based on published geological information in *The Physiography of Southern Ontario* by Chapman and Putnam (1984), the site lies within the physiographic region known as the Ottawa Valley Clay Plains. The Ottawa Valley Clay Plains are characterized primarily by clay plains deposited by the Champlain Sea (Leda Clay) interrupted by ridges of rock or sand.

Ontario Geological Survey Map 2460 for Precambrian Geology for the Cobden Area suggests the bedrock is comprised of calcitic carbonate metasedimentary bedrock including calcitic and siliceous marble.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field-testing program was carried multiple phases; May 11 to May 12, 2020, April 26, 2021 and May 14 to May 18, 2021. The field investigation consisted of advancing



6 boreholes identified as Boreholes CV-4, CV 5, CV-6, CV-24, N20-1 and N20-2. Prior to commencement of drilling, utility clearances were obtained in the vicinity of the borehole locations.

The locations and elevations of the boreholes were surveyed by Thurber with a Trimble Catalyst DA1 antenna with centimeter accuracy. The northing, easting and elevation of the boreholes are shown on the Borehole Location and Soil Strata Drawing No. 1 in Appendix A, the individual Record of Borehole sheets in Appendix B, and in Table 3-1 below. The site is located within MTM Zone 9.

Table 3-1: Borehole Summary

Borehole No.	Drilled Location	Northing (Latitude)	Easting (Longitude)	Ground Surface Elevation (m)	Termination Depth (m)
CV-4	Proposed EBL Culvert Inlet	5 040 358.9 (45.503018)	291 160.7 (-76.674536)	145.6	11.9
CV-5	Proposed EBL Embankment	5 040 353.2 (45.502967)	291 176.9 (-76.674329)	145.5	11.9
CV-6	Proposed EBL Culvert Outlet / Proposed WBL Culvert Inlet	5 040 346.9 (45.502911)	291 194.2 (-76.674107)	145.2	11.9
CV-24	Proposed WBL Culvert Outlet	5 040 356.6 (45.502999)	291 241.4 (-76.673503)	145.3	9.8
N20-1	Proposed WBL Existing Hwy 17	5 040 349.3 (45.502933)	291 226.9 (-76.673688)	149.0	15.8
N20-2	Proposed WBL Existing Hwy 17	5 040 344.3 (45.502888)	291 220.5 (-76.67377)	149.1	15.8

The investigation for on-road Boreholes N20-1 and N20-2 was carried out using a truck-mounted CME 55 drill rig equipped with HW rotary diamond drilling equipment. A track-mounted CME 45 drill rig equipped with hollow stem augers was used to carry out the off-road drilling for Boreholes CV-4, CV-5, CV-6 and CV-24.

Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). In situ vane shear testing was completed in cohesive soils with an MTO 'N' sized vane.

Monitoring wells, 50 mm in diameter, were installed in Boreholes CV-4 and CV-24. The installation details are illustrated on the respective Record of Borehole sheets provided in Appendix B. The boreholes were backfilled in accordance with MOE requirements (O.Reg 903, as amended). The monitoring wells will be decommissioned by Thurber, as outlined in the Hydrogeological Investigation and Design Report...



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

4 LABORATORY TESTING

Laboratory testing was selected in accordance with the current MTO Guideline for Foundation Engineering Services, Section 5. Geotechnical laboratory testing consisted of natural moisture content determination and visual identification of all retained soil samples. At least 25% of the recovered soil samples were subjected to testing for grain size distribution analysis and, where appropriate, Atterberg Limits in accordance with MTO and ASTM standards. Chemical analysis for determination of pH, conductivity, resistivity, sulphide, sulphate and chloride was carried out on a sample of the soil.

The results of the geotechnical tests are summarized on the Record of Borehole sheets included in Appendix B and all laboratory results are presented on the figures included 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 Location and Soil Strata Drawing included in Appendix A. A general description of the stratigraphy based on the conditions encountered in the boreholes is given in the following sections. However, the factual data presented on the Borehole Records 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. Soil classification is in accordance with ASTM D2487. Cohesive soils are described per current MTO protocols.

In general terms, beneath the pavement asphalt, embankment fill comprising sand with silt trace gravel to silty sand was encountered where boreholes were advanced from the existing Highway 17 roadway. Topsoil was encountered at the ground surface in the off-road boreholes. The native soils under the existing and proposed embankment comprised weathered clayey silt to silty clay crust underlain by clayey silt to silty clay. All boreholes were terminated in the clayey silt to silty clay deposit.

5.1 Embankment Fill

5.1.1 Asphalt

Asphalt ranging in thickness from 255 mm to 350 mm was encountered in on-road Boreholes N20-1 and N20-2.

5.1.2 Silty Sand to Sand with Silt, Trace Gravel (Fill)

A fill layer consisting of silty sand with gravel to silty sand trace gravel was encountered below the asphalt in Boreholes N20-1 and N20-1. The thickness of the layer ranges from 5.0 m to 5.2 m

with base depths ranging from 5.3 m to 5.6 m (base elevations ranging from 143.8 m to 143.4 m). The SPT N-values ranged from 3 to 85; indicating a very loose to very dense condition.

The moisture content of the samples tested ranged from 3% to 16%. The results of grain size analyses conducted on two samples of this fill material are summarized below and are illustrated on Figure C1 in Appendix C.

Summary of Grain Size Distribution Testing - Fill

Soil Particle	Percentage (%)
Gravel	2 – 14
Sand	75 – 82
Silt & Clay	11 – 16

5.2 Topsoil

A layer of topsoil was encountered at the ground surface in Boreholes CV-4, CV-5, CV-6 and CV-24. It is noted that several of the boreholes were located within farmland and the extent of the topsoil will reflect the dept of the tilled layer. The topsoil was observed to range in thickness from 200 mm to 460 mm in the four boreholes. One recorded moisture content of 45% was obtained. It should be noted that the topsoil thickness may vary between boreholes and in other areas of the site. This limited data should not be used for estimating topsoil stripping quantities.

5.3 Weathered Clayey Silt (CL) to Silty Clay (CI) Crust

A weathered crust layer consisting of grey-brown clayey silt to silty clay was encountered below the topsoil in Boreholes CV-4, CV-5, CV-6 and CV-24. The thickness of this layer ranged from 1.6 m to 2.1 m with base depths ranging from 2.1 m to 2.3 m (base elevations ranging from 143.5 m to 142.9 m).

SPT N-Values ranged from 1 to 4; indicating a stiff to very stiff condition.

The moisture content of the samples tested ranges from 29% to 49%. The results of grain size analyses conducted on four samples of the crust material are summarized below and are illustrated on Figure C2 in Appendix C.

Summary of Grain Size Distribution Testing – Weathered Crust

Soil Particle	Percentage (%)
Gravel	0
Sand	0 – 1
Silt	45 – 59
Clay	41 – 55



The results of Atterberg Limits testing carried out on four samples of this material are summarized below and are illustrated on Figure C5 in Appendix C. The laboratory results indicate that the material ranges from a clayey silt (CL) to a silty clay of intermediate plasticity (CI).

Summary of Atterberg Limit Testing – Weathered Crust

Parameter	Value
Liquid Limit	34 – 50
Plastic Limit	19 – 21
Plasticity Index	13 – 29

5.4 Clayey Silt (CL) to Silty Clay (CI)

A native deposit of clayey silt to silty clay was encountered below the weathered crust in Boreholes CV-4, CV-5, CV-6 and CV-24, and below the fill in Boreholes N20-1 and N20-2. All boreholes were terminated in this deposit at base depths ranging from 9.8 m to 15.8 m (base elevations ranging from 135.5 m to 133.2 m). Sand partings were noted throughout this layer in Boreholes CV-5 and Borehole CV-6.

SPT tests conducted within the cohesive unit gave N-values ranging from weight of hammer to 11. In situ shear vane tests indicated undrained shear strengths ranging from greater than 100 to 31 kPa with increasing depth indicating a very stiff to firm consistency. Sensitivity typically ranged from 1.8 to 9.5; the largest sensitivity reported was 22.5.

The moisture content of the samples tested ranged from 27 to 48%. The results of twelve grain size analysis tests conducted on samples of this material are summarized below and are illustrated on Figures C3 and C4 in Appendix C.

Summary of Grain Size Distribution Testing – Clayey Silt to Silty Clay

Soil Particle	Percentage (%)
Gravel	0 – 2
Sand	0 – 4
Silt	43 – 61
Clay	37 – 54

The results of Atterberg Limits testing carried out on ten samples of this material are summarized below and are illustrated on Figures C6 and C7 in Appendix C. The laboratory results indicate that the material ranges from a clayey silt of low plasticity (CL) to a silty clay of intermediate plasticity (CI).



Summary of Atterberg Limit Testing – Clayey Silt to Silty Clay

Parameter	Value
Liquid Limit	26 – 40
Plastic Limit	16 – 22
Plasticity Index	10 – 19

5.5 Groundwater

Monitoring wells with diameters of 50 mm were installed in Boreholes CV-4 and CV-24. Groundwater levels recorded in the wells are presented in Table 5-1 below:

Table 5-1: Summary of Groundwater Levels

Borehole No.	Bottom of Screen Elevation (m)	Groundwater Depth (m)	Groundwater Elevation (m)	Date of Measurement
CV-4	141.0	0.7	144.9	August 4, 2021
		1.0	144.6	September 22, 2021
		0.7	144.9	October 5, 2021
		0.8	144.8	October 20, 2021
		1.0	144.6	January 19, 2022
CV-24	140.7	0.4	144.9	August 4, 2021
		0.8	144.5	September 22, 2021
		0.2	145.1	October 5, 2021
		0.6	144.7	January 19, 2022

Water was observed while drilling at depths of 3.0 m and 3.8 m in Boreholes N20-1 and N20-2, respectively (elevations 146.0 m to 145.3 m, respectively).

On April 27, 2021, the water level in the creek was reported to be at elevation 144.8 m.

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.

5.6 Analytical Testing

One sample of the native clay was submitted to Paracel Laboratories in Ottawa, Ontario for analysis of pH, water soluble sulphate, sulphide and chloride concentrations, resistivity and

conductivity. The analysis results are summarized in Table 5-2. Copies of the test results are provided in Appendix C.

Table 5-2: Results of Chemical Analysis

Borehole	Sample	Depth (m)	Chloride (µg/g)	Sulphate (µg/g)	Sulphide (%)	pH (-)	Resistivity (Ohm-cm)
CV-6	SS3	1.5 – 2.1	168	63	0.05	7.73	1,980

6 MISCELLANEOUS

Borehole locations were selected by Thurber relative to existing site features. The as-drilled locations and ground surface elevation of the boreholes were surveyed by Thurber following completion of the field program. The elevation survey was carried out with reference to geodetic elevation benchmarks provided by the MTO.

Marathon Underground of Greely, Ontario supplied and operated the drilling equipment and carried out the drilling, soil sampling, in-situ testing, monitoring well installation and borehole decommissioning. The field investigation was supervised on a full-time basis by Nick Weil and Anderson de Oliveira of Thurber. Overall supervision of the investigation program was provided by Justin Gray, P.Eng.

Routine geotechnical laboratory testing was completed by Thurber's laboratory in Ottawa, Ontario. Analytical testing was completed by Paracel Laboratories in Ottawa.

Overall project management and direction of the field program was provided by Fred Griffiths, P.Eng. Interpretation of the factual data and preparation of this report were carried out by Fred Griffiths, P.Eng. The report was reviewed by P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.



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PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 INTRODUCTION

Part 2 of the report provides an interpretation of the factual data from Part 1 and presents geotechnical recommendations to assist the project team in designing the foundations for a culvert crossing to be located at approximate Station 17+893 on Highway 17, about 675 m north of Bruce Street in Horton Township, Renfrew County. The existing Highway 17 alignment at this site will become the future Highway 17 westbound lanes and new eastbound lanes will be constructed 45 m west of the existing alignment at this location. The culvert currently present under the existing Highway 17 lanes will require replacement while a new culvert will be required under the proposed eastbound lanes. These culverts will convey Little Halliday Creek under the existing and proposed highway embankments.

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 design-build contractors. It should be noted that the use of and reliance on Part 1 of the Report is governed by and limited to the terms and conditions set out in the Report and a reliance letter. The Preferred Proponent remains responsible to assess the need for additional investigations and to complete that work. The Preferred Proponent must make their own interpretation based on the factual data in Part 1 of the report. The information included in Part 2 is not to be relied upon for design purposes and foundation design is the sole responsibility of the Preferred Proponent. No use shall be made of Part 2 or any part thereof. The Preferred Proponent must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

The following sections provide preliminary geotechnical recommendations for the construction of foundation elements for the proposed culvert. The discussions and recommendations presented in this report are based on the information provided by the Ministry of Transportation of Ontario (MTO) and on the factual data obtained during the course of this investigation.



For project purposes, Highway 17 is herein described as oriented north-south and Halliday Creek flows from west to east. The ground surface elevation outside the highway embankment footprint ranges from 145.2 m to 145.6 m; at existing and proposed alignment. The existing road elevation at the culvert crossing ranges from approximately 149.1 m to 149.0 m.

The native soils at the site comprised a stiff to very stiff clayey silt to silty clay crust over very stiff to firm clayey silt to silty clay. All boreholes were terminated in the lower clay layer. It is noted that the ground water level in both of the monitoring wells was at elevation 144.9 on August 4, 2021.

The 2003 Stormwater Management and Drainage Report by National Capital Engineering (NCE) in support of the Preliminary Design Report for this project indicates a culvert is present beneath the existing highway (proposed westbound lanes) at approximately Sta. 17+893. The existing culvert is described as a 2.4 m diameter CSP. This report recommended a replacement CSP with the same diameter. For the new culvert under the proposed eastbound lanes, the report recommended a 4.8 m by 2.8 m closed bottom box culvert (CBC).

It is understood from the 2018 RFP that the proposed culverts at Sta. 17+893 are 4.8 m by 2.8 m CBCs.

A survey report from Callon Dietz Inc. under Assignment 4014-E-0034 from November 2019 reports the existing culvert invert elevation as 144.396 m and 144.014 m at the inlet and outlet, respectively.

7.1 Proposed Structure

Per the Preliminary General Arrangement Drawing dated June 16, 2021, included in Appendix F, the proposed structural culverts under the existing Highway 17 (proposed westbound lanes) and proposed eastbound lanes have a 4.8 m span and a height of 2.8 m. It is anticipated, they will be constructed such that the culvert invert elevation does not vary significantly from existing. Similarly, it is anticipated that the finished grade of the new eastbound and westbound embankments will be similar to that of the existing highway.

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 S6:19.

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

It is understood that the new culvert structure is being designed to the “Major Route” importance category.



This project has been assigned Typical Consequence Classification, in accordance with Section 6.5.1 of the CHBDC. Accordingly, a consequence factor (Ψ) of 1.0, as per Table 6.1 of the CHBDC, has been used in assessing factored geotechnical resistances.

The degree of site and prediction model understanding for this site has been assessed to be typical understanding (Section 6.5.3 of CHBDC).

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 online 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 E.

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). The PGA at this site for a *reference* Site Class C with a 2% probability of exceedance in 50 years (2475-year event) is 0.229g. This value is to be scaled by the $F(PGA)$ based on the site-specific Site Class.

8.2 CHBDC Seismic Site Classification

In accordance with the CHBDC, the selection of the seismic site classification is based on the soil conditions encountered in the upper 30 m of the stratigraphy. Based on the average undrained shear strengths measured below the anticipated culvert foundation elevation, the site is classified as a Seismic Site Class D in accordance with Table 4.1 of the CHBDC.

As per Table 4.8 of the CHBDC, Site Class D yields a PGA_{ref} of 0.183 and $F(PGA)$ of 1.132 for the site. These values give a factored PGA of 0.259 g.

8.3 Seismic Liquefaction Potential

The susceptibility of the cohesive soils at this site to experience liquefaction/cyclic softening was assessed following the Boulanger and Idriss (2007)ⁱ criteria using measured undrained shear strengths. The results of the analysis indicate the clayey silt to silty clay layer are not susceptible to cyclic mobility.

The susceptibility of the cohesionless embankment fill soils at the site to experience liquefaction was assessed using the SPT data following the simplified method for cohesionless soil as outlined in Boulanger and Idriss (2014)ⁱⁱ. The cohesionless embankment fill below the water table is considered susceptible to liquefaction (base elevation about 143.5 m). It appears that this



liquefiable soil is localized to the creek channel; it is anticipated that this cohesionless soil will be excavated and replaced with compacted granular as part of the culvert replacement.

9 STRUCTURE FOUNDATION ALTERNATIVES

9.1 Foundation Alternatives

Selection of the culvert type must consider the proposed construction procedures, staging requirements, geotechnical resistance available in the foundation soils, 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, a pipe culvert is a technically feasible alternative. The size of the pipe culvert will depend on the required hydraulic capacity. Multiple smaller pipes may be required to carry the flow.

- Open-Bottom Culvert (Box, Arch)

The construction of an open-bottom culvert will have greater construction concerns due to the high water table and requirement for greater excavation depths to construct the culvert footings to satisfy frost depth requirements. The use of an open-bottom culvert would require greater dewatering efforts and has the potential for larger settlement following construction when compared to other culvert options. The footings will be founded in native clay.

- Closed-Bottom Box Culvert

A precast, segmental, closed-bottom, box culvert 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.

A comparison of these alternatives, based on their respective advantages and disadvantages, is included in Appendix F. 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

Temporary excavations will extend below the water level of the creek. An adequate and effective dewatering plan including surface water management, cofferdams, creek diversion and excavation dewatering will be required to enable excavation to the required founding elevation and construction of the foundations in the dry (See Section 11.3).

At the time of preparation of this report, a construction staging plan has not yet been developed. The foundation recommendations presented herein have been prepared based on the assumption that construction of the culvert will be carried out either under full road closure using

a detour on to the new westbound Highway 17 alignment or with the use of temporary roadway protection allowing one lane of traffic through the construction zone.

9.3 Recommended Approach

From a geotechnical perspective, a closed-bottom, box culvert is recommended at this site. It is anticipated that construction for the eastbound lanes would be carried out while traffic remains on the existing alignment. Once the new lanes are open, all traffic would be rerouted onto the new lanes, while the culvert structure under the existing lanes is replaced.

Multiple pipe culverts would also be considered a feasible alternative. Construction staging would be similar to that for the closed bottom box culvert option.

10 FOUNDATION DESIGN RECOMMENDATIONS

From a foundation engineering perspective, a concrete, closed-bottom, box culvert is recommended. The following are key elevations for the existing culvert.

- Proposed top of pavement eastbound Highway 17 149.0 m
- Culvert inlet invert elevation 144.4 m
- Culvert outlet invert elevation 144.0 m
- Proposed elevation of underside of base slab of culvert (at centerline) 143.8 m
- Groundwater elevation 144.9 m

It is assumed that the new culvert under the proposed eastbound embankment will have similar elevations.

10.1 Culvert Foundation Bearing Resistances

It is assumed that the existing Highway 17 embankment (proposed westbound lanes) following the culvert replacement will be similar to the existing dimensions. It is not anticipated that the subgrade soils within the proposed culvert footprint will be subjected to any additional loads when compared to the existing embankment footprint.

It is assumed the proposed eastbound lanes will have a similar geometry to the existing Highway 17 geometry. The construction of the new embankment will add additional loads within and beyond the culvert footprint. Further discussion on the potential settlement of the subgrade soils due to the placement of the new eastbound embankment is provided in Section 10.6.

The subgrade should be prepared as described in Section 10.3. Surface water diversion and dewatering will be required to place the bedding material and install the culvert in the dry (Section 11.3).

The recommended geotechnical resistances for a 5.4 m wide (exterior) pre-cast, closed-bottom, box culvert with the underside of culvert base slab at or below approximate elevation 143.8 m,



installed on a bedding layer as described in Section 10.3 placed on an undisturbed native silty clay to clayey silt crust are as follows:

- Factored Geotechnical Resistance at ULS of 200 kPa
- Factored Geotechnical Resistance at SLS* of 100 kPa

Note (*): The SLS value provided is for settlements up to 25 mm. It should be noted that the placement of new fill will cause more than 150 mm of settlement for the new eastbound lane as noted in Section 10.6. The eastbound culvert site will need to be pre-loaded to satisfy the 25 mm limitation.

It is noted that the culvert opening will be substantially larger than the existing pipe culvert under the existing embankment, thus the result of the construction will be a net unloading for the culvert below the westbound lanes.

The factored geotechnical resistances include the following factors:

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

The bearing resistance values are for vertical, concentric loading. In the case of eccentric or inclined loading, the bearing resistance must be reduced in accordance with CHBDC Clause 6.10.3 and Clause 6.10.4.

Resistance to lateral forces/sliding resistance between the precast concrete and the underlying Granular 'A' bedding (Section 10.3) should be evaluated in accordance with the CHBDC assuming an unfactored coefficient of friction of 0.45. A reduction factor of 0.8 (as per CHBDC Table 6.2) should be used to estimate the sliding resistance between the culvert and Granular A. An unfactored coefficient of friction of 0.35 can be assumed for the interface between the Granular 'A' and the clayey subgrade. A reduction factor of 0.6 (as per CHBDC Table 6.2) should be used to estimate the sliding resistance between the Granular A and the clayey subgrade.

10.2 Wingwalls / Retaining Walls

Based on General Arrangement Drawing dated June 16, 2021 (See Appendix F), no retaining walls or wingwalls are proposed at this location. If required, concrete retaining walls or wingwalls could be supported on spread footings. It is noted that wingwalls are not required if the culvert structure length is sufficient to allow the sloped embankment fill recommended in Section 10.6.

Footings for wingwalls or retaining walls should be founded at a depth, when measured perpendicular to the ground surface, that is greater than the depth of frost (see Section 10.4). The subgrade and granular pad should be prepared based on the recommendations provided in Section 10.3.



The geotechnical resistance values provided in Section 10.1 are applicable for a 2 m to 3 m wide shallow footing up to 10 m long. It should be noted that the placement of new eastbound embankment fill will cause more than 150 mm of settlement as noted in Section 10.6. If the wingwall/retaining wall structures for the eastbound lanes cannot accommodate that amount of settlement, the site will have to be pre-loaded or the culvert should be lengthened to eliminate the need for wingwalls / retaining walls.

A retained soil system (RSS) for a culvert wingwall or retaining wall is not recommended at this site as it is located within a watercourse and could be affected by fluctuating water levels.

10.3 Subgrade Preparation, Bedding and Backfilling

“Granular A” and “Granular B Type II” in this section refer to OPSS Granular A or Granular B Type II meeting the specifications of OPSS.PROV 1010 and SP110S06. “Granular A” is further defined as “Quarry-Source Granular A” unless specifically described as “Pit-Source Granular A”.

10.3.1 Culverts

The foundation subgrade should be prepared as per OPSS 422.07.06 using Granular A material as backfill of over-excavated areas, where required. The granular shall be compacted as per OPSS.PROV 501. The cohesionless fills below the water table in Boreholes N20-1 and N20-2 are considered unsuitable (See Section 8.3) and should be removed.

In order to provide a more uniform foundation subgrade condition for the culvert foundations, a bedding layer and levelling course shall be provided as per OPSD 803.010 (notwithstanding culvert span) and OPSS 422. A minimum bedding thickness of 0.3 m of Granular A is recommended.

Given the sensitive subgrade clay soils anticipated at the founding level of the culverts, construction equipment should not be permitted to travel on the exposed subgrade. The compaction of granular bedding directly above the subgrade may result in disturbance of the material with pumping of fines into the granular bedding and difficulty achieving the specified degree of compaction. After inspection and approval of the subgrade, protection of the subgrade should include installation of a Class II, non-woven geotextile with a maximum FOS of 150 μ m (OPSS.PROV 1860) installed beneath the Granular A material. The geotextile should be placed as soon as possible after preparation of the final subgrade level. Alternately, the geotextile and bedding material could be replaced with a 200 mm thick, concrete working slab placed on the prepared subgrade prior to placement of the levelling course. The working slab should extend at least 0.5 m beyond the outside dimensions of the culvert. An NSSP is provided in Appendix H to include in the contract documents to alert the Contractor of the sensitive nature of the foundation soils.

It is noted that construction will extend below groundwater elevation. Creek diversion and 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.



The limits of structural backfill should be in accordance with OPSD 3101.150. Structural backfill adjacent to the culvert should consist of Granular A or Granular B Type II placed and compacted in accordance with OPSS.PROV 501. Heavy compaction equipment used adjacent to the culvert must be restricted in accordance with OPSS.PROV 501.07.02a).

10.3.2 Wingwalls / Retaining Walls

The foundation subgrade should be prepared as per OPSS.PROV 902 using Granular A material as backfill of over-excavated areas, where required. The cohesionless fills below the water table in Boreholes N20-1 and N20-2 are considered unsuitable (See Section 8.3) and should be removed.

The walls should be founded on a granular pad with a minimum thickness of 0.3 m consisting of Granular A material. The top of the Granular A pad must extend to 0.5 m beyond the outside edge of all sides of the footing and sloped away from the footing at 1H:1V, or flatter. The granular shall be compacted as per OPSS.PROV 501.

Given the sensitive subgrade clay soils anticipated at the founding level of the wingwalls/retaining walls, construction equipment should not be permitted to travel on the exposed subgrade. The compaction of granular directly above the subgrade may result in disturbance of the material with pumping of fines into the granular and difficulty achieving the specified degree of compaction. After inspection and approval of the subgrade, protection of the subgrade should include installation of a Class II, non-woven geotextile with a maximum FOS of 150 μm (OPSS.PROV 1860) installed beneath the Granular A material. The geotextile should be placed as soon as possible after preparation of the final subgrade level. Alternately, the geotextile and granular pad could be replaced with a 200 mm thick, concrete working slab placed on the prepared subgrade. The working slab should extend at least 0.5 m beyond the outside dimensions of the footing. An NSSP is provided in Appendix H to include in the contract documents to alert the Contractor of the sensitive nature of the foundation soils.

It is noted that construction will extend below groundwater elevation. Creek diversion and 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.

The limits of structural backfill should be in accordance with OPSD 3101.150. Structural backfill adjacent to the wingwalls/retaining walls should consist of OPSS Granular A or Granular B Type II placed and compacted in accordance with OPSS.PROV 501. Heavy compaction equipment used adjacent to the retaining walls must be restricted in accordance with OPSS.PROV 501.07.02a).

10.4 Frost Penetration Depth

The depth of frost penetration at this site is estimated to be 1.9 m (as per OPSD 3090.101); shallow foundations should be founded at or below this depth or provided with equivalent insulation. Closed-bottom, box culverts are not typically provided with frost protection.

Please refer to the pavement design report for frost taper recommendations for the pavement.



10.5 Backfill and Lateral Earth Pressures

Structural backfill material should consist of Granular A or Granular B Type II meeting the OPSS.PROV 1010 and SP110S06 specifications. Large scale direct shear box testing on samples of Granular A and Granular B Type II from numerous nearby aggregate sources was completed for this project. The results indicate that for design of structural backfill for this project, an internal angle of friction of 40 degrees and 42 degrees can be used for quarry-sourced Granular A and Granular B Type II, respectively in this area provided the effective vertical pressure on the material is less than 150 kPa (Geocres Memorandum 31F-213). An Operational Constraint will be required in the contract restricting the source of Granular A to quarries. Throughout this report, the term “Granular A” is defined as “Quarry-Source Granular A” unless specifically described as “Pit-Source Granular A”.

The backfill must be in accordance with OPSS 902 and placed to the extents shown on OPSD 3101.150 for the culvert and wingwalls/retaining walls. The design of the wingwalls/retaining walls, where required, must incorporate a subdrain as shown in OPSD 3101.150.

Lateral earth pressure parameters provided in Table 10-1 and Table 10-2 in the sections below are based on the assumptions that the wall is vertical and the backfill is fully drained so that there are no unbalanced hydrostatic pressures above the permanent groundwater level. If adequate drainage cannot be confirmed, the potential for buildup of hydrostatic pressures should be considered in design.

Where back slopes are horizontal, the corresponding coefficients provided in Table 10-1 and Table 10-2 should be used. For other backfill and wall geometries, Thurber will need to calculate the appropriate earth pressure coefficients once the final geometry is confirmed.

10.5.1 Static Lateral Earth Pressure

Lateral earth pressures acting on structures should be computed in accordance with the CHBDC. Under drained conditions the lateral earth pressure is generally given by the following expression:

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

where:

σ_h	=	horizontal pressure on the wall at depth h (kPa)
K	=	earth pressure coefficient (see table below) (K_a for yielding walls, K_o for non-yielding walls)
γ	=	unit weight of retained soil (see table below), use submerged unit weight below 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 OPSS Granular A and OPSS Granular B Type II backfill are shown in Table 10-1.

Table 10-1: Static Earth Pressure Coefficients

Condition	Quarry Sourced OPSS Granular A $\phi = 40^\circ, \gamma = 22.8 \text{ kN/m}^3$	Pit Sourced OPSS Granular A $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$	Quarry Sourced OPSS Granular B Type II $\phi = 42^\circ, \gamma = 22.8 \text{ kN/m}^3$
Coefficient of at Rest Earth Pressure, K_o (Restrained Wall)	0.36	0.43	0.33
Coefficient of Active Earth Pressure, K_A (Unrestrained Wall)	0.22	0.27	0.20

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 movement required can be assessed from Table C6.12 of the Commentary to the CHBDC. Active earth pressures should be used for any wingwalls or unrestrained walls. For rigid structures, at-rest horizontal earth pressures would apply for design.

10.5.2 Combined Static and Seismic Lateral Earth Pressure

In accordance with Clause 6.14 of the current version of CHBDC, retaining structures should be designed using dynamic earth pressure coefficients that incorporate the effects of earthquake loading. The following recommendations are per Section C6.14 of the Commentary of the CHBDC which states that seismically induced lateral soil pressures may be calculated using the Mononobe-Okabe Method with:

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

The coefficients of horizontal earth pressure for combined static and 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 with a 2% probability of exceedance in 50 years of 0.227g (Geological Survey of Canada – Fifth Generation) and a $F(\text{PGA})$ of 1.135 as per Table 4.8 of the current version of CHBDC.

Table 10-2: Combined Static and Seismic Earth Pressure Coefficients

Condition	Quarry Sourced OPSS Granular A $\phi = 40^\circ, \gamma = 22.8 \text{ kN/m}^3$	Pit Sourced OPSS Granular A $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$	Quarry Sourced OPSS Granular B Type II $\phi = 42^\circ, \gamma = 22.8 \text{ kN/m}^3$
Coefficient of Active Earth Pressure, K_{AE} (Restrained Wall)	0.37	0.44	0.34
Coefficient of Active Earth Pressure, K_{AE} (Unrestrained Wall)	0.28	0.35	0.26

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:

σ_h	=	lateral earth pressure at depth d (kPa)
d	=	depth below the top of the wall (m)
K	=	static earth pressure coefficient (K_A for yielding walls, K_o for non-yielding walls)
γ	=	unit weight of retained soil, use submerged unit weight below groundwater level
K_{AE}	=	combined static and seismic earth pressure coefficient
H	=	total height of the wall (m)

10.6 Embankment Fill

Embankments should be constructed in accordance with OPSS.PROV 206. Local marine clay must not be used as embankment fill.

10.6.1 Embankment Stability

Embankment stability has been assessed perpendicular to the highway alignment. Analyses were completed for the proposed eastbound embankment and the reinstatement of the existing highway embankment (proposed westbound).

The slope stability analyses were carried out using GeoStudio 2020 Slope/W software for limit equilibrium analysis. Input parameters for the embankment fill and foundation soils for the analysis are based on the SPT N values, undrained shear strength and the results of laboratory testing

and are summarized on the stability analyses outputs provided in Appendix G. The following additional parameters and assumptions were used in the analysis:

- The soil stratigraphy is based on the nearest boreholes.
- A maximum fill height of 3.9 m.
- Eastbound embankment: options for conventional 2H:1V SSM/Granular B Type I, 1.25H:1V rockfill or retaining wall.
- Westbound embankment: reinstatement of conventional 2H:1V SSM/Granular B Type I and retaining wall.
- Retaining walls: concrete retaining walls must be founded at or below the frost depth outlined in Section 10.4 on a granular pad as outlined in Section 10.2. The recommendations provided for retaining walls are based on the strength parameters of quarry-source Granular A material.
- A site adjusted PGA value of 0.130 g, equal to ½ of the site adjusted PGA value (0.259 g), was used for seismic analysis, as per Section 4.4.3.3, of the CHBDC and outlined in Section 8.2 above.
- A traffic surcharge of 17 kPa has been applied as a temporary load.

Copies of the output from the stability analyses are provided in Appendix G. Each output figure shows the slope geometry, groundwater conditions, soil stratigraphy and soil strength parameters utilized in the analysis.

The stability analyses generated the following factor of safety values for the proposed eastbound embankment design:

Table 10-3 Slope Stability Analysis Results for Eastbound Embankment

Condition	Case	Factor of Safety		
		2H:1V [SSM/Granular BI]	1.25H:1V [Rockfill]	Retaining Wall [Granular A*]
Temporary (traffic loading)	Short Term (Undrained)	1.9 (Fig G1-1)	1.7 (Fig G2-1)	3.0 (Fig G3-1)
Permanent (no traffic loading)	Long Term (Drained)	1.6 (Fig G1-2)	1.5 (Fig G2-2)	1.9 (Fig G3-2)
Temporary (includes seismic)	Pseudo-Static Seismic (Undrained)	1.4 (Fig G1-3)	1.4 (Fig G2-3)	1.9 (Fig G3-3)

Note: * Quarry Sourced Granular A

The stability analyses generated the following factor of safety values for the reinstated westbound embankment design:

Table 10-4 Slope Stability Analysis Results for Westbound Embankment

Condition	Case	Factor of Safety [GBI]	
		2H:1V [SSM/Granular BI]	Retaining Wall [Granular A*]
Temporary (no traffic loading)	Short Term (Undrained)	1.9 (Fig G4-1)	3.3 (Fig G5-1)
Permanent (no traffic loading)	Long Term (Drained)	1.6 (Fig G4-2)	1.9 (Fig G5-2)
Temporary (includes seismic)	Pseudo-Static Seismic (Undrained)	1.4 (Fig G4-3)	2.2 (Fig G5-3)

Note: * Quarry Sourced Granular A

Table 6.2 of the CHBDC for embankment fills with a typical degree of understanding and a Ψ of 1.0 generates minimum Factors of Safety of 1.5 and 1.3 for permanent and temporary conditions respectively. All of the static results presented in Table 10-3 and Table 10-4 meet or exceed the target Factors of Safety.

Table 6.3 in Section 6.14.4.1 of the CHBDC indicates a minimum seismic resistance factor of 0.95 for force-based design and 1.0 for performance-based design. Based on these values and Ψ of 1.0, a target Factor of Safety of 1.1 for this temporary condition with a typical degree of understanding is appropriate for the pseudo-static seismic analysis. The pseudo-static result presented in Table 10-3 and Table 10-4 above, exceeds the target Factor of Safety for seismic design. It is noted that some displacement of the embankment can occur where the pseudo-static Factor of Safety is less than 1.3. However, as noted in Table 10-3 and Table 10-4 this criterion has also been satisfied for all cases.

The proposed embankment slopes satisfy all of the static and pseudo-static slope stability requirements.

Should slope flattening of the rock fill embankments be used onsite with surplus excavated material, slope protection and drainage measures will be required to ensure the long-term surficial stability of the embankment slopes, see Section 11.4. Slope flattening should meet the requirements of OPSD 202.010 and OPSD 202.020.

10.6.2 Embankment Settlement

The reinstated eastbound embankment will have a similar height and footprint to the existing. The proposed culvert opening is greater than the existing, thus, the construction represents a net unloading. No additional settlement is expected along the existing alignment. However, settlement should be reviewed if the embankments are widened or reinstated to design grades greater than the existing grades.

The proposed westbound lanes will result in a fill height of about 3.9 m across the proposed culvert. Settlement of the future highway embankment needs to be considered not only in terms



of pavement performance on the approaches but also in selection and design of the culvert foundations.

An assessment of the time dependent settlement that would result from construction of the proposed Highway 17 WBL embankment was carried out using Rocscience's Settle3 modelling software with a Boussinesq stress distribution. The soil stratigraphy was defined based on borehole data and the water table was defined based on piezometer readings. It is noted that engineering judgment and experience were used to select the material properties based on the stress range anticipated due to loading.

The following has been assumed for the embankment geometry:

- Height = 3.9 m
- Length = 100 m
- Platform Width = 14.75 m (assuming ramp lane width of 3.75 m)
- Side slopes (Granular) = 2H:1V
- Side Slopes (Rockfill) = 1.25H:1V

It is recommended that slope flattening not be used in the area within 50 m of the culvert to reduce the culvert length and to reduce the magnitude of settlement.

The geotechnical parameters used in the settlement analysis were based on an average of the borehole stratigraphies and consolidation test results from similar soils at the Bruce Street site, approximately 700 m east of the Culvert at 17+893 (Gecores Report No. 31F-234).

The cohesive stratum was separated into two sub-layers, upper and lower. Table 10-5 presents the properties used in the Settle3 analysis for the various sub-layers.

Table 10-5: Settle3 Inputs

Layer	Elevation (m)	C _c (-)	c _v (cm ² /s)	C _r (-)	c _{vr} (cm ² /s)	P _c ' (kPa)	e _o (-)
Upper Silt/Clay	145 to 143	0.7	0.0009	0.04	0.003	400	1.2
Lower Silt/Clay	143 to 134	0.5	0.006	0.04	0.03	400 to 200	1.1
	134 to 110					200 to 400	

At the proposed eastbound embankment, the following settlement magnitude and durations are expected:

- Granular: 150 mm of settlement with substantial completion in 20 months
- Rockfill: 135 mm of settlement with substantial completion in 20 months

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



Settlement of the existing highway (proposed westbound) due to the construction of the new eastbound embankment is expected to be less than 25 mm.

MTO guidelines for settlement of freeway approach embankments within structure transition zones over a period of 20 years after paving is outlined below:

- 25 mm within 20 m of the structure;
- 50 mm from 20 to 50 m from the structure;
- 75 mm from 50 to 75 m from the structure; and
- 100 mm greater than 75 m from the structure

Based on these guidelines, the total embankment settlement of the eastbound embankment exceed these criteria. Therefore, it is recommended that a full height preload and a temporary CSP culvert be constructed and left in place for a duration of 20 months to ensure that post-construction settlement meets the above guidelines. The end of preload will need to be confirmed with a settlement monitoring program. The preload material would then be excavated to remove the temporary CSP and construct the permanent highway culvert.

A pre-load will also be required to facilitate the construction of retaining walls / wingwalls, if required.

10.7 Cement Type and Corrosion Potential

Chemical analysis for determination of pH, water soluble sulphate, sulphides, chloride concentrations, resistivity and electrical conductivity was carried out on samples of the native materials. The analysis results are summarized in Section 5.6 and a copy of the test results is provided in Appendix C.

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 5.6 were compared with Table 3.2 of the MTO Gravity Pipe Design Guideline and indicate a severe corrosive environment. The test results provided in Section 5.6 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects.

The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with the soil and groundwater at the site. The sulphate results in were compared with Table 3 of Canadian Standards Association Standards A23.1-19 (CSA A23.1) and indicate a low degree of sulphate attack potential on concrete structures at this site.

The corrosive effects of road de-icing salts should also be considered.



11 CONSTRUCTION CONSIDERATIONS

11.1 Temporary Excavations

All temporary excavations must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of OHSA, the stiff to very stiff clayey silt and clay soils are considered Type 3 soils. Side slopes for excavations through more than one soil type must be entirely based on the highest soil type number. Unsupported excavations made in Type 3 soils must have side slopes no steeper than 1H:1V from the base of the excavation.

Excavation should be carried out in accordance OPSS 902. The management and disposal of excess material shall be in accordance with OPSS.PROV 180. Excavations will extend into the underlying native deposits (clay to clayey silt). 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.

Although not anticipated, at locations where there are space restrictions, the excavations could 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 (TPS) could be used for excavation support or groundwater control, they must be implemented in accordance with OPSS.PROV 539 and designed for Performance Level 2. 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 protection system should be installed at a suitable distance away from the new structures to limit the disturbance to subgrade associated with removal of the protection system following completing of construction. Alternatively, the protection system near the structures could be left in place and cut off in accordance with OPSS.PROV 903 to limit the disturbance of subgrade during removal of the TPS.

Lateral earth pressure coefficients, 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. The lateral earth pressure coefficients for the underlying native soils are given below for a vertical wall and a horizontal backslope:



Existing Fill:

$$\begin{array}{rcl} \gamma & = & 21.0 \text{ (kN/m}^3 \text{ bulk unit weight of soil, to be adjusted below water)} \\ K_A & = & 0.33 \\ K_P & = & 3.0 \end{array}$$

Native clay to clayey silt:

$$\begin{array}{rcl} \gamma & = & 17.0 \text{ (kN/m}^3 \text{ bulk unit weight of soil, to be adjusted below water)} \\ K_A & = & 0.36 \\ K_P & = & 2.8 \end{array}$$

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.

When designing roadway protection systems, the Contractor should consider the potential for obstructions such as cobbles and boulders in existing embankment. Although not encountered in the on-road boreholes at this site, rockfill embankments have been noted along Highway 17 within the project limits. Installation of interlocking sheet piles should be feasible at this site given the contractor has the equipment necessary to deal with the potential obstructions. A soldier pile lagging system is also a feasible option. Lateral support for either alternative can be enhanced by using bracing or rakers. Suggested wording for an NSSP for obstructions is included in Appendix H.

11.3 Surface and Groundwater Control

Culvert and wingwall/retaining wall construction (if required), subgrade preparation and placement and compaction of granular bedding must be carried out in the dry. Based on the groundwater elevation at the time of the investigation, it is anticipated that the site will require dewatering to lower the groundwater to below the final excavation or footing level. Furthermore, surface runoff will tend to seep into and accumulate into the excavations. The Contractor must control groundwater, perched groundwater and surface water flow at the site to permit construction in a dry and stable excavation.

Subgrade preparation, placement and compaction of granular bedding, culvert and retaining wall construction must be carried out with a properly designed dewatering system to control groundwater and creek/surface water and may include cofferdams, creek diversion, pumping etc. The temporary flow diversion pipe should be placed outside the construction area. The dewatering system will be required to remain operational and effective until the temporary excavations are backfilled and then should be decommissioned and removed.

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 SP No. FOUN0003 which amends OPSS 902 and SP517F01 which amends OPSS.PROV 517. Given the site conditions and anticipated works, the Designer Fill-In ***** in SP517F01 Table A



should be “No”; the design Engineer and design-checking Engineer do not need a minimum of 5 years of experience in designing similar dewatering systems. A preconstruction survey is not required, thus Designer Fill-In ** in this SP should be “NA”.

The water level will fluctuate and the minimum groundwater elevation for the site at the time of the excavation should be taken as the expected high water level defined in SP517F01 and SP FOUN0003.

It is anticipated that sump pumps will likely be sufficient to extract water from the excavation for the culverts. Pumping from within a sandbag cofferdam system is one option. A sheet pile cofferdam enclosure driven into the foundation clay may also be considered, see Section 11.2 above). The groundwater level within the work zone should be lowered by pumping from sumps to a minimum of 0.5 m below the underside of the planned excavation base prior to each stage of excavation.

Further assessment of dewatering requirements and the need for a Permit to take Water (PTTW) should be carried out by specialists experienced in this field.

It is noted that a Hydrogeological Investigation and Design Report is under preparation for the Highway 17 Twinning Project. Please refer to that document for additional discussion on dewatering with respect to this assignment.

11.4 Erosion and Scour Control

The Contractor should provide silt fences and erosion control blankets as per OPSS 805 throughout the duration of construction to prevent transport of silt/sediment into the creek.

Slope protection and drainage measures will be required to ensure the long-term surficial stability of the earth and granular embankment slopes. A vegetation cover should be established on exposed earth surfaces to protect against surficial erosion in general accordance with OPSS.PROV 804. Slope vegetation should be established as soon as possible after completion of the embankment fills in order to limit surficial erosion.

Particle size analysis on samples of the existing embankment materials and native silts indicate that the soils have a low and moderate potential for soil erodibility respectively (Wischmeier Nomograph factor, K of 0.15 and 0.2, respectively).

Scour protection should be provided at the culvert inlet and outlet areas. Effective scour and erosion protection should be provided along the waterline, ditches and around footings. Design of the erosion protection measures must consider hydrologic and hydraulic factors and shall be carried out by specialists experienced in this field. Typically, rock protection as per OPSS.PROV 511 should be provided over all surfaces with which creek water is likely to be in contact. Treatment at the inlet and outlet of culverts shall be in accordance with OPSD 810.010.



Liaison between the Foundations Consultant, Structural Engineer and Hydraulic/Drainage Engineer will be required in design to ensure that scour protections, if required, is adequately addressed.

12 CONSTRUCTION CONCERNS

The likely construction methodology includes open cut excavations for the installation of foundation elements of new culverts. Potential construction concerns may include, but are not necessarily limited to:

- Construction will extend below the water level in the creek. An adequate and effective surface water management and dewatering plan must be implemented to construct the culverts and wingwall/retaining wall foundations in the dry.
- The native soil which will be exposed beneath a culvert bedding layer or wing wall/retaining wall spread footings is sensitive and readily disturbed. A suggested Notice to Contractor is provided in Appendix H.
- The Contractor's selection of construction equipment and methodology must include assessment of the capability of the existing soils to support the proposed construction equipment and supplies.
- Obstructions could be encountered in the existing embankment fill and may limit choice of equipment and methods used.
- Mitigation of the settlement induced by the new westbound embankment will require a preload or a structure designed to accommodate the movements. An instrumentation and monitoring program will need to be implemented to assess the progress of the preload. Given the limited project length, the monitoring program would include approximately six settlement rods located on the new alignment with a nominal spacing of 25 m. The base plates should be installed prior to fill placement and the rods will require extension as fill is placed around them. The top of the settlement rods should be surveyed every week during preload construction, then every two weeks for four months, then every month for the duration of the anticipated preload period (see Section **Error! Reference source not found.**). The installation of the monitoring equipment and surveying would typically be carried out by the Contractor, with the results evaluated by the Contract Administration team.

The successful performance of the structure installations will depend largely upon good workmanship and quality control during construction. Observation of the excavation and backfilling operations will be required as per OPSS 902 during construction to confirm that the foundation recommendations are correctly implemented, and material specifications are met.



13 CLOSURE

Engineering analysis and preparation of this report was carried out by Dr. Fred Griffiths, 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:



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Senior Geotechnical Engineer,
Senior Associate



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MTO Review Principal,
Senior Geotechnical Engineer



REFERENCES

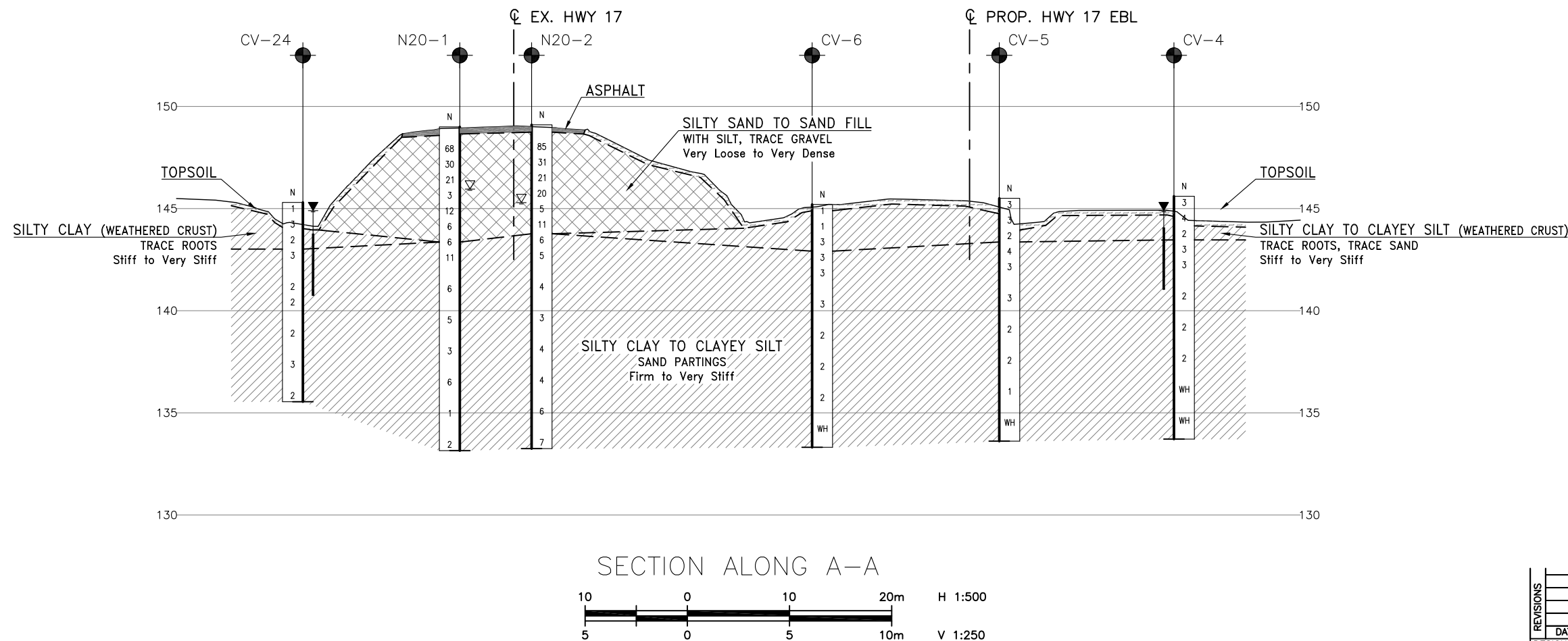
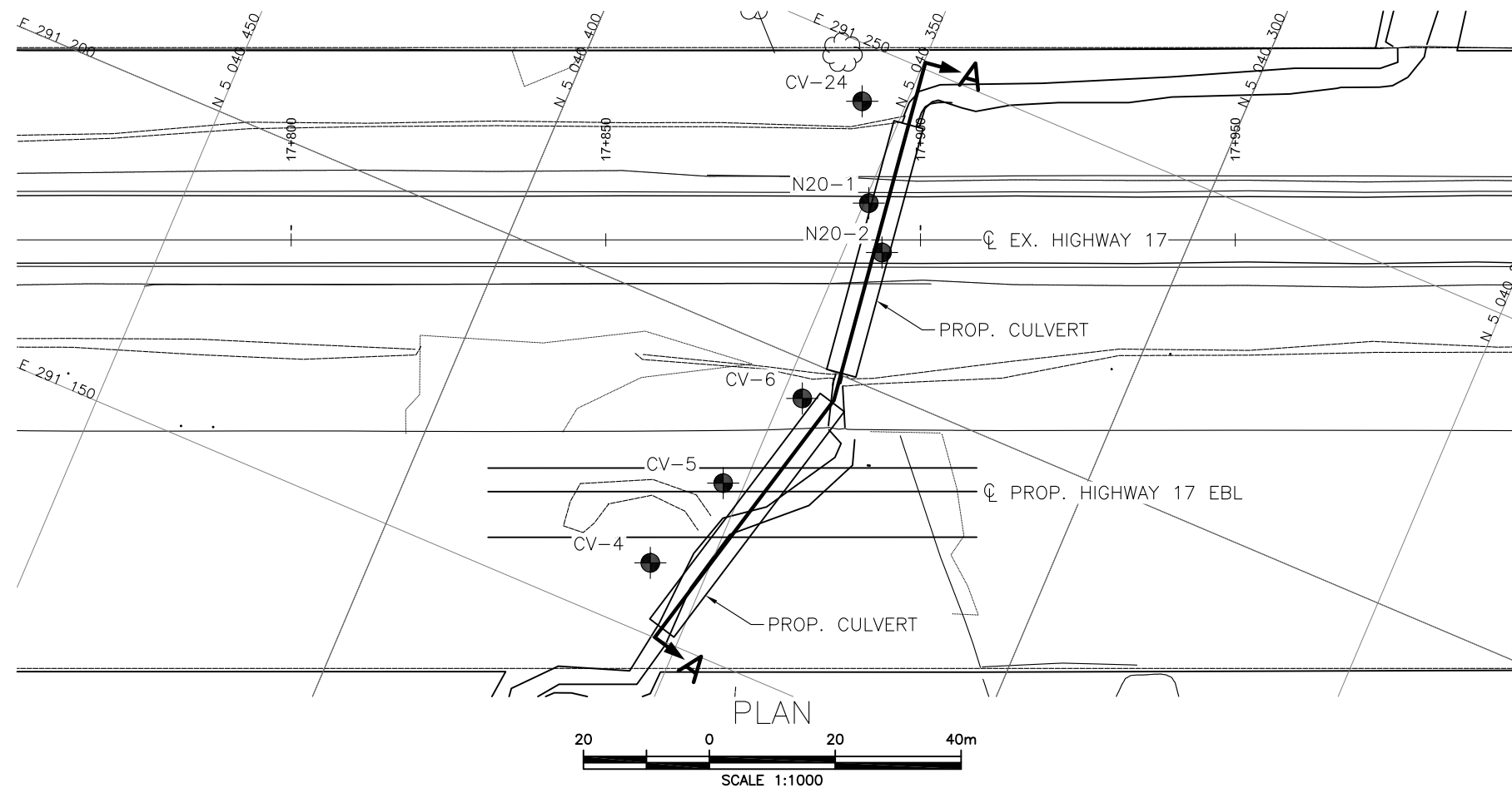
ⁱ Boulanger, R. W. and Idriss, I. M. (2007). Evaluation of cyclic softening in silts and clays, ASCE, Journal of Geotechnical and Geoenvironmental Engineering, 133(6), 641-652.

ⁱⁱ Boulanger, R. W., and Idriss, I. M. (2014). CPT and SPT based liquefaction triggering procedures, Report No. UCD/CGM-14/01, Center for Geotechnical Modeling, Department of Civil and Environmental Engineering, University of California, Davis, CA, 134 pp.6

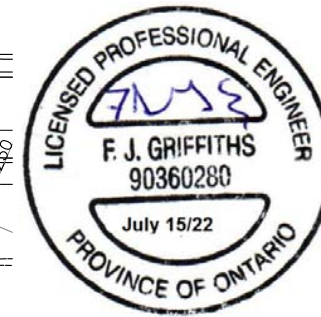




Appendix A.

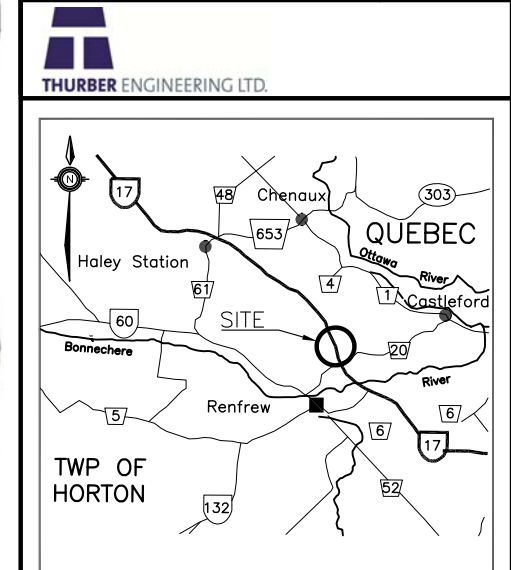
Borehole Location Plan and Stratigraphic Drawings



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







CONT No WP No	
HIGHWAY 17 TWINNING CULVERT STA. 17+893	SHEET
BOREHOLE LOCATIONS AND SOIL STRATA	



KEYPLAN

LEGEND

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

[illegible]

-NOTES-

- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Structural elements, surface details and features are for conceptual illustration.
- 3) Coordinate system is MTM NAD 83 Zone 9.

GEOCRES No. 31F-228

REVISIONS									
	DATE	BY	DESCRIPTION						
DESIGN	DP	CHK	FG	CODE	LOAD	DATE		JUL 2022	
DRAWN	MFA	CHK	PKC	SITE	STRUCT	DWG		1	



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).

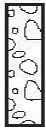
DYNAMIC CONE PENETRATION TEST (DCPT):

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 CV-24

1 OF 2

METRIC

WP# 4068-09-00 LOCATION Culvert 17+893 MTM Zone 9: N 5 040 356.6 E 291 241.4 ORIGINATED BY AO
 HWY 17 BOREHOLE TYPE CME45 Trackmount, HSA COMPILED BY AO
 DATUM Geodetic DATE 2021.04.26 - 2021.04.26 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W _P W W _L			
145.3	Ground Surface							20 40 60 80 100					
0.0	TOPSOIL (200 mm)							20 40 60 80 100					
0.2	SILTY CLAY (CI), trace roots Stiff to very stiff Grey-brown with yellow mottles (WEATHERED CRUST)		1	SS	1		145						
			2	SS	3								
							144						
			3	SS	2								
							143						
143.0			4	SS	3								
2.3	SILTY CLAY (CI) Firm to very stiff Grey						142						
			5	SS	2								
			6	SS	2								
			7	SS	2								
							140						
							139						
							138						
			8	SS	3								
							137						
			9	SS	2								
135.5							136						
9.8	End of Borehole												

Continued Next Page

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 (%) STRAIN AT FAILURE

ONTMT4S 24726 CULVERT 17+893 GINT.GPJ 2012TEMPLATE(MTO).GDT 22-6-23

RECORD OF BOREHOLE No CV-24

2 OF 2

METRIC

WP# 4068-09-00 LOCATION Culvert 17+893 MTM Zone 9: N 5 040 356.6 E 291 241.4 ORIGINATED BY AO
 HWY 17 BOREHOLE TYPE CME45 Trackmount, HSA COMPILED BY AO
 DATUM Geodetic DATE 2021.04.26 - 2021.04.26 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	Continued From Previous Page																
	Monitoring well installation consists of 50-mm diameter Schedule 40 PVC pipe with a 3-m slotted screen																
	DATE DEPTH (m) ELEV. (m)																
	2021.08.04 0.4 144.9																
	2021.09.22 0.8 144.5																
	2021.10.05 0.2 145.1																
	2022.01.19 0.6 144.7																

ONTMT4S 24726 CULVERT 17+893 GINT.GPJ 2012TEMPLATE(MTO).GDT 22-6-23

RECORD OF BOREHOLE No CV-4

1 OF 2

METRIC

WP# 4068-09-00 LOCATION Culvert 17+893 MTM Zone 9: N 5 040 358.9 E 291 160.7 ORIGINATED BY AO
 HWY 17 BOREHOLE TYPE CME45 Trackmount, HSA COMPILED BY AO
 DATUM Geodetic DATE 2021.05.18 - 2021.05.18 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)			
145.6	Ground Surface							20 40 60 80 100		W _P W W _L			
0.0	TOPSOIL (300 mm)							○ UNCONFINED + FIELD VANE					
145.3			1	SS	3			● QUICK TRIAXIAL × LAB VANE					
0.3	SILTY CLAY (CI), trace roots Stiff to very stiff Grey-brown with yellow mottles (WEATHERED CRUST)						145			○			
			2	SS	4					○			
			3	SS	2					— ○		0 0 46 54	
143.5													
2.1	CLAYEY SILT (CL) Firm to very stiff Grey		4	SS	3		143			○			
			5	SS	3		142			○			
								+ +					
			6	SS	2		141			○			
								+ +					
			7	SS	2		139			— ○		0 0 48 52	
								4.3 + 3.8 +					
			8	SS	2		138			○			
								4.0 + 4.7 +					
			9	SS	WH					○		0 0 48 52	

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

RECORD OF BOREHOLE No CV-4

2 OF 2

METRIC

WP# 4068-09-00 LOCATION Culvert 17+893 MTM Zone 9: N 5 040 358.9 E 291 160.7 ORIGINATED BY AO
 HWY 17 BOREHOLE TYPE CME45 Trackmount, HSA COMPILED BY AO
 DATUM Geodetic DATE 2021.05.18 - 2021.05.18 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	WATER CONTENT (%)					
	Continued From Previous Page													
	CLAYEY SILT (CL) Firm to very stiff Grey													
133.7			10	SS	WH									
11.9	End of Borehole Monitoring well installation consists of 50-mm diameter Schedule 40 PVC pipe with a 3-m slotted screen DATE DEPTH (m) ELEV. (m) 2021.08.04 0.7 144.9 2021.09.22 1.0 144.6 2021.10.05 0.7 144.9 2021.10.20 0.8 144.8 2022.01.19 0.6 144.7													




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RECORD OF BOREHOLE No CV-5

1 OF 2

METRIC

WP# 4068-09-00 LOCATION Culvert 17+893 MTM Zone 9: N 5 040 353.2 E 291 176.9 ORIGINATED BY AO
 HWY 17 BOREHOLE TYPE CME45 Trackmount, HSA COMPILED BY AO
 DATUM Geodetic DATE 2021.05.17 - 2021.05.18 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				
145.5	Ground Surface							20 40 60 80 100				
0.0	TOPSOIL (460 mm)		1	SS	3		145	○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				
145.0								20 40 60 80 100				
0.5	SILTY CLAY (CI), trace roots Stiff to very stiff Grey-brown with yellow mottles (WEATHERED CRUST)		2	SS	3		144	20 40 60 80 100				0 1 46 53
								20 40 60 80 100				
			3	SS	2			20 40 60 80 100				
143.4								20 40 60 80 100				
2.1	SILTY CLAY (CI) Contains sand partings Firm to very stiff Grey-brown		4	SS	4		143	20 40 60 80 100				
								20 40 60 80 100				
			5	SS	3		142	20 40 60 80 100				0 0 49 51
								20 40 60 80 100				
								20 40 60 80 100				
			6	SS	3		141	20 40 60 80 100				
								20 40 60 80 100				
								20 40 60 80 100				
			7	SS	2		140	20 40 60 80 100				
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			8	SS	2		139	20 40 60 80 100				
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								20 40 60 80 100				
								20 40 60 80 100				
								20 40 60 80 100				
								20 40 60 80 100				
			9	SS	1		138	20 40 60 80 100				
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(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No CV-5

2 OF 2

METRIC

WP# 4068-09-00 LOCATION Culvert 17+893 MTM Zone 9: N 5 040 353.2 E 291 176.9 ORIGINATED BY AO
 HWY 17 BOREHOLE TYPE CME45 Trackmount, HSA COMPILED BY AO
 DATUM Geodetic DATE 2021.05.17 - 2021.05.18 CHECKED BY FG




SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL LIMIT MOISTURE LIQUID CONTENT LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					WATER CONTENT (%) w _P w w _L					
	Continued From Previous Page							20	40	60	80	100		20	40	60		
133.6 11.9	SILTY CLAY (CI) Contains sand partings Firm to very stiff Grey-brown						135											0 2 52 46
			10	SS	WH		134											
	End of Borehole																	

RECORD OF BOREHOLE No CV-6

1 OF 2

METRIC

WP# 4068-09-00 LOCATION Culvert 17+893 MTM Zone 9: N 5 040 346.9 E 291 194.2 ORIGINATED BY AO
 HWY 17 BOREHOLE TYPE CME45 Trackmount, HSA COMPILED BY AO
 DATUM Geodetic DATE 2021.05.14 - 2021.05.17 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
145.2	Ground Surface							<div><div>20406080100</div><div>○ UNCONFINED + FIELD VANE</div><div>● QUICK TRIAXIAL × LAB VANE</div></div>					
0.0	TOPSOIL (300 mm)							<div><div>20406080100</div><div>PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT</div><div>W_P — W — W_L</div><div>WATER CONTENT (%)</div></div>					
144.9			1	SS	1		145						
0.3	CLAYEY SILT (CL), trace roots, trace sand Stiff to very stiff Grey-brown with yellow mottles (WEATHERED CRUST)												
			2	SS	1		144						
			3	SS	3								
							143						0 0 59 41
142.9													
2.3	SILTY CLAY (CI) Contains sand partings Stiff to very stiff Grey-brown		4	SS	3								
			5	SS	3		142						
							141						
			6	SS	3								0 0 49 51
							140						
			7	SS	2		139						
							138						
			8	SS	2								0 0 46 54
							137						

Continued Next Page

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ONTMT4S 24726 CULVERT 17+893 GINT.GPJ 2012TEMPLATE(MTO).GDT 22-6-23

RECORD OF BOREHOLE No CV-6

2 OF 2

METRIC

WP# 4068-09-00 LOCATION Culvert 17+893 MTM Zone 9: N 5 040 346.9 E 291 194.2 ORIGINATED BY AO
 HWY 17 BOREHOLE TYPE CME45 Trackmount, HSA COMPILED BY AO
 DATUM Geodetic DATE 2021.05.14 - 2021.05.17 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE							
	Continued From Previous Page															
133.3 11.9	SILTY CLAY (CI) Contains sand partings Stiff to very stiff Grey-brown						135									
			10	SS	WH		134									
	End of Borehole															

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

RECORD OF BOREHOLE No N20-1

1 OF 2

METRIC

WP# 4068-09-00 LOCATION Culvert 17+893 MTM Zone 9: N 5 040 349.3 E 291 226.9 ORIGINATED BY NW
 HWY 17 BOREHOLE TYPE CME55 Truckmount, HQ Casing COMPILED BY MW
 DATUM Geodetic DATE 2020.05.11 - 2020.05.11 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				GR	SA	SI	CL
149.0	Pavement Surface																		
0.0	ASPHALT (350 mm)							○ UNCONFINED + FIELD VANE											
148.6								● QUICK TRIAXIAL × LAB VANE											
0.4	SILTY SAND to SAND with silt, trace gravel Very loose to very dense Brown Moist to Wet (FILL)		1	SS	68		148							○					
			2	SS	30		147							○				2 82 16 (SI+CL)	
			3	SS	21									○					
			4	SS	3		146												
			5	SS	12		145												
			6	SS	6		144												
			7	SS	6										○				
			8	SS	11		143								○				1 4 43 52
			9	SS	6		142												
			10	SS	5		141									○			
143.4	SILTY CLAY (CI) Stiff to very stiff Grey						140												

Continued Next Page

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

ONTMT4S 24726 CULVERT 17+893 GINT.GPJ 2012TEMPLATE(MTO).GDT 22-6-23

RECORD OF BOREHOLE No N20-1

2 OF 2

METRIC

WP# 4068-09-00 LOCATION Culvert 17+893 MTM Zone 9: N 5 040 349.3 E 291 226.9 ORIGINATED BY NW
 HWY 17 BOREHOLE TYPE CME55 Truckmount, HQ Casing COMPILED BY MW
 DATUM Geodetic DATE 2020.05.11 - 2020.05.11 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE				w _p w w _L				
						● QUICK TRIAXIAL × LAB VANE										
	Continued From Previous Page						20 40 60 80 100									
	SILTY CLAY (CI) Stiff to very stiff Grey						7.2 +									
		11	SS	3		138									0 2 61 37	
		12	SS	6		137										
		13	SS	1		135										
							13.3 +									
							22.5 +									
			14	SS	2											
133.2																
15.8	End of Borehole Water observed at 3.0m during drilling.															



ONTMT4S 24726 CULVERT 17+893 GINT.GPJ 2012TEMPLATE(MTO).GDT 22-6-23

RECORD OF BOREHOLE No N20-2

1 OF 2

METRIC

WP# 4068-09-00 LOCATION Culvert 17+893 MTM Zone 9: N 5 040 344.3 E 291 220.5 ORIGINATED BY NW
 HWY 17 BOREHOLE TYPE CME55 Truckmount, HQ Casing COMPILED BY MW
 DATUM Geodetic DATE 2020.05.12 - 2020.05.12 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	W _P W W _L	WATER CONTENT (%)					
149.1	Pavement Surface														
0.0 148.8	ASPHALT (255 mm)						149								
0.3	SILTY SAND to SAND with silt, trace gravel Compact Brown Moist (FILL)		1	SS	85		148								
			2	SS	31		147								
			3	SS	21		146								
			4	SS	20		145								
			5	SS	5		144								
			6	SS	11		143								
			7	SS	6		142								
			8	SS	5		141								
			9	SS	4		140								
			10	SS	3										
143.8	CLAYEY SILT (CL) to SILTY CLAY (CI) Stiff to very stiff Grey														
7			SS	6											
8			SS	5											
9			SS	4											
5.3															

ONTMT4S 24726 CULVERT 17+893 GINT.GPJ 2012TEMPLATE(MTO).GDT 22-6-23

Continued Next Page

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

RECORD OF BOREHOLE No N20-2

2 OF 2

METRIC

WP# 4068-09-00 LOCATION Culvert 17+893 MTM Zone 9: N 5 040 344.3 E 291 220.5 ORIGINATED BY NW
 HWY 17 BOREHOLE TYPE CME55 Truckmount, HQ Casing COMPILED BY MW
 DATUM Geodetic DATE 2020.05.12 - 2020.05.12 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE								
								20 40 60 80 100	20 40 60							
	Continued From Previous Page						139									
	CLAYEY SILT (CL) to SILTY CLAY (CI) Stiff to very stiff Grey		11	SS	4											
				12	SS	4										
				13	SS	6										
			14	SS	7											
133.3																
15.8	End of Borehole Water observed at 3.8m during drilling.															

$+^3, \times^3$: Numbers refer to Sensitivity
 20
15
10
5
0
(%) STRAIN AT FAILURE



Appendix C.
Laboratory Testing

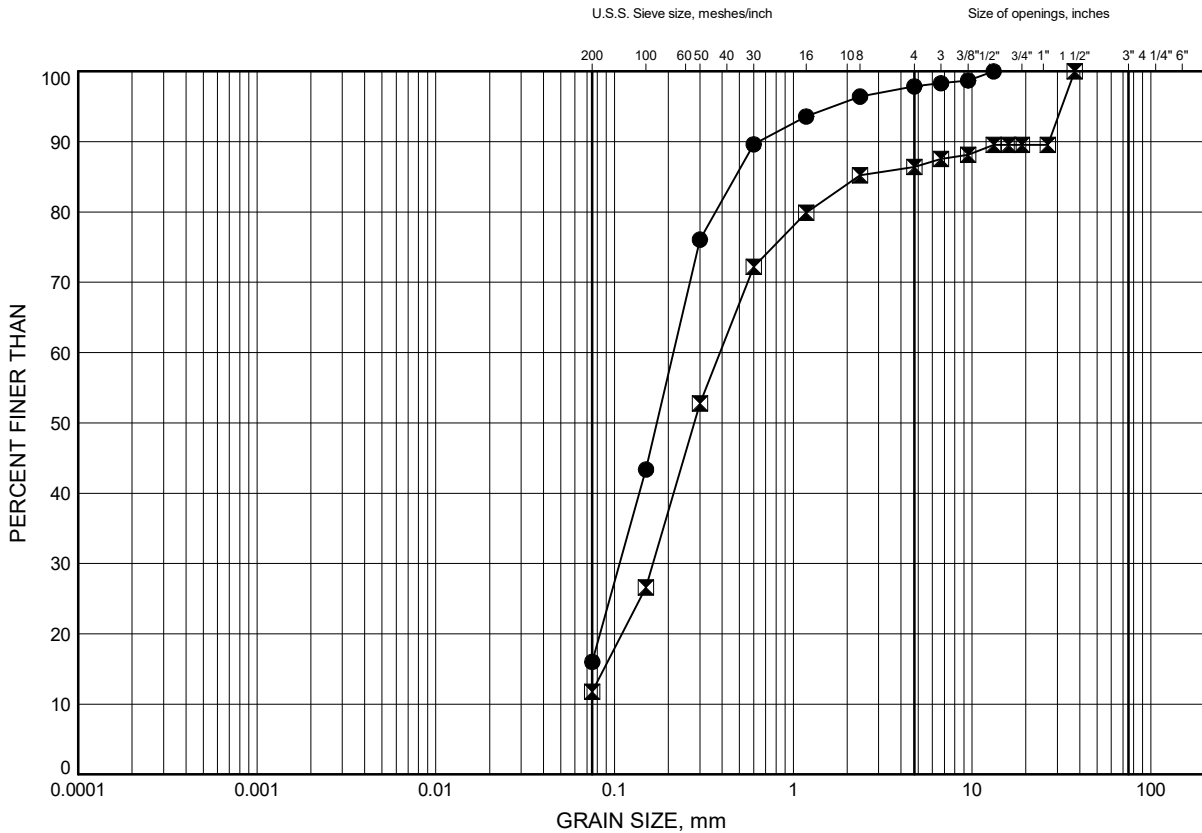


Appendix C.1
Particle Size Analysis Figures
Atterberg Limit Test Results

Highway 17 Twinning GRAIN SIZE DISTRIBUTION

FIGURE C1

Silty Sand to Silty Sand with Silt, Trace Gravel (Fill)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	N20-1	1.8	147.2
⊠	N20-2	2.6	146.5

Date August 2021
WP# 4068-09-00

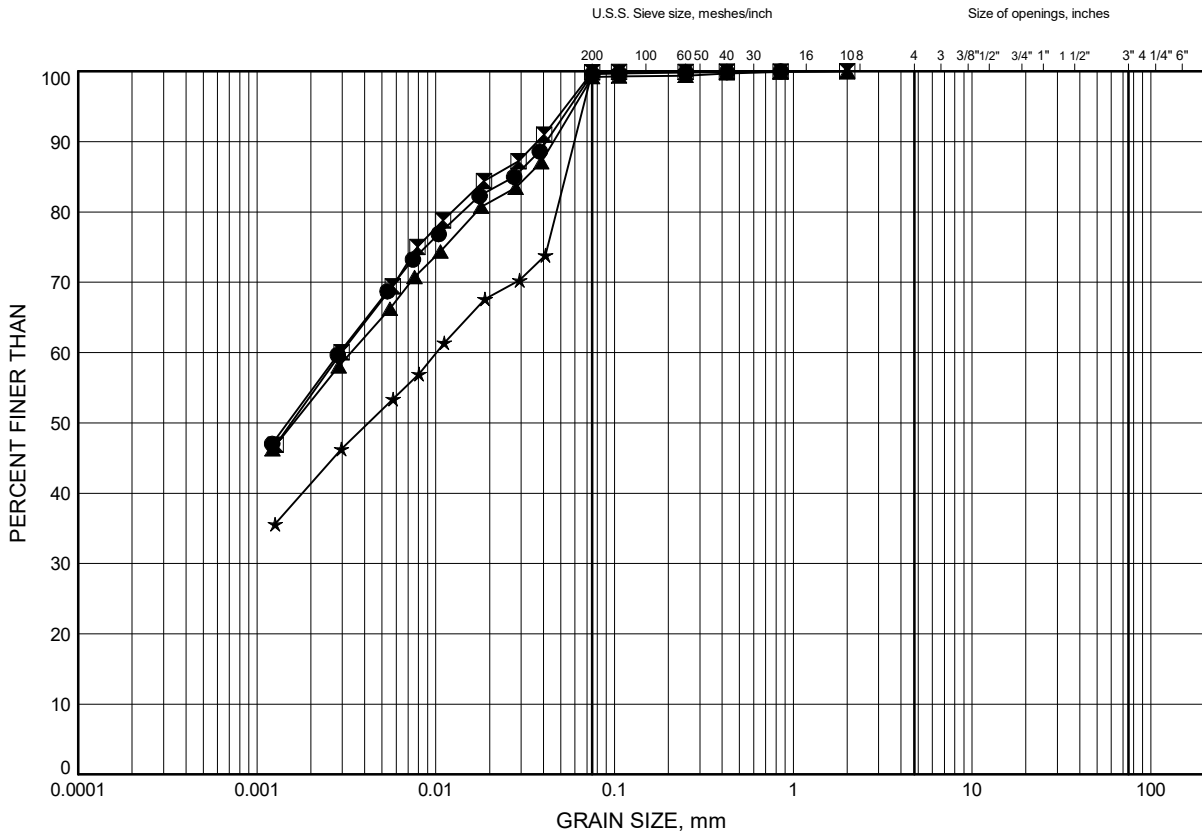


Prep'd DP
Chkd. FG

Highway 17 Twinning GRAIN SIZE DISTRIBUTION

FIGURE C2

Weathered Clayey Silt (CL) to Silty Clay (CI) Crust



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	CV-24	1.1	144.2
⊠	CV-4	1.8	143.8
▲	CV-5	0.9	144.6
★	CV-6	1.8	143.4

Date August 2021
WP# 4068-09-00

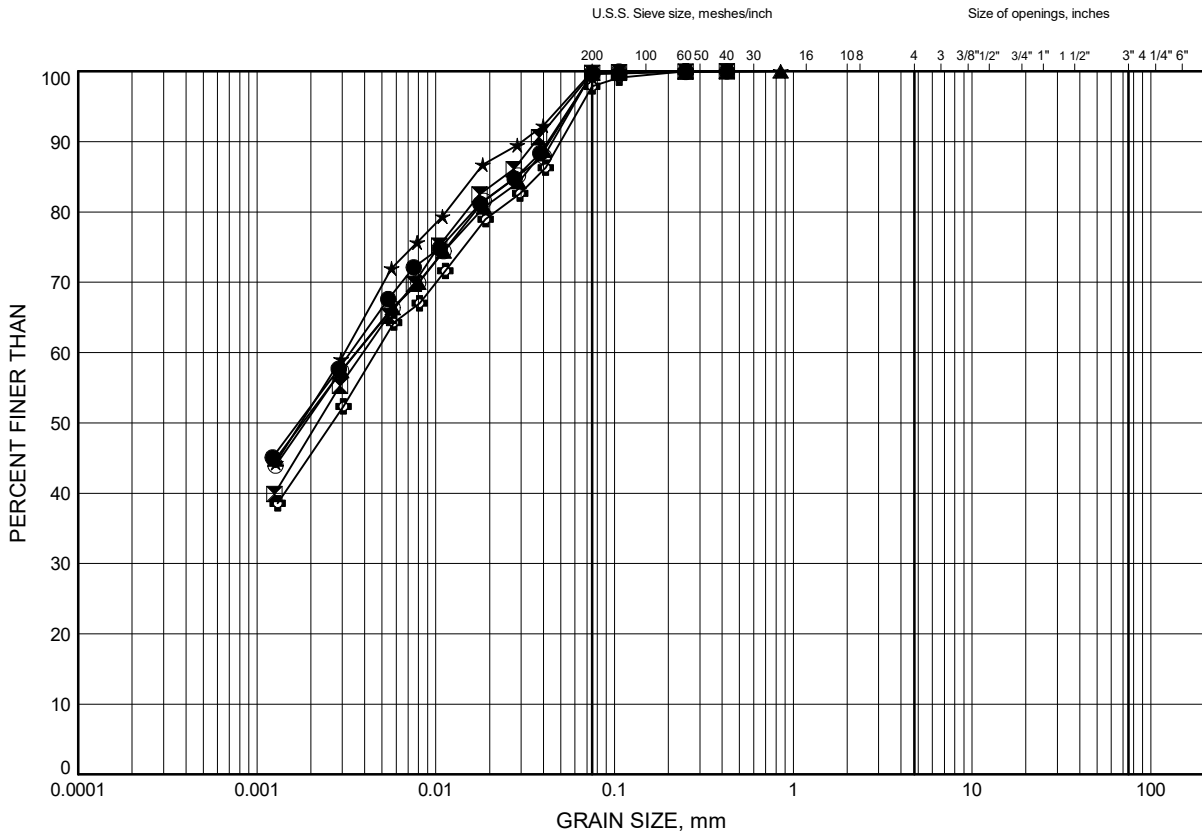


Prep'd DP
Chkd. FG

Highway 17 Twinning GRAIN SIZE DISTRIBUTION

FIGURE C3

Clayey Silt (CL) to Silty Clay (CI)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	CV-24	4.1	141.2
⊠	CV-24	7.9	137.4
▲	CV-4	6.4	139.2
★	CV-4	9.4	136.2
⊙	CV-5	3.4	142.1
⊕	CV-5	11.0	134.5

Date August 2021
WP# 4068-09-00

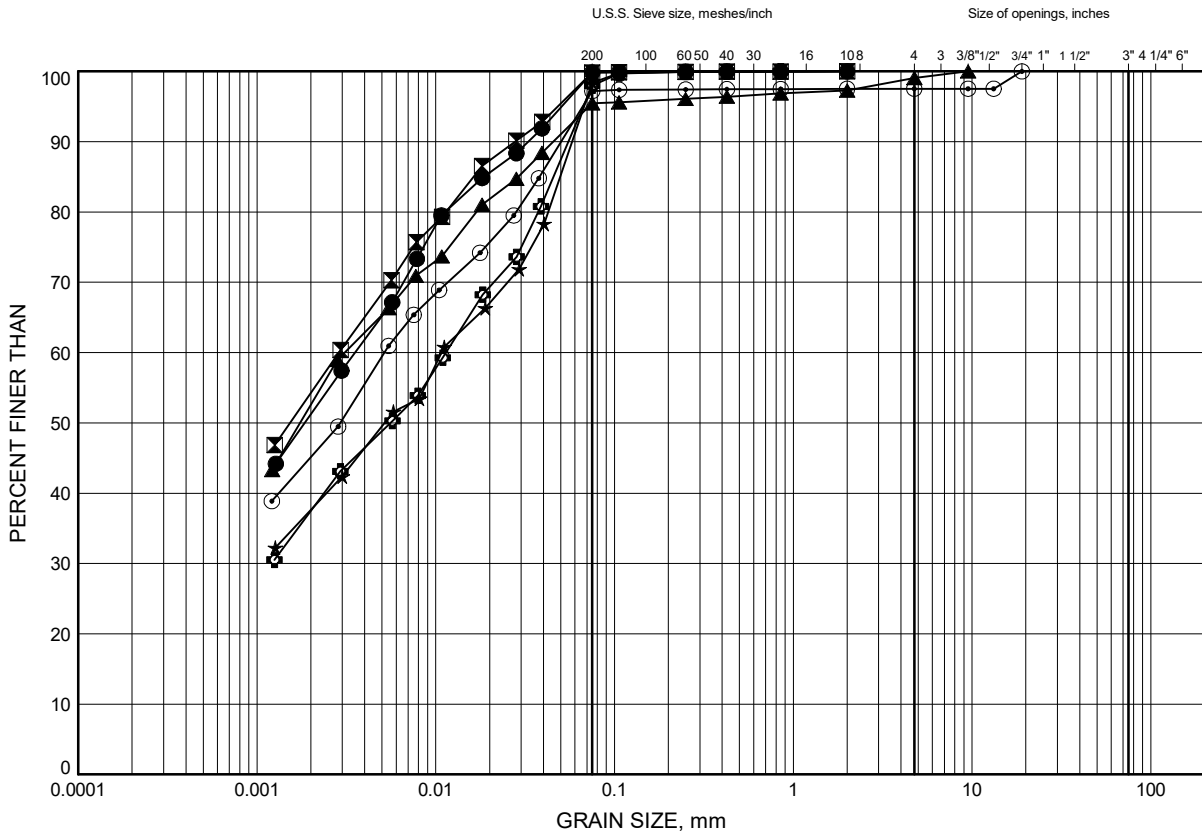


Prep'd DP
Chkd. FG

Highway 17 Twinning GRAIN SIZE DISTRIBUTION

FIGURE C4

Clayey Silt (CL) to Silty Clay (CI)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	CV-6	4.9	140.3
⊠	CV-6	7.9	137.3
▲	N20-1	5.8	143.2
★	N20-1	11.0	138.0
⊙	N20-2	7.9	141.2
⊕	N20-2	12.5	136.6

Date August 2021
WP# 4068-09-00

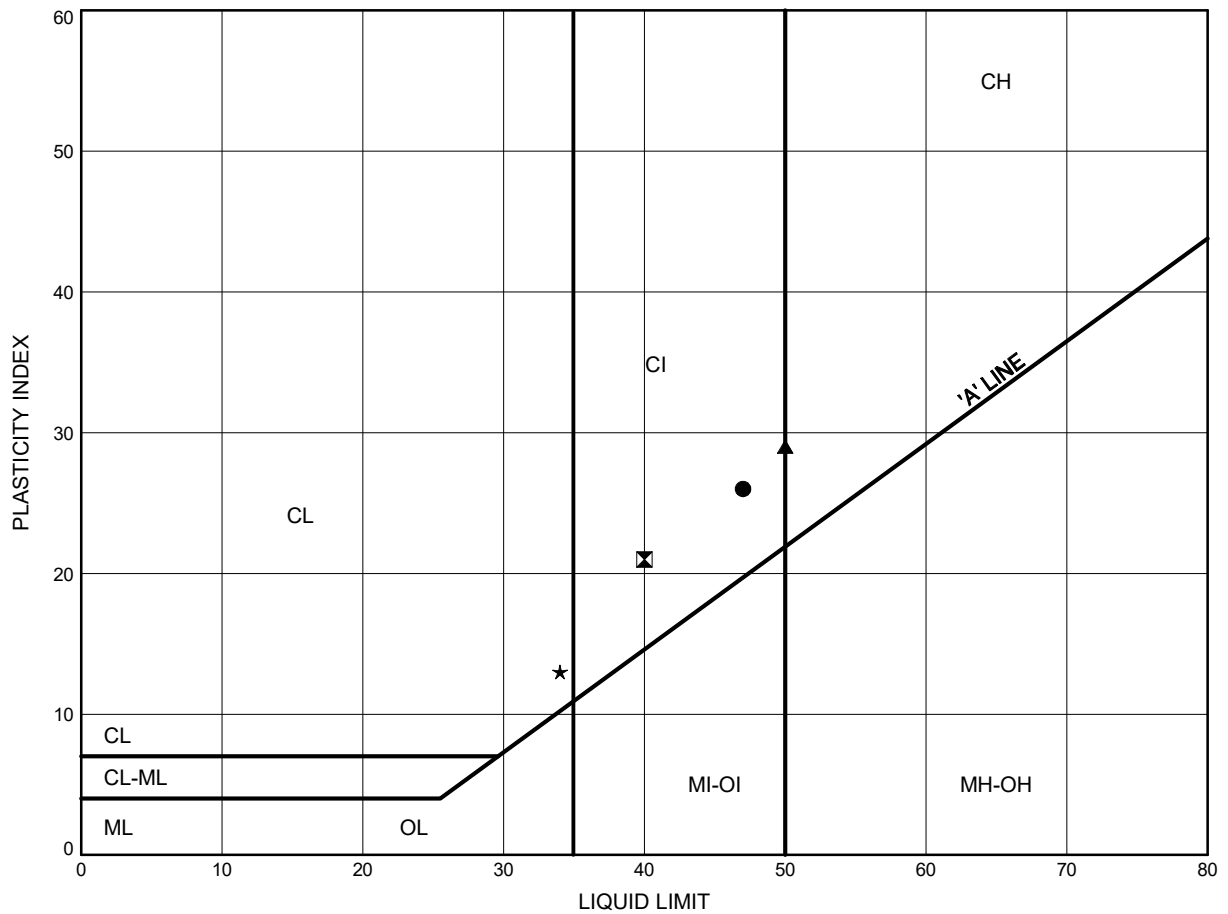


Prep'd DP
Chkd. FG

Highway 17 Twinning ATTERBERG LIMITS TEST RESULTS

FIGURE C5

Weathered Clayey Silt (CL) to Silty Clay (CI) Crust



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	CV-24	1.1	144.2
⊠	CV-4	1.8	143.8
▲	CV-5	1.1	144.4
★	CV-6	1.8	143.4

Date August 2021
 WP# 4068-09-00

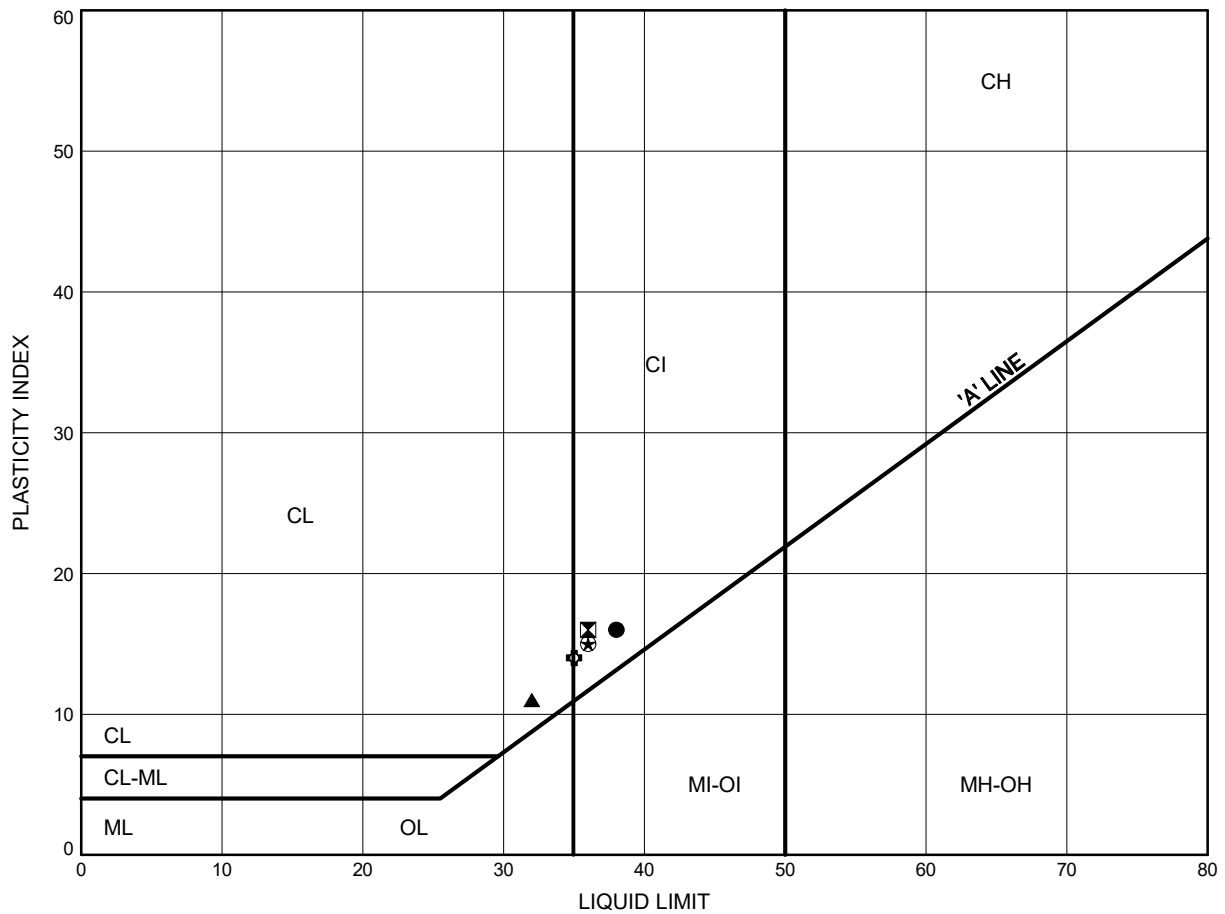


Prep'd DP
 Chkd. FG

Highway 17 Twinning ATTERBERG LIMITS TEST RESULTS

FIGURE C6

Clayey Silt (CL) to Silty Clay (CI)



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	CV-24	4.1	141.2
⊠	CV-24	7.9	137.4
▲	CV-4	6.4	139.2
★	CV-5	3.4	142.1
⊙	CV-6	4.9	140.3
⊕	CV-6	7.9	137.3

Date August 2021
 WP# 4068-09-00

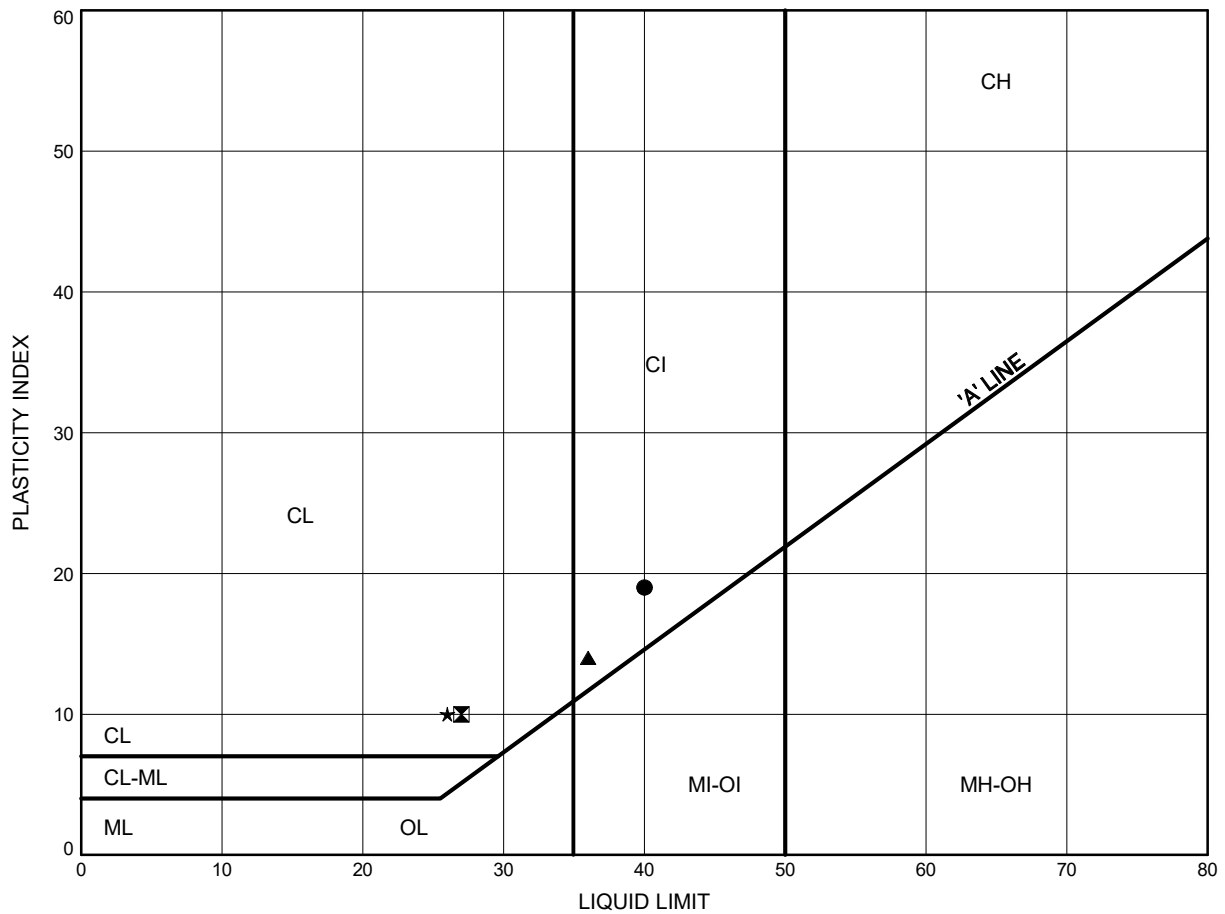


Prep'd DP
 Chkd. FG

Highway 17 Twinning ATTERBERG LIMITS TEST RESULTS

FIGURE C7

Clayey Silt (CL) to Silty Clay (CI)



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	N20-1	5.8	143.2
⊠	N20-1	11.0	138.0
▲	N20-2	7.9	141.2
★	N20-2	12.5	136.6

Date August 2021
 WP# 4068-09-00



Prep'd DP
 Chkd. FG



Appendix C.2

Analytical Testing Results

Certificate of Analysis

Thurber Engineering Ltd.

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

Client PO: 24726
Project: Culverts 17+570 and 17+893
Custody: 48670

Report Date: 21-May-2021
Order Date: 17-May-2021

Order #: 2121164

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

Paracel ID	Client ID
2121164-01	CV2 SS2 2'6"-4'6"
2121164-02	CV6 SS3 5'-7'

Approved By:



Mark Foto, M.Sc.
Lab Supervisor

Certificate of Analysis

Report Date: 21-May-2021

Client: Thurber Engineering Ltd.

Order Date: 17-May-2021

Client PO: 24726

Project Description: Culverts 17+570 and 17+893

Analysis Summary Table

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	21-May-21	21-May-21
Conductivity	MOE E3138 - probe @25 °C, water ext	20-May-21	21-May-21
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	18-May-21	19-May-21
Resistivity	EPA 120.1 - probe, water extraction	20-May-21	21-May-21
Solids, %	Gravimetric, calculation	18-May-21	19-May-21

Certificate of Analysis

Report Date: 21-May-2021

Client: Thurber Engineering Ltd.

Order Date: 17-May-2021

Client PO: 24726

Project Description: Culverts 17+570 and 17+893

		Client ID:	CV2 SS2 2'6"-4'6"	CV6 SS3 5'-7'	-	-
		Sample Date:	13-May-21 09:00	14-May-21 14:00	-	-
		Sample ID:	2121164-01	2121164-02	-	-
		MDL/Units	Soil	Soil	-	-
Physical Characteristics						
% Solids	0.1 % by Wt.		67.3	70.5	-	-
General Inorganics						
Conductivity	5 uS/cm		458	504	-	-
pH	0.05 pH Units		7.66	7.73	-	-
Resistivity	0.10 Ohm.m		21.4	19.8	-	-
Anions						
Chloride	5 ug/g dry		192	168	-	-
Sulphate	5 ug/g dry		30	63	-	-

Certificate of Analysis

Report Date: 21-May-2021

Client: Thurber Engineering Ltd.

Order Date: 17-May-2021

Client PO: 24726

Project Description: Culverts 17+570 and 17+893

Method Quality Control: Blank

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

Certificate of Analysis

Report Date: 21-May-2021

Client: Thurber Engineering Ltd.

Order Date: 17-May-2021

Client PO: 24726

Project Description: Culverts 17+570 and 17+893

Method Quality Control: Duplicate

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	53.7	5	ug/g dry	51.6			4.1	20	
Sulphate	79.3	5	ug/g dry	77.9			1.8	20	
General Inorganics									
Conductivity	467	5	uS/cm	468			0.2	5	
pH	7.20	0.05	pH Units	7.23			0.4	2.3	
Resistivity	21.4	0.10	Ohm.m	21.4			0.2	20	
Physical Characteristics									
% Solids	93.4	0.1	% by Wt.	94.2			0.9	25	

Certificate of Analysis

Report Date: 21-May-2021

Client: Thurber Engineering Ltd.

Order Date: 17-May-2021

Client PO: 24726

Project Description: Culverts 17+570 and 17+893

Method Quality Control: Spike

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	142	5	ug/g	51.6	90.2	82-118			
Sulphate	165	5	ug/g	77.9	87.0	80-120			

Certificate of Analysis

Client: Thurber Engineering Ltd.

Client PO: 24726

Report Date: 21-May-2021

Order Date: 17-May-2021

Project Description: Culverts 17+570 and 17+893

Qualifier Notes:

None

Sample Data Revisions

None

Work Order Revisions / Comments:

None

Other Report Notes:

n/a: not applicable

ND: Not Detected

MDL: Method Detection Limit

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

%REC: Percent recovery.

RPD: Relative percent difference.

NC: Not Calculated

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 **2121164**

Client Project(s): **Culverts 17+570 and 17+893**

Client PO: **24726**

Reference: **Standing Offer**

CoC Number: **48670**

Order Date: 17-May-21

Report Date: 21-May-21

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
2121164-01	CV2 SS2 2'6"-4'6"	Sulphide, solid
2121164-02	CV6 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, Canada

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

27-May-2021

Date Rec. : 19 May 2021
LR Report: CA13681-MAY21
Reference: Project#: 2121164

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

Sample ID	Sample Date & Time	Sulphide (Na ₂ CO ₃) %
1: Analysis Start Date		26-May-21
2: Analysis Start Time		15:06
3: Analysis Completed Date		26-May-21
4: Analysis Completed Time		17:03
5: QC - Blank		< 0.04
6: QC - STD % Recovery		111%
7: QC - DUP % RPD		ND
8: RL		0.02
9: CV2 SS2 2'6"-4'6"	13-May-21 09:00	< 0.04
10: CV6 SS3 5'-7'	14-May-21 14:00	0.05

RL - SGS Reporting Limit
ND - Not Detected

Kimberley Didsbury
Project Specialist,
Environment, Health & Safety



Appendix D.
Site Photographs



Photo 1. Culvert inlet looking south-east; proposed EBL to south (2021/04/27)
Note: residential properties to south of culvert.



Photo 2. Culvert outlet looking north-east (2021/04/27)



Photo 3. Culvert inlet (2021/04/27)



Photo 4. Culvert outlet (2021/04/27)



Photo 5. Highway 17 looking east (2021/04/27)



Appendix E.

GSC Seismic Hazard Calculation

2015 National Building Code Seismic Hazard Calculation

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

Site: 45.503N 76.674W

User File Reference: Highway 17; Culvert at Sta. 17+893

2021-08-05 17:05 UT

Requested by: Thurber Engineering Ltd.

Probability of exceedance per annum	0.000404	0.001	0.0021	0.01
Probability of exceedance in 50 years	2 %	5 %	10 %	40 %
Sa (0.05)	0.361	0.185	0.106	0.031
Sa (0.1)	0.428	0.230	0.138	0.045
Sa (0.2)	0.357	0.199	0.124	0.043
Sa (0.3)	0.271	0.155	0.098	0.035
Sa (0.5)	0.193	0.113	0.072	0.026
Sa (1.0)	0.098	0.059	0.038	0.013
Sa (2.0)	0.048	0.028	0.018	0.005
Sa (5.0)	0.013	0.007	0.004	0.001
Sa (10.0)	0.005	0.003	0.002	0.001
PGA (g)	0.229	0.126	0.076	0.025
PGV (m/s)	0.161	0.091	0.056	0.018

Notes: Spectral ($S_a(T)$, where T is the period in seconds) and peak ground acceleration (PGA) values are given in units of g (9.81 m/s^2). Peak ground velocity is given in m/s . Values are for "firm ground" (NBCC2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are highlighted in yellow. 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.**

References

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

Structural Commentaries (User's Guide - NBC 2015: Part 4 of Division B)
Commentary J: Design for Seismic Effects

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

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



Natural Resources
Canada

Ressources naturelles
Canada

Canada



Appendix F.

Foundation Comparison Preliminary General Arrangement

COMPARISON OF ALTERNATIVE FOUNDATION TYPES

	Pipe Culverts	Open-Bottom Box Culvert	Closed- Bottom Box Culvert
Advantages	<ul style="list-style-type: none"> • Relatively expedient installation if precast units are used. • Smaller magnitude of settlement than open footing culvert due to lower bearing stress on subgrade. 	<ul style="list-style-type: none"> • Relatively expedient installation if precast units are used. • Possibility to maintain work zone outside of existing waterway. 	<ul style="list-style-type: none"> • Relatively expedient installation if precast units are used. • Smaller magnitude of settlement than open footing culvert due to lower bearing stress on subgrade.
Disadvantages	<ul style="list-style-type: none"> • Requires a temporary by-pass to maintain waterflow • Several parallel pipes required to provide hydraulic opening equivalent to box culvert 	<ul style="list-style-type: none"> • May require protection system for construction of foundations. • Deepest excavation, increases quantities and dewatering concerns. • Lower geotechnical resistances. • Potential for post construction settlement. 	<ul style="list-style-type: none"> • Requires a temporary by-pass to maintain waterflow
Risks/ Consequences	<ul style="list-style-type: none"> • Potential for damage due to settlement 	<ul style="list-style-type: none"> • Increased risk of basal instability of footing excavation due to depth of excavation below water table. • Potential for damage due to settlement 	<ul style="list-style-type: none"> • Potential for damage due to settlement
Relative Cost	Low to Moderate	Moderate	Moderate
Recommendation	Feasible	Not Recommended	Recommended



METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN
DRAWING NOT TO BE SCALED
100mm ON ORIGINAL DRAWING

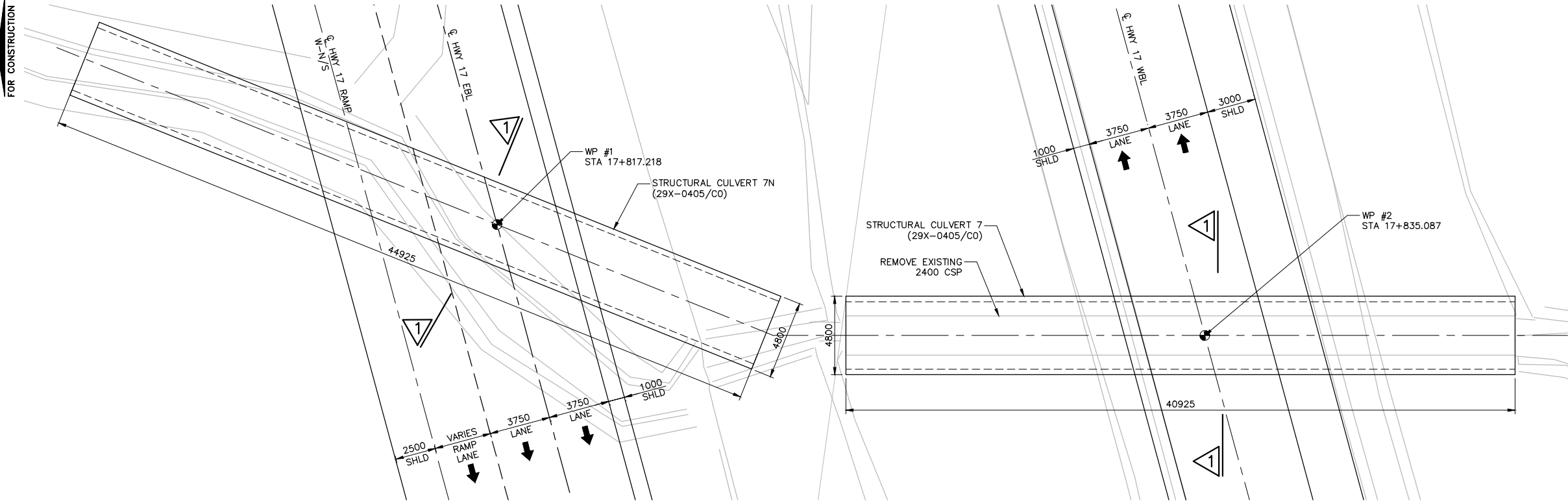
PARSONS

CONT No
WP

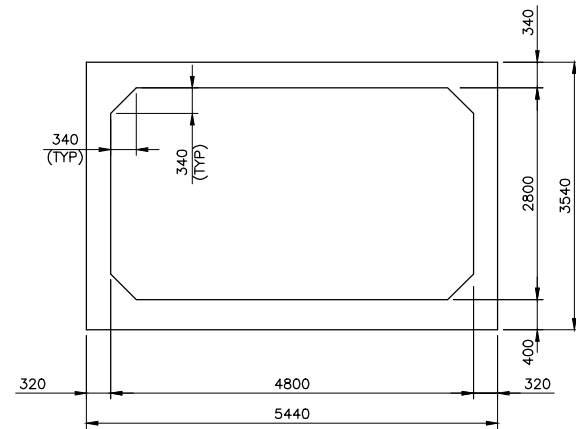
HWY 17 TWINNING
LITTLE HALLIDAY CREEK
CULVERT
GENERAL ARRANGEMENT



SHEET
-



PLAN
1:150



1
1:50

REVISIONS				
	NO	DATE	BY	DESCRIPTION
DESIGN	AL	CHK	CODE	CAN/CSA S6-14
DRAWN	FP	CHK	AL	SITE
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				LOAD CL-625-ONT
				DATE
				DWG

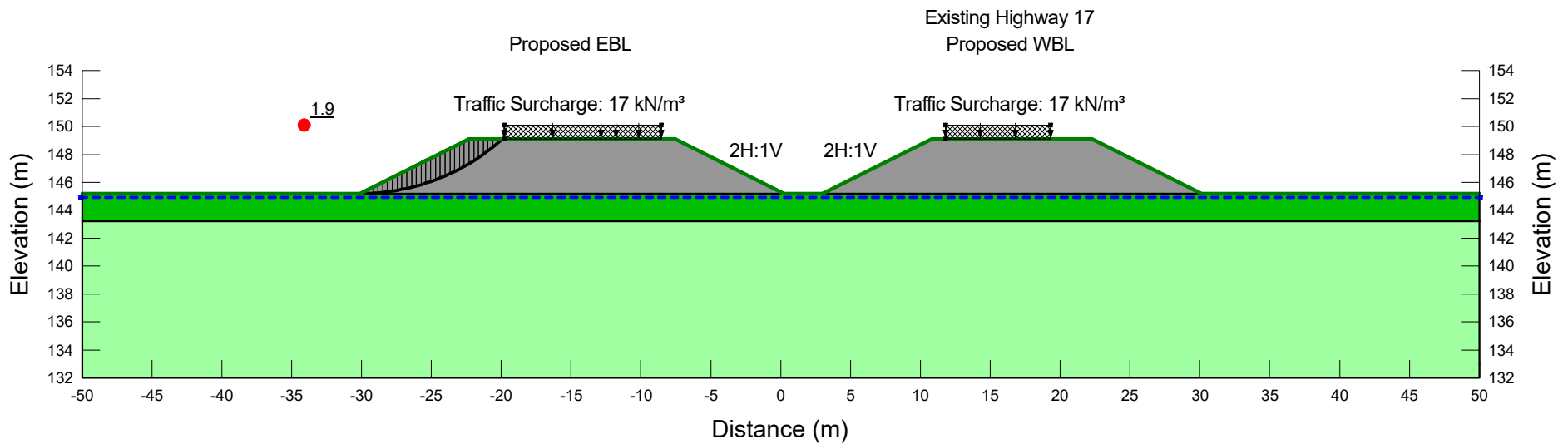
DOCUMENT CODE:



Appendix G.

Slope Stability Analysis Figures

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	C-Top of Layer (kPa)	C-Rate of Change ((kN/m²)/m)	C-Maximum (kPa)	Total Cohesion (kPa)	Effective Cohesion (kPa)	Effective Friction Angle (°)
■	00: FILL: Gran. B I	Mohr-Coulomb	21					0	32
■	02: CLAY/SILT Crust (TSA)	Undrained (Phi=0)	17				75		
■	03: CLAY/SILT (TSA)	S=f(depth)	17	100	-7.5	40			

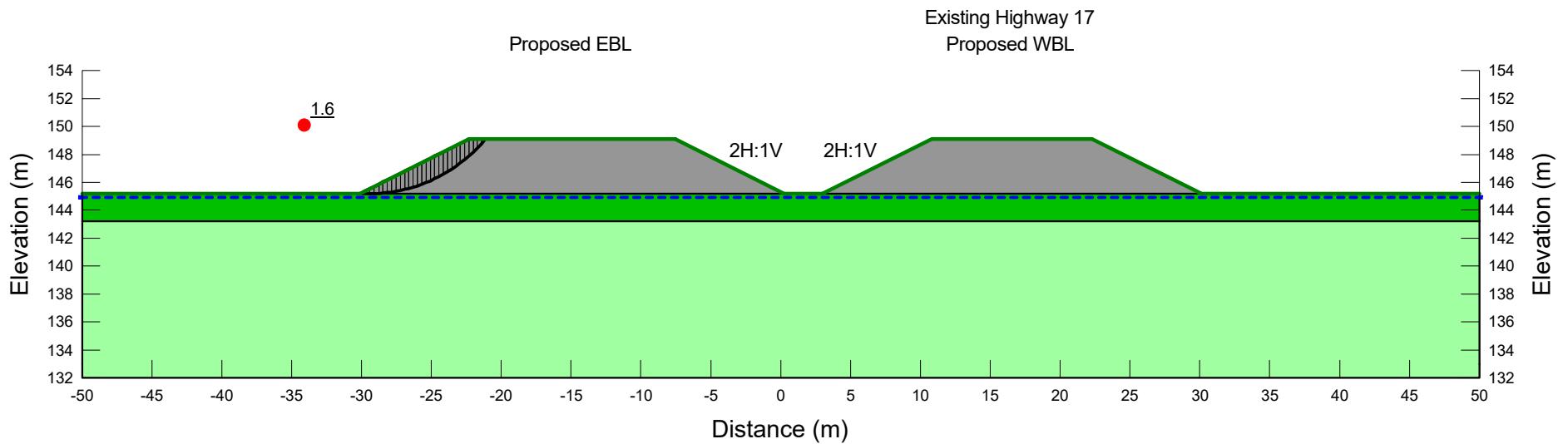


Project		
Highway 17 Twinning - Culvert 17+893		
Analysis		
G1.1 EB Temporary - Static (Undrained)		
Seismic Coefficient	Last Run	Scale
H: 0g, V: 0g	2022/06/22, 05:06:08 PM	1:450

Additional Details
Name: 1. EB Embankment (2H:1V)
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1.52 m
Entry: (-19.94, 149.1) m, Exit: (-30.2, 145.2) m
Center: (-30.025719, 160.18735) m, Radius: 14.988367 m
Surcharge Load: 17 kN/m³

Figure G1-1

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
■	00: FILL: Gran. B I	Mohr-Coulomb	21	0	32
■	02: CLAY/SILT Crust (ESA)	Mohr-Coulomb	17	5	28
■	03: CLAY/SILT (ESA)	Mohr-Coulomb	17	5	28



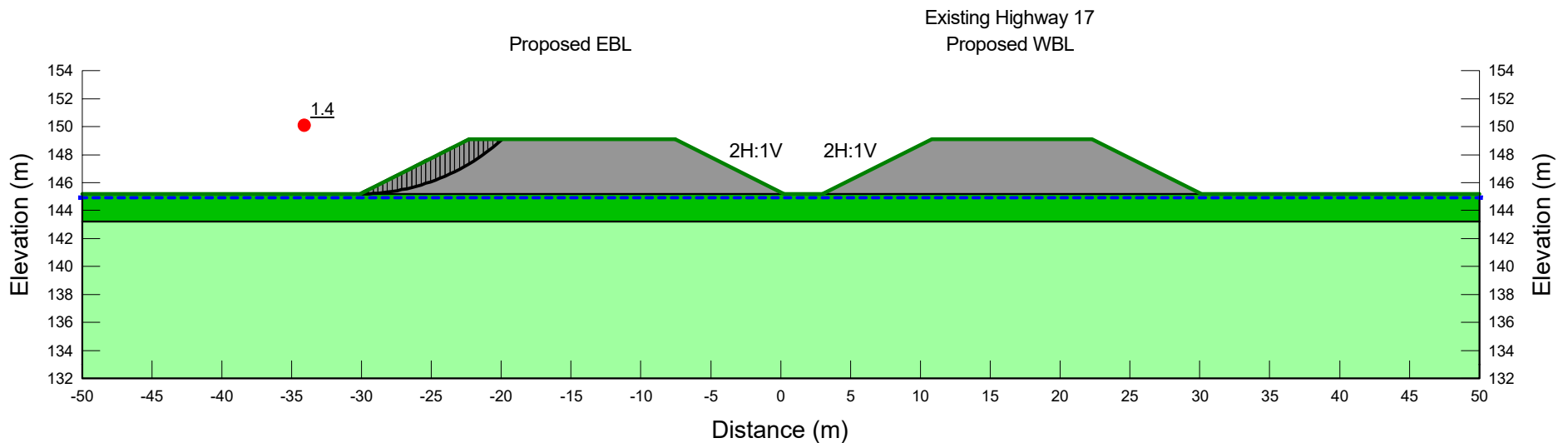
Project		
Highway 17 Twinning - Culvert 17+893		
Analysis		
G1.2 EB Permanent - Static (Drained)		
Seismic Coefficient	Last Run	Scale
H: 0g, V: 0g	2022/06/22, 05:06:12 PM	1:450

Additional Details

Name: 1. EB Embankment (2H:1V)
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1.52 m
Entry: (-21.12, 149.1) m, Exit: (-30.2, 145.2) m
Center: (-29.480086, 156.04394) m, Radius: 10.867814 m

Figure G1-2

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	C-Top of Layer (kPa)	C-Rate of Change ((kN/m²)/m)	C-Maximum (kPa)	Total Cohesion (kPa)	Effective Cohesion (kPa)	Effective Friction Angle (°)
■	00: FILL: Gran. B I	Mohr-Coulomb	21					0	32
■	02: CLAY/SILT Crust (TSA)	Undrained (Phi=0)	17				75		
■	03: CLAY/SILT (TSA)	S=f(depth)	17	100	-7.5	40			



Project		
Highway 17 Twinning - Culvert 17+893		
Analysis		
G1.3 EB Temporary - Seismic (Undrained)		
Seismic Coefficient	Last Run	Scale
H: 0.13g, V: 0g	2022/06/22, 05:06:17 PM	1:450

Additional Details

Name: 1. EB Embankment (2H:1V)





Method: Morgenstern-Price, Half-Sine

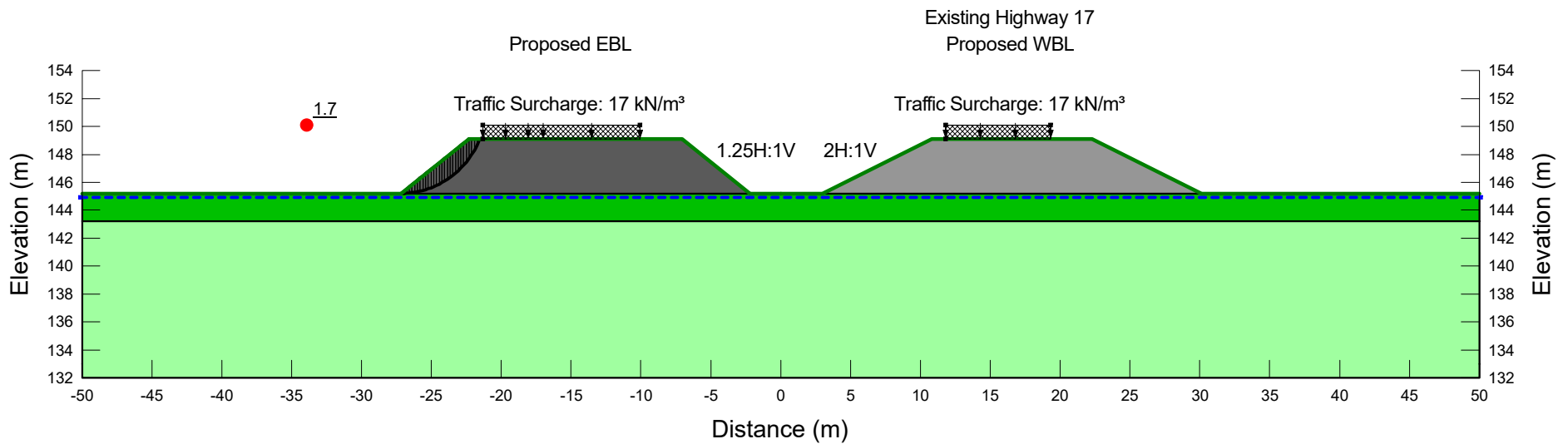
Minimum Slip Surface Depth: 1.52 m

Entry: (-19.94, 149.1) m, Exit: (-30.2, 145.2) m

Center: (-30.025719, 160.18735) m, Radius: 14.988367 m

Figure G1-3





Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	C-Top of Layer (kPa)	C-Rate of Change ((kN/m²)/m)	C-Maximum (kPa)	Total Cohesion (kPa)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	00: FILL: Gran. B I	Mohr-Coulomb	21					0	32
	01: FILL: Rock Fill	Mohr-Coulomb	20					0	42
	02: CLAY/SILT Crust (TSA)	Undrained (Phi=0)	17				75		
	03: CLAY/SILT (TSA)	S=f(depth)	17	100	-7.5	40			

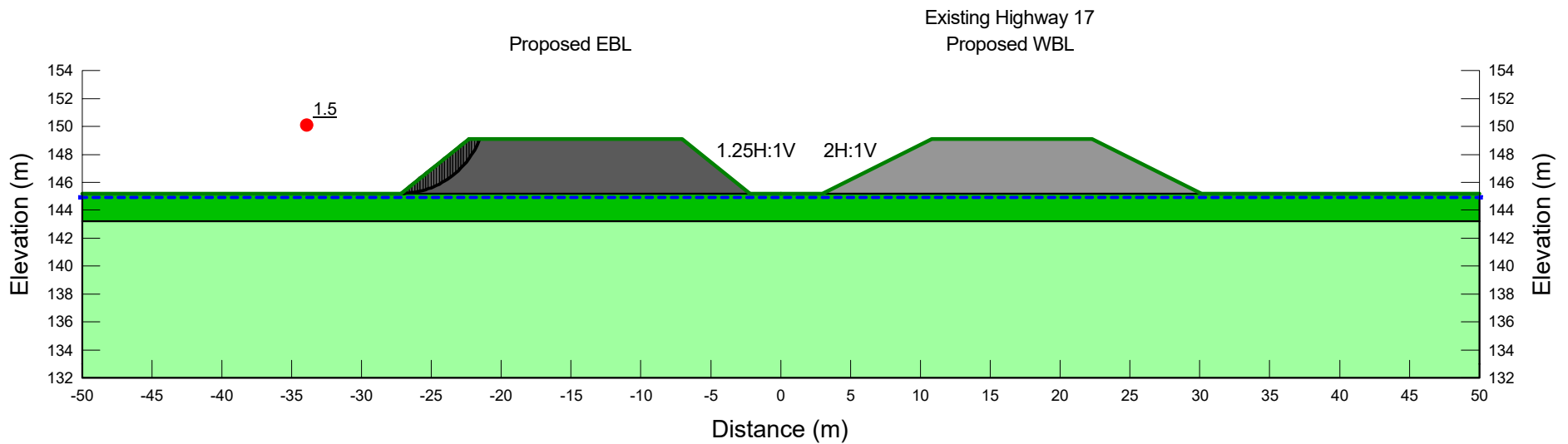


Project		
Highway 17 Twinning - Culvert 17+893		
Analysis		
G2.1 EB Temporary - Static (Undrained)		
Seismic Coefficient	Last Run	Scale
H: 0g, V: 0g	2022/06/22, 05:06:22 PM	1:450

Additional Details
Name: 2. EB Embankment (1.25H:1V)
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1.52 m
Entry: (-21.5375, 149.1) m, Exit: (-27.3, 145.2) m
Center: (-27.227322, 151.29984) m, Radius: 6.1002779 m
Surcharge Load: 17 kN/m³

Figure G2-1

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	00: FILL: Gran. B I	Mohr-Coulomb	21	0	32
	01: FILL: Rock Fill	Mohr-Coulomb	20	0	42
	02: CLAY/SILT Crust (ESA)	Mohr-Coulomb	17	5	28
	03: CLAY/SILT (ESA)	Mohr-Coulomb	17	5	28



Project		
Highway 17 Twinning - Culvert 17+893		
Analysis		
G2.2 EB Permanent - Static (Drained)		
Seismic Coefficient	Last Run	Scale
H: 0g, V: 0g	2022/06/22, 05:06:27 PM	1:450

Additional Details

Name: 2. EB Embankment (1.25H:1V)





Method: Morgenstern-Price, Half-Sine

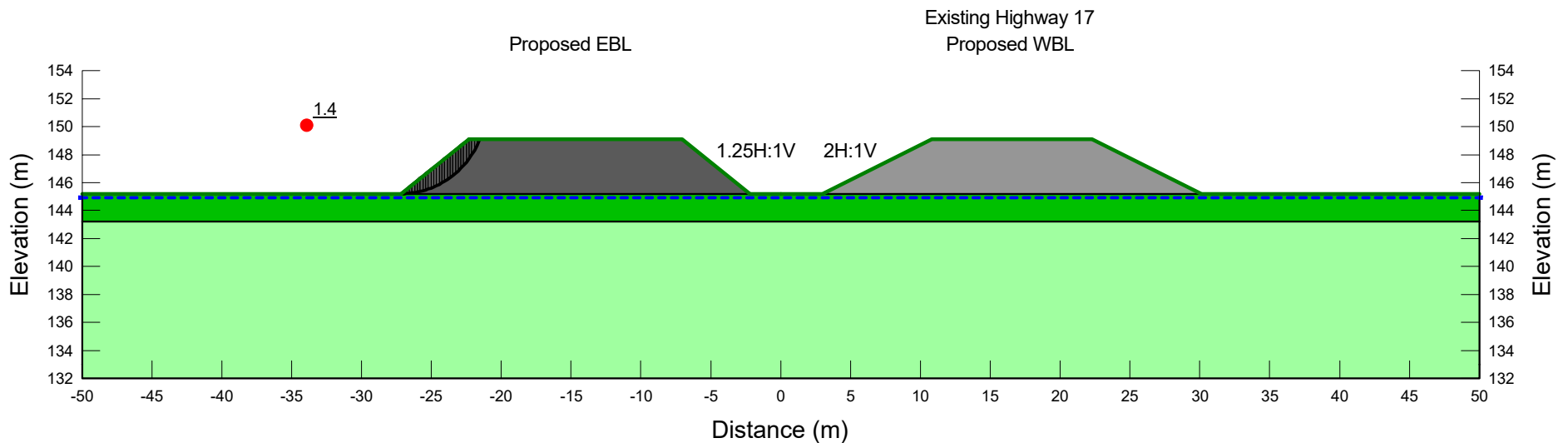
Minimum Slip Surface Depth: 1.52 m

Entry: (-21.5375, 149.1) m, Exit: (-27.3, 145.2) m

Center: (-27.227322, 151.29984) m, Radius: 6.1002779 m

Figure G2-2

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	C-Top of Layer (kPa)	C-Rate of Change ((kN/m²)/m)	C-Maximum (kPa)	Total Cohesion (kPa)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	00: FILL: Gran. B I	Mohr-Coulomb	21					0	32
	01: FILL: Rock Fill	Mohr-Coulomb	20					0	42
	02: CLAY/SILT Crust (TSA)	Undrained (Phi=0)	17				75		
	03: CLAY/SILT (TSA)	S=f(depth)	17	100	-7.5	40			

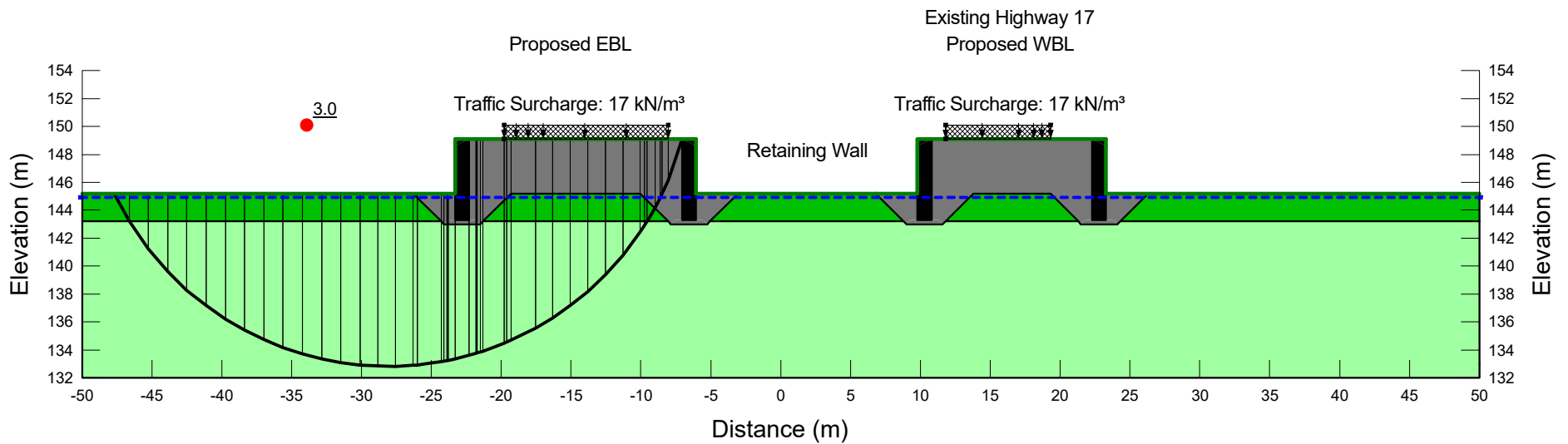


Project Highway 17 Twinning - Culvert 17+893		
Analysis G2.3 EB Temporary - Seismic (Undrained)		
Seismic Coefficient H: 0.13g, V: 0g	Last Run 2022/06/22, 05:06:31 PM	Scale 1:450

Additional Details
 Name: 2. EB Embankment (1.25H:1V)
 Method: Morgenstern-Price, Half-Sine
 Minimum Slip Surface Depth: 1.52 m
 Entry: (-21.5375, 149.1) m, Exit: (-27.3, 145.2) m
 Center: (-27.227322, 151.29984) m, Radius: 6.1002779 m

Figure G2-3

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	C-Top of Layer (kPa)	C-Rate of Change ((kN/m²)/m)	C-Maximum (kPa)	Total Cohesion (kPa)	Effective Cohesion (kPa)	Effective Friction Angle (°)
■	00: Concrete	High Strength	24						
■	00: FILL: Gran. A	Mohr-Coulomb	22.8					0	40
■	02: CLAY/SILT Crust (TSA)	Undrained (Phi=0)	17				75		
■	03: CLAY/SILT (TSA)	S=f(depth)	17	100	-7.5	40			

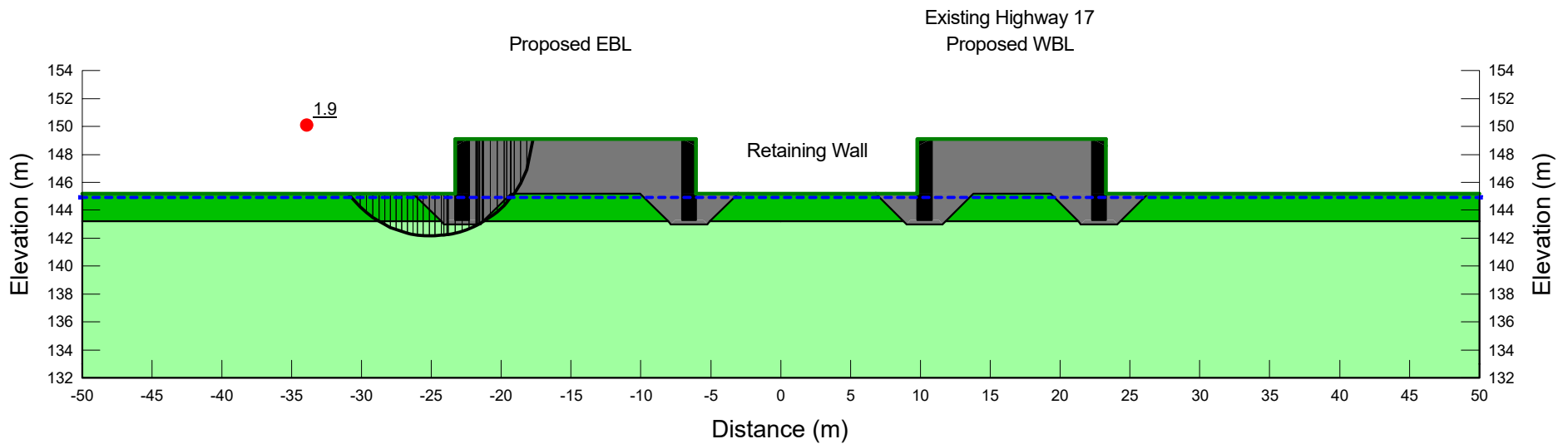


Project Highway 17 Twinning - Culvert 17+893		
Analysis G3.1 EB Temporary - Static (Undrained)		
Seismic Coefficient H: 0g, V: 0g	Last Run 2022/06/22, 05:06:45 PM	Scale 1:450

Additional Details
 Name: 3. EB Embankment (Retaining Wall)
 Method: Morgenstern-Price, Half-Sine
 Minimum Slip Surface Depth: 1.52 m
 Entry: (-7.05, 149.1) m, Exit: (-47.711429, 145.2) m
 Center: (-28.092021, 154.56609) m, Radius: 21.740394 m
 Surcharge Load: 17 kN/m³

Figure G3-1

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
■	00: Concrete	High Strength	24		
■	00: FILL: Gran. A	Mohr-Coulomb	22.8	0	40
■	02: CLAY/SILT Crust (ESA)	Mohr-Coulomb	17	5	28
■	03: CLAY/SILT (ESA)	Mohr-Coulomb	17	5	28



Project		
Highway 17 Twinning - Culvert 17+893		
Analysis		
G3.2 EB Permanent - Static (Drained)		
Seismic Coefficient	Last Run	Scale
H: 0g, V: 0g	2022/06/22, 05:06:49 PM	1:450

Additional Details

Name: 3. EB Embankment (Retaining Wall)

Method: Morgenstern-Price, Half-Sine

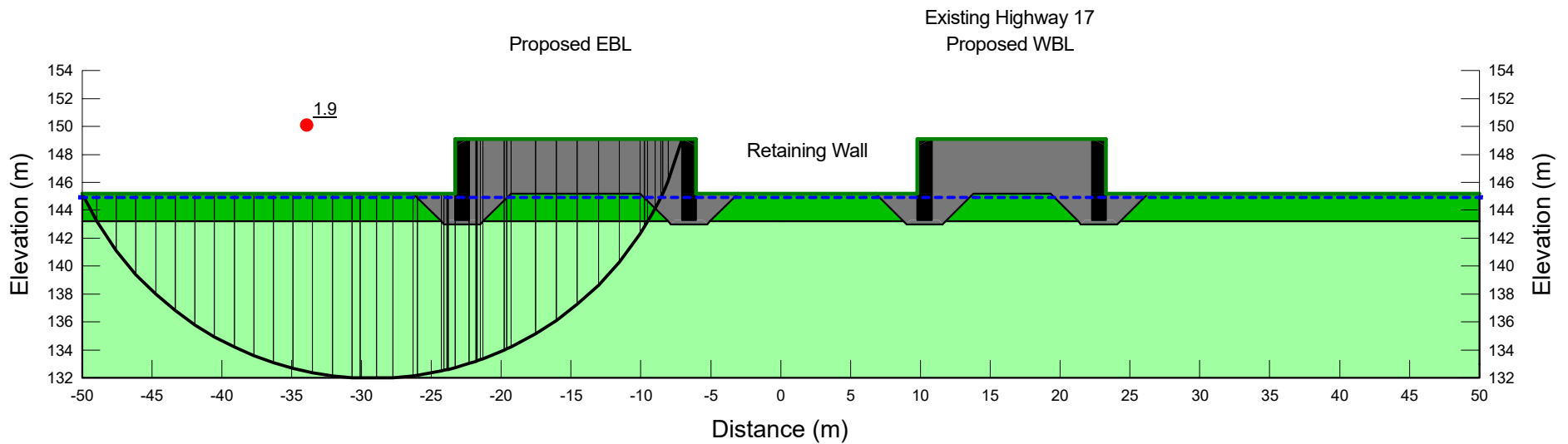
Minimum Slip Surface Depth: 1.52 m

Entry: (-17.725, 149.1) m, Exit: (-30.928571, 145.2) m

Center: (-25.007864, 149.45581) m, Radius: 7.2915504 m

Figure G3-2

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	C-Top of Layer (kPa)	C-Rate of Change ((kN/m²)/m)	C-Maximum (kPa)	Total Cohesion (kPa)	Effective Cohesion (kPa)	Effective Friction Angle (°)
■	00: Concrete	High Strength	24						
■	00: FILL: Gran. A	Mohr-Coulomb	22.8					0	40
■	02: CLAY/SILT Crust (TSA)	Undrained (Phi=0)	17				75		
■	03: CLAY/SILT (TSA)	S=f(depth)	17	100	-7.5	40			



Project		
Highway 17 Twinning - Culvert 17+893		
Analysis		
G3.3 EB Temporary - Seismic (Undrained)		
Seismic Coefficient	Last Run	Scale
H: 0.13g, V: 0g	2022/06/22, 05:06:53 PM	1:450

Additional Details

Name: 3. EB Embankment (Retaining Wall)

Method: Morgenstern-Price, Half-Sine

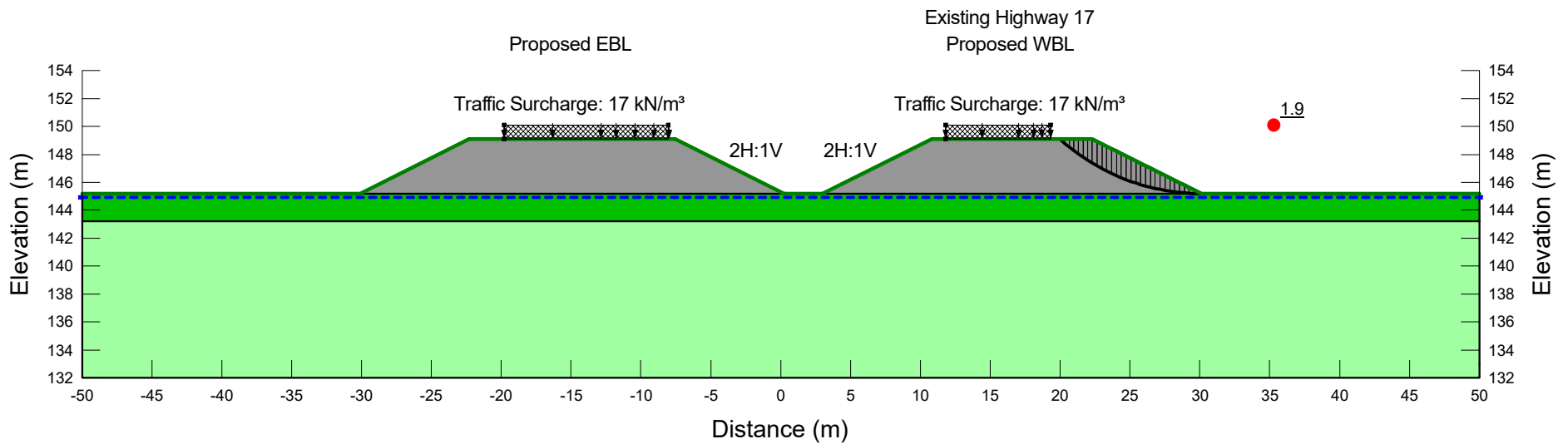
Minimum Slip Surface Depth: 1.52 m

Entry: (-7.05, 149.1) m, Exit: (-50, 145.2) m

Center: (-29.225753, 154.86727) m, Radius: 22.913433 m

Figure G3-3

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	C-Top of Layer (kPa)	C-Rate of Change ((kN/m²)/m)	C-Maximum (kPa)	Total Cohesion (kPa)	Effective Cohesion (kPa)	Effective Friction Angle (°)
■	00: FILL: Gran. B I	Mohr-Coulomb	21					0	32
■	02: CLAY/SILT Crust (TSA)	Undrained (Phi=0)	17				75		
■	03: CLAY/SILT (TSA)	S=f(depth)	17	100	-7.5	40			

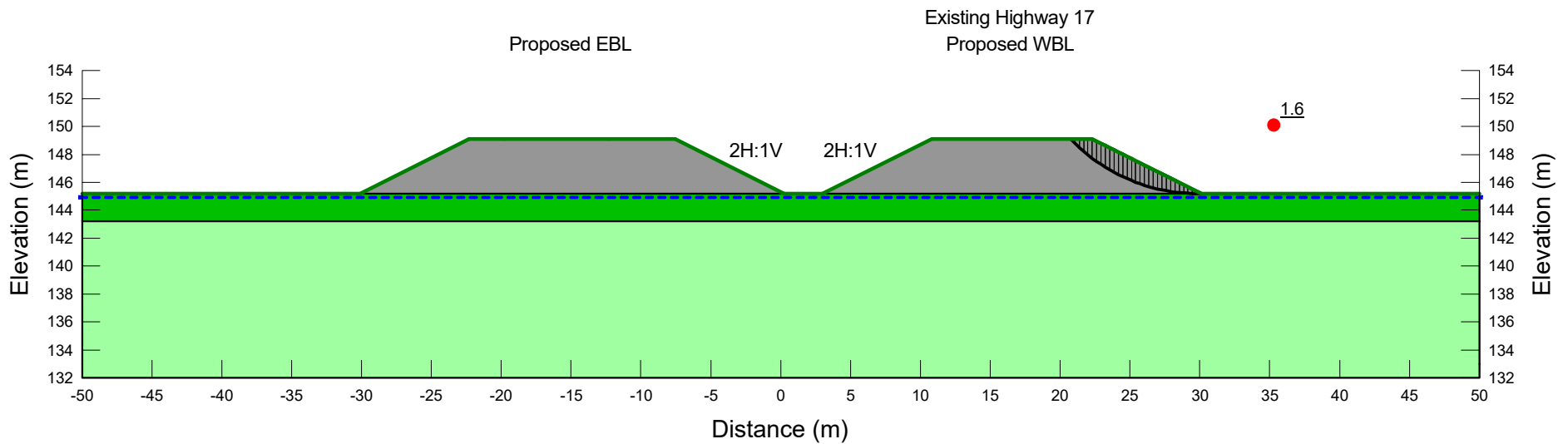


Project		
Highway 17 Twinning - Culvert 17+893		
Analysis		
G4.1 WB Temporary - Static (Undrained)		
Seismic Coefficient	Last Run	Scale
H: 0g, V: 0g	2022/06/22, 05:06:35 PM	1:450

Additional Details
Name: 4. WB Embankment (2H:1V)
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1.52 m
Entry: (20, 149.1) m, Exit: (30.2, 145.2) m
Center: (30.066857, 160.14024) m, Radius: 14.940834 m
Surcharge Load: 17 kN/m³

Figure G4-1

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
■	00: FILL: Gran. B I	Mohr-Coulomb	21	0	32
■	02: CLAY/SILT Crust (ESA)	Mohr-Coulomb	17	5	28
■	03: CLAY/SILT (ESA)	Mohr-Coulomb	17	5	28

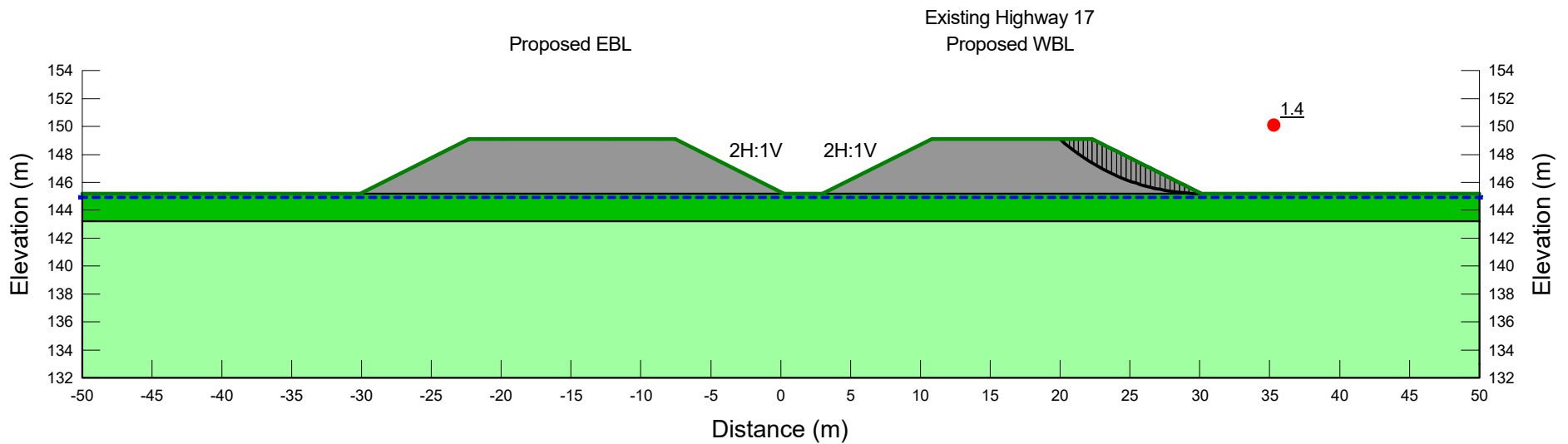


Project		
Highway 17 Twinning - Culvert 17+893		
Analysis		
G4.2 WB Permanent - Static (Drained)		
Seismic Coefficient	Last Run	Scale
H: 0g, V: 0g	2022/06/22, 05:06:37 PM	1:450

Additional Details
 Name: 4. WB Embankment (2H:1V)
 Method: Morgenstern-Price, Half-Sine
 Minimum Slip Surface Depth: 1.52 m
 Entry: (20.766667, 149.1) m, Exit: (30.2, 145.2) m
 Center: (29.83137, 157.66705) m, Radius: 12.472495 m

Figure G4-2

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	C-Top of Layer (kPa)	C-Rate of Change ((kN/m²)/m)	C-Maximum (kPa)	Total Cohesion (kPa)	Effective Cohesion (kPa)	Effective Friction Angle (°)
■	00: FILL: Gran. B I	Mohr-Coulomb	21					0	32
■	02: CLAY/SILT Crust (TSA)	Undrained (Phi=0)	17				75		
■	03: CLAY/SILT (TSA)	S=f(depth)	17	100	-7.5	40			

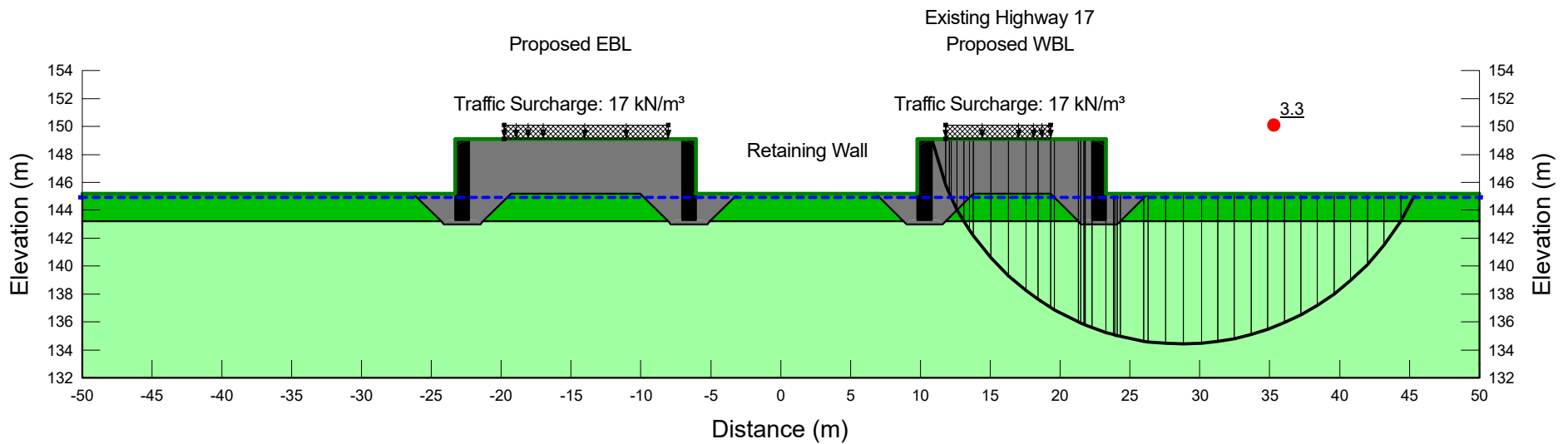


Project		
Highway 17 Twinning - Culvert 17+893		
Analysis		
G4.3 WB Temporary - Seismic (Undrained)		
Seismic Coefficient	Last Run	Scale
H: 0.13g, V: 0g	2022/06/22, 05:06:41 PM	1:450

Additional Details
Name: 4. WB Embankment (2H:1V)
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1.52 m
Entry: (20, 149.1) m, Exit: (30.2, 145.2) m
Center: (30.066857, 160.14024) m, Radius: 14.940834 m

Figure G4-3

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	C-Top of Layer (kPa)	C-Rate of Change ((kN/m²)/m)	C-Maximum (kPa)	Total Cohesion (kPa)	Effective Cohesion (kPa)	Effective Friction Angle (°)
■	00: Concrete	High Strength	24						
■	00: FILL: Gran. A	Mohr-Coulomb	22.8					0	40
■	02: CLAY/SILT Crust (TSA)	Undrained (Phi=0)	17				75		
■	03: CLAY/SILT (TSA)	S=f(depth)	17	100	-7.5	40			



Project
Highway 17 Twinning - Culvert 17+893

Analysis
G5.1 EB Temporary - Static (Undrained)

Seismic Coefficient
H: 0g, V: 0g

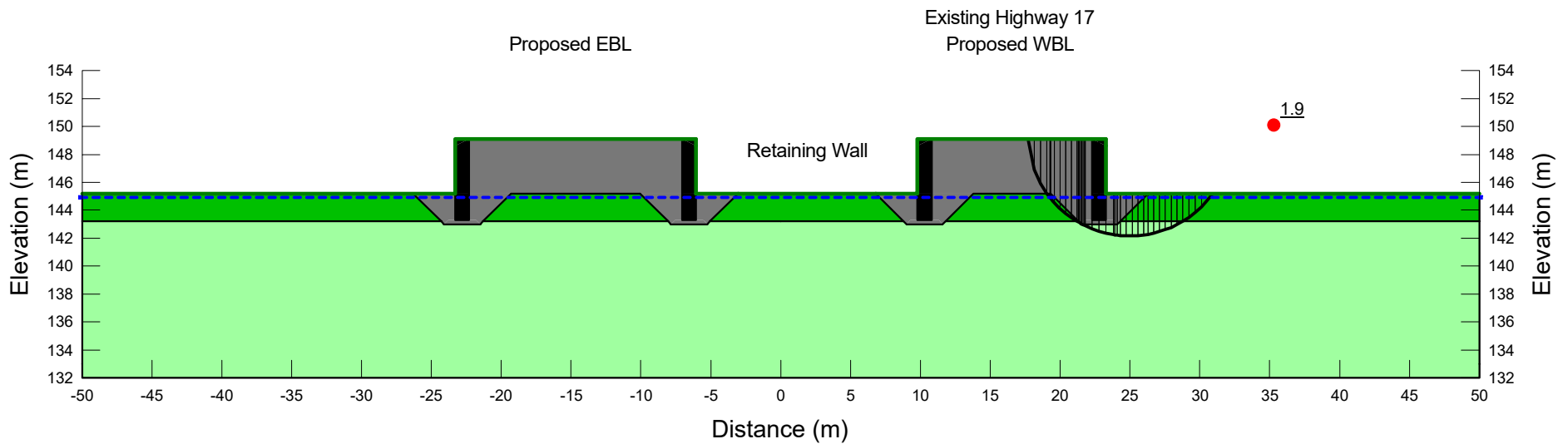
Last Run
2022/06/22, 05:06:56 PM

Scale
1:450

Additional Details
Name: 5. WB Embankment (Retaining Wall)
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1.52 m
Entry: (10.8, 149.1) m, Exit: (45.422857, 145.2) m
Center: (28.739928, 152.7296) m, Radius: 18.303414 m
Surcharge Load: 17 kN/m²

Figure G5-1

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
■	00: Concrete	High Strength	24		
■	00: FILL: Gran. A	Mohr-Coulomb	22.8	0	40
■	02: CLAY/SILT Crust (ESA)	Mohr-Coulomb	17	5	28
■	03: CLAY/SILT (ESA)	Mohr-Coulomb	17	5	28

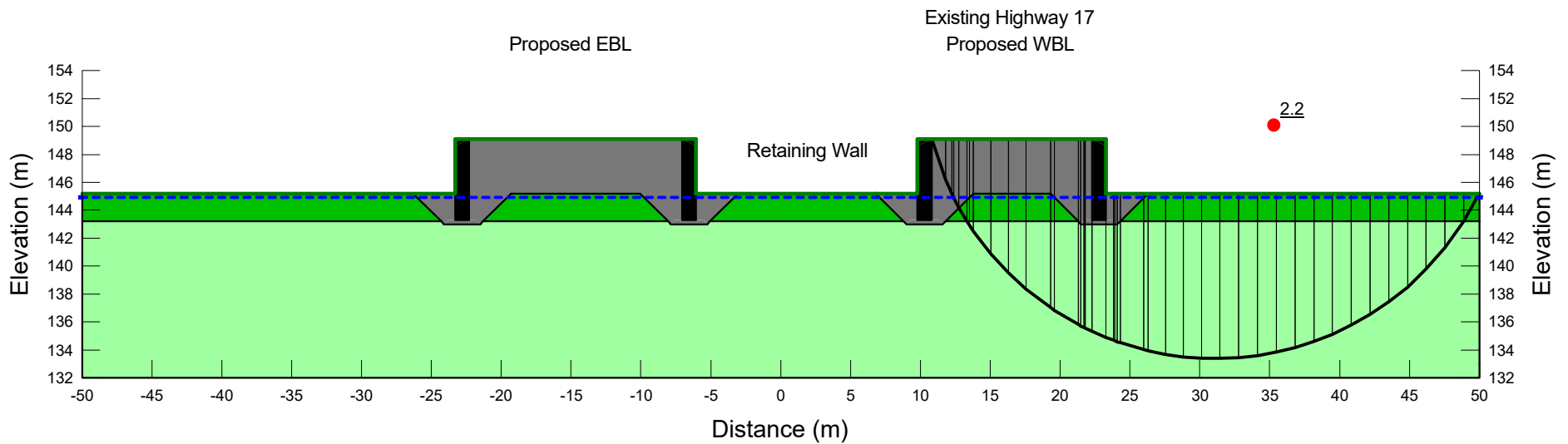


Project Highway 17 Twinning - Culvert 17+893		
Analysis G5.2 EB Permanent - Static (Drained)		
Seismic Coefficient H: 0g, V: 0g	Last Run 2022/06/22, 05:06:59 PM	Scale 1:450

Additional Details
 Name: 5. WB Embankment (Retaining Wall)
 Method: Morgenstern-Price, Half-Sine
 Minimum Slip Surface Depth: 1.52 m
 Entry: (17.7, 149.1) m, Exit: (30.928571, 145.2) m
 Center: (24.994258, 149.45643) m, Radius: 7.3029611 m

Figure G5-2

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	C-Top of Layer (kPa)	C-Rate of Change ((kN/m²)/m)	C-Maximum (kPa)	Total Cohesion (kPa)	Effective Cohesion (kPa)	Effective Friction Angle (°)
■	00: Concrete	High Strength	24						
■	00: FILL: Gran. A	Mohr-Coulomb	22.8					0	40
■	02: CLAY/SILT Crust (TSA)	Undrained (Phi=0)	17				75		
■	03: CLAY/SILT (TSA)	S=f(depth)	17	100	-7.5	40			



Project		
Highway 17 Twinning - Culvert 17+893		
Analysis		
G5.3 EB Temporary - Seismic (Undrained)		
Seismic Coefficient	Last Run	Scale
H: 0.13g, V: 0g	2022/06/22, 05:07:02 PM	1:450

Additional Details

Name: 5. WB Embankment (Retaining Wall)

Method: Morgenstern-Price, Half-Sine

Minimum Slip Surface Depth: 1.52 m

Entry: (10.8, 149.1) m, Exit: (50, 145.2) m

Center: (31.118698, 154.37384) m, Radius: 20.991971 m

Figure G5-3



Appendix H.

List of Referenced Specifications Non-Standard Special Provisions



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

OPSS 422	Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS.PROV 206	Construction Specification for Grading
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 511	Construction Specification for Rip-Rap, Rock Protection, and Granular Sheetting
OPSS.PROV 517	Construction Specification for Dewatering
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS.PROV 805	Construction Specification for Temporary Erosion and Sediment Control Measures
OPSS.PROV 902	Construction Specification for Excavating and Backfilling Structures
OPSS.PROV 903	Construction Specification for Deep Foundations
OPSS.PROV 1010	Material Specification for Aggregates Base, Subbase, Select Subgrade, and Backfill Material
OPSS.PROV 1860	Material Specification for Geotextiles
OPSD 202.010	Slope Flattening Using Surplus Excavated Material on Earth or Rock Embankment
OPSD 202.020	Drainage Gap for Slope Flattening on Rock or Granular Embankment
OPSD 208.010	Benching of Earth Slopes
OPSD 803.010	Backfill and Cover for Concrete Culverts with Spans Less than or Equal to 3.0M
OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
OPSD 3090.101	Foundation Frost Depths for Southern Ontario
OPSD 3101.150	Walls Abutment, Backfill Minimum Granular Requirement
SP FOUN0003	Amendment to OPSS 902 – Dewatering Structure Excavations
SP 517F01	Amendment to OPSS 517 - Construction Specification for Dewatering
SP110S06	Amendment to OPSS 1010, April 2013



2. Suggested wording for NSSPs

“Notice to Contractor: Protection of Sensitive Foundation Soils”

The Contractor is advised that the native silty and clayey soils that will be exposed at the subgrade are moisture sensitive and may become disturbed or otherwise negatively impacted when subjected to construction or personnel traffic, freeze-thaw actions, ingress or ponding water. The Contractor shall be responsible for selecting appropriate construction equipment, implementing adequate groundwater control measures and to minimize construction and personnel traffic on the founding subgrade.

“Structural Backfill”

Structural backfill for the culvert and retaining walls shall consist of OPSS Granular B Type II or Quarry Sourced OPSS Granular A material.

“Notice to Contractor: Obstructions”

The Contractor is hereby notified that the existing embankments within the overall project limits have been constructed with rock fill. Considerations of these potential obstructions must be made in the selection of appropriate equipment and procedures for excavations, installations of cofferdams and temporary protection systems.