

FINAL v2
FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 11 CALAMITY CREEK CULVERT REPLACEMENT
2.9 KM NORTH OF NORTH JUNCTION OF HWY 11 AND HWY 65
SITE NO.: 47-273C
GWP No. 5159-12-00
5013-E-0031

Geocres No.: 31M-119

Report to:

MMM Group Limited

Latitude: 47.555742

Longitude. -79.674656

June 2017

Thurber File: 19-5161-208, Assignment #6

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PART 1. FACTUAL INFORMATION

1 INTRODUCTION

This section of the report presents the factual findings obtained from a foundation investigation completed for the proposed culvert replacement at the Highway 11 crossing of Calamity Creek, GWP 5159-12-00. The structure is located approximately 2.9 km North of the North Junction of Highway 11 and Highway 65, New Liskeard Area. Thurber Engineering Limited (Thurber) carried out the current investigation as a sub-consultant to MMM Group Limited under Agreement No. 5013-E-0031, Assignment No. 6.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide a borehole location plan, records of boreholes, stratigraphic profile, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions was developed in the course of the current investigation and with data available from previous foundation investigations.

Earlier foundation investigation reports that have been provided to Thurber and reviewed in preparation of this report are as follows:

Preliminary Foundation Investigation Report and Design Report, Calamity Creek Culvert, Highway 11, Assignment No. 5013-E-0018, G.W.P. 5159-12-00, Site 47-273C, (*GEOCRES 31M-109*), dated April 2016 and prepared by Terraprobe Inc. (Terraprobe)

Exploratory Boreholes, W.P. 147-98-00, Agreement No. PO5005A000062, (*GEOCRES 31M-66*), dated December 1999 and prepared by Shaheen & Peaker Limited (S&P).

The Record of Borehole sheets for Boreholes BH1, BH3, BH4, BH5 and BH6 from the Terraprobe Report and Boreholes DB3 and DB4 from the S&P Report are provided in Appendix B and their location has been shown on the Borehole Location and Soil Strata drawing included in Appendix A. Additional boreholes (BH2, DB1, DB2 and DB5) from the above mentioned reports were drilled at a distance away from the current and proposed culvert alignments and are not provided within this report. The Terraprobe and S&P borehole logs and soil strata drawing should be included in the Tender Documents. It must be noted that Terraprobe and S&P are solely responsible for the accuracy and quality of the subsurface information in their respective reports.

2 SITE DESCRIPTION

The existing culvert is a concrete box culvert located near Sta. 17+645 on Highway 11 (Linear Highway Referencing System: 17320, Offset: 2.850). The culvert is reported to be 3.05 m wide by 2.45 m high at the inlet and approximately 236 m long in a non-linear arrangement with a generally northeast to southwest alignment. The flow through the culvert ultimately drains into the Wabi River to the west.

At the location of the culvert, Highway 11 is a two-lane highway with a rural cross-section and gravel shoulders. The road surface of the Highway 11 embankment is approximately 16.3 m above the top of the culvert at an elevation of 213.4 m. The existing slopes are inclined at approximately 2.1H:1V for the upper 6 m of embankment and flatter below this level. Steel guiderails are present on both sides of Highway 11 in the area of the culvert. The land adjacent to the highway is undeveloped and undulating with vegetation consisting of grasses on the embankment and natural slopes and shrubs and trees located at higher elevations. The creek runs through an incised valley which is approximately 125 m to 150 m in width. The natural soil slopes vary significantly but are generally flatter than 2H:1V with the exception of those areas which have undergone erosion either from cattle or overland flow of water. Erosion and surficial slumps were noted in the native materials near the inlet and outlet of the culvert. The existing terrain adjacent to the gulch is approximately 15-18 m above the elevation of the culvert invert within a horizontal distance of approximately 100 m of the culvert alignment. Groundwater seepage from this higher elevation flowing towards the base of the gulch/culvert and environmental effects (wetting/drying) is anticipated to have contributed to the surficial erosion that was observed. However, groundwater was not observed to be exiting the slopes at the time of the investigation. Bedrock outcrops were not observed on site. Traffic volumes are understood to be less than 7,050 AADT (2012). Overhead utilities are present on the west side of the highway.

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

3 SITE INVESTIGATION AND FIELD TESTING

The current site investigation and field testing program was carried out between August 9th and 16th, 2016. Drilling consisted of advancing eight boreholes identified as 16-01 through 16-08 and was carried out using portable equipment for the seven off road boreholes and a truck mounted drill rig for the one borehole advanced from the road surface. The truck mounted drill rig was equipped with hollow stem augers with an internal diameter of 250 mm. The portable gear utilized NW casing (76 mm internal diameter). Prior to commencement of drilling, utility clearances were obtained in the vicinity of the borehole locations.

Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). Two Thin Walled (Shelby) Tube samples of a clay deposit were retrieved from Borehole 16-04 to obtain a relatively undisturbed soil sample for further laboratory testing. The boreholes were extended to depths ranging from 8.8 to 26.9 m (elev. 188.4 to 185.5 m) below the existing ground surface.

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

A vibrating wire piezometer was installed, within filter sand, in Boreholes 16-01, 16-06, 16-07 and 16-08 to observe the piezometric pressure within the clay deposit. A standpipe piezometer, consisting of 38 mm diameter Schedule 40 PVC pipe with a 1.5 m long slotted screen, was installed within Boreholes 16-03 and 16-05 to observe groundwater conditions after completion of drilling operations. The standpipe screens were installed within a filter sand to permit groundwater level monitoring at a tip elevation of 186.7 m and 188.6 m, respectively.

A rising head conductivity test was completed within the standpipe piezometers between October 18th and 21th, 2016. The test consisted of lowering the water level within the standpipe piezometer and then recording the recovery of the water level with the use of a datalogger over an elapsed time of approximately 20 to 24 hrs.

Boreholes 16-02 and 16-04 were backfilled with a low-permeability mixture of auger cuttings and bentonite pellets in general accordance with Ontario MOE Regulation 903. Borehole 16-04 was capped with 150 mm of cold patch asphalt to reinstate the travelling surface. The boreholes which were completed with standpipe or vibrating wire piezometers are still available for additional monitoring. The standpipe piezometers should be abandoned as part of the construction contract.

The approximate borehole locations are shown on the Borehole Locations and Soil Strata Drawing included in Appendix A. The coordinates and elevation of the boreholes are provided on this drawing and on the individual Record of Borehole sheets.

4 LABORATORY TESTING

The recovered soil samples were subjected to visual identification and to natural moisture content determination. Selected samples were also subjected to Atterberg Limit testing and gradation analysis (hydrometer and/or sieve). The results of these tests are summarized on the Record of Borehole sheets included in Appendix B. A single soil sample, obtained with a Thin Walled (Shelby) Tube, underwent one-dimensional consolidation testing. Three samples of soil recovered from within the boreholes were selected and submitted for analytical testing of corrosivity parameters and sulphate content. All laboratory test results from the current field investigation are provided in Appendix C.

5 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 paragraphs. However, the factual data presented on the Record of Borehole sheets takes precedence over this general description for interpretation of the site conditions. It must be recognized that the soil and groundwater conditions may vary between and beyond borehole locations.

In general terms, the site was found to be underlain by a pavement structure and embankment fill overlying a deposit of predominantly clay over a thin deposit of clayey sand till over bedrock. A surficial topsoil layer was present at the location of the off-road boreholes. SPT refusal or casing advancement refusal was noted on probable bedrock in each of the investigated boreholes.

5.1 Topsoil

Boreholes 16-01 through 16-03 and 16-05 through 16-08 were drilled adjacent to the Highway 11 embankment alignment and encountered a 50 to 100 mm thick layer of topsoil at the surface.

5.2 Fill

5.2.1 Pavement Structure

Borehole 16-04 was drilled through the existing Highway 11 embankment and encountered a layer of asphalt approximately 260 mm in thickness at the surface of the roadway. A buried layer of asphalt, with a thickness of 280 mm, was also encountered at a depth of 0.9 m below the roadway surface between layers of granular fill consisting of sand with silt with gravel. A 455 mm diameter boulder was reported within this unit in historic Borehole 3 from Terraprobe's field investigation (GEOCRES 31M-109) at approximate elevation 209 m. A 280 mm diameter boulder was noted at elevation 211.6 m in Borehole 16-4.

5.2.2 Clayey Sand Fill

Below the granular fill in Borehole 16-04 and below the topsoil in Boreholes 16-02, 16-03, 16-05, 16-07 and 16-08 was a layer of fill consisting of clayey sand to clayey sand with gravel. Trace wood was also noted in the fill. The clayey sand fill had an underside depth of 0.9 to 9.1 m (elev. 204.3 to 198.2 m) below the existing ground surface

SPT tests recorded N-values in the clayey sand fill typically ranging from 4 to 24 blows per 300 mm of penetration indicating a loose to compact relative density. Elevated SPT N-values were encountered locally near the surface of Borehole 16-07 and 16-08 where the presence of cobbles was observed. Recorded moisture contents ranged from 8 to 33%.

Gradation analyses were completed on six samples of the clayey sand fill layer. The grain size distribution curves for these samples are included in Figure C1 of Appendix C. The results of the tests are summarized below and are presented on the corresponding Record of Borehole sheets in Appendix B and indicate an SC material.

Soil Particle	Percentage (%)	
Gravel	14 - 30	
Sand	35 - 49	
Silt	23 - 30	32 - 43
Clay	9 - 17	

Atterberg Limit testing was completed on two samples of the clayey sand fill layer. The results are summarized on the Record of Borehole sheets in Appendix B and the Atterberg Limit graphs are included in Figure C8 of Appendix C. The laboratory results are summarized below and indicate that the clayey sand fill exhibits low plasticity

Parameter	Value
Liquid Limit	25 - 26
Plastic Limit	14 - 16
Plasticity Index	10 - 11

5.2.3 Clay Fill

A layer of fill consisting of clay to clay with sand was encountered under the clayey sand fill in boreholes 16-03, 16-04, 16-05, 16-07 and 16-08. The clay fill layer was 1.7 to 6.4 m in thickness with an underside elevation at 201.8 to 196.6 m. It is noted from Terraprobe's field investigation (GEOCRE 31M-109) that wood fragments were observed at the base of this unit in historic Borehole 3 and cobbles were noted in historic Borehole 4. A trace of wood fragments and cobbles were noted in the Borehole 16-4 of the current field investigation.

SPT tests recorded N-values in the clay fill typically ranging from 1 to 15 blows per 300 mm of penetration. A higher SPT N-Value of 41 blows per 300 mm of penetration was recorded locally within Borehole 16-08. Field vane tests were performed within the fill layer and recorded undrained shear strengths typically ranging from 32 to 56 kPa indicating a firm to stiff consistency. Remolded field vane testing indicates that the clay shows some sensitivity. The recorded moisture contents varied from 38 to 56%.

Gradation analyses were completed on three samples of the clay fill layer. The grain size distribution curves for these samples are included in Figure C2 of Appendix C. The results of the tests are summarized below and are presented on the corresponding Record of Borehole sheets in Appendix B.

Soil Particle	Percentage (%)
Gravel	0 - 5
Sand	2 - 18
Silt	20 - 36
Clay	41 - 78

Atterberg Limit testing was completed on three samples of the clay fill layer. The results are summarized on the Record of Borehole sheets in Appendix B and the Atterberg Limit graphs are included in Figure C9 of Appendix C. The laboratory results are summarized below and indicate that the clay fill exhibits medium to high plasticity (CI to CH).

Parameter	Value
Liquid Limit	45 - 66
Plastic Limit	20 - 23
Plasticity Index	25 - 43

5.3 Clay

A native deposit of clay was encountered beneath the topsoil and fill materials noted above in all eight boreholes. The investigated thickness of the deposit ranged from 7.7 to 15.1 m (base elev. 188.5 to 186.5 m). The clay deposit was noted to be varved based on examination of Shelby tube samples taken from BH16-04.

SPT tests performed within the clay deposit gave N-values typically ranging from weight of hammer to 8 blows per 300 mm of penetration but also exhibited localized higher blow counts up to a maximum of 25 blows per 300 mm of penetration. Field vane tests were performed within the deposit and recorded undrained shear strengths typically ranging from 39 to 78 kPa indicating a firm to stiff consistency. Remolded field vane testing indicates that the clay shows some sensitivity, generally decreasing in with depth. The recorded moisture contents varied from 22 to 63%

Gradation analyses were completed on seventeen samples of the clay deposit. The grain size distribution curves for these samples are included in Figure C3, C4, C5 and C6 of Appendix C. The results of the tests are summarized below and are presented on the corresponding Record of Borehole sheets in Appendix B.

Soil Particle	Percentage (%)	
	Clay	Varved Clay
Gravel	0 - 15	0 - 6
Sand	0 - 23	0 - 17
Silt	24 - 29	33 - 70
Clay	33 - 76	26 - 67

Atterberg Limit testing was completed on seventeen samples of the clay deposit. The results are summarized on the Record of Borehole sheets in Appendix B and the Atterberg Limit graphs are included in Figure C10, C11, C12 and C13 of Appendix C. The laboratory results are summarized below and indicate that the clay varies from low to high plasticity (CL to CH).

Parameter	Value	
	Clay	Varved Clay
Liquid Limit	60 - 68	27 - 54
Plastic Limit	23	16 - 22
Plasticity Index	37 - 45	8 - 32

An Oedometer (one-dimensional consolidation) test was carried out on a relatively undisturbed sample obtained from a Thin Walled (Shelby) tube sample taken at a depth of 21.6m during the current field investigation. The sample was varved with 10mm to 30mm thick layers of silt and clay. The results are presented in Appendix C and summarized in the following table. The compressibility characteristics will vary with depth in accordance with the soil index parameters and stress history.

Table 5-1. Summary of Oedometer Test Results and Interpretations

Parameter		Units	Borehole BH16-04
Sample Depth (Elevation)		m	21.6 (191.8)
Natural Moisture Content, w_n		%	34
Initial Void Ratio, e_o		-	1.05
Unit Weight, γ		kN/m ³	17.5
Existing Vertical Effective Stress, σ'_{vo}		kPa	310
Preconsolidation Pressure(*), σ'_c		kPa	300
Over Consolidation Ration, OCR		-	~1
Recompression Zone	Recompression Index, C_r	-	0.05
	Coefficient of Consolidation, c_{vr}	cm ² /s	3.5 to 10.1 x 10 ⁻³
	Average Permeability, k_{vr}	m/s	2 x 10 ⁻⁹
Virgin Compression Zone	Compression Index, C_c	-	0.44
	Coefficient of Consolidation, c_v	cm ² /s	1.9 to 6.2 x 10 ⁻³
	Average Permeability, k_v	m/s	4 x 10 ⁻¹⁰
Modulus of Elasticity (Constrained), E_c		kPa	1,750

Note: (*) estimated via: Becker et al., 1987 "Work as a criterion for determining in situ and yield stresses in clays"

5.4 Clayey Sand Till

A clayey sand till deposit was encountered directly below the clay. The deposit ranged in thickness from 0 to 1.0 m prior to meeting refusal on inferred bedrock at a base elevation ranging from 188.4 to 185.5 m.

SPT tests gave N-values typically ranging from 10 to 25 blows per 300 mm of penetration indicating a loose to compact relative density. The moisture content within the clayey sand deposit ranged between 8 to 11%

Gradation analysis were completed on three samples of the clayey sand deposit. The grain size distribution curves for these samples are included in Figure C7 of Appendix C. The results of the tests are summarized below and are presented on the corresponding Record of Borehole sheets in Appendix B.

Soil Particle	Percentage (%)	
Gravel	14 - 24	
Sand	36 - 41	
Silt	28 - 37	39 - 50
Clay	13 - 17	

5.5 Groundwater

Observations for water levels were completed in the open boreholes during and upon completion of drilling. A standpipe piezometer was installed in two boreholes to monitor groundwater levels and conduct a rising head test after drilling and a vibrating wire piezometer was installed in four boreholes to observe the piezometric pressure within the clay deposit. The measured groundwater levels are summarized in the table below. The artesian pressures noted within Table 5-2 are attributed to be sourced from the till layer which is confined below the lower permeability native clay deposits.

Table 5-2. Measured Groundwater Levels

Borehole	Date	Ground Surface Elevation (m)	Groundwater Level		Comment
			Depth (m)	Elevation (m)	
16-01	2016-09-23	194.3	-	194.6 ^(*)	Vibrating Wire Piezometer
	2016-10-16		-	194.4 ^(*)	
16-02	2016-08-11	200.5	0.4	200.1	Open Borehole
16-03	2016-09-22	203.2	2.4	200.8	Standpipe Piezometer
	2017-05-16		0.5	202.7	
16-05	2016-09-22	204.0	3.6	200.4	Standpipe Piezometer
	2017-05-16		2.7	201.3	
16-06	2016-09-23	198.1	-	200.6 ^(*)	Vibrating Wire Piezometer
	2016-10-16		-	200.7 ^(*)	
16-07	2016-09-23	204.2	-	201.2	Vibrating Wire Piezometer
	2016-10-16		-	201.0	
16-08	2016-09-23	206.9	-	200.8	Vibrating Wire Piezometer
	2016-10-16		-	200.9	
BH1 ^(**)	2014-11-24	201.8	-0.6	202.4 ^(*)	Standpipe Piezometer
BH6 ^(**)	2014-11-24	197.7	-0.4	198.1 ^(*)	Standpipe Piezometer
DB3 ^(***)	1999-10-14	213.9	13.8	200.1	Standpipe Piezometer

Note: () Groundwater level/pressure was noted to be above the existing ground surface (artesian flow conditions), (**) Geocres 31M-109, (***) Geocres 31M-66*

It should be noted that the values shown above are considered short-term readings and may not reflect groundwater levels at the time of construction and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant and/or prolonged precipitation events.

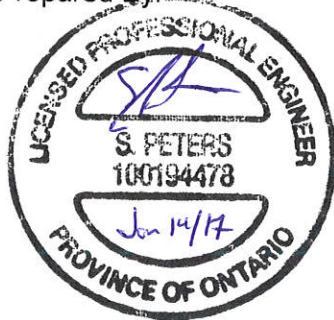
6 MISCELLANEOUS

Borehole locations were laid out with a handheld GPS and were positioned relative to existing site features and proposed foundation locations. After completion of drilling, the ground surface elevation were measured by Thurber relative to benchmarks provided by MMM Group Limited.

Landcore Drilling from Chelmsford, Ontario supplied the drill rigs and conducted the drilling, soil sampling, in-situ testing and installation of standpipe piezometer and vibrating wire piezometer for the current field program. The field investigation was supervised on a full time basis by Mr. Justin Gray, E.I.T. of Thurber. Overall supervision of the investigation program was conducted by Mr. Stephen Peters, P.Eng.

Routine geotechnical laboratory testing and one-dimensional consolidation testing was completed by Stantec's laboratory in Ottawa, Ontario. Analytical testing was completed by Paracel Laboratories. Interpretation of the factual data and preparation of this report were carried out by Dr. Fred Griffiths, P.Eng. and Mr. Stephen Peters, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng. a Designated Principal Contact for MTO Foundation Projects.

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PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 INTRODUCTION

This section of the report provides an interpretation of the factual data and presents geotechnical recommendations to assist the design team in designing a suitable foundation for the proposed replacement of the existing Calamity Creek culvert crossing Highway 11. The discussion and recommendations presented in this report are based on the information provided by MMM Group Limited and on the factual data obtained during the course of the investigation.

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

The existing culvert, conveying Calamity Creek under Highway 11, is a concrete box culvert approximately 236 m long with 5 bends along the alignment. The cross-section of the culvert varies along its length but has an opening of 3.05 by 2.45 m at the inlet. The invert of the existing culvert is reported to be at elevation 196.77 m and 194.15 m at the inlet and outlet respectively. The embankment fill height above the culvert is in the order of 16.3 m high. The creek flows in an east to west direction at this site and drains into the Wabi River.

Thurber Engineering Limited (Thurber) carried out the current investigation as a sub-consultant to MMM Group Limited under Contract No. 5013-E-0031, Assignment No. 6.

8 CULVERT FOUNDATIONS

8.1 General

A General Arrangement (GA) drawing of the proposed culvert replacement structure was provided on November 23, 2016 and is included in Appendix A. A review of the culvert replacement options has been carried out at a previous design stage. It included consideration of rehabilitating the existing culvert with and without a second culvert as well as replacement with one or twin culverts. It is understood that the preferred alternative,

replacement with twin 2.1 m diameter concrete culverts approximately 212.8 m long, will be constructed along an alignment south of the existing culvert. A temporary flow passage may not be required during construction if the existing culvert remains operational during construction. The replacement culvert is proposed to have an invert elevation similar to the existing culvert and be at elev. 194.15 m and 196.77 for the outlet and inlet, respectively.

In general terms, the site was found to be underlain by a pavement structure and embankment fill overlying a deposit of native clay over a deposit of clayey sand till followed by inferred bedrock. Conditions are similar to those described in the previous report (Geocres No. 31M-109). Adjacent to the embankment, a surficial topsoil layer was present in the off road boreholes. Groundwater level measurements near the ends of the culvert where the existing ground surface is lower indicated artesian pressures.

8.2 Construction Methodology Alternative

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

- Open Cut with Full Road Closure

Installation of a new culvert using open cut techniques and a full road closure would allow for an expedited construction schedule and could reduce costs associated with requiring roadway protection and creek diversion. However, this method would require a large excavation without the use of a temporary protection system as well as induce significant traffic disruptions which makes this alternative not feasible.

- Open Cut with Staged Temporary Widening and/or Lowering

Widening of the existing highway and/or construction of a detour embankment to accommodate a temporary traffic passage is not preferred due to the compressibility characteristics of the clay subgrade. Placement of additional fill will cause an increase in loading on the subgrade soils and will induce time-dependant settlement for both the temporary detour and existing embankment and may lead to the possibility of causing slope instability. Additionally, property acquisition may be required to complete this option.

Temporary grade lowering can be incorporated into the design to reduce the overall height of embankment above the base of the proposed excavation while maintaining traffic within the existing embankment footprint. Given the height of the embankment at this site, it is unlikely that grade lowering alone would allow culvert replacement in an open cut; additional measures such as a temporary protection system would also be needed. Furthermore, the vertical road alignment constraints will need to be reviewed from a highway design perspective.

- Open Cut with Staged Construction and Temporary Protection Systems

The use of open cut techniques in conjunction with staged culvert replacement is a potentially feasible construction staging option. This option will require roadway protection, as discussed further in Section 14, installed along the embankment centerline to maintain a single lane of traffic flow along the current highway alignment. However, due to its height, the roadway protection would need bracing such as struts, deadman and anchors to reduce lateral deflections as well as adequate embedment depth of the protection system.

The use of open cut techniques can be considered a feasible option for culvert installation adjacent to the highway alignment where the height of soil to be supported is reduced.

- Trenchless Techniques

Trenchless techniques would have the advantage of minimum disruption to traffic and would avoid a large excavation through the existing highway embankment. However, the size and type of replacement culvert, potential to encounter obstruction within the existing embankment fill, characteristics of the subgrade soils, and the topography of the surrounding terrain will need to be taken into consideration.

8.3 Culvert Type and Foundation Alternatives

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

- Circular Pipes (Concrete, HDPE, Steel)

From a foundation engineering perspective, pipe culverts are a technically feasible alternative, provided that other design issues including flow capacity, hydraulic properties and durability can be satisfied. Pipe culverts would allow the use of trenchless installation methods.

- Open Bottom Culvert (Box, Arch)

Open bottom culverts are not recommended for this site from a foundation engineering perspective since the post construction settlement in the foundation clay from this type of culvert would be greater than alternative options and would also require greater excavation and dewatering efforts during construction to place the foundation in the dry.

- Closed Culvert (Box)

Precast segmental box culvert in an open cut construction is considered a feasible option from a foundation engineering perspective. Precast sections, rather than cast-in-place construction, can be installed expediently with less potential for disturbance of the founding soils during installation. However, the open cut construction would require a very deep excavation through the embankment and a robust roadway protection design.

- Precast Cap Panel on Sheet Piles

Another culvert alternative from a geotechnical perspective is precast concrete cap panels supported on steel sheet piles. The depth of excavation at the highway centreline would require excessive sheet pile length. This technique was considered for use near the culvert ends to shorten the trenchless installation as temporary protection systems are required at the entry and exit pits. The connection between the sheet pile supported segment and the trenchless installation however may be problematic due to the conflicting culvert bottom condition. .

A comparison of these alternatives, based on their respective advantages and disadvantages, is included in Appendix E. It is not considered to be economical or practical to support a culvert on deep foundations at this site and therefore this option is not presented in this report. This report will focus on providing foundation recommendations on the design and construction of pipe culverts installed with either trenchless methods or open cut techniques and box culverts installed with open cut techniques.

8.4 Trenchless Recommendations

Trenchless methods that are typically considered to install pipes under highways include: jack and bore, pipe ramming, microtunneling (MTBM), hand mining and horizontal directional drilling. A table with comparisons of the different trenchless installation methods has been provided in Appendix E. Pipe ramming is not considered suitable due to the diameter of culvert anticipated to be required at this site in addition to the limited control of line and grade during ramming. The overall length of trenchless culvert installation may also dictate whether jack and bore is a feasible alternative. Note, it should be feasible to install the east and west portions of the culvert as open cut to reduce the trenchless length and an initial assessment of this arrangement has been completed and discussed further in Section 11.2. For the design of the open cut portion of the culvert, please refer to Sections 8.5, 11.1, and 11.3 for discussion and recommendations concerning box culvert bearing resistance, subgrade preparation, cut slope designs, temporary protection systems and groundwater control

Typically, embankment boreholes drilled through the south bound lane (BH3, DB4) encountered granular embankment fill and boreholes drilled through the north bound lane (BH4, DB3, 16-4) encountered embankment fill with cohesion. This soil description separation may indicate historic use of centerline sheet piling and separate backfilling operations. The granular non-cohesive embankment fill is noted to be above the elevation of trenchless installation but may be encountered in the area of launch pits or open cut installations. If centerline sheet piling was utilized during previous construction activities, it is unknown if remnants still exist buried below the existing road grade.

It is anticipated that the soils which will be encountered during tunneling will consist of clay fill, clay, varved clay and to a limited extent clayey sand fill. The soils at the front face of the trenchless tunnel excavation will predominantly be wet clay and based on the Tunnelman's Ground Classification System (modified by Heuer 1974 from Terzaghi 1950) the soils are described as 'squeezing' to 'slow raveling'. The observed groundwater levels were generally higher than elevation 200 m which is more than 4 m above planned invert for most of the culvert length and artesian at the culvert inlet and outlet areas, therefore closed face techniques are preferred.

Selection of the appropriate trenchless method is the responsibility of the Contractor and will depend on the relative costs associated with each method. The experience of the Contractor is of primary importance for trenchless installation. Based on the results of the investigation and the size and invert elevation of the culvert, a microtunneling (MTBM) with pipe jacking is likely the preferred approach.

Trenchless installation should be completed by a Contractor supported by a Foundation Engineering tunneling speciality firm with a complexity rating of High and carried out in accordance with the requirements of the Non-Standard Special Provision (NSSP) "Pipe

Installation by Trenchless Methods provided in Appendix G. Amongst the important issues discussed in the Nssp are maintenance of alignment, handling of oversized obstructions and disposal of cuttings.

Monitoring of the roadway surface will be required during trenchless installation. The settlement monitoring program and condition survey should follow Section 7.06 of the Nssp in Appendix G.

The design of safe and stable entry and exit pits for the trenchless installation is also the responsibility of the Contractor. Available geotechnical bearing resistances at the base of entry and exit pits shall follow recommendations and values provided in Section 8.5.1. Entry and exit pits shall be cut with side slopes following the recommendations provided in Section 11.1 or, depending on the Contractor's location of the entry and exit pits, global stability of the embankment may dictate the requirement for temporary protection systems to support temporary excavations. The temporary excavation support system should be designed and constructed as outlined in Section 14. Dewatering and surface water control must be employed as necessary to keep the entry and exit pits dry as discussed further in Section 11.3.

8.5 Foundation Design for Open Cut Installation

Foundation design aspects for a replacement culvert includes subgrade conditions, geotechnical resistances, settlements of founding soils, imposed loading pressures, erosion control, protection system design, groundwater control, staged excavation and stability of detour embankment. The culvert must be designed to resist loadings including lateral earth pressures, hydrostatic pressure, weight of embankment fill, traffic loading and any surcharge due to construction equipment and activities under static and seismic conditions.

Provided the embankment is reconstructed with no grade raise or widening, it is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading.

8.5.1 Box Culvert Geotechnical Resistances

The recommended geotechnical resistances for a pre-cast box culvert installed at the founding elevation of the current culvert are as follows:

At centerline of embankment

- Factored Geotechnical Resistance at ULS of 300 kPa
- Geotechnical Resistance as SLS of 150 kPa

Outside of embankment footprint (inlet/outlet of culvert)

- Factored Geotechnical Resistance at ULS of 125 kPa
- Geotechnical Resistance as SLS of 75 kPa

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 6.7.3 and Clause 6.7.4. Foundation settlement, based on the supplied SLS resistance, is expected to be less than 25 mm.

Resistance to lateral forces/sliding resistance between the precast concrete and the underlying Granular 'A' bedding (Section 8.6) should be evaluated in accordance with the CHBDC assuming an ultimate coefficient of friction of 0.45.

8.5.2 Pipe Culvert Geotechnical Resistances

Geotechnical resistance values are not required for pipe culverts. A modulus of subgrade reaction of 7 MN/m³ can be used for a pipe culvert installed in the native clay at this site if required.

8.5.3 Wingwalls

If wingwalls are required as part of the culvert design, the footings should be founded on a leveling pad with a minimum thickness of 0.5 m consisting of Granular 'A' material at or below the depth of frost (Section 8.7). The engineered pad can bear on the native subgrade provided that it is undisturbed, uniformly competent and free of any soft and deleterious materials. 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. The engineered fill pad must be placed in maximum 150 mm lifts and compacted to 100% standard proctor maximum dry density (SPMDD) with a placement moisture content $\pm 2\%$ of optimum. The following geotechnical resistance values are recommended for wingwalls at this site:

- Factored Geotechnical Resistance at ULS of 125 kPa
- Geotechnical Resistance as SLS of 75 kPa

The recommended values presented above are for an assumed vertical concentric loading only. Effects of load eccentricity and inclination need to be taken into account. Higher bearing capacity can be obtained, if required, by increasing the thickness of the Granular 'A' pad.

8.6 Subgrade Preparation and Bedding

All organics, existing fill, soft or loose deposits, disturbed soils and deleterious materials must be stripped from the footprint of the foundation to expose competent native subgrade material at or below the desired founding elevations. The exposed subgrade must be inspected to confirm that the subgrade is suitable and uniformly competent. Any soft or organic materials should be sub-excavated and backfilled and compacted as per OPSS.PROV 501 with granular fill consisting of OPSS.PROV 1010 Granular A material as soon as practical to protect the subgrade from disturbance during construction. In order to provide a more uniform foundation subgrade condition for the culvert, a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A requirements must be provided under the base of the culvert as per OPSS 422 and OPSD 803.010 (box culvert) or OPSD 802.032 (pipe culvert).

Given the firm conditions anticipated at the founding level of the replacement culvert, construction equipment should not be permitted to travel on the exposed subgrade. In addition, the compaction of granular bedding directly above the subgrade is likely to result in disturbance of the material with pumping of fines into the granular bedding and difficulty achieving the specified degree of compaction. Protection of the subgrade should include over excavation to allow placement of a mud slab 100 mm thick beneath the 300 mm thick Granular A bedding layer. The mud slab should be poured as soon as possible after

reaching the subgrade level and confirmation of QVE acceptance in order to protect the subgrade from construction traffic and weather.

Dewatering will be required to prepare the subgrade in the dry. Please refer to Section 11 for additional comments on groundwater and surface water control.

8.7 Frost Depth

The depth of frost penetration at this site is 2.3 m. It is not necessary to found a pipe or closed box culvert at a depth below frost penetration. Frost tapers are not required due to the depth of the culvert beneath the roadway.

9 BACKFILL AND EARTH PRESSURE

It is recommended that culvert cover consist of free-draining, non-frost susceptible granular materials such as Granular A material meeting the requirements of OPSS.PROV 1010. The cover must be in accordance with OPSS 902 (box culvert) or OPSS.PROV 401 (pipe culvert) and placed to the extent shown on OPSD 3101.150 (box culvert) or OPSD 802.032 (pipe culvert).

Culvert backfill should consist of material meeting the requirements of OPSS Select Subgrade Material and should be compacted in regular lifts. Heavy compaction equipment, used adjacent to structure, must be restricted in accordance with OPSS.PROV 501. The top of the backfill elevation should be within 500 mm on both sides of the culvert at all times. Care must be exercised when compacting the fill adjacent to and above the culvert in order not to damage the culvert.

Earth pressures acting on a box culvert may be assumed to be triangular and to be governed by the characteristics of the backfill. For a fully drained condition, the pressures should be computed in accordance with the CHBDC but generally are given by the following expression:

$$p_h = K (\gamma h + q) \quad (\text{kN/m}^3)$$

where:

p_h	=	horizontal pressure on the wall at depth h (kPa)
K	=	earth pressure coefficient (see table below)
γ	=	unit weight of retained soil (see table below)
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 6.9.3 of the CHBDC. Typical earth pressure coefficients for backfill are shown in Table 9-1.

Table 9-1. Earth Pressure Coefficients

Condition	Earth Pressure Coefficient (K)					
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$		OPSS SSM and Existing Clayey Sand Fill and Clay Fill $\phi = 30^\circ, \gamma = 20.0 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)
Active, K_A (Yielding Wall)	0.27	0.40	0.31	0.48	0.33	0.54
At Rest, K_O (Non-Yielding Wall)	0.43	-	0.47	-	0.50	-
Passive, K_P (Movement towards Soil Mass)	3.7	-	3.3	-	3.0	-
Soil Group(*)	"medium dense sand"		"loose to medium dense sand"		"loose sand"	

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

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

The parameters in the table correspond to full mobilization of active and passive earth pressures and require certain relative movements between the wall and adjacent soil to produce these conditions. The values to be used in design can be assessed from Figure C6.16 of the Commentary to the CHBDC using the soil group designation as outlined in Table 9-1. Active pressures should be used for any head walls or unrestrained walls. For rigid structures such as a concrete box culvert, it is recommended that at-rest horizontal earth pressures be used for design. Where ground surfaces are sloped behind the walls, the corresponding coefficients provided in the Table 9-1 should be used.

The culvert must be designed to withstand full hydrostatic pressure assuming a water level at least equal to the design creek water level. This is applicable when the water level behind the culvert is higher than the creek level.

10 SEISMIC CONSIDERATIONS

The soil profile at this site has been classified as a Site Class E in accordance with Section 4.4.3.2 of the CHBDC (S6-14). The seismic hazard for this site has been obtained from the Geological Survey of Canada (GSC). The data includes a peak ground acceleration (GPA), peak ground velocity (PGV) and the 5% spectral response acceleration values ($S_a(T)$) for the reference ground condition (Site Class C) for a range of periods (T) and for a range of return periods including 475-year, 975-year and 2475-year events. The GSC seismic hazard calculated data sheet for this site is included in Appendix F.

In accordance with Clause 4.6.5 of the CHBDC (S-14), retaining structures should be designed using dynamic earth pressure coefficient that incorporate the effects of earthquake loading. The coefficients of horizontal earth pressure for seismic loading presented in Table 10-1 may be used. The provided earth pressure coefficients are based on a PGA with a 2% probability of exceedance in 50 years of 0.127g (Geological Survey of Canada – Fifth Generation) and a F(PGA) of 1.81 as per Table 4.8 of the CHBDC (S6-14 update No. 1, April 2016).

Table 10-1. Dynamic Earth Pressure Coefficients

Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)
Active, K_{AE} Yielding Wall	0.34	0.53	0.38	0.61
Active, K_{AE} Non-Yielding Wall	0.42	0.71	0.47	0.81

Provided construction of embankment and cut slopes are carried out in accordance with recommendations provided within this report, the minimum required factor of safety will be maintained for seismic loading conditions (see Section 12.2).

Based on the subsurface condition encountered at the drilled locations at this site the foundation soils are considered to be not susceptible to moderately susceptible to liquefaction during a seismic event in accordance with CHBDC (S6-14) Clause C4.6.6. Liquefaction is not considered to be a concern at this site; some surficial and/or toe failure may occur but it is expected to be of limited nature and readily repairable.

11 EXCAVATION AND GROUNDWATER CONTROL

11.1 Excavations

All excavation must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of OHSA, the fill and native soils above as well as the native clay soils below the water table may be classified as Type 3 soil. The organics soils, alluvial deposits and any cohesionless soils below the water table are classified as Type 4 soils.

Excavation for the culvert replacement must be carried out in accordance with OPSS 902 and will be carried out through the existing embankment fill and extend into the underlying native clay deposit. The sides of temporary excavations must be sloped in accordance with the requirement of the OHSA. A detailed cut slope and embankment stability assessment should to be carried out but the Contractor prior to construction when a preferred culvert replacement strategy and methodology has been determined.

At locations where there are space restrictions or where a slope has to be retained, the excavations will need to be carried out within a protection system. Further discussion is presented in Section 13.

11.2 Temporary Excavations for Entrance and Exit Pits

The design of safe and stable entry and exit pits for the trenchless installation is the responsibility of the Contractor. However, a global stability analysis was completed to assess the feasibility of reducing the overall length of a trenchless culvert installation by constructing the entrance and exit pits within the embankment slopes. The stability analysis was carried out utilizing the commercially available slope stability program Slope/W (version 8) of the GeoStudio software package developed by Geo-Slope International. The analysis utilized two-dimensional geometry and Morgenstern-Price method of slices for limit equilibrium with the soil properties and pore water pressures encountered during the current field investigation. Undrained and drained analyses were completed and the existing slopes were found to exceed a factor of Safety of 1.3 for both the east and west sides of the embankment.

The lateral extent of the pits should be selected to limit the encroachment into the embankment core and therefore the depth of the excavation and to reduce the potential to destabilize the road. A location of 35 m measured perpendicular to the highway alignment (approximately 50 m measured in-line with the skewed culvert) was used in the analysis. With this arrangement, a sloped open cut is not adequately stable and the pits must be excavated within a protective enclosure extending to the underlying bedrock surface. The free height of the protection system would be approximately 10 m on the upslope side of the excavation at this location. Using a two-dimensional analysis resulted in an upper bound calculation of an 11 to 16% reduction in the Factor of Safety from the current state. Given that the benefits of three-dimensional geometry which have not been included in the analyses, this reduction to the Factor of Safety is viewed to be acceptable for a temporary construction condition. Given the geometry of the embankment, the free height of the protection system would increase significantly with a shorter tunnelled length than that analysed, particularly on the west side, to become impractical.

Due to the height of the retained soils and the available penetration depth to bedrock, a suitable bracing and anchoring system will most likely need to be incorporated into the protection system design to resist the lateral loadings. Further design parameters can follow the recommendations outlined in Section 14.

11.3 Surface and Groundwater Control

Culvert construction, subgrade preparation and placement and compaction of granular bedding must be carried out in the dry. Provided the existing culvert is maintained operational during construction, a temporary flow passage is not expected to be required to convey creek flow around the construction site. Construction of cofferdams will be required to divert the creek flow away from the culvert subgrade area.

Excavation below the groundwater level to construct the culvert foundation will be required. The culvert subgrade will be formed in the native firm clay under a head of approximately 5 to 6 m with artesian pressure near the outlet and inlet of the culvert.

Excavation below the groundwater level without prior dewatering is not recommended since the inflow of groundwater will cause base heave and sloughing of the soil below the water level, making it difficult to maintain a dry, sound base on which to work. Temporary groundwater and surface water control measures will be required to remain operational during construction until the culvert is installed and backfilled. Dewatering systems must be designed by a dewatering specialist. Dewatering systems should be design, operated, and removed in accordance with OPSS.PROV 517.

Based on the groundwater and soil conditions, special attention must be paid to construction dewatering. It is recommended that excavations be enclosed within a water tight sheet pile enclosure. The groundwater level within the enclosure should be lowered by pumping from sumps prior to excavation to a minimum of 500 mm below the underside of the final subgrade. It is expected that approximately 6-7 m of clay will be present between the underlying pressurized till layer and the base of the culvert. Therefore the artesian pressure within the native deposits should not need to be depressurized prior to excavation for entry/exit pits for trenchless installation methods provided that the excavation's horizontal extents are limited and the till layer is not penetrated by temporary protection systems (see Section 14). As indicated in Section 8.6, a mud slab should be poured with lean mix concrete to protect the exposed subgrade surface within the excavation from disturbance.

Further assessment of dewatering requirements and the need for a PTTW should be carried out by specialists experienced in this field. An NSSP is recommended for this contract; a version is included in Appendix G. Hydraulic conductivities that were derived during the current investigation are given below:

Material	Type of Analysis	Hydraulic Conductivity (m/s)
Native Clay	Oedometer Testing	$k_y = 3 \text{ to } 0.2 \times 10^{-9}$
	Rising Head Test	$k_{xy} = 8 \text{ to } 1 \times 10^{-9}$

12 EMBANKMENT DESIGN

12.1 Embankment Reconstruction

Embankment reconstruction after culvert replacement should be carried out in accordance with OPSS.PROV 206. The embankment should be reinstated with side slopes of 2H:1V (or flatter) if constructed using Select Subgrade Material (SSM) or Granular B Type I. The existing clayey sand fill and clay fill materials are not considered acceptable materials for reuse during reconstruction of the embankment core. However, existing fill that is free of organics can be reused as backfill in the areas above the culvert cover/embedment and outside of the embankment core, defined as the area outside of a 2H:1V from the edge of pavement.

Embankment slopes must be provided with erosion protection in accordance with OPSS.PROV 804. Where new embankment fill is placed against existing embankment slopes or on a sloping ground surface steeper than 3H:1V, benching of the existing slope should be carried out in accordance with OPSD 208.010. Construction of embankments

should be carried out in accordance with OPSS.PROV 209 "Construction Specification for Embankments over Swamps and Compressible Soils"

12.2 Embankment Settlement and Stability

The condition of the embankment slopes was examined in the field during the field investigation; no evidence of instability (tension cracks etc.) was noted, at that time. Erosion and surficial slumps were noted in the native materials near the inlet and outlet.

Provided no grade raise or embankment widening is required and proper construction methods are used, no long term or global stability issues are anticipated for embankments built at this site. Material stockpiling above the existing grades is a temporary construction measure and the stability implication should be reviewed by the Contractor. In addition, the Contractor's selection and placement of construction equipment (such as heavy cranes) must be included in the stability assessment.

It is understood that no grade raise is anticipated along the alignment of Highway 11 and therefore negligible foundation settlement is expected to occur. Further assessment should be carried out where construction staging dictates the requirement for additional loading.

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

13 SCOUR PROTECTION AND EROSION CONTROL

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

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

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

14 ROADWAY PROTECTION

Roadway protection will be required during various stages of construction. Roadway protection must be implemented in accordance with OPSS.PROV 539 and designed for Performance Level 2 (maximum 25 mm horizontal deflection). The actual pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall and these factors must be considered when designing the shoring system. It is recommended that an NSSP be included in the tender documents to

alert the Contractor to the height of the protection system required and the potential need for deadman tie-backs, struts and/or raker supports to achieve the specified performance level

Lateral earth pressure coefficients, under fully mobilized conditions, that can be used in design for the embankment fill and culvert backfill are provided in Table 9-1. The lateral earth pressure coefficients for the underlying native clay soils are given below:

$$\begin{aligned}\gamma_w &= 10 && (\text{kN/m}^3, \text{unit weight of water}) \\ \gamma &= 18 && (\text{kN/m}^3, \text{bulk unit weight of soil}) \\ K_A &= 0.39 \\ K_P &= 2.6\end{aligned}$$

Roadway protection is the responsibility of the Contractor and should be designed by a licenced Professional Engineer experienced in such designs and retained by the Contractor. The design of the roadway protection system should ensure the base of the sheet pile does not penetrate into the underlying artesian till layer. A suitable bracing system may need to be incorporated into the roadway protection design to resist the lateral loadings including traffic loading and surcharge loading due to construction equipment and operations. To reduce the disturbance to the culvert, it is advised that the sheet piles be left in place upon completion of construction and cut off at or below the depth of frost from beneath the finished pavement grade.

15 CORROSION AND SULPHATE ATTACK POTENTIAL

The results of the corrosivity and sulphate analytical testing indicates the following conditions at the locations tested:

- The potential for corrosion or sulphate attack on concrete foundations from the surrounding soil is considered negligible due to the low concentrations of sulphate and chloride in the samples tested
- The potential for soil corrosion on metal is considered to be mild
- Appropriate protection measures are recommended if metal structural elements are used

16 CONSTRUCTION CONCERNS

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

- Disturbance of the soil subgrade. Where fine-grained soils are exposed following clearing, grubbing and stripping activities, these areas will be soft and moisture sensitive and may become heavily disturbed when subjected to construction traffic. Site and subgrade drainage will be critical to maintain subgrade condition. The contractor must be aware of the issue so that he may adjust his operations to suit the subgrade conditions
- Cobbles, boulders or other buried obstructions which may include remnants of buried sheet piles could be encountered. Obstructions could interfere with

tunneling, excavation and/or roadway protection installation. An NSSP should be included in the contract alerting the Contractor to these conditions.

- Groundwater levels may fluctuate. Excavation will involve lowering the groundwater level below the excavation base to maintain a reasonably dry excavation and stable side slopes. Depressurization of the underlying till deposit will be required to reduce the possibility of base heave should the culvert be replaced in an open cut. The dewatering scheme will be critical for culvert construction at this site. An NSSP should be included in the contract alerting the Contractor to these conditions.
- The Contractor's selection of construction equipment and methodology must include assessment of the capability of the existing embankment to support the proposed construction equipment and any temporary structure fill (i.e., as a pad for crane support).

The successful performance of the culvert will depend largely upon good workmanship and quality control during construction. Subgrade examination and field density testing should be carried out by qualified geotechnical personal during construction to confirm that foundation recommendations are correctly implemented and material specifications are met.

17 CLOSURE

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

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Appendix A.

**Borehole Location Plan and Stratigraphic Drawings
General Arrangement Drawing**

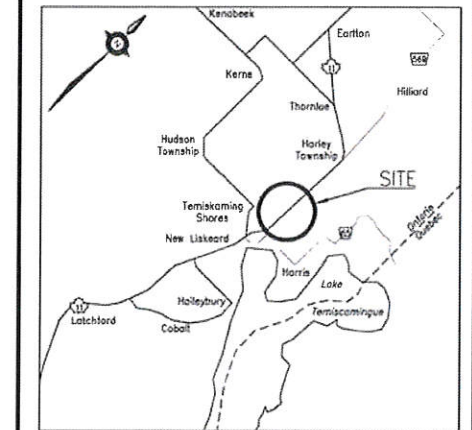
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CONT No
GWP No 5159-12-00



HIGHWAY 11
CALAMITY CREEK
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



KEYPLAN

LEGEND

•	Borehole (by Thurber)
•	Borehole (by Others)
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60' Cone, 475J/blow)
PH	Pressure, Hydraulic
W	Water Level
W	Water Level
P	Piezometer (SP, VWP)
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
16-1	194.3	5 269 287.6	404 445.1
16-2	200.5	5 269 303.9	404 471.5
16-3	203.2	5 269 323.0	404 488.4
16-4	213.4	5 269 372.9	404 540.7
16-5	204.0	5 269 411.0	404 578.4
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16-8	206.9	5 269 397.6	404 565.3

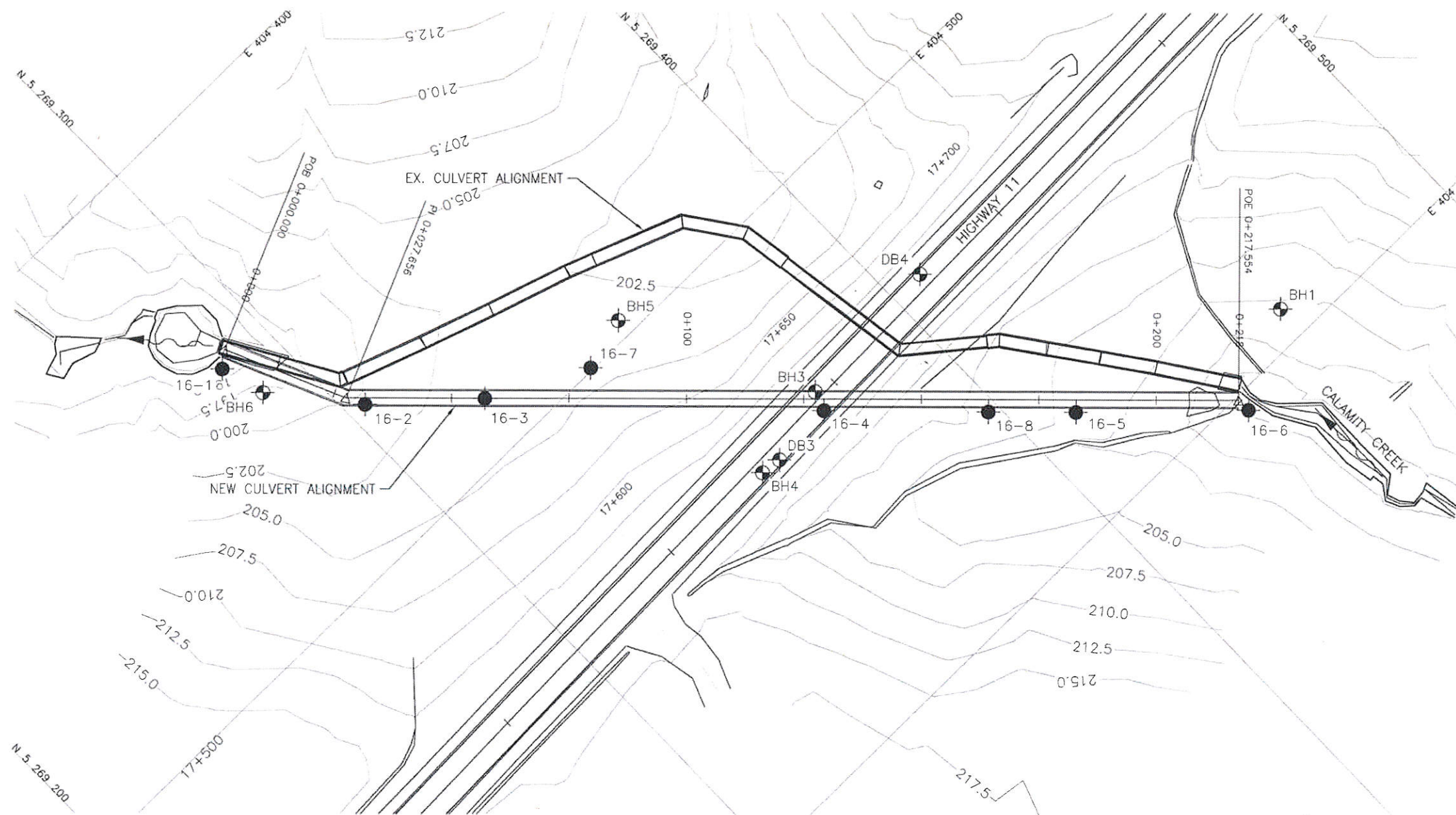
-NOTES-

- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- 3) Borehole locations are shown in MTM Zone 12 coordinates.

GEOCRES No. 31M-119

REVISIONS	DATE	BY	DESCRIPTION
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DRAWN	MFA	CHK JG	SITE
			LOAD
			DATE DEC 2016
			STRUCT
			DWG 1

FILENAME: H:\Drawing\1515161\208\1208 - Plan\Profile (Calamity Creek Culvert).dgn
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PLAN

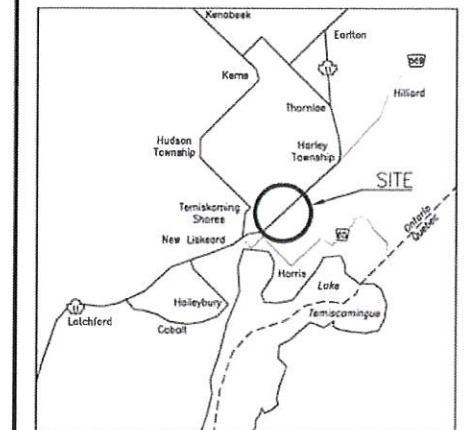


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UNLESS OTHERWISE SHOWN

CONT No
GWP No 5159-12-00

HIGHWAY 11
CALAMITY CREEK
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



KEYPLAN LEGEND

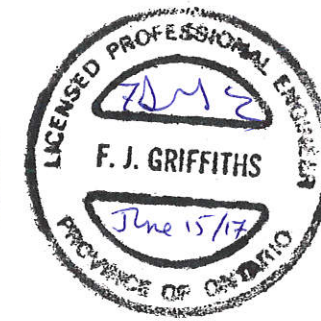
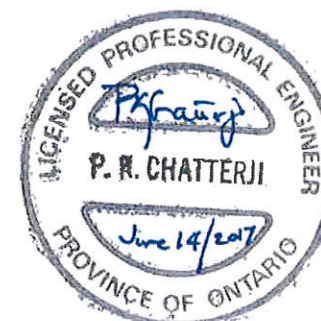
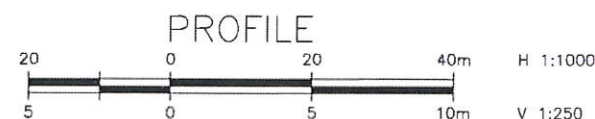
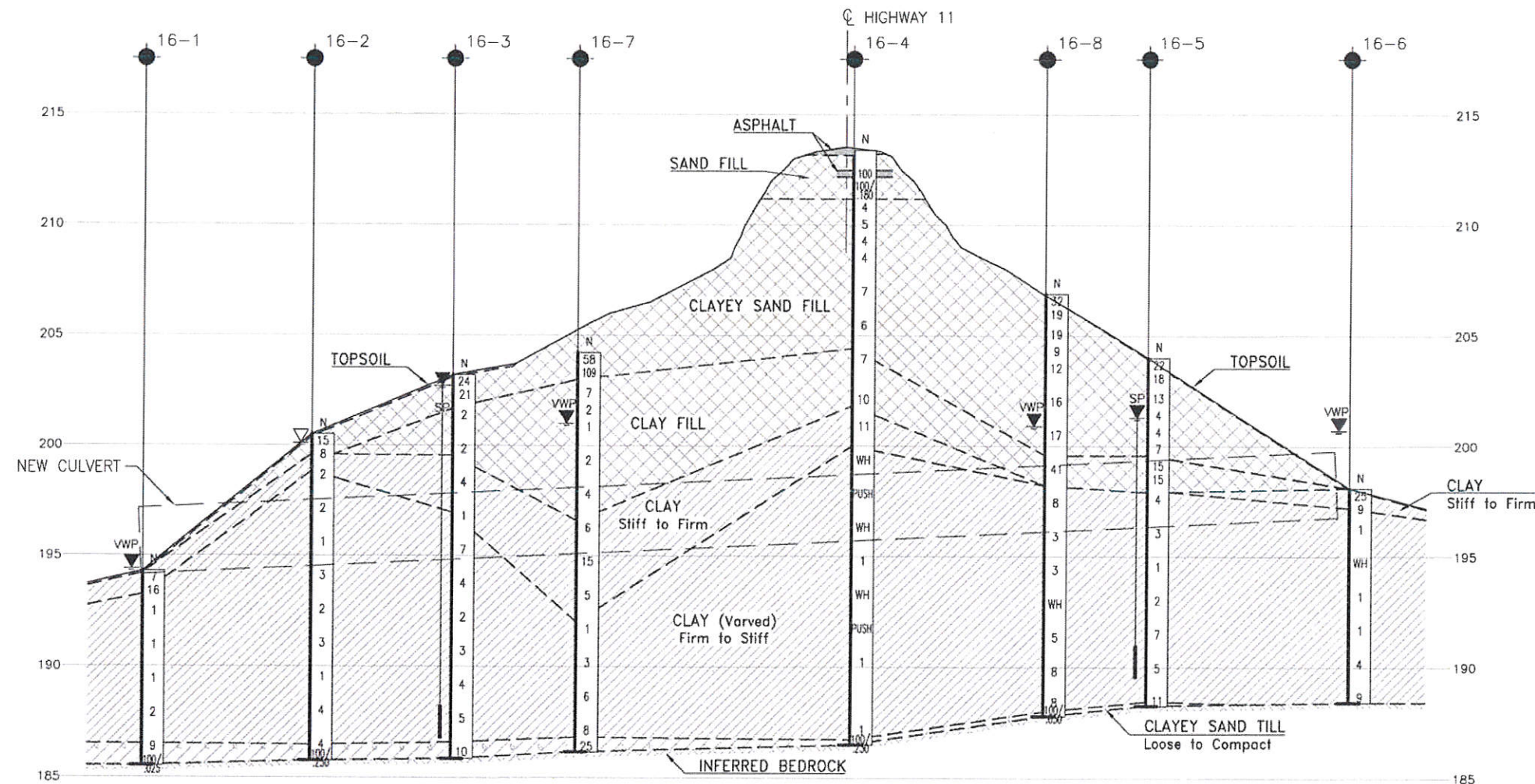
- Borehole (by Thurber)
- Borehole (by Others)
- N Blows /0.3m (Std Pen Test, 475J/blow)
- CONE Blows /0.3m (60' Cone, 475J/blow)
- PH Pressure, Hydraulic
- W Water Level
- W Water Level
- SP Piezometer (SP, WVP)
- 90% Rock Quality Designation (RQD)
- A/R Auger Refusal

NO	ELEVATION	NORTHING	EASTING
16-1	194.3	5 269 287.6	404 445.1
16-2	200.5	5 269 303.9	404 471.5
16-3	203.2	5 269 323.0	404 488.4
16-4	213.4	5 269 372.9	404 540.7
16-5	204.0	5 269 411.0	404 578.4
16-6	198.1	5 269 437.6	404 603.8
16-7	204.2	5 269 343.6	404 499.5
16-8	206.9	5 269 397.6	404 565.3

NOTES-

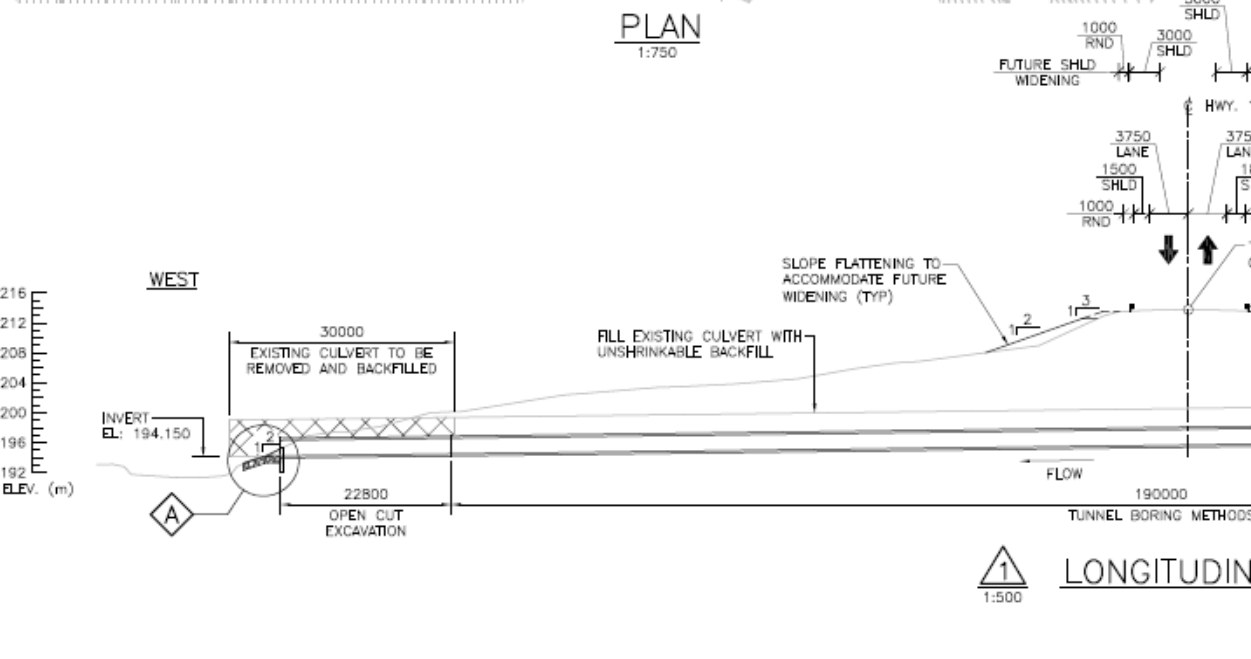
- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Borehole locations are shown in MTM Zone 12 coordinates.

GEOCRES No. 31M-119



REVISIONS	DATE	BY	DESCRIPTION
DESIGN	JG	CHK	SP
DRAWN	MFA	CHK	JG
CODE	SITE	STRUCT	DWG 2
DATE	JUN 2017		

PLAN: 145001119 5159-12-00-PlanProfile(CalamityCreekCulvert) dwg
PLOTDATE: 6/15/2017 8:15 PM

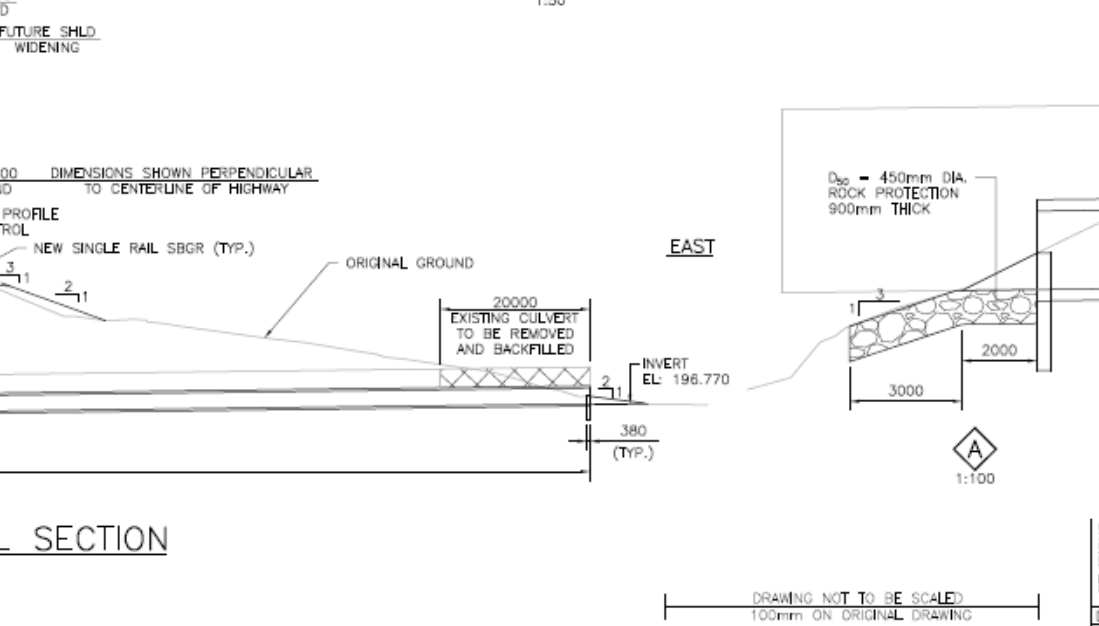
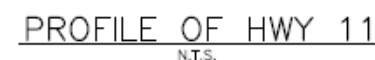


STA. 17 + 63.612

TOP OF PAVEMENT
PROFILE CONTROL

K = 55

LIMITS OF STRUCTURE



GENERAL NOTES:

PRECAST CONCRETE	50 ± 15
CAST-IN-PLACE CONCRETE	
BOTTOM OF WALL	100 ± 25
REMAINDER UNLESS NOTED OTHERWISE	70 ± 20

CONSTRUCTION NOTIFS:

THE CONTRACTOR SHALL VERIFY ALL DIMENSIONS, DETAILS AND ELEVATIONS OF THE EXISTING STRUCTURE THAT ARE RELEVANT TO THE WORK SHOWN ON THE DRAWINGS PRIOR TO THE COMMENCEMENT OF THE WORK. ANY DISCREPANCIES SHALL BE REPORTED TO THE CONTRACT ADMINISTRATOR AND THE REQUIRED ADJUSTMENT OF THE WORK REQUIRED TO MATCH THE EXISTING STRUCTURE SHALL BE SUBMITTED FOR APPROVAL.

BACKFILL SHALL BE PLACED SIMULTANEOUSLY BEHIND BOTH SIDES OF CULVERT KEEPING THE HEIGHT OF THE BACKFILL APPROXIMATELY THE SAME. AT NO TIME SHALL THE DIFFERENCE IN ELEVATION BE GREATER THAN 400mm.

NO GEOTEXTILE, GRANULAR BEDDING OR PRECAST UNITS SHALL BE PLACED UNTIL THE DEPTH OF THE EXCAVATION AND THE CHARACTER OF THE FOUNDATION HAVE BEEN APPROVED BY THE CONTRACT ADMINISTRATOR. ORGANICS OR UNSUITABLE MATERIALS SHALL BE EXCAVATED AND REPLACED WITH COMPACTED GRANULAR "A" AS DIRECTED BY THE CONTRACT ADMINISTRATOR.

THE AVERAGE FLOW RESULTING FROM A STORM EVENT
CORRESPONDING TO THE 2-YEAR RETURN PERIOD IS 5.93 m³/s.
IN-WATER WORK IS ONLY PERMITTED BETWEEN JULY 1 AND
MARCH 31.

CONTRACTOR IS FULLY RESPONSIBLE FOR ADEQUATE PROTECTION OF UTILITIES, SERVICES, ROADWAYS, ETC. DURING CONSTRUCTION OPERATION.

APPLICABLE STANDARD DRAWINGS:

OPSD 219.200	SANDBAG FLOOD CHECK DAM
OPSD 802.032	RIGID PIPE BEDDING, COVER, AND BACKFILL
	TYPE 4 SOIL - EARTH EXCAVATION
OPSD 810.010	RIP-RAP TREATMENT FOR SEWER AND
	CULVERT OUTLETS
OPSD 912.130	GUIDE RAIL SYSTEM, STEEL BEAM STEEL POST
	WITH OFFSET BLOCK ASSEMBLY INSTALLATION
	- SINGLE RAIL
OPSD 3121.150	MINIMUM GRADUAL BACKFILL REQUIREMENTS
OPSD 3941.200	FIGURES IN CONCRETE SITE, NUMBER AND
	DATE LAYOUT

LIST OF ABBREVIATIONS:

WP - DENOTES WORKING POINT

LIST OF DRAWINGS:

P1. GENERAL ARRANGEMENT

		DESCRIPTION

IN	KY	CHK	TPS	CODE	CHBDC	2014	LOAD	CL-625-ONT	DATE	MAY/16
----	----	-----	-----	------	-------	------	------	------------	------	--------

N	WA	CHK	KY	SITE 47-273C	STRUCT	SCHEME	DWG	P1
---	----	-----	----	--------------	--------	--------	-----	----

Appendix B.

Record of Borehole Sheets

Appendix B.1
Current Investigation

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):

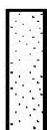
Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to an "A" size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone 0.3 m into the soil. The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

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 (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.

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 16-1

1 OF 1

METRIC

GWP# 5013-E-0031 LOCATION Calamity Creek Culvert, MTM Z12: N 5 269 287.6 E 404 445.1 ORIGINATED BY JG
 HWY 11 BOREHOLE TYPE NW casing COMPILED BY JG
 DATUM Geodetic DATE 2016.08.11 - 2016.08.11 CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE ▼	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
194.3								20 40 60 80 100					
0.0	TOPSOIL (100 mm)							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					
0.1	CLAY stiff brown		1	SS	7		194	20 40 60 80 100					
			2	SS	16			20 40 60 80 100					
193.2								20 40 60 80 100					
1.1	CLAY, varved firm to stiff grey						193	20 40 60 80 100					
			3	SS	1			20 40 60 80 100					
							192	20 40 60 80 100					
								20 40 60 80 100					
			4	SS	1		191	20 40 60 80 100					0 0 46 54
								20 40 60 80 100					
								20 40 60 80 100					
							190	20 40 60 80 100					
			5	SS	1			20 40 60 80 100					
							189	20 40 60 80 100					
								20 40 60 80 100					
			6	SS	2		188	20 40 60 80 100					
								20 40 60 80 100					
							187	20 40 60 80 100					
186.5								20 40 60 80 100					
7.8	Clayey SAND with gravel loose grey		7	SS	9		186	20 40 60 80 100					24 37 39 (SH+CL)
185.5								20 40 60 80 100					
8.8	Borehole terminated on inferred bedrock at 8.8 m Ground water level measured in VWP at: 0.1 m above ground surface (Elev. 194.4 m) on 2016/10/16 0.3 m above ground surface (Elev. 194.6 m) on 2016/09/23		8	SS	100/ 25 mm			20 40 60 80 100					

ONTMT4S 19-5161-208 CALAMITY CREEK CULVERT.GPJ 2012TEMPLATE(MTO).GDT 14/6/17

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

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 16-2

2 OF 2

METRIC

GWP# 5013-E-0031 LOCATION Calamity Creek Culvert, MTM Z12: N 5 269 303.9 E 404 471.5 ORIGINATED BY JG
 HWY 11 BOREHOLE TYPE NW casing COMPILED BY JG
 DATUM Geodetic DATE 2016.08.10 - 2016.08.10 CHECKED BY SP

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 (%)			
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE											
								20 40 60 80 100								20 40 60			
	Continued From Previous Page						190	5.0 +							0 0 61 39				
	CLAY, varved firm to stiff grey		9	SS	1		189	6.7 +											
								188	5.8 +										
								187	4.8 +										
								186	4.4 +										
186.5			11	SS	4										14 41 28 17				
14.0	Clayey SAND loose grey TILL		12	SS	100/ 250mm														
185.8																			
14.7	Borehole terminated on inferred bedrock at 14.7 m Borehole open upon completion Ground water level at 0.4 m BGS (Elev. 200.1 m) on completion of drilling																		

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

RECORD OF BOREHOLE No 16-3

1 OF 2

METRIC

GWP# 5013-E-0031 LOCATION Calamity Creek Culvert, MTM Z12: N 5 269 323.0 E 404 488.4 ORIGINATED BY JG
 HWY 11 BOREHOLE TYPE NW casing COMPILED BY JG
 DATUM Geodetic DATE 2016.08.11 - 2016.08.12 CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE								
								WATER CONTENT (%) W P W W L								
203.2							20	40	60	80	100					
0.0	TOPSOIL (100 mm)															
0.1	Clayey SAND compact brown FILL		1	SS	24								○			
			2	SS	21									○		
201.7																
1.5	CLAY firm brown FILL		3	SS	2										○	
			4	SS	2											
199.5																
3.7	CLAY stiff brown															
			5	SS	4										○	
							</									

Continued Next Page

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



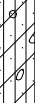

ONTMT4S 19-5161-208 CALAMITY CREEK CULVERT.GPJ 2012TEMPLATE(MTO).GDT 14/6/17

RECORD OF BOREHOLE No 16-3

2 OF 2

METRIC

GWP# 5013-E-0031 LOCATION Calamity Creek Culvert, MTM Z12: N 5 269 323.0 E 404 488.4 ORIGINATED BY JG
 HWY 11 BOREHOLE TYPE NW casing COMPILED BY JG
 DATUM Geodetic DATE 2016.08.11 - 2016.08.12 CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
								WATER CONTENT (%)									
	Continued From Previous Page						20 40 60 80 100	20 40 60 80 100	20 40 60								
	CLAY, varved firm to stiff grey						193	4.5 +	10.0 +								
			9	SS	2		192	8.4 +	6.9 +								
							191										
			10	SS	3		190	5.0 +	4.2 +								
							189										
			11	SS	4		188	7.7 +	3.3 +								
							187	4.3 +	4.7 +								
186.6																	
16.6	Clayey SAND loose grey TILL		13	SS	10		186										
185.9																	
17.3	Borehole terminated on inferred bedrock at 17.3 m Borehole open to 16.4 m upon completion Ground water level measured in standpipe piezometer at: 0.5 m BGS (Elev. 202.7 m) on 2017/05/16 2.4 m BGS (Elev. 200.8 m) on 2016/09/22																

ONTMT4S 19-5161-208 CALAMITY CREEK CULVERT.GPJ 2012TEMPLATE(MTO).GDT 14/6/17

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

RECORD OF BOREHOLE No 16-4

1 OF 3

METRIC

GWP# 5013-E-0031 LOCATION Calamity Creek Culvert, MTM Z12: N 5 269 372.9 E 404 540.7 ORIGINATED BY JG
 HWY 11 BOREHOLE TYPE NW casing COMPILED BY JG
 DATUM Geodetic DATE 2016.08.08 - 2016.08.09 CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
213.4								20	40	60	80	100		
0.0 213.1	ASPHALT (260 mm)													
0.3 212.5	SAND with silt and gravel brown FILL		1	AS			213							
0.9 212.2	ASPHALT (280 mm)		2	SS	100									
1.2 211.1	SAND with silt and gravel, occasional cobbles and boulders loose FILL -280 mm diameter boulder at 1.8 m		3	SS	100/ 180 mm		212							
2.3 211.1	Clayey SAND with gravel brown loose FILL		4	SS	4		211							
			5	SS	5		210							14 43 26 17
			6	SS	4									
			7	SS	4		209							
							208							
			8	SS	7		207							30 35 25 10
							206							
			9	SS	6		205							
204.3 9.1	Clay firm brown to grey FILL -25 mm fine fibrous organic layer at 9.6 m		10	SS	7		204							

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 16-4

2 OF 3

METRIC

GWP# 5013-E-0031 LOCATION Calamity Creek Culvert, MTM Z12: N 5 269 372.9 E 404 540.7 ORIGINATED BY JG
 HWY 11 BOREHOLE TYPE NW casing COMPILED BY JG
 DATUM Geodetic DATE 2016.08.08 - 2016.08.09 CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				
								20 40 60 80 100				
								20 40 60 80 100				
	Continued From Previous Page											
201.8	Clay firm brown to grey FILL -150 mm diameter cobble at 10.7 m -trace wood pieces		11	SS	10							
11.6	CLAY, trace roots/wood stiff greyish brown		12	SS	11							
200.0												
13.4	CLAY, varved firm to stiff grey		13	SS	WH							
			14	ST	PUSH							
			15	SS	WH							
			16	SS	1							
									</			

Continued Next Page

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

RECORD OF BOREHOLE No 16-4

3 OF 3

METRIC

GWP# 5013-E-0031 LOCATION Calamity Creek Culvert, MTM Z12: N 5 269 372.9 E 404 540.7 ORIGINATED BY JG
 HWY 11 BOREHOLE TYPE NW casing COMPILED BY JG
 DATUM Geodetic DATE 2016.08.08 - 2016.08.09 CHECKED BY SP

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		W P W W L					
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	WATER CONTENT (%)						
	Continued From Previous Page						20 40 60 80 100								
	CLAY, varved firm to stiff grey		17	SS	WH										
				18	ST	PUSH									0 0 53 47
				19	SS	1									0 0 37 63

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

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

ONTMT4S 19-5161-208 CALAMITY CREEK CULVERT.GPJ 2012TEMPLATE(MTO).GDT 14/6/17

METRIC

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			20 40 60 80 100	W P W W L				
	Continued From Previous Page												
	CLAY, varved firm to stiff grey												
			12	SS	2								
			13	SS	7								
			14	SS	5								
188.5													
186.5													
15.7	Clayey SAND compact grey TILL Borehole terminated on inferred bedrock at 17.3 m Ground water level measured in standpipe piezometer at: 2.7 m BGS (Elev. 201.3 m) on 2017/05/16 3.6 m BGS (Elev. 200.4 m) on 2016/09/22		15	SS	11								

+³, ×³: Numbers refer to Sensitivity



RECORD OF BOREHOLE No 16-6

1 OF 2

METRIC

GWP# 5013-E-0031 LOCATION Calamity Creek Culvert, MTM Z12: N 5 269 437.6 E 404 603.8 ORIGINATED BY JG
 HWY 11 BOREHOLE TYPE NW casing COMPILED BY JG
 DATUM Geodetic DATE 2016.08.14 - 2016.08.14 CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				
								20 40 60 80 100				
198.1								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				
0.0	TOPSOIL (50 mm)							20 40 60 80 100				
	CLAY stiff brown		1	SS	25			PLASTIC LIMIT W _p NATURAL MOISTURE CONTENT W LIQUID LIMIT W _L				
197.2			2	SS	9			WATER CONTENT (%)				
0.9	CLAY, varved firm to stiff grey							20 40 60				
			3	SS	1							
			4	SS	WH							
			5	SS	1							
			6	SS	1							
			7	SS	4							
			8	SS	9							
188.4												
9.7	Borehole terminated on inferred bedrock at 9.7 m											

ONTMT4S 19-5161-208 CALAMITY CREEK CULVERT.GPJ 2012TEMPLATE(MTO).GDT 14/6/17

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

METRIC

[illegible]

RECORD OF BOREHOLE No 16-7

1 OF 2

METRIC

GWP# 5013-E-0031 LOCATION Calamity Creek Culvert, MTM Z12: N 5 269 343.6 E 404 499.5 ORIGINATED BY JG
 HWY 11 BOREHOLE TYPE NW casing COMPILED BY JG
 DATUM Geodetic DATE 2016.08.12 - 2016.08.13 CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						
								20 40 60 80 100						
						PLASTIC LIMIT W P			NATURAL MOISTURE CONTENT W			LIQUID LIMIT W L		
						WATER CONTENT (%)								
						20 40 60								
204.2														
0.0	TOPSOIL (100 mm)													
0.1	Clayey SAND with gravel, occasional cobbles very dense brown FILL		1	SS	58		204							
			2	SS	109								20 44 36 (SI+CL)	
203.0							203							
1.2	Clay firm brown to grey FILL		3	SS	7									
			4	SS	2		202							
			5	SS	1		201							
			6	SS	2		200	6.8 +	10.4 +				5 18 36 41	
							199	9.5 +	9.0 +					
			7	SS	4		198							
							197	14.0 +	6.3 +					
196.6														
7.6	CLAY stiff brown		8	SS	6		196							
			9	SS	15		195						15 23 29 33	

Continued Next Page

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

ONTMT4S 19-5161-208 CALAMITY CREEK CULVERT.GPJ 2012TEMPLATE(MTO).GDT 14/6/17

RECORD OF BOREHOLE No 16-7

2 OF 2

METRIC

GWP# 5013-E-0031 LOCATION Calamity Creek Culvert, MTM Z12: N 5 269 343.6 E 404 499.5 ORIGINATED BY JG
 HWY 11 BOREHOLE TYPE NW casing COMPILED BY JG
 DATUM Geodetic DATE 2016.08.12 - 2016.08.13 CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
								20 40 60 80 100 20 40 60 80 100									
	Continued From Previous Page																
192.0			10	SS	5		194										

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

ONTMT4S 19-5161-208 CALAMITY CREEK CULVERT.GPJ 2012TEMPLATE(MTO).GDT 14/6/17

RECORD OF BOREHOLE No 16-8

1 OF 3

METRIC

GWP# 5013-E-0031 LOCATION Calamity Creek Culvert, MTM Z12: N 5 269 397.6 E 404 565.3 ORIGINATED BY JG
 HWY 11 BOREHOLE TYPE NW casing COMPILED BY JG
 DATUM Geodetic DATE 2016.08.15 - 2016.08.16 CHECKED BY SP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
								WATER CONTENT (%)					
206.9													
0.0	TOPSOIL (50 mm)												
0.1	Clayey SAND with gravel, occasional cobbles loose to dense brown FILL		1	SS	32								
			2	SS	19		206						
			3	SS	19		205						
			4	SS	9		204						14 47 30 9
			5	SS	12		203						
			6	SS	16		202						
							201						
			7	SS	17		200						21 42 23 14
199.6													
7.3	Clay firm brown to grey FILL		8	SS	41		199						0 2 33 65
198.2													
8.7	CLAY, varved firm to stiff grey		9	SS	8		198						
							197						

Continued Next Page

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

ONTMT4S 19-5161-208 CALAMITY CREEK CULVERT.GPJ 2012TEMPLATE(MTO).GDT 14/6/17

RECORD OF BOREHOLE No 16-8

2 OF 3

METRIC

GWP# 5013-E-0031 LOCATION Calamity Creek Culvert, MTM Z12: N 5 269 397.6 E 404 565.3 ORIGINATED BY JG
 HWY 11 BOREHOLE TYPE NW casing COMPILED BY JG
 DATUM Geodetic DATE 2016.08.15 - 2016.08.16 CHECKED BY SP

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 (%)				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						
	Continued From Previous Page							20 40 60 80 100	20 40 60				GR SA SI CL	
	CLAY, varved firm to stiff grey							8.7 14.4						
			10	SS	3		196			○				
							195	5.3 8.7						
			11	SS	3		194			▬	○		0 0 54 46	
							194	8.0 7.5						
			12	SS	WH		193			○				
							192	5.6 4.7						
			13	SS	5		191	6.6		○				
							190	4.0						
			14	SS	8		189			○				
	-silty						188							
188.0														
187.8	Clayey SAND		16	SS	100/		188			○				
19.1	TILL				50 mm								1 3 70 26	
	Borehole terminated on inferred bedrock at 19.1 m Vibrating Wire Piezometer installed at 17.5 m Ground water level measured in VWP													

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

ONTMT4S 19-5161-208 CALAMITY CREEK CULVERT.GPJ 2012TEMPLATE(MTO).GDT 14/6/17

RECORD OF BOREHOLE No 16-8

3 OF 3

METRIC

GWP# 5013-E-0031 LOCATION Calamity Creek Culvert, MTM Z12: N 5 269 397.6 E 404 565.3 ORIGINATED BY JG
 HWY 11 BOREHOLE TYPE NW casing COMPILED BY JG
 DATUM Geodetic DATE 2016.08.15 - 2016.08.16 CHECKED BY SP

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																
	at: 6.0 m BGS (Elev. 200.9 m) on 2016/10/16 6.1 m BGS (Elev. 200.8 m) on 2016/09/23																

ONTMT4S 19-5161-208 CALAMITY CREEK CULVERT.GPJ 2012TEMPLATE(MTO).GDT 14/6/17

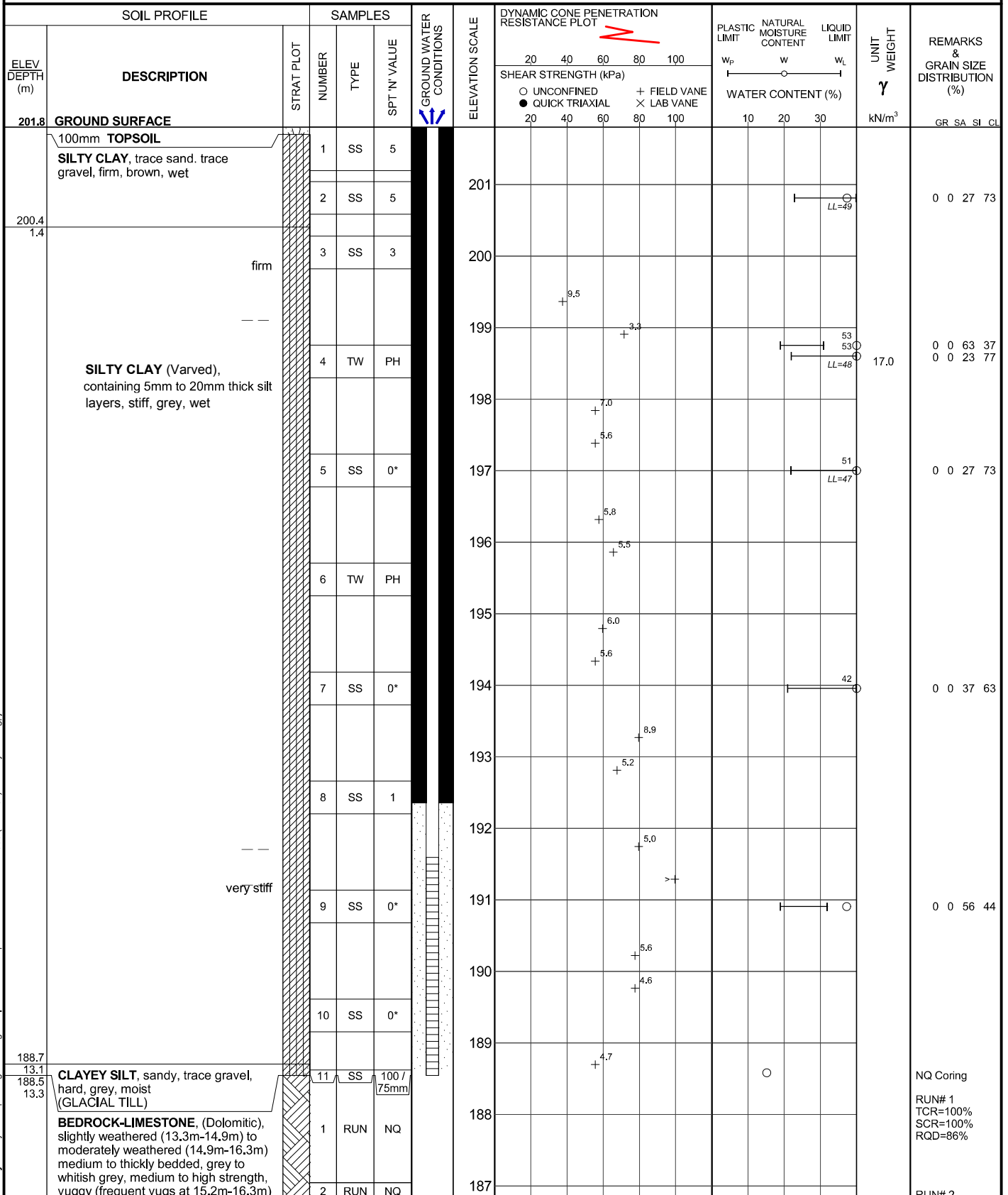
Appendix B.2
Previous Investigation
(*GEOCRES 31M-109*)

RECORD OF BOREHOLE No 1

1 of 2

METRIC

G.W.P. 5159-12-00 LOCATION Coords: E:404593.1 N:5269457.4 ORIGINATED BY S.M
DIST HWY 11 BOREHOLE TYPE CASING AND WASH BORING/NQ CORING COMPILED BY A.A
DATUM GEODETIC DATE 2014-9-4 CHECKED BY R.A




Continued Next Page

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

2 of 2

METRIC

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 (m)	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	SPT 'N' VALUE			SHEAR STRENGTH (kPa)					WATER CONTENT (%)				
								20	40	60	80	100	W _P	W	W _L		
	(continued)																
185.5	BEDROCK-LIMESTONE, (Dolomitic), slightly weathered (13.3m-14.9m) to moderately weathered (14.9m-16.3m) medium to thickly bedded, grey to whitish grey, medium to high strength, vuggy (frequent vugs at 15.2m-16.3m)		2	RUN	NQ		186									GR=100% SCR=92% RQD=37%	

*(aq) - above ground.

<u>Date</u>	<u>Water Depth (m)</u>	<u>Elevation (m)</u>
-------------	------------------------	----------------------

<u>Date</u>	<u>Water Depth (m)</u>	<u>Elevation</u>
Sep 17, 2014	-0.1 (ag)*	n/a
Oct 28, 2014	-0.5 (ag)*	n/a
Nov 24, 2014	-0.6 (ag)*	n/a

RECORD OF BOREHOLE No 3

1 of 3

METRIC

G.W.P. 5159-12-00 LOCATION Coords: E:404536.5 N:5269374.3 ORIGINATED BY S.M
DIST HWY 11 BOREHOLE TYPE HOLLOW STEM AUGERS / CASING AND WASH BORING/NQ CORING COMPILED BY A.A
DATUM GEODETIC DATE 2014-8-27 - 2014-8-28 CHECKED BY R.A

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 (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	SPT 'N' VALUE			20 40 60 80 100									
								SHEAR STRENGTH (kPa)									
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W _p W W _L								WATER CONTENT (%)									
213.7	GROUND SURFACE													GR SA SI CL			
213.4	270mm ASPHALTIC CONCRETE																
0.3	530mm FILL-SAND, some silt. some gravel, very dense, brown, dry		1	SS	75		213							commence casing and washboring			
212.9	300mm ASPHALTIC CONCRETE		2	SS	31												
0.8	150mm FILL-GRAVELLY SAND, trace silt, dense, brown, wet		3	SS	21		212										
212.6	FILL, gravelly sand to silty sand, trace clay, containing crushed limestone fragments, loose to dense, brown, moist to wet		4	SS	48												
1.1							211										
212.4			5	SS	7												
1.3			6	SS	16		210										
 455 diameter boulder		7	SS	15		209										
		8	SS	5		208										
			9	SS	13												
							207										
			10	SS	5		206										
			11	SS	5												
			12	SS	4		205										
204.7																	
9.0	FILL, silty clay, sandy, trace to some gravel, trace organics, firm, grey, moist to wet		13	SS	6		204										
			14	SS	7												
							203										
			15	SS	5												
			16	SS	6		202										
			17	SS	5		201										
	... containing wood fragments, very stiff		18	SS	17												
200.1							200										
13.6	SILTY CLAY, trace sand, very stiff, brown, wet		19	SS	16												
199.4																	
14.3			20	SS	4		199										

Continued Next Page

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

RECORD OF BOREHOLE No 3

2 of 3

METRIC

G.W.P. 5159-12-00 LOCATION Coords: E:404536.5 N:5269374.3 ORIGINATED BY S.M
DIST HWY 11 BOREHOLE TYPE HOLLOW STEM AUGERS / CASING AND WASH BORING/NQ CORING COMPILED BY A.A
DATUM GEODETIC DATE 2014-8-27 - 2014-8-28 CHECKED BY R.A

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 (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	SPT 'N' VALUE			SHEAR STRENGTH (kPa)							WATER CONTENT (%)								
								20	40	60	80	100			○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE	w _p	w	w _L		
								20	40	60	80	100	10	20	30	kN/m ³	GR	SA	SI	CL			
(continued)																							
	SILTY CLAY (Varved), containing 10mm to 30mm thick silt layers, stiff, grey, wet		21	SS	0*					4.2											0 0 38 62		
			22	TW	PH						3.8											0 0 45 55	
			23	SS	0*																	August 27, 2014 August 28, 2014 0 0 43 57	
			24	TW	PH																		
			25	SS	0*																		
187.2 26.5 186.5 27.2	CLAYEY SILT, trace to some sand, trace gravel, occasional cobbles, hard, grey, moist (GLACIAL TILL) BEDROCK-LIMESTONE, (Dolomitic), slightly weathered to 29.3m, moderately weathered below, medium to thickly bedded, grey to whitish grey, medium to high strength, vuggy (frequent vugs at 29.3m-30.3m)																						
			26	SS	1																		
			27	SS	0*																		
			28	SS	8																		
			29	SS	106 / 225mm															NQ Coring			
			1	RUN	NQ															RUN #1 TCR=100% SCR=97% RQD=94%			
			2	RUN	NQ															RUN #2 TCR=100% SCR=100% RQD=61%			

Continued Next Page


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

RECORD OF BOREHOLE No 3

3 of 3

METRIC

G.W.P. 5159-12-00 LOCATION Coords: E:404536.5 N:5269374.3 ORIGINATED BY S.M
 DIST HWY 11 BOREHOLE TYPE HOLLOW STEM AUGERS / CASING AND WASH BORING/NQ CORING COMPILED BY A.A
 DATUM GEODETIC DATE 2014-8-27 - 2014-8-28 CHECKED BY R.A

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	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE								
	(continued)		2	RUN	NQ							
183.5 30.3												

END OF BOREHOLE

Borehole filled with drill water upon completion of drilling.

*Sampler sinking under weight of hammer and/ or rods.

Consolidation test performed on TW22

RECORD OF BOREHOLE No 4

1 of 3

METRIC

G.W.P. 5159-12-00 LOCATION Coords: E:404541 N:5269354.3 ORIGINATED BY S.M
DIST HWY 11 BOREHOLE TYPE CASING AND WASH BORING/NQ CORING COMPILED BY A.A
DATUM GEODETIC DATE 2014-8-26 - 2014-8-27 CHECKED BY R.A

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 (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	SPT 'N' VALUE			SHEAR STRENGTH (kPa)										WATER CONTENT (%)		
								20 40 60 80 100										10 20 30		

213.9	GROUND SURFACE															
213.5	360mm ASPHALTIC CONCRETE															
0.4	540mm FILL, SAND, some silt, some gravel, trace clay, very dense, brown, drv		1	SS	50 / 100mm		213									
213.0	FILL, silty clay, trace sand to sandy, trace gravel, trace organics below 6.9m, occasional cobbles, firm to very stiff, brown, moist to wet		2	SS	7		212									
0.9			3	SS	9		211									6 34 34 26
			4	SS	13		210									
			5	SS	30		209									
			6	SS	8		208									
			7	SS	6		207									
			8	SS	3		206									
			9	SS	7		205									
206.4			10	SS	7		204									
7.5	SILTY CLAY, trace sand, trace organics, firm, brown to grey, wet		11	SS	4		203									0 2 21 77
			12	SS	5		202									
			13	SS	0*		201									0 1 47 52
203.8	SILTY CLAY (Varved), containing 10mm to 20mm thick silt layers, stiff, grey, wet		14	TW	PH		200									
10.1			15	SS	0		199									

213

212

211

210

209

208

207

206

205

204

203

202

201

200

199

20

40

60

80

100

10

20

30

4.1

4.1

5.1

4.8

4.3

4.0

10.0

44

LL=52

August 26, 2014

August 27, 2014

Continued Next Page

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

August 26, 2014
August 27, 2014

RECORD OF BOREHOLE No 4

2 of 3

METRIC

G.W.P. 5159-12-00 LOCATION Coords: E:404541 N:5269354.3 ORIGINATED BY S.M
DIST HWY 11 BOREHOLE TYPE CASING AND WASH BORING/NQ CORING COMPILED BY A.A
DATUM GEODETIC DATE 2014-8-26 - 2014-8-27 CHECKED BY R.A

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 (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	SPT 'N' VALUE			SHEAR STRENGTH (kPa)		WATER CONTENT (%)					
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE	W _p	W	W _L			
						20	40	60	80	100	10	20	30	kN/m ³	GR SA SI CL
	(continued)														
	SILTY CLAY (Varved), containing 10mm to 20mm thick silt layers, stiff, grey, wet		16	TW	PH										
				17	SS	0*									
				18	SS	1									
				19	SS	0*									
				20	SS	0*									
				21	SS	1									
			22	SS	0*										
			23	SS	0*										
187.1	BEDROCK-LIMESTONE, (Dolomitic), slightly weathered, thinly to thickly bedded, grey to whitish grey, high strength, vuggy		1	RUN	NQ										
26.8															
				2	RUN	NQ									
183.9															

Continued Next Page

END OF BOREHOLE

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

library: library - terraprobe gint.gdb report: mto-terraprobe soil file: 11-14-4086 (47-273c) calanity creek.gpj

RECORD OF BOREHOLE No 4

3 of 3

METRIC

G.W.P. 5159-12-00 LOCATION Coords: E:404541 N:5269354.3 ORIGINATED BY S.M
DIST HWY 11 BOREHOLE TYPE CASING AND WASH BORING/NQ CORING COMPILED BY A.A
DATUM GEODETIC DATE 2014-8-26 - 2014-8-27 CHECKED BY R.A

SOIL PROFILE		SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT NUMBER	TYPE			SHEAR STRENGTH (kPa)		W _p	W	W _L	γ	
						20 40 60 80 100	20 40 60 80 100					
						○ UNCONFINED	+ FIELD VANE	WATER CONTENT (%)				
						● QUICK TRIAXIAL	× LAB VANE					
						20 40 60 80 100	20 40 60 80 100	10	20	30	kN/m ³	GR SA SI CL

(continued)

30.0

Borehole filled with drill water
upon completion of drilling.

*Sampler sinking under weight of
hammer and/ or rods

Insufficient sample available for
Atterberg limits test at SS12

RECORD OF BOREHOLE No 5

1 of 2

METRIC

G.W.P. 5159-12-00 LOCATION Coords: E:404496.3 N:5269354.8 ORIGINATED BY S.M
 DIST HWY 11 BOREHOLE TYPE HOLLOW STEM AUGERS/CASING AND WASH BORING/NQ CORING COMPILED BY A.A
 DATUM GEODETIC DATE 2014-8-29 - 2014-9-3 CHECKED BY R.A

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 (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	SPT 'N' VALUE			SHEAR STRENGTH (kPa)								
								20	40	60	80	100				
○ UNCONFINED ● QUICK TRIAXIAL								+ FIELD VANE × LAB VANE		PLASTIC LIMIT W _p						
										NATURAL MOISTURE CONTENT W						
										LIQUID LIMIT W _L						
										WATER CONTENT (%)						
								20	40	60	80	100	10	20	30	
203.5	GROUND SURFACE															
203.4 0.2	150mm TOPSOIL															
	FILL, sand and silt, some clay, trace gravel, very loose to compact, brown, wet			1	SS	7										
				2	SS	12										
				3	SS	2										
201.4 2.1	SILTY CLAY, trace sand, trace gravel, soft to stiff, brown, wet			4	SS	2									4 45 37 14	
	...			5	SS	4										
	containing organics															
				6	SS	13										
197.9 5.6	SILTY CLAY (Varved), containing 10mm to 20mm thick silt layers, firm to stiff, grey, wet			7	TW	PH										
				8	SS	0*										
				9	TW	PH										
				10	SS	0*										
				11	SS	0*										
				12	SS	0*										

Continued Next Page

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

library: library - terraprobe gint - md.gib report: mto-terraprobe soil file: 11-14-4086 (47-273c) calanity creek.gpj

RECORD OF BOREHOLE No 5

2 of 2

METRIC

G.W.P. 5159-12-00 LOCATION Coords: E:404496.3 N:5269354.8 ORIGINATED BY S.M
DIST HWY 11 BOREHOLE TYPE HOLLOW STEM AUGERS/CASING AND WASH BORING/NQ CORING COMPILED BY A.A
DATUM GEODETIC DATE 2014-8-29 - 2014-9-3 CHECKED BY R.A

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 (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	SPT 'N' VALUE			SHEAR STRENGTH (kPa)							WATER CONTENT (%)		
	(continued)						20	40	60	80	100	w _p	w	w _L	kN/m ³	GR SA SI CL	
	SILTY CLAY (Varved), containing 10mm to 20mm thick silt layers, firm to stiff, grey, wet		13	SS	0*												
186.8																	
16.7	CLAYEY SILT, sandy, trace gravel, firm to hard, grey, moist (GLACIAL TILL)		14	SS	5												9 29 47 15
186.0			15	SS	100 / 50mm												NQ Coring
17.5	BEDROCK-LIMESTONE, (Dolomitic), slightly weathered, thinly to medium bedded, grey to whitish grey, high strength, vuggy		1	RUN	NQ												RUN #1 TCR=100% SCR=95% RQD=80%
			2	RUN	NQ												RUN #2 TCR=100% SCR=100% RQD=85%
183.0																	

END OF BOREHOLE

Borehole filled with drill water upon
completion of drilling.

*Sampler sinking under weight of
hammer and/ or rods.

Insufficient sample available for
Atterberg limits test at SS6

RECORD OF BOREHOLE No 6

1 of 2

METRIC

G.W.P. 5159-12-00 LOCATION Coords: E:404454.7 N:5269290.3 ORIGINATED BY S.M
DIST HWY 11 BOREHOLE TYPE HOLLOW STEM AUGERS/CASING AND WASH BORING/NQ CORING COMPILED BY A.A
DATUM GEODETIC DATE 2014-9-3 CHECKED BY R.A

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 (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	SPT 'N' VALUE			20 40 60 80 100						
								SHEAR STRENGTH (kPa)						
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						
								WATER CONTENT (%)						
								w _p w w _L						
								20 40 60 80 100					10 20 30	
197.7	GROUND SURFACE													
197.6 0.2	150mm TOPSOIL		1	SS	3								○	
	SILTY CLAY, trace sand, trace organics, soft to firm, brown, wet		2	SS	4		197							
			3	SS	2		196						41	commence casing and washboring 0 1 43 56
195.6 2.1	SILTY CLAY (Varved), containing 5mm to 20mm thick silt layers, firm to stiff, grey, wet		4	TW	PH		195	3.7						
			5	SS	0*		194	3.7						
			6	TW	PH		193	8.0					43	0 0 53 47
			7	SS	0*		192	5.1						
			8	SS	0*		191	7.4						
			9	SS	0*		190	3.6					47	0 0 40 60
			10	SS	100 / 50mm		189	5.6						
			1	RUN	NQ		188	5.8						
			2	RUN	NQ		187	7.5						0 1 69 30
185.6 12.1	BEDROCK-LIMESTONE, (Dolomitic), slightly weathered, medium to thickly bedded, grey to whitish grey, high strength, vuggy						186	5.0						NQ Coring
							185	7.3						RUN #1 TCR=100% SCR=97% RQD=88%
							184	5.6						RUN #2 TCR=100% SCR=100% RQD=95%
							183	5.2						

Continued Next Page

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



library: library - terraprobe gint - md.gdb report: mto-terraprobe soil file: 11-14-4086 (47-273c) calanity creek.gpj

RECORD OF BOREHOLE No 6

2 of 2

METRIC

G.W.P. 5159-12-00 LOCATION Coords: E:404454.7 N:5269290.3 ORIGINATED BY S.M
 DIST HWY 11 BOREHOLE TYPE HOLLOW STEM AUGERS/CASING AND WASH BORING/NQ CORING COMPILED BY A.A
 DATUM GEODETIC DATE 2014-9-3 CHECKED BY R.A

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	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE								
182.5 15.2	(continued)		2	RUN	NQ							GR SA SI CL

END OF BOREHOLE

Borehole filled with drill water upon completion of drilling.

*Sampler sinking under weight of hammer and/ or rods.

Piezometer installation consists of a 25mm diameter schedule 40PVC pipe with a 3.0m slotted screen.

*(ag) - above ground.

WATER LEVEL READINGS

Date	Water Depth (m)	Elevation (m)
Sep 17, 2014	-0.3 (ag)*	n/a
Oct 28, 2014	-0.4 (ag)*	n/a
Nov 24, 2014	-0.4 (ag)*	n/a

Appendix B.3
Previous Investigation
(*GEOCRES 31M-66*)

RECORD OF BOREHOLE No DB3

1 OF 2

W.P. WP147-98-00 LOCATION Hwy 11 Dymond Twp Stn 17 + 630 O/S 3.1 m Rt.
 DIST Northern HWY Hwy 11 BOREHOLE TYPE Solid Stem Augers
 DATUM _____ DATE 10.05.99 & 10.05.99

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT		NATURAL MOISTURE CONTENT	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W _p	W		
213.9	Ground Surface															
0.0	220 mm Asphalt															
0.2	50 mm Sand and gravel, brown, moist															
0.3																
0.4	70 mm Asphalt															
0.6	170 mm Sand and gravel															
0.7	70 mm Asphalt, over Sand and gravel		1	SPT	19											
	FILL: clayey silt with trace organics and some gravel sizes, grey, moist, very stiff, over (possible fill) grey, moist clayey silt with trace organics 25 mm thick layer of topsoil		2	SPT	32											
			3	SPT	20											
207.6			4	SPT	6											
6.3	SILTY CLAY: greenish, moist, stiff very soft		5	SPT	11											
			6	SPT	21											
			7	SPT	19											
			8	SPT	10											
			9	SPT	7											
	with layers of organics becoming brown, very stiff fissured, stiff		10	SPT	3											
202.4	becoming wet at 10.7 m		11	SPT	4											
11.5	VARVED CLAY: rhythmic layers of dark grey silty clay to clay and light grey clayey silt to silt.		12	SHELBY												
			13	SPT	5											

Continued Next Page

3, X 3 Numbers refer to Sensitivity 20 15 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No DB3

2 OF 2

M

W.P. WP147-98-00 LOCATION Hwy 11 Dymond Twp Str 17 + 630 O/S 3.1 m Rt.
DIST Northern HWY Hwy 11 BOREHOLE TYPE Solid Stem Augers
DATUM DATE 10.05.99 & 10.05.99

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIMIT MOISTURE CONTENT		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		20	40	60	80	100	W _p	W	L _c
			14	SHELBY										
			15	SHELBY										
			16	SPT	1									
			17	SHELBY										
			18	SPT	5									
			19	SHELBY										
			20	SPT	5									
			21	SHELBY										
			22	SPT 50/8 cm										
188.4 25.5	SILTY CLAY TILL: gray, moist													
189.3 26.6	End of borehole Refusal to further augering at 26.6 m Notes Borehole dry on completion: Water on piezometer at 13.8 m on 10.13.99 and on 10.14.99													

+ 3, x 3; Numbers refer to
Sensitivity

20
15 5
10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No DB4

1 OF 2

W.P. WP147-98-00 LOCATION Hwy 11 Dymond Twp Stn 17+679 O/S 2.9 m Lt.
 DIST Northern HWY Hwy 11 BOREHOLE TYPE Solid Stem Augers
 DATUM DATE 10.05.99 & 10.05.99

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		20	40	60	80	100	W _p	W	
<u>313.8</u>	Ground Surface													
0.0	195 mm Asphalt													
0.2	FILL: sand and gravel, moist													
			1	SPT	27									
			2	SPT	11									
			3	SPT	27									
	with trace clay		4	SPT	10									
			5	SPT	8									
<u>304.7</u>	CLAYEY SILT: with some sand and gravel, brown		6	SPT	15									
<u>303.2</u>	with some organics													
10.6	CLAYEY SILT: with some gravel and organics, brown, moist		7	SPT	14									
			8	SPT	20									
<u>301.0</u>	SILTY CLAY: grey, organics		9	SPT	27									
12.8			10	SPT	19									
<u>199.0</u>	becoming brown with trace		11	SPT	9									

Continued Next Page

+ 3, x 3; Numbers refer to 20
Sensitivity 15-25 10 (%) STRAIN AT FAILURE

W.P. WP147-98-00 LOCATION Hwy 11 Dymond Twp Stn 17+679 O/S 2.9 m Lt. O
DIST Northern HWY Hwy 11 BOREHOLE TYPE Solid Stem Algers C
DATUM DATE 10.05.99 & 10.05.99 C

[illegible]

Appendix C.

Laboratory Testing

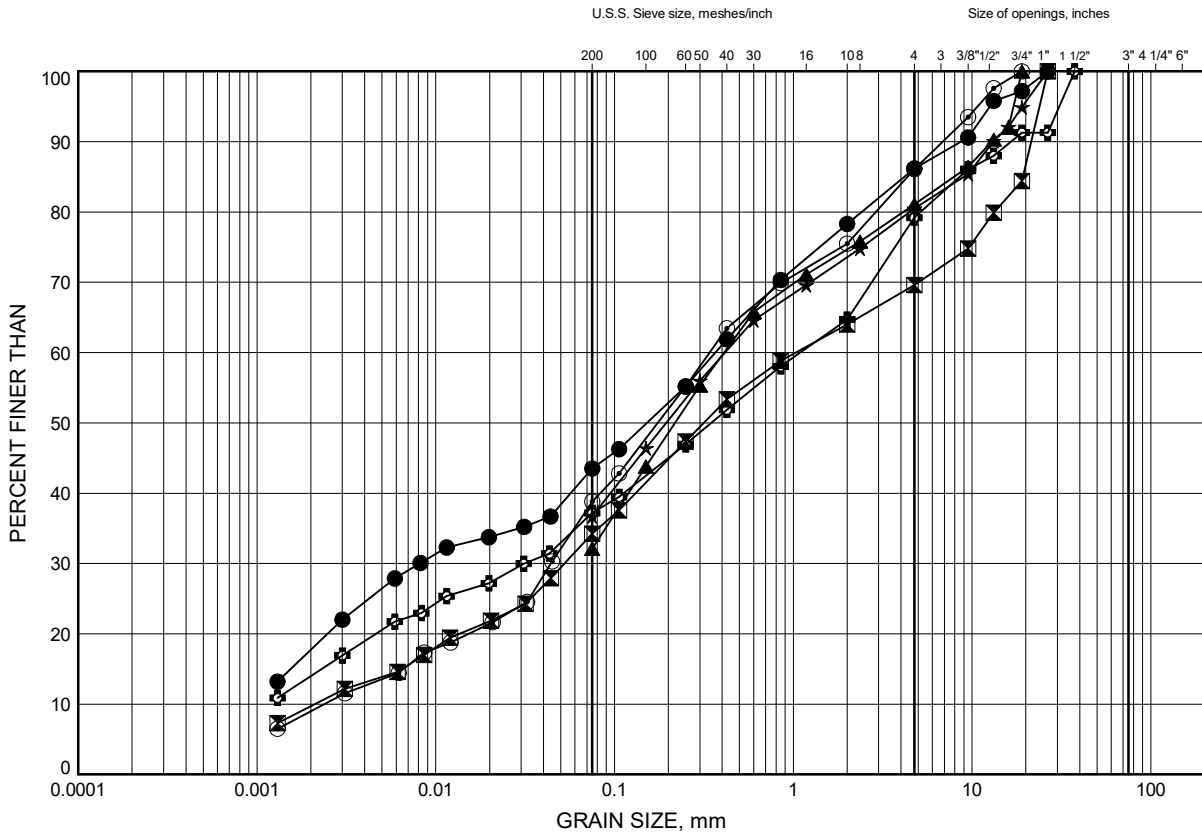
Appendix C.1

Particle Size Analysis Figures

Calamity Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE C1

Clayey SAND FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-4	3.35	210.05
⊠	16-4	6.40	207.00
▲	16-5	0.30	203.70
★	16-7	0.91	203.29
⊙	16-8	2.59	204.31
⊞	16-8	6.40	200.50

Date ..October 2016.....

GWP# ..5013-E-0031.....



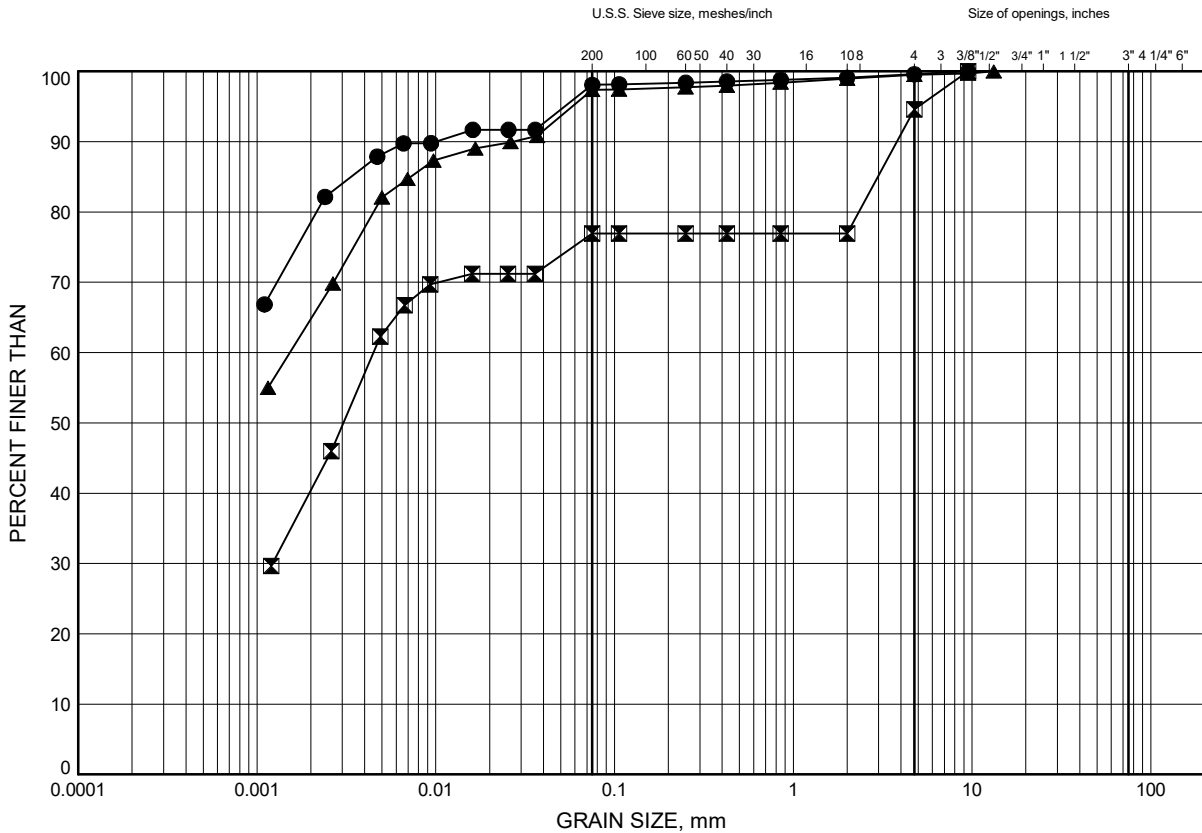
Prep'dSBP.....

Chkd.FJG.....

Calamity Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE C2

CLAY FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-3	3.35	199.85
⊠	16-7	4.88	199.32
▲	16-8	7.92	198.98

Date ..October 2016.....

GWP# ..5013-E-0031.....

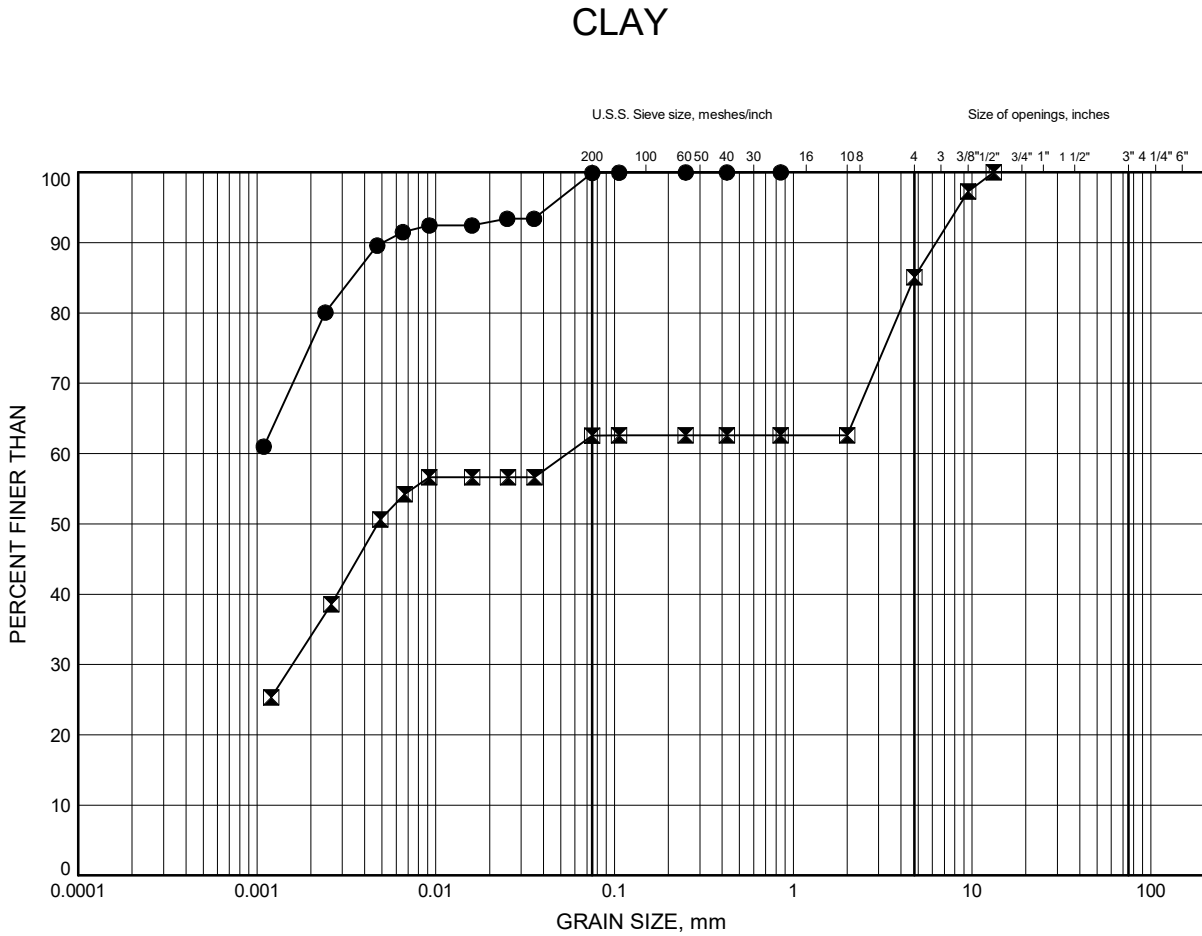


Prep'd ..SBP.....

Chkd.FJG.....

Calamity Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE C3



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-4	12.50	200.90
⊠	16-7	9.45	194.75

Date ..October 2016.....

GWP# ..5013-E-0031.....



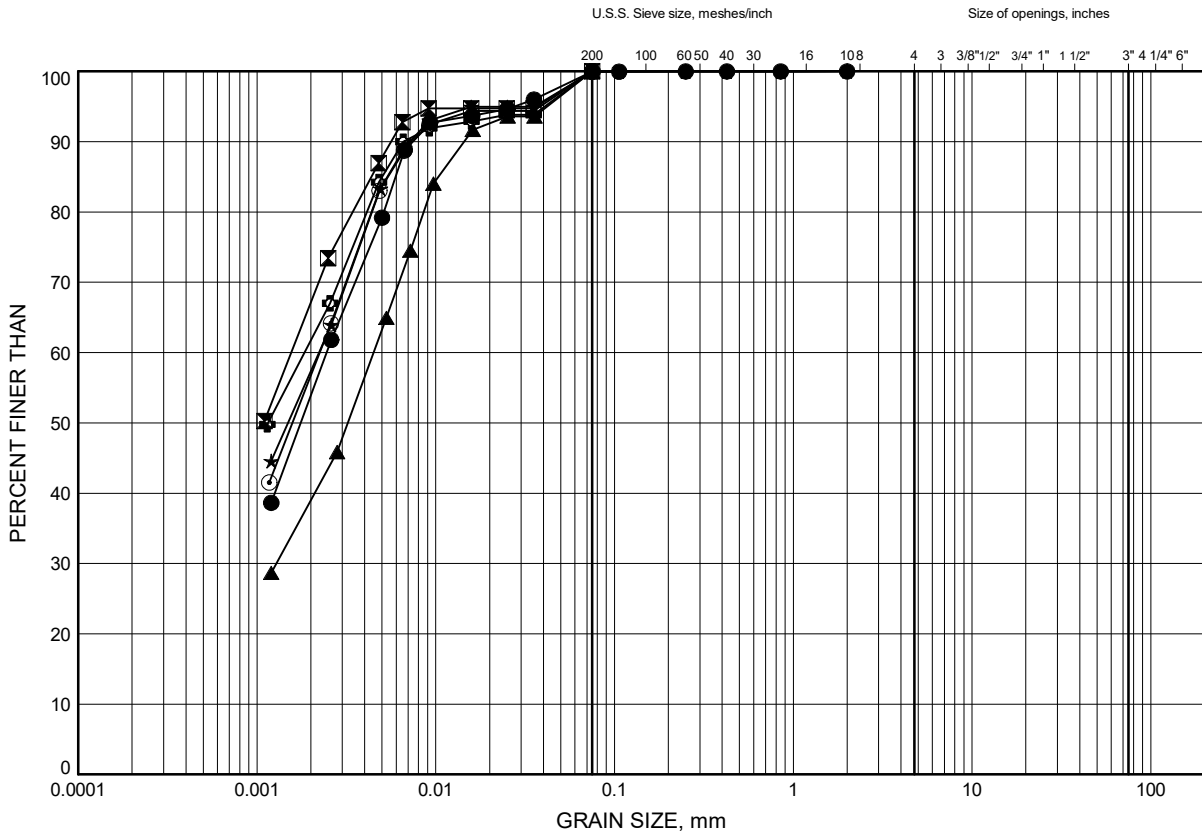
Prep'd ..SBP.....

Chkd.FJG.....

Calamity Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE C4

CLAY (Varved)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-1	3.35	190.95
⊠	16-2	4.88	195.62
▲	16-2	10.97	189.53
★	16-3	7.92	195.28
⊙	16-3	14.02	189.18
⊕	16-4	17.07	196.33

Date ..October 2016.....

GWP# ..5013-E-0031.....



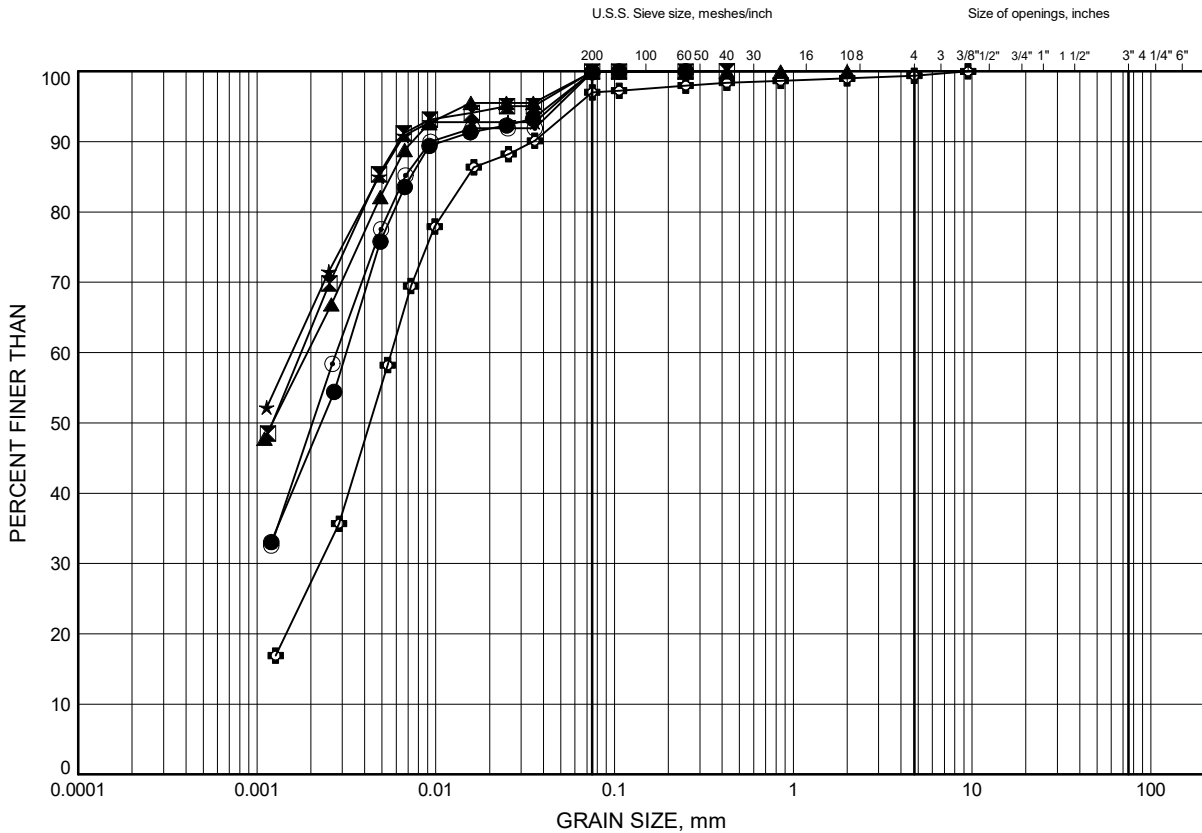
Prep'd ..SBP.....

Chkd.FJG.....

Calamity Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE C5

CLAY (Varved)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-4	21.64	191.76
⊠	16-4	23.16	190.24
▲	16-5	6.40	197.60
★	16-5	12.50	191.50
⊙	16-6	3.35	194.75
⊕	16-6	9.37	188.73

Date ..October 2016.....

GWP# ..5013-E-0031.....



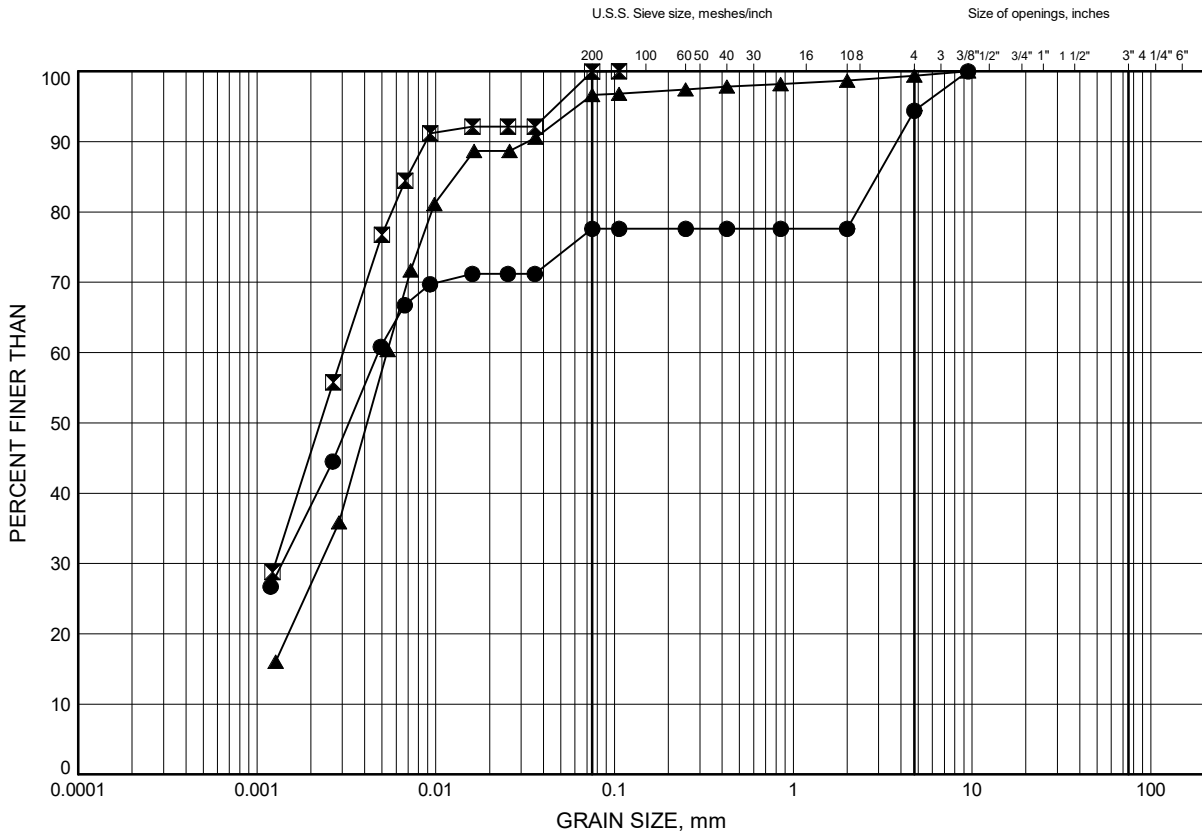
Prep'd ..SBP.....

Chkd.FJG.....

Calamity Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE C6

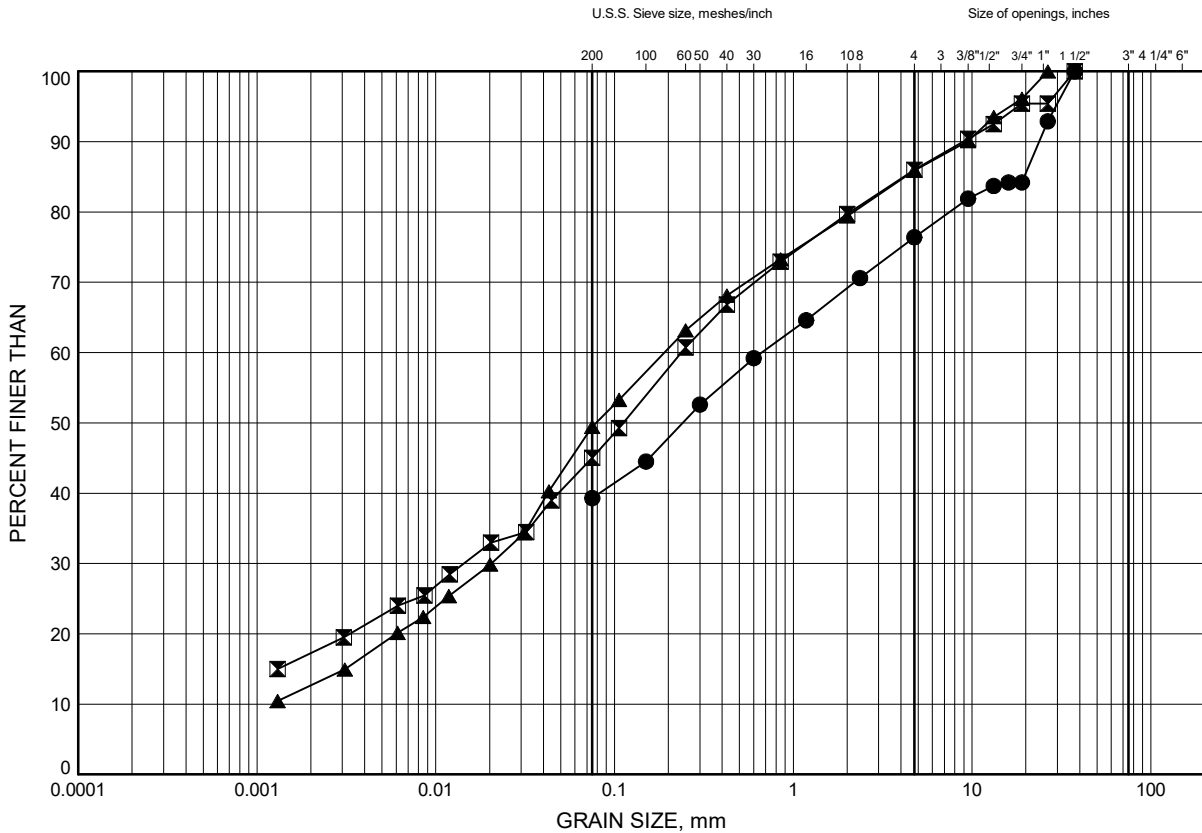
CLAY (Varved)



Calamity Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE C7

Clayey SAND TILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-1	8.00	186.30
⊠	16-2	14.17	186.33
▲	16-4	26.75	186.65

Date ..October 2016.....

GWP# ..5013-E-0031.....



Prep'd ..SBP.....

Chkd.FJG.....

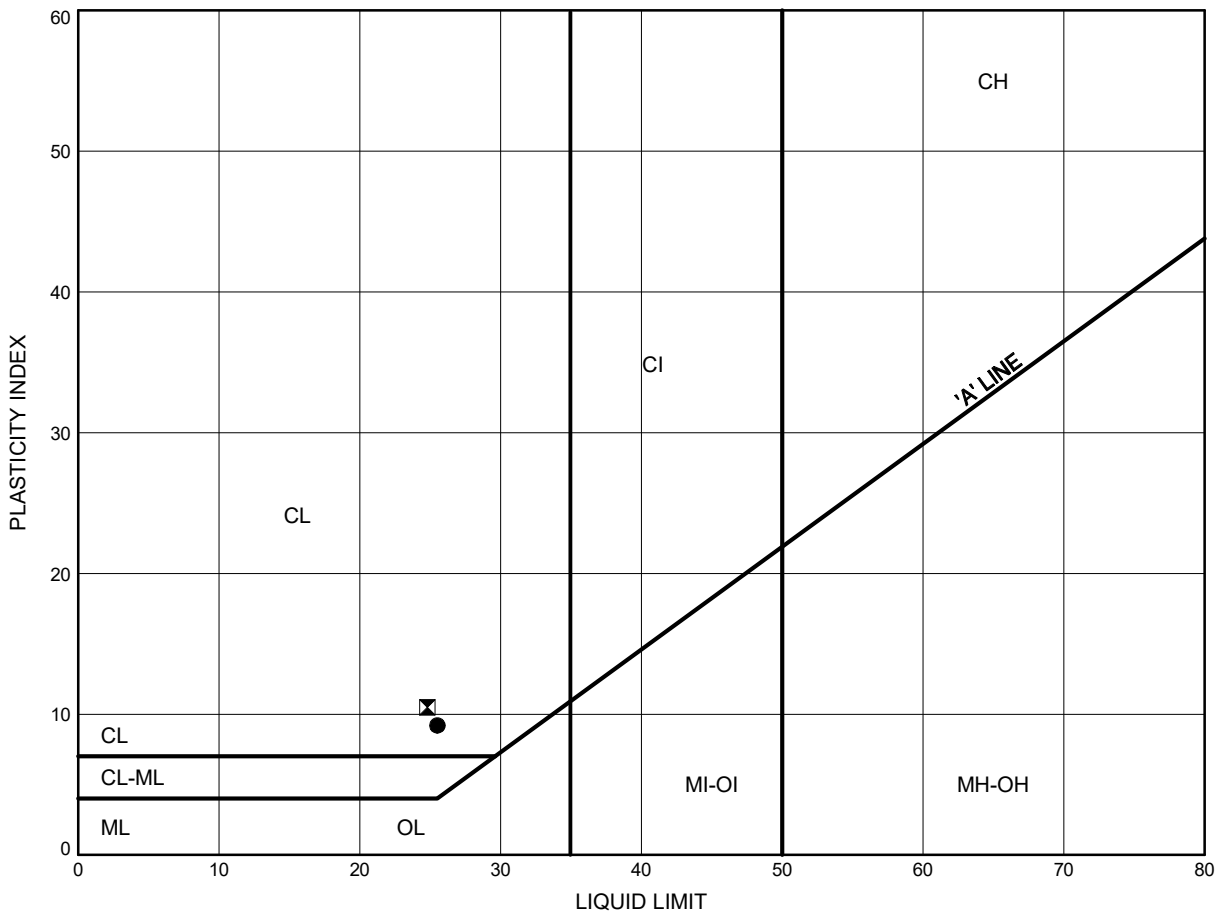
Appendix C.2

Atterberg Limit Analysis Figures

Calamity Creek Culvert
ATTERBERG LIMITS TEST RESULTS

FIGURE C8

Clayey SAND FILL



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-4	3.35	210.05
⊠	16-8	6.40	200.50

Date ..October 2016.....
 GWP# ..5013-E-0031.....

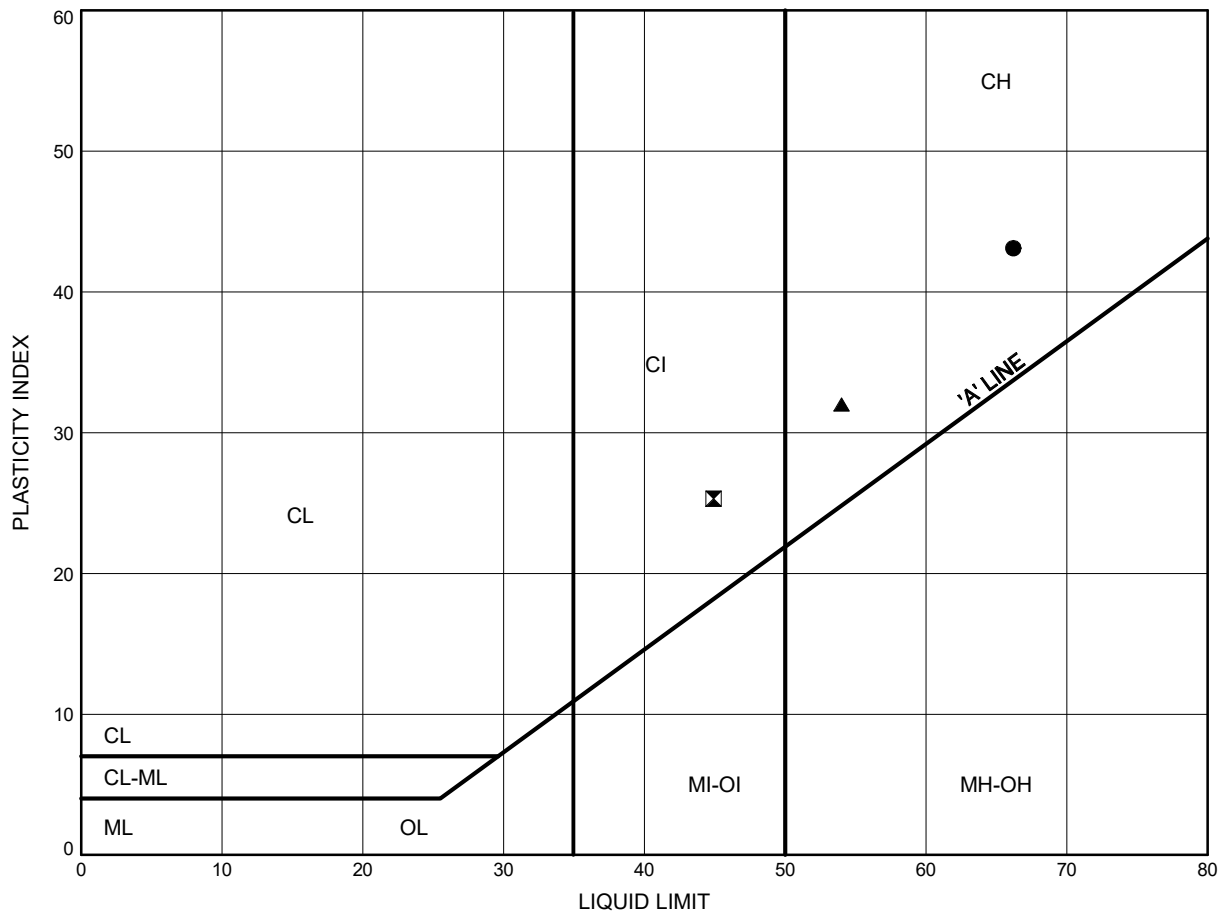


Prep'd ..SBP.....
 Chkd.FJG.....

Calamity Creek Culvert
ATTERBERG LIMITS TEST RESULTS

FIGURE C9

CLAY FILL



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-3	3.35	199.85
⊠	16-7	4.88	199.32
▲	16-8	7.92	198.98

Date October 2016
 GWP# 5013-E-0031

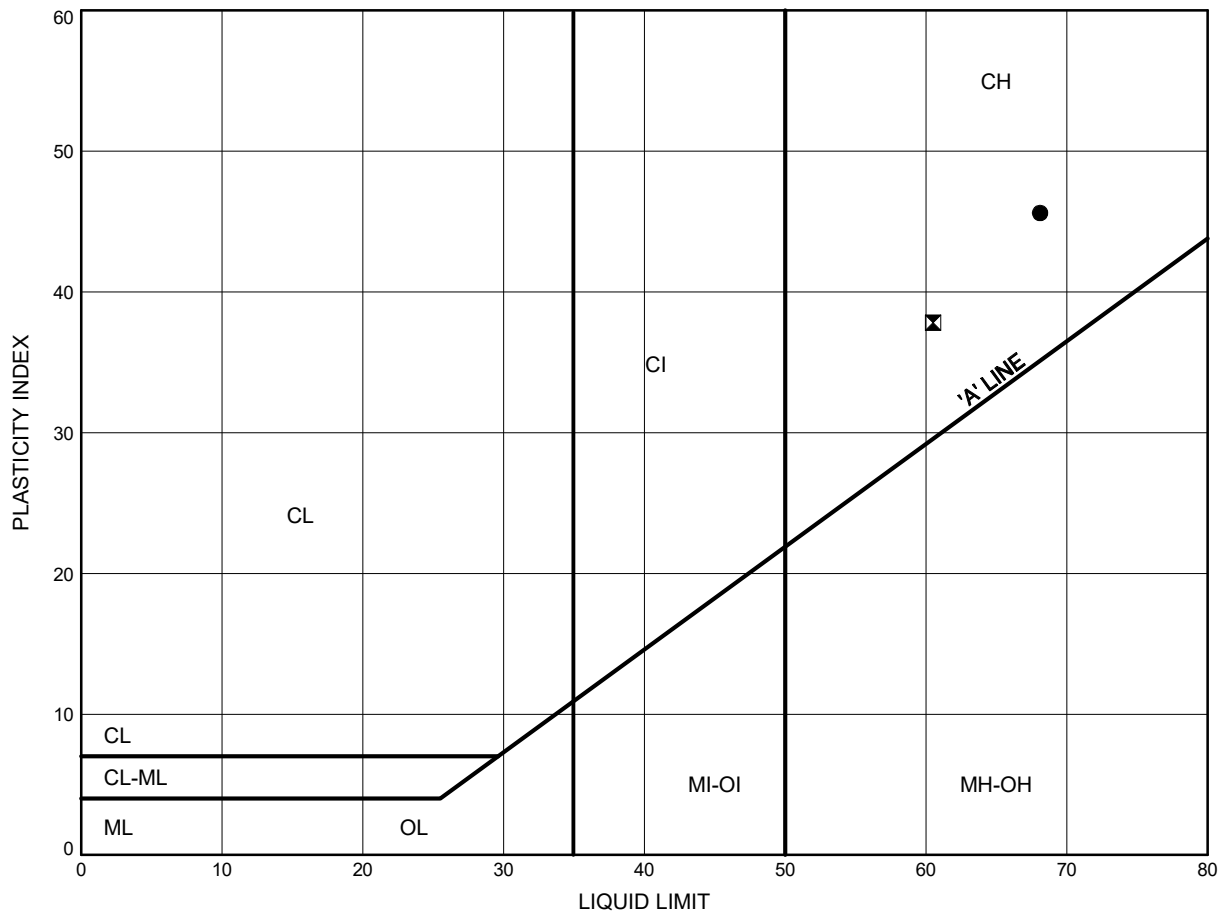


Prep'd SBP
 Chkd. FJG

Calamity Creek Culvert
ATTERBERG LIMITS TEST RESULTS

FIGURE C10

CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-4	12.50	200.90
⊠	16-7	9.45	194.75

Date ..October 2016.....
 GWP# ..5013-E-0031.....

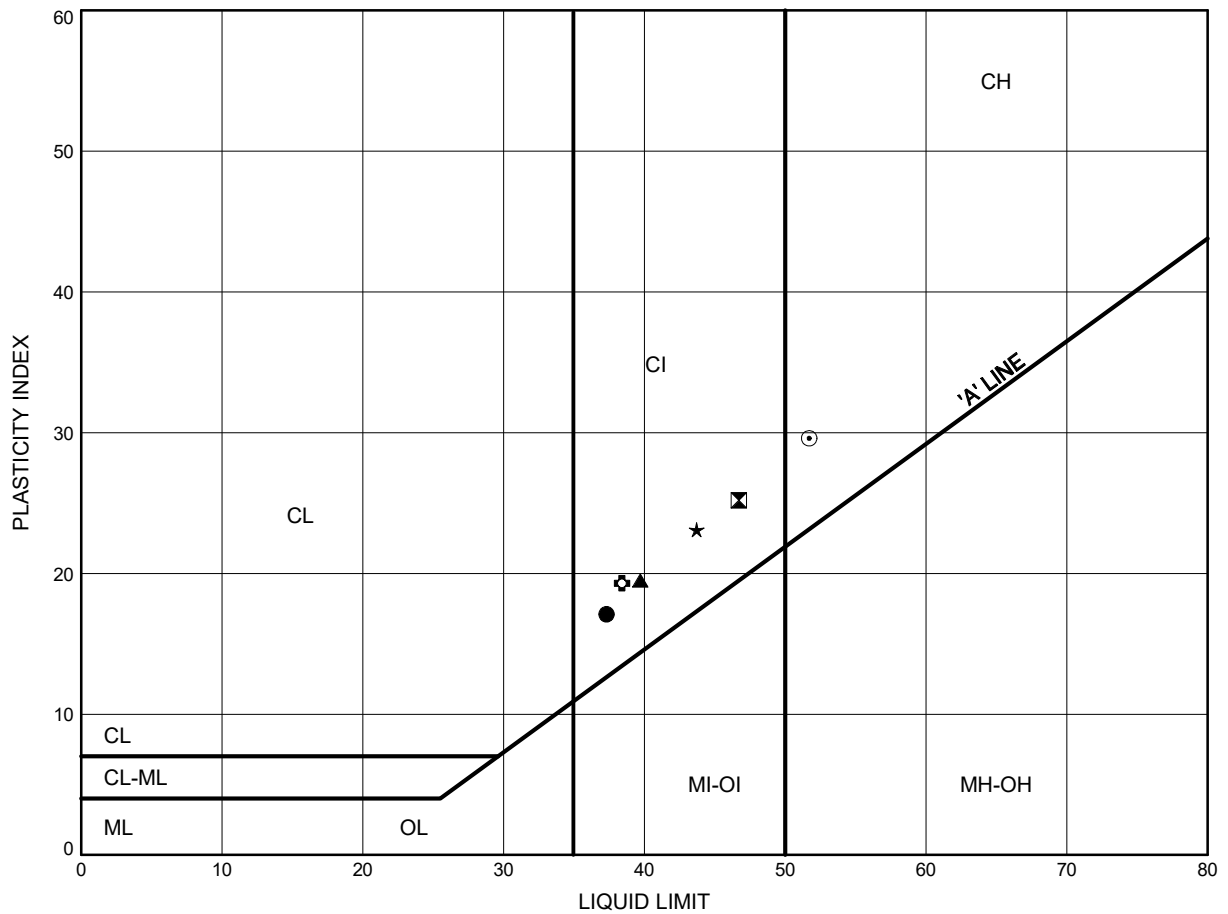


Prep'd ..SBP.....
 Chkd.FJG.....

Calamity Creek Culvert
ATTERBERG LIMITS TEST RESULTS

FIGURE C11

CLAY (Varved)



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-1	3.35	190.95
⊠	16-2	4.88	195.62
▲	16-2	10.97	189.53
★	16-3	7.92	195.28
⊙	16-3	14.02	189.18
⊕	16-4	17.07	196.33

Date October 2016
 GWP# 5013-E-0031

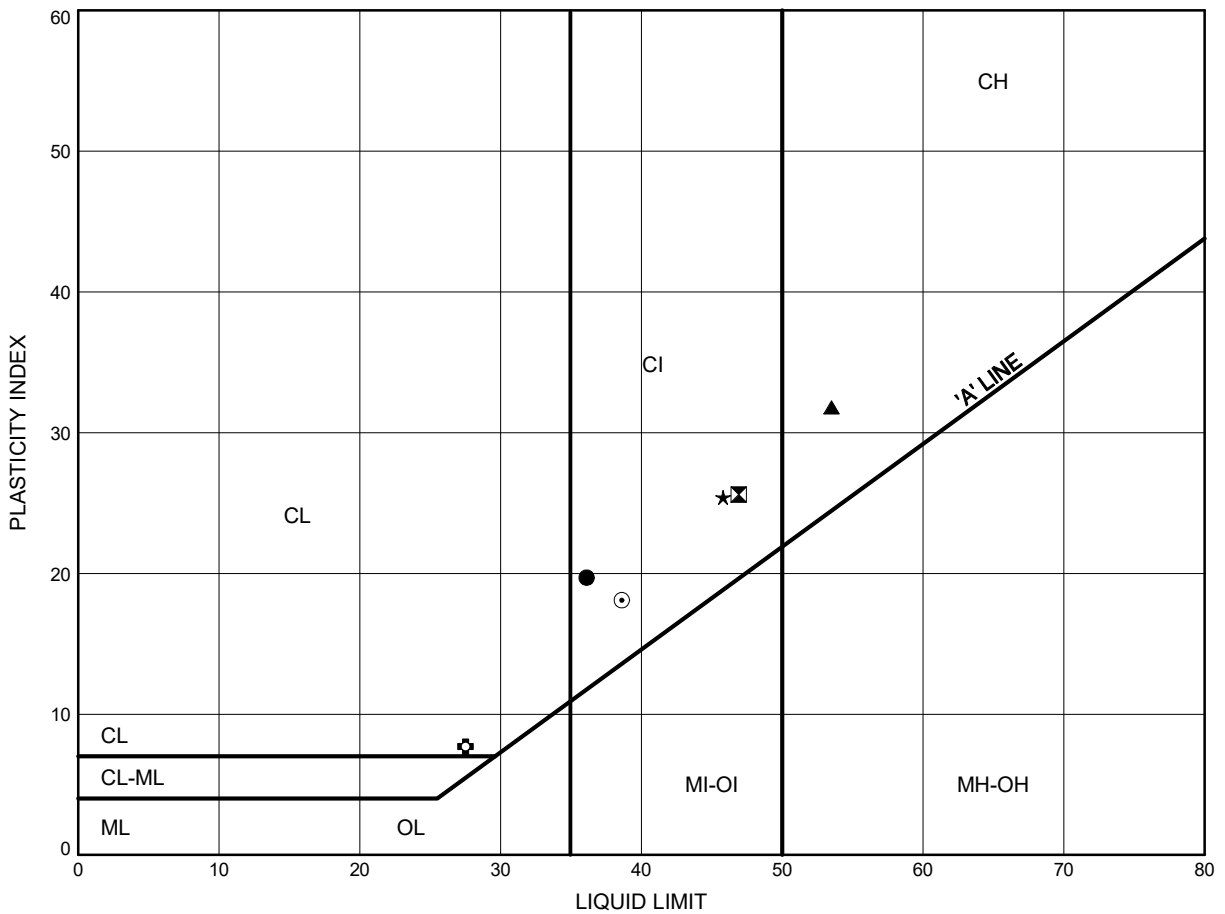


Prep'd SBP
 Chkd. FJG

Calamity Creek Culvert
ATTERBERG LIMITS TEST RESULTS

FIGURE C12

CLAY (Varved)



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-4	21.64	191.76
⊠	16-4	23.16	190.24
▲	16-5	6.40	197.60
★	16-5	12.50	191.50
⊙	16-6	3.35	194.75
⊕	16-6	9.37	188.73

Date October 2016
 GWP# 5013-E-0031

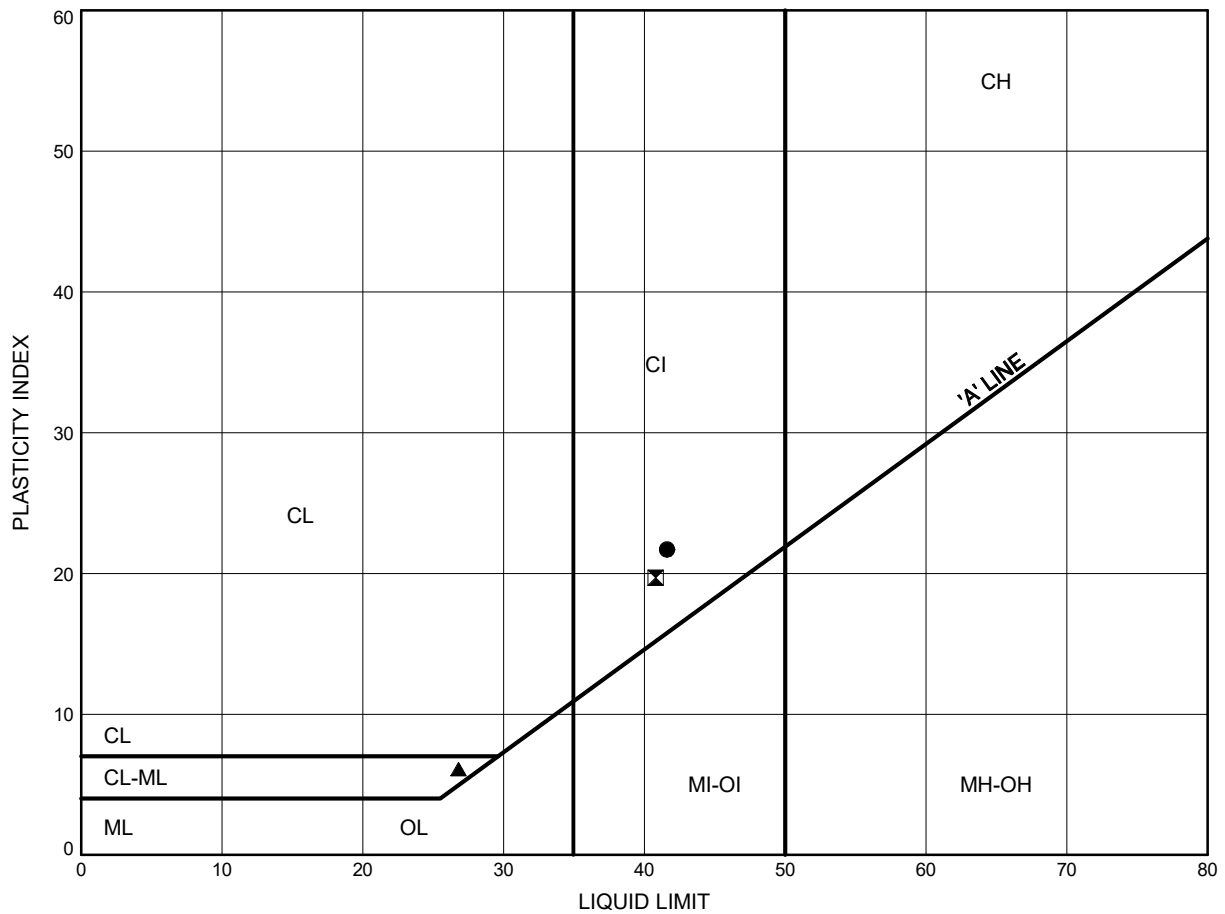


Prep'd SBP
 Chkd. FJG

Calamity Creek Culvert
ATTERBERG LIMITS TEST RESULTS

FIGURE C13

CLAY (Varved)



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-7	14.02	190.18
⊠	16-8	12.50	194.40
▲	16-8	18.59	188.31

Date ..October 2016.....
 GWP# ..5013-E-0031.....



Prep'd ..SBP.....
 Chkd.FJG.....

Appendix C.3
Oedometer Testing Results



Stantec Consulting Ltd.
400 - 1331 Clyde Avenue
Ottawa ON K2C 3G4
Tel: (613) 722-4420
Fax: (613) 722-2799

September 19, 2016
File: 122410864

Attention: Stephen Peters
Thurber Engineering Ltd.
104 – 2460 Lancaster Road
Ottawa, Ontario, Canada, K1B 4S5
Tel: 613-274-2121
e-mail: speters@thurber.ca

Dear Mr. Peters,

**Reference: Consolidation Test Results for Calamity Creek Culvert Project, Thurber Consulting Ltd.,
File #19-5161-208: BH 16-4, ST-18, sampled on August 9 7, 2016**

This letter presents the results of a one-dimensional consolidation test carried out on the above referenced sample in accordance with ASTM D2435/D2435M - 11. The test results are provided in the attached tables and figures.

This letter provides test results only and does not constitute any interpretation or engineering recommendations with respect to material suitability or specification compliance.

We trust the information presented herein meets your present requirements. Should you have any questions or require additional information, please do not hesitate to contact us.

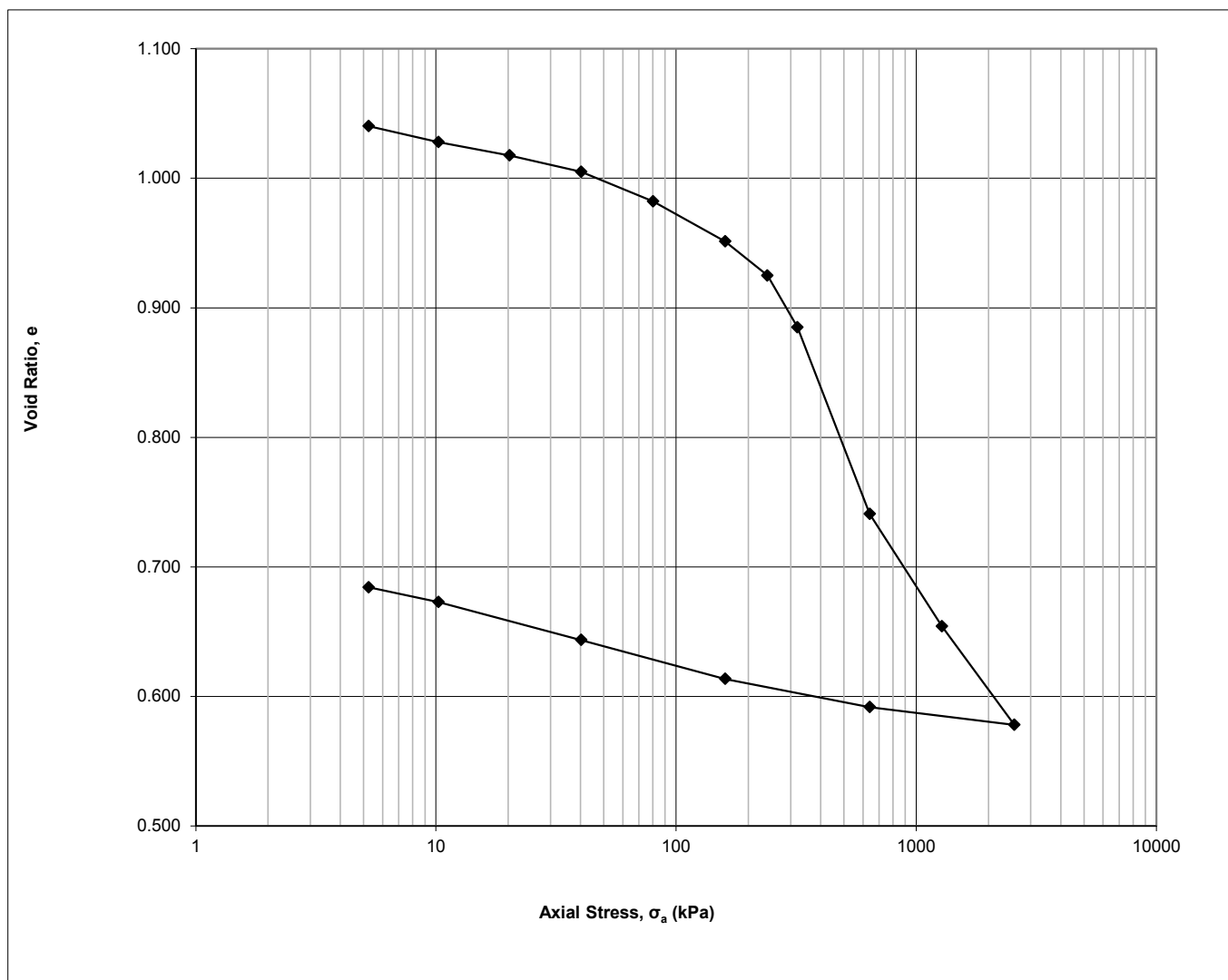
Regards,

STANTEC CONSULTING LTD.

Raymond Haché, M.Sc., P.Eng.
Senior Principal, Geotechnical Engineer
Phone: (613) 738-6055
Fax: (613) 722-2799
Raymond.Hache@stantec.com

Project
Project No.
Borehole No.
Sample No.
Sample Depth

Thurber Engineering, File#19-5161-208
122410864
BH 16-4
ST 18
70-72 ft



One-Dimensional Consolidation Test using Incremental Loading

ASTM D2435/D2435M - 11

Specimen Details

Project Name	Thurber Engineering, File#19-5161-208
Project Location	Calamity Creek
Borehole	BH 16-4
Sample No.	ST 18
Depth	70-72 ft
Sample Date	August 9, 2016
Test Number	One
Technician Name	Daniel Boateng

Soil Description & Classification

CI	
Specific Gravity of Solids	2.708
Liquid Limit %	36
Plastic Limit %	20
Plasticity Index %	16
Average water content of trimmings %	34
Additional Notes (Information source, occurrence and size of large isolated particles etc.)	

Initial Specimen Conditions

Height	mm	20.00
Diameter	mm	50.00
Area	mm ²	1963
Volume	mm ³	39270
Mass	g	69.31
Dry Mass	g	51.86
Density	Mg/m ³	1.765
Dry Density	Mg/m ³	1.321
Water Content	%	33.65
Degree of Saturation	%	86.7
Height of Solids	mm	9.75
Initial Void Ratio		1.051

Final Specimen Conditions

Water Content	%	30.77
Final Void Ratio		0.684

One-Dimensional Consolidation Test using Incremental Loading

ASTM D2435/D2435M - 11

Specimen Details

Project Name	Thurber Engineering, File#19-5161-208
Project Location	Calamity Creek
Borehole	BH 16-4
Sample No.	ST 18
Depth	70-72 ft
Sample Date	August 9, 2016
Test Number	One
Technician Name	Daniel Boateng

Test Procedure

Date Started	August 29, 2016
Date Finished	September 13, 2016
Machine Number	Frame D
Cell Number	D
Ring Number	D
Trimming Procedure	Turntable
Moisture Condition	Inundated
Axial Stress at Inundation kPa	5
Water Used	Distilled
Test Method	A
Interpretation Procedure for c_v	2

All Departures from Outlined ASTM D2435/D2435M-11 Procedure

--

Calculations

Load Increment	Increment Duration min	Axial Stress σ_a kPa	Corrected Deformation ΔH mm	Specimen Height H mm	Axial Strain ϵ_a %	Void Ratio e
Seating	0.0	5	0.0000	20.0000	0.00	1.051
1	1440.0	5	0.0999	19.9001	0.50	1.040
2	1440.0	10	0.2202	19.7798	1.10	1.028
3	1440.0	20	0.3207	19.6793	1.60	1.018
4	1440.0	40	0.4449	19.5551	2.22	1.005
5	1440.0	80	0.6670	19.3330	3.34	0.982
6	1440.0	160	0.9691	19.0309	4.85	0.951
7	1440.0	240	1.2251	18.7749	6.13	0.925
8	1440.0	320	1.6150	18.3850	8.08	0.885
9	1440.0	640	3.0211	16.9789	15.11	0.741
10	1440.0	1280	3.8675	16.1325	19.34	0.654
11	1440.0	2560	4.6097	15.3903	23.05	0.578
12	1440.0	640	4.4757	15.5243	22.38	0.592
13	1440.0	160	4.2635	15.7365	21.32	0.613
14	1440.0	40	3.9703	16.0297	19.85	0.644
15	1440.0	10	3.6846	16.3154	18.42	0.673
16	1440.0	5	3.5743	16.4257	17.87	0.684

One-Dimensional Consolidation Test using Incremental Loading

ASTM D2435/D2435M - 11

Specimen Details

Project Name	Thurber Engineering, File#19-5161-208
Project Location	Calamity Creek
Borehole	BH 16-4
Sample No.	ST 18
Depth	70-72 ft
Sample Date	August 9, 2016
Test Number	One
Technician Name	Daniel Boateng

Calculations

Load Increment	Axial Stress σ_a , average kPa	Calculated using Interpretation Procedure 2				Interpretation Procedure 1		Interpretation Procedure 2	
		Corrected Deformation ΔH_{50} mm	Specimen Height H_{50} mm	Axial Strain $\epsilon_{a,50}$ %	Void Ratio e_{50}	Time t_{50} sec	Coeff. Consol. c_v mm ² /s	Time t_{90} sec	Coeff. Consol. c_v mm ² /s
Seating	3								
1	5	0.0605	19.9395	0.30	1.044			426	1.98E-01
2	8	0.1564	19.8436	0.78	1.035			562	1.48E-01
3	15	0.2589	19.7411	1.29	1.024			239	3.46E-01
4	30	0.3689	19.6311	1.84	1.013			91	8.96E-01
5	60	0.5454	19.4546	2.73	0.995			142	5.64E-01
6	120	0.7630	19.2370	3.81	0.972			78	1.01E+00
7	200	1.0224	18.9776	5.11	0.946			135	5.67E-01
8	280	1.3641	18.6359	6.82	0.911			9582	7.68E-03
9	480	2.1178	17.8822	10.59	0.833			355	1.91E-01
10	960	3.2764	16.7236	16.38	0.715			151	3.92E-01
11	1920	4.1215	15.8785	20.61	0.628			86	6.24E-01
12	1600	4.5023	15.4977	22.51	0.589				
13	400	4.3396	15.6604	21.70	0.606				
14	100	4.0894	15.9106	20.45	0.631				
15	25	3.9543	16.0457	19.77	0.645				
16	8	3.6813	16.3187	18.41	0.673				

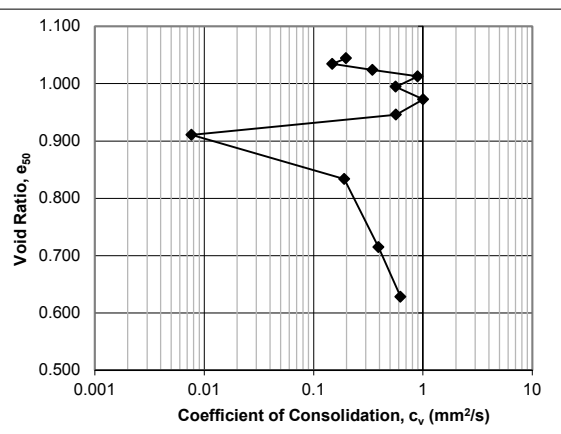
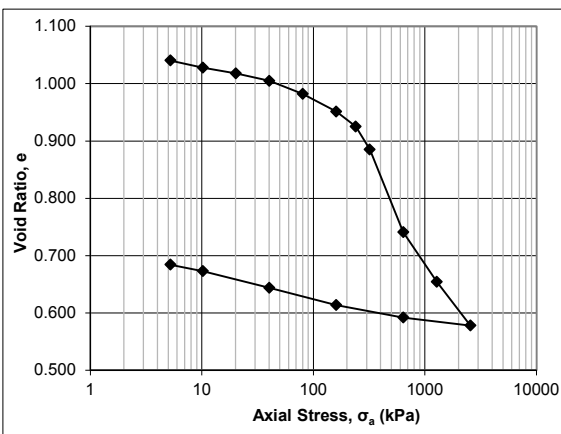




Photo C1. Shelby tube sample ST14 @ 15.2 to 15.9 m from Borehole 16-4

Appendix C.4
Analytical Testing Results

Certificate of Analysis

Thurber Engineering Ltd.

2460 Lancaster Rd, Suite 104
Ottawa, ON K1B4S5
Attn: Stephen Peters

Client PO: 19-5161-208
Project: Calamity Creek
Custody: 27364

Report Date: 29-Aug-2016
Order Date: 24-Aug-2016

Order #: 1635297

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

Paracel ID	Client ID
1635297-01	16-1, SS3, 5'-7'
1635297-02	16-4, SS16, 60'-62'
1635297-03	16-6, SS3, 5'-7'

Approved By:



Tim McCooeye
Senior Advisor

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 19-5161-208

Report Date: 29-Aug-2016

Order Date: 24-Aug-2016

Project Description: Calamity Creek

Analysis Summary Table

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	29-Aug-16	29-Aug-16
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	25-Aug-16	25-Aug-16
Resistivity	EPA 120.1 - probe, water extraction	26-Aug-16	26-Aug-16
Solids, %	Gravimetric, calculation	25-Aug-16	25-Aug-16

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 19-5161-208

Report Date: 29-Aug-2016

Order Date: 24-Aug-2016

Project Description: Calamity Creek

Client ID:	16-1, SS3, 5'-7'	16-4, SS16, 60'-62'	16-6, SS3, 5'-7'	-
Sample Date:	11-Aug-16	09-Aug-16	14-Aug-16	-
Sample ID:	1635297-01	1635297-02	1635297-03	-
MDL/Units	Soil	Soil	Soil	-

Physical Characteristics

% Solids	0.1 % by Wt.	71.6	70.9	65.2	-
----------	--------------	------	------	------	---

General Inorganics

pH	0.05 pH Units	8.05	8.06	7.92	-
Resistivity	0.10 Ohm.m	52.3	52.2	56.8	-

Anions

Chloride	5 ug/g dry	20	8	17	-
Sulphate	5 ug/g dry	24	32	28	-

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 19-5161-208

Report Date: 29-Aug-2016

Order Date: 24-Aug-2016

Project Description: Calamity Creek

Method Quality Control: Blank

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

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 19-5161-208

Report Date: 29-Aug-2016

Order Date: 24-Aug-2016

Project Description: Calamity Creek

Method Quality Control: Duplicate

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	135	5	ug/g dry	134			0.2	20	
Sulphate	517	5	ug/g dry	494			4.4	20	
General Inorganics									
pH	8.08	0.05	pH Units	8.05			0.4	10	
Resistivity	52.2	0.10	Ohm.m	52.2			0.2	20	
Physical Characteristics									
% Solids	83.6	0.1	% by Wt.	82.1			1.8	25	

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 19-5161-208

Report Date: 29-Aug-2016

Order Date: 24-Aug-2016

Project Description: Calamity Creek

Method Quality Control: Spike

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	240	5	ug/g	134	106	78-113			
Sulphate	588	5	ug/g	494	93.6	78-111			

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 19-5161-208

Report Date: 29-Aug-2016
Order Date: 24-Aug-2016
Project Description: Calamity Creek

Qualifier Notes:

None

Sample Data Revisions

None

Work Order Revisions / Comments:

None

Other Report Notes:

n/a: not applicable
ND: Not Detected
MDL: Method Detection Limit
Source Result: Data used as source for matrix and duplicate samples
%REC: Percent recovery.
RPD: Relative percent difference.

Soil results are reported on a dry weight basis when the units are denoted with 'dry'.
Where %Solids is reported, moisture loss includes the loss of volatile hydrocarbons.

Appendix D.

Site Photographs



Photo D1. Looking South toward culvert inlet.



Photo D2. Looking South toward East embankment slope.



Photo D3. Looking North toward culvert outlet.



Photo D4. Looking Southeast toward West embankment slope.

HIGHWAY 11 CALAMITY CREEK CULVERT REPLACEMENT
2.9 KM NORTH OF NORTH JUNCTION OF HWY 11 AND HWY 65



Photo D5. Looking North along Highway 11.



Photo D6. Looking South along Highway 11.

Appendix E.

**Foundation Comparison
Trenchless Installation Comparison**

COMPARISON OF ALTERNATIVE FOUNDATION TYPES

<i>Culvert Type</i>	<i>Closed Culvert</i>	<i>Circular Pipe Culvert (Trenchless Installation)</i>	<i>Open Bottom Culvert</i>
<i>Advantages</i>	<ul style="list-style-type: none"> i. Smaller magnitude of settlement than open footing culvert due to lower bearing stress on subgrade. ii. Relatively expedient installation if precast units. 	<ul style="list-style-type: none"> i. Can tolerate larger magnitude of settlement than concrete (rigid frame) culverts). ii. Lower cost than concrete (rigid frame) culverts. iii. Possibly allows two lanes of traffic to be maintained throughout 	<ul style="list-style-type: none"> i. Relatively expedient installation if precast units are used.
<i>Disadvantages</i>	<ul style="list-style-type: none"> i. Requires compacted granular pad on subgrade. ii. Requires large excavation and roadway protection 	<ul style="list-style-type: none"> i. Requires construction of entry and exit pits and access to toe of slope. ii. Feasibility also depends on flow capacity and other hydraulic properties. 	<ul style="list-style-type: none"> i. Compressible founding subgrade will provide very low geotechnical resistances. ii. Potential for post construction settlement. iii. Requires deeper excavation increasing excavation volume and dewatering concern
<i>Risks/ Consequences</i>	<ul style="list-style-type: none"> i. Groundwater control may require sheet pile enclosed excavation 	<ul style="list-style-type: none"> i. Groundwater control may require sheet pile enclosed excavation for entry and exit pits ii. Possibility of encountering obstructions 	<ul style="list-style-type: none"> i. Groundwater control may require sheet pile enclosed excavation ii. Increased risk of basal instability of footing excavation due to artesian conditions in underlying clay
<i>Relative Cost</i>	Moderate to High	Moderate to High	Moderate to High
<i>Recommendation</i>	Generally Feasible	Recommended	Not Recommended

COMPARISON OF ALTERNATIVE TRENCHLESS INSTALLATION METHODS

Method	Jack and Bore	Pipe Ramming	Microtunneling (MTBM)	Hand Mining	Horizontal Directional Drilling
<i>Advantages</i>	<ul style="list-style-type: none"> - Equipment and crew readily available 	<ul style="list-style-type: none"> - Able to access the tunnel face - Suitable for clay soils 	<ul style="list-style-type: none"> - High precision in alignment - Worker safety is enhanced - Suitable for clay soils - Allows access to tunnel face to deal with obstructions 	<ul style="list-style-type: none"> - Equipment and crew readily available 	<ul style="list-style-type: none"> - Limited requirement for shafts and pits
<i>Disadvantages</i>	<ul style="list-style-type: none"> - Incapable of handling unforeseen obstructions - Prone to misalignment 	<ul style="list-style-type: none"> - Worker safety issues during tunnel face access - Minimal precision in alignment control - Suitable for pipe diameters between 0.5 and 3.6 m and length < 100 m - Need to excavate into slopes for pits to meet length restrictions 	<ul style="list-style-type: none"> - Unforeseen oversized obstruction may slow progress - High operator skill required 	<ul style="list-style-type: none"> - Worker safety issues during tunnel face access - Slow process 	<ul style="list-style-type: none"> - Diminishing accuracy - Suitable for pipes diameter < 2 m
<i>Risks/Consequences</i>	MODERATE	MODERATE	LOW to MODERATE	HIGH	HIGH
<i>Recommendation</i>	Generally Feasible	Generally Feasible	Recommended	Not Recommended	Not Feasible

Appendix F.

GSC Seismic Hazard Calculation

2015 National Building Code Seismic Hazard Calculation

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

October 05, 2016

Site: 47.5544 N, 79.6731 W User File Reference: Calamity Creek Culvert

Requested by: ,

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

Sa(0.05)	Sa(0.1)	Sa(0.2)	Sa(0.3)	Sa(0.5)	Sa(1.0)	Sa(2.0)	Sa(5.0)	Sa(10.0)	PGA (g)	PGV (m/s)
0.180	0.228	0.202	0.160	0.118	0.064	0.031	0.0080	0.0033	0.127	0.096

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

Ground motions for other probabilities:

Probability of exceedance per annum	0.010	0.0021	0.001
Probability of exceedance in 50 years	40%	10%	5%
Sa(0.05)	0.016	0.061	0.102
Sa(0.1)	0.024	0.083	0.135
Sa(0.2)	0.024	0.077	0.122
Sa(0.3)	0.021	0.062	0.097
Sa(0.5)	0.016	0.047	0.072
Sa(1.0)	0.0078	0.025	0.039
Sa(2.0)	0.0033	0.012	0.019
Sa(5.0)	0.0007	0.0027	0.0045
Sa(10.0)	0.0004	0.0012	0.0019
PGA	0.013	0.045	0.074
PGV	0.0099	0.034	0.056

References

National Building Code of Canada 2015 NRCC no. 58190;
Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

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

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

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

Aussi disponible en français



Natural Resources
Canada

Ressources naturelles
Canada

Canada

Appendix G.

**List of Special Provisions and OPSS Documents Referenced in this Report,
Draft NSSPs**

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

- OPSS.PROV 206
- OPSS.PROV 209
- OPSS.PROV 401
- OPSS 422
- OPSS.PROV 501
- OPSS.PROV 517
- OPSS.PROV 539
- OPSS.PROV 804
- OPSS 902
- OPSS.PROV 1010
- OPSS.PROV 1205

- OPSD 208.010
- OPSD 802.032
- OPSD 803.010
- OPSD 810.010
- OPSD 3101.150

2. Suggested text for a NSSP on “Obstructions”

“Tunneling or installation of a sheet piled protection system could encounter obstructions such as cobbles or boulders embedded in the fill or remnants of buried sheet piles. Such obstructions may impede tunneling operations and sheetpile installation and prohibit reaching the designed installation. The Contractor shall be prepared to remove, drill through and/or penetrate these obstructions and extend the sheetpiles to the design depths or allow for tunneling to pass through.”

Suggest text for a NSSP on “Basal Heave”

“Dewatering shall be provided by the Contractor during structure excavation and backfilling as per OPSS 902. The Contractor is advised that the soils underlying this site include both cohesive and cohesionless strata and the observed groundwater table lies above the surface at the embankment base. Excavation below the groundwater level in cohesionless soil is expected to lead to instability and slough of the sides of the excavation and boiling of the base, accompanied by loss in geotechnical resistance of the soils. Basal heave due to unbalanced hydrostatic forces beneath the clay layers are also possible. If excavation is required to be carried out below the groundwater level prevailing at the time of construction, appropriate means of dewatering must be implemented to depress the groundwater level a minimum of 0.5 m below the base of the excavation to prevent any instability, sloughing, heave or boiling and so as to preserve the stability of the excavation and to allow the work to proceed in the dry.”

PIPE INSTALLATION BY TRENCHLESS METHOD – Item No.

Special Provision

1. SCOPE

This specification covers the general requirements for the installation of pipes by trenchless methods, including Jack & Bore, Pipe Ramming, Directional Drilling, and Tunnelling. The Contractor shall determine the most appropriate method of installation for each of the crossing locations.

This specification shall supersede OPSS 415 (Construction Specification for Pipeline Installation by Tunneling), OPSS 416 (Construction Specification for Pipeline and Utility Installation by Jacking and Boring) and OPSS 450 (Construction Specification for Pipeline and Utility Installation in Soil by Horizontal Directional Drilling).

2. REFERENCES

This specification refers to the following standards, specifications, or publications:

Ontario Provincial Standard Specifications, General

OPSS 180	Management and Disposal of Excess Materials
----------	---

Ontario Provincial Standard Specifications, Construction

OPSS 401	Trenching, Backfilling, and Compacting
OPSS 404	Support Systems
OPSS 491	Preservation, Protection, and Reconstruction of Existing Facilities
OPSS 492	Site Restoration Following Installation of Pipelines, Utilities and Associated Structures
OPSS 517	Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS.PROV 539	Temporary Protection Systems

Ontario Provincial Standard Specifications, Material

OPSS.PROV 1004	Aggregates - Miscellaneous
OPSS.PROV 1350	Concrete - Materials and Production
OPSS.PROV 1440	Steel Reinforcement for Concrete
OPSS 1802	Smooth Walled Steel Pipe
OPSS.PROV 1820	Circular and Elliptical Concrete Pipe
OPSS 1840	Non-Pressure Polyethylene (PE) Plastic Pipe Products

American Society for Testing and Materials (ASTM) International Standards

ASTM A252-93	Welding and Seamless Steel Pipe Piles
ASTM D2657-03	Standard Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings
ASTM D3350	Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
ASTM F894	Polyethylene Large Diameter Profile Wall Sewer and Drain Pipe

Canadian Standards Association Standards:

CSA B182.6	Profile Polyethylene Sewer Pipe and Fittings.
CAN/CSA A5-93	Portland Cement
CSA W59	Welded Steel Construction (Metal Arc Welding)

3. DEFINITIONS

For the purpose of this specification, the following definitions apply:

Auger Jack & Bore: a method of forming a horizontal bore in the subsurface by essentially simultaneously jacking ahead and rotating a cutter head, followed by removal of material from inside the bore by using an auger.

Backreamer: a cutting head suitably designed for the subsurface conditions that is attached to the end of a drill string to enlarge the pilot bore during a pullback operation.

Bore Path: a drilled path according to the grade and alignment tolerances specified in the Contract Documents.

Design Engineer: means the Engineer retained by the Contractor who produces the original design and working drawings. The design engineer shall be licensed to practice in the Province of Ontario.

Design Checking Engineer: means the Engineer retained by the Contractor who checks the original design and working drawings. The design checking engineer shall be licensed to practice in the Province of Ontario.

Digger Shield/Hand Mining: a method of forming a horizontal bore in the subsurface by essentially simultaneously jacking ahead while tunnelling advances using hand-mining (man-entry operation or “Jack and Mine) or a “digger” type shield with a hydraulic excavator arm to remove materials from inside the liner pipe.

Drilling Fluids: a mixture of water and additives, such as bentonite, polymers, surfactants, and soda ash, designed to block the pore space on a bore wall, reduce friction in the bore, and to suspend and carry cuttings to the surface.

Drilling Fluid Fracture or Frac Out: a condition where the drilling fluid’s pressure in the bore is sufficient to overcome the in situ confining stress, thereby fracturing the soil and/or rock materials and allowing the drilling fluids to migrate to the surface at an unplanned location.

Engineer: a Professional Engineer licensed by the Professional Engineers of Ontario to practice in the Province of Ontario.

Excavation: includes all materials encountered regardless of type and extent. Excavation shall include removal of natural soil, large boulders, cobbles, wood and fill regardless of means necessary to break consolidated materials for removal.

Environmentally Sensitive Area (ESA): areas adjacent to construction that are off limits to the Contractor as specified elsewhere in the Contract.

Fill: man-made mixture of previously placed/handled materials such as sand, clay, silt, gravel, broken rock, sometimes containing organic and/or deleterious materials, placed in an excavation or other area to raise the surface elevation.

Grouting: injection of grout into voids.

Guidance System: an electronic system capable of locating the position, depth and orientation of the drill head during the directional drilling process.

Directional Drilling (DD): directional boring or guided boring.

HDPE: high density polyethylene.

Inadvertent Returns: the flow of unexpected fluids, saturated materials (or running soil) towards the drilling rig that typically originated from an artesian aquifer encountered during the drilling process.

Loss of Circulation: the discontinuation of the flow of drilling fluid in the bore back to the entry or exit point or other planned recovery points.

Pilot Bore: the initial bore to set directional controlled horizontal and vertical alignment between the connecting points.

Pipe Jacking: a method for installing steel casing or concrete pipe in the subsurface utilizing hydraulically operated jacks of adequate number and capacity to ensure smooth and uniform advancement without overstressing the liner/pipe.

Pipe Ramming: a method for installing steel casings utilizing the energy from a percussion hammer to advance a steel casing with a cutting shoe attached at the front end of the casing.

Primary Liner (Support): system installed prior to or concurrent with excavation, to maintain stability of an excavation and to support earth or rock and any structure utilities or other facilities in or on the supported earth or rock mass, until the excavation is completed.

Product: pipe culverts, pipe sewers, watermain pipe and sanitary pipe.

Pullback: that part of the DD method in which the drill string is pulled back through the bore path to the entry point.

Quality Verification Engineer (QVE): an Engineer who has a minimum of five (5) years experience in the field of pipe installation using trenchless methods or alternatively has demonstrated expertise by providing satisfactory quality verification services for the work at a minimum of two (2) projects of similar scope to the contract. The Quality Verification Engineer shall be retained by the Contractor to certify that the work is in general conformance with the contract documents and to issue Certificate(s) of Conformance.

Reaming: a process for pulling a tool attached to the end of the drill string through the bore path to enlarge the bore and mix the cuttings with the drilling fluid. This typically includes multiple passes.

Rock: natural beds or massive fragments, or the hard, stable, cemented part of the earth's crust, igneous, metamorphic, or sedimentary in origin, which may or may not be weathered and includes boulders having a size equivalent to 0.3 m in diameter or greater.

Secondary Liner: concrete pipe, HDPE pipe or un-reinforced cast-in-place concrete, installed subsequent to tunnel excavation.

Shaft: vertically sided excavation used as entry and/or exit points from which the trenchless method is initiated or directed for the installation of product.

Strike Alert: a system that is intended to alert and protect the operator in the case of inadvertent drilling into an electrical utility cable. The strike alert system consists of a sensor and an alarm connected to the drill rig and a grounding stake. The alarm may be audio or visual or both.

Slurry: a mixture of soil and/or rock cuttings, and drilling fluid.

Soil: all materials except those defined as rock, and excludes stone masonry, concrete, and other manufactured materials; includes rock fragments having an equivalent size less than 0.3 m in diameter.

Trenchless Installation: an underground method of constructing a passage open at both ends that involves installing a pipe. For the purpose of this specification, the pipe may be installed by any of the various methods defined herein such as Auger Jack & Boring, Pipe Jacking, Pipe Ramming, Directional Drilling, or using a tunnelling machine or hand mining methods.

Tunnelling: An underground method of constructing a passage using a tunnel boring machine (TBM), a microtunnel boring machine (MTBM) or hand mining using a shield to support the opening.

4. DESIGN AND SUBMISSION REQUIREMENTS

4.01 General

The Contractor's documentation, submission requirements and installation methods shall specifically consider and address the subsurface conditions at each pipe crossing as identified in the Foundation Investigation Report or elsewhere in the Contract Documents.

4.02 Working Drawings

Three copies of stamped working drawings for portal or shaft construction, primary liner, excavation, secondary lining, dewatering and groundwater control and grouting shall be submitted to the Contract Administrator (CA) at least one week prior to the commencement of the work for information purposes. All submissions shall bear the seal and signature of the Design Engineer and Design Checking Engineer. The Contractor shall have a copy of the stamped working drawings at the site during construction.

As a minimum, working drawings/details pertaining to the tunnel design and construction shall include the following (as appropriate):

a) Plans, Elevations and Details:

- A work plan outlining the materials, procedures, methods and schedule to be used to execute the work;
- A list of personnel, including backup personnel, and their qualifications and experience;
- A safety plan including the company safety manual and emergency procedures;
- The work area layout;
- An erosion and sediment control plan that includes a contingency plan in the event the erosion and sediment control measures fail;
- A drilling fluid management plan, if applicable, that addresses control of frac-out pressures, any potential environmental impacts and includes a contingency plan detailing emergency procedures in the event that the fluid management plan fails;

- Lighting, ventilation and fire safety details as may be required by applicable occupational health and safety regulations; and
- Excavated materials disposal plan.

b) Design Criteria:

- Primary liner design details, if applicable;
- Design assumption and material data when materials other than those specified are proposed for use; and
- Drill path design, details of alignment and alignment control, maximum curvature and reaming stages.

c) Materials:

- Certification from the manufacturer that the product furnished on the contract meets the specifications cited in the manufacturer's product specification and that the materials supplied are suitable for the application; and
- Material mixture for filling voids and installation procedures.

d) Upstream/Downstream Portal Installation Procedure:

- The access shaft or entry/exit pit details designed and stamped/signed by the Design Engineer, as applicable; and
- Face support and other temporary support details, if applicable.

e) Primary Liner/Secondary Liner Installation and Grouting Procedure:

- Excavation and pipe installation procedures, including methods to handle obstructions and prevent soil cave-in; and
- Details of tunnelling equipment/methods to be used for the works.

f) Excavation and Dewatering:

- Ground control/dewatering details, as applicable, describing the proposed method for control, handling, treatment, and disposal of water.

g) Monitoring Method:

- The methods to be employed to monitor and maintain the alignment of the installation.

4.03 Site Survey

Prior to commencing the work, the Contractor shall, at each pipe location, lay-out the alignment and install settlement monitoring points.

4.04 Certificate of Conformance

The Contractor shall submit details of the sequence and method of construction to the Quality Verification Engineer for review, prepared and stamped by the Design Engineer. The Contractor shall submit to the Contract Administrator a Certificate of Conformance sealed and signed by the Quality Verification Engineer a minimum of one week prior to commencement of work under this item. The Certificate shall state that the construction procedures are in conformance with the requirements and specifications of the contract documents.

The Contractor shall submit to the Contract Administrator a Certificate of Conformance sealed and signed by the Quality Verification Engineer upon completion of each of the following operations and prior to

commencement of each subsequent operation for each pipe installation:

- Site Surveying (as noted in Section 4.02)
- Excavation for pits including dewatering of excavations
- Jacking/Ramming/Directional Drilling of Casing/Liner
- Installation of the Product
- Grouting Operations

Each Certificate of Conformance shall state that the work has been carried out in general conformance with the contract documents, specifications and/or stamped working drawings.

In addition, upon completion of the installation of the pipe at each location, the Contractor shall submit to the Contract Administrator a final Certificate of Conformance sealed and signed by the Quality Verification Engineer. The Certificate shall state that the pipe has been installed in general conformance with the Contractor's Submission and Design Requirements, stamped working drawings and contract documents.

The Design Engineer will not be permitted to carry out the work of the Quality Verification Engineer.

5. MATERIALS

5.01 Product

The product shall be concrete pipe or high density polyethylene pipe as specified.

5.02 Concrete

Concrete shall be according to OPSS.PROV 1350. The concrete strength shall be as specified in the Contractor's design submission.

5.03 Concrete Reinforcement

Steel reinforcing for concrete work shall be according to OPSS.PROV 1440.

5.04 Timber

Timber shall be sound, straight, and free from cracks, shakes and large or loose knots.

5.05 Grout

The Contractor shall submit the proposed grout mix design for grouts to be used for lubricating jacking pipe and for filling of voids and annular spaces. Purging grout shall consist of a mixture of one part Portland cement conforming to the requirements of CAN/CSA A5-93 and two parts mortar sand conforming to OPSS.PROV 1004 wetted with only sufficient water to make the mixture plastic.

5.06 Auger Jack & Bore Materials

5.06.01 Pipe Materials

Steel pipe shall conform with ASTM A252-93 welded joints suitable for jacking operations. The Contractor shall select pipe class for pipe jacking.

Concrete pipe as per OPSS.PROV 1820.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

5.07 Pipe Ramming Materials

5.07.01 Pipe Materials

Steel pipe shall conform with ASTM A 252-93 welded joints.

New steel casing when specified shall be smooth wall carbon steel pipe according to ASTM A252-93 Grade 2.

Used steel casing can be used provided that the steel casing can resist the applicable static and dynamic loadings.

Pipe wall thickness shall be determined by the Contractor based on static and dynamic loads from traffic loading and anticipated ramming forces for selected pipe and driven pipe lengths. The wall thickness shall be increased as required to ensure the casing is not damaged during handling and installation. The pipe minimum wall thickness shall be as per Table 1 of OPSS 1802.

Pipe segments shall be determined by the Contractor.

Steel pipe joints shall be pressure fit type or welded.

All steel casing pipe shall be square cut.

Steel casing pipe shall have roundness such that the difference between the major and minor outside diameters shall not exceed 1% of the specified nominal outside diameter or 6 mm, whichever is less.

Steel casing pipe shall have a minimum allowable straightness of 1.5 mm maximum per metre of length.

5.07.02 Mill Certificates

For permanent casing, the Contractor shall submit to the Contract Administrator at the time of delivery one copy of the mill certificate, indicating that the steel meets the requirements for the appropriate standards for casings.

Where mill test certificates originate from a mill outside Canada or the United States of America the Contractor shall have the information on the mill certificate verified by testing by a Canadian laboratory. The laboratory shall be accredited by a Canadian National Accreditation Body to comply with the requirements of ISO/IEC Guide 25 for the specific tests or type of tests required by the material standard specified on the mill test certificate. The mill test certificates shall be stamped with the name of the Canadian testing laboratory and appropriate wording stating that the material conforms to the specified material requirements. The stamp shall include the appropriate material specification number, the date and the signature of an authorized officer of the Canadian testing laboratory.

5.08 Directional Drilling Materials

5.08.01 Drilling Fluids

The drilling fluids shall be mixed according to the manufacturer's recommendations and be appropriate for the anticipated subsurface conditions.

5.08.02 Pipe Materials

High Density Polyethylene (HDPE) pipe as per OPSS 1840 shall be used in accordance with ASTM D3350.

The requirements for fittings shall be suitable for and compatible with the class and type of pipe with which they will be used and in according to CAN/CSA-B182.6 or ASTM F894.

The Contractor shall determine the required dimensional ratio (DR) of the HDPE pipe to support all subsurface conditions and hydrostatic pressures, and to withstand the grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

The Contractor's submission shall demonstrate, in conjunction with the manufacturer's specifications, that the heat resistance of the pipe material is sufficient to tolerate without damage the heat of hydration generated by grout curing.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

Jointing of HDPE piping shall be completed by thermal butt fusion in accordance with manufacturer's recommended procedures and as outlined in the latest revision of ASTM D2657. All manufacturer's recommendations and procedures shall be followed during the jointing process.

Jointing of HDPE piping to other piping materials or appurtenances shall be completed using flanged connections.

5.09 Tunnelling Materials

5.09.01 Primary Liner

Tunnelling methods will require installation of a primary liner. The primary liner shall be designed by the Contractor and the design/drawings shall be stamped/signed by the Design Engineer. The design shall be submitted to the Contract Administrator as specified herein.

5.09.02 Secondary Liner

Concrete or High Density Polyethylene Pipe shall be used according to the following requirements.

5.09.02.01 Concrete Pipe

Concrete pipe as per OPSS.PROV 1820 shall be used. The Contractor shall select the pipe class to withstand grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

5.09.02.02 High Density Polyethylene (HDPE)

High Density Polyethylene (HDPE) pipe as per OPSS 1840 shall be used in accordance with ASTM D3350.

The requirements for fittings shall be according to CAN/CSA-B182.6 or ASTM F894.

The Contractor shall determine the required dimensional ratio (DR) to withstand the grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

Jointing of HDPE piping shall be completed by thermal butt fusion in accordance with manufacturer's recommended procedures and as outlined in the latest revision of ASTM D2657. All manufacturer's recommendations and procedures shall be followed during the jointing process.

Jointing of HDPE piping to other piping materials shall be completed using flanged connections.

6. EQUIPMENT

6.01 Auger Jack & Bore Equipment

Pipe auger jack & bore equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

Specific details of the manner in which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the liner shall be submitted to the Contract Administrator for information purposes prior to proceeding with the works.

6.02 Pipe Ramming Equipment

Pipe ramming equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

The pipe ramming hammer(s) shall be capable of driving the pipe casing from the drive pit through the existing subsurface conditions at the site.

Specific details of the manner in which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the pipe shall be submitted to the Contract Administrator for information purposes prior to proceeding with the works.

6.03 Directional Drilling Equipment

6.03.01 General

The directional drilling equipment shall consist of a directional drilling rig and a drilling fluid mixing and delivery system of sufficient capacity to successfully complete the product installation without exceeding the maximum tensile strength of the product being installed.

6.03.02 Drilling Rig

The directional drilling rig shall:

- consist of a leak free hydraulically powered boring system to rotate, push, and pull hollow drill pipe into the ground at a variable angle while delivering a pressurized fluid mixture to a guidable drill head;
- contain a guidance system to accurately guide boring operations;
- be anchored to the ground to withstand the rotating, pushing, and pulling forces required to complete the product installation; and
- be grounded during all operations unless otherwise specified by the drilling rig manufacturer.

6.03.03 Drill Head

The drill head shall be steerable by changing its rotation, be equipped with the necessary cutting surfaces and drilling fluid jets, and be of the type for the anticipated subsurface conditions,

6.03.04 Guidance System

The guidance system shall be setup, installed, and operated by trained and experienced personnel. The operator shall be aware of any magnetic or electromagnetic anomalies and shall consider such influences in the operation of the guidance system when a magnetic or electromagnetic system is used.

6.03.05 Drilling Fluid Mixing System

The drilling fluid mixing system shall be of sufficient size to thoroughly and uniformly mix the required drilling fluid.

6.03.06 Drilling Fluid Delivery System

The delivery system shall have a means of measuring and controlling fluid pressures and be of sufficient flow capacity to ensure that all slurry volumes are adequate for the length and diameter of the final bore and the anticipated subsurface conditions. Connections between the delivery pump and drill pipe shall be leak-free.

6.04 Tunnelling Equipment

Tunnelling equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

Specific details of the manner in which rock or boulders will be broken and removed from the tunnel face shall be submitted to the Contract Administrator information purposes. Use of rock fracturing chemicals shall only be considered subject to a field demonstration satisfactory to the Ministry prior to its use.

Use of explosives is prohibited.

7. CONSTRUCTION

7.01 General

The Contractor shall notify the Contract Administrator at least 48 hours in advance of starting work. The proposed method of pipe installation to be used by the Contractor shall be submitted to the Contract

Administrator for information purposes prior to commencing the work and shall be subject to the limitations presented in the following subsections.

7.01.01 Layout, Alignment and Depth Control

The location of the installation shall be established from the lines, elevations and tolerances specified in the Contract Documents. The pipe installation shall be to the horizontal and vertical alignments specified in the Contract Drawings. Deviations from location, alignment, grades and/or invert levels shall be corrected by the Contractor at no cost to the Ministry.

All reference points necessary to construct the pipe installation and appurtenances shall be laid out.

The Contractor shall calibrate tracking and locating equipment at the beginning of each work day, and shall monitor and record the alignment and depth readings provided by the tracking system at every 5 m in normal conditions and every 2 m where precise alignment control is necessary;

The Contract Administrator shall be provided with the assistance and access necessary to check the layout of the pipe installation and associated appurtenances.

All excavations shall be carried out in accordance with the Occupational Health and Safety Act (OHSA) of Ontario.

For directional drilling, the contractor shall ensure that during pilot hole drilling the maximum degree of deviation or “dog-leg” shall be 2.5 degrees per 9m drill pipe length. Any deviation exceeding 2.5 degrees will necessitate a pull-back and straightening of the alignment at the Contractor’s sole expense. The pilot hole exit location shall be within 0.5m of the target location.

7.01.02 Construction Shafts

Construction shafts shall be specified in the Contractor's submission. The boundaries and protection of these shall be as required to contain all disturbances to areas outside of the ESA limits.

Shafts shall be maintained in a drained condition.

A minimum 2.4 m high secure fence shall be installed around the perimeter of the construction shaft area with gates and truck entrances. The fence shall be removed on completion of the work.

7.01.03 Protection Systems

The construction of all protection systems shall be according to OPSS.PROV 539. Where the stability, safety, or function of an existing roadway, watercourse, other works, proposed works or ESA’s may be impaired due to the method of operation, protection shall be provided. Protection may include sheathing, shoring, and piles where necessary to prevent damage to such works or proposed works.

7.01.04 Settlement or Heave

Any disturbance to the ground surface (settlement or heave) as a result of the pipe installation shall be immediately corrected by the Contract, at no additional cost to the Ministry.

7.01.05 Stability of Excavation

The construction methods, plant, procedures, and precautions employed shall ensure that excavations are stable, free from disturbance, and maintained in a drained condition.

The construction methods, plant, and materials employed shall prevent the migration of soil and/or rock material into the excavation from adjacent ground.

7.01.06 Preservation and Protection of Existing Facilities

Preservation and protection of existing facilities shall be according to OPSS 491.

Minimum horizontal and vertical clearances to existing facilities as specified in the Contract Documents shall be maintained. Clearances shall be measured from the nearest edge of the largest cut diameter required to the nearest edge of the facility being paralleled or crossed.

Existing underground facilities shall be exposed to verify its horizontal and vertical locations when the outlet pipe path comes within 1.0 m horizontally or vertically of the existing facility. Existing facilities shall be exposed by non-destructive methods. The number of exposures required to monitor work progress shall be as specified in the Contract Documents.

7.01.07 Transporting, Unloading, Storing and Handling Materials

Manufacturer's handling and storage recommendations shall be followed.

7.01.08 Trenching, Backfilling and Compacting

Trenching, backfilling, and compacting for entry and exit points or other locations along the pipe path shall be according to OPSS 401.

7.01.09 Support Systems

Support systems shall be according to OPSS 404.

If any open excavation will encroach into the highway embankment the protection system shall satisfy the requirements for Performance Level 2 as specified in OPSS.PROV 539.

7.01.10 Dewatering

The work of this Section includes control, handling, treatment, and disposal of groundwater. The Contractor shall review the foundation investigation report for reference to soil and groundwater conditions on the project site and plan a dewatering scheme accordingly.

The Contractor shall control groundwater inflows to excavations to maintain stability of surrounding ground, to prevent erosion of soil, to prevent softening of ground exposed in the excavation, and to avoid interfering with execution of the work.

The Contractor shall maintain excavations free of standing water at all times during excavation, including while concrete is curing.

Should water enter the excavation in amounts that could adversely affect the performance of the work or

could cause loss of ground, the Contractor shall take immediate steps to control the inflow.

The Contractor is alerted that seepage zones of perched water within the fill materials should be expected, particularly where granular materials are excavated.

Dewatering shall be according to OPSS 517.

7.01.11 Removal of Boulders

The Contractor is alerted that cobbles and boulders should be anticipated in the soil deposits at the site. Accordingly, the Contractor shall address the removal of cobbles and boulders in the proposed method of construction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered.

7.01.12 Record Keeping

Verification record requirements of the alignment and depth of the installation shall be as specified in the Contract Documents. A copy of the verification records shall be given to the Contract Administrator at the completion of the installation.

7.01.13 Testing

Testing of the product installation shall consist of verifying the specified grade between the two ends of the pipe and passing of water from the inlet end of the pipe to the outlet end to confirm gravity flow conditions.

7.01.14 Management and Disposal of Excess Material

Management and disposal of excess material shall be according to OPSS 180. Satisfactory re-usable excavated material required for backfill shall be separated from unsuitable excavated material.

7.01.15 Site Restoration

Site restoration shall be according to OPSS 492.

7.01.16 Supervision

A qualified individual, who is experienced in the pipe installation by trenchless methods shall supervise the work at all times.

7.02 Auger Jack & Bore Installation

7.02.01 Method of Installation Procedure

The installation procedure to be used shall be subject to the following limitations:

- Hydraulically operated jacks of adequate number and capacity shall be provided to ensure smooth and uniform advancement without over-stressing of the pipe.
- A suitably padded jacking head or collar shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.
- The jacking pipe shall be fully supported in the jacking pit at the specified line and grade.

- Selection of the excavation method and jacking equipment shall take into consideration the conditions at each pipe crossing.

7.02.02 Pipe Installation

Concrete pipe joints shall be water tight and according to OPSS.PROV 1820 and must withstand jacking forces, determined by the Contractor.

During the jacking of the liner the space between the liner and the wall of the excavation shall be kept filled with bentonite slurry. Upon completion of jacking, the space between the liner and the wall of the excavation shall be filled with grout.

The annular space between the liner and the product shall be fully grouted with a water tight, expandable and stable grout.

7.03 Pipe Ramming Installation

For pipe ramming installation the following requirements apply:

Only smooth walled steel pipe shall be used. But welding of pipe joints shall conform to CAS W59.

Ramming equipment of adequate capacity shall be provided to ensure smooth and uniform advancement without overstressing of the pipe. Delays shall be avoided between ramming operations.

A ramming head shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.

Two or more lubricated guide rails or sills shall be provided of sufficient length to fully support the pipe at the specified line and grade in the ramming pit. Pipe shall be installed to the line and grade specified.

Following installation of the liner pipe, all material shall be removed from the pipe to the satisfaction of the Contract Administrator. Any voids remaining between the pipe and the excavation wall shall be grouted as soon as the pipe is rammed. The annular space between the liner pipe and the product shall be fully grouted with a water tight, expandable and stable grout.

7.04 Directional Drilling Installation

7.04.01 General

When strike alerts are provided on a drilling rig, they shall be activated during drilling and maintained at all times.

7.04.02 Site Preparation

The work site shall be graded or filled to provide a level working area for the drilling rig. No alterations beyond what is required for DD operations are to be made. All activities shall be confined to designated work areas.

7.04.03 Pilot Bore

The pilot bore shall be drilled along the bore path in accordance with the grade, alignment, and tolerances as

indicated on the Contractor's submitted drilling plan to ensure that the product is installed to the line and grade shown on the Contract Drawings. The Contractor's methods shall take into consideration the conditions at each crossing within the pipe alignment and shall be suitable to advance through such obstructions such as cobbles and boulders and address the potential for deflection off these obstruction and/or soil conditions.

In the event the pilot bore deviates from the submitted path, the Contract Administrator shall be notified. The Contract Administrator may require the Contractor to pullback and re-drill from the location along the bore path before the deviation.

In the event that a drilling fluid fracture, inadvertent returns, or loss of circulation occurs during pilot bore drilling operations, the Contract Administrator shall be advised of the event and action shall be taken in accordance with the Contractor's submitted contingency plan.

At the entry and exit points, there is potential for ravelling of the existing soil, fill and or weathered rock areas along the alignment. This is conventionally addressed by the use of drilling fluid. However, casing may be required. The Contractor's methods shall take into consideration the potential need to install sections of casing to manage ravelling at or near ground surface.

If a drill hole beneath the highway must be abandoned, the hole shall be backfilled with grout or bentonite to prevent future subsidence.

The Contractor shall maintain drilling fluid pressure and circulation throughout the DD process, including during the initial pilot bore and during the reaming process.

The Contractor shall at all times and for the entire length of the installation alignment be able to demonstrate the horizontal and vertical position of the alignment, the fluid volume used, return rates and pressures.

7.04.04 Drilling Fluid Fracture (Frac-Out)

In order to reduce the potential for hydraulic fracturing of the hole during directional drilling, a minimum depth of cover of 5m is normally maintained between the pipe and the ground surface. Sections of the pipe close to the exit pit with less than 5m cover shall be cased. The Contractor shall ensure that drilling fluid pressures are properly set and controlled to prevent frac-out, for the depth of cover available between the bottom of the pavement structure (bottom of the subbase material) and the top of the bore.

Since fluid loss normally occurs in fault zones, fracture zones, or seams of coarse material, fluid migration does not always gravitate to the surface, thus making detection difficult. Once a fluid loss is detected, the Contractor shall halt operations immediately and conduct a detailed examination of the drill path and implement measures to mitigate fluid loss. If no surface migration is evident, resume operation while paying particular attention to fluid monitoring.

In the event of a fluid migration to the surface occurring, the Contractor shall halt all operations immediately, isolate the migration site, and recover fluids. Once the fracture is controlled, continue drilling operations with the operator paying particular attention to the fracture points

7.04.05 Reaming

The bore shall be reamed using the appropriate tools to a diameter at least 50% greater than the outside diameter of the product.

7.04.06 Product Installation

7.04.06.0 General

The product shall be jointed according to manufacturer's recommendations. The length of the product to be pulled shall be jointed as one length before commencement of the continuous pulling operation.

The product shall be protected from damage during the pullback operation.

The minimum allowable bending radius for the product shall not be exceeded.

Product shall be allowed to recover before connections to new or existing facility are made. Product recovery time shall be according to manufacturers recommendations.

7.04.06.02 Pullback and Grouting

After successfully reaming the bore to the required diameter, the product shall be pulled through the bore path. Once the pullback operation has commenced, it shall continue without interruption until the product is completely pulled into bore unless otherwise approved by the Contract Administrator.

A swivel shall be used between the reamer and the product being installed to prevent rotational forces from being transferred to the product. When specified in the Contract Documents, a weak link or breakaway connector shall be used to prevent excess pulling force from damaging the product.

The product shall be inspected for damage where visible at excavation pits and where it exits the bore. Any damage noted shall be rectified to the satisfaction of the Contract Administrator,

The pull back and reaming operations shall not exceed the fluid circulation rate capabilities. Reaming and back pulling operations shall be planned to insure that, once started, all reaming and back pulling operations are completed without stopping and within the permitted work hours.

The space between the pipe and the excavation walls shall be filled with grout.

7.05 Tunnelling Installation

7.05.01 General

The method of tunnelling shall be selected by the Contractor and shall be submitted to the Contract Administrator prior to commencement of the work for information purposes.

Excavation of native soil and fill shall be done in a manner to control groundwater inflow to the excavation and to prevent loss of ground into the excavation.

Methods of excavating the tunnel shall be capable of fully supporting the face and shall accommodate the removal of boulders and other oversize objects from the face. Continuous ground support shall be maintained during excavation.

As the excavation progresses, the Contractor shall continuously monitor (every 2 m) indications of support distress, such as cracking, deflection or failure of support system and subsidence of ground near the excavation.

The Contractor shall advance the ventilation system as a regular part of the normal excavation cycle.

The Contractor shall provide lighting in accordance with OSHA requirements for the entire length of the tunnel.

The tunnel is to be kept sufficiently dry at all times to permit work to be performed in a safe and satisfactory manner.

The Contractor shall maintain clean working conditions at all times in tunnels.

In the event that excavation threatens to endanger personnel, the Work, or adjacent property, the Contractor shall cease excavation. The Contractor shall then evaluate methods of construction and revise as necessary to ensure the safe continuation of the work.

The Contractor shall maintain tunnel excavation line and grade to provide for construction of final lining within specified tolerances.

7.05.01 Tunnelling Method

The tunnelling method shall be suitable to provide face support in changing ground conditions that may be encountered during the progress of the work. The selection of the tunnelling method should consider the soil conditions at each pipe crossing and the presence of obstructions, such as cobbles and boulders, with respect to the tunnel alignment.

7.05.02 Primary Liner (Support System)

Primary support systems shall prevent deterioration, loosening, or unravelling of ground surfaces exposed by excavation.

The primary liner support system shall be designed and installed to achieve the intended performance requirements.

Primary liner support system shall maintain the safety of personnel, minimize ground movement into the excavation, ensure stability and maintain strength of ground surrounding the excavation.

The primary liner shall be designed to support all subsurface conditions and hydrostatic pressures and to withstand any additional loads caused by installation and grouting, and shall ensure that no ground loading or other loading will be placed on the new work until after design strength has been reached.

The primary liner shall be installed so that the exterior is as tight as possible to the excavated surface of the tunnel and allows the placement of the full design thickness of the secondary lining.

Primary support systems shall be compatible with the encountered ground conditions, with the method of excavation, with methods for control of water, and with placement of the permanent lining.

All voids between the primary lining and the surface of the excavation shall be filled with cement grout. If an unexpanded liner is used, the space outside the liner plates shall be grouted at least daily.

7.05.03 Secondary Liner

7.05.03.01 Placing of Grout

The void outside the finished secondary liner shall be filled with cement grout according to the Contractor's submission.

Grout shall not be placed until the lining has achieved 85% of its specified strength or 30 MPa. Grouting shall be limited to such sequences and programs as are necessary to avoid damaging any part of the works or any other structure or property.

7.06 Instrumentation Monitoring

The work specified in this Section includes furnishing and installing instruments for monitoring of settlement and ground stability.

Surface settlement markers for monitoring ground stability shall be installed at the pavement/ground surface level on the shoulder, side slope and pavement at not greater than 5 m intervals along the tunnel alignment and as an array of three in-ground (1.5 m depth) measurement points on the shoulder of the highway perpendicular to the alignment. The equipment and procedures used for settlement monitoring during construction must be capable of surveying the settlement point elevations to within ± 1 mm of the actual elevation.

Surface settlement markers shall be hardened steel markers treated or coated to resist corrosion, with an exposed convex head having a minimum diameter of 12 mm and similar to surveyor's PK nails. Markers shall be rigidly affixed so as not to move relative to the surface to which it is attached. Traffic shall be managed by the contractor using short-term lane closures in accordance with the Ontario Traffic Manual (OTM).

In general, settlement monitoring points shall be 12-18 mm rebar encased in a 50-70 mm, SCH40 PVC pipe, set to a depth of 1.5 m below ground surface. The assembly shall be placed in a drill hole and backfilled with uniform sand.

The Contractor shall install all surface settlement instruments a minimum of one week prior to the start of works.

The surface settlement instruments shall be clearly labelled for easy identification.

The Contractor shall submit to the Contract Administrator a site plan showing the locations of the monitoring points, a geodetic survey of the settlement monitoring points including station, offset and elevation recorded at the following time intervals:

- Three consecutive readings at least one week prior to commencement of the work (Baseline Reading);
- Once per shift during tunnelling operations period; and
- Weekly after completion of the work for one month, or until such time at which all parties agree that further movement has stopped.

All readings shall be submitted to the Contract Administrative for information purposes on a weekly basis. Each report shall include all survey data collected in tabular and graphical format as plots of time versus settlement in comparison to survey data collected prior to commencement of the work.

7.07 Criteria for Assessment of Roadway Subsidence/Heave

Based on the monitoring of ground movement as specified in Subsections 4.02 and 7.06, the following represents trigger levels that define magnitude of movement and corresponding action:

- **Review Level:** If a maximum value of 10 mm relative to the baseline readings is reached, the Contractor shall review or modify the method, rate or sequence of construction or ground stabilization measures to mitigate further ground displacement. If this Review Level is exceeded, the Contractor shall immediately notify the CA and review and discuss response actions. The Contractor shall submit a plan of action to prevent Alert Levels from being reached. All construction work shall be continued such that the Alert Level is not reached.
- **Alert Level:** If a maximum value of 15 mm relative to the baseline readings is reached, the Contractor shall cease construction operations, inform the Contract Administrator and execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic. No construction shall take place until all of the following conditions are satisfied:
 - The cause of the settlement has been identified.
 - The Contractor submits a corrective/preventive plan.
 - Any corrective and/or preventive measure deemed necessary by the Contractor is implemented.
 - The CA deems it is safe to proceed.

The Contractor shall avoid damaging instrumentation during construction. Instrumentation that is damaged as a result of the Contractor's operation shall be repaired or replaced by the Contractor within one business day. The costs for replacement/repair shall be borne by the Contractor.

At the completion of the job, the Contractor shall abandon all instrumentations installed during the course of the Work.

9. MEASUREMENT FOR PAYMENT

Measurement shall be by Plan Quantity Payment as may be revised by Adjusted Plan Quantity Payment in metres, following along the centre line of the pipes from centre to centre of maintenance holes or chambers (catch basins) or from/to the end of the pipe where no maintenance hole or chamber is installed, of the actual length of pipe installed by trenchless methods.

10. BASIS OF PAYMENT

Payment at the contract price shall be full compensation for all labour, equipment and materials required for excavation (regardless of material encountered), dewatering, sheathing and shoring, supply and installation of pipe liners, settlement instrumentation and monitoring, site restoration, and all other work necessary to complete the installation as specified.

Payment for the rigid or flexible pipe conduits installed inside the pipe liners shall be paid separately under the appropriate tender items.

Where a protection system is made necessary because of the Contractor's operations (e.g. choice of trenchless

installation method), the cost shall be included in this item and shall be full compensation for all labour, equipment and materials required to carry out the work including subsequently removing the temporary protection system and performing any necessary restoration work.

Payment for connecting intercepted drains and service connections shall be made on the following basis:

- (a) Where such drains and service connections are shown on the contract drawings the cost of connections shall be included in the contract price for pipe installation.
- (b) Where such drains and service connections are not shown on the contract drawings, the cost of connections will be considered an allowable extra to the contract.

Payment for removal of boulders/obstructions greater than an equivalent 0.3 m in diameter shall be on a time and materials basis. The Contractor shall inform the Contract Administrator when boulders/obstructions are encountered and prior to removal to allow for proper and accurate tracking of time and material charges.