

**FOUNDATION INVESTIGATION AND DESIGN REPORT
ITZCAULDE CREEK CULVERT
HIGHWAY 11/17 RED ROCK TO NIPIGON
FROM 4.8 KM WEST OF HWY 628 TO 1.5 KM WEST OF HWY 585
TOWNSHIP OF RED ROCK**

G.W.P. 647-89-00, SITE No. 48C-352

Geocres Number: 52A-179

Report to

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted at the proposed location of the Itzcaulde Creek culvert to be installed under the eastbound and westbound lanes of Highway 11/17 in the Township of Red Rock, Ontario. The new culvert is planned as part of the Highway 11/17 four-laning project, involving construction of a divided highway from 4.8 km west of Highway 628 to 1.5 km west of Highway 585 in the District of Thunder Bay.

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 written descriptions of the subsurface conditions. A model of the subsurface conditions was developed from the data obtained in the course of the investigation.

Thurber carried out the investigation as a sub-consultant to Hatch Mott MacDonald (HMM), under the Ministry of Transportation Ontario (MTO) Agreement Number 6010-E-0006.

2 SITE DESCRIPTION

The site is located approximately 13 km (by highway) southwest of Nipigon, Ontario and about 1.5 km southwest of the intersection of Highway 11/17 and Highway 628. At the culvert site, the new eastbound lanes of Highway 11/17 will be located approximately 10 m east of the existing highway alignment and the new westbound lanes will be approximately 20 m to the west.

At the existing Highway 11/17 crossing, Itzcaulde Creek flows in a northwest to southeast direction within an approximate 45 m wide, low-lying wet area. The culvert under the existing highway embankment consists of an 1800 mm diameter CSP and the highway embankment is approximately

6 m high. An approximate 2.5 m high embankment from a former highway alignment runs adjacent to the northwest side of the existing highway, and the creek is carried under this embankment in a 900 mm diameter CSP. An open timber box forms the connection between the two different size culverts.

Preliminary drawings provided by HMM indicate creek water levels of Elev. 212.7 at the inlet and Elev. 212.0 at the outlet in November 2010.

The surrounding lands are typically treed with occasional areas of grass and shrubs. Occasional residential dwellings, businesses and sideroads are present along the highway corridor.

Photographs in Appendix C show the existing Itzcaulde Creek culvert and the general nature of the site.

The site lies within the physiographic region known as the Quetico Subprovince of the Superior Province of the Canadian Shield. The region is characterized by early Precambrian felsic igneous (granite) and metamorphic (granitic gneiss) bedrock. The bedrock is mantled by a thin discontinuous layer of drift or deeper deposits of glaciolacustrine clay.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing in the vicinity of this structure was carried out in several stages as the design evolved and the culvert alignment was revised:

- Initially during the period February 6 to 23, 2013, investigation was completed through this area for assessment of proposed high fill embankments. The investigation included advancing ten boreholes and nine dynamic cone penetration tests (DCPT) along the proposed eastbound and westbound lanes. Four of the boreholes and one DCPT were located within 20 m of the currently proposed culvert alignment, and this information has been incorporated into this report. The boreholes and DCPT are identified by Station and Offset as follows: 13+321 17.4L, 13+324 27L (DCPT), 13+340 19R, 13+350 19L, and 13+375 30R.
- Subsequently during May 4 to 9, 2013, three boreholes designated SB-01 to SB-03 were drilled along the culvert alignment proposed at that time. The culvert alignment was subsequently revised such that only Boreholes SB-01 and SB-03 are located within 20 m of the currently proposed alignment, and these two boreholes are included in this report.
- On March 25, 2014, three additional boreholes were drilled along the existing highway embankment to determine the composition of the embankment fill. These boreholes are identified by Station and Offset as follows: 13+318 01L, 13+342 07R, and 13+380 07R. The boreholes at Stations 13+318 and 13+342 are located within 20 m of the currently proposed culvert alignment and are included in this report.

- On May 5, 2014, an additional borehole designated SB-04 was drilled near the west end of the culvert alignment to prove bedrock.

All borehole logs from the high fill section, including those not incorporated in this report, are presented in the Foundation Investigation Report for the high fill embankments, along with stratigraphic profiles along the eastbound and westbound lanes.

The approximate borehole locations near the culvert are shown on the attached Borehole Locations and Soil Strata drawing included in Appendix F.

The boreholes were advanced to depths of 13.3 to 18.4 m (Elev. 205.8 to 194.4 m), including recovery of 3.0 to 3.2 m of bedrock core from Boreholes SB-03 and SB-04 using NQ coring techniques. Two of the boreholes (SB-01 and 13+321 17.4L) and the DCPT (13+324 27L) were terminated upon refusal on probable bedrock or boulders.

The borehole locations were marked in the field and utility clearances were obtained prior to drilling. The boreholes were relocated as necessary subject to access constraints, steep slopes and overhead utilities.

Drilling was carried out using track and truck mounted drill rigs and the boreholes were advanced with hollow-stem augers and NQ coring techniques. Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). In situ vane shear testing was conducted to further assess the undrained shear strength of the cohesive deposits. All rock cores were logged, and the Total Core Recovery (TCR), Rock Quality Designation (RQD) and the Fracture Indices (FI) were determined.

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

Groundwater conditions were observed in the open boreholes upon completion of the drilling operations, except where bedrock coring was performed, since water is added to the borehole during coring operations. A standpipe piezometer was installed in one borehole to measure groundwater levels. The piezometer was subsequently decommissioned in general accordance with MOE Regulation 903. The piezometer installation and borehole completion details are summarized in Table 3.1.

Table 3.1 – Borehole Completion and Piezometer Installation Details

Borehole	Piezometer Tip Depth/ Elev. (m)	Completion and Installation Details
SB-01	None installed	Backfilled with bentonite holeplug to 2.4 m, then cuttings to surface.
SB-03	None installed	Backfilled with bentonite holeplug to surface.
SB-04	None installed	Backfilled with bentonite holeplug to surface.
13+318 01L	None installed	Backfilled with bentonite holeplug to 1.5 m, then cuttings to surface.
13+321 17.4L	None installed	Backfilled with bentonite holeplug to 1.5 m, then cuttings to surface.
13+324 27L	None installed	(DCPT)
13+340 19R	13.1 / 201.1	19 mm diameter piezometer installed with filter sand from 13.1 m to 11.3 m, clay cuttings from 11.3 m to 1.2 m, then bentonite holeplug to surface.
13+342 07R	None installed	Backfilled with bentonite holeplug to 1.4 m, then cuttings to surface.
13+350 19L	None installed	Backfilled with bentonite holeplug to 2.3 m, then cuttings to surface.
13+375 30R	None installed	Backfilled with bentonite holeplug to surface.

4 LABORATORY TESTING

The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected samples were also subjected to gradation analysis (hydrometer and sieve) and Atterberg Limits testing, where appropriate. The results of these tests are summarized on the Record of Borehole sheets included in Appendix A and are presented on the figures included in Appendix B.

Point load tests were carried out on selected samples of intact bedrock to evaluate the unconfined compressive strength (UCS) of the bedrock. The UCS values of the rock assessed from the point load data are reported on the borehole logs (as average per run).

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets included in Appendix A. Details of the encountered soil stratigraphy are presented in these sheets and on the “Borehole Locations and Soil Strata” drawing included in Appendix F. An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole sheets governs any interpretation of the site conditions.

In general, the subsurface stratigraphy encountered at the culvert site consisted of existing embankment fill, peat and organics, overlying a thick deposit of silty clay, underlain by a layer of gravelly sand to sand and silt, overlying bedrock and probable bedrock. More detailed descriptions of the individual strata are presented below.

A description of the subsurface conditions within the overall embankment area is presented under separate cover in the Foundation Investigation Report prepared for the high fill embankments.

5.1 Sand Fill

Sand fill was encountered in the boreholes drilled on both the former and the existing Highway 11/17 embankments.

In Boreholes 13+318 01L and 13+342 07R drilled on the shoulder of the existing highway, the fill consisted of a 0.4 to 0.7 m thick layer of granular material underlain by silty sand to sand with some silt and trace of gravel. The sand fill in these boreholes extended to depths of 5.1 and 7.1 m (Elev. 214.0 and 211.6), and was interrupted in Borehole 13+342 07R by a 0.6 m thick layer of clay fill at 5.7 m depth.

In boreholes drilled through the former highway embankment, sand fill was encountered below a surficial organic layer (Borehole SB-01), below silty clay fill at 1.8 m depth (Borehole 13+321 17.4L), and at the ground surface (Boreholes SB-04 and 13+350 19L). The sand fill varied from gravelly to silty. The thickness of the sand fill ranged from 1.2 to 1.9 m, with a lower boundary at depths of 1.2 to 3.6 m (Elev. 213.9 to 211.9).

In general, SPT N-values recorded in the sand fill varied widely from 0 to 30 blows for 0.3 m penetration, indicating a very loose to compact relative density. Higher N-values of 89 blows for 0.3 m to 50 blows for 0.05 m of penetration were obtained in the upper frozen material. Moisture contents of 4% to 30% were measured, reflecting the presence of silty/clayey zones or organic inclusions in samples of the sand fill.

Three samples of the sand fill were selected for laboratory grain size analysis testing. The results of the tests are summarized below and are presented on the corresponding Record of Borehole sheets included in Appendix A. The grain size distribution curves for the samples are plotted on Figure B1, Appendix B.

Gravel %	0 to 29
Sand %	50 to 74
Silt and Clay %	21 to 28

5.2 Silty Clay (Fill and Possible Fill)

Silty clay identified as fill or possible fill was encountered below the sand fill at depths of 1.2 to 1.8 m (Elev. 213.6 to 213.9) in Boreholes SB-01, SB-04 and 13+350 19L drilled

from the former embankment level, and at depths of 5.1 and 5.7 m (Elev. 214.0 and 213.0) in Boreholes 13+318 01L and 13+342 07R drilled on the existing highway embankment. The clay (fill) contained organic seams, wood fibres/fragments, roots/rootlets and peat layers. Of note are a 0.7 m thick layer of silty sand with peat encountered in Borehole 13+350 19L and a 0.8 m thick sand layer in Borehole 13+342 07R. The colour of the silty clay (fill) was generally brown to dark brown.

The thickness of the silty clay (fill) including the intermixed peat and sand layers ranged from 2.4 to 4.6 m, with a lower boundary at depths of 4.6 to 9.8 m (Elev. 211.6 to 208.9).

Silty clay fill was also encountered below a thin organic layer and above the sand fill in Borehole 13+321 17.4L drilled on the former highway alignment. The clay fill was 1.5 m thick with a lower boundary at 1.7 m depth (Elev. 213.8) in this borehole.

SPT N-values recorded in the silty clay (fill) ranged from 0 to 12 blows for 0.3 m penetration, indicating a very soft to stiff consistency. An N-value of 21 blows for 0.3 m was recorded in frozen material in Borehole 13+321 17.4L. An undrained shear strength of 52 kPa was measured by in situ vane testing in Borehole SB-01. Moisture contents ranged from about 23% to 53% in the silty clay fill.

The results of grain size distribution analyses conducted on three samples of the silty clay fill are presented on the Record of Borehole sheets in Appendix A and on the grain size distribution curves plotted on Figure B2, Appendix B. The results of Atterberg Limits testing conducted on the samples are presented on the Record of Borehole sheets and plotted on Figure B7 of Appendix B. The results are summarized below.

Gravel%	0 to 9
Sand%	11 to 19
Silt%	43 to 61
Clay%	28 to 38
Liquid Limit	34 to 36
Plastic Limit	17 to 20

5.3 Organics and Organic Clay with Peat

A thin layer of organic material was encountered at the ground surface in Boreholes SB-01, 13+321 17.4L and 13+340 19R. The organic layer was 50 to 175 mm thick at these locations. The thickness of the organic layer may vary between and beyond the borehole locations.

A layer of organic clay with peat was encountered at the ground surface in Boreholes SB-03 and 13+375 30R drilled to the east of the existing highway embankment, and below

the embankment fill in Boreholes SB-04 and 13+318 01L. The organic layer was 3.0 m thick in Borehole 13+375 30R and 0.8 to 1.5 m thick in the remaining boreholes. The lower boundary was at Elev. 212.0 to 208.7.

SPT N-values recorded in the organic clay ranged from 0 to 4 blows for 0.3 m penetration, locally 16 blows in Borehole 13+318 01L. Moisture contents ranged from 47 to 74%.

A further 0.9 m of sandy clayey silt with organics was encountered below the organic clay in Borehole SB-04. An N-value of 4 blows for 0.3 m and a moisture content of 53% were obtained in this layer. The lower boundary was at 7.0 m depth (Elev. 207.8). The results of a grain size distribution analysis conducted on this layer are presented on Figure B3 of Appendix B, and are summarized below.

Gravel%	0
Sand%	34
Silt%	43
Clay%	23

5.4 Silty Clay

Native silty clay was encountered below the organic layer, organic clay deposits and fill in all boreholes. The silty clay was typically grey and occasionally brown in the upper 2 to 3 m.

Where fully penetrated, the silty clay layer was 5.7 to 12.3 m thick, with a lower boundary encountered at depths of 12.5 to 14.2 m (Elev. 203.0 to 200.2 m). Boreholes 13+318 01L, 13+375 30R, and 13+342 07R were terminated within the silty clay layer at depths of 13.3 to 13.7 m (Elev. 205.8 to 198.4 m), indicating a thickness of at least 3.5 to 10.7 m.

SPT N-values recorded in the silty clay ranged from 0 to 6 blows for 0.3 m penetration, typically less than 3. In situ shear vane testing indicated undrained shear strengths in the order of 22 to 84 kPa, typically 22 to 44 kPa. Based on this data, the consistency of the silty clay is generally soft to firm with stiff zones.

The moisture content of the silty clay typically ranged from 29% to 60%. A value of 91% was measured in one sample from about 1.0 m depth in Borehole 13+340 19R.

The results of grain size distribution analyses conducted on samples of the silty clay are presented on the Record of Borehole sheets in Appendix A and on Figures B4 and B5 in Appendix B. The results of Atterberg Limits testing conducted on the samples are presented on the Record of Borehole sheets and plotted on Figures B8 and B9 of Appendix B. The results are summarized below.

Gravel%	0
Sand%	0 to 1
Silt%	25 to 67
Clay%	32 to 75
Liquid Limit	28 to 57
Plastic Limit	16 to 25

The results of the Atterberg Limits tests indicate that the silty clay is typically of intermediate plasticity (CI), varying from low to high plastic (CL to CH).

5.5 Sand and Silt to Gravelly Sand

A cohesionless deposit varying in gradation from sand and silt to gravelly sand was encountered below the silty clay layer in Boreholes SB-01, SB-03, SB-04, 13+321 17.4L, 13+340 19R, and 13+350 19L. Boreholes SB-01, SB-03, SB-04 and 13+321 17.4L were terminated upon encountering bedrock or refusal below the cohesionless material at depths of 14.0 to 17.4 m (Elev. 197.4 to 201.4), indicating a thickness of 1.3 to 3.2 m. Boreholes 13+340 19R and 13+350 19L were terminated in the buried cohesionless layer at 13.7 and 14.3 m depth (Elev. 200.5 and 200.8).

SPT N-values recorded within the cohesionless deposit ranged from 1 blow for 0.3 m penetration to 100 blows for 0.075 m penetration, indicating a widely variable relative density of very loose to very dense. An SPT N-value of 100 blows with no penetration was recorded on a probable cobble above the bedrock in Borehole SB-03. Moisture contents ranged from 5% to 23%.

Two samples of the silty sand were selected for laboratory grain size analysis testing, the results of which are summarized below. The results are also presented on the Record of Borehole sheets included in Appendix A and grain size distribution curves on Figure B6, Appendix B.

Gravel%	10 to 11
Sand%	53 to 54
Silt%	32 to 33
Clay%	3 to 4

5.6 Bedrock and Probable Bedrock

Bedrock or refusal on probable bedrock was encountered below the cohesionless sand layer in Boreholes SB-01, SB-03, SB-04 and 13+321 17.4L, as well as in DCPT 13+324 27L. The depths and elevations of bedrock and probable bedrock are summarized in Table 5.1

Table 5.1 – Depth to Bedrock and Refusal on Probable Bedrock

Borehole / DCPT	Bedrock or Probable Bedrock	
	Depth (m)	Elevation
SB-01	17.4	198.3
SB-03	15.4*	197.4
SB-04	14.0*	200.8
13+321 17.4L	14.1	201.4
13+324 27L	15.2	200.2

* Proven by coring

A 3.0 to 3.2 m length of rock core was recovered from Boreholes SB-03 and SB-04. The bedrock recovered in the core samples was described as grey gneiss. Total core recovery was 100% in both all runs. RQD values of 95 to 100% were recorded, indicating excellent rock quality. The Fracture Index (FI) of the rock, expressed as fractures per 0.3 m of core, ranged from 0 to 5.

Average unconfined compressive strengths (UCS) of 219 and 356 MPa were assessed from the results of point load tests conducted on the rock core samples, indicating a very strong to extremely strong intact rock strength. The UCS results are included on the borehole logs in Appendix A (as average per run).

5.7 Water Levels

Groundwater levels in the boreholes were observed during drilling and a standpipe piezometer was installed in one borehole to monitor groundwater levels after completion of drilling. A summary of the recorded groundwater levels is provided below.

Table 5.2 - Groundwater Level Measurements

Borehole	Date	Groundwater Level		Comment
		Depth (m)	Elevation	
SB-01	May 7, 2013	4.8	210.9	In open borehole
13+318 01L	Mar. 25, 2014	7.7	211.4	In open borehole
13+340 19R	May 22, 2013	1.3	212.9	In piezometer
13+342 07R	Mar. 25, 2014	7.7	211.0	In open borehole
13+350 19L	Feb. 9, 2013	5.2	209.9	In open borehole
13+375 30R	Feb. 23, 2013	3.9	208.2	In open borehole

The recorded groundwater levels are considered short-term readings and seasonal fluctuations of the groundwater level are to be expected, particularly after spring snowmelt as well as periods of prolonged and/or significant precipitation.

The groundwater level is also expected to be influenced by the water level in Itzcaulde Creek, which is shown on the preliminary drawings provided by HMM to be at Elev. 212.7 at the inlet and Elev. 212.0 at the outlet in November 2010.

6 MISCELLANEOUS

In general, the borehole locations were positioned in the field by TBT Engineering Limited surveyors who also provided co-ordinates and ground surface elevations at the boreholes. Where boreholes required relocation from the staked location, field measurements were recorded and the surveyed coordinates and elevations were adjusted accordingly.

TBT Engineering Limited from Thunder Bay, Ontario supplied a track mounted CME 55 drill rig and conducted the drilling, sampling and in-situ testing operations.

Full time supervision of the field activities was carried out by Ms. Eckie Siu, Mr. Stephane Loranger, and Mr. George Azzopardi of Thurber. Overall supervision of the field program was conducted by Mr. Mark Farrant, P. Eng.

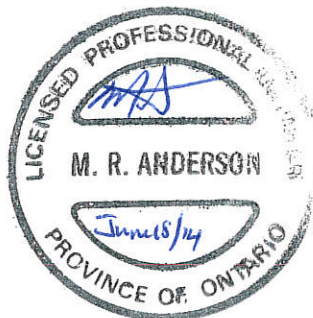
Interpretation of the data and preparation of this report were carried out by Mr. Mark Farrant, P.Eng. and Mr. Murray R. Anderson, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 INTRODUCTION

This report presents interpretation of the geotechnical data provided in the factual report and presents geotechnical recommendations for a new culvert to be constructed at the Highway 11/17 crossing of Itzcaulde Creek in the Township of Red Rock, Ontario.

The existing Itzcaulde Creek culvert under Highway 11/17 consists of an 1800 mm diameter CSP. The creek flows in a northwest to southeast direction at the site, within an approximate 45 m wide, low-lying wet area. The height of the existing Highway 11/17 embankment at the crossing is approximately 6.5 m.

An approximate 2.5 m high embankment from a former highway alignment runs adjacent to the northwest side of the existing highway, and the creek is carried under this embankment in a 900 mm diameter CSP. An open timber box forms the connection between the 900 mm and 1800 mm diameter culverts.

Four-laning of Highway 11/17 including replacement of the existing culverts is planned. At the culvert site, the new eastbound lanes of Highway 11/17 will be located approximately 10 m east of the existing highway alignment and the new westbound lanes will be approximately 20 m to the west. This section of highway is designated as a high fill embankment, and the proposed culvert design must be consistent with embankment construction procedures, discussed in a separate Foundation Investigation and Design Report.

The preliminary GA drawing indicates that the proposed culvert will consist of two parallel sheet pile walls and a precast concrete panel cap. The culvert span will be 4.3 m and the length will be

71.5 m. The invert level will vary from Elev. 212.0 at the inlet to Elev. 211.7 at the outlet. The clear height within the culvert will range from 2.5 to 2.8 m, and the fill height over the culvert will be approximately 3.8 m. Finished road grade will be near Elev. 219.0.

The discussions and recommendations presented in this report are based on the factual data obtained during the course of the investigation. The preliminary General Arrangement drawings used for preparation of this report were provided by Hatch Mott MacDonald.

8 CULVERT FOUNDATIONS

8.1 General

In general, the subsurface stratigraphy encountered at the site consisted of existing embankment fill, organics and organic clay, overlying native silty clay, underlain by a layer of gravelly sand to sand and silt, overlying bedrock and probable bedrock. The silty clay layer has a soft to firm consistency and a thickness of 5.7 to 12.3 m where fully penetrated in the boreholes. The depth to bedrock and probable bedrock ranged from 14.0 to 17.4 m.

A groundwater level at Elev. 212.9 m was measured in a standpipe piezometer installed at the site. The preliminary GA indicates a water level Elev. 212.0 to 212.7 m in Itzcaulde Creek on November 2010.

8.2 Embankment Construction and Staging Considerations

Finished grade on the new eastbound lanes will be approximately 0.3 m above existing highway grade, and the widened embankment will have a total height of about 6.5 m. Embankment construction for the new westbound lanes will require placement of about 4 m of new fill over the former highway embankment to achieve a total embankment height of approximately 6.5 m. Some excavation of the existing embankment will be required to form the median ditch.

A Foundation Investigation was carried out for this section of embankment. The stability of the embankments and the long-term settlement to be expected due to consolidation of the foundation soils under the embankment loads was evaluated, and discussion of these analyses are presented in a separate report.

The post-construction settlement anticipated under the new embankment loads is expected to be in the order of 400 to 500 mm. The settlement will be non-uniform along the culvert profile, as the loading conditions will vary from a new 6.5 m height of fill for embankment widening to an unloading condition at the new median ditch. MTO's Embankment Settlement Criteria for Design requires the 20-year post-construction settlement to be less

than 50 mm for embankment widening and 100 mm for new embankments, with a differential settlement rate of 200:1.

Stability analyses indicated that stability berms and staged fill placement will be required to enable construction of the embankment to the full height while maintaining stability.

To meet the post-construction settlement criteria and maintain stability of the embankments in this section, a staged construction program is required, including stability berms, wick drains, preloading and surcharging. This program must also consider the staging requirements for the proposed four-laning procedure. Through discussions with the design team, we understand staging will involve widening of the existing embankment approximately 10 m to the east and constructing the new westbound embankment, then shifting two-way traffic onto the widened eastbound embankment to accommodate completion of the westbound lanes, followed by shifting traffic to the new westbound lanes and completion of the new eastbound lanes.

In addition to the embankment construction and staging requirements, evaluation of the preferred culvert type/foundation system at this site must consider the tolerable settlement along the length of the culvert and at the approaches. The MTO settlement criteria specify that differential post-construction settlement within 20 m of a fixed (non-settling) structure must be less than 25 mm with no abrupt step deeper than 5 mm. Settlement analysis and incorporation of remedial measures (such as lightweight backfill) are necessary to achieve these requirements.

Assessment of the magnitude and rate of primary consolidation settlement of the underlying silty clay occurring under the weight of the new embankment fill was carried out utilizing the commercially available settlement program Settle^{3D} developed by Rocscience Inc. with the option of Terzaghi's one-dimensional consolidation theory and three dimensional Boussinesq stress computation. The parameters used in the analyses were determined by laboratory oedometer tests conducted during the High Fill Embankment study and soil moisture correlations developed during past projects.

8.3 Selection of Culvert Type

Selection of the culvert type and foundation system must consider the proposed procedures for construction of the overall embankment, the staging requirements for four-laning of the highway, the low geotechnical resistance available in the native silty clay, the depth to suitable bearing material, and the post-construction settlement criteria.

In view of the conditions and requirements specific to this site, the following culvert types were considered through consultation with the design team:

- Concrete box culvert founded on native silty clay;

- Arch culvert supported on footings on native silty clay or engineered fill;
- Arch culvert supported on piles driven to bedrock; and
- Steel sheet piles driven to bedrock and capped with precast concrete panels.

A comparison of alternative culvert/foundation systems, based on advantages and disadvantages of each, is included in Appendix D. Further comments regarding the culvert alternatives as well as recommendations for the feasible foundation options are provided below. The foundation scheme preferred from a foundations perspective is also identified.

The culvert must be designed to resist external loadings including frost forces, 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.

8.4 Concrete Box Culvert

From a geotechnical perspective, installation of a precast concrete box culvert is considered feasible at this site. However, construction staging and embankment preloads will need to be specifically adapted to reduce differential settlement along the culvert to acceptable limits and meet MTO criteria for post-construction settlement of the approaches.

The design invert levels for the culvert range from Elev. 212.0 at the inlet to Elev. 211.7 at the outlet. Assuming the combined thickness of the culvert base, bedding layer and river stone lining is approximately 0.9 m, the anticipated elevation of the underside of the bedding layer will be Elev. 211.1 to 210.8. The subgrade at this level is expected to vary from soft to firm silty clay to possible silty clay fill, and granular fill placed during swamp excavation for embankment widening.

The recommended geotechnical resistances for a box culvert placed on the silty clay and fill at the anticipated base level are as follows:

Factored Geotechnical Resistance at ULS	=	120 kPa
Geotechnical Resistance at SLS	=	80 kPa

It is recommended that a minimum 500 mm thick layer of bedding material comprising OPSS.PROV. 1010 Granular A be provided under the base of the box culvert as per OPSS 422 and OPSD 803.010. Placement of the bedding material and levelling course must be carried out in the dry. All organic soil and excessively loose material exposed on the culvert subgrade must be removed prior to placement of the culvert bedding material.

The resistance values provided are for vertical, concentric loads. Where eccentric or inclined loads are applied, the resistance used in design must be reduced in accordance with the CHBDC Clause 6.7.3 and Clause 6.7.4.

The geotechnical SLS resistance value given above is based on an estimated total settlement not exceeding 25 mm. However, the actual culvert settlement will be governed by the settlement of the foundation soils under the loading of the new embankment fill. The anticipated non-uniform settlements along the culvert length due to embankment construction are in the order of 0 to 500 mm, and are expected to exceed the levels that can be accommodated by the culvert. Therefore measures will be required to reduce the post-construction settlement.

To assess settlement-reduction measures, post-construction settlements under the maximum embankment height of 6.5 m were estimated for different preload and surcharge scenarios. To accommodate staging requirements, preload/surcharge periods of 6 and 12 months were considered. The estimated post-construction settlements for three different treatment options are as follows:

<u>Treatment Option</u>	<u>20-year Post-Construction Settlement (mm)</u>
1. Six month preload period with full embankment height, wick drains and no surcharge.	160
2. Twelve month preload period with full embankment height, wick drains and 1.0 m surcharge.	105
3. Six month preload period with full embankment height and wick drains, and a further six month preload period with 1.0 m surcharge. Excavate and place 2.5 m thickness of EPS adjacent to culvert.	25

Based on these results, Option 3 will be required to achieve the MTO settlement criteria. The box culvert must be installed after the preload and surcharge periods. Post-construction settlement of the culvert and embankment fill will generally occur in unison, and therefore longitudinal settlement at the transition to the culvert will not be an issue.

It is noted that preloading/surcharging of different sections of the culvert at sequential times to accommodate traffic staging and maintain differential settlement to tolerable levels will add to the overall duration of construction. In addition, staged construction to limit the height of embankment fill placed at one time is required to maintain stability of the embankment. Further details with regards to construction sequencing and EPS placement are presented in Section 11.

The capability of the existing culverts to carry the increased embankment loads and accommodate the anticipated differential settlement during the preload/surcharge periods must be reviewed. Installation of a sacrificial culvert and placing the box culvert on a different alignment than the existing culvert may be necessary to maintain stream flow during construction. Backfill over a sacrificial culvert should comprise granular material (not rock fill) to facilitate subsequent excavation and replacement.

Use of pre-cast culvert sections with articulated joints is preferable to allow movement between the segments. The culvert should be wrapped with geotextile filter fabric at the joints to prevent infiltration of soil fines through the joints.

8.5 Arch Culvert on Footings or Piles

Consideration was given to installation of an arch culvert supported on spread footings founded on native silty clay or engineered fill. However this option is not recommended for the following reasons:

- The geotechnical resistance available in the silty clay is inadequate for the support of spread footings carrying the relatively high loads imposed by an arch culvert.
- Competent native soils are not present within a reasonable depth of excavation.
- Silty clay (possible fill) with peat and organic layers, possibly comprising fill used to replace peat deposits during construction of the existing and former highway embankments, extends to depths in the order of 4.0 m below the groundwater level. Construction of engineered fill to support footings would require excavation and replacement of this material under water and is not considered practical.
- The non-uniform settlements anticipated along the length of the culvert are likely to exceed the tolerable limits of an arch culvert.

In view of the geotechnical resistance and settlement concerns, supporting the arch culvert on steel H-piles driven to bedrock was also considered. This option would address support and settlement of the culvert structure, however differential settlement would occur at the transition between the rigidly supported culvert and the approach embankments constructed over the compressible foundation soils. As outlined for the sheet pile option (below), the use of EPS in the approaches would be required to manage this settlement. We understand however that use of EPS as backfill may impact the structural functioning of the arch culvert, and therefore this option is not recommended.

In light of the above factors, the arch culvert option was not developed further.

8.6 Steel Sheet Pile Culvert

A culvert consisting of two parallel sheet pile walls capped with precast concrete panels is considered feasible at this site. In view of the low geotechnical resistance available in the foundation soils and the potential for consolidation settlement of the silty clay under the embankment loads, it is recommended that the sheet piles be driven to refusal on the underlying bedrock.

Based on the borehole information, the recommended sheet pile tip elevations and estimated pile lengths, are shown in the table below:

Table 8.1 – Estimated Sheet Pile Tip Elevations and Lengths

Borehole Designation	Bedrock/Probable Bedrock Elevation	Estimated Sheet Pile Length* (m)
13+324 27L	200.2	14.6
13+321 17.4L	201.4	13.4
SB-04	200.8	14.0
SB-01	198.3	16.5
SB-03	197.4	17.4

* Based on top of sheet pile Elevation 214.8 shown on preliminary GA drawing.

The resistance of sheet piles driven to refusal on unyielding bedrock will be controlled by the structural capacity of the selected sheet pile section. For a XZ95 sheet pile section (section area of 155 cm²/m and steel yield strength of 350 kPa), the recommended geotechnical resistance at factored ULS (per linear meter width) is 1,800 kN. This resistance includes a reduction to account for subsurface uncertainties.

The SLS capacity will not govern for steel sheet piles driven to bedrock.

Steel sheet pile installation should be in accordance with OPSS 903. The appropriate pile driving note is “Sheet piles to be driven to bedrock or refusal”.

Sheet piles should be provided with tip protection to minimize tip damage when setting on bedrock and while driving through the sand layer with possible cobbles and boulders above the bedrock surface.

As noted previously, differential post-construction settlement of the approach embankments within 20 m of a fixed (non-settling) sheet pile structure must be less than 25 mm. Preloading and surcharging of the embankment will therefore be required to reduce the differential settlement to tolerable levels. As discussed for the box culvert option, this will involve preloading with the full embankment height and wick drains for a six month period, placement of a 1.0 m surcharge for a further six months, and then excavation of backfill and placement of a 2.5 m thickness of EPS adjacent to culvert. Further details with regards to construction sequencing and EPS placement are presented in Section 11.

Design of the permanent sheet pile walls must consider environmental conditions such as road salts and fluctuating water levels that may cause corrosion and reduce the service life of the structure. The native soils in front of the sheet pile should be protected from creek erosion so that the sheet piles do not lose lateral support.

It is understood that the sheet pile walls will be extended to form wing walls beyond the capped portion of the culvert. In view of the expected consolidation settlement and downdrag forces, it is recommended that the wing wall sheet piles also be driven to refusal on bedrock.

8.6.1 Downdrag

Downdrag forces will develop along the sides of the sheet piles as a result of consolidation of the silty clay deposit under the weight of the new embankment fill and surcharge. Drag forces will also act on the sides of the block of soil directly above the culvert.

For design purposes, an unfactored downdrag load of 550 kN per meter width of sheet pile is recommended to evaluate the impact of downdrag on the sheet piles.

This downdrag load should be multiplied by a load factor of 1.25 as per CHBDC Commentary Clause C6.8.4 to obtain a factored downdrag load. In accordance with Section 6.8.4 of the CHBDC and Clause C6.8.4 of the Commentary, in the structural design of a pile, the factored downdrag load should be added to the factored permanent loads to assess the effects of downdrag. In geotechnical analysis of downdrag, live load effects should not be considered.

The location of the neutral plane for a pile should be determined by using unfactored loads and unfactored geotechnical parameters.

As indicated in Clause C6.8.4 of the Commentary, the factored dead and downdrag load should not exceed the factored structural resistance of the pile.

8.6.2 Lateral Resistance of Sheet Piles

The ultimate lateral resistance of a steel sheet pile wall may be assessed using the expression and earth pressure coefficients presented in Section 9.

For soil-spring analysis, the spring constant, K_s , may be obtained by the expression $K_s = k_s L$ (kN/m), where k_s is the coefficient of horizontal subgrade reaction (kN/m³) and L is the length (m) of the pile segment or element used in the analysis. For the soft to firm silty clay at the site, a k_s value of 1,500 kN/m² is recommended for analysis. This value may be assumed to be constant with depth.

8.7 Recommended Foundation

From a geotechnical perspective, a precast concrete box culvert is the preferred culvert type for this site provided adequate preloading/surcharging periods are available to reduce the differential settlement along the culvert to acceptable limits. We understand however that this option is considered unacceptable due to issues with the construction schedule, staging, fisheries impacts and maintenance of water flow. A steel sheet pile wall culvert is therefore the proposed culvert type at this location.

8.8 Frost Cover

The design depth of frost penetration at this site is 2.3 m. The base of all footings or pile caps, if employed, must be provided with a minimum of 2.3 m of earth cover as protection against frost action. Frost treatment for a box culvert should be as per OPSD 803.010.

9 CULVERT BACKFILL AND LATERAL EARTH PRESSURES

Culvert backfill should consist of granular material conforming to OPSS.PROV.1010 Granular A, Granular B Type II or Granular B Type III specifications. Backfilling to the culvert should be in accordance with OPSS 902. Rock fill should not be used adjacent to the sheet pile wall.

Backfill should be placed and compacted in simultaneous equal lifts on both sides of the culvert, and the top of backfill elevation should be within 400 mm on both sides of the culvert at all times. The precast concrete cap panels must be in place prior to backfilling. Heavy compaction equipment should not be used adjacent to the walls and roof of the culvert. Compaction equipment to be used adjacent to culverts should be restricted in accordance with OPSS 501 and SP 105S21.

Lateral earth pressures acting on the culvert walls and wing walls may be assumed to be triangularly distributed and to be governed by the characteristics of the abutment backfill and the underlying soils. For a fully drained condition, the pressures should be computed in accordance with the CHBDC but generally are given by the expression:

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

Where: p_h = horizontal pressure on the wall at depth h (kPa)

K = earth pressure coefficient (see Table 9.1)

γ = unit weight of retained soil (see Table 9.1)

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

q = value of any surcharge (kPa)

Earth pressure coefficients for backfill to the culvert and wingwalls are dependent on the material used as backfill and the inclination of the ground surface behind the wall. Recommended values are shown in Table 9.1.

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. The at-rest coefficients should be employed for a rigid concrete box culvert. Active pressures should be used for any wingwalls or unrestrained walls.

Table 9.1 – Earth Pressure Coefficients (K)

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/III or Existing Sand Fill $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$		Silty Clay $\phi' = 27^\circ$ $\gamma' = 9.5^* \text{ kN/m}^3$
	Horizontal Surface	Sloping Surface behind Wall (2H:1V)	Horizontal Surface	Sloping Surface behind Wall (2H:1V)	Horizontal Surface
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48	0.38
At rest (Restrained Wall)	0.43	-	0.47	-	0.55
Passive (Movement Towards Soil Mass)	3.7	-	3.3	-	2.7

* Use submerged unit weight below groundwater level.

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.

In accordance with Clause 6.9.3 of the CHBDC, a compaction surcharge should be added. The magnitude should be 12 kPa at the top of fill and decreasing to 0 kPa at a depth of 2.0 m for Granular B Type I or Type III or at a depth of 1.7 m for Granular A or Granular B Type II.

10 SEISMIC CONSIDERATIONS

The following seismic parameters should be used for design:

- Velocity Related Seismic Zone 0
- Zonal Velocity Ratio 0.0
- Acceleration Related Seismic Zone 0
- Zonal Acceleration Ratio 0.0
- Peak Horizontal Acceleration 0.011g

The soil profile type at this site has been classified as Type III. Therefore, according to Clause 4.4.6 of the CHBDC, Site Coefficients “S” (ground motion amplification factor) of 1.5 should be used in seismic design.

In accordance with Clause 4.6.4 of the CHBDC, retaining structures should be designed using active (K_{AE}) and passive (K_{PE}) earth pressure coefficients that incorporate the effects of earthquake loading. The coefficients of horizontal earth pressure for seismic loading presented in Table 10.1 may be used.

Table 10.1 – Earth Pressure Coefficients for Earthquake Loading

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 or Type III $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	Silty Clay $\phi = 27^\circ$ $\gamma = 9.5 \text{ kN/m}^3$
Active (K_{AE})*	0.28	0.32	0.38
Passive (K_{PE})	3.70	3.20	2.60
At Rest (K_{OE})**	0.45	0.50	0.57

* After Mononobe and Okabe, passive case assumes a horizontal surface in front of the wall.

** After Woods

The site is underlain primarily by soft to firm silty clay. In view of these conditions and the velocity related seismic zone of zero, liquefaction is not considered to be a concern at this site.

11 APPROACH EMBANKMENTS

The Itzcaulde Creek culvert is located within a section of highway designated as a high fill. A Foundation Investigation has been carried out and design recommendations prepared to address embankment stability and settlement concerns for the full length of this section of embankment (Station 13+300 to 13+425). The approach embankments to the culvert will be constructed in accordance with the recommendations presented in the Foundation Design Report for the embankments (ie., wick drains, stability berms, preload and surcharge).

As the proposed sheet pile wall culvert founded on bedrock will not settle in unison with the embankments, specific construction sequencing must also be adopted to provide a smooth transition between the culvert and approach embankments. Based on MTO’s Embankment Settlement Criteria for Design, the 20-year post-construction differential settlement within 20 m of the culvert must be less than 25 mm with no abrupt step deeper than 5 mm.

On the basis of the stability and settlement analyses carried out for embankment design, and through discussion with the highway engineers and structural designers, the following construction sequencing has been established for culvert and approach construction:

1. Excavate peat from footprint of embankment widening and backfill to existing grade with granular material.
2. Cut diversion channel through former highway embankment at upstream end of culvert, install diversion pipe within existing CSP under existing highway embankment to beyond downstream limit of construction, and remove existing CSP under former highway embankment.
3. Install sheet pile walls along both sides of diversion pipe and diversion channel, for the full length of the culvert with the exception of shoulder round to shoulder round of existing highway. Provide traffic protection and maintain two-way traffic on existing highway.
4. Excavate to channel grade between the sheet piles and place precast concrete cap panels.
5. Install wick drains and drainage blanket under entire footprint of new WBL embankment, EBL embankment widening and stabilizing berms (Station 13+300 to 13+410), right up to the sheet piles.
6. Install geotechnical instrumentation for monitoring of settlement and pore pressures within the foundation soils.
7. Construct stabilizing berms (2.5 m high by 12.5 m wide), new WBL embankment and EBL embankment widening up to the final pavement grade (approximately fill height of 6.0 to 6.5 m). Maintain preload for six months.
8. After six month waiting period, construct 1 m surcharge. Maintain surcharge for a further six months (or as determined by the instrumentation monitoring program).
9. At end of surcharge period, remove surcharge then subexcavate backfill adjacent to sheet pile walls to place a 2.5 m thickness of EPS adjacent to the culvert. Extend full 2.5 m thickness of EPS in both directions from sheet pile walls a distance of 5.0 m, then reduce EPS thickness at a taper of 5H:1V beyond this point.
10. Construct temporary traffic lanes and shift two-way traffic over east end of new culvert.
11. Install the remainder of sheet pile walls through existing highway embankment, excavate to channel grade between the sheet piles and place precast concrete cap panels.
12. Complete ultimate WBL pavement and temporarily shift two-way traffic over these lanes.
13. Complete ultimate EBL pavement and median ditch, and install median ditch inlet structure.

This construction sequence along with application of wick drains, surcharging and wait times will allow for completion of a significant portion of the primary consolidation in the foundation soils which is estimated to be in the order of 400 to 500 mm. However, placement of EPS backfill is still required to meet MTO's post-construction settlement criteria of 25 mm within 20 m of the culvert. Delaying of surcharge placement (ie., not constructing the full height of embankment plus surcharge at one time) is required to maintain stability of the embankment foundation during all stages of construction.

Embankment fill within the limits of the culvert and EPS must comprise granular material (not rock fill) to enable sub-excavation for culvert and EPS placement after the surcharge period. Sub-excavation of the granular backfill adjacent to the culvert must extend at least 3.5 m below the design pavement elevation for placement of the 2.5 m layer of EPS plus a minimum 1.0 m of granular cover.

Prior to placement of new embankment fill and EPS against the existing embankment, the existing embankment slope should be benched in accordance with OPSD 208.010. To enhance drainage of the bedding and backfill surrounding the EPS, a perforated subdrain should be installed adjacent to the culvert below the base of the EPS.

12 SCOUR PROTECTION AND EROSION CONTROL

Scour and erosion protection should be provided for the culvert channel as well as at 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 with which stream flow is likely to be in contact. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion, in general accordance with OPSS 804.

13 DITCH INLET STRUCTURE

A precast concrete ditch inlet maintenance hole structure (OPSD 702.050) will be installed in the median ditch to transfer ditch flow into the culvert. The base of the structure will be at Elev. 212.5.

Based on the borehole data, the foundation soil at the structure base level will consist of soft to stiff silty clay (possible fill) with peat layers and organic seams. To improve the bearing resistance and provide a more uniform foundation subgrade, it is recommended that a minimum 500 mm thick layer of OPSS Granular A bedding material be placed under the base slab. Any organic material exposed on the base of the excavation should be subexcavated prior to placement of the bedding material.

The geotechnical resistances available for a maintenance hole structure placed on a minimum 500 mm thick granular bedding layer at Elev. 212.5 m are as follows:

- factored geotechnical resistance at ULS of 120 kPa
- geotechnical resistance at SLS of 80 kPa.

The geotechnical resistances recommended above are for vertical, concentric loads only. Effects of load inclination and eccentricity should be taken into account as illustrated in CHBDC Clause 6.7.3 and Clause 6.7.4.

The bedding material must be placed on the approved subgrade as soon as practical to protect the subgrade from softening and disturbance following its inspection and approval. Temporary shoring may be required to facilitate bedding placement and structure installation.

It is recommended that the structure be installed following the preload and surcharge periods to minimize any settlement due to consolidation of the foundation soils. A tight, flexible seal should be provided at the connection to the sheet pile wall to avoid development of a void and loss of soil.

The potential for uplift forces acting on the structure due to buoyancy effects during periods of fluctuating water levels must be considered in the design.

14 EXCAVATION AND GROUNDWATER CONTROL

All excavation must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, embankment fill and native silty clays at this site are classified as Type 3 soils above the water level and Type 4 soils below the water level. Peat and surficial alluvial deposits that are anticipated in the inlet and outlet areas are classified as Type 4 soils.

The excavation and backfilling for foundations must be carried out in accordance with OPSS 902.

Excavation for installation of the proposed sheet pile wall culvert is expected to be limited to removal of the preload embankment fill for installation of EPS backfill, excavation within the existing highway embankment for placement of the cap panels, excavation between the sheet pile walls for channel construction, and installation of the median inlet structure. In general, this excavation will be carried out within embankment fill above the groundwater level.

Any excavation extending below the creek water level should be carried out in the dry. Excavation below the water level without prior dewatering is not recommended since the inflow of water will cause sloughing of the soil below the water table making it difficult to maintain a dry, sound base on which to place the bedding material. It is envisioned that installation in this case will be carried out within a sheet pile cofferdam enclosure. Pumping from sumps within the enclosure will be required to remove water from within the excavation.

Roadway protection will be required during various stages of construction. Roadway protection should be provided in accordance with OPSS 539 and designed for Performance Level 2. The

design of roadway protection is the responsibility of the Contractor and all shoring should be designed by a Professional Engineer experienced in such designs.

Selection of the equipment and methodology to excavate and prepare the founding surface is the responsibility of the Contractor. The design of the shoring and dewatering system that may be required is also the responsibility of the Contractor and the Contract Documents must alert him to this responsibility.

15 CONSTRUCTION CONCERNS

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

- The thickness and depth to the base of the peat and soft streambed deposits may vary at locations away from the boreholes.
- Buried obstructions in the existing embankment fill that may be encountered during excavation or interfere with driving of sheet piles.
- The sheet piles may encounter refusal at varying depths on possible cobbles or boulders in the sand layer overlying bedrock. In addition, the bedrock elevation may vary between and beyond the borehole locations.
- The duration of the preload and surcharge periods may need to be modified as a result of the geotechnical monitoring program, and consequently the construction schedule may be impacted. The construction contract should include flexibility in the construction schedule and an allowance for such delays. Detailed and regular analysis of the results of the monitoring program during construction is considered critical.
- Movement of construction equipment may be difficult in areas of organic or excessively soft, loose and/or saturated subgrade. Disturbance of the subgrade by construction traffic should be minimized.
- 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 structures or fill (i.e., as a pad for crane support). Site conditions may limit the type of equipment suitable for use. The design and safety of any temporary works is the responsibility of the Contractor.

16 CLOSURE

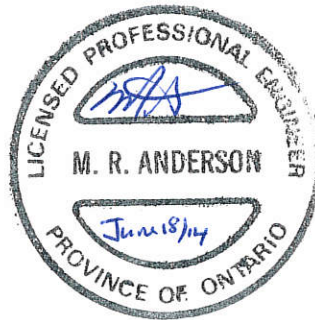
Engineering analysis and preparation of the report were carried out by Mr. Stephen Peters, P.Eng and Mr. Murray Anderson, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng. a Designated Principal Contact for MTO Foundations Projects.

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Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

CLASSIFICATION	PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	Greater than 200mm	same
Cobbles	75 to 200mm	same
Gravel	4.75 to 75mm	5 to 75mm
Sand	0.075 to 4.75mm	Not visible particles to 5mm
Silt	0.002 to 0.075mm	Non-plastic particles, not visible to the naked eye
Clay	Less than 0.002mm	Plastic particles, not visible to the naked eye

2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

TERMINOLOGY	PROPORTION
Trace or Occasional	Less than 10%
Some	10 to 20%
Adjective (e.g. silty or sandy)	20 to 35%
And (e.g. sand and gravel)	35 to 50%

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT ⁽¹⁾ 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

- 1) Laboratory Triaxial Testing
- 2) Field Insitu Vane Testing
- 3) Laboratory Vane Testing
- 4) SPT value
- 5) Pocket Penetrometer


4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

DESCRIPTIVE TERM	SPT "N" VALUE
Very Loose	Less than 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	Greater than 50

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE	SS Split Spoon Sample	WS Wash Sample	AS Auger (Grab) Sample
	TW Thin Wall Shelby Tube Sample	TP Thin Wall Piston Sample	
	PH Sampler Advanced by Hydraulic Pressure	PM Sampler Advanced by Manual Pressure	
	WH Sampler Advanced by Self Static Weight	RC Rock Core	SC Soil Core

$$\text{Sensitivity} = \frac{\text{Undisturbed Shear Strength}}{\text{Remoulded Shear Strength}}$$

 Water Level

C_{pen} Shear Strength Determination by Pocket Penetrometer

- (1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.
- (2) DCPT Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

UNIFIED SOILS CLASSIFICATION

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	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	SILTS AND CLAYS $W_L < 50\%$	ML	Inorganic silts and 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. ($W_L < 30\%$).
		CI	Inorganic clays of medium plasticity, silty clays. ($30\% < W_L < 50\%$).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

EXPLANATION OF ROCK LOGGING TERMS


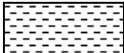



ROCK WEATHERING CLASSIFICATION

Fresh (FR)	No visible signs of weathering.
Fresh Jointed (FJ)	Weathering limited to the surface of major discontinuities.
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.
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 structure are preserved.

DISCONTINUITY SPACING

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

SYMBOLS

	CLAYSTONE
	SILTSTONE
	SANDSTONE
	COAL
	BEDROCK

STRENGTH CLASSIFICATION

Rock Strength	Approximate Uniaxial Compressive Strength (MPa)	Approximate Uniaxial Compressive Strength (psi)	Field Estimation of Hardness*
Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail

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 0.1m in length or larger as a % of total core run length.
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen
Fracture Index:(FI)	Frequency of natural fractures per 0.3m of core run.

RECORD OF BOREHOLE No SB-01

1 OF 2

METRIC

WP# 607189-0237 LOCATION N 5 424 383.5 E 205 713.3 ORIGINATED BY ES
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2013.05.07 - 2013.05.07 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				W P W W L				GR	SA	SI	CL
								20 40 60 80 100				WATER CONTENT (%)							
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE											
215.7																			
0.0	ORGANICS: (50mm) SAND , some gravel, occasional cobble Loose Brown Moist (FILL) Sandy silt layer (410mm) at 0.9m																		
			1	SS	6		215												
213.9			2	SS	6		214												
1.8	Silty CLAY , some sand to sandy, occasional organic seams (25mm to 75mm) Firm to Very Soft Brown (Possible FILL)																		
			3	SS	3		213												
			4	SS	0		212												
	Organics seam (200mm thick) at 4.5m		5	SS	2		211												
							210												
209.3	Wood fibres, trace roots and trace rootlets		6	SS	1		209												
6.4	Silty CLAY , trace sand Very Soft Grey																		
			7	SS	0		208												
							207												
			8	SS	1		206												

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

METRIC

SOIL PROFILE					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES	GROUND WATER CONDITIONS	DYNAMIC CONE PENETRATION RESISTANCE PLOT
			NUMBER	TYPE	"N" VALUES
<div>Continued From Previous Page</div>					
201.5 14.2	Silty CLAY , trace sand Very Soft Grey		9	SS	0
			10	SS	0
			11	SS	0
	Auger grinding				
		Gravelly SAND Very Dense Grey Wet		12	SS
199.5 16.2			13	SS	100/ 0.150
198.3 17.4	END OF BOREHOLE AT 17.4m UPON AUGER REFUSAL ON PROBABLE BEDROCK. WATER LEVEL AT 4.8m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 2.4m, THEN CUTTINGS TO SURFACE.				

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No SB-03

1 OF 2

METRIC

WP# 60718910237 LOCATION N 5 424 344.9 E 205 733.6 ORIGINATED BY ES
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2013.05.09 - 2013.05.09 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								20 40 60 80 100				W P W W L				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE								
212.8																
0.0	Organic CLAY , with peat, some sand, trace rootlets Dark Brown Wet															
212.0																
0.8	Silty CLAY , trace sand, trace roots and rootlets Very Soft to Soft Brown		1	SS	1		212									
			2	SS	2		211								0 0 36 64	
			3	SS	1		210									
	Grey															
			4	SS	0											
							209									
								5.0 +								
			5	SS	0		208									
							207									
			6	SS	0		206									
								5.0 +								
	Occasional sand seams		7	SS	0		205									
							204									
			8	SS	0			6.0 +							0 0 25 75	
							203									

Continued Next Page

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

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No SB-04

1 OF 2

METRIC

WP# 6071891037 LOCATION N 5 424 381.6 E 205 694.8 ORIGINATED BY ES
 HWY 11/17 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2014.05.07 - 2014.05.07 CHECKED BY MEF

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	SHEAR STRENGTH kPa				
								○ UNCONFINED + FIELD VANE						
								● QUICK TRIAXIAL × LAB VANE						
214.8														
0.0	SAND , some gravel Loose to Compact Reddish Brown Moist (FILL)		1	SS	9		214							
213.6			2	SS	15									0 11 61 28
1.2	Silty CLAY , some sand, occasional cobbles Stiff Brown to Grey (FILL)		3	SS	12		213							
			4	SS	10		212							
	Occasional wood fibres		5	SS	8		211							
210.2			6	SS	4		210							
4.6	ORGANIC CLAY , some sand, with roots, rootlets and wood fibres Firm Dark Brown						209							
208.7			7	SS	4		208							0 34 43 23
6.1	Sandy Clayey SILT , with wood fibres Soft to Firm Dark Grey Wet						207							
207.8			8	SS	0		206							
7.0	Silty CLAY , occasional silt seams Very Soft Grey		9	SS	0		205							0 0 34 66

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

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15
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(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No SB-04

2 OF 2

METRIC

WP# 607189-10237 LOCATION N 5 424 381.6 E 205 694.8 ORIGINATED BY ES
 HWY 11/17 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2014.05.07 - 2014.05.07 CHECKED BY MEF

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 (%)							
	Continued From Previous Page						20	40	60	80	100	W P	W	W L	
202.1			10	SS	0										
12.7	SAND and SILT , trace gravel Compact Grey Moist														
200.8	cobbles		11	SS	1										
14.0	BEDROCK , gneiss, grey, with quartz veins Sub-horizontal fracture at 14.5m Sub-vertical fractures at 14.8m, 15.1m and 15.6m		1	RUN											
			2	RUN											
			3	RUN											
197.6															
17.2	END OF BOREHOLE AT 17.2m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.														

ONTMT4S 1237.GPJ 2012TEMPLATE(MTO).GDT 5/23/14

RECORD OF BOREHOLE No 13+318 01L

1 OF 2

METRIC

WP# 607189-0237 LOCATION N 5 424 359.6 E 205 690.8 ORIGINATED BY SLL
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MFA
 DATUM Geodetic DATE 2014.03.25 - 2014.03.25 CHECKED BY MEF

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		
219.1								20	40	60	80	100															
0.0	SAND , some gravel Brown to Reddish Brown Frozen (FILL)		1	GS			219																				
218.4			2	GS																							
0.7	Silty SAND , trace gravel, trace clay Very Dense Brown Frozen to 2.0m (FILL)		1	SS	89		218													0 72 26 2							
	Dense Moist		2	SS	30																						
	Becoming Loose to Very Loose		3	SS	5		217																				
			4	SS	1		216																				
							215																				
	Becoming Compact Grey Wet		5	SS	11		214																				
5.1	Silty CLAY Firm to Stiff Dark Brown (FILL)						213																				
	Trace wood fragments Brown		6	SS	11		212																				
							211																				
211.6							210																				
7.5	ORGANIC CLAY , with fibrous peat Very Stiff Dark Brown Wet		7	SS	16																						
210.8																											
8.3	Silty CLAY , with wood fragments Stiff Grey																										
			8	SS	6																						

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15 10 5 0
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 13+318 01L

2 OF 2

METRIC

WP# 607189-0237 LOCATION N 5 424 359.6 E 205 690.8 ORIGINATED BY SLL
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MFA
 DATUM Geodetic DATE 2014.03.25 - 2014.03.25 CHECKED BY MEF

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	WATER CONTENT (%)		
	Continued From Previous Page						209	1.5						
			9	SS	2		208							
	With thin silty sand seams						207							
			10	SS	3		206	1.6						
205.8 13.3	END OF BOREHOLE AT 13.3m. BOREHOLE OPEN TO 11.4m AND WATER LEVEL AT 7.7m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 1.5m, THEN CUTTINGS TO SURFACE.													

+³, ×³: Numbers refer to
Sensitivity




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15
10
5
0
5
10
15
20
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 13+321 17.4L

1 OF 2

METRIC

WP# 607189-0237 LOCATION N 5 424 375.5 E 205 685.5 ORIGINATED BY SLL
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY SBP
 DATUM Geodetic DATE 2013.02.11 - 2013.02.11 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)							
								○ UNCONFINED + FIELD VANE				w _p w w _L							
								● QUICK TRIAXIAL × LAB VANE											
215.5							20	40	60	80	100								
0.0	ORGANICS: (175mm)																		
0.2	Silty CLAY , trace organics Brown Frozen (FILL)																		
			1	SS	21														
213.8																			
1.7	SAND , some silt to silty, trace clay Loose to Compact Brown Moist (FILL)		2	SS	5														
			3	SS	2														
			4	SS	26														
211.9																			
211.8	ORGANICS																		
3.7	Silty CLAY , trace roots, trace rootlets Firm to Soft Brown to Grey																		
			5	SS	3														
	Grey		6	SS	0														
	Soft																		
													</						

Continued Next Page



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

RECORD OF BOREHOLE No 13+321 17.4L

2 OF 2

METRIC

WP# 60718910237 LOCATION N 5 424 375.5 E 205 685.5 ORIGINATED BY SLL
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY SBP
 DATUM Geodetic DATE 2013.02.11 - 2013.02.11 CHECKED BY MEF

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						
Continued From Previous Page							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W P W W L WATER CONTENT (%)			
203.0	Silty CLAY Firm Grey						205	3.1						
			9	SS	2									
								204						
								2.8						
12.5	SAND , some silt to silty, trace clay Loose Grey Wet		10	SS	6		203							
								202						
201.4			11	SS	100/ .075									
14.1	END OF BOREHOLE AT 14.1m UPON REFUSAL ON PROBABLE BEDROCK OR BOULDER. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 1.5m, THEN CUTTINGS TO SURFACE.													

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

METRIC[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 13+324 27L

2 OF 2

METRIC

WP# 607189-10237 LOCATION N 5 424 385.3 E 205 683.4 ORIGINATED BY SLL
 HWY 11/17 BOREHOLE TYPE Dynamic Cone Penetration Test COMPILED BY AN
 DATUM Geodetic DATE 2013.02.09 - 2013.02.09 CHECKED BY MEF

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								
	Continued From Previous Page							SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					
							205						
							204						
							203						
							202						
							201						
200.2													
15.2	END OF DCPT AT 15.2m UPON REFUSAL ON PROBABLE BEDROCK. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.												

ONTMT4S 1237.GPJ 2012TEMPLATE(MTO).GDT 5/23/14

RECORD OF BOREHOLE No 13+340 19R

1 OF 2

METRIC

WP# 607189-1037 LOCATION N 5 424 353.2 E 205 720.2 ORIGINATED BY GA
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2013.02.20 - 2013.02.20 CHECKED BY MEF

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 (%)			
214.2								20 40 60 80 100	○ UNCONFINED + FIELD VANE	W _P W W _L			
0.0	ORGANICS: (150mm)							20 40 60 80 100	● QUICK TRIAXIAL × LAB VANE				GR SA SI CL
0.2	Silty CLAY , trace rootlets, trace organics Firm Brown						214						
	occasional rootlets		1	SS	4		213					91	
			2	SS	3		212						0 1 31 68
	trace sand seams		3	SS	0		211						
	Grey		4	SS	0		210	3.5 +					
			5	SS	0		209	3.6 +					
			6	SS	1		208	3.1 +					
			7	SS	2		207						0 1 50 49
			8	SS	2		206	2.7 +					
	trace gravel						205						

Continued Next Page

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

RECORD OF BOREHOLE No 13+340 19R

2 OF 2

METRIC

WP# 6071891037 LOCATION N 5 424 353.2 E 205 720.2 ORIGINATED BY GA
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2013.02.20 - 2013.02.20 CHECKED BY MEF

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							
	Continued From Previous Page							20 40 60 80 100							
								○ UNCONFINED + FIELD VANE							
								● QUICK TRIAXIAL × LAB VANE							
								20 40 60 80 100							
									20 40 60						

RECORD OF BOREHOLE No 13+342 07R

1 OF 2

METRIC

WP# 60718910237 LOCATION N 5 424 364.6 E 205 716.1 ORIGINATED BY SLL
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MFA
 DATUM Geodetic DATE 2014.03.25 - 2014.03.25 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)						
								○ UNCONFINED + FIELD VANE				w P w w L						
								● QUICK TRIAXIAL × LAB VANE										
218.7							20	40	60	80	100							
0.0	SAND , some gravel Brown Frozen (FILL) SAND , trace gravel Very Dense Brown Frozen to 2.0m (FILL) Some silt With clayey silt pockets Becoming Loose to Very Loose Moist Becoming Very Dense		1	GS									○					
218.3														○				
0.4																		
			1	SS	50/ .050		218								○			
			2	SS	100/ 275		217								○			
			3	SS	6		216								○			
			4	SS	0		215											
			5	SS	52		214								○			
213.0																		
5.7	Silty CLAY Firm Mottled Brown/Grey (FILL)																	
212.4																		
6.3	SAND , some silt Compact Grey Wet (FILL)		6	SS	10									○				
211.6																		
7.1	Silty CLAY , trace roots and rootlets Firm Brown (Possible FILL) With organics, trace wood fragments Dark Brown																	
208.9																		
9.8	Silty CLAY																	

Continued Next Page

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

METRIC

[illegible]

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 13+350 19L

2 OF 2

METRIC

WP# 607189-10237 LOCATION N 5 424 391.1 E 205 710.3 ORIGINATED BY SLL
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY SBP
 DATUM Geodetic DATE 2013.02.09 - 2013.02.09 CHECKED BY MEF

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						205	2.7 +												
			9	SS	1		204						○							
								2.9 +												
			10	SS	0		203						○							
							202	2.5 +												
201.5	Silty CLAY Soft Grey																			
13.6	SAND and SILT , trace gravel Very Loose Grey Wet		11	SS	1		201						○							
200.8																				
14.3	END OF BOREHOLE AT 14.3m. BOREHOLE OPEN TO 12.6m AND WATER LEVEL AT 5.2m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 2.3m, THEN CUTTINGS TO SURFACE.																			


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

RECORD OF BOREHOLE No 13+375 30R

1 OF 2

METRIC

WP# 60718910237 LOCATION N 5 424 361.2 E 205 756.5 ORIGINATED BY GA
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2013.02.23 - 2013.02.23 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				GR	SA	SI	CL
								20 40 60 80 100				W _P W W _L							
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE											
212.1	ORGANIC CLAY, with peat, trace sand, trace rootlets Dark Brown Soft Moist																		
0.0																			
	trace grey sand seams																		

Continued Next Page

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

RECORD OF BOREHOLE No 13+375 30R

2 OF 2

METRIC

WP# 60718910237 LOCATION N 5 424 361.2 E 205 756.5 ORIGINATED BY GA
 HWY 11/17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2013.02.23 - 2013.02.23 CHECKED BY MEF

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						PLASTIC LIMIT W _P NATURAL MOISTURE CONTENT W LIQUID LIMIT W _L WATER CONTENT (%)
	Continued From Previous Page							20 40 60 80 100						
198.4 13.7	Silty CLAY Firm Grey						202							0 1 67 32
	9		SS	0		201								
						3.5 +								
	10		SS	5		200					11 ○			
							199							
	END OF BOREHOLE AT 13.7m. BOREHOLE OPEN TO 13.7m AND WATER LEVEL AT 3.9m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.													

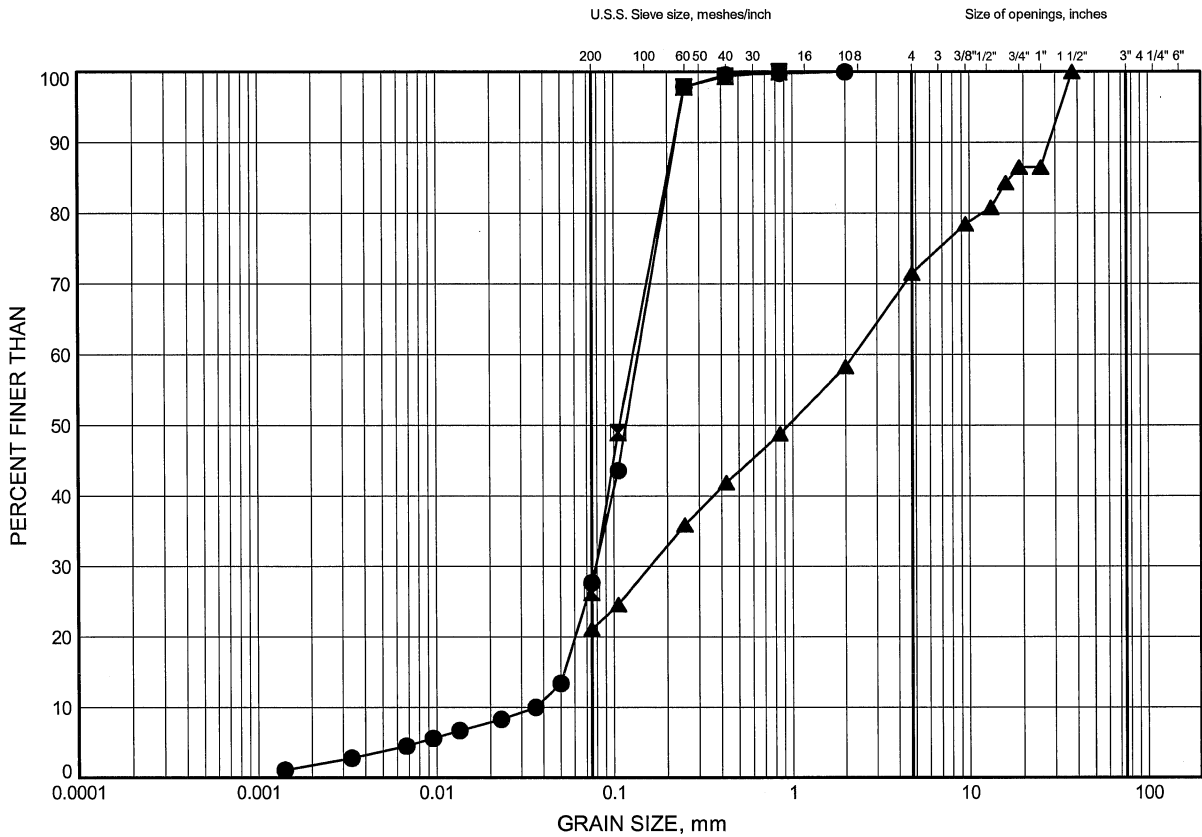
Appendix B

Laboratory Test Results

Itzcaulde Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B1

SILTY SAND to GRAVELLY SAND FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	13+318 01L	1.07	218.03
⊠	13+321 17.4L	2.59	212.87
▲	13+350 19L	0.46	214.67

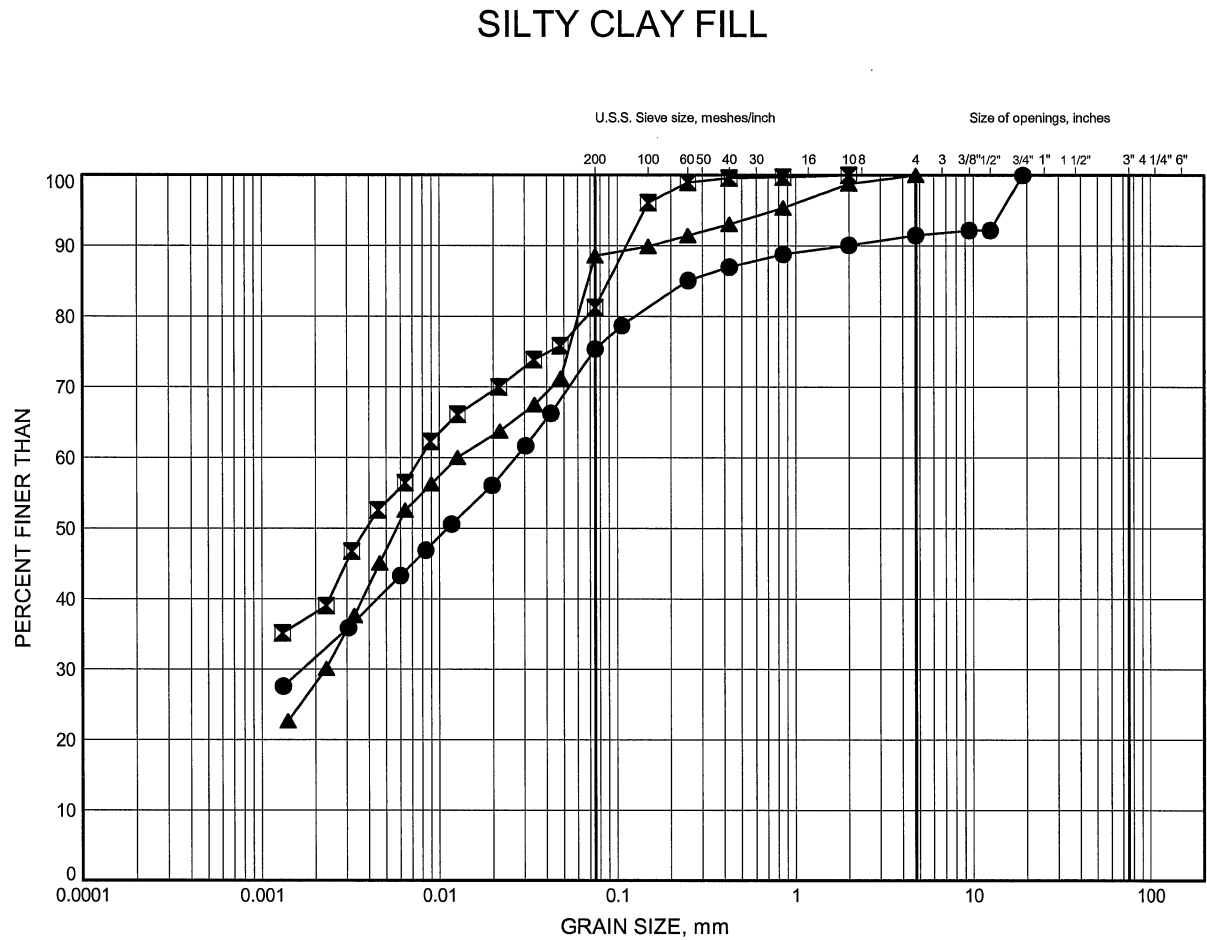
Date April 2014
WP# 647-89-00



Prep'd AN
Chkd. MRA

Itzcaulde Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B2



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	13+350 19L	3.35	211.78
⊠	SB-01	2.59	213.11
▲	SB-04	1.07	213.73

Date May 2014
WP# 647-89-00

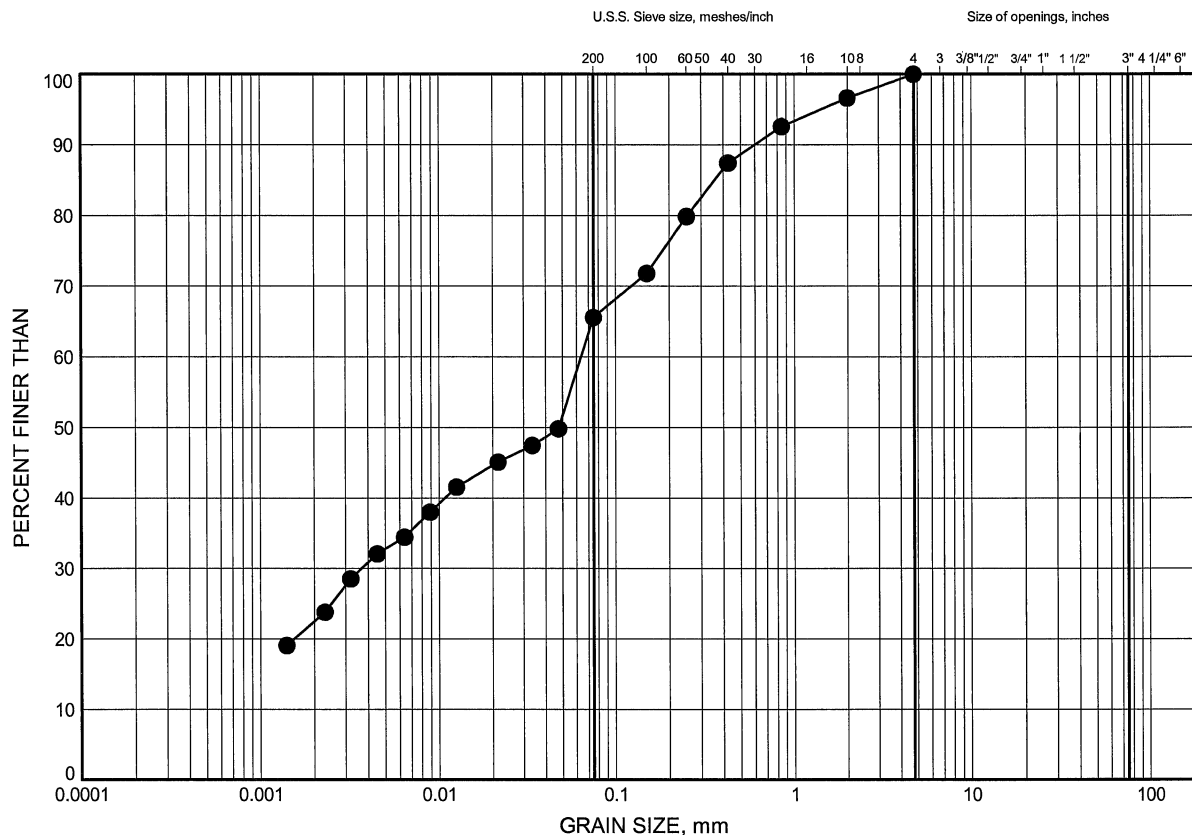


Prep'd AN
Chkd. MRA

Itzcaulde Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B3

SANDY CLAYEY SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SB-04	6.40	208.40

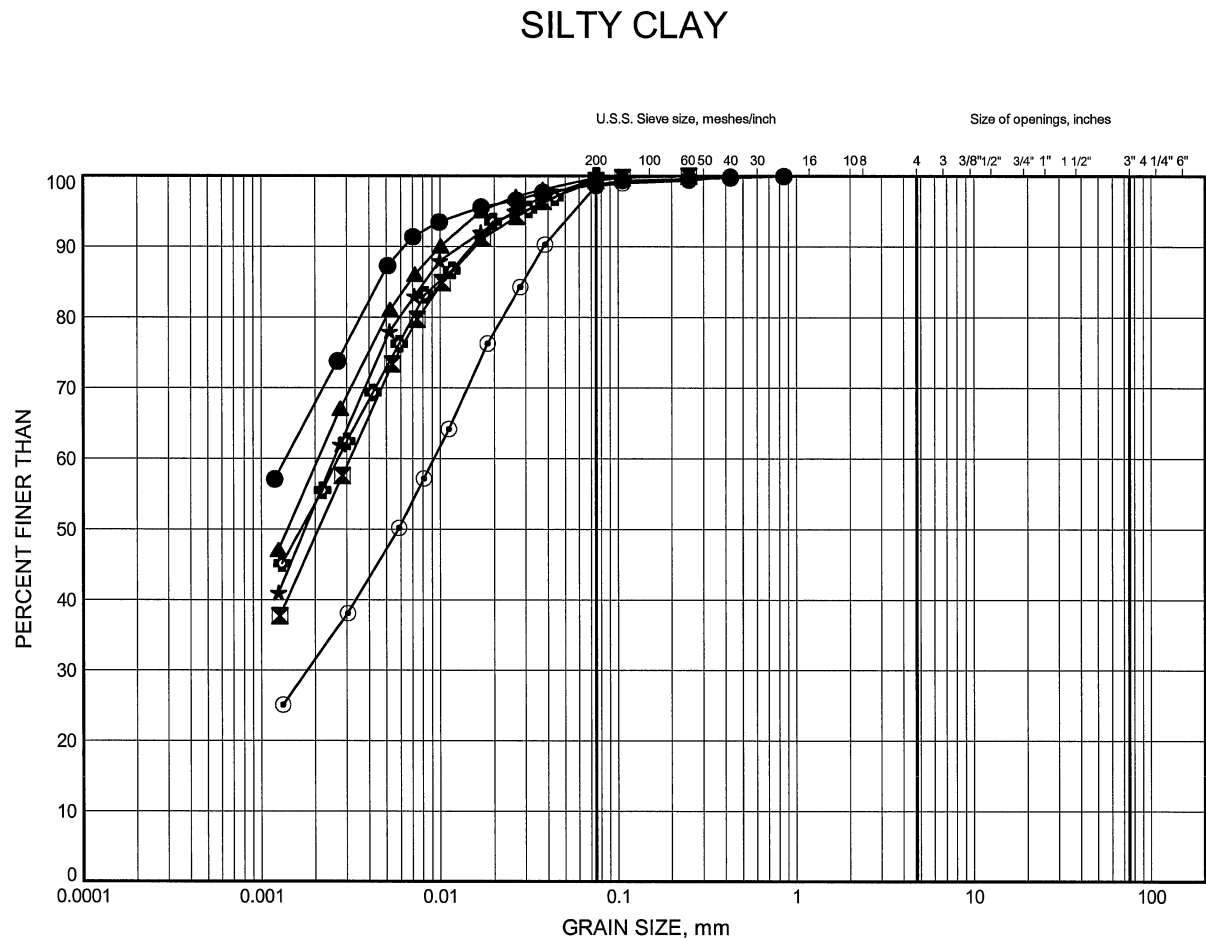
Date May 2014
WP# 647-89-00



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Chkd. MRA

Itzcaulde Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B4



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	13+340 19R	1.83	212.38
⊠	13+340 19R	7.92	206.29
▲	13+350 19L	9.45	205.68
★	13+375 30R	6.40	205.74
⊙	13+375 30R	12.50	199.64
⊕	SB-01	7.92	207.78

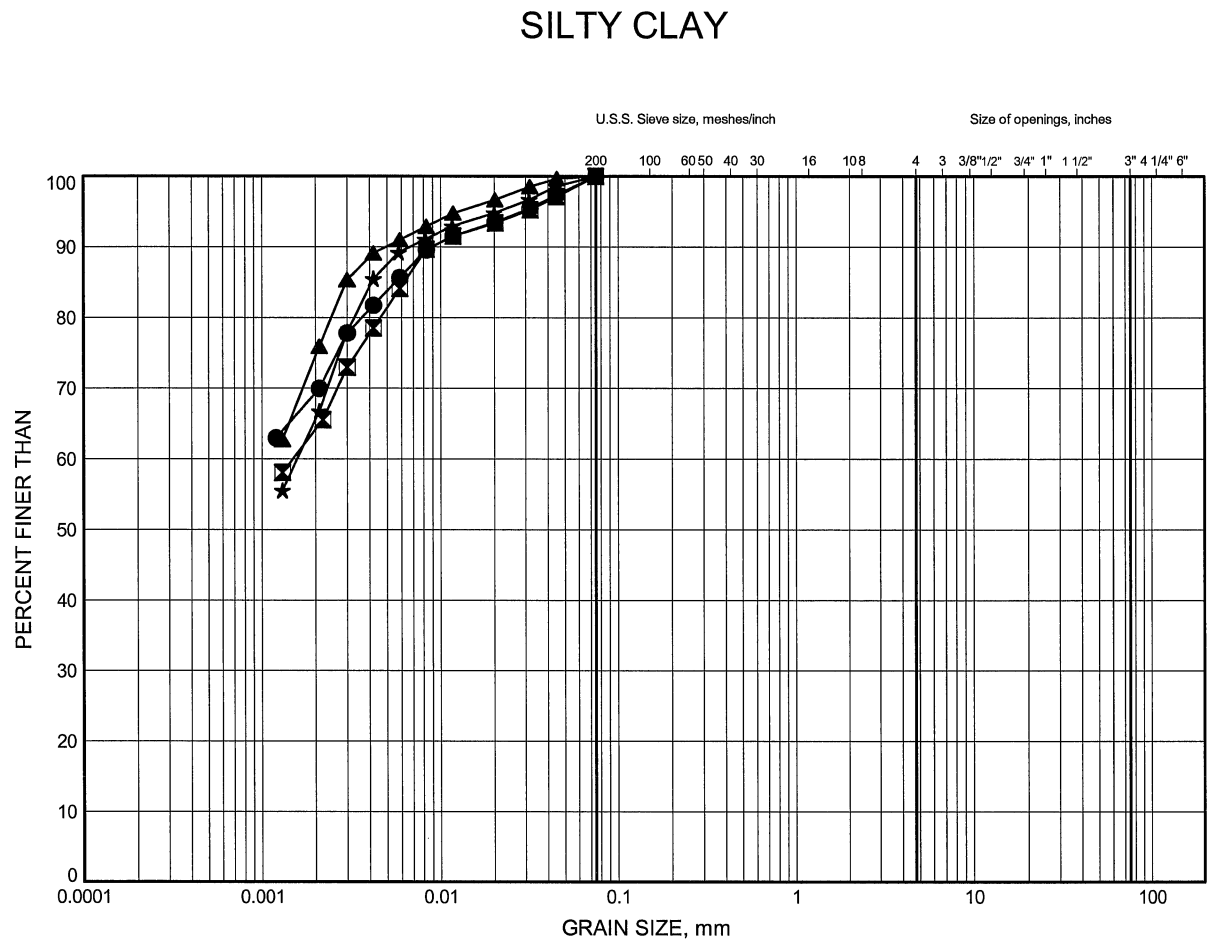
Date May 2014
WP# 647-89-00



Prep'd AN
Chkd. MRA

Itzcaulde Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B5



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SB-01	12.50	203.20
⊠	SB-03	1.83	210.97
▲	SB-03	9.45	203.35
★	SB-04	9.45	205.35

Date May 2014
WP# 647-89-00

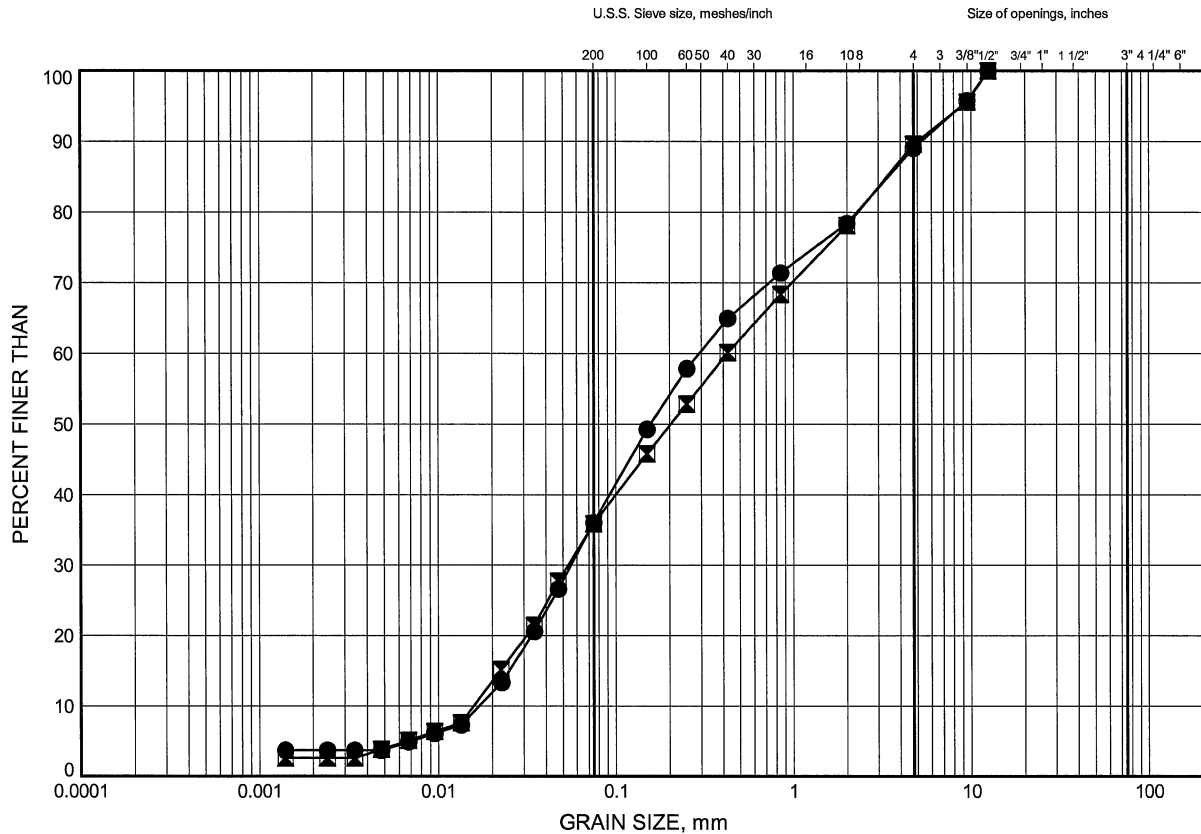


Prep'd AN
Chkd. MRA

Itzcaulde Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B6

SILTY SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SB-01	15.54	200.16
■	SB-03	14.02	198.78

Date May 2014
WP# 647-89-00

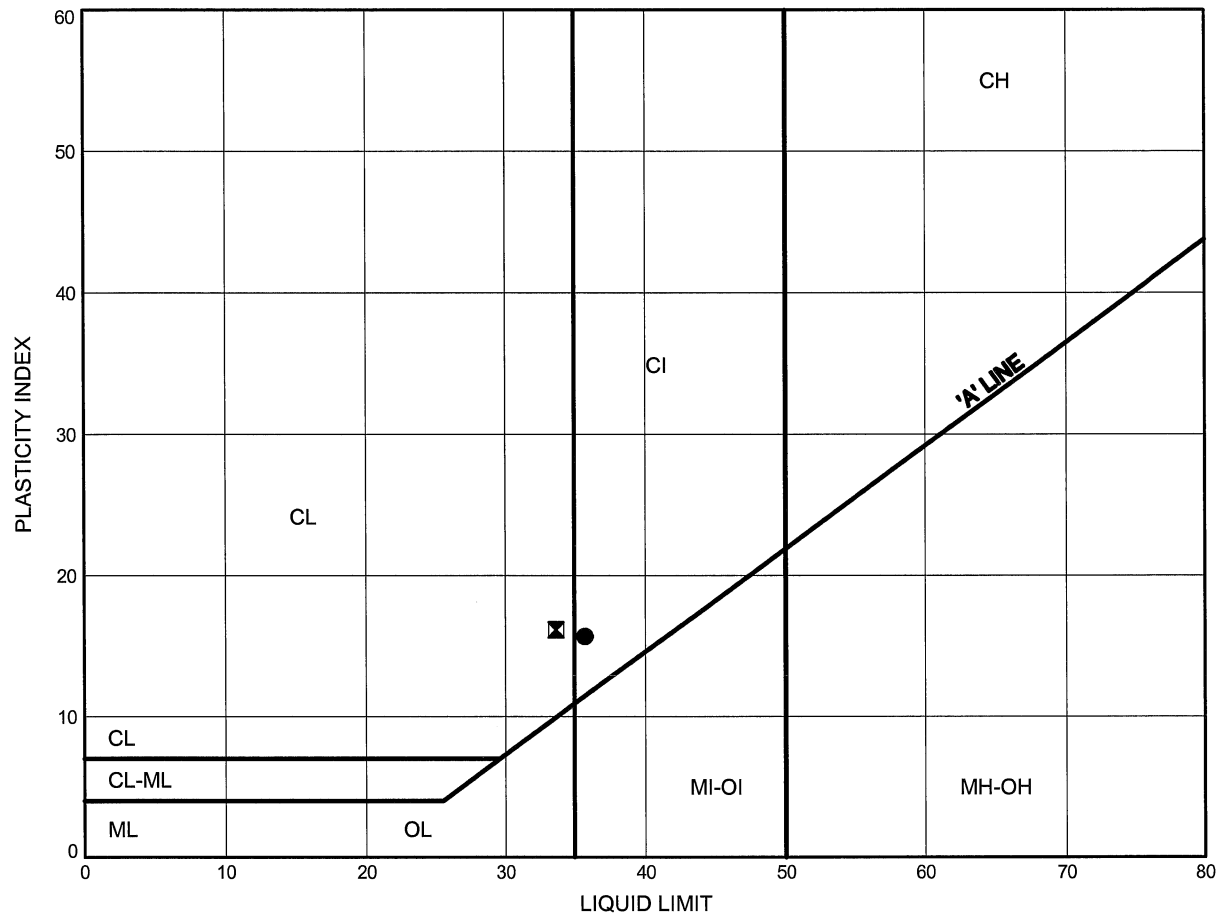


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Chkd. MRA

Itzcaulde Creek Culvert
ATTERBERG LIMITS TEST RESULTS

FIGURE B7

SILTY CLAY FILL



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	13+350 19L	3.35	211.78
⊠	SB-01	2.59	213.11

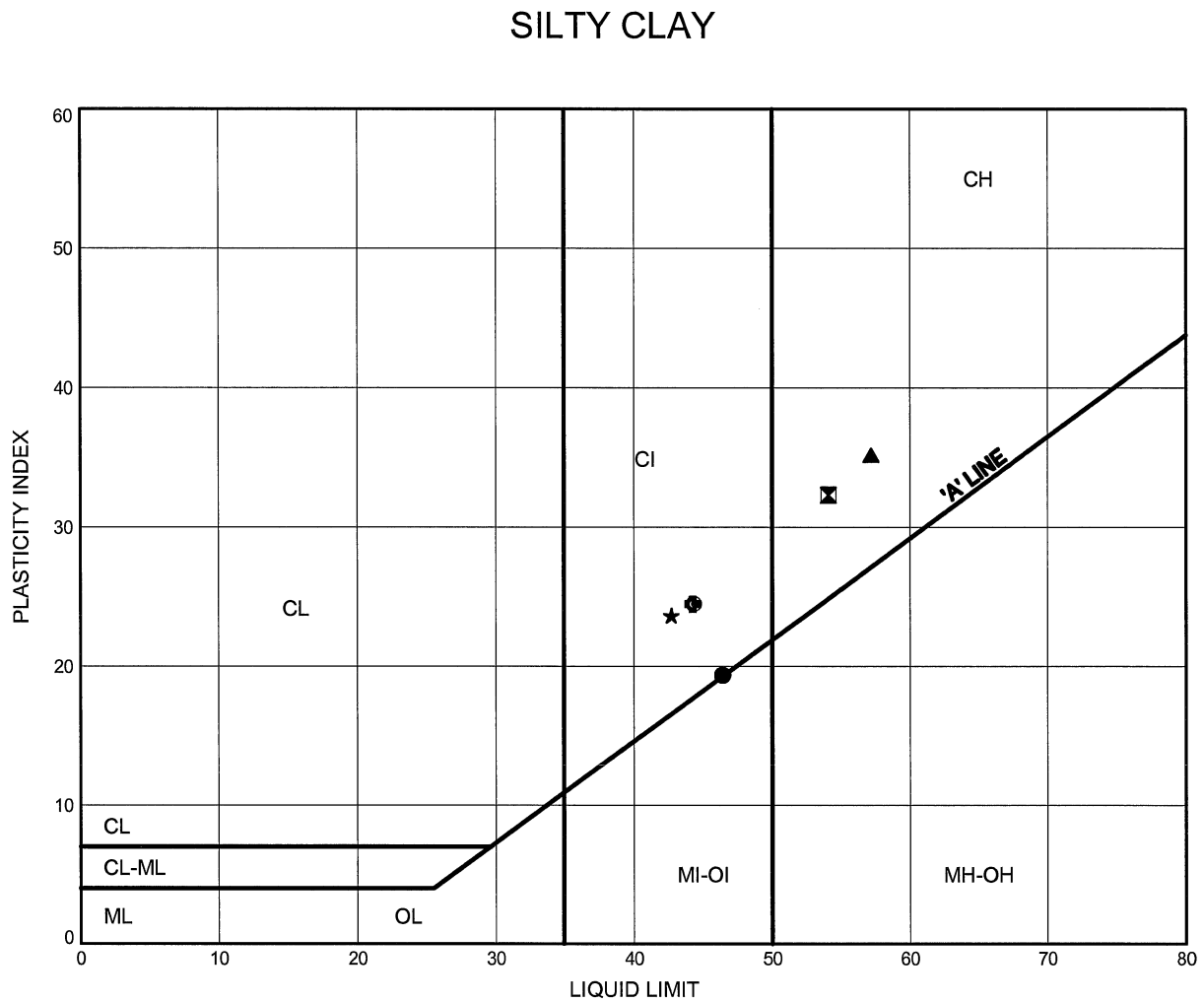
Date May 2014
 WP# 647-89-00



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Itzcaulde Creek Culvert
ATTERBERG LIMITS TEST RESULTS

FIGURE B8



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	13+321 17.4L	4.88	210.59
⊠	13+321 17.4L	10.97	204.49
▲	13+340 19R	1.83	212.38
★	13+340 19R	7.92	206.29
⊙	13+350 19L	9.45	205.68
⊕	13+375 30R	6.40	205.74

Date May 2014
 WP# 647-89-00

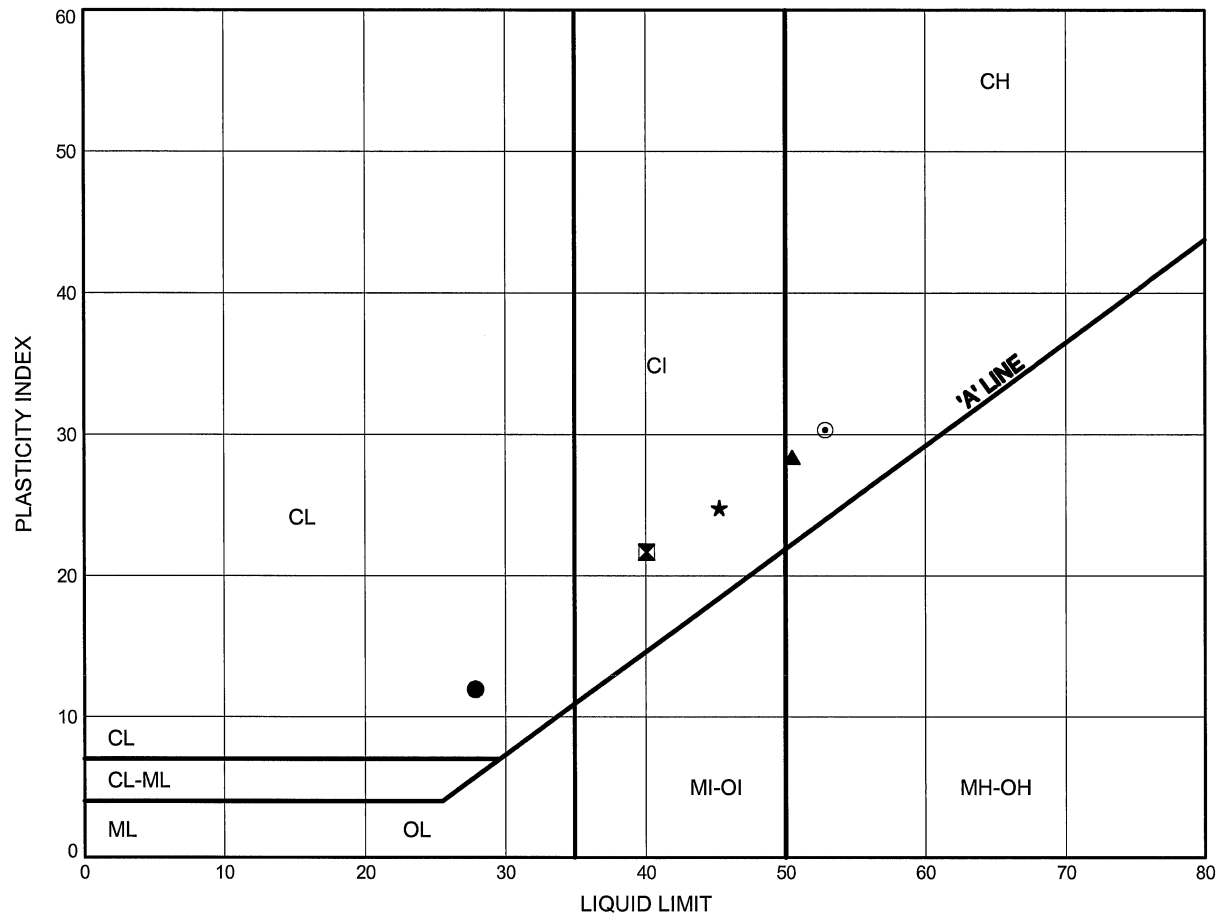


Prep'd AN
 Chkd. MRA

Itzcaulde Creek Culvert
ATTERBERG LIMITS TEST RESULTS

FIGURE B9

SILTY CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	13+375 30R	12.50	199.64
⊠	SB-01	7.92	207.78
▲	SB-01	12.50	203.20
★	SB-03	1.83	210.97
⊙	SB-03	9.45	203.35

Date May 2014
 WP# 647-89-00



Prep'd AN
 Chkd. MRA

Appendix C

Site Photographs



Photograph 1: North side of existing embankment looking west.



Photograph 2: Former highway alignment looking east.



Photograph 3: South side of existing embankment looking east.



Photograph 4: South side of existing embankment looking west.



Photograph 5: Existing Itzcaulde Creek culvert outlet.



Photograph 6: Embankment above existing Itzcaulde Creek culvert outlet.



Photograph 7: Existing Itzcaulde Creek culvert outlet.



Photograph 8: Existing Itzcaulde Creek culvert Inlet.

Appendix D

Foundation Comparison

COMPARISON OF CULVERT TYPE / FOUNDATION ALTERNATIVES

Concrete Box Culvert	Arch Culvert on Footings	Arch Culvert on Piles	Sheet Pile Culvert
<p><i>Advantages:</i></p> <ul style="list-style-type: none"> i. Typically least costly culvert type. ii. Conventional culvert design. iii. Ease of installation. iv. Differential settlement between culvert and approach fill is minimized. 	<p><i>Advantages:</i></p> <ul style="list-style-type: none"> i. Relatively straightforward construction. ii. Less costly than pile or sheet pile options. 	<p><i>Advantages:</i></p> <ul style="list-style-type: none"> i. High geotechnical resistance is available for piles driven to bedrock. ii. Settlement of culvert is not an issue. iii. Installation of piles could continue in freezing weather. iv. Reduced excavation below water level. 	<p><i>Advantages:</i></p> <ul style="list-style-type: none"> i. Ease of construction. ii. Potentially minimizes volume of excavation and roadway protection requirements. iii. Maintains water flow throughout construction. iv. Minimizes potential for disturbance of streambed. v. Installation of piles could continue in freezing weather
<p><i>Disadvantages:</i></p> <ul style="list-style-type: none"> i. Excavation to place bedding material will extend below water level. ii. Complex staging including preloading, surcharging, wick drains and EPS backfill will be required to address potential differential settlement along culvert profile. iii. Maintenance of water flow may be an issue and require a sacrificial culvert. iv. Potential impact on fisheries. v. Cambering required. 	<p><i>Disadvantages:</i></p> <ul style="list-style-type: none"> i. Inadequate geotechnical resistance available in native soils. ii. Excavation for construction of engineered fill to improve the bearing resistance would extend below water levels. iii. Potential for settlement in underlying silty clay under embankment loads. iv. Differential settlement cannot be accommodated. 	<p><i>Disadvantages:</i></p> <ul style="list-style-type: none"> i. Higher cost than spread footings. ii. Differential settlement will occur between non-yielding culvert and approach fill. iii. Use of EPS backfill to reduce differential settlement may affect structural functioning of culvert. 	<p><i>Disadvantages:</i></p> <ul style="list-style-type: none"> i. Large quantity and high cost of sheet piles. ii. Unconventional design. iii. Differential settlement will occur between non-yielding culvert and approach fill. iv. Preloading, surcharging, wick drains and EPS backfill will be required to address potential differential settlement.
FEASIBLE	NOT RECOMMENDED	NOT RECOMMENDED	RECOMMENDED

Appendix E

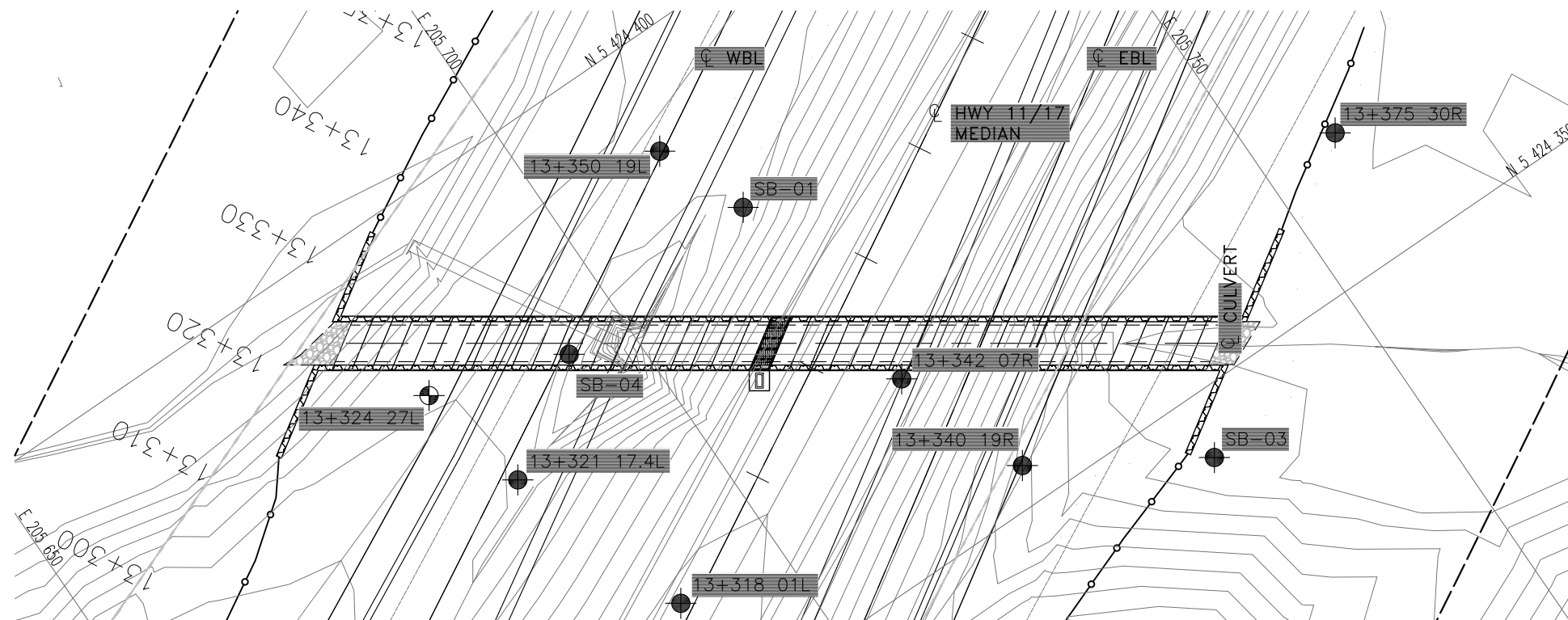
List of SPs and OPSS, and Suggested Text for Selected NSSP

1. List of Special Provisions and OPSS Documents Referenced in this Report:

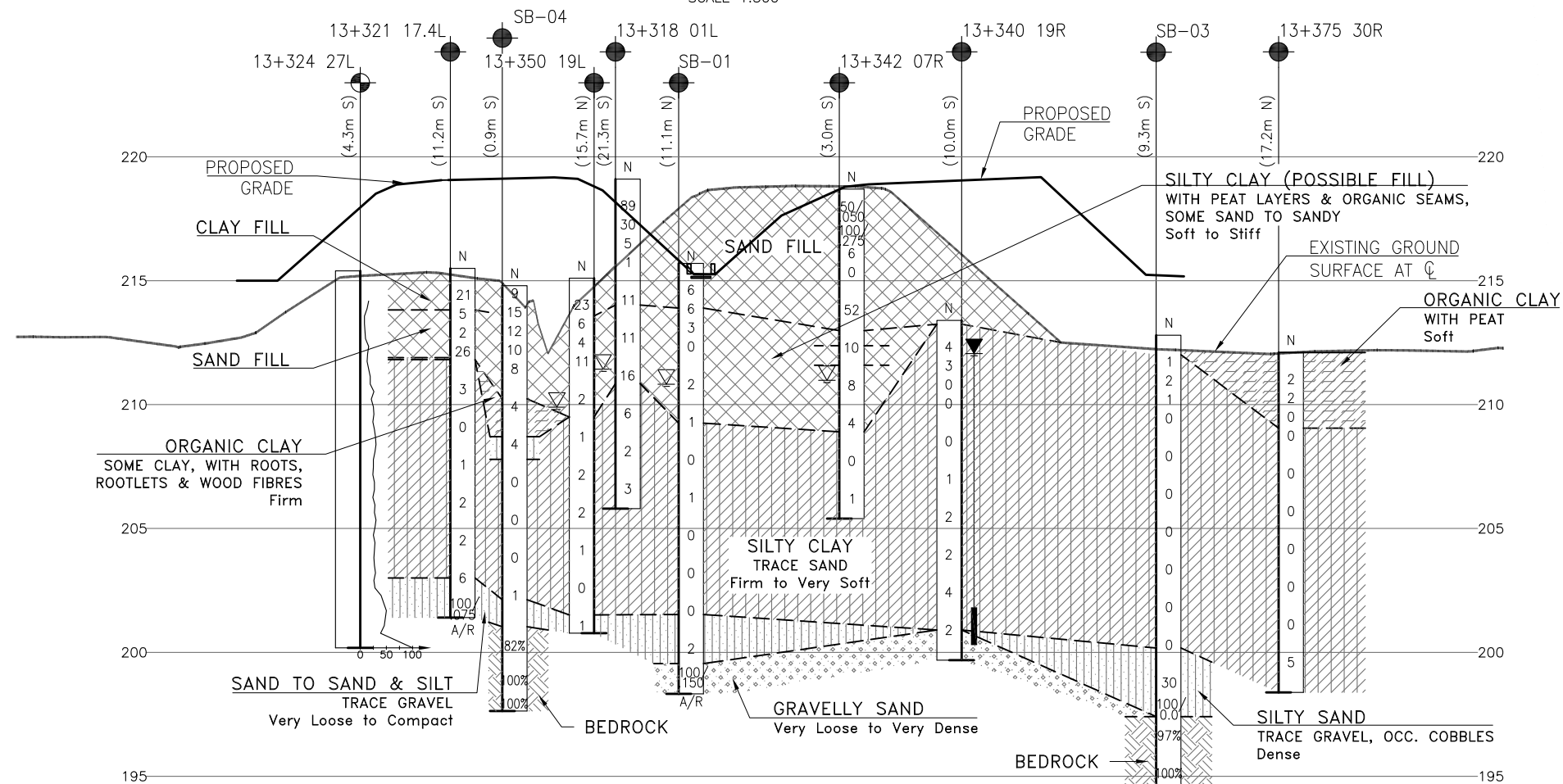
- OPSS 501
- OPSS 539
- OPSS 804
- OPSS 902
- OPSS 903
- SP 105S21
- OPSD 208.010
- OPSD 702.050
- OPSD 803.010

Appendix F

Borehole Locations and Soil Strata Drawing



PLAN
SCALE 1:500



PROFILE ALONG ϕ CULVERT

SCALE 1:250
H 1:500
V 1:250

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



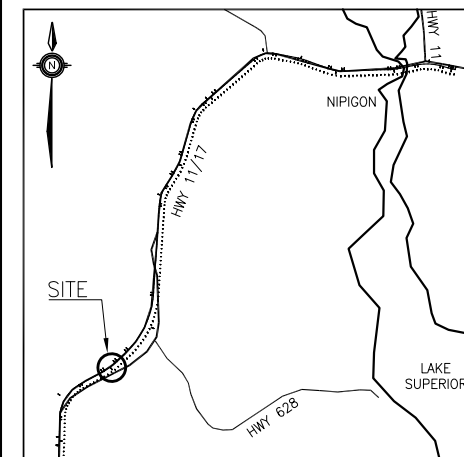
CONT No
WP No 6647-13-01

HIGHWAY 11/17 FOUR LANING
ITZCAULDE CREEK CULVERT
EBL & WBL
BOREHOLE LOCATIONS AND SOIL STRATA

**Hatch Mott
MacDonald**



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

	Borehole (Current Investigation)
	DCPT (Dynamic Cone Penetration Test)
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60' Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level During Drilling
	Water Level In Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
SB-01	215.7	5 424 383.5	205 713.3
SB-03	212.8	5 424 344.9	205 733.6
SB-04	214.8	5 424 381.6	205 694.8
13+318 01L	219.1	5 424 359.6	205 690.8
13+321 17.4L	215.5	5 424 375.5	205 685.5
13+324 27L	215.5	5 424 385.3	205 683.4
13+340 19R	214.2	5 424 353.2	205 720.2
13+342 07R	218.7	5 424 364.6	205 716.1
13+350 19L	215.1	5 424 391.1	205 710.3
13+375 30R	212.1	5 424 361.2	205 756.5

-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.

GEOCREs No. 52A-179

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	MEF	CHK MEF	CODE
DRAWN	AN	CHK MRA	SITE 48C-352 STRUCT
DATE	JUN 2014	DATE	JUN 2014
DWG	1	DWG	1