

**FOUNDATION INVESTIGATION AND DESIGN REPORT
BIG TROUT CREEK CULVERT
HIGHWAY 628
TOWNSHIP OF RED ROCK, ONTARIO**

G.W.P. 497-93-00, SITE No. 48C-192/C

Geocres Number: 52A-181

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 replacement culvert carrying Highway 628 over Big Trout Creek, located in the Township of Red Rock, Ontario.

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

Thurber carried out the investigation as a sub-consultant to MMM Group Limited (MMM), under the Ministry of Transportation Ontario (MTO) Agreement Number 6010-E-0011.

2 SITE DESCRIPTION

The existing Big Trout Creek culvert is located in the Township of Red Rock, Ontario, about 2.5 km southeast of the intersection of Highway 628 and Highway 11/17. At the crossing of Highway 628, Big Trout Creek flows in a general north to south direction. The culvert under the existing highway embankment consists of a 27.8 m long corrugated steel arch culvert with an approximate 3.0 x 5.0 m opening. The interior of the arch was noted to be strutted with timber supports.

Existing road grade on Highway 628 is at approximate Elev. 196.4 and the culvert invert is at approximate Elev. 192.0. The embankment height adjacent to the culvert is about 2.5 m. Preliminary drawings provided by MMM indicate a water level at Elev. 192.9 m in February 2011.

The surrounding lands are mainly treed with grass and shrubs in close proximity to the highway. Residential properties are located on the south side of Highway 628, to the west and east of the

culvert. Photographs in Appendix C show the existing Big Trout 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, characterized by early Precambrian metasedimentary bedrock (paragneiss and migmatites) (OGS Map 2664, “Precambrian Geology Compilation Series, Thunder Bay Sheet” dated 2001). At the site, the metasedimentary bedrock is overlain by sedimentary bedrock (primarily shale, mudstone and sandstone) of the Sibley Formation. The bedrock is mantled by deep deposits of glaciolacustrine clay and a surficial organic terrain.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing for this project was carried out between April 12 and May 1, 2014. The investigation comprised drilling and sampling four boreholes identified as Boreholes BTC-01 to BTC-04 along the proposed replacement culvert alignment. Boreholes BTC-01 and BTC-04 were drilled near the proposed inlet and outlet respectively, and Boreholes BTC-02 and BTC-03 were drilled on the east and west sides of the culvert alignment through the shoulders of the existing highway embankment.

The approximate borehole locations are shown on the attached Borehole Locations and Soil Strata Drawing in Appendix F.

The borehole locations were marked in the field and utility clearances were obtained prior to drilling.

Boreholes BTC-02 and BTC-03 were advanced to depths of 33.5 to 35.8 m (Elev. 162.9 and 160.4 m), with drilling carried out using a truck mounted drill rig with NW casing and NQ coring techniques. NQ coring was used to advance the boreholes between 0.3 and 3.0 m into bedrock. Boreholes BTC-01 and BTC-04 were drilled using portable tripod equipment and wash boring to advance NW casing until encountering refusal at depths of 15.8 m (Elev. 178.2 to 177.9 m). Dynamic Cone Penetration Tests (DCPTs) were conducted from the bottom of boreholes BTC-01 and BTC-04 to advance to total depths of 28.6 and 27.7 m (Elev. 165.4 and 166.0 m) respectively upon encountering DCPT refusal. Soil samples were obtained at selected intervals in the boreholes 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.

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 and rock samples 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. Standpipe piezometers were installed in two boreholes to measure groundwater levels. The piezometers were subsequently decommissioned in general accordance with MOE Regulation

903 following completion of the final water level reading. 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
BTC-01	24.7 / 169.3	19 mm diameter piezometer installed with filter sand from 28.6 m to 21.3 m, then bentonite holeplug to surface.
BTC-02	None installed	Backfilled with bentonite holeplug to 0.1 m, then asphalt to surface.
BTC-03	None installed	Backfilled with bentonite holeplug to 0.2 m, then sand and gravel to surface.
BTC-04	27.7 / 166.0	19 mm diameter piezometer installed with filter sand from 27.7 m to 23.9 m, then 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 topsoil or asphalt overlying existing embankment fill underlain by native deposits of sand and silt to sand and gravel, a thick deposit of silty clay, and a layer of sand and silt overlying bedrock. More detailed descriptions of the individual strata are presented below.

5.1 Topsoil

A thin layer of topsoil was encountered at the ground surface in Boreholes BTC-01 and BTC-04. The topsoil layer was 75 to 125 mm thick at these locations. The thickness of the topsoil layer may vary between and beyond the borehole locations.

5.2 Asphalt

An 80 mm thick layer of asphalt was encountered on the roadway shoulder in Borehole BTC-02.

5.3 Embankment Fill

Cohesionless embankment fill comprising sand and gravel to gravelly sand was encountered below the asphalt in Borehole BTC-02 and at the surface in Borehole BTC-03 drilled on the highway shoulder. The base of the granular fill was encountered at depths of 4.9 and 4.7 m (Elev. 191.3 and 191.7).

Fill comprising silty sand to sand, some silt was encountered below the topsoil in Boreholes BTC-01 and BTC-04 drilled adjacent to the ends of the culvert. This fill layer was 0.8 and 1.2 m thick with a lower boundary at depths of 0.9 and 1.3 m (Elev. 192.8 and 192.7).

SPT N-values recorded in the granular embankment fill ranged from 23 to 66 blows for 0.3 m penetration, indicating a compact to very dense condition. An N-value of 50 blows for 0.1 m penetration was recorded on probable cobbles in the fill in Borehole BTC-02. N-values of 10 to 33 blows for 0.3 m (compact to dense) were obtained in the fill adjacent to the embankment, however the higher value may reflect a frozen condition.

Moisture contents ranged from 8% to 15% in the granular fill, and 33% to 39% in the sand fill.

Three samples of the embankment 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 %	21 to 38
Sand %	57 to 69
Silt and Clay %	5 to 10

5.4 Sand and Silt to Sand and Gravel

Native deposits of sand, sand and gravel, and sand and silt were encountered beneath the fill in Boreholes BTC-01, BTC-03 and BTC-04. These deposits were 1.4 to 3.1 m thick, with a lower boundary at depths of 3.3 to 6.1 m (Elev. 190.7 to 189.7 m). Wood fibres, organics and occasional cobbles were noted in these deposits.

SPT N-values recorded within the sand/gravel deposits ranged from 0 to 15 blows for 0.3 m penetration, indicating a very loose to compact relative density. Higher N-values of 66 blows/0.3 m and 114 blows/0.175 m were obtained in the sand and silt in Borehole BTC-04, reflecting a frozen condition. Moisture contents ranged from 19% to 30%.

Grain size analyses were undertaken on samples of the sand/gravel/silt deposits. The results are presented on the Record of Borehole sheets included in Appendix A and on Figures B2 and B3 of Appendix B. The results are summarized below.

	Sand & Silt	Sand	Sand & Gravel
Gravel %	3	0	46
Sand %	47	92	45
Silt %	37	8	9
Clay %	13		

5.5 Silty Clay

Native silty clay was encountered below the fill in Borehole BTC-02 and below the sand/gravel/silt deposits in the remaining boreholes. The silty clay was typically grey with occasional silt seams.

Where fully penetrated in Boreholes BTC-02 and BTC-03, the silty clay layer was 24.4 to 25.6 m thick, with a lower boundary encountered at a depth of 30.5 m (Elev. 165.7 to 165.9). Sampling in Boreholes BTC-01 and BTC-04 was terminated within the silty clay layer at 15.8 m depth (Elev. 178.2 to 177.9 m).

SPT N-values recorded in the silty clay ranged from 0 to 6 blows for 0.3 m penetration, typically less than 2. In situ shear vane testing indicated undrained shear strengths in the order of 22 to 75 kPa, typically about 30 to 40 kPa. Based on this data, the consistency of the silty clay ranges from soft to stiff, and is typically firm.

The moisture content of the silty clay generally ranged from 31% to 57%, with one value of 121% measured in Borehole BTC-01.

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 to B6 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
Silt %	32 to 57
Clay %	43 to 68
Liquid Limit	31 to 44
Plastic Limit	18 to 20

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

5.6 Lower Sand and Silt

A deposit of sand and silt with some clay, trace to some gravel, and occasional cobbles was encountered below the silty clay in Boreholes BTC-02 and BTC-03. The sand and silt deposit was 2.3 to 2.7 m thick with a lower boundary at 32.8 to 33.2 m depth (Elev. 163.4 to 163.2 m).

SPT N-values of 60 and 64 blows for 0.3 m penetration were recorded in the silt and sand, indicating that the material has a very dense relative density. The moisture content was measured as 8% to 9%.

A grain size analysis was undertaken on one sample of the sand and silt. The results are presented on the Record of Borehole sheets included in Appendix A and on Figure B7 of Appendix B. The results are summarized below.

Gravel %	1
Sand %	46
Silt %	42
Clay %	11

5.7 Bedrock

Bedrock was encountered below the sand and silt deposit in Boreholes BTC-02 and BTC-03 at depths of 32.8 and 33.2 m (Elev. 163.4 and 163.2 m).

Boreholes BTC-02 and BTC-03 were extended 3.0 and 0.3 m respectively into bedrock by coring (further coring in Borehole BTC-03 was obstructed by casing damage). The bedrock recovered in the boreholes was described as red shale with grey mottles and calcareous zones. Total core recovery was 100% in both runs from Borehole BTC-02.

RQD values of 77 to 98% were recorded, indicating good to excellent rock quality. The Fracture Index (FI) of the rock, expressed as fractures per 0.3 m of core, ranged from 0 to greater than 10 (typically under 3).

Average unconfined compressive strengths (UCS) of 150 and 133 MPa were assessed from the results of point load tests conducted on the rock core samples, indicating a very strong intact rock strength. The strength results are included on the borehole logs in Appendix A (as average per run).

5.8 Water Levels

Groundwater levels in the boreholes were observed during drilling and standpipe piezometers were installed in two boreholes to monitor groundwater levels after completion of drilling. A summary of the recorded groundwater levels is provided below.

Table 5.1 - Groundwater Level Measurements

Borehole	Date	Groundwater Level		Comment
		Depth (m)	Elevation	
BTC-01	May 01, 2014	-1.0*	195.0	In piezometer
BTC-04	May 01, 2014	-1.0*	194.7	In piezometer

* indicates artesian groundwater level above the ground surface

The water levels measured above the ground surface are indicative of artesian pressures present in the cohesionless deposits below the silty clay layer.

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 Big Trout Creek, which is shown on the preliminary drawings provided by MMM to be at Elev. 192.9 m in February 2011.

6 MISCELLANEOUS

In general, the borehole locations were positioned in the field by Thurber staff and were established relative to site features. The co-ordinates and ground surface elevations at the boreholes were inferred from the MMM Group Limited General Arrangement drawing dated March 2014.

Eastern Ontario Diamond Drilling Limited from Hawkesbury, Ontario supplied a tri-pod and truck mounted CME 75 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 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 discussions and geotechnical design recommendations for replacement of the Big Trout Creek culvert on Highway 628 in the Township of Red Rock, Ontario.

The existing Big Trout Creek culvert consists of a 27.8 m long corrugated steel arch culvert with an approximate 3.0 x 5.0 m opening. The interior of the arch is presently strutted with timber supports. The creek flows in a general north to south direction at the site. The existing highway embankment adjacent to the culvert is approximately 2.5 m high.

The preliminary GA drawing (May 2014) indicates that the proposed replacement structure will consist of two parallel sheet pile walls and a precast concrete panel cap. The culvert span will be 8.0 m wide and the length of the sheet pile walls will be 35.5 m, of which 16.5 m will be capped. The top of the river stone substrate will be at approximate Elev. 192.1 to 192.5 m. The clear height within the culvert will be approximately 3.0 m, and the fill height above the concrete panels will be approximately 0.8 m. The finished road grade will be near elevation 196.4 m.

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 drawing used for preparation of this report was provided by MMM Group Limited.

8 CULVERT FOUNDATION

8.1 General

In general, the subsurface stratigraphy encountered at the site consisted of topsoil or asphalt overlying existing embankment fill underlain by native deposits of sand and silt to sand and gravel, a thick deposit of silty clay, and a layer of sand and silt overlying bedrock.

The silty clay layer has a firm consistency and a thickness of 24.4 to 25.6 m. Bedrock was proven at depths of 32.8 and 33.2 m (Elev. 163.4 and 163.2 m).

Groundwater levels measured in standpipe piezometers installed at the site ranged from Elev. 194.7 to 195.0 m and indicated artesian pressures of 1.0 m above the ground surface. The preliminary GA drawing indicates a water level at Elev. 192.9 m in Big Trout Creek in February 2011.

8.2 Selection of Culvert Type

We understand that a sheet pile wall design was selected as the preferred culvert type for considerations other than the geotechnical conditions on site. From a geotechnical perspective, the proposed culvert design is considered to be suitable.

Geotechnical recommendations for the proposed sheet pile culvert design are provided below. The culvert must be designed for static and seismic conditions to resist external loadings including lateral earth pressures, hydrostatic pressure, weight of embankment fill, traffic loading and any surcharge due to construction equipment and activities.

Potential alternatives to the sheet pile design include a concrete box culvert placed on the native silt or an arch/open footing culvert supported on piles. The geotechnical resistance of the native silt and silty clay is considered inadequate for the use of spread footings and therefore an arch/open footing culvert on footings is not recommended. A comparison of alternative culvert/foundation systems, based on advantages and disadvantages of each, is included in Appendix D. The alternative systems were not developed further.

8.3 Steel Sheet Pile Culvert

Sheet piles will be driven through the native sand/silt/gravel layer and into the firm silty clay to develop resistance primarily through adhesion along the pile walls. Based on the borehole information, the recommended axial geotechnical resistance of EZ88 sheet piles driven to various tip elevations are provided in Table 8.1. Intermediate values may be obtained by linear interpolation between the values shown.

Table 8.1 - Recommended Axial Resistance of EZ88 Sheet Piles

Alignment	Sheet Pile Tip Elevation (m)	Approximate Length of Sheet Pile ⁽¹⁾ (m)	Factored Geotechnical Resistance at ULS (kN/linear m)	Reaction at SLS (kN/linear m)
Both West and East Sheet Pile Walls	190.5	4.5	No Resistance (Frost Zone)	
	187.5	7.5	65	55
	182.5	12.5	225	185
	177.5	17.5	445	370
	172.5	22.5	725	600

Note: (1) below top of sheet pile, approximate Elev. 195.0 m shown on GA drawing.

Steel sheet pile installation should be in accordance with OPSS 903. The appropriate pile driving note is “SHEET PILES TO BE DRIVEN TO EL” An additional note should be included to indicate that installation of permanent sheet pile walls by vibratory equipment is not permitted.

As the sheet piles will derive resistance through friction/adhesion along the pile walls, tip protection should not be provided.

Cobbles were encountered in the highway embankment fill and underlying sand layer. These obstructions may impede pile driving and if encountered, they will need to be removed in order to continue driving of the sheet piles. Care must be taken not to damage piles by overdriving them if refusal is encountered on cobbles, particularly in the absence of pile tip protection.

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.

8.3.1 Downdrag

Downdrag on the sheet piles is not considered to be an issue at this site since there is no proposed grade raise. Downdrag will need to be reassessed if any additional fill will be added above or adjacent to the existing embankment.

8.3.2 Sheet Pile Lateral Resistance

Design for lateral resistance of the sheet piles may be carried out using the earth pressure coefficients (K_a = active, K_o = at rest, K_p = passive) and soil unit weights provided in Table 8.2 below and Table 9.1 in Section 9.

The interaction between the sheet pile wall and the adjacent soil may be analysed using a soil-spring model and a coefficient of horizontal subgrade reaction, k_s . The value of k_s for cohesive soils is shown in the table below and may be assumed to be constant with depth. In cohesionless soils, the horizontal subgrade reaction per linear meter varies with depth and can be calculated as follows:

$$k_s = n_h z \quad (\text{kN/m}^3)$$

where z = depth of embedment of pile in metres

n_h = coefficient related to soil density, see table below (kN/m^3)

Table 8.2 – Parameters for Estimating Lateral Pile Resistance

Alignment	Elevation	K_a	K_o	K_p	k_s (kPa/m)	n_h (kN/m^3)	Unit Weight ⁽¹⁾ (kN/m^3)	Soil Type
West Sheet Pile Wall	196.4 to 192.9	0.31	0.47	3.2	-	5,500	20	Embankment Fill
	192.9 to 191.7	0.31	0.47	3.2	-	4,000	10	Embankment Fill
	191.7 to 190.5	0.33	0.50	3.0	-	2,500	10	Sand
	190.5 to 165.9	0.44	-	2.3	1,300	-	9	Silty Clay
	165.9 to 163.2	0.27	-	3.7	-	8,000	10	Sand and Silt
East Sheet Pile Wall	196.2 to 192.9	0.31	0.47	3.2	-	5,500	20	Embankment Fill
	192.9 to 191.3	0.31	0.47	3.2	-	4,000	10	Embankment Fill
	191.3 to 165.7	0.44	-	2.3	-	-	9	Silty Clay
	165.7 to 163.4	0.27	-	3.7	1,300	8,000	10	Sand and Silt

Note: (1) submerged unit weight below water level.

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/m^3) and L is the length (m) of the pile segment or element used in the analysis.

8.4 Frost Cover

The design depth of frost penetration at this site is 2.3 m. The base of all foundation elements must be provided with a minimum of 2.3 m of earth cover as protection against frost action.

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.

Table 9.1 - Earth Pressure Coefficients

Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I/III or Existing Sand & Gravel Fill $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface	Sloping Surface behind Wall (2H:1V)	Horizontal Surface	Sloping Surface behind Wall (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48
At rest (Restrained Wall)	0.43	-	0.47	-
Passive (Movement Towards Soil Mass)	3.7	-	3.3	-

* 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.

The parameters in the tables 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. Active pressures should be used for any wingwalls or unrestrained walls.

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/III or Existing Fill $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	Silty Clay $\phi = 23^\circ$ $\gamma = 9 \text{ kN/m}^3$
Active (K_{AE})*	0.28	0.32	0.45
Passive (K_{PE})	3.70	3.20	2.30
At Rest (K_{OE})**	0.45	0.50	-

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

** After Woods

The silty clay and sandy soils at this site are not prone to liquefaction. In view of the velocity related seismic zone of zero, liquefaction is not considered to be a concern at this site.

11 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.

12 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, the embankment fill and native soils at this site are classified as Type 3 soils above the water level and Type 4 soils below the water level.

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 the existing highway embankment for placement of the cap panels and excavation between the sheet pile walls for channel construction. In general, this excavation will be carried out within embankment fill above the groundwater level.

Excavation will extend below the water level for channel construction and placement of the river stone substrate between the sheet pile walls. Excavation must be carried out in a manner that minimizes sloughing and disturbance of the subgrade on which the substrate will be placed. Relatively flat side slopes will be required for any unsupported excavation sidewalls.

Selection of the equipment and methodology to excavate and prepare the subgrade 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.

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.

13 CONSTRUCTION CONCERNS

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

- Cobbles or other buried obstructions may be encountered during excavation in the existing embankment fill or interfere with driving of sheet piles.
- The water levels in the creek may fluctuate.

- 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.

14 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.

Thurber Engineering Ltd

Stephen Peters, P.Eng.
Geotechnical Engineer



Murray R. Anderson, P.Eng., M.Eng.
Senior Foundations Engineer



P. K. Chatterji, P.Eng., Ph.D.
Review Principal



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
 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


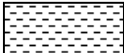



ROCK WEATHERING CLASSIFICATION

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		Field Estimation of Hardness*
	(MPa)	(psi)	
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 BTC-01

1 OF 3

METRIC

WP# 4497-93-01 LOCATION Big Trout Creek Culvert N 5 423 171.0 E 208 286.3 ORIGINATED BY ES
 HWY 628 BOREHOLE TYPE Tripod/Wash Boring COMPILED BY AN
 DATUM Geodetic DATE 2014.04.13 - 2014.04.13 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 (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										
194.0								20	40	60	80	100						
0.0	TOPSOIL: (75mm) SAND , silty to trace silt, trace to some gravel, trace rootlets Compact Brown Wet (FILL)		1	SS	10													
0.1			2	SS	11													
192.7	SAND and GRAVEL , trace silt, occasional wood fibres Compact Brown Wet																	
1.3			3	SS	15													
			4	SS	12													
			5	SS	5													
190.7	Silty CLAY Firm Grey (Cl)																	
3.3			6	SS	1													
			7	SS	0													
			8	SS	1													
			9	SS	3													

Continued Next Page

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

RECORD OF BOREHOLE No BTC-01

2 OF 3

METRIC

WP# 4497-93-01 LOCATION Big Trout Creek Culvert N 5 423 171.0 E 208 286.3 ORIGINATED BY ES
HWY 628 BOREHOLE TYPE Tripod/Wash Boring COMPILED BY AN
DATUM Geodetic DATE 2014.04.13 - 2014.04.13 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 (%)					
	Continued From Previous Page													
	Silty CLAY , occasional silt seams Firm Grey		10	SS	0		183	5.0 +					121	
			11	SS	1		182	5.0 +						
			12	SS	0		180	4.0 +						0 0 44 56
			13	SS	1		179	4.0 +						
178.2	DCPT starts at 15.8m						178							
15.8							177							
							176							
							175							

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Sensitivity

20
15 10 5
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No BTC-01

3 OF 3

METRIC

WP# 4497-93-01 LOCATION Big Trout Creek Culvert N 5 423 171.0 E 208 286.3 ORIGINATED BY ES
 HWY 628 BOREHOLE TYPE Tripod/Wash Boring COMPILED BY AN
 DATUM Geodetic DATE 2014.04.13 - 2014.04.13 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			20 40 60 80 100	20 40 60	W P W W L				
	Continued From Previous Page													
165.4														
28.6	END OF BOREHOLE AT 28.6m UPON DCPT REFUSAL. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) May 01/14 1.0* 195.0 * Above ground surface													

ONTMT4S 1197.GPJ 2012TEMPLATE(MTO).GDT 7/3/14

RECORD OF BOREHOLE No BTC-02

1 OF 4

METRIC

WP# 4497-93-01 LOCATION Big Trout Creek Culvert N 5 423 153.5 E 208 291.3 ORIGINATED BY ES
HWY 628 BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY AN
DATUM Geodetic DATE 2014.05.01 - 2014.05.01 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
								○ UNCONFINED + FIELD VANE	● QUICK TRIAXIAL × LAB VANE										
196.2								20	40	60	80	100	W _P	W	W _L				
0.0								20	40	60	80	100							
0.1	ASPHALT: (80mm)																		
	SAND and GRAVEL, trace silt Compact to Very Dense Brown Moist (FILL)		1	GS									○						
			1	SS	29								○						
			2	SS	23								○					38	57
			3	SS	66								○					5	(SI+CL)
	Occasional cobbles		4	SS	50/ 0.100								○						
			5	SS	2									○					
191.3	Silty CLAY Firm Grey (Cl)		6	SS	2										○				
4.9			7	SS	0											○			
			8	SS	0											○			
															</				

Continued Next Page


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

RECORD OF BOREHOLE No BTC-02

2 OF 4

METRIC

WP# 4497-93-01 LOCATION Big Trout Creek Culvert N 5 423 153.5 E 208 291.3 ORIGINATED BY ES
HWY 628 BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY AN
DATUM Geodetic DATE 2014.05.01 - 2014.05.01 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			
								○ UNCONFINED + FIELD VANE													
								● QUICK TRIAXIAL × LAB VANE													
	Continued From Previous Page							20 40 60 80 100													
	Silty CLAY Firm Grey (Cl)						186	4.0 +													
			9	SS	1											0	0	43	57		
			10	SS	1																
			11	SS	0																
			12	SS	0																
								</													

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+³, ×³: Numbers refer to
Sensitivity

20
15 10 5 0
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No BTC-02

3 OF 4

METRIC

WP# 4497-93-01 LOCATION Big Trout Creek Culvert N 5 423 153.5 E 208 291.3 ORIGINATED BY ES
HWY 628 BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY AN
DATUM Geodetic DATE 2014.05.01 - 2014.05.01 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								
							20	40	60	80	100	20	40	60		
	Continued From Previous Page															
	Silty CLAY Firm Grey (Cl)						176									
	Occasional silt seams		15	SS	3		175									
	Becoming Stiff						174			5.0						
							173									
							172									
			16	SS	2		171			4.0						
							170									
							169									
			17	SS	6		168			3.0						
							167									

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+³, ×³: Numbers refer to
Sensitivity

20
15 10 5 0
(%) STRAIN AT FAILURE

METRIC

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+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No BTC-03

1 OF 4

METRIC

WP# 4497-93-01 LOCATION Big Trout Creek Culvert N 5 423 155.4 E 208 279.5 ORIGINATED BY ES
HWY 628 BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY AN
DATUM Geodetic DATE 2014.04.30 - 2014.04.30 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	
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE										
196.4																					
0.0	Gravelly SAND , trace silt Very Dense to Dense Brown Moist to Wet (FILL)		1	SS	65														32 60 8 (SI+CL)		
			2	SS	32																
			3	SS	62																21 69 10 (SI+CL)
			4	SS	31																
			5	SS	50																
191.7																					
4.7	SAND , trace gravel, trace silt, trace organics, occasional cobbles Loose Dark Brown Wet		6	SS	8																
190.3																					
6.1	Silty CLAY Firm to Stiff Grey (CI-CL)		7	SS	1														0 0 39 61		
					8	SS	0														
					9	SS	0														

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+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

METRIC

SOIL PROFILE						SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	SHEAR STRENGTH kPa				WATER CONTENT (%)										
						○ UNCONFINED + FIELD VANE														
Continued From Previous Page										20	40	60	80	100	20	40	60			
	Silty CLAY Firm Grey (CI-CL)								6.0 +											
			10	SS	0															
			11	SS	1						7.0 +									
			12	SS	0						5.0 +									
			13	SS	0						6.0 +									
			14	SS	0						7.0 +									
			15	SS	0						7.0 +									
									5.0 +											


+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No BTC-03

3 OF 4

METRIC

WP# 4497-93-01 LOCATION Big Trout Creek Culvert N 5 423 155.4 E 208 279.5 ORIGINATED BY ES
HWY 628 BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY AN
DATUM Geodetic DATE 2014.04.30 - 2014.04.30 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 ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE							
	Continued From Previous Page							20 40 60 80 100	20 40 60							
	Silty CLAY Firm Grey (CI-CL)						176							0 0 38 62		
			16	SS	4		175									o
							174			7.0 +						
							173									
			17	SS	2		172									o
							171			6.0 +						
							170									
			18	SS	5		169									o
						168										
						167										

Continued Next Page

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

RECORD OF BOREHOLE No BTC-03

4 OF 4

METRIC

WP# 4497-93-01 LOCATION Big Trout Creek Culvert N 5 423 155.4 E 208 279.5 ORIGINATED BY ES
HWY 628 BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY AN
DATUM Geodetic DATE 2014.04.30 - 2014.04.30 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									
	Continued From Previous Page																
165.9	Silty CLAY Firm Grey						166										
30.5	SAND and SILT , some gravel, occasional cobbles Very Dense Reddish Brown Wet		19	SS	60												
							165										
							164										
163.2																	
33.2	BEDROCK , red shale with grey mottles		1	RUN			163										
162.9																	
33.5	END OF BOREHOLE AT 33.5m. 1.2m OF ARTESIAN PRESSURE INSIDE NW CASING UPON COMPLETION. WATER LEVEL AT 0.9m BELOW GROUND SURFACE IN OPEN BOREHOLE. BOREHOLE BACKFILLD WITH BENTONITE HOLEPLUG TO 0.2m, THEN SAND AND GRAVEL TO SURFACE.																

METRIC

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+³, ×³: Numbers refer to Sensitivity

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No BTC-04

3 OF 3

METRIC

WP# 4497-93-01 LOCATION Big Trout Creek Culvert N 5 423 139.2 E 208 276.3 ORIGINATED BY ES
HWY 628 BOREHOLE TYPE Tripod/Wash Boring COMPILED BY AN
DATUM Geodetic DATE 2014.04.12 - 2014.04.12 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	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												
							173						
							172						
							171						
							170						
							169						
							168						
							167						
166.0 27.7	<p>END OF BOREHOLE AT 27.7m UPON DCPT REFUSAL. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen.</p> <p>WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) May 01/14 1.0* 194.7 * Above ground surface</p>												

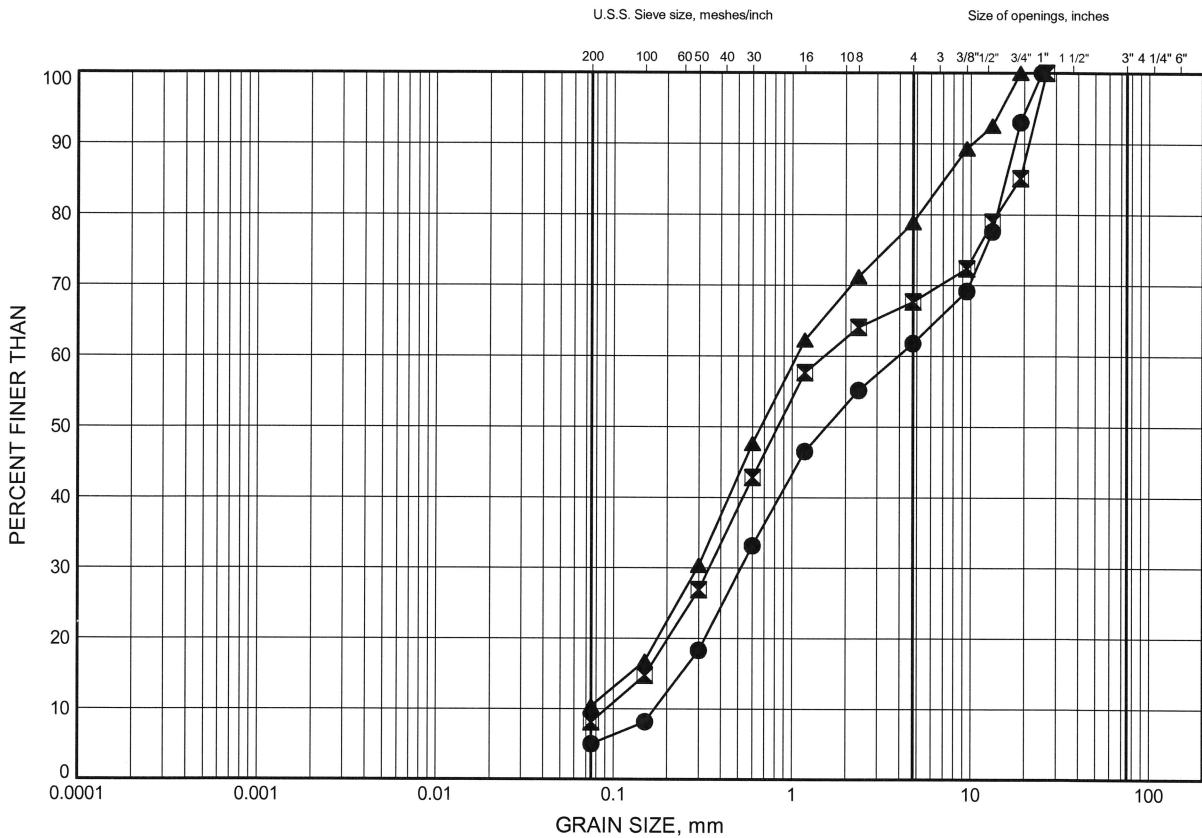
Appendix B

Laboratory Test Results

Big Trout Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B1

SAND to SAND & GRAVEL FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BTC-02	1.83	194.37
⊠	BTC-03	0.30	196.10
▲	BTC-03	1.75	194.65

Date July 2014

WP# 4497-93-01



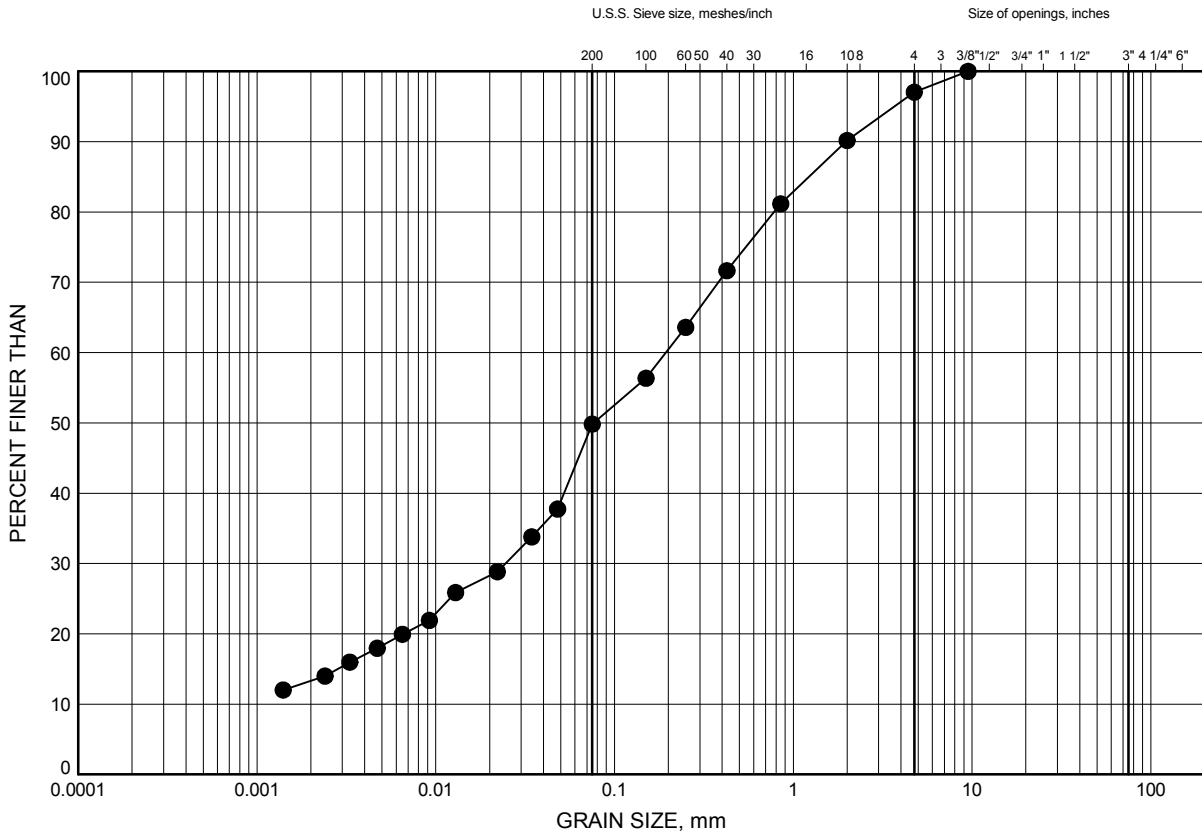
Prep'd AN

Chkd. MEF

Big Trout Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B2

Upper SAND & SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BTC-04	1.07	192.63

Date June 2014
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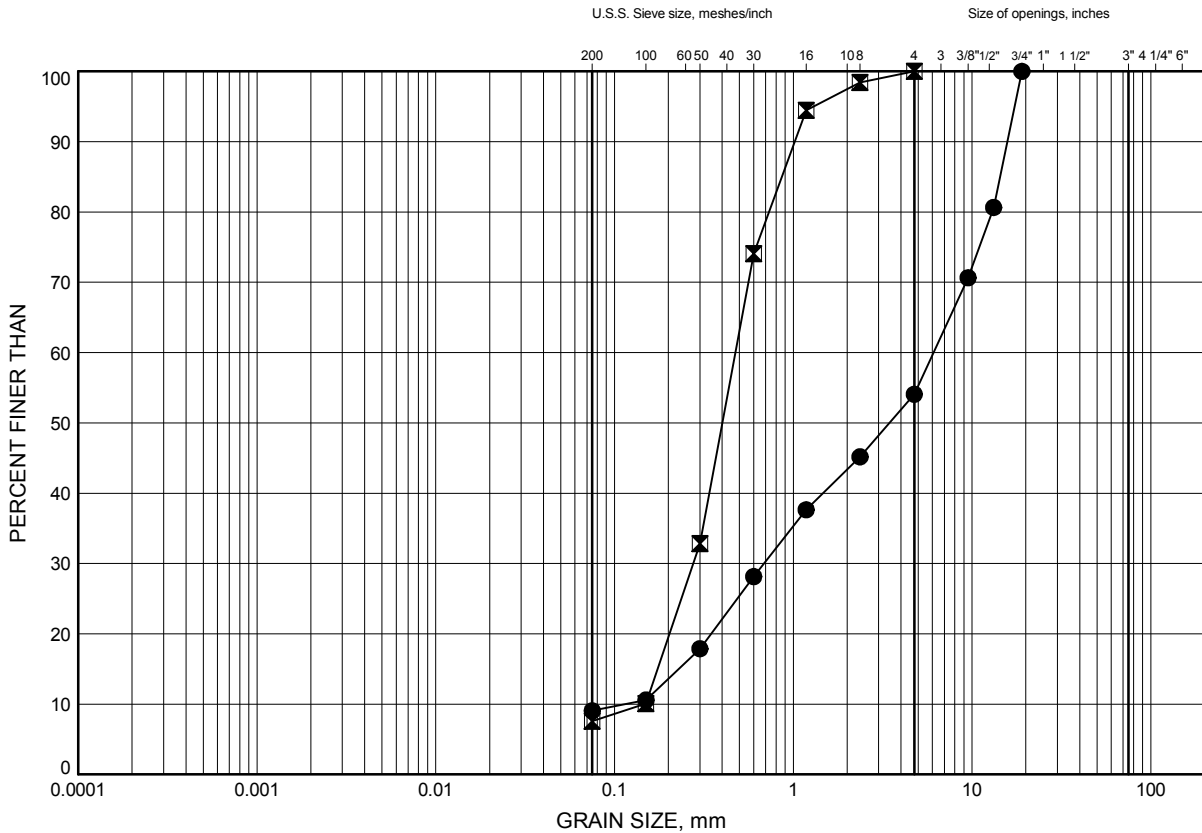


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Big Trout Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B3

SAND to SAND & GRAVEL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BTC-01	2.59	191.41
⊠	BTC-04	3.35	190.35

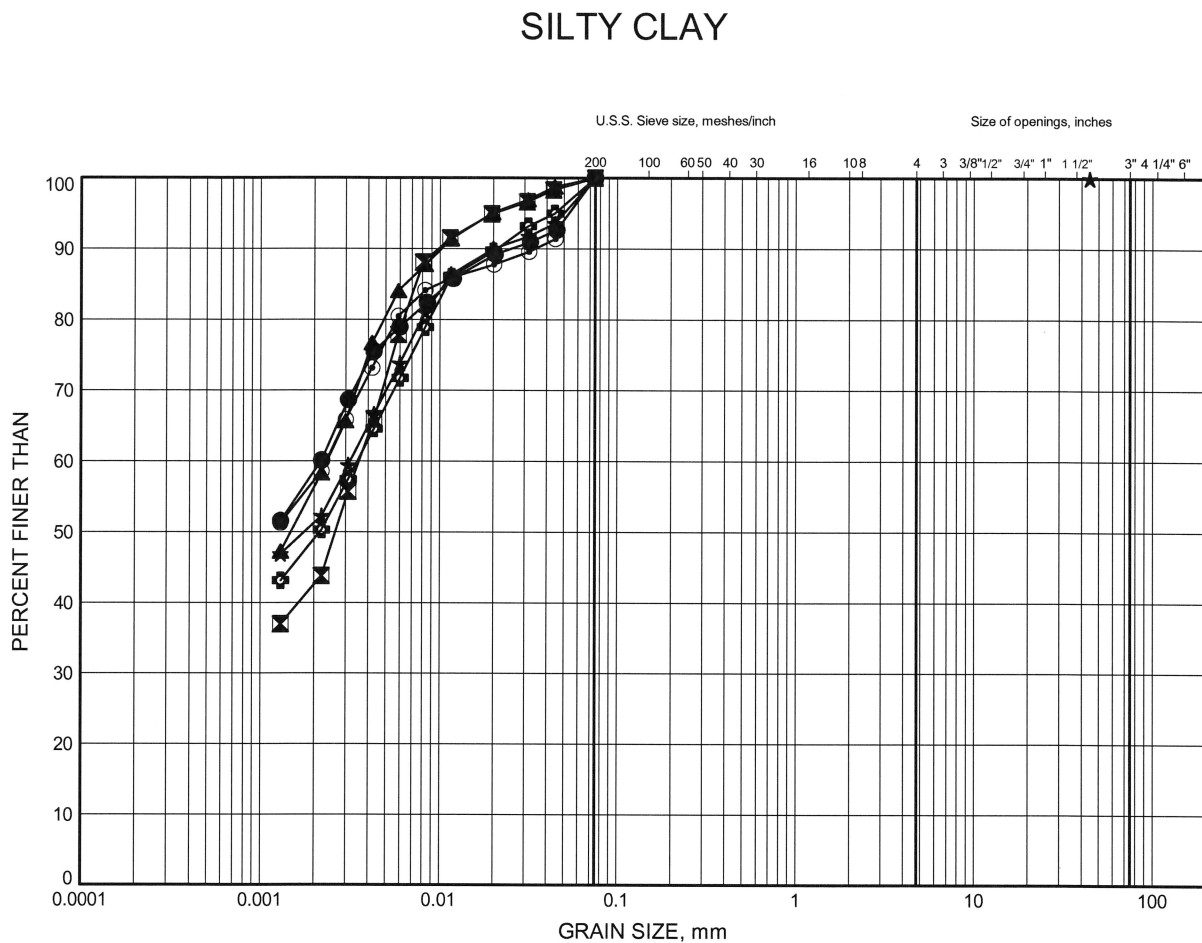
Date June 2014
WP# 4497-93-01



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Big Trout 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)
●	BTC-01	4.88	189.12
⊠	BTC-01	9.45	184.55
▲	BTC-01	14.02	179.98
★	BTC-02	6.40	189.80
⊙	BTC-02	10.97	185.23
⊕	BTC-02	17.07	179.13

Date July 2014

WP# 4497-93-01

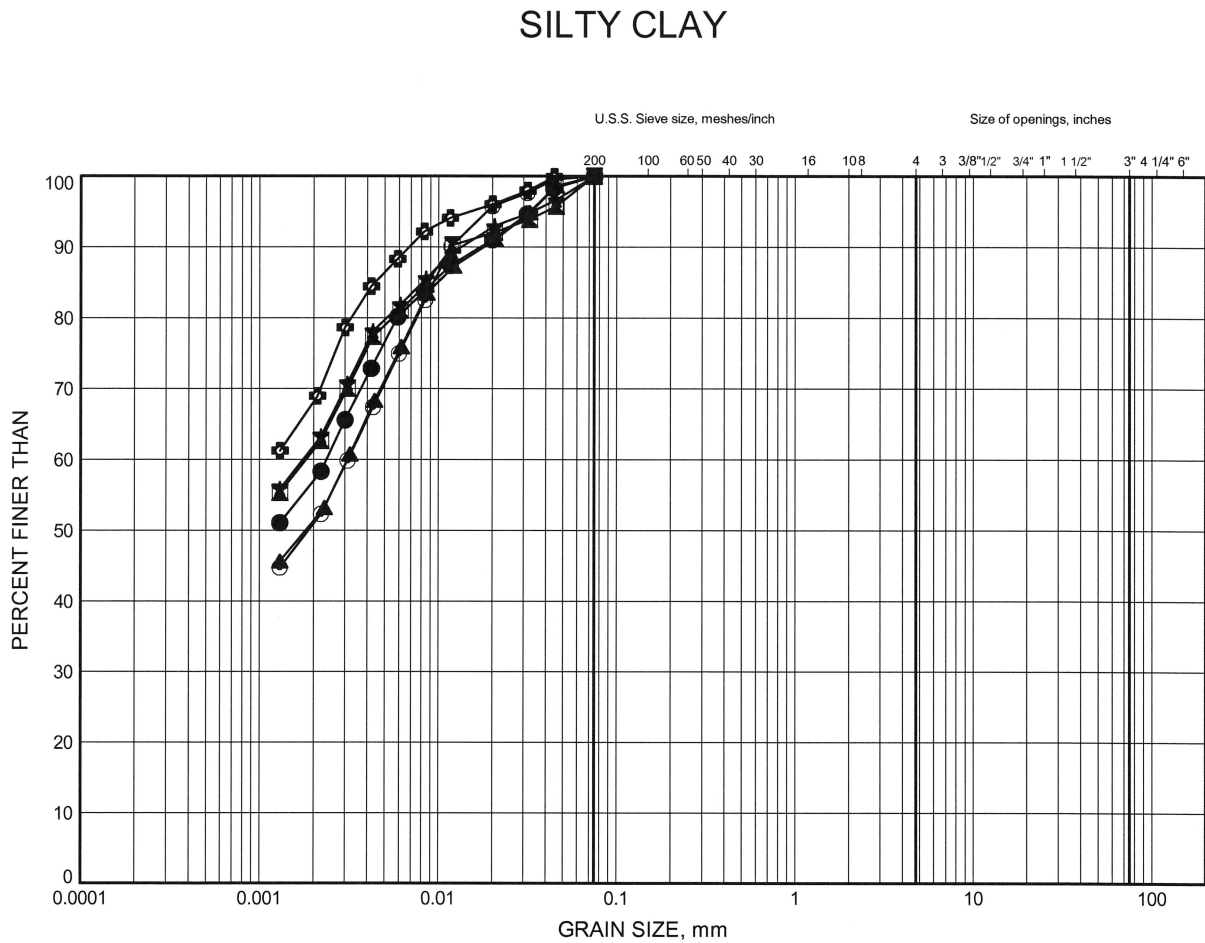


Prep'd AN

Chkd. MEF

Big Trout 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)
●	BTC-02	24.69	171.51
⊠	BTC-03	6.40	190.00
▲	BTC-03	15.54	180.86
★	BTC-03	21.64	174.76
⊙	BTC-03	27.74	168.66
⊕	BTC-04	7.92	185.78

Date July 2014
WP# 4497-93-01

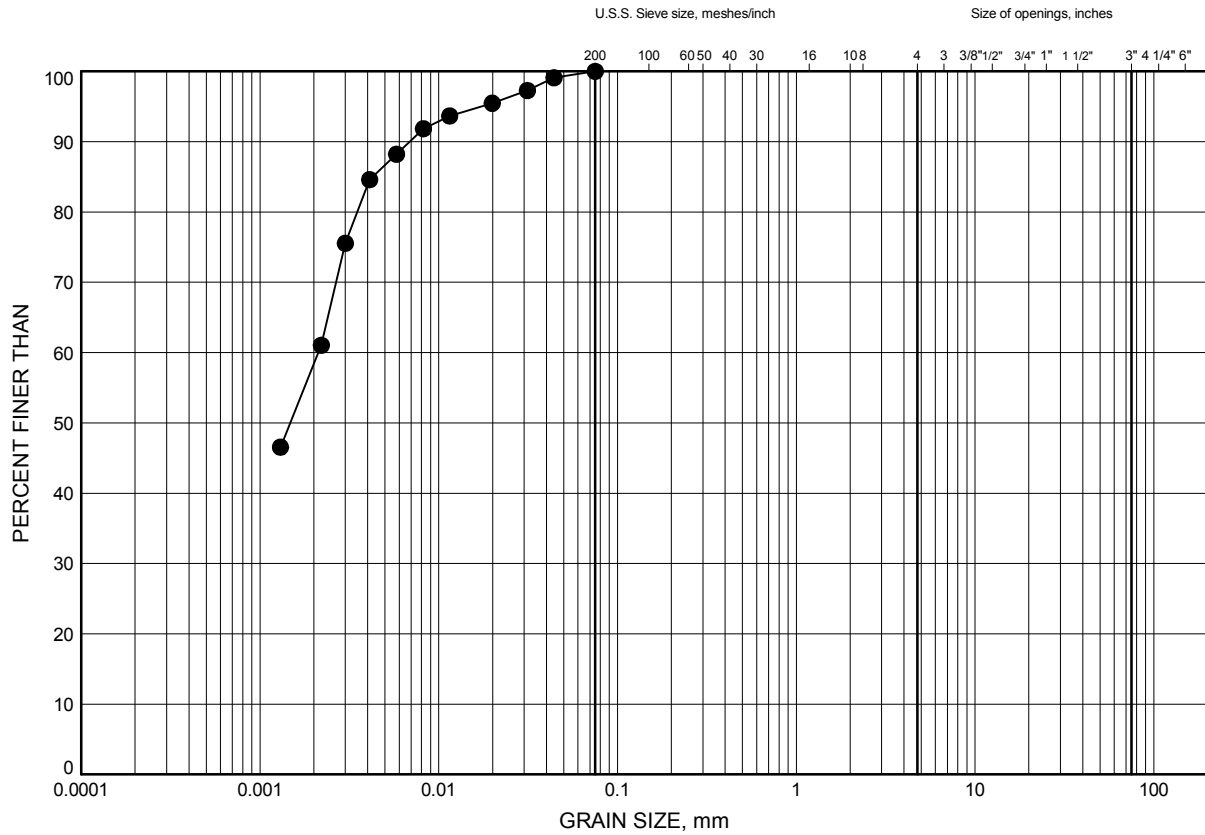


Prep'd AN
Chkd. MEF

Big Trout Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B6

SILTY CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BTC-04	12.50	181.20

Date June 2014
WP# 4497-93-01

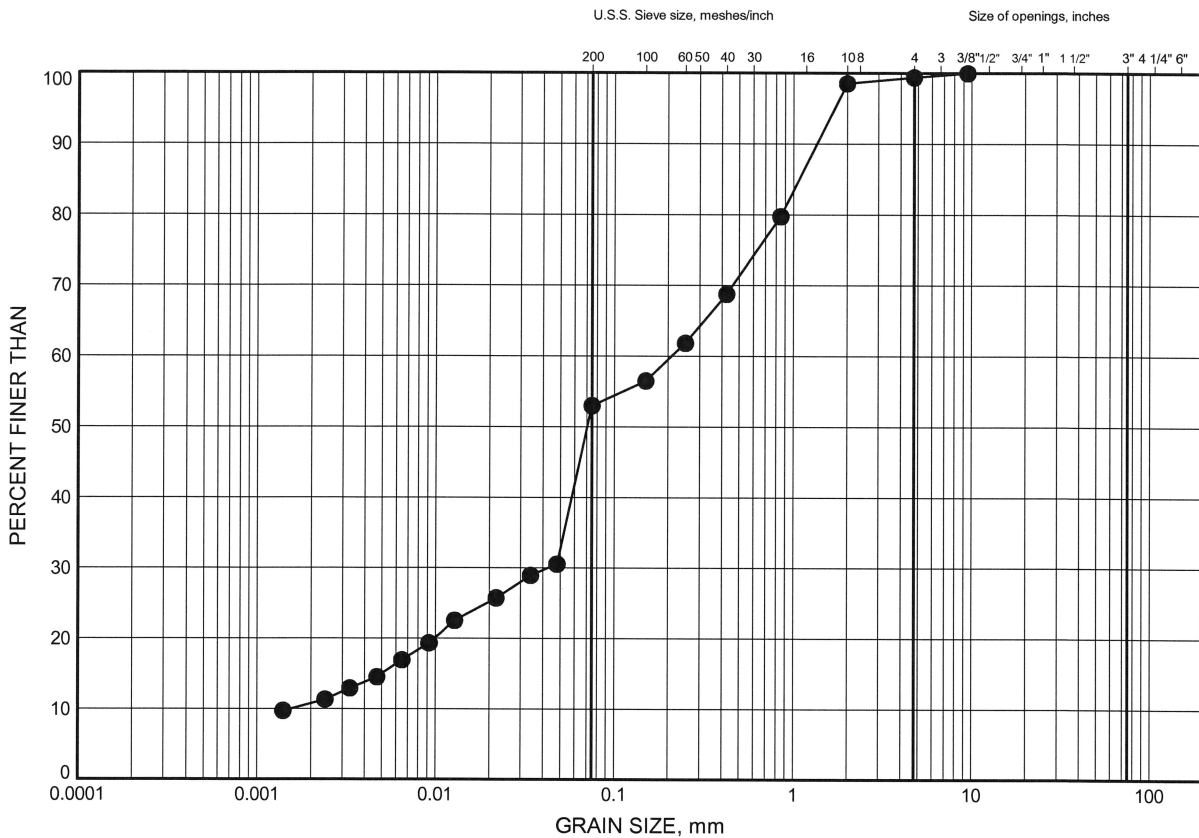


Prep'd AN
Chkd. MEF

Big Trout Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B7

Lower SAND & SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BTC-02	30.75	165.45

Date July 2014
WP# 4497-93-01

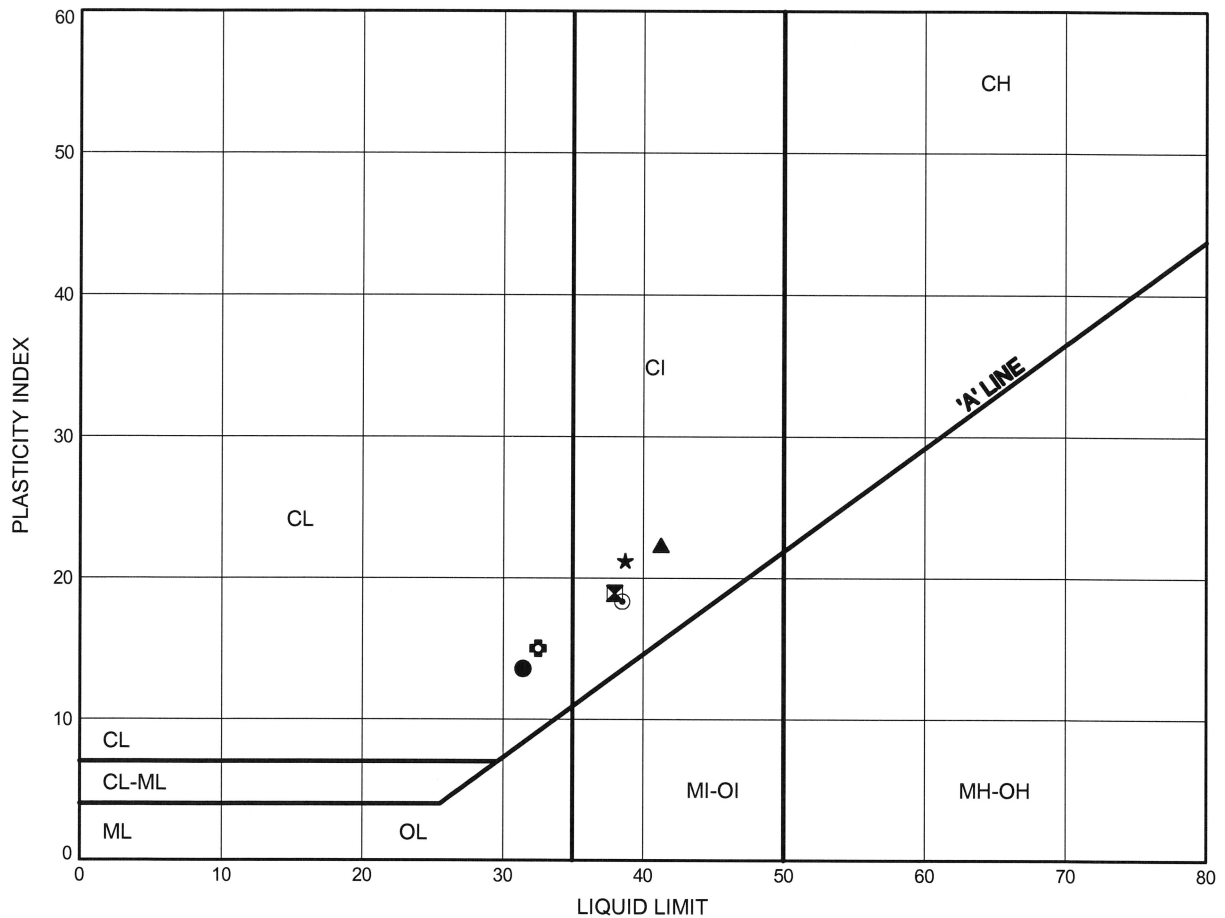


Prep'd AN
Chkd. MEF

Big Trout Creek Culvert ATTERBERG LIMITS TEST RESULTS

FIGURE B8

SILTY CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BTC-01	9.45	184.55
⊠	BTC-01	14.02	179.98
▲	BTC-02	10.97	185.23
★	BTC-02	24.69	171.51
⊙	BTC-03	15.54	180.86
⊕	BTC-03	27.74	168.66

Date July 2014
 WP# 4497-93-01

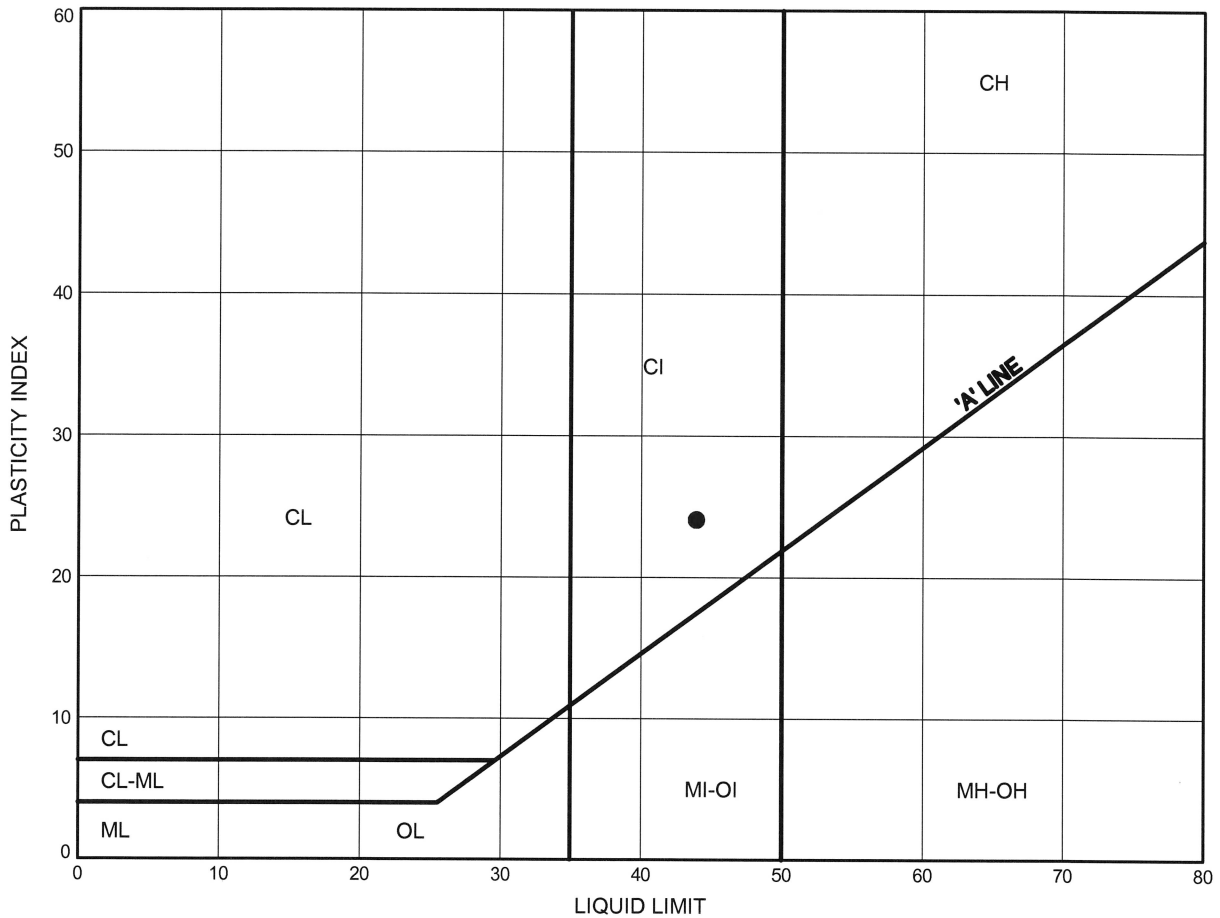


Prep'd AN
 Chkd. MEF

Big Trout Creek Culvert
ATTERBERG LIMITS TEST RESULTS

FIGURE B9

SILTY CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BTC-04	7.92	185.78

Date July 2014

WP# 4497-93-01



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Chkd. MEF

Appendix C

Site Photographs



Photograph 1: West culvert approach looking east.



Photograph 2: East culvert approach looking west.



Photograph 3: Existing culvert inlet.



Photograph 4: Existing culvert outlet.

Appendix D

Foundation Comparison

COMPARISON OF CULVERT TYPE / FOUNDATION ALTERNATIVES

Concrete Box Culvert	Arch/Open Culvert on Footings	Arch/Open Culvert on Piles	Sheet Pile Culvert
<p>Advantages:</p> <ul style="list-style-type: none"> i. Typically least costly culvert type. ii. Conventional culvert design. iii. Ease of installation. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Relatively straightforward construction. ii. Less costly than pile or sheet pile options. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. High geotechnical resistance is available for piles driven to very dense soil or 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>Advantages:</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. Installation of piles could continue in freezing weather
<p>Disadvantages:</p> <ul style="list-style-type: none"> i. Excavation to place bedding material will extend below water level. ii. Maintenance of water flow may be an issue and require a sacrificial culvert. iii. Potential impact on fisheries. 	<p>Disadvantages:</p> <ul style="list-style-type: none"> i. Inadequate geotechnical resistance available in native soils. ii. Excavation for footing construction will extend below water level. iii. Potential for settlement in underlying silty clay under new culvert loads. 	<p>Disadvantages:</p> <ul style="list-style-type: none"> i. Higher cost than spread footings. ii. Pile bearing material is very deep. 	<p>Disadvantages:</p> <ul style="list-style-type: none"> i. Large quantity and high cost of sheet piles. ii. Unconventional design.
FEASIBLE	NOT RECOMMENDED	NOT RECOMMENDED	RECOMMENDED

Appendix E

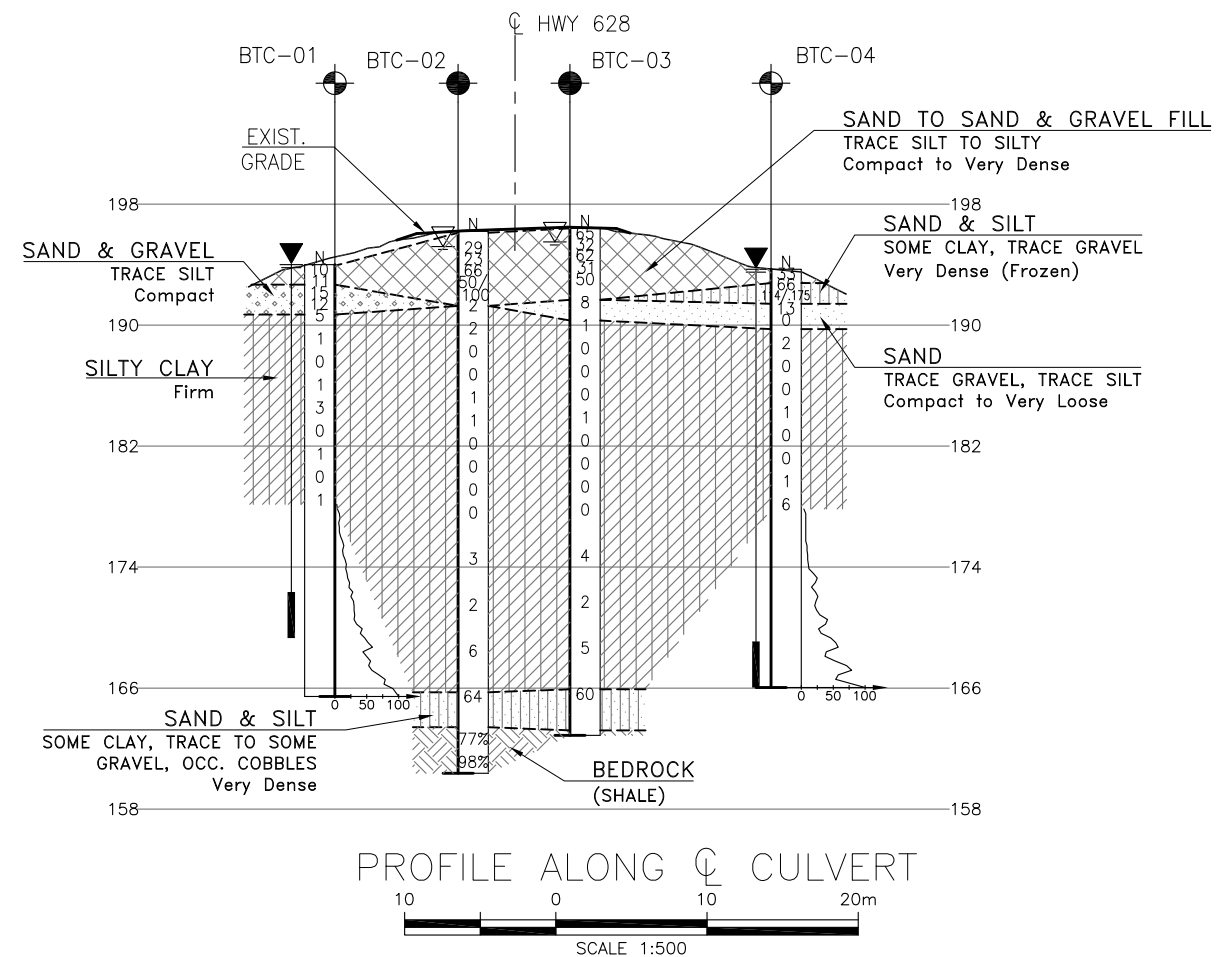
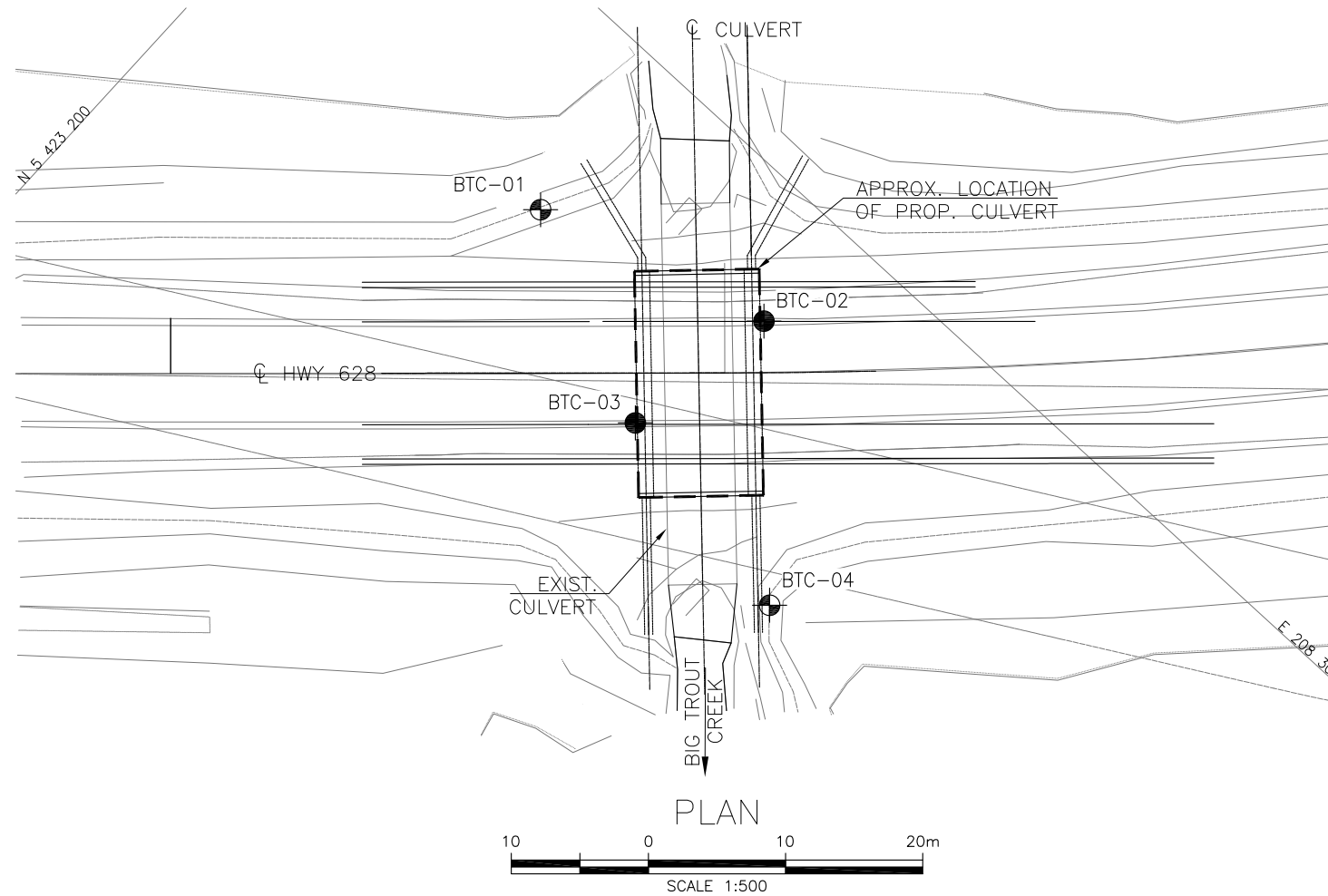
List of SPs and OPSS, and Suggested Text for Selected NSSP

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

- OPSS 501
- OPSS 539
- OPSS 804
- OPSS 902
- OPSS 903
- OPSS.PROV 1010
- SP 105S21

Appendix F

Borehole Locations and Soil Strata Drawing



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








CONT No
WP No 497-93-01

HIGHWAY 628
BIG TROUT CREEK
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA



KEYPLAN

LEGEND

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

[illegible]

-NOTES-

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

GEOCRES No. 52A-181

REVISIONS									
	DATE	BY	DESCRIPTION						
DESIGN	MEF	CHK	MEF	CODE	LOAD	DATE	AUG 2014		
DRAWN	AN	CHK		SITE 48C-192/C1STRUCT		DWG	1		