

**FOUNDATION INVESTIGATION AND DESIGN REPORT
PAGWACHUAN RIVER EAST CULVERT REPLACEMENT
HIGHWAY 11
DISTRICT OF THUNDER BAY, ONTARIO**

G.W.P. 6134-04-00, SITE No. 48E-71/C

Geocres Number: 42F-30

Report to

MMM GROUP LIMITED

Thurber Engineering Ltd.
2010 Winston Park Drive, Suite 103
Oakville, Ontario
L6H 5R7
Phone: (905) 829 8666
Fax: (905) 829 1166

August 28, 2014
File: 19-1351-197

TABLE OF CONTENTS

PART 1 FACTUAL INFORMATION

1	INTRODUCTION.....	1
2	SITE DESCRIPTION.....	1
3	SITE INVESTIGATION AND FIELD TESTING	2
4	LABORATORY TESTING	3
5	DESCRIPTION OF SUBSURFACE CONDITIONS	3
5.1	Pavement Structure	3
5.2	Embankment Fill	4
5.3	Organic Deposits	5
5.4	Silty Clay	5
5.5	Silty Sand to Sand.....	5
5.6	Sand and Gravel.....	6
5.7	Sandy Silt Till.....	6
5.8	Water Levels.....	7
6	MISCELLANEOUS.....	8

PART 2 ENGINEERING DISCUSSION AND RECOMMENDATIONS

7	INTRODUCTION.....	9
8	CULVERT FOUNDATION	9
8.1	General.....	9
8.2	Selection of Culvert Type.....	10
8.3	Steel Sheet Pile Culvert	10
8.3.1	Downdrag.....	11
8.3.2	Sheet Pile Lateral Resistance.....	11
8.4	Frost Cover	12
9	CULVERT BACKFILL AND LATERAL EARTH PRESSURES	12
10	SEISMIC CONSIDERATIONS.....	14
11	SCOUR PROTECTION AND EROSION CONTROL	15
12	EXCAVATION AND GROUNDWATER CONTROL	15
13	CONSTRUCTION CONCERNS	15

14 CLOSURE..... 16

Appendices

Appendix A	Record of Borehole Sheets
Appendix B	Laboratory Test Results
Appendix C	Site Photographs
Appendix D	Comparison of Culvert Type / Foundation Alternatives
Appendix E	List of SPs and OPSS, and Suggested Text for NSSP
Appendix F	Borehole Locations and Soil Strata Drawing

**FOUNDATION INVESTIGATION AND DESIGN REPORT
PAGWACHUAN RIVER EAST CULVERT REPLACEMENT
HIGHWAY 11
DISTRICT OF THUNDER BAY, ONTARIO**

G.W.P. 6134-04-00, SITE No. 48E-71/C

Geocres Number: 42F-30

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 11 over Pagwachuan River East, approximately 80 km east of Longlac, in the District of Thunder Bay, 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 Pagwachuan River East culvert is located approximately 80 km (by highway) east of Longlac, Ontario and about 3 km west of the intersection of Highway 11 and South Pagwachuan Road. Pagwachuan River East is a tributary of the main Pagwachuan River, which runs in a meandering west to east direction, south of Highway 11. At the existing Highway 11 crossing, the tributary flows in a general north to south direction before meeting the main Pagwachuan River.

The existing culvert under the highway embankment consists of a 36.2 m long cast-in-place concrete box culvert with a 3.1 by 3.1 m opening and the highway embankment is approximately 7.0 m high. Preliminary drawings provided by MMM indicate a water level of Elev. 221.3 m at the outlet of the culvert in April 2011.

The surrounding lands are densely treed with grass and shrubs in close proximity to the highway. Photographs in Appendix C show the existing Pagwachuan River East 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. Based on Ontario Geological Survey (OGS) Map s365, titled “Algoma-Cochrane Surficial Geology”, dated 1962, the site is located in an area consisting of lacustrine deposits of varved clay and silt, fine sand, and clayey till ground moraine. The bedrock in the region is early Precambrian and based on OGS Map 2543, titled “Bedrock Geology of Ontario, East-Central Sheet”, dated 1991, the bedrock consists of metasedimentary bedrock (paragneiss and migmatites).

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing for this project was carried out between June 7 and 12, 2014. The investigation comprised drilling and sampling four boreholes identified as Boreholes PCE-01 to PCE-04 along the proposed replacement culvert alignment. Boreholes PCE-01 and PCE-04 were drilled near the proposed inlet and outlet respectively, and Boreholes PCE-02 and PCE-03 were drilled on the west and east sides of the culvert alignment through 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 PCE-02, PCE-03 and PCE-04 were advanced to depths between 12.7 and 14.8 m (Elev. 207.9 to 214.5 m), with drilling carried out using a track mounted CME 55 drill rig with NW casing and wash boring techniques. Borehole PCE-01 was drilled using portable tripod equipment until encountering refusal material at a depth of 4.4 m (Elev. 216.5 m). 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 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. A standpipe piezometer was installed in one borehole to measure groundwater levels. The piezometer was 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
PCE-01	None installed	Borehole sloughed in to 1.2m, backfilled with cuttings to surface.
PCE-02	None installed	Backfilled with bentonite holeplug to 0.6m, concrete to 0.1 m, then asphalt cold patch to surface.
PCE-03	None installed	Backfilled with bentonite holeplug to 0.6m, concrete to 0.1 m, then asphalt cold patch to surface.
PCE-04	5.2 / 215.4	19 mm diameter piezometer installed with bentonite holeplug from 3.3 m 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.

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” drawings 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, overlying deposits of organic sandy silt and peat/topsoil, underlain by silty sand to sand and gravel. Sandy silt till was encountered below the sand and gravel in one borehole. More detailed descriptions of the individual strata are presented below.

5.1 Pavement Structure

A pavement structure comprising 115 to 125 mm of asphalt over sand and gravel fill was encountered in Boreholes PCE-02 and PCE-03 drilled on the highway. The sand and gravel fill extended to depths of 1.4 and 1.8 m (Elev. 226.3 and 225.9 m).

SPT N-values recorded in the sand and gravel fill ranged from 55 to 64 blows per 0.3 m, indicating a very dense relative density. An N-value of 50 blows for 0.15 m penetration

was recorded upon encountering a cobble in Borehole PCE-02. Moisture contents of the sand and gravel fill ranged from 4 to 12%.

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

Gravel %	42 to 64
Sand %	34 to 52
Silt and Clay %	2 to 6

5.2 Embankment Fill

Existing embankment fill was encountered below the pavement structure in Boreholes PCE-02 and PCE-03. The fill consisted of silt and sand over silty clay in Borehole PCE-02, and silty clay enclosing a 0.8 m thick zone of silty sand with wood pieces in Borehole PCE-03. The thickness of the embankment fill was 5.6 and 5.8 m, with a lower boundary encountered at depths of 7.0 and 7.6 m (Elev. 220.7 and 220.1 m).

SPT N-values recorded in the upper 1.5 m of the fill ranged from 11 to 15 blows per 0.3 m penetration, indicating a compact/stiff condition. Below this level, the N-values varied from 2 to 6 blows per 0.3 m, indicating a loose/soft to firm consistency. Moisture contents ranged from 15 to 26% in the silt/sand fill and 23 to 34% in the silty clay fill.

The results of grain size distribution analyses conducted on samples of the fill are presented on the Record of Borehole sheets in Appendix A and on Figures B2 and B3 in Appendix B. The results of Atterberg Limits testing conducted on two samples of the clay fill are presented on the Record of Borehole sheets and plotted on Figure B8 of Appendix B. The results are summarized below.

	<u>Silty Clay Fill</u>	<u>Silt and Sand Fill</u>
Gravel %	0 to 4	6
Sand %	4 to 21	36
Silt %	38 to 49	42
Clay %	26 to 50	16
Liquid Limit %	29 to 40	-
Plastic Limit %	15 to 19	-

5.3 Organic Deposits

Organic deposits primarily consisting of dark brown silt to sandy silt, some clay to clayey, were encountered at the ground surface in Boreholes PCE-01 and PCE-04, and beneath the existing embankment fill in Boreholes PCE-02 and PCE-03. These deposits contained peat inclusions and wood pieces. Locally, a 0.6 m thick layer of brown sand with trace organics was encountered within the organic silt in Borehole PCE-01, and a 0.9 m thick layer of peat and clayey silt was encountered in Borehole PCE-04.

The thickness of the organic deposits ranged from 1.8 to 2.4 m with a lower boundary encountered at depths varying from 1.8 to 9.4 m (Elev. 218.2 to 219.1 m).

SPT N-values recorded in the organic deposits ranged from 1 to 9 blows per 0.3 m penetration, indicating a very soft to stiff consistency, typically soft to firm. Moisture contents ranged from 16 to 80%, locally up to 126% in the peat and clayey silt layer.

Three samples of the organic silt 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 B4 of Appendix B.

Gravel %	0 to 2
Sand %	24 to 40
Silt %	42 to 51
Clay %	16 to 28

5.4 Silty Clay

A localized 1.0 m thick layer of silty clay with trace sand was encountered beneath the peat and clayey silt in Borehole PCE-04. The lower boundary of the silty clay was encountered at a depth of 3.4 m (Elev. 217.2 m).

A single SPT N-value of 4 blows per 0.3 m penetration was recorded in the silty clay. In situ shear vane testing indicated an undrained shear strength of 48 kPa. Based on this data, the consistency of the silty clay is generally firm. The measured sensitivity of 7, from remoulded field vane testing, indicates that the silty clay is sensitive. The measured moisture contents varied between 26 and 28%.

5.5 Silty Sand to Sand

A layer ranging in composition from silty sand with trace gravel and trace clay to sand with some gravel, some cobbles and trace silt was encountered beneath the organic silt in Boreholes PCE-01 and PCE-02. This deposit became gravelly with depth in Borehole

PCE-02. Both boreholes were terminated within this deposit at depth of 4.4 and 14.8 m (Elev. 216.5 to 212.9 m).

SPT N-values ranged from 12 to 19 blows per 0.3 m penetration in the upper 2.0 m of this layer, indicating a compact condition. N-values of 73 blows per 0.3 m to 100 blows per 0.1 m of penetration were recorded below this level, indicating a very dense relative density. Moisture contents varied between 9 and 25%.

Two samples of the silty sand to sand 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 B5 of Appendix B.

Gravel %	4 to 15
Sand %	67 to 68
Silt and Clay %	18 to 28

5.6 Sand and Gravel

A deposit of sand and gravel with trace to some silt and occasional cobbles and pockets of clay and silt was encountered beneath the organic silt and silty clay layer in Boreholes PCE-03 and PCE-04. The sand and gravel deposit had a thickness of 1.5 m and a lower boundary at 4.9 m depth (Elev. 215.7 m) in Borehole PCE-04. Borehole PCE-03 was terminated within the sand and gravel deposit at a depth of 13.2 m (Elev. 214.5 m).

SPT N-values recorded in the sand and gravel ranged from 51 blows per 0.3 m penetration to 50 blows per 0.075 m of penetration, indicating a very dense relative density. Moisture contents varied between 6 and 15%.

One sample of the sand and gravel was selected for laboratory grain size analysis testing. The results of the test are summarized below and are presented on the corresponding Record of Borehole sheet included in Appendix A. The grain size distribution curve for the sample is plotted on Figure B6 of Appendix B.

Gravel %	46
Sand %	47
Silt and Clay %	7

5.7 Sandy Silt Till

A deposit of sandy silt till with some clay (to clayey) and trace gravel, cobbles and boulders was encountered beneath the sand and gravel deposit at 4.9 m depth (Elev. 215.7)

in Borehole PCE-04. The borehole was terminated within this layer at a depth of 12.7 m (Elev. 207.9 m).

SPT N-values recorded in the sandy silt till ranged from 113 blows per 0.3 m penetration to 50 blows per 0.1 m of penetration, indicating a very dense relative density. Moisture contents measured in the sandy silt till were between 9 and 12%.

One sample of the sandy silt till was selected for laboratory grain size analysis testing. The results of the test are summarized below and are presented on the corresponding Record of Borehole sheet included in Appendix A. The grain size distribution curve for the sample is plotted on Figure B7 of Appendix B.

Gravel %	3
Sand %	29
Silt %	47
Clay %	21

5.8 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 5.1 - Groundwater Level Measurements

Borehole	Date	Groundwater Level		Comment
		Depth (m)	Elevation	
PCE-02	June 11, 2014	6.4	221.3	Open Borehole
PCE-04	June 11, 2014	-0.8*	221.4	In piezometer
	June 12, 2014	-0.8*	221.4	

* indicates artesian groundwater level above the ground surface

The water levels recorded above the ground surface are indicative of artesian pressures present in the sand and gravel layer below the silty clay.

The recorded groundwater levels are considered short-term readings and seasonal fluctuations of the groundwater level are to be expected. Higher water levels may occur, 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 the Pagwachuan River East, which is shown on the preliminary drawings provided by MMM to be at Elev. 221.3 at the outlet in April 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 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 Mr. Matthew Whalen of Thurber. Overall supervision of the field program was conducted by Mr. Mark Farrant, P. Eng.

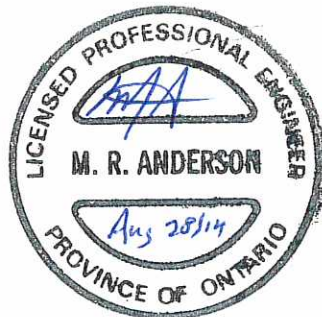
Interpretation of the data and preparation of this report were carried out by Mr. Michael Eastman and Mr. Murray R. Anderson, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd

Michael Eastman, M.A.Sc.
Geotechnical Engineer-in-Training

Michael Eastman Aug 28/14

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



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



**FOUNDATION INVESTIGATION AND DESIGN REPORT
PAGWACHUAN RIVER EAST CULVERT REPLACEMENT
HIGHWAY 11
DISTRICT OF THUNDER BAY, ONTARIO**

G.W.P. 6134-04-00, SITE No. 48E-71/C

Geocres Number: 42F-30

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 Pagwachuan River East culvert on Highway 11 in the District of Thunder Bay, Ontario.

The existing Pagwachuan River Tributary culvert consists of a 36.2 m long cast-in-place concrete box culvert with a 3.1 by 3.1 m opening. The river flows in a north to south direction at the site. The existing highway embankment at the crossing is approximately 7.0 m high.

The preliminary GA drawing (July 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 will be 37.0 m of which 22.5 m will be capped. The top of the river stone substrate will be at approximate Elev. 220.9 to 220.1 m. The clear height within the culvert will be approximately 4.1 m, and the fill height above the concrete panels will be approximately 2.5 m. The finished road grade will be near elevation 227.7 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 culvert site consisted of existing embankment fill, overlying 1.8 to 2.4 m of organic deposits, typically underlain by native silty sand to sand and gravel, locally sandy silt till.

Groundwater levels measured in a standpipe piezometer installed at the site and in an open borehole ranged from Elev. 221.3 to 221.4 m. The preliminary GA drawing indicates a water level at Elev. 221.3 m in Pagwachuan River East on April 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 inorganic silty sand to sand and gravel, or an arch/open footing culvert supported on spread footings bearing on the native silty sand to sand and gravel. 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

It is anticipated that sheet piles driven for culvert installation at this site will encounter refusal at approximate Elev. 213.5 in the very dense silty sand, sand and gravel and silty sand till deposits. The axial geotechnical resistances recommended for design of EZ88 sheet piles driven to Elev. 213.5 are as follows:

Factored Geotechnical Resistance at ULS = 500 kN per lineal meter width

Geotechnical Resistance at SLS = 400 kN per lineal metre width

The sheet piles will derive resistance through both frictional resistance along the sides of the sheet piles and end-bearing at the pile tip. As the sheet piles will derive resistance through friction along the pile walls, tip protection should not be provided.

Steel sheet pile installation should be in accordance with OPSS 903. The appropriate pile driving note is “SHEET PILES TO BE DRIVEN TO EL”.

Cobbles were encountered in the highway embankment fill and rock fill is present on the embankment slope at the culvert. These obstructions may impede pile driving and if encountered, will need to be removed in order to drive the sheet piles.

Cobbles and boulders may also be encountered within the underlying silty sand, sand and gravel and silty sand till deposits. Care must be taken not to damage the sheet piles by

overdriving them if refusal is encountered in the very dense soils, 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.

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 8.1 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)

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.

Table 8.1 – 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	227.7 to 226.3	0.28	0.44	3.5	-	5,000	21	Granular Fill
	226.3 to 223.6	0.35	0.52	2.9	-	2,500	20	Embankment Fill
	223.6 to 221.3	0.35	0.52	2.9	3,000	-	20	Embankment Fill
	221.3 to 220.7	0.35	0.52	2.9	3,000	-	10	Embankment Fill
	220.7 to 218.3	0.38	0.55	2.6	-	1,000	9	Organic Silt
	218.3 to 217.5	0.35	0.52	2.9	2,000	-	9	Silty Clay
	217.5 to 216.0	0.28	-	3.5	-	6,000	11	Sand
	216.0 to 213.5	0.24	0.38	4.2	-	10,000	11	Sand or Till
East Sheet Pile Wall	227.7 to 225.9	0.28	0.44	3.5	-	5,000	21	Granular Fill
	225.9 to 221.3	0.35	0.52	2.9	3,000	-	20	Embankment Fill
	221.3 to 220.1	0.35	0.52	2.9	3,000	-	10	Embankment Fill
	220.1 to 218.3	0.38	0.55	2.6	-	1,000	9	Organic Silt
	218.3 to 216.0	0.28	-	3.5	-	6,000	11	Sand and Gravel
	216.0 to 213.5	0.24	0.38	4.2	-	10,000	11	Sand and Gravel

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

8.4 Frost Cover

The design depth of frost penetration at this site is 2.5 m. The base of all foundation elements must be provided with a minimum of 2.5 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 0.019g

The soil profile type at this site has been classified as Type I. Therefore, according to Clause 4.4.6 of the CHBDC, a Site Coefficient “S” (ground motion amplification factor) of 1.0 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 Sand/Gravel $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	Existing Embankment Fill $\phi = 29^\circ$ $\gamma = 10 \text{ kN/m}^3$
Active (K_{AE})*	0.28	0.32	0.36
Passive (K_{PE})	3.70	3.20	2.90
At Rest (K_{OE})**	0.45	0.50	0.54

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

** After Woods

The compact to very dense cohesionless 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 the 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 sheet piles may encounter refusal at varying depths above the design tip elevation in the very dense sand/gravel/till or on possible cobbles or boulders.
- 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

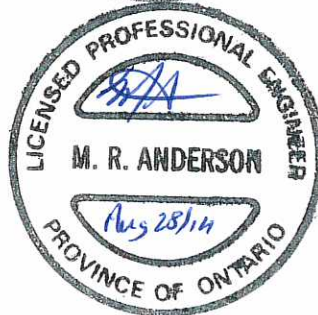
Engineering analysis and preparation of the report were carried out by Mr. Stephen Peters, P.Eng. and Mr. Murray Anderson, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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


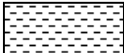



ROCK WEATHERING CLASSIFICATION

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 (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.

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		W P W W L				
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE			WATER CONTENT (%)
220.9 0.0	<p>ORGANIC SILT, trace peat, trace to some sand, trace gravel Very Soft to Soft Dark Brown Wet</p> <p>SAND, some silt, some gravel, trace organics Loose Brown Wet</p> <p>ORGANIC SILT, sandy, some clay, trace gravel, trace wood Firm Dark Brown Wet</p> <p>Silty SAND, trace gravel, trace clay Compact Brown Wet</p>		1	SS	2								2 40 42 1	
220.3 0.6			2	SS	5									4 68 28 (SI+CL)
219.7 1.2			3	SS	5									
219.1 1.8			4	SS	12									
			5	SS	14									
			6	SS	17									
216.5 4.4			7	SS	100/									
	END OF BOREHOLE AT 4.4m. BOREHOLE SLOUGHED IN TO 1.2m, BACKFILLED WITH CUTTINGS TO SURFACE.													

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No PCE-02

1 OF 2

METRIC

WP# 6134-04-01 LOCATION Pagwachuan River East Culvert N 5 514 925.1 E 203 454.3 ORIGINATED BY MNW
 HWY 11 BOREHOLE TYPE NW Casing & Wash Boring COMPILED BY AN
 DATUM Geodetic DATE 2014.06.11 - 2014.06.11 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 (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	W _P W W _L	WATER CONTENT (%)						
227.7																
0.0	ASPHALT: (115mm)															
0.1	SAND and GRAVEL, trace silt Very Dense Dark Brown Moist (FILL)		1	SS	64		227								64 34 2 (SI+CL)	
			2	SS	50/ 0.150											
226.3	Cobble at 1.1m															
1.4	SILT and SAND, some clay to clayey, trace gravel Compact to Loose Brown Moist (FILL)		3	SS	15		226									
			4	SS	11		225									
			5	SS	4		224								6 36 42 16	
223.6			6	SS	5		223									
4.1	Silty CLAY, trace sand, trace gravel, trace oxide lenses Firm Brown (FILL)															
			7	SS	5		222								0 4 46 50	
							221									
220.7			8	SS	5		220									
7.0	ORGANIC SILT, sandy, some clay to clayey, trace peat, trace wood pieces Firm Dark Brown Moist															
			9	SS	6		219								0 31 51 18	
218.3							218									
9.4	SAND, some gravel, some silt, with cobbles Compact Brown															

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No PCE-02

2 OF 2

METRIC

WP# 6134-04-01 LOCATION Pagwachuan River East Culvert N 5 514 925.1 E 203 454.3 ORIGINATED BY MNW
 HWY 11 BOREHOLE TYPE NW Casing & Wash Boring COMPILED BY AN
 DATUM Geodetic DATE 2014.06.11 - 2014.06.11 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 (%)				
								20	40	60	80	100	W _P	W	W _L		
	Continued From Previous Page																
212.9 14.8	SAND , some gravel, some silt, with cobbles Compact Brown Wet 																

RECORD OF BOREHOLE No PCE-03

1 OF 2

METRIC

WP# 6134-04-01 LOCATION Pagwachuan River East Culvert N 5 514 920.4 E 203 463.0 ORIGINATED BY MW
HWY 11 BOREHOLE TYPE NW Casing & Wash Boring COMPILED BY AN
DATUM Geodetic DATE 2014.06.11 - 2014.06.12 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			WATER CONTENT (%)						
						○ UNCONFINED + FIELD VANE											
						● QUICK TRIAXIAL × LAB VANE											
227.7							20 40 60 80 100	20 40 60								GR SA SI CL	
0.0	ASPHALT: (125mm)																
0.1	SAND and GRAVEL, trace silt Very Dense Brown/Dark brown Damp (FILL)		1	SS	62											42 52 6 (SI+CL)	
			2	SS	55												
225.9																	
1.8	Silty CLAY, some sand, trace gravel, trace till pockets Stiff to Soft Brown (FILL)		3	SS	14												
			4	SS	12											1 17 38 44	
			5	SS	5												
	Trace oxides																
223.6			6	SS	2												
4.1	Silty SAND, trace gravel, trace wood pieces Loose Light Brown Moist (FILL)																
222.8																	
4.9	Silty CLAY, some sand, trace gravel, trace sand and gravel pockets Soft to Firm Brown (FILL)		7	SS	3											4 21 49 26	
			8	SS	6												
220.1																	
7.6	ORGANIC SILT, sandy, some clay to clayey, trace wood pieces Stiff Dark Brown Moist		9	SS	9												
218.3																	
9.4	SAND and GRAVEL, trace silt, trace pockets of clay and silt Very Dense																

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

METRIC[illegible]

RECORD OF BOREHOLE No PCE-04

1 OF 2

METRIC

WP# 6134-04-01 LOCATION Pagwachuan River East Culvert N 5 514 901.5 E 203 449.2 ORIGINATED BY MNW
 HWY 11 BOREHOLE TYPE NW Casing & Wash Boring COMPILED BY AB
 DATUM Geodetic DATE 2014.06.07 - 2014.06.07 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 (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
220.6								20 40 60 80 100						
0.0	ORGANIC SILT , sandy, some clay to clayey, trace peat Very Soft to Soft Brown Wet		1	SS	2		220							0 24 48 28
			2	SS	2									
219.1							219							
1.5	PEAT and Clayey SILT , trace wood Very Soft Dark Brown		3	SS	1									125 82
218.2														
2.4	Silty CLAY , trace sand, trace oxides Soft to Firm Brown		4	SS	4		218							7.0
217.2			5	SS	9									
3.4	SAND and GRAVEL , trace to some silt, trace cobbles Compact Light Brown Wet						217							
215.7			6	SS	50/ 0.100		216							3 29 47 21
4.9														
	Sandy SILT , some clay to clayey, trace gravel, cobbles and boulders Very Dense Dark Greyish Brown Moist (TILL)		7	SS	50/ 0.100		215							
							214							
			8	SS	113		213							
							212							
			9	SS	50/ 0.100		211							

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No PCE-04

2 OF 2

METRIC

WP# 6134-04-01 LOCATION Pagwachuan River East Culvert N 5 514 901.5 E 203 449.2 ORIGINATED BY MNW
HWY 11 BOREHOLE TYPE NW Casing & Wash Boring COMPILED BY AB
DATUM Geodetic DATE 2014.06.07 - 2014.06.07 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 (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%) W _p W W _L				
	Continued From Previous Page															
			10	SS	50/ 0.100		210									
							209									
207.9			11	SS	91/ 0.200		208									
12.7	<p>END OF BOREHOLE AT 12.7m. ARTESIAN WATER ENCOUNTERED AT 3.4m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.8m slotted screen.</p> <p>WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2014.06.11 0.8* 221.4 2014.06.12 0.8* 221.4</p> <p>*Measured above ground level.</p>															

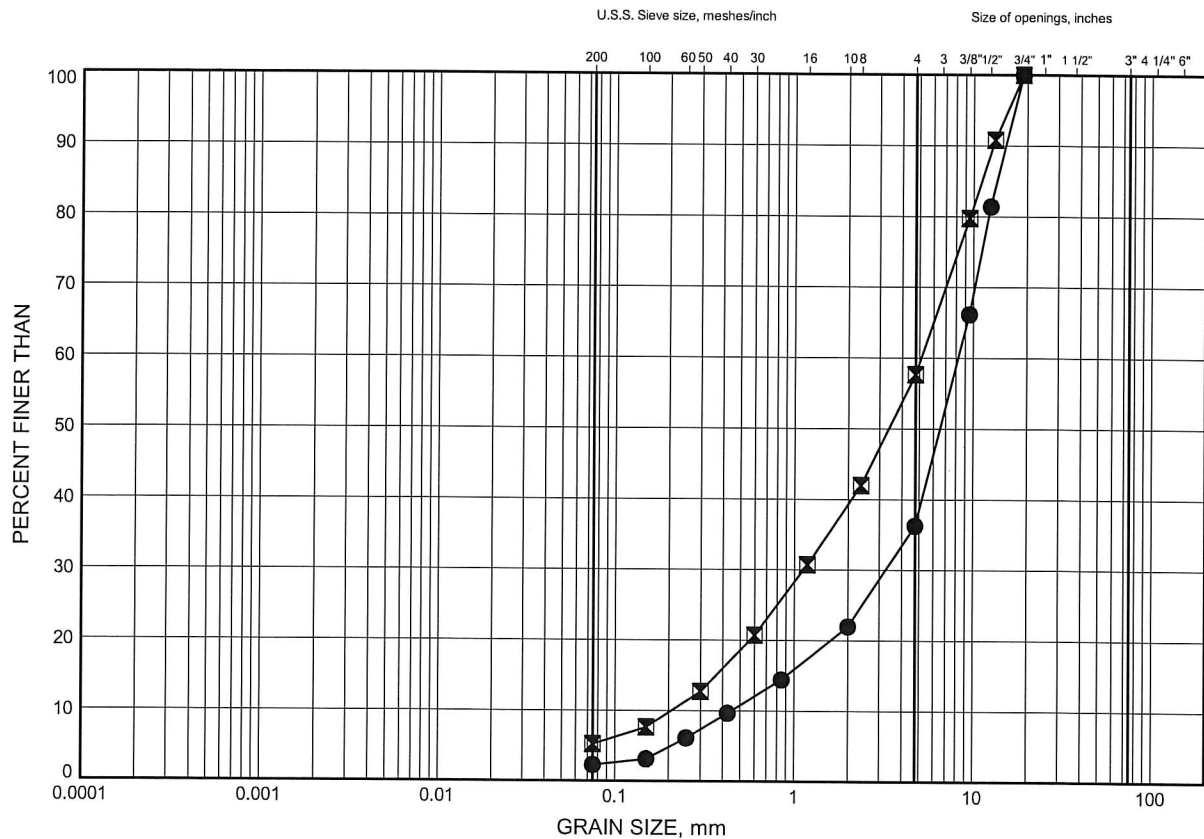
Appendix B

Laboratory Test Results

Pagwachuan River East Culvert GRAIN SIZE DISTRIBUTION

FIGURE B1

SAND & GRAVEL FILL



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

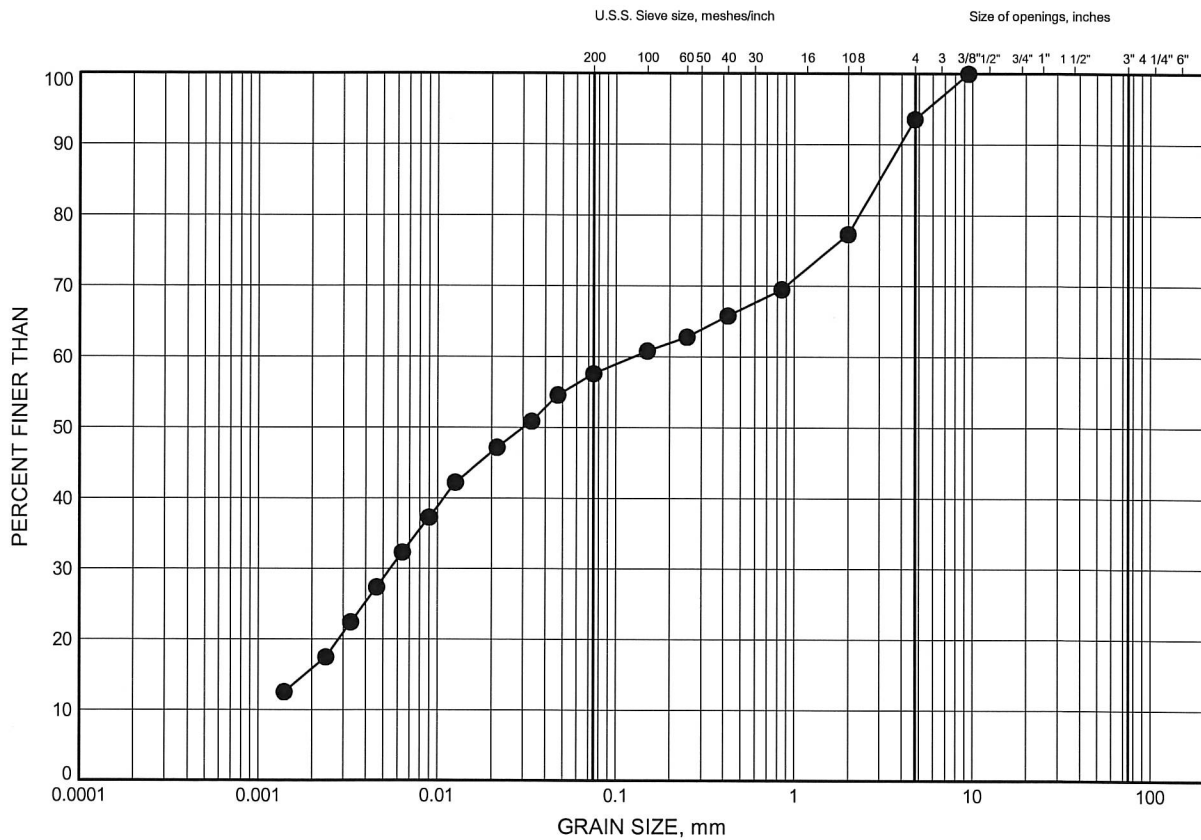
LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PCE-02	1.07	226.63
■	PCE-03	0.43	227.27

Pagwachuan River East Culvert
GRAIN SIZE DISTRIBUTION

FIGURE B2

SILT & SAND FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PCE-02	3.35	224.35

Date August 2014
WP# 6134-04-01

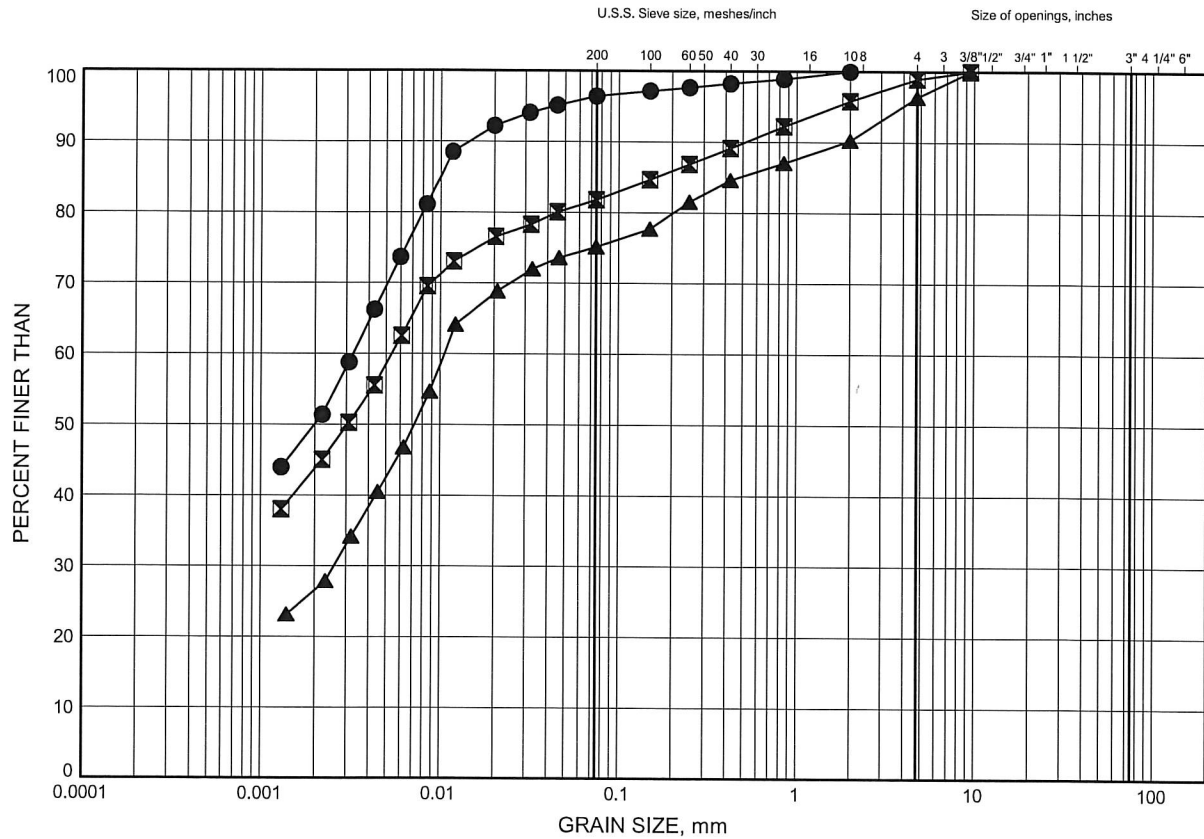


Prep'd AN
Chkd. MKE

Pagwachuan River East Culvert GRAIN SIZE DISTRIBUTION

FIGURE B3

SILTY CLAY FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PCE-02	5.64	222.06
■	PCE-03	2.59	225.11
▲	PCE-03	5.64	222.06

GRAIN SIZE DIST. - THURBER 1197.GPJ 7/31/14

Date July 2014
WP# 6134-04-01

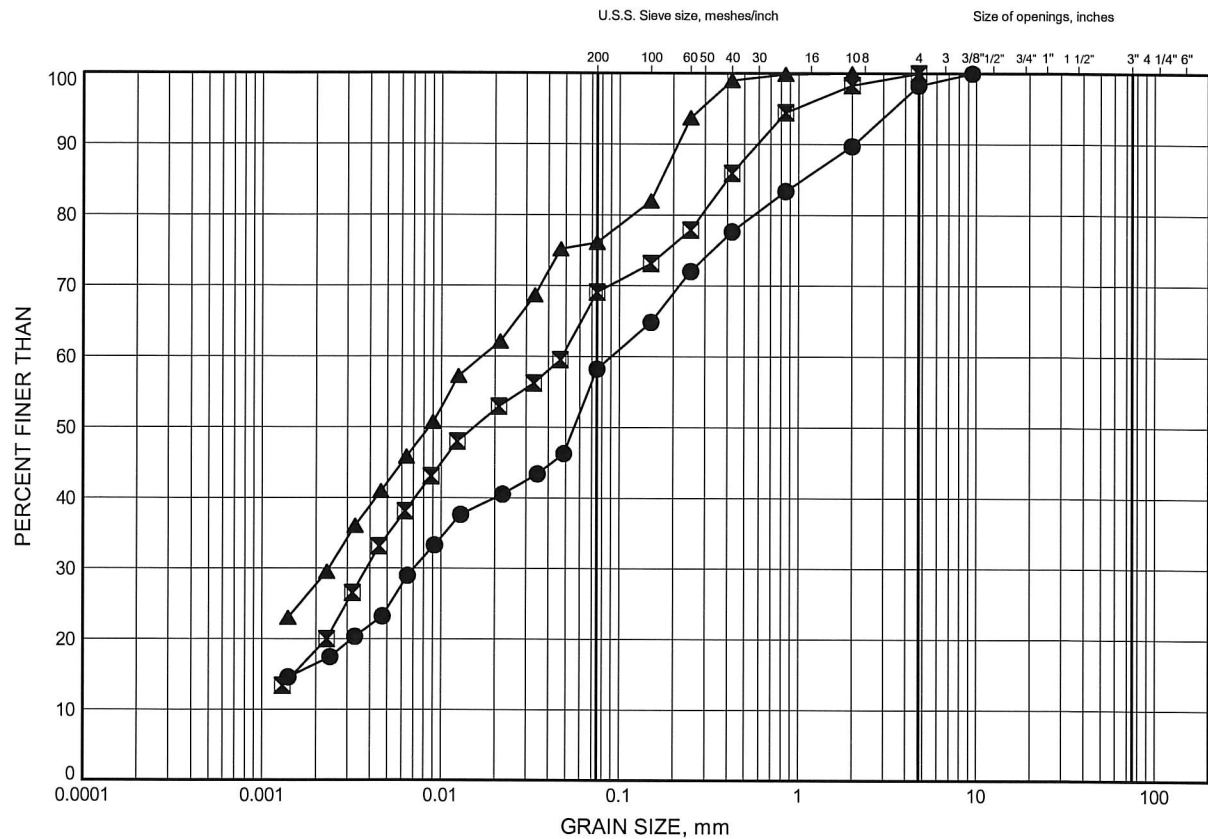


Prep'd AN
Chkd. MKE

Pagwachuan River East Culvert
GRAIN SIZE DISTRIBUTION

FIGURE B4

ORGANIC SANDY SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PCE-01	1.68	219.22
⊠	PCE-02	8.65	219.05
▲	PCE-04	1.14	219.46

GRAIN SIZE DISTRIBUTION - THURBER 1197.GPJ 8/8/14

Date August 2014
WP# 6134-04-01

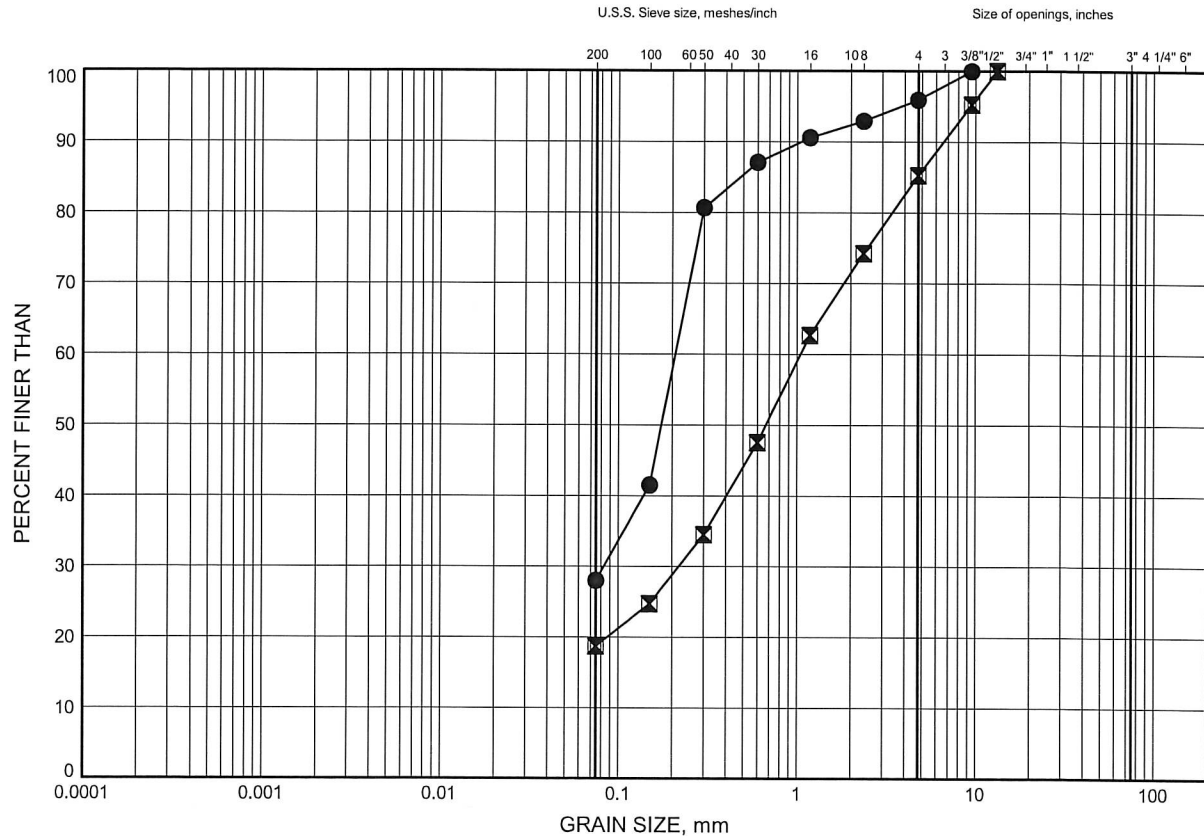


Prep'd AN
Chkd. MKE

Pagwachuan River East Culvert
GRAIN SIZE DISTRIBUTION

FIGURE B5

SILTY SAND to SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PCE-01	2.13	218.77
⊠	PCE-02	11.89	215.81

Date July 2014
WP# 6134-04-01

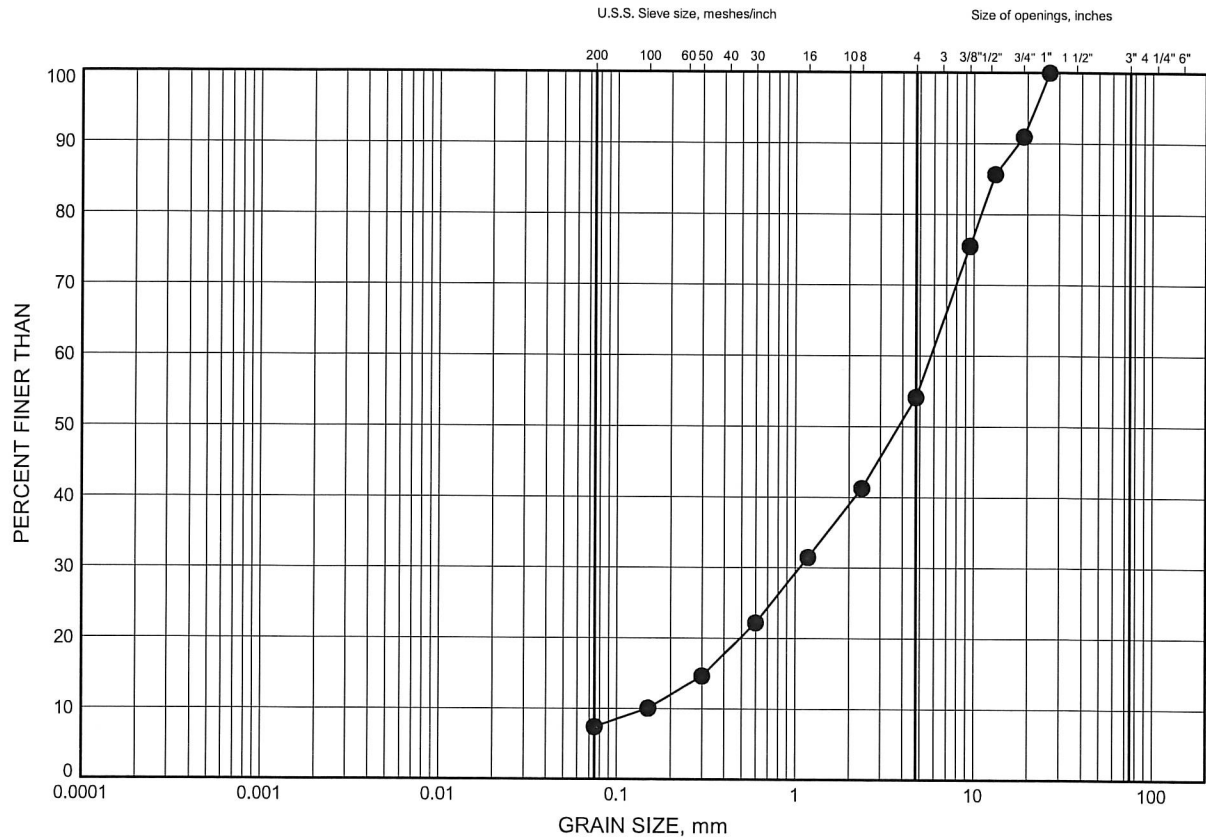


Prep'd AN
Chkd. MKE

Pagwachuan River East Culvert
GRAIN SIZE DISTRIBUTION

FIGURE B6

SAND & GRAVEL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PCE-03	11.70	216.00

GRAIN SIZE DIST. - ION - THURBER 1197.GPJ 7/31/14

Date July 2014
WP# 6134-04-01

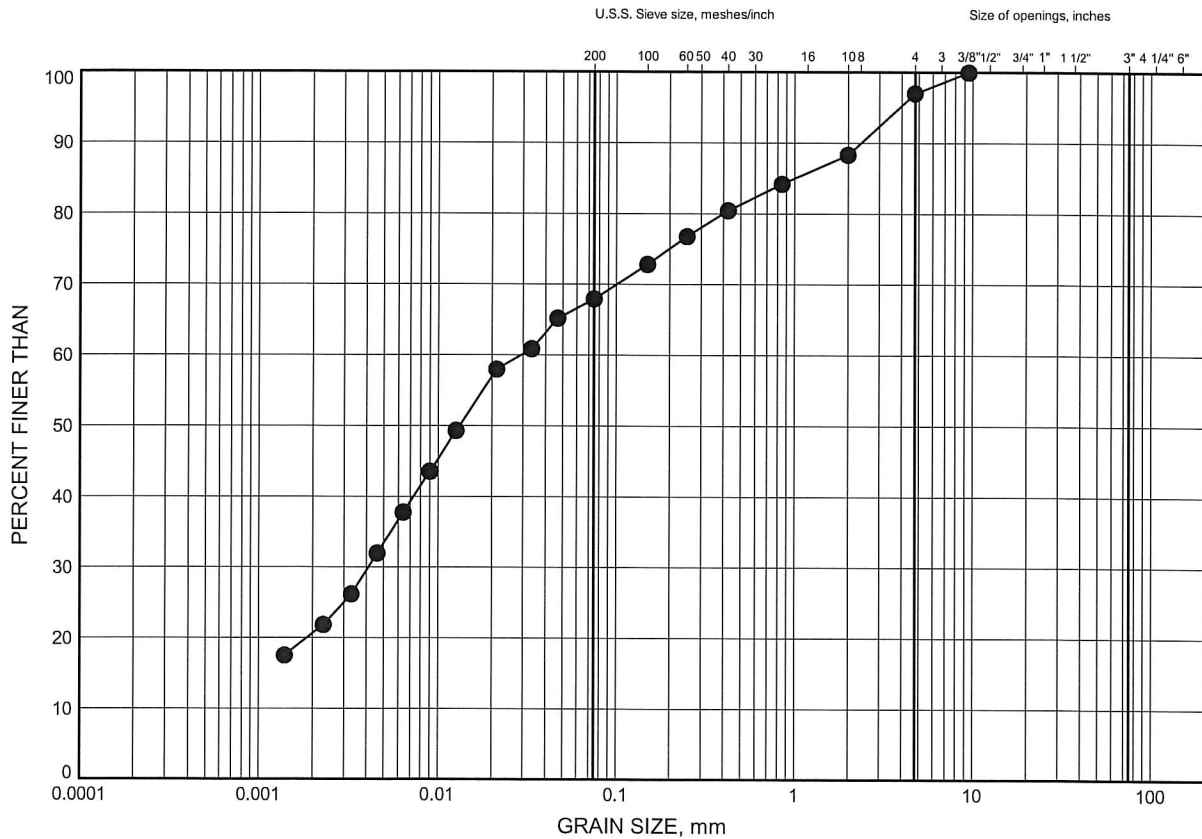


Prep'd AN
Chkd. MKE

Pagwachuan River East Culvert GRAIN SIZE DISTRIBUTION

FIGURE B7

SANDY SILT TILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PCE-04	6.22	214.38

Date July 2014
WP# 6134-04-01

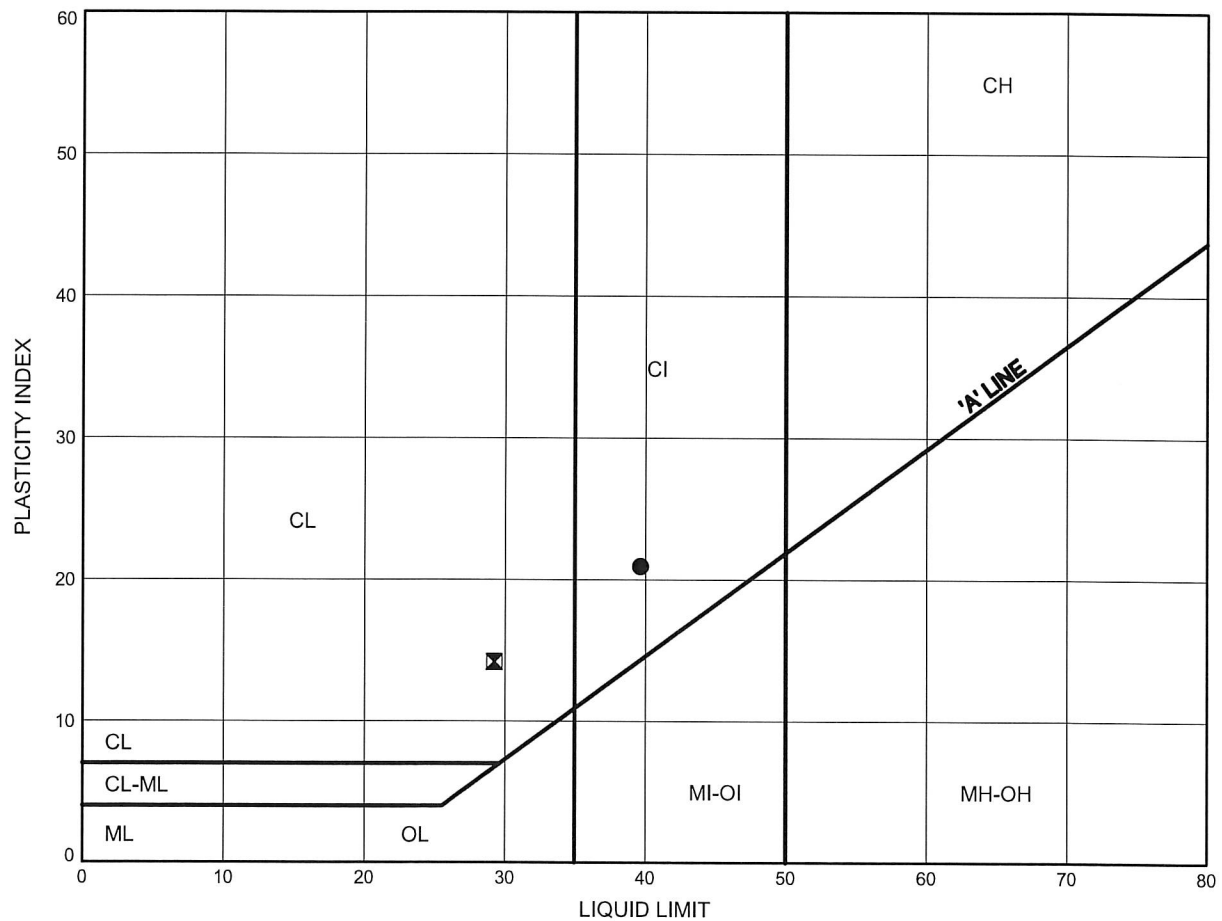


Prep'd AN
Chkd. MKE

Pagwachuan River East Culvert
ATTERBERG LIMITS TEST RESULTS

FIGURE B8

SILTY CLAY FILL



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PCE-02	5.64	222.06
⊠	PCE-03	5.64	222.06

Appendix C

Site Photographs



Photograph 1 – South end of existing culvert



Photograph 2 – South end of culvert, looking west at culvert outlet



Photograph 3 – North end of existing culvert



Photograph 4 – North end of culvert, looking east at culvert inlet

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. 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. Relatively deep excavation in existing embankment requiring significant roadway protection system. ii. Excavation to place bedding material will extend below water level. iii. Maintenance of water flow may be an issue and require a sacrificial culvert. iv. Potential impact on fisheries. 	<p>Disadvantages:</p> <ul style="list-style-type: none"> i. Relatively deep excavation in existing embankment requiring significant roadway protection system. ii. Excavation for footing construction will extend through organic soils below water level. iii. Potential impact on fisheries. 	<p>Disadvantages:</p> <ul style="list-style-type: none"> i. Higher cost than spread footings. ii. Relatively deep excavation in existing embankment requiring significant roadway protection system. 	<p>Disadvantages:</p> <ul style="list-style-type: none"> i. Large quantity and high cost of sheet piles. ii. Unconventional design.
FEASIBLE	FEASIBLE	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:

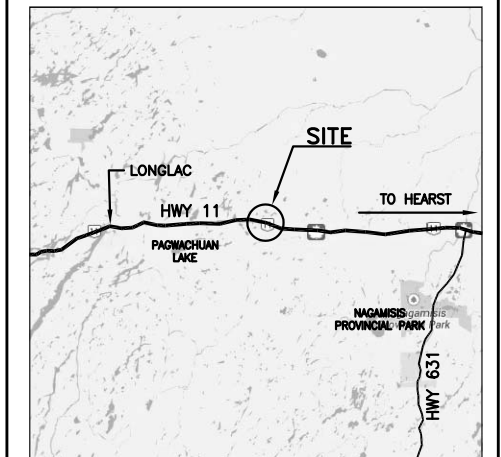
- OPSS 501
- OPSS 539
- OPSS 804
- OPSS 902
- OPSS 903
- OPSS.PROV 1010
- SP 105S21

Appendix F





Borehole Locations and Soil Strata Drawing

The image contains two circular professional engineer stamps from the Province of Ontario. The top stamp is for M. R. Anderson, dated Aug 28/14. The bottom stamp is for P. K. Chatterji, dated Aug 28/14. Both stamps include the text 'LICENSED PROFESSIONAL ENGINEER' and 'PROVINCE OF ONTARIO'.

SHEET
43



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 During Drilling
	Water Level In Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
PCE-01	220.9	5 514 942.1	203 469.0
PCE-02	227.7	5 514 925.1	203 454.3
PCE-03	227.7	5 514 920.4	203 463.0
PCE-04	220.6	5 514 901.5	203 449.2

- 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.

[illegible]