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

G.W.P. 6134-04-00, SITE No. 48E-85/C

Geocres Number: 42F-29

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 11 over Pagwachuan River West, located 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 West culvert is located approximately 80 km (by highway) east of Longlac, Ontario and about 6 km west of the intersection of Highway 11 and South Pagwachuan Road. Pagwachuan River West 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 northeast to southwest direction for approximately 3 km before meeting the main Pagwachuan River.

The culvert under the existing highway embankment consists of a 26 m long by 4.2 m wide, twin-cell timber culvert and the highway embankment is approximately 3 m high. Preliminary drawings provided by MMM indicate a water level of Elev. 224.3 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 West 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 April 8 and 28, 2014. The investigation comprised drilling and sampling four boreholes identified as Boreholes PWC-01 to PWC-04 along the proposed replacement culvert alignment. Boreholes PWC-01 and PWC-04 were drilled near the proposed inlet and outlet respectively, and Boreholes PWC-02 and PWC-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 PWC-02 and PWC-03 were advanced to depths of 21.6 and 30.6 m (Elev. 205.4 and 196.4 m) respectively, with drilling carried out using a truck mounted drill rig with NW casing and wash boring techniques. Boreholes PWC-01 and PWC-04 were drilled using portable tripod equipment and wash boring to advance NW casing until encountering refusal at depths of 12.8 and 11.0 m respectively. Dynamic Cone Penetration Tests (DCPTs) were conducted from the bottom of Boreholes PWC-01 and PWC-04 to advance to total depths of 14.0 and 11.5 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 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
PWC-01	12.5 / 212.5	19 mm diameter piezometer installed with filter sand from 12.5 m to 9.0 m, then bentonite holeplug to surface.
PWC-02	None installed	Backfilled with bentonite holeplug to 0.1m, then sand to surface.
PWC-03	None installed	Backfilled with bentonite holeplug to 0.1 m, then sand and gravel to surface.
PWC-04	10.8 / 214.7	19 mm diameter piezometer installed with filter sand from 10.8 m to 7.0 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.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

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

In general, the subsurface stratigraphy encountered at the culvert site consisted of existing embankment fill, overlying native deposits comprising silt, a thick deposit of silty clay, and layers of gravelly sand and sandy silt till. 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 PWC-01 and PWC-04. The topsoil layer was 100 to 125 mm thick at these locations. The thickness of the topsoil layer may vary between and beyond the borehole locations.

5.2 Fill

Cohesionless embankment fill consisting of sand and gravel was encountered at the ground surface in Boreholes PWC-02 and PWC-03, which were drilled through the highway shoulders. The fill contains trace to some silt and some cobbles. The base of the fill was encountered at 3.3 to 3.4 m depth (Elev. 223.6 to 223.7 m).

SPT N-values recorded in the sand and gravel fill typically ranged from 65 blows for 0.3 m penetration to 50 blows for 0.125 m penetration, indicating a very dense condition and/or possible cobbles. An N-value of 20 blows for 0.3 m penetration (compact condition) was also recorded near the base of the fill in Borehole PWC-03. Moisture contents of the sand and gravel fill ranged from 8% to 22%.

Two samples of the sand and gravel 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 %	49 to 51
Sand %	35 to 43
Silt and Clay %	6 to 16

Underlying the topsoil in Boreholes PWC-01 and PWC-04, a layer of fill was encountered, which ranged in composition from silty sand to clayey silt. Trace gravel and organic material was noted in the fill. The thickness of the silty sand to clayey silt fill ranged from 0.4 to 0.8 m, with the lower boundary at a depth of 0.5 to 0.9 m (Elev. 225.0 to 224.1 m).

SPT N-values recorded in the silty sand to clayey silt fill were 4 and 11 blows for 0.3 m penetration respectively, indicating that the silty sand fill is loose and the clayey silt fill is stiff. The measured moisture contents were 31% and 25% respectively.

5.3 Silt

Native deposits of silt were encountered below the fill in all of the boreholes. In Borehole PWC-04, a 1.0 m thick layer of sandy silt with trace clay was encountered to a depth of 1.5 m (Elev. 224.0 m). An SPT N-value of 16 blows for 0.3 m penetration was recorded in the sandy silt, indicating that the material is compact. The moisture content of the sandy silt was measured at 20%.

Underlying the fill in Boreholes PWC-01 to PWC-03, and the sandy silt in PWC-04, a cohesive silt layer ranging from some clay to clayey was encountered. The cohesive silt layer ranged in thickness from 1.3 to 2.7 m, and the lower boundary was at depths of 3.0 to 6.1 m (Elev. 222.4 to 220.9 m).

SPT N-values recorded in the cohesive silt ranged between 5 and 16 blows for 0.3 m penetration, indicating a firm to very stiff condition. In situ shear vane tests conducted in the cohesive silt indicated undrained shear strengths of 53 to 62 kPa, indicating a stiff condition.

Moisture contents in the cohesive silt between 18% and 41% were measured.

Grain size analysis testing was undertaken on four samples of the deposit. The results are presented on the Record of Borehole sheets included in Appendix A and on Figure B2 of Appendix B. The results are are summarized below.

Gravel%	0
Sand%	0
Silt%	63 to 86
Clay%	14 to 37

5.4 Silty Clay

Native silty clay was encountered below the silt deposit in all of the boreholes. The silty clay was typically brown to grey with trace sand and trace gravel.

The silty clay layer was 4.8 to 9.2 m thick, with a lower boundary encountered at depths of 10.5 to 13.3 m (Elev. 216.1 to 212.8 m).

SPT N-values recorded in the silty clay ranged from 0 to 24 blows for 0.3 m penetration, typically less than 3. In situ shear vane testing indicated undrained shear strengths in the order of 22 to 44 kPa. Based on this data, the consistency of the silty clay is generally soft to firm.

The moisture content of the silty clay ranged from 18% to 60%, typically 20% to 40%.

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 B3 and B4 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 B7 and B8 of Appendix B. The results are are summarized below.

Gravel%	0 to 2
Sand%	0 to 16
Silt%	23 to 54
Clay%	36 to 77
Liquid Limit	31 to 75
Plastic Limit	15 to 27

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

5.5 Gravelly Sand to Sand

Underlying the silty clay deposit, the boreholes encountered interbedded deposits of sand and sandy silt till.

The sand deposit was encountered in all of the boreholes and ranged in composition from gravelly sand with some silt and occasional cobbles to sand with trace silt and trace gravel. Where fully penetrated in Boreholes PWC-02 and PWC-03, an upper sand layer was encountered with a thickness of 1.8 to 2.5 m with a lower boundary of 13.4 to 15.1 m depth (Elev. 213.6 to 211.9 m). A lower sand layer was also encountered below the sandy silt till with a thickness ranging from 1.8 to 8.6 m and a lower boundary at 19.4 to 27.2 m depth (Elev. 207.6 to 199.8 m). Boreholes PWC-01 and PWC-04 were terminated within the sand deposit upon DCPT refusal at depths from 11.5 to 14.0 m (Elev. 214.0 to 211.0 m).

SPT N-values recorded within the sand deposit ranged from 22 to 61 blows for 0.3 m penetration to 100 blows for 0.025 m penetration, indicating a variable relative density of compact to very dense. Moisture contents ranged from 10% to 20%.

Three samples of the sand were selected for laboratory grain size analysis testing, the results of which are summarized below. The results are also presented on the Record of Borehole sheets included in Appendix A and grain size distribution curves on Figure B5, Appendix B.

Gravel%	2 to 33
Sand%	52 to 89
Silt & Clay%	9 to 17

5.6 Sandy Silt Till

Two layers of sandy silt till with some clay and trace gravel were encountered below the upper sand layer in Boreholes PWC-02 and PWC-03. The upper till layer was 3.5 to 4.2 m thick with a lower boundary of 17.6 to 18.6 m depth (Elev. 209.4 to 208.4 m). Both boreholes were terminated in a second till layer underlying the lower sand layer. The boreholes were terminated at depths of 21.6 to 30.6 m (Elev. 205.4 to 196.4 m), indicating that the lower till layer is at least 2.2 to 3.4 m thick.

SPT N-values recorded in the till deposit were all greater than 50 blows for 0.3 m penetration (typically greater than 100 blows for 0.3 m penetration), indicating that the sandy silt till is very dense. Moisture contents from 7% to 14% were measured.

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

Gravel%	0 to 4
Sand%	20 to 28
Silt%	55 to 65
Clay%	9 to 24

Glacial till deposits inherently contain cobbles and boulders.

5.7 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 5.2 - Groundwater Level Measurements

Borehole	Date	Groundwater Level		Comment
		Depth (m)	Elevation	
PWC-01	April 22, 2014	-0.5*	225.5	In piezometer
	April 29, 2014	-0.5*	225.5	
PWC-04	April 22, 2014	-0.6*	226.1	In piezometer
	April 29, 2014	-0.6*	226.1	

* indicates artesian groundwater level above the ground surface

The water levels recorded above the ground surface are indicative of artesian pressures present in the gravelly sand 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, 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 West tributary, which is shown on the preliminary drawings provided by MMM to be at Elev. 224.3 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 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 Pagwachuan River West culvert on Highway 11 in the District of Thunder Bay, Ontario.

The existing Pagwachuan River West culvert consists of a 26 m long twin-cell timber culvert approximately 4.2 m wide by 2.1 m high. The river flows in a northeast to southwest direction at the site. The existing highway embankment at the crossing is approximately 3.0 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 and the length of the sheet pile walls will be 27.0 m, of which 19.0 m will be capped. The top of the river stone substrate will be at approximate Elev. 223.9 to 224.1 m. The clear height within the culvert will be approximately 1.7 m, and the fill height above the concrete panels will be approximately 1.2 m. The finished road grade will be near elevation 227.2 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 existing embankment fill, overlying a layer of silt to clayey silt, underlain by silty clay which was further underlain by deposits of sand to gravelly sand and sandy silt till. The silty clay layer has a firm consistency and a thickness of 4.8 to 9.2 m.

Groundwater levels measured in standpipe piezometers installed at the site ranged from Elev. 225.5 to 226.1 m. The preliminary GA drawing indicates a water level at Elev. 224.3 m in Pagwachuan River West in 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 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

Depending upon the axial loads imposed by the culvert, sheet piles may be driven through the native silt deposit and into the firm silty clay to develop resistance primarily through adhesion along the pile walls, or extended to the underlying very dense sand/till deposits to develop both skin friction and end-bearing resistance.

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)
West Sheet Pile Wall (BH PWC-03)	222.0	3.5	No Resistance (Frost Zone)	
	219.0	6.5	60	50
	214.0	11.5	200	165
	210.8(2)	14.7	445	370
East Sheet Pile Wall (BH PWC-02)	222.0	3.5	No Resistance (Frost Zone)	
	219.0	6.5	60	50
	216.0	9.5	145	120
	212.2(2)	13.3	390	325

Notes: (1) below top of sheet pile, approximate Elev. 225.5 m shown on GA drawing, (2) expected depth of refusal.

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

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

Cobbles were encountered in the highway embankment fill. These obstructions may impede pile driving and if encountered, they will need to be removed in order to continue driving of the sheet piles.

It is possible that cobbles or boulders will also be encountered if sheet pile driving is continued into the sand and till deposits below the silty clay. Care must be taken not to damage 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 8.2 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:

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

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	227.0 to 225.0	0.31	0.47	3.3	-	5,000	20	Embankment Fill
	225.0 to 223.5	0.31	0.47	3.3	-	2,750	10	Embankment Fill
	223.5 to 222.0	0.35	0.52	2.9	-	1,250	10	Silt
	222.0 to 214.0	0.44	-	2.3	2,000	-	9	Silty Clay
	214.0 to 210.8	0.25	-	3.9	-	6,000	10	Sand to Sandy Silt Till
East Sheet Pile Wall	227.0 to 225.0	0.31	0.47	3.3	-	5,000	20	Embankment Fill
	225.0 to 223.5	0.31	0.47	3.3	-	2,750	10	Embankment Fill
	223.5 to 222.0	0.35	0.52	2.9	-	1,250	10	Silt
	222.0 to 216.0	0.44	-	2.3	2,000	-	9	Silty Clay
	216.0 to 212.2	0.25	-	3.9	-	6,000	10	Sand to Sandy Silt Till

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 2.5 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 $\phi = 35°, \gamma = 22.8$ kN/m^3		OPSS Granular B Type I/III or Existing Sand & Gravel Fill $\phi = 32°, \gamma = 21.2$ 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 III. Therefore, according to Clause 4.4.6 of the CHBDC, a Site Coefficient "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 $\phi = 35°$, $\gamma = 22.8$ kN/m^3	**OPSS Granular B Type I/III or Existing Fill $\phi = 32°$, $\gamma = 21.2$ kN/m^3**	**Silt or Silty Clay $\phi = 23°$ $\gamma = 9$ 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	0.64

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

The silty clay and underlying dense to very dense cohesionless soils at this site are not prone to liquefaction. Portions of the silt layer may be susceptible 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 on possible cobbles or boulders in the sand layer underlying the silty clay.
- 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

C_{pen} Shear Strength Determination by Pocket Penetrometer

(1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.

(2) DCPT Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

UNIFIED SOILS CLASSIFICATION

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILTS AND CLAYS $W_L < 50\%$	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. ($W_L < 30\%$).
		CI	Inorganic clays of medium plasticity, silty clays. ($30\% < W_L < 50\%$).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No PWC-01

METRIC

WP#	6134-04-00	LOCATION	Pagwachuan West Culvert N 5 515 653.6 E 200 276.0	ORIGINATED BY	ES
HWY	11	BOREHOLE TYPE	Tripod/NW Wash Boring	COMPILED BY	AN
DATUM	Geodetic	DATE	2014.04.08 - 2014.04.08	CHECKED BY	MEF

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	SHEAR STRENGTH kPa (field vane, sensitivity)	WATER CONTENT (%)	GR	SA	SI	CL
225.0											
0.0	**TOPSOIL**, rootlets, Dark Brown (100mm)										
0.1	Silty **SAND**, trace gravel, trace organics, Loose, Brown, Moist (FILL)	1	SS	4							
224.1 / 0.9	**SILT**, some clay to clayey, Stiff, Brown	2	SS	13	224						
		3	SS	12	223			0	0	73	27
		4	SS	8							
222.0 / 3.0	Silty **CLAY**, Firm, Brown (CI)	5	SS	4	222		Wp–WL range plotted	0	0	46	54
					221	+ (5.0)					
		6	SS	3	220						
					219	+ (5.0)					
	Occasional sand seams	7	SS	4	218	+ (2.0)					
	Some sand, trace gravel, Occasional gravel seams	8	SS	5	217	+ (3.0)		2	16	46	36
		9	SS	1	216						

Continued Next Page

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20, 40, 60; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%).

+³, ×³: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No PWC-01

METRIC

WP#	6134-04-00	LOCATION	Pagwachuan West Culvert N 5 515 653.6 E 200 276.0	ORIGINATED BY	ES
HWY	11	BOREHOLE TYPE	Tripod/NW Wash Boring	COMPILED BY	AN
DATUM	Geodetic	DATE	2014.04.08 - 2014.04.08	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 — WATER CONTENT (%) (20, 40, 60) | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%)

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	SHEAR STRENGTH	GR	SA	SI	CL
	Continued From Previous Page					3.0 (field vane)				
		10	SS	24	214		0	0	34	66
					213					
212.8 / 12.2	Gravelly **SAND**, some silt Very Dense Grey Moist	11	SS	50						
	DCPT started at 12.8m				212					
211.0 / 14.0	END OF BOREHOLE AT 14.0m 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)
Apr. 22/14	0.5*	225.5
Apr. 29/14	0.5*	225.5

* Artesian Condition (Above Ground Surface)

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+ 3 , × 3 : Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

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Ontario

THURBER

RECORD OF BOREHOLE No PWC-02

METRIC

WP#	6134-04-00	LOCATION	Pagwachuan West Culvert N 5 515 640.2 E 200 283.9	ORIGINATED BY	ES
HWY	11	BOREHOLE TYPE	NW Casing	COMPILED BY	AN
DATUM	Geodetic	DATE	2014.04.28 - 2014.04.28	CHECKED BY	MEF

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	SHEAR STRENGTH kPa (Field Vane)	WATER CONTENT (%)	GR	SA	SI	CL
227.0 / 0.0	**SAND** and **GRAVEL**, trace to some silt Very Dense Brown Moist (FILL) Occasional cobbles	1	SS	99/ 0.275			~8				
		2	SS	65	226		~8	51	43	6 (SI+CL)	
		3	SS	86/ 0.275	225		~13				
		4	SS	50/ 0.125			~22				
		5	SS	9	224		~24	0	0	86	14
223.6 / 3.4	**SILT**, some clay to clayey, occasional oxide staining Firm to Stiff Brown				223						
		6	SS	5	222		~25				
						+4.0					
220.9 / 6.1	Silty **CLAY** Firm Grey (CI)	7	SS	0	221		wP ~22, w ~40, wL ~51	0	0	40	60
					220	+5.0					
		8	SS	1	219		~29				
						+4.0					
		9	SS	0	218		~31				

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

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Ministry of Transportation
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THURBER

RECORD OF BOREHOLE No PWC-02

METRIC

WP#	6134-04-00	LOCATION	Pagwachuan West Culvert N 5 515 640.2 E 200 283.9	ORIGINATED BY	ES
HWY	11	BOREHOLE TYPE	NW Casing	COMPILED BY	AN
DATUM	Geodetic	DATE	2014.04.28 - 2014.04.28	CHECKED BY	MEF

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	SHEAR STRENGTH kPa	WATER CONTENT (%)	GR	SA	SI	CL
						6.0 (field vane)					
216.1 / 10.9	Gravelly **SAND**, some silt, some cobbles Very Dense	10	SS	9	216		~58	0	0	23	77
		11	SS	100/ 0.025	215						
213.6 / 13.4	Sandy **SILT**, some clay, trace gravel Very Dense Grey Moist (TILL)	12	SS	50/ 0.050	214, 213		~10	0	28	55	17
		13	SS	50/ 0.100	212, 211		~11				
	Some gravel	14	SS	106/ 0.175	210		~11				
209.4 / 17.6	Gravelly **SAND**, some silt, occasional cobbles Very Dense Grey Wet	15	SS	88/ 0.250	209, 208		~10	33	52	15 (SI+CL)	
207.6 / 19.4	Sandy **SILT**, some clay, trace gravel Very Dense Grey Moist										

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DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE
PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L
UNIT WEIGHT γ kN/m³
REMARKS & GRAIN SIZE DISTRIBUTION (%)

+ 3, × 3: Numbers refer to Sensitivity

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

RECORD OF BOREHOLE No PWC-02

METRIC

WP#	6134-04-00	LOCATION	Pagwachuan West Culvert N 5 515 640.2 E 200 283.9	ORIGINATED BY	ES
HWY	11	BOREHOLE TYPE	NW Casing	COMPILED BY	AN
DATUM	Geodetic	DATE	2014.04.28 - 2014.04.28	CHECKED BY	MEF

ELEV / DEPTH	DESCRIPTION (Continued From Previous Page)	STRAT PLOT	NUMBER	TYPE	"N" VALUES	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)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Sandy **SILT**, some clay, trace gravel Very Dense Grey Moist (TILL)						206				
205.4 / 21.6			16	SS	105/ 0.250				○ (approx. 17)		
	END OF BOREHOLE AT 21.6m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.1m, THEN SAND TO SURFACE.										

+ ³, × ³: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

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RECORD OF BOREHOLE No PWC-03

METRIC

WP#	6134-04-00	LOCATION	Pagwachuan West Culvert N 5 515 635.4 E 200 271.4	ORIGINATED BY	ES
HWY	11	BOREHOLE TYPE	NW Casing	COMPILED BY	AN
DATUM	Geodetic	DATE	2014.04.27 - 2014.04.27	CHECKED BY	MEF

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m3	GR	SA	SI	CL
227.0														
0.0	**SAND** and **GRAVEL**, trace to some silt Very Dense to Compact Brown Moist (FILL) Occasional cobbles		1	SS	89/ 0.275									
			2	SS	98/ 0.250		226				49	35	16 (SI+CL)	
			3	SS	69		225							
			4	SS	20		224							
223.7 3.3	**SILT**, some clay to clayey, trace organics Stiff Brown		5	SS	12		223				0	0	63	37
222.4 4.6	Silty **CLAY**, trace sand, trace gravel Firm Brown to Grey (CL)		6	SS	5		222							
								3.0 (field vane)						
			7	SS	1		221							
							220	5.0 (field vane)						
			8	SS	1		219				0	7	54	39
							218	4.0 (field vane)						
			9	SS	0									

Continued Next Page

+3, ×3: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

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RECORD OF BOREHOLE No PWC-03

METRIC

WP# 6134-04-00	LOCATION Pagwachuan West Culvert N 5 515 635.4 E 200 271.4		ORIGINATED BY ES
HWY 11	BOREHOLE TYPE NW Casing		COMPILED BY AN
DATUM Geodetic	DATE 2014.04.27 - 2014.04.27		CHECKED BY MEF

Continued From Previous Page

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	SHEAR STRENGTH kPa	WATER CONTENT (%)	GR	SA	SI	CL
	Silty **CLAY**, trace sand, trace gravel Firm Grey (CH)					Field vane 4.0					
		10	SS	0	216						
						Field vane 5.0					
					215						
		11	SS	1				0	0	29	71
					214						
213.7 13.3	Gravelly **SAND**, some silt, some cobbles Compact Grey Wet										
		12	SS	22	213			21	62	17 (SI+CL)	
211.9 15.1	Sandy **SILT**, trace clay, trace gravel Very Dense to Dense Grey Moist (TILL)				212						
		13	SS	100/ 0.125							
					211						
		14	SS	97/ 0.250	210			4	22	65	9
					209						
208.4 18.6	**SAND**, trace silt, trace gravel Dense Grey Wet	15	SS	49							
					208						

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No PWC-03

METRIC

WP# 6134-04-00
LOCATION Pagwachuan West Culvert N 5 515 635.4 E 200 271.4
ORIGINATED BY ES

HWY 11
BOREHOLE TYPE NW Casing
COMPILED BY AN

DATUM Geodetic
DATE 2014.04.27 - 2014.04.27
CHECKED BY MEF

Continued From Previous Page

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m3	GR	SA	SI	CL
	SAND, trace silt, trace gravel Dense to Very Dense Grey Wet					206						
		16	SS	34			~20					
						205						
						204						
						203						
		17	SS	61			~20		2	89	9 (SI+CL)	
						202						
						201						
199.8						200						
27.2	Sandy **SILT**, some clay, trace gravel Very Dense Grey Moist (TILL)	18	SS	110/ 0.275			~15					
						199						
		19	SS	106/ 0.225		198	~14		0	20	56	24

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; WATER CONTENT (%) 20 40 60

Continued Next Page

+3, ×3: Numbers refer to Sensitivity

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

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Ontario

THURBER

RECORD OF BOREHOLE No PWC-03

METRIC

WP# 6134-04-00	LOCATION Pagwachuan West Culvert N 5 515 635.4 E 200 271.4		ORIGINATED BY ES
HWY 11	BOREHOLE TYPE NW Casing		COMPILED BY AN
DATUM Geodetic	DATE 2014.04.27 - 2014.04.27		CHECKED BY MEF

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	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 — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
196.4			20	SS	100/				○		
30.6	END OF BOREHOLE AT 30.6m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.1m, THEN SAND AND GRAVEL TO SURFACE.				0.150						

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No PWC-04

METRIC

WP#	6134-04-00	LOCATION	Pagwachuan West Culvert N 5 515 623.9 E 200 281.4	ORIGINATED BY	ES
HWY	11	BOREHOLE TYPE	Tripod/NW Wash Boring	COMPILED BY	AN
DATUM	Geodetic	DATE	2014.04.08 - 2014.04.08	CHECKED BY	MEF

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	SHEAR STRENGTH kPa (Field Vane, sensitivity)	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
225.5								
0.0	**TOPSOIL**, rootlets: (125mm)							
0.1	Clayey **SILT**, some sand, trace gravel, trace organics, Stiff, Dark Brown (FILL)	1	SS	11			~22	
225.0 / 0.5	Sandy **SILT**, trace clay, Compact, Brown, Damp	2	SS	16	225		~20	
224.0 / 1.5	**SILT**, some clay to clayey, Very Stiff to Firm, Brown	3	SS	8	224		~20	
		4	SS	16	223		~21	0 0 72 28
		5	SS	6	222		~23	
221.4 / 4.1	Silty **CLAY**, trace to some sand, Soft to Firm, Brown (CI)					+ 3.0		
		6	SS	0	221		w_P ~20, w ~36, w_L ~42	0 0 43 57
					220	+ 4.0		
		7	SS	0	219		~24	
						+ 3.0		
		8	SS	3	218		~26	
					217	+ 3.0		
		9	SS	3	216		w_P ~22, w_L ~50, w ~51	0 10 38 52

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No PWC-04

METRIC

WP#	6134-04-00	LOCATION	Pagwachuan West Culvert N 5 515 623.9 E 200 281.4	ORIGINATED BY	ES
HWY	11	BOREHOLE TYPE	Tripod/NW Wash Boring	COMPILED BY	AN
DATUM	Geodetic	DATE	2014.04.08 - 2014.04.08	CHECKED BY	MEF

ELEV / DEPTH	SOIL PROFILE: DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	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 — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
215.0	Silty **CLAY** Very Soft Grey						215	+ 4.0			
10.5	Gravelly **SAND**, some silt Very Dense Grey Wet DCPT started at 11.0m		10	SS	50/ 0.100				○		
214.0 11.5	END OF BOREHOLE AT 11.5m 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) Apr. 22/14 0.6* 226.1 Apr. 29/14 0.6* 226.1 * Artesian Condition (Above Ground Surface)										

+³, ×³: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Appendix B

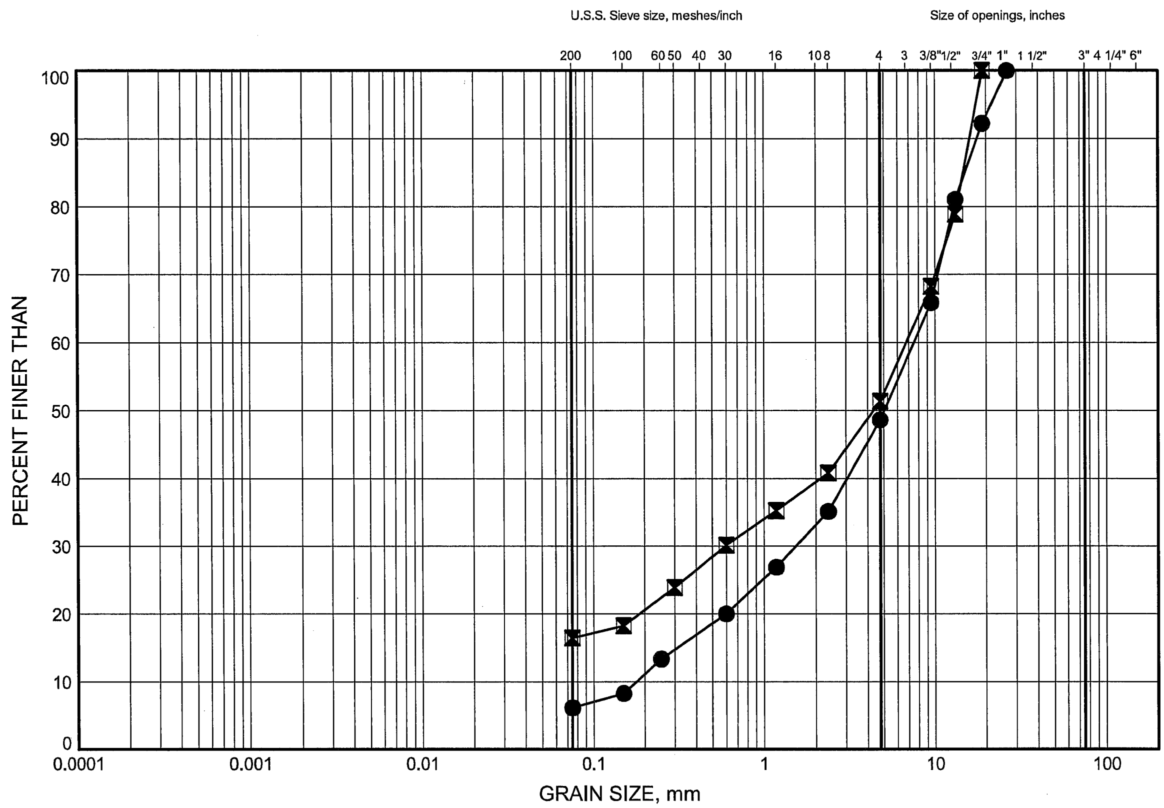
Laboratory Test Results

Pagwachaun West 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)
●	PWC-02	1.07	225.93
⧗	PWC-03	0.97	226.03

GRAIN SIZE DISTRIBUTION - THURBER 1197.GPJ 6/6/14

Date June 2014

GWP# 6134-04-00

THURBER

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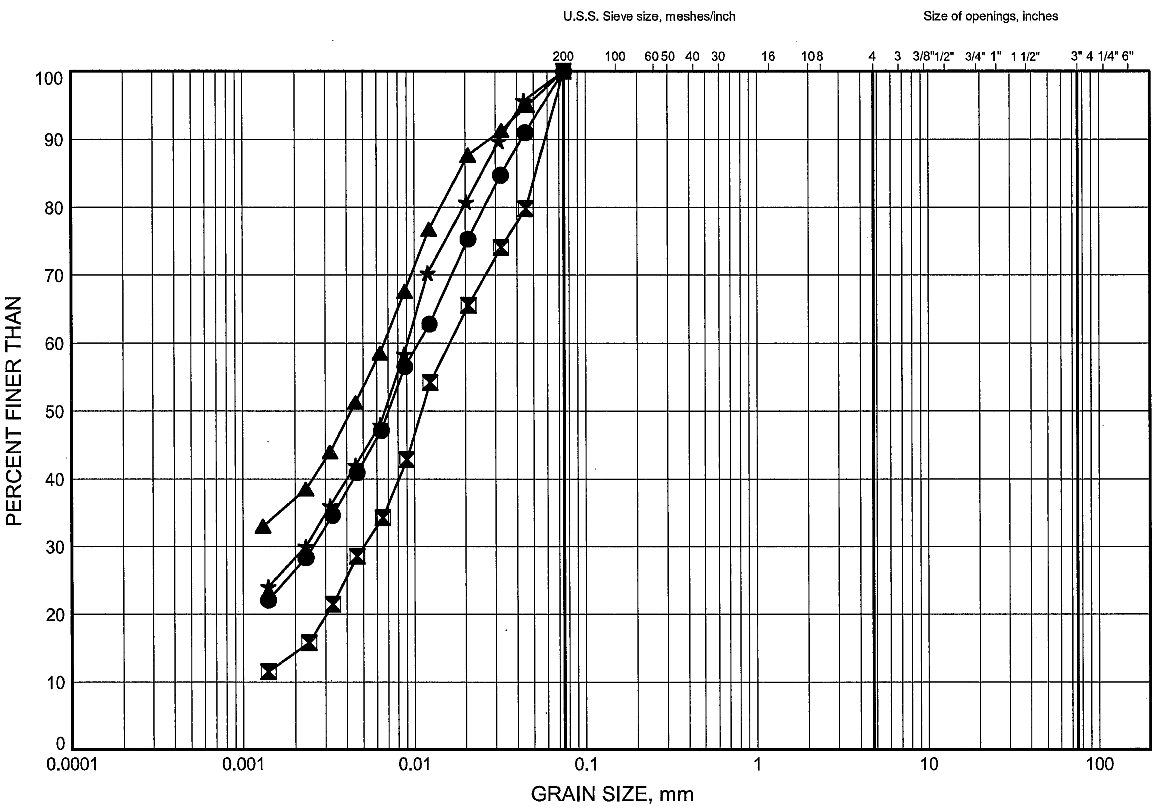
Pagwachaun West Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B2

SILT, Some Clay to Clayey



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PWC-01	1.83	223.17
⊠	PWC-02	3.35	223.65
▲	PWC-03	3.35	223.65
★	PWC-04	2.59	222.91

Date June 2014

GWP# 6134-04-00

THURBER

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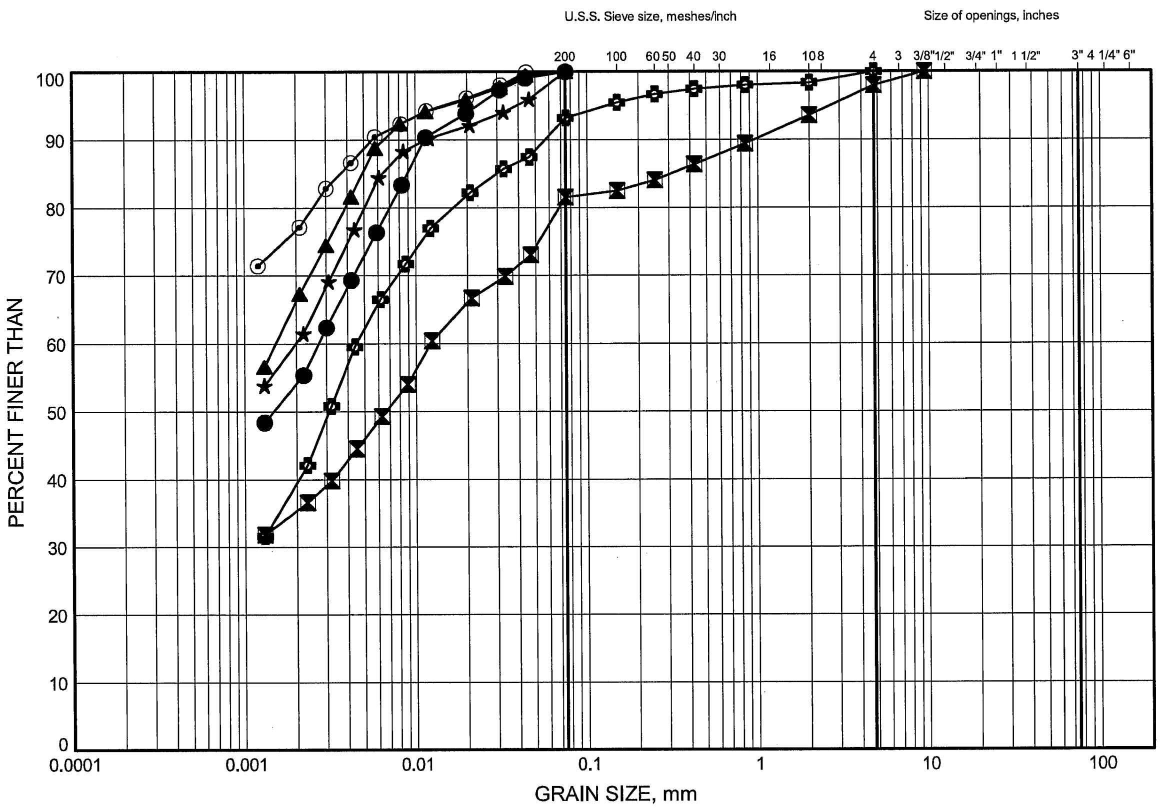
GRAIN SIZE DISTRIBUTION - THURBER 1197.GPJ 6/6/14

Pagwachaun West Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B3

SILTY CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PWC-01	3.35	221.65
⧗	PWC-01	7.92	217.08
▲	PWC-01	10.97	214.03
★	PWC-02	6.40	220.60
⊙	PWC-02	10.97	216.03
✿	PWC-03	7.92	219.08

Date June 2014

GWP# 6134-04-00

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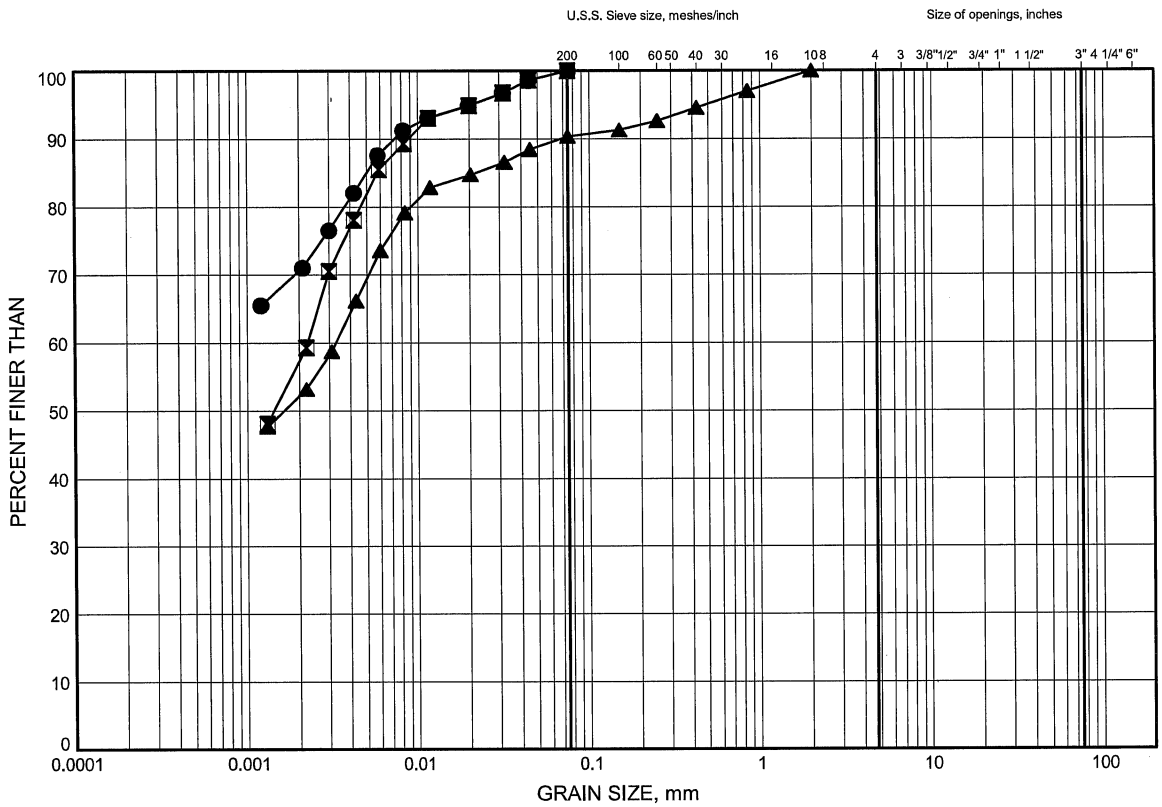
GRAIN SIZE DISTRIBUTION - THURBER 1197.GPJ 6/6/14

Pagwachaun West Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B4

SILTY CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PWC-03	12.50	214.50
⊠	PWC-04	4.88	220.62
▲	PWC-04	9.45	216.05

GRAIN SIZE DISTRIBUTION - THURBER 1197.GPJ 6/6/14

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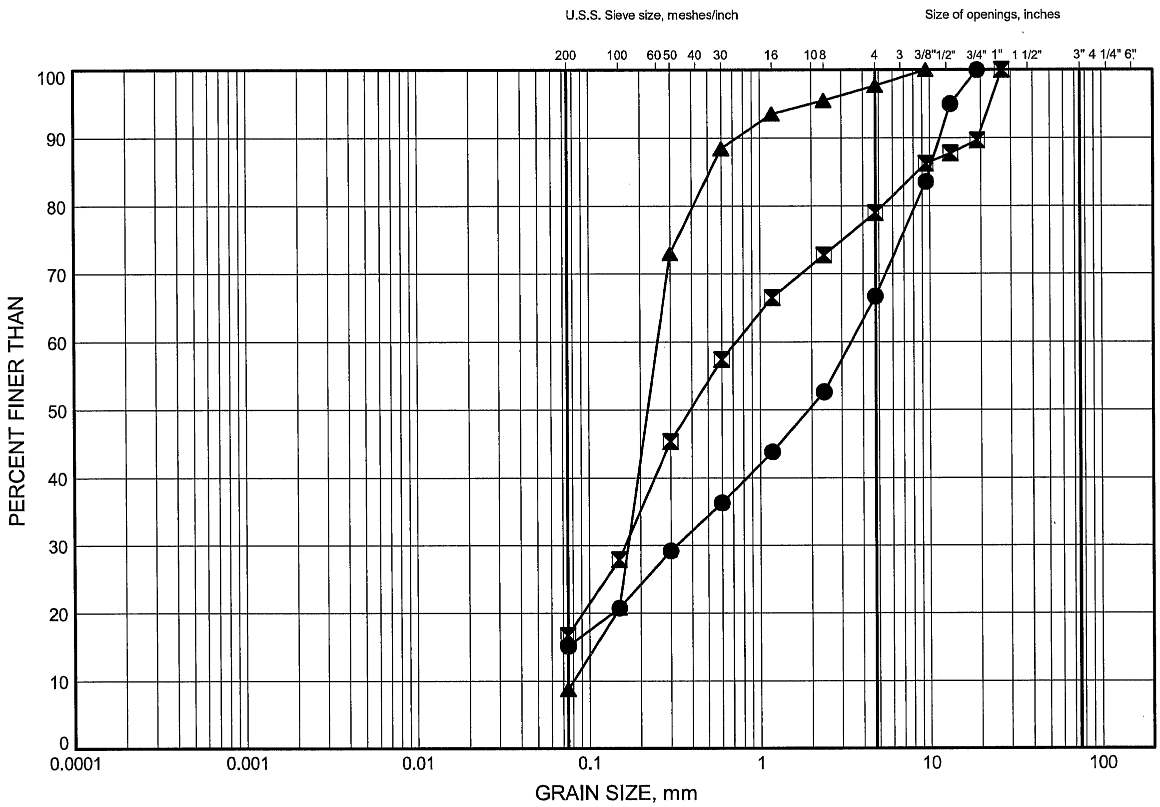
Pagwachaun West Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B5

GRAVELLY SAND TO SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PWC-02	18.49	208.51
⧗	PWC-03	14.02	212.98
▲	PWC-03	24.69	202.31

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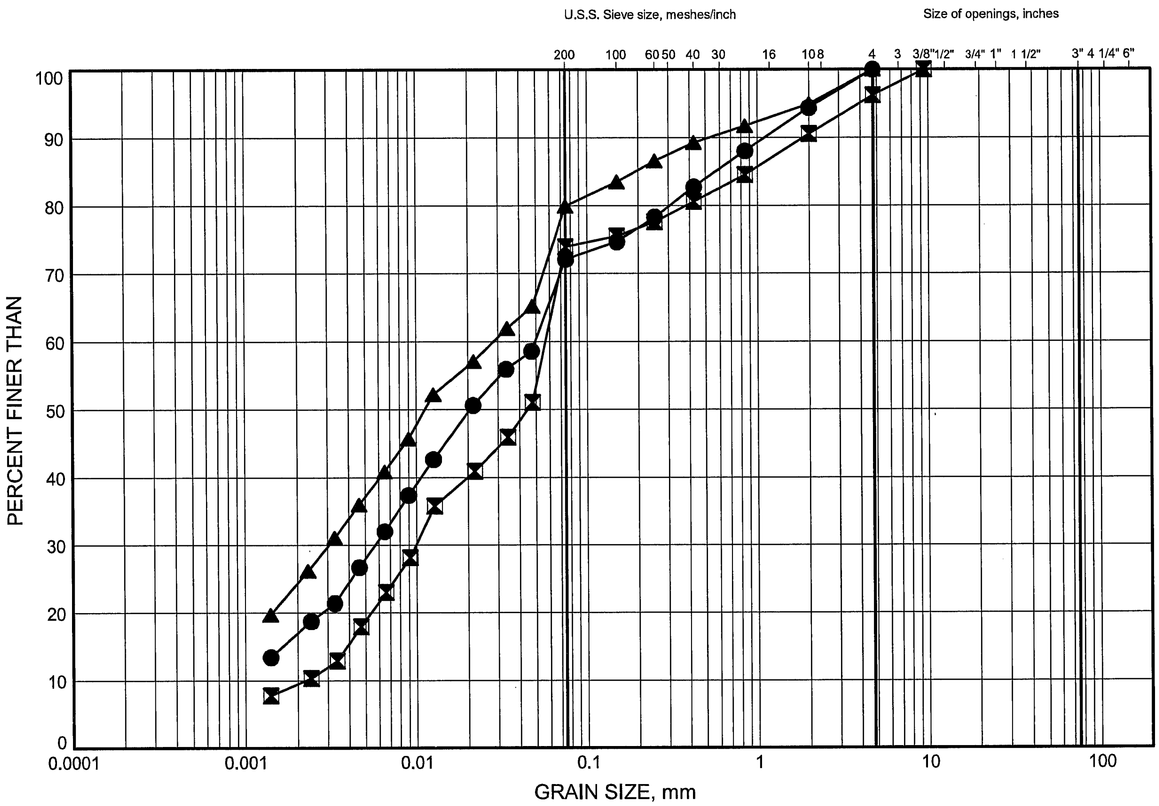
Pagwachaun West Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B6

SANDY SILT TILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PWC-02	13.82	213.18
⧗	PWC-03	16.89	210.11
▲	PWC-03	29.07	197.93

GRAIN SIZE DISTRIBUTION - THURBER 1197.GPJ 6/6/14

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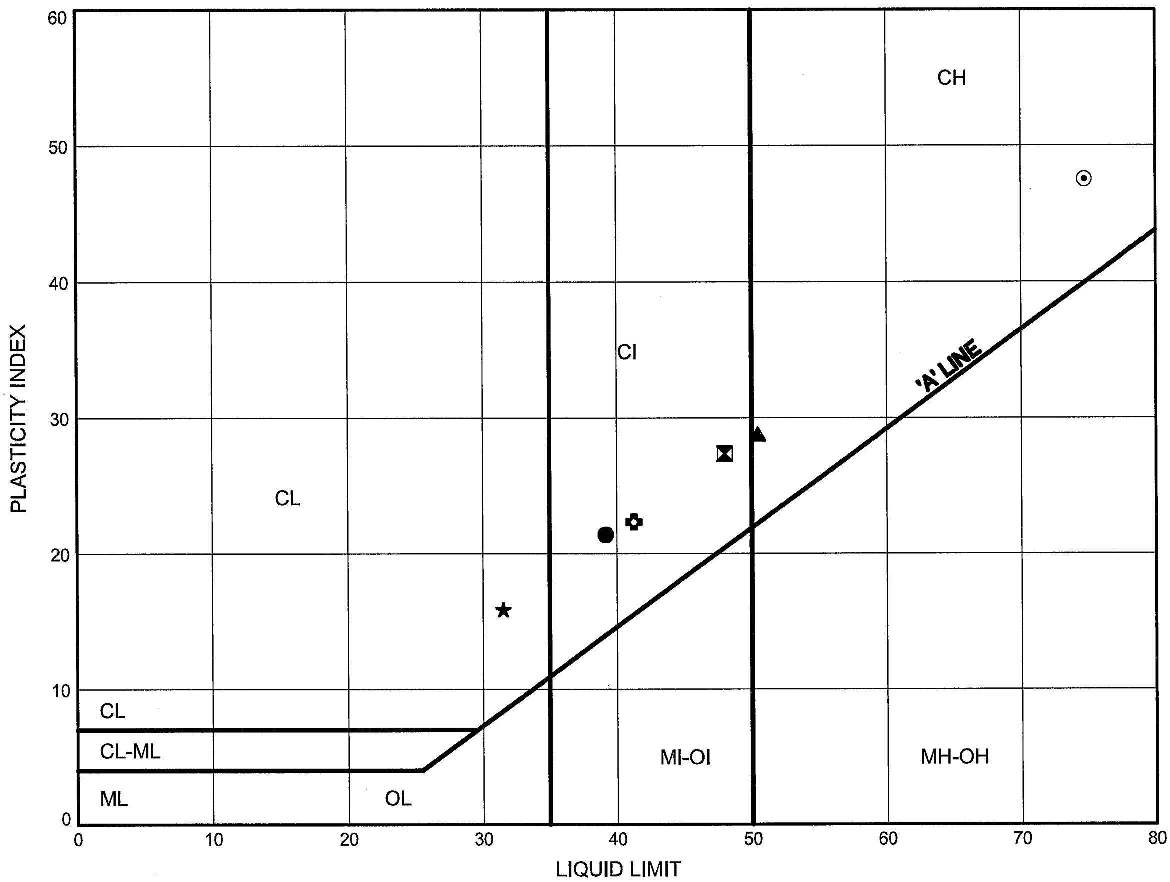
Pagwachaun West Culvert

ATTERBERG LIMITS TEST RESULTS

FIGURE B7

SILTY CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PWC-01	3.35	221.65
⌧	PWC-01	10.97	214.03
▲	PWC-02	6.40	220.60
★	PWC-03	7.92	219.08
⊙	PWC-03	12.50	214.50
✿	PWC-04	4.88	220.62

Date June 2014

GWP# 6134-04-00

THURBER

Prep'd AN

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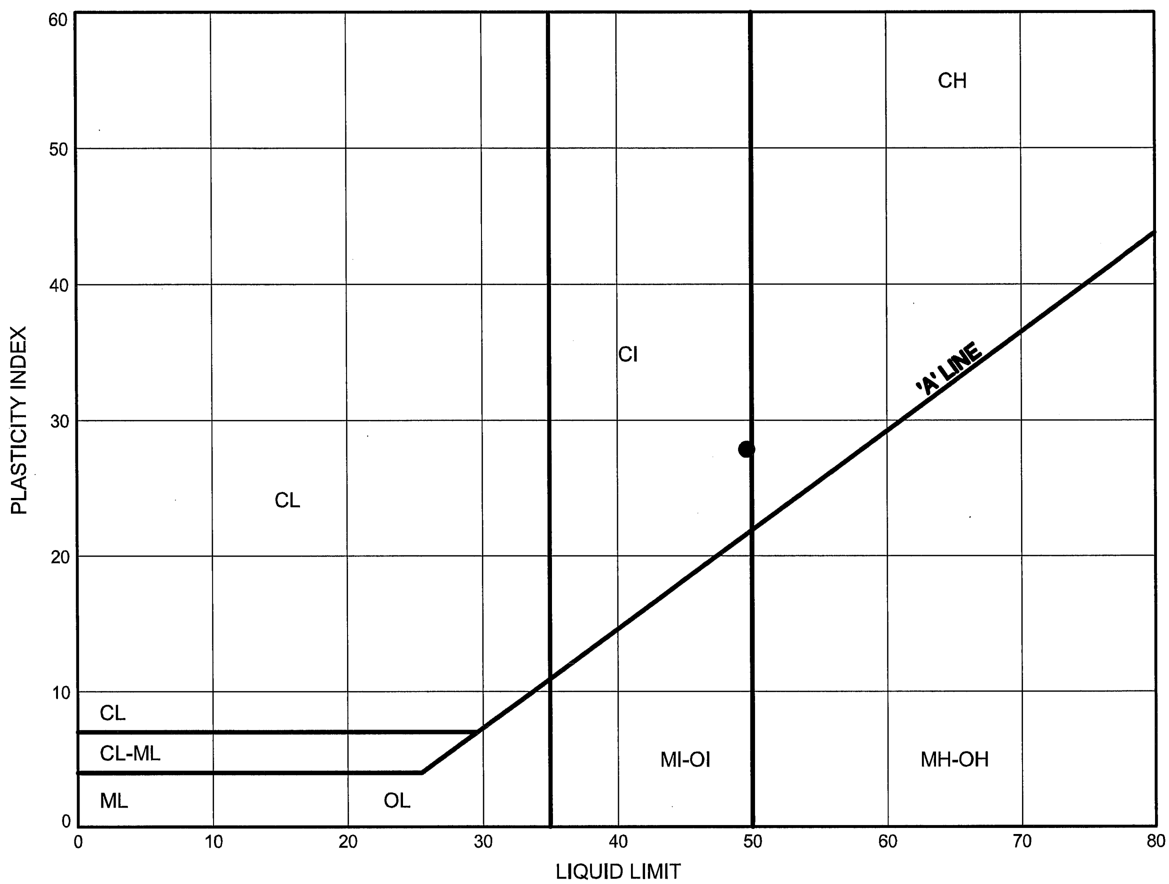
THURBALT 1197.GPJ 6/6/14

Pagwachaun West Culvert

ATTERBERG LIMITS TEST RESULTS

FIGURE B8

SILTY CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PWC-04	9.45	216.05

THURBALT 1197.GPJ 6/6/14

Date June 2014

GWP# 6134-04-00

THURBER

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Chkd. MEF

Appendix C

Site Photographs

Photograph 1 – North end of culvert, looking east at culvert inlet and highway embankment

Photograph 2 – North end of culvert, looking west at culvert inlet

Photograph 3 – South end of culvert, looking east at culvert outlet and highway embankment

Photograph 4 – South end of culvert, looking southwest at 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
Advantages: i. Typically least costly culvert type. ii. Conventional culvert design. iii. Ease of installation.	***Advantages:*** i. Relatively straightforward construction. ii. Less costly than pile or sheet pile options.	***Advantages:*** 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.	***Advantages:*** 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
Disadvantages: 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.	***Disadvantages:*** 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.	***Disadvantages:*** i. Higher cost than spread footings.	***Disadvantages:*** i. Large quantity and high cost of sheet piles. ii. Unconventional design.
FEASIBLE	**NOT RECOMMENDED**	**FEASIBLE**	**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

THURBER

MINISTRY OF TRANSPORTATION, ONTARIO

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

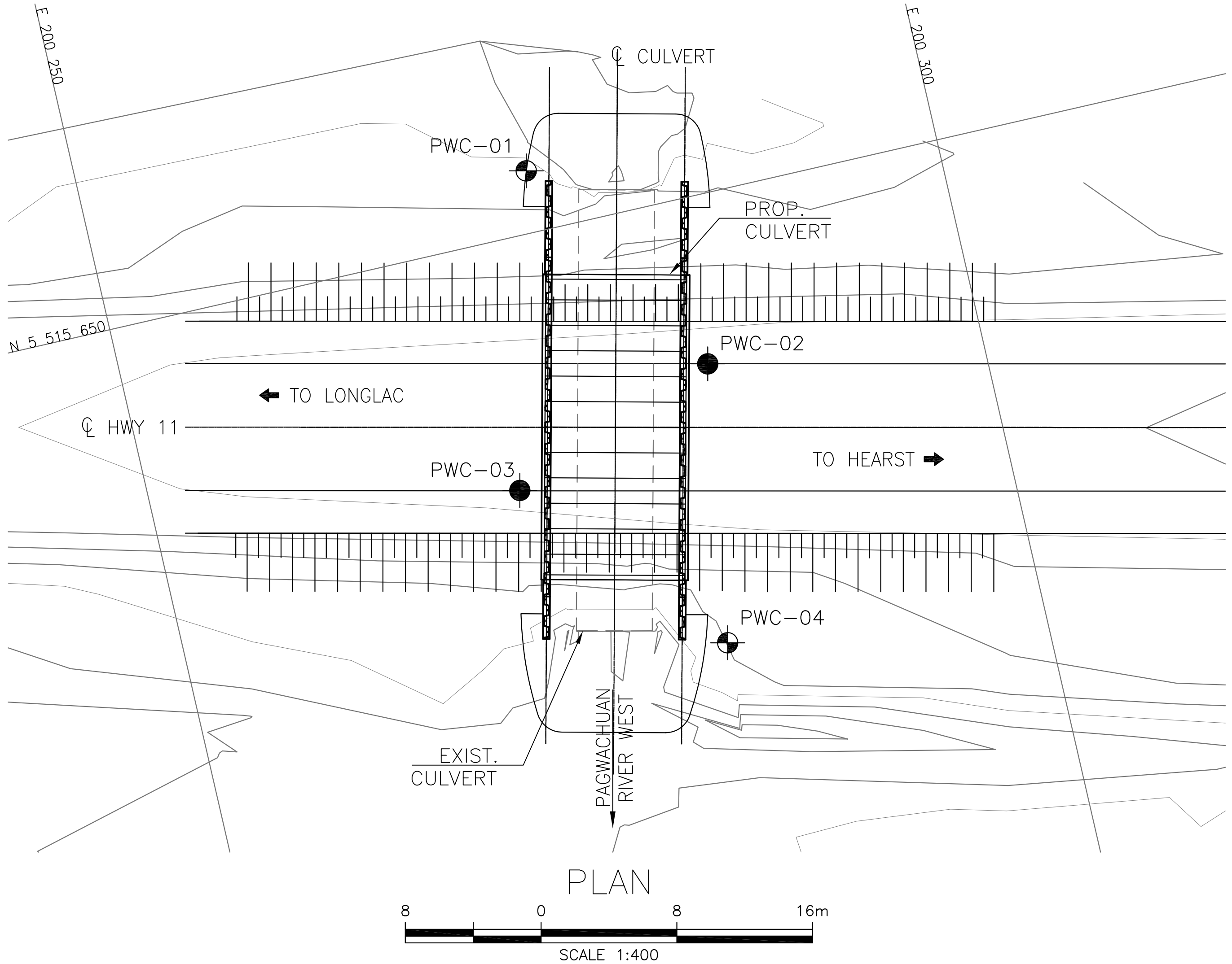
CONT No
WP No 6163-04-01

HIGHWAY 11
PAGWACHUAN RIVER WEST
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

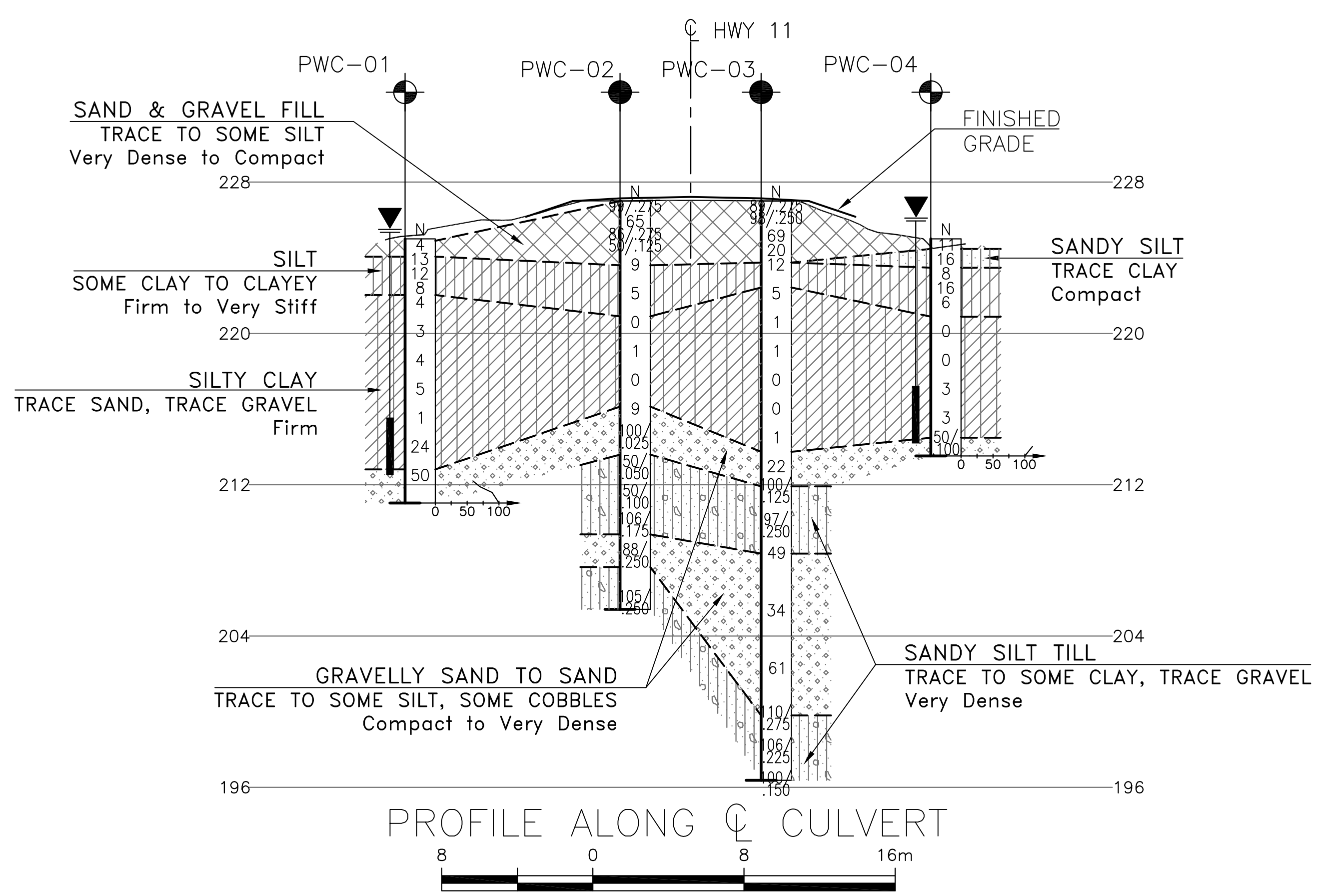
SHEET S02

MMM GROUP

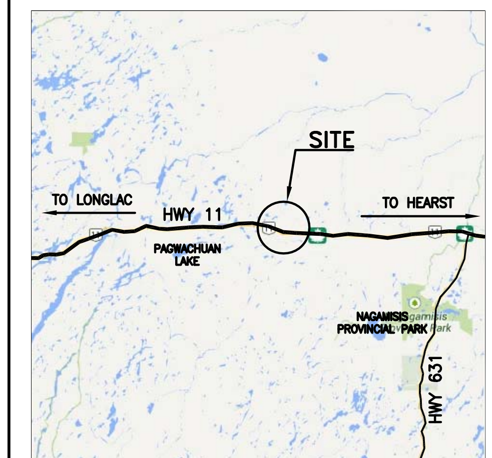
THURBER ENGINEERING LTD.



PLAN



PROFILE ALONG ℄ CULVERT



KEYPLAN

LEGEND

Symbol	Description
●	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
PWC-01	225.0	5 515 653.6	200 276.0
PWC-02	227.0	5 515 640.2	200 283.9
PWC-03	227.0	5 515 635.4	200 271.4
PWC-04	225.5	5 515 623.9	200 281.4

-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. 42F-29

REVISIONS	DATE	BY	DESCRIPTION

DESIGN MEF	CHK SBP	CODE	LOAD	DATE AUG 2014
DRAWN AN	CHK	SITE 48E-85/C	STRUCT	DWG 2

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