

**FOUNDATION INVESTIGATION AND DESIGN REPORT
GRANDVIEW CREEK CULVERT – EBL
HIGHWAY 11/17 - FOUR LANING
FROM 0.36 km EAST OF HIGHWAY 527 EASTERLY 12.6 km
TO 1 km WEST OF MACKENZIE STATION ROAD
G.W.P. 623-89-00, SITE 48C-349/C1**

Geocres Number: 52A-157

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 location of the Grandview Creek culvert under existing Highway 11/17 in the Township of MacGregor, District of Thunder Bay. Replacement of the existing culvert is planned as part of the proposed Highway 11/17 four-laning project extending from 0.36 km east of Highway 527 to 1 km west of MacKenzie Station Road. The existing Highway 11/17 will become the new eastbound lanes of the four-lane divided highway.

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 sections, laboratory test results and written descriptions of the subsurface conditions. A model of the subsurface conditions was developed from the data obtained in the course of the investigation.

Thurber carried out the investigation as a sub-consultant to McCormick Rankin Corporation, under the Ministry of Transportation Ontario (MTO) Agreement Number 6009-E-0017.

2 SITE DESCRIPTION

The proposed Grandview Creek culvert is located approximately 14 km east of Thunder Bay, Ontario and approximately 10.5 km east of Highway 527. The new culvert will be situated at the location of the existing culvert under the existing Highway 11/17 alignment. The existing roadway embankment is approximately 5 to 6 m in height.

The existing culvert comprises a 1.4 m diameter corrugated steel pipe (CSP) with a length of 34.8 m. The invert level of the existing culvert ranges from approximate elevation 239.5 at the inlet (north end) to elevation 238.5 at the outlet (south end).

Lands surrounding the culvert site consist of forested areas with bedrock outcrops. Cobbles and boulders are present in the creek channel at the inlet, and rock fill exists on the south facing embankment slope.

Photographs in Appendix C show the general nature of the site.

The site lies near the border of the Superior and Southern Geological Provinces of the Canadian Shield. According to bedrock geology maps produced by the Ontario Geological Survey, the culvert site lies near a boundary between massive granodiorite to granite rocks and metasedimentary rocks. Bedrock core samples confirm that the site is underlain by fine grained metasedimentary rocks. Locally, the overburden consists of cohesionless deposits of gravelly sand to silty sand containing occasional cobbles and boulders.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing for this project were carried out in several stages between October 22, 2011 and February 1, 2012. Six boreholes, identified as GCE-1 to GCE-6, were drilled and sampled at the site.

Boreholes GCE-1 and GCE-4 were located near the proposed culvert inlet, Boreholes GCE-2 and GCE-5 were located on the existing highway embankment, and Boreholes GCE-3 and GCE-6 were located near the culvert outlet. The approximate borehole locations are shown on the attached Borehole Locations and Soil Strata drawing included in Appendix G.

The boreholes were advanced to depths of 2.9 m to 13.0 m (elevations 235.7 to 228.3). Bedrock was proven by coring 2.7 m to 3.7 m in all boreholes except Borehole GCE-3.

The borehole locations were marked in the field and utility clearances were obtained prior to drilling. Clearing and access preparation were required prior to commencement of the borehole drilling. Silt fencing was installed between the drill area and the creek to prevent migration of core water sediment into the adjacent creek.

A track mounted CME 45 drill rig was used to drill all boreholes except Borehole GCE-3, and a combination of hollow-stem augers, casing and NQ coring techniques were used to advance the boreholes. Borehole GCE-3 was advanced with a portable tripod rig using solid-stem augers. Overburden samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). All rock cores were logged, and the Total Core Recovery (TCR), Rock Quality Designation (RQD) and the Fracture Indices (FI) were determined.

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

Groundwater conditions were observed in the open boreholes during and upon completion of the drilling operations. Groundwater conditions observed after completion of coring were not

representative of site conditions as water was introduced into the borehole during coring. Standpipe piezometers were installed in two boreholes for subsequent monitoring of groundwater levels. The completion details of the piezometers and boreholes are summarized in Table 3.1. The piezometers were decommissioned in general accordance with MOE Regulation 903 in late July 2012.

Table 3.1 – Piezometer and Borehole Completion Details

Borehole	Borehole Depth/ Elevation (m)	Completion Details
GCE-1	-	Backfilled with a mixture of bentonite and auger cuttings to surface.
GCE-2	-	Backfilled with bentonite holeplug to 1.8 m, auger cuttings from 1.8 m to 0.07 m, then asphalt to surface.
GCE-3	-	Backfilled with holeplug to surface.
GCE-4	8.5 / 232.0	Holeplug from 12.2 m to 8.5 m. Piezometer installed at 8.5 m. Filter sand from 8.5 m to 4.6 m and holeplug from 4.6 m to surface.
GCE-5	9.1 / 235.3	Holeplug from 13.0 m to 9.1 m. Piezometer installed at 9.1 m. Filter sand from 9.1 m to 5.6 m, holeplug from 5.6 m to 1.0 m, sand from 1.0 m to 0.03 m, then asphalt to surface.
GCE-6	-	Backfilled with holeplug to 0.9 m, then cuttings 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. The results of these tests are summarized on the Record of Borehole sheets included in Appendix A and are presented on the figures included in Appendix B.

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

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 G. 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 site consisted of sand and gravel embankment fill overlying native deposits of gravelly sand and silty sand, underlain by bedrock. Localized units of silt and sandy silt were also encountered. More detailed descriptions of the individual strata are presented below.

5.1 Topsoil

Topsoil was encountered at the surface in Boreholes GCE-1 and GCE-4 drilled near the culvert inlet. The topsoil is dark brown and described as sandy with some silt. The topsoil was 500 mm thick in Borehole GCE-1 and 200 mm thick in Borehole GCE-4.

An SPT N-value of 4 blows for 0.3 m penetration was recorded in Borehole GCE-1, indicating a loose relative density. A moisture content of 13% was measured.

5.2 Asphalt

Asphalt was encountered surficially in Boreholes GCE-2 and GCE-5 drilled on the shoulders of Highway 11/17. The asphalt was 100 mm and 125 mm thick.

5.3 Sand and Gravel Fill

Sand and gravel fill was encountered below the asphalt in Boreholes GCE-2 and GCE-5, and at the ground surface in Borehole GCE-6. The sand and gravel fill was brown and contained trace silt and clay and occasional cobbles and/or boulders.

The sand and gravel fill was 4.5 m thick in Boreholes GCE-2 and GCE-5 drilled through the existing highway embankment, and 0.5 m thick in Borehole GCE-6 drilled at the embankment toe. The lower boundary of the fill was encountered at depths varying from 0.5 m to 4.6 m (elevation 239.8 to 239.7).

SPT N-values recorded in the fill typically ranged from 33 to 46 blows for 0.3 m penetration, indicating a dense relative density. An SPT 'N' value of 67 blows per 0.275 m was obtained on probable cobbles in Borehole GCE-2. In Borehole GCE-6, an N-value of 11 blows per 0.3 m penetration was recorded, indicating a compact condition.

The moisture content of samples of the sand and gravel fill typically ranged from 7% to 10%. A value of 20% was measured in Borehole GCE-6 which may be attributed to the presence of organics in the sample.

Two samples of the sand and gravel fill underwent laboratory gradation analysis. The results of these tests are summarized on the Record of Borehole sheets in Appendix A and the grain size distribution curves are plotted on Figure B1, Appendix B. The results of the gradation analyses are as follows.

Gravel%	30 to 40
Sand%	54 to 62
Silt and Clay%	6 to 8

5.4 Gravelly Sand

Native gravelly sand was encountered below the topsoil in Boreholes GCE-1 and GCE-4, beneath the sand and gravel fill in Borehole GCE-5, and below sand and silt layers in Borehole GCE-3. The gravelly sand was brown, dark brown or grey and contained trace to some silt and cobbles. A 400 mm thick layer of sandy silt was encountered within the gravelly sand in Borehole GCE-4. The use of coring methods was required to advance the boreholes through cobbles and possible boulders within the gravelly sand in Boreholes GCE-1 and GCE-4.

The gravelly sand layer was 0.6 to 3.9 m thick. The base of the gravelly sand layer was encountered at depths of 1.7 m to 6.1 m (elevations 238.8 to 235.7).

SPT N-values recorded in the native gravelly sand typically ranged from 9 to 35 blows for 0.3 m penetration, indicating a loose to dense relative density. In Boreholes GCE-1 and GCE-4, N-values of 50 blows per 0.05 m penetration and 102 blows per 0.3 m penetration were recorded on probable cobbles.

The moisture content of samples of the gravelly sand ranged from 7% to 13%.

5.5 Silty Sand

Silty sand was encountered at the ground surface in Borehole GCE-3 and below the sand and gravel fill or native gravelly sand in all other boreholes. The silty sand was brown to grey and contained trace to some gravel and occasional cobbles and boulders. Layers of silt, 150 mm and 700 mm thick, were encountered within the silty sand in Boreholes GCE-1 and GCE-3. Coring was required to advance Boreholes GCE-1, GCE-4 and GCE-6 through the silty sand, indicating the presence of cobbles and boulders.

The thickness of the silty sand ranged from 2.3 m to 5.3 m, with the lower boundary of the silty sand encountered at depths of 2.3 m to 9.4 m (elevations 237.4 to 231.1).

SPT N-values recorded in the native silty sand typically ranged from 31 blows for 0.3 m penetration to 46 blows for 0.025 m penetration, indicating a dense to very dense relative density and/or the presence of cobbles and boulders. Lower SPT N-values of 5 blows to 26 blows for 0.3 m penetration were recorded in Boreholes GCE-2 and GCE-3, indicating loose to compact conditions.

The moisture content of samples of the silty sand ranged from 9% to 21%, with single values of 25% and 34% measured near the upper boundary of this layer in Boreholes GCE-1 and GCE-3.

Five samples of the silty sand underwent laboratory gradation analysis, the results of which are summarized below. These results are also presented on the Record of Borehole sheets included in Appendix A and are plotted on Figure B2, Appendix B.

Gravel%	0 to 16
Sand%	40 to 63
Silt%	22 to 46
Clay%	2 to 9

5.6 Silt to Sandy Silt

A 0.7 m thick layer of silt was encountered locally within the silty sand in Borehole GCE-3. The silt was brown and contained some sand. An SPT N-value of 18 blows for 0.3 m penetration was recorded, indicating a compact condition. A moisture content of 23% was measured.

A 0.4 m thick layer of grey sandy silt was encountered at a depth of 1.7 m within the gravelly sand in Borehole GCE-4. An SPT N-value of 11 blows for 0.3 m penetration was recorded in the sandy silt, indicating a compact condition. The moisture content of a sample of the sandy silt was 20%.

A sample of the sandy silt underwent laboratory gradation analysis, the results of which are summarized below. The results of this test are also presented on the Record of Boreholes sheets in Appendix A and the grain size distribution curve for this sample is plotted on Figure B3, Appendix B.

Gravel%	8
Sand%	32
Silt%	56
Clay%	4

5.7 Bedrock

Bedrock was proven below the silty sand in all boreholes except Borehole GCE-3, where auger refusal was met on probable bedrock or boulders below the gravelly sand. The depths to bedrock proven by coring or inferred by auger refusal are summarized in Table 5.1.

The bedrock recovered in the cores was described as fine grained metasedimentary bedrock with occasional quartz veins and quartz interbeds. The bedrock is greenish grey to dark grey in colour with occasional white bands.

Table 5.1 – Depth to Bedrock or Probable Bedrock/Boulders at Borehole Locations

Borehole	Depth to Bedrock (m)	Top of Bedrock Elevation (m)	Method
GCE-1	4.9	235.6	Cored
GCE-2	7.0	237.4	Cored
GCE-3	2.9	235.7	Auger refusal
GCE-4	9.4	231.1	Cored
GCE-5	9.3	235.1	Cored
GCE-6	2.8	237.4	Cored

Core recovery ranged from 61% to 100%. RQD values ranged from 0% to 23% in the initial core run at the bedrock surface in Boreholes GCE-1, GCE-2, GCE-4 and GCE-5, indicating very poor rock quality. RQD values in subsequent runs and in Borehole GCE-6 ranged from 47% to 100%, indicating poor to excellent rock quality, typically good to excellent. The Fracture Index (FI) of the rock, expressed as fractures per 0.3 m of core, was generally less than 5, with many values over 5 in Boreholes GCE-2 and GCE-5.

The unconfined compressive strength of the rock, estimated from the results of point load tests conducted on the rock core samples, ranged from 130 to 204 MPa, indicating a strong to very strong intact rock. The results are summarized on the Record of Borehole sheets in Appendix A (as average per run).

5.8 Water Levels

Groundwater was measured at 0.8 m depth (elevation 237.8) in Borehole GCE-3 upon completion of the drilling. Water was added to the boreholes during coring operations and therefore natural water levels were not recorded in the remaining boreholes upon completion.

Standpipe piezometers were installed in Boreholes GCE-4 and GCE-5 following completion of drilling. The ground water depths and levels measured in the piezometers and in open Borehole GCE-3 upon completion are summarized in Table 5.2.

Table 5.2 – Water Level Measurements

Borehole	Date	Water Level (m)		Comment
		Depth	Elevation	
GCE-3	Feb. 01, 2012	0.8	237.8	Upon completion
GCE-4	Jan. 30, 2012	1.8	238.7	Piezometer
GCE-5	Dec. 02, 2011	7.2	237.2	Piezometer

The water level in the creek at the time of the fieldwork was in the order of 0.2 m above the culvert invert level. Based on this observation and the culvert invert levels shown on the preliminary design drawings, the creek water level is estimated to be between elevation 239.7 at the inlet and 238.7 at the outlet.

The above values are short-term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after the spring snowmelt or after periods of heavy rainfall, and will reflect the water level in the creek.

6 MISCELLANEOUS

The borehole locations were selected by Thurber Engineering Ltd. and staked in the field by McCormick Rankin Corporation (MRC). The co-ordinates and ground surface elevations at the boreholes were surveyed by MRC. Where boreholes required relocation from the staked location, field measurements were recorded and the surveyed coordinates and elevations adjusted accordingly.

Thurber obtained utility clearances for the borehole locations prior to drilling.

Eastern Ontario Diamond Drilling Ltd. from Hawkesbury, Ontario supplied a track mounted CME 45 drill rig and conducted the drilling, sampling and in-situ testing operations. Thunder Bay Testing from Thunder Bay, Ontario supplied the portable tripod rig and conducted the drilling, sampling and in-situ testing operation for one borehole.

The field program was supervised on a full time basis by Ms. Eckie Siu and Mr. Ryan Kromer, E.I.T. of Thurber.

Routine laboratory testing was carried out by Thurber Engineering Ltd.

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 Ms. Lindsey Blaine, E.I.T.

The report was reviewed by Mr. Murray R. Anderson, M.Eng., P.Eng. and 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 in the factual report and presents geotechnical recommendations for replacement of the culvert carrying Grandview Creek under Highway 11/17. The culvert replacement is part of the Highway 11/17 four-laning project, in which the existing highway will become the new eastbound lanes of the four-lane divided highway.

The existing culvert comprises a 1.4 m diameter corrugated steel pipe (CSP) with a length of 34.8 m. The invert level of the existing culvert ranges from approximate elevation 239.5 at the inlet (north end) to elevation 238.5 at the outlet (south end).

The proposed replacement structure consists of a segmental precast concrete arch culvert with a span of 10.9 m, a rise of 3.4 m and a length of 23.8 m (preliminary General Arrangement drawing dated June 2012). The culvert will be supported on precast concrete footings with a thickness of 0.6 m and a design top of footing level at Elev. 240.2 (north/inlet) to Elev. 239.6 (south/outlet). The proposed culvert design was selected on the basis of considerations other than foundations.

The embankment height at the proposed culvert location will be in the order of 5 to 6 m with a proposed finished road grade at Elev. 244.6 (essentially unchanged).

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

8 CULVERT FOUNDATIONS

The existing highway embankment consists of sand and gravel fill and is underlain primarily by native deposits of gravelly sand and silty sand. Cobbles and boulders were encountered in the fill and native deposits. Bedrock was encountered below the silty sand at depths of 2.8 to 9.4 m (elevation 231.1 to 237.4).

The groundwater level at the site is expected to be near the water level in the creek, estimated to be between elevation 239.7 at the inlet and 238.7 at the outlet at the time of drilling.

Foundation recommendations for design of poured in-place or precast spread footings to support the proposed culvert are provided in the following sections. Comments regarding alternative foundation systems (steel piles, augered caissons) are also presented in the event that the design concept changes.

A comparison of the foundation alternatives based on advantages and disadvantages of each is included in Appendix D. A foundation scheme preferred from a foundations perspective is recommended.

8.1 Spread Footings on Native Soils

The anticipated founding level for spread footings supporting an open footing culvert, assuming 2.2 m of frost cover between the footing base and the finished ground surface within the culvert (from preliminary GA drawing), will range from Elev. 238.0 at the inlet to Elev. 237.4 at the outlet. Based on the borehole information, the soil conditions at this level will consist of the following:

Table 8.1 – Anticipated Soil Conditions at Founding Level

Location		Borehole	Founding Level	Anticipated Foundation Subgrade
West Side	Inlet	GCE-1	238.0	Very dense silty sand
	Middle	GCE-2	237.8	Very dense silty sand
	Outlet	GCE-3	237.4	Compact silt and silty sand
East Side	Inlet	GCE-4	238.0	Compact gravelly sand
	Middle	GCE-5	237.6	Very dense silty sand
	Outlet	GCE-6	237.4	Bedrock

The following geotechnical resistances are recommended for design of spread footings founded on the compact to very dense native soils or bedrock at the anticipated founding levels:

Footing Width (m)	<u>0.9</u>	<u>1.2</u>	<u>1.5</u>
Factored Geotechnical Resistance at ULS (kPa)	350	375	400
Geotechnical Resistance at SLS (kPa)	270	240	200

The width of footing must be designed based on the load demand from the culvert structure and overlying embankment fill.

The geotechnical resistances are based on a footing subjected to vertical concentric loading. Where eccentric or inclined loads are applied, the resistance used in the design must be reduced in accordance with the CHBDC Clause 6.7.3 and 6.7.4.

The geotechnical resistance at SLS is based on an estimated total settlement not exceeding 25 mm. The SLS values take into consideration the potential for some disturbance of the founding surface during excavation for footing construction “in the wet”.

The anticipated founding levels are up to 1.7 m below the approximate creek and groundwater levels measured at the respective inlet and outlet locations. In view of the proximity of the footings to the creek, the high permeability of the soils, and the presence of cobbles and boulders potentially obstructing installation of sheet pile shoring, dewatering of the excavation and construction of the culvert footings in the dry at the design founding level is likely to be impractical. Therefore, construction of spread footings will require subexcavation to the design level below water (“in the wet”) in short sections of about 2 m length followed by immediate placement of concrete using tremie methods.

Consideration could be given to raising the founding levels and providing frost protection for the founding surfaces using equivalent thermal insulation. However, the use of insulation is generally not practical for culvert foundations. Further, excavation to depths of about 0.9 m below the creek/groundwater levels would still be required to extend the footings to competent native soils. From this viewpoint, use of higher founding levels is not the recommended option.

The lateral resistance of the footings may be computed using an unfactored friction coefficient of 0.55 on gravelly sand and silty sand. This value requires a degree of sliding movement to occur to fully mobilize the resistance.

The structural designers must ensure that the geometry of the proposed footing and the limits of subexcavation do not encroach into the creek.

8.2 Spread Footings on Rock Fill

In view of the high groundwater conditions, the high permeability of the soils, and the impracticality of dewatering excavations for footing construction, placement of spread footings on compacted rock fill may be considered as an option to establish the top of footing level above the water level.

The rock fill must be a minimum 0.5 m thick and be placed on native, compact to very dense silty sand to gravelly sand. Accordingly, the base of the rock fill must be placed no

higher than the elevations indicated in Table 8.2, and deeper as required to provide a minimum 0.5 m thickness of rock fill below the base of the footing.

Table 8.2 – Highest Level for Underside of Rock Fill

Location		Borehole	Highest Recommended Base Level	Underlying Soil
West Side	Inlet	GCE-1	240.0	Very dense gravelly sand
	Middle	GCE-2	238.5	Very dense silty sand
	Outlet	GCE-3	238.6	Compact silty sand
East Side	Inlet	GCE-4	240.0	Very dense gravelly sand
	Middle	GCE-5	238.3	Very dense silty sand
	Outlet	GCE-6	239.7	Very dense silty sand

Rock fill placement will generally be carried out below the water level, and should involve subexcavation in short sections followed by immediate backfilling to above the water level to permit placement of the footings in the dry. The rock fill should be placed in accordance with OPSS 206 including compaction by several passes of heavy tracked equipment.

The recommended gradation of the rock fill is as follows:

<u>Sieve Size</u>	<u>Percent Passing</u>
150 mm	100
106 mm	50 – 100
75 mm	15 – 80
26.5 mm	0 – 15

A minimum 150 mm thick layer of compacted 19 mm clear stone should be placed above rock fill to provide an even founding surface for placement of the footings. Details of footing construction on rock fill are presented in Figure F1, Appendix F.

The geotechnical resistances recommended for design of spread footings founded on a minimum 0.5 m thickness of rock fill are as follows:

Footing Width (m)	<u>0.9</u>	<u>1.2</u>	<u>1.5</u>
Factored Geotechnical Resistance at ULS (kPa)	450	525	600
Geotechnical Resistance at SLS (kPa)	450	425	400

The geotechnical resistances are based on a footing subjected to vertical concentric loading. The width of footing must be designed based on the load demand from the culvert structure and overlying embankment fill. Where eccentric or inclined loads are applied, the

resistance used in the design must be reduced in accordance with the CHBDC Clause 6.7.3 and 6.7.4.

The geotechnical resistance at SLS provided is based on an estimated total settlement on the culvert structure not exceeding 25 mm.

The lateral resistance of the footings may be computed using an unfactored friction coefficient of 0.6 assuming a friction angle of 31° between the footing concrete and underlying clear stone. This value requires a degree of sliding movement to occur to fully mobilize the resistance.

8.3 Driven Steel Piles

The native soils at this site are typically dense to very dense and contain cobbles and boulders. Use of rock coring equipment was required to penetrate cobbles and boulders in three of the boreholes. In addition, bedrock was encountered at relatively shallow depths below the culvert level in several boreholes. The use of driven steel H-piles or sheet piles is not recommended in these conditions and these alternatives have not been further developed.

8.4 Augered Caissons

Installation of caissons at this site is not recommended due to the presence of cobbles and boulders as well as the potential for base and sidewall instability in the cohesionless soils below the groundwater level. In view of these factors, this alternative has not been further developed.

8.5 Recommended Foundation

From a geotechnical perspective and based on the subsurface conditions, spread footings on rock fill placed to raise the founding level above the groundwater level are considered the most cost effective and practical foundation option for supporting the culvert type selected for this site. This option will enable footing construction above the water level, reduce excavation and dewatering requirements, and provide a more uniform founding surface than footings on native soils.

Alternative culvert types (ie., box culvert) may be preferable at this site based solely on foundation design and construction considerations. However, selection of the proposed culvert type was based on considerations other than foundations.

8.6 Frost Cover

The depth of frost penetration at this site is 2.2 m. The base of all footings on native soil must be provided with a minimum of 2.2 m of earth cover as protection against frost action.

Frost protection is not required for footings constructed on a minimum 0.5 m layer of rock fill placed to establish founding levels above the groundwater level.

9 CULVERT BACKFILL AND LATERAL EARTH PRESSURES

Culvert backfill should consist of free-draining granular material conforming to OPSS Granular A, Granular B Type II or Granular B Type III specifications.

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. Heavy compaction equipment should not be used adjacent to the walls and roof of the culvert. Compaction should be carried out in accordance with OPSS 501.

In general, earth pressures acting on the culvert walls may be assumed to impose a triangular distribution governed by the characteristics of the backfill. For a fully drained condition, the pressures should be computed in accordance with the CHBDC but generally are given by the expression:

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

- where: p = horizontal pressure on the wall at depth h (kPa)
 K = earth pressure coefficient (see Table 9.1)
 γ = bulk 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 are dependent on the material used as backfill. Recommended unfactored values are shown in Table 9.1. The at-rest coefficients should be employed for restrained culvert walls. Active pressures should be used for any wingwalls or unrestrained walls.

Table 9.1 – Earth Pressure Coefficients (K)

Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I or Type III $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)
Active (Unrestrained Wall)	0.27	0.38*	0.31	0.46*
At Rest (Restrained Wall)	0.43	-	0.47	-
Passive	3.7	-	3.3	-

* For wing walls.

The parameters in the table correspond to full mobilization of active and passive earth pressures, and require certain relative movements between the wall and adjacent soil to produce these conditions. The values to be used in design can be assessed from Figure C6.16 of the Commentary to the CHBDC.

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 at a depth of 1.7 m for Granular A or Granular B Type II.

The design of the culvert must incorporate measures such as weepholes or subdrains to permit drainage of the culvert backfill, or alternatively the culvert walls should be designed to withstand the potential build-up of hydrostatic pressures behind the walls.

10 EROSION CONTROL

Erosion and scour protection must be provided for the culvert foundations. In general, this will involve placing the footings below the level of potential scour and/or providing rock protection over the footings to prevent erosion and undermining of the foundations. Design of the erosion protection measures must consider hydrologic and hydraulic concerns and should be carried out by specialists experienced in this field.

A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion, in general accordance with OPSS 804.

11 EXCAVATION AND GROUNDWATER CONTROL

The excavation and backfilling for foundations must be carried out in accordance with OPSS 902. Construction staging will include temporary detouring of traffic onto the new WBL during culvert construction and therefore roadway protection will not be required.

All excavation must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the native gravelly sand and silty sand above the water table may be classed as Type 3 soils. This classification is based on the lack of cohesion in the soils. The cohesionless soils below the water table are classified as Type 4 soil.

Excavation for footing construction and/or placement of rock fill to prepare the founding surface is expected to extend up to about 1.7 m below the groundwater levels within cohesionless soils containing cobbles and boulders. In these conditions, installation of sheet pile shoring, dewatering of the excavation and construction of culvert footings in the dry within close proximity to the creek is considered impractical.

The recommended procedure for preparation of the founding surface entails subexcavation in the wet to the depths outlined in Section 8 in short sections of about 2 m length followed by immediate backfilling with rock fill to the required founding level (allowing for the clear stone layer) and/or

placement of tremie concrete. The contractor must ensure that the excavation does not encroach into the creek by controlling the length of excavation open at any one time.

Selection of the equipment and methodology to excavate and prepare the founding surface is the responsibility of the Contractor. The Contract Documents should contain a NSSP advising the Contractor of the high groundwater levels, cohesionless soils and cobbles and boulders at this site that may impact foundation construction. Suggested wording is provided in Appendix E.

12 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 0.02

The soil profile type at this site has been classified as Type I. Therefore, according to Table 4.4 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 earth pressure coefficients that incorporate the effects of earthquake loading. The seismic component of the earth pressure distribution is additional to the static earth pressure distribution and may be taken as an inverted triangle with the maximum pressure at the top of the wall and the minimum pressure at the toe. The seismic earth pressure parameters (ΔK_{AE}) recommended for determining the seismic component are presented in Table 12.1:

Table 12.1 – Earth Pressure Coefficients for Earthquake Loading

Condition	Seismic Earth Pressure Coefficient (ΔK_E)			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I or Type III $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active (ΔK_{AE})*	0.01	0.03	0.01	0.03
At Rest (ΔK_{OE})**	0.02	-	0.03	-
Passive (ΔK_{PE})	-	-	-0.1	-

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

** After Woods

The foundation soils at the site are assessed as not being prone to liquefaction.

13 CONSTRUCTION CONCERNS

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

- Preparation of the founding surfaces for spread footings will require excavation below the groundwater level within cohesionless soils containing cobbles and boulders. This work will require excavation in short sections (in the wet) followed by immediate backfilling with rock fill or tremie concrete. Driving of sheet piling is not considered feasible.
- Large boulders may be encountered within the excavation depth. Removal of these boulders will require suitable excavating equipment, and may result in areas of over-excavation requiring additional rock fill to backfill.

The successful performance of the culvert will depend largely upon good workmanship and quality control during construction. Observation of the excavation and backfilling operations by the QVE will be required during construction to confirm that the foundation recommendations are correctly implemented and material specifications are met.

14 CLOSURE

Engineering analysis and preparation of the report were carried out by Ms. Mei T. Cheong, M.Phil.

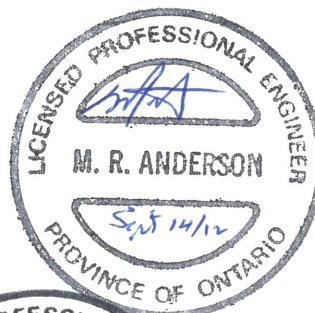
The report was reviewed by Mr. Murray R. Anderson, P.Eng. and Dr. P.K. Chatterji, P.Eng. a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd

Mei T. Cheong, M.Phil.
Geotechnical Specialist

 14 Sept, 10

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

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


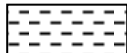



 Water Level
 Shear Strength Determination by Pocket Penetrometer

- (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

<u>ROCK WEATHERING CLASSIFICATION</u>		<u>SYMBOLS</u>	
Fresh (FR)	No visible signs of weathering.		
Fresh Jointed (FJ)	Weathering limited to the surface of major discontinuities.		CLAYSTONE
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.		SILTSTONE
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.		SANDSTONE
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.		COAL
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structure are preserved.		Bedrock (general)

<u>DISCONTINUITY SPACING</u>		<u>STRENGTH CLASSIFICATION</u>			
Bedding	Bedding Plane Spacing	Rock Strength	Approximate Uniaxial Compressive Strength		Field Estimation of Hardness*
			(MPa)	(psi)	
Very thickly bedded	Greater than 2m	Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Thickly bedded	0.6 to 2m				
Medium bedded	0.2 to 0.6m	Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Thinly bedded	60mm to 0.2m	Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Very thinly bedded	20 to 60mm				
Laminated	6 to 20mm	Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Thinly Laminated	Less than 6mm				





<u>TERMS</u>					
Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.	Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.	Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a percentage of total core run length.	Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen				
Fracture Index: (FI)	Frequency of natural fractures per 0.3m of core run.				

RECORD OF BOREHOLE No GCE-1

1 OF 1

METRIC

W.P. 623-89-00 LOCATION N 5 376 238.7 E 378 262.8 Grandview Creek EBL ORIGINATED BY RK
HWY 11/17 BOREHOLE TYPE HW and NW Casing/NQ Coring COMPILED BY AN
DATUM Geodetic DATE 2011.11.14 - 2011.11.14 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)
240.5								20	40	60	80	100					
0.0	TOPSOIL, sandy Dark Brown Moist		1	SS	4												
240.0																	
0.5	Gravelly SAND, some cobbles Very Dense Dark Brown Wet Cored through gravel and cobbles (possible boulders) from 0.5m to 1.5m		2	SS	50/ 0.050												
238.8																	
1.7	Silty SAND, trace clay Dense to Very Dense Brown Wet Layer of silt (150mm) at 2.0m Cored through cobbles and boulders from 2.1m to 3.0m		3	SS	31												0 51 46 3
			4	SS	54												
	Some gravel Cored through cobbles and boulders from 3.0m to 4.7m Grey		5	SS	80												16 40 37 7
235.6	Moist		6	SS	46/ 0.025												
4.9	METASEDIMENTARY BEDROCK, moderately to slightly weathered, dark greenish grey, occasional quartz veins		1	RUN													RUN #1 TCR=92% SCR=42% RQD=23% UCS=170MPa (Average)
	Rubble zone (100mm) at 6.0m																RUN #2 TCR=98% SCR=82% RQD=47% UCS=154MPa (Average)
			2	RUN													
232.7																	
7.8	END OF BOREHOLE AT 7.8m. BOREHOLE BACKFILLED WITH MIXTURE OF BENTONITE AND AUGER CUTTINGS TO SURFACE.																

ONTMT4S 1182.GPJ 1/27/12

METRIC

[illegible]

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No GCE-2

2 OF 2

METRIC

W.P. 623-89-00 LOCATION N 5 376 229.2 E 378 265.9 Grandview Creek EBL ORIGINATED BY ES
HWY 11/17 BOREHOLE TYPE Hollow Stem Augers/Casing/NQ Coring COMPILED BY AN
DATUM Geodetic DATE 2011.10.24 - 2011.10.24 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE						
	Continued From Previous Page							20 40 60 80 100						
234.1 10.3	METASEDIMENTARY BEDROCK , slightly to moderately weathered, occasional quartz interbeds, grey END OF BOREHOLE AT 10.3m. BOREHOLE BACKFILLED WITH HOLEPLUG TO 1.8m, CUTTINGS TO 0.07m, THEN ASPHALT TO SURFACE.													

RECORD OF BOREHOLE No GCE-3

1 OF 1

METRIC

W.P. 623-89-00 LOCATION N 5 376 205.8 E 378 277.5 Grandview Creek EBL ORIGINATED BY GA
 HWY 11/17 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2012.02.01 - 2012.02.01 CHECKED BY LRB

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										
								○ UNCONFINED + FIELD VANE										
								● QUICK TRIAXIAL × LAB VANE										
							WATER CONTENT (%)											
							20 40 60 80 100					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT						
							20 40 60 80 100					w _p w w _L						
238.6																		
0.0	Silty SAND , trace clay, trace gravel, occasional blast rock, occasional rootlets Compact Brown Damp		1	SS	26	▽	238										6 63 22 9	
237.8																		
0.8	SILT , some sand Compact Brown Wet		2	SS	18													
237.1																		
1.5	Silty SAND , trace gravel Compact Grey Wet		3	SS	20		237										15 51 32 2	
236.3																		
2.3	Gravelly SAND , trace silt Dense Grey Wet		4	SS	35		236											
235.7																		
2.9	END OF BOREHOLE AT 2.9m UPON AUGER REFUSAL. WATER LEVEL AT 0.8m UPON COMPLETION. BOREHOLE BACKFILLED WITH HOLEPLUG TO SURFACE.																	

RECORD OF BOREHOLE No GCE-4

1 OF 2

METRIC

W.P. 623-89-00 LOCATION N 5 376 243.7 E 378 272.1 Grandview Creek EBL ORIGINATED BY RK
HWY 11/17 BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY AN
DATUM Geodetic DATE 2011.11.17 - 2011.11.17 CHECKED BY RPR

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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						WATER CONTENT (%) w _p w w _L								
240.5								20	40	60	80	100										
0.0	TOPSOIL: (200mm)																					
0.2	Gravelly SAND , some silt, occasional cobbles Loose to Very Dense Brown Moist to Wet Cored through occasional cobbles from 0.2m to 1.5m		1	SS	9		240															
			2	SS	102																	
238.8							239															
1.7	Layer of sandy silt (400mm) Trace clay		3	SS	11													8	32	56	4	
238.4																						
2.1	Compact		4	SS	29		238															
	No recovery		5	SS	18		237															
236.4																						
4.1	Silty SAND , trace gravel, trace clay Very Dense Grey Wet Cored through gravel and occasional cobbles from 4.6m to 9.1m		6	SS	50/ 0.150		236															
							235															
			7	SS	61/ 0.150		234												3	59	35	3
							233															
			8	SS	50/ 0.075																	
							232															
231.1																						
9.4	METASEDIMENTARY BEDROCK, slightly weathered to fresh, dark greenish grey, occasional quartz veins						231											FI 5 1				

Continued Next Page

+³ × 3³: Numbers refer to
Sensitivity

20
15 5
10 (%) STRAIN AT FAILURE

METRIC

[illegible]

RECORD OF BOREHOLE No GCE-5

1 OF 2

METRIC

W.P. 623-89-00 LOCATION N 5 376 221.7 E 378 280.1 Grandview Creek EBL ORIGINATED BY ES
 HWY 11/17 BOREHOLE TYPE Casing/NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2011.10.22 - 2011.10.22 CHECKED BY RPR

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			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
244.4												
0.0	ASPHALT: (125mm)											
0.1	SAND and GRAVEL, trace silt and clay, occasional cobbles and boulders Dense Brown Moist (FILL) Cored through boulders from 0.1m to 0.8m		1	SS	34		244					
			2	SS	33		243					
			3	SS	46		242					
			4	SS	46		241					
239.8							240					
4.6	Gravelly SAND, occasional cobbles Loose Brown Moist		5	SS	9		239					
238.3												
6.1	Silty SAND, trace gravel, occasional cobbles Very Dense Grey Wet		6	SS	57		238					
			7	SS	50/ 0.125		237					
			8	SS	50/ 0.100		236					
235.1							235					
9.3	METASEDIMENTARY BEDROCK, moderately to slightly weathered, grey, occasional quartz interbeds		1	RUN								

Continued Next Page

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

RECORD OF BOREHOLE No GCE-5

2 OF 2

METRIC

W.P. 623-89-00 LOCATION N 5 376 221.7 E 378 280.1 Grandview Creek EBL ORIGINATED BY ES
HWY 11/17 BOREHOLE TYPE Casing/NQ Coring COMPILED BY AN
DATUM Geodetic DATE 2011.10.22 - 2011.10.22 CHECKED BY RPR

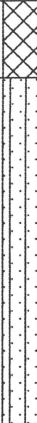

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)																																																																																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

RECORD OF BOREHOLE No GCE-6

1 OF 1

METRIC

W.P. 623-89-00 LOCATION N 5 376 214.6 E 378 282.8 Grandview Creek EBL ORIGINATED BY ES
 HWY 11/17 BOREHOLE TYPE Casing/NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2011.11.23 - 2011.11.23 CHECKED BY RPR

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			20 40 60 80 100	PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w			LIQUID LIMIT w _L	GR SA SI CL
240.2	SAND and GRAVEL , trace organics Compact Brown Moist (FILL) Silty SAND , trace gravel, occasional organics Very Dense Brown Moist Cored through cobbles and boulders from 0.5m to 1.3m		1	SS	11							RUN #1 TCR=100% SCR=100% RQD=96% UCS=196MPa (Average)		
239.7														
0.5														
			2	SS	50/ 0.125								RUN #2 TCR=100% SCR=100% RQD=100% UCS=197MPa (Average)	
			3	SS	50/ 0.050									
237.4	METASEDIMENTARY BEDROCK , slightly weathered, occasional quartz interbeds, grey with white bands Sub-vertical fracture (between 25mm to 100mm) at 2.8m, 3.3m, 3.7m, 4.8m 300mm at 4.0m Vertical fracture (25mm to 75mm) at 3.8m, 3.9m Quartz interbed (25mm to 100mm) at 2.7m, 3.0m, 3.4m, 4.7m		1	RUN										
2.8														
					2	RUN								
234.7														
5.5	END OF BOREHOLE AT 5.5m. BOREHOLE BACKFILLED WITH HOLEPLUG TO 0.9m THEN CUTTINGS TO SURFACE.													

+³, ×³: Numbers refer to
Sensitivity

20
15 5
10 (%) STRAIN AT FAILURE

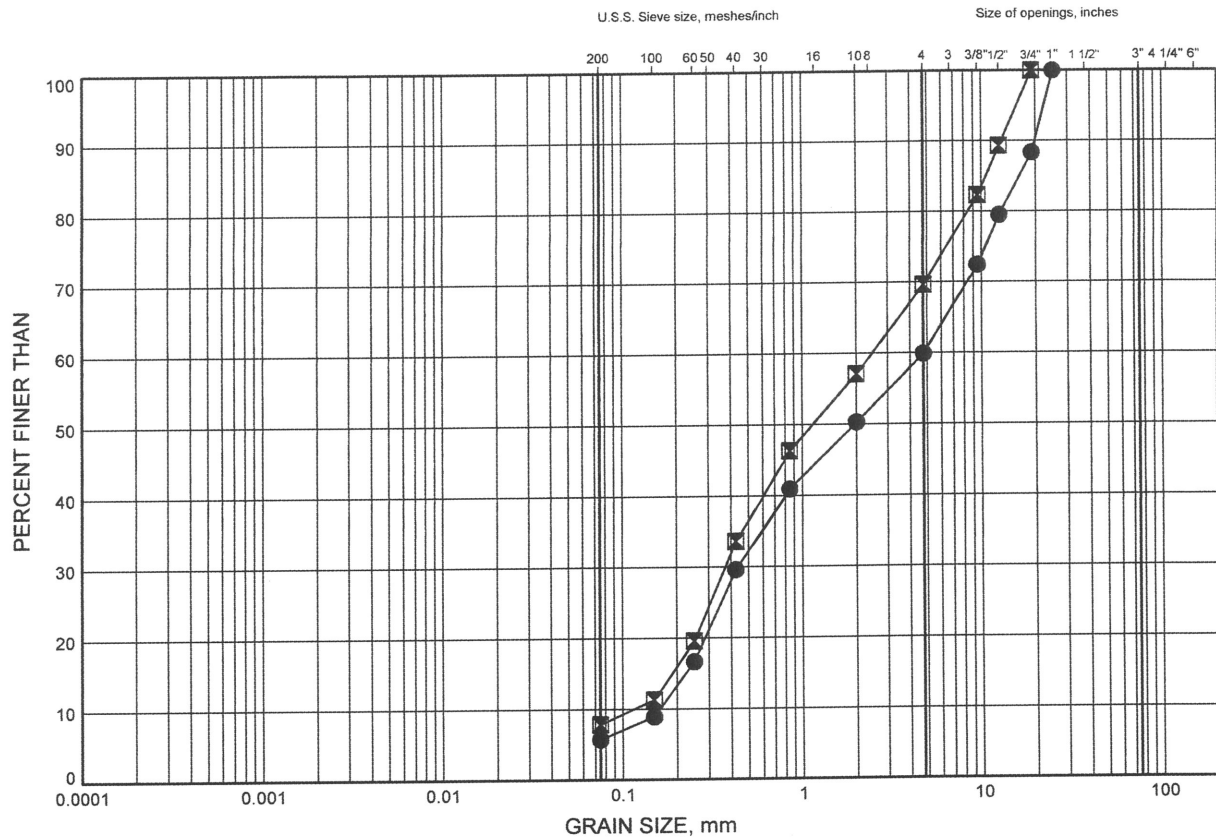
Appendix B

Laboratory Test Results

Grandview Creek - EBL GRAIN SIZE DISTRIBUTION

FIGURE B1

SAND & GRAVEL FILL



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

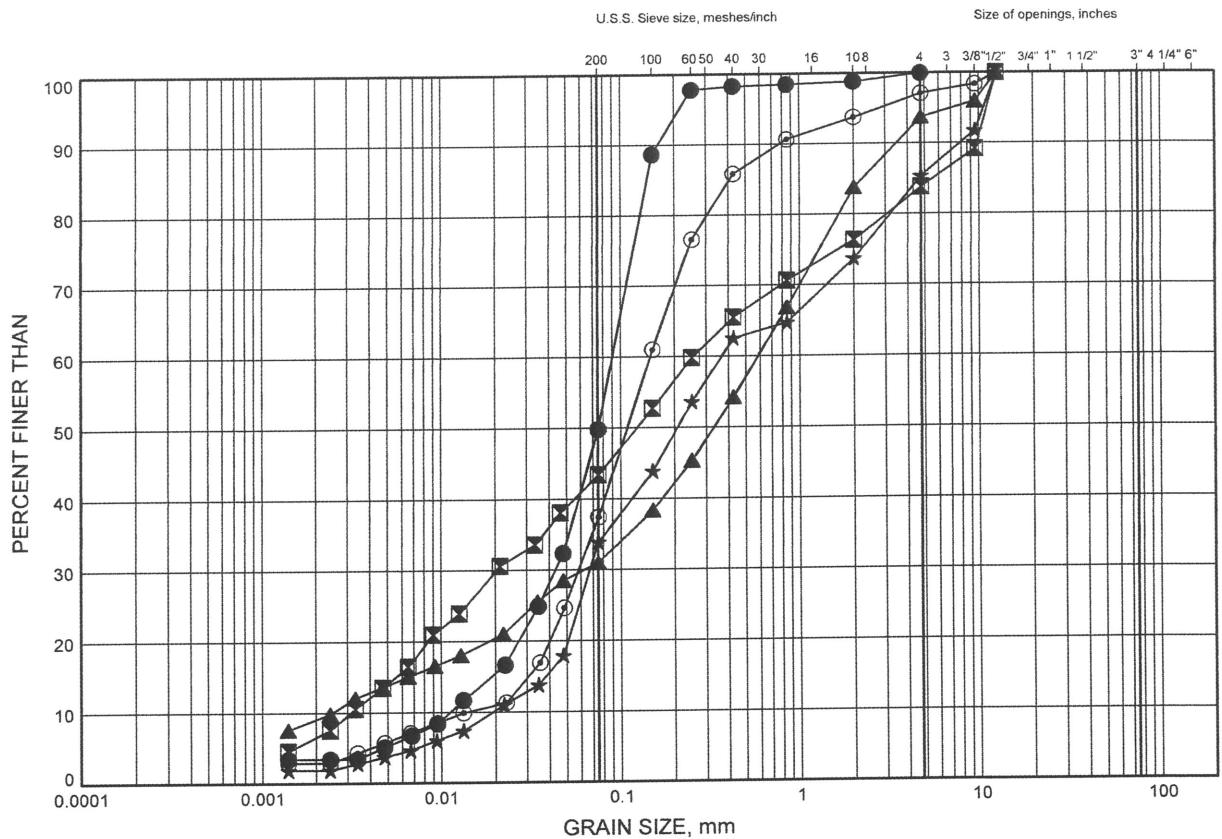
LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	GCE-2	2.59	241.81
■	GCE-5	1.83	242.57

Grandview Creek Culvert - EBL GRAIN SIZE DISTRIBUTION

FIGURE B2

Silty SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	GCE-1	1.83	238.67
⊠	GCE-1	3.35	237.15
▲	GCE-3	0.30	238.30
★	GCE-3	1.83	236.77
⊙	GCE-4	6.40	234.10

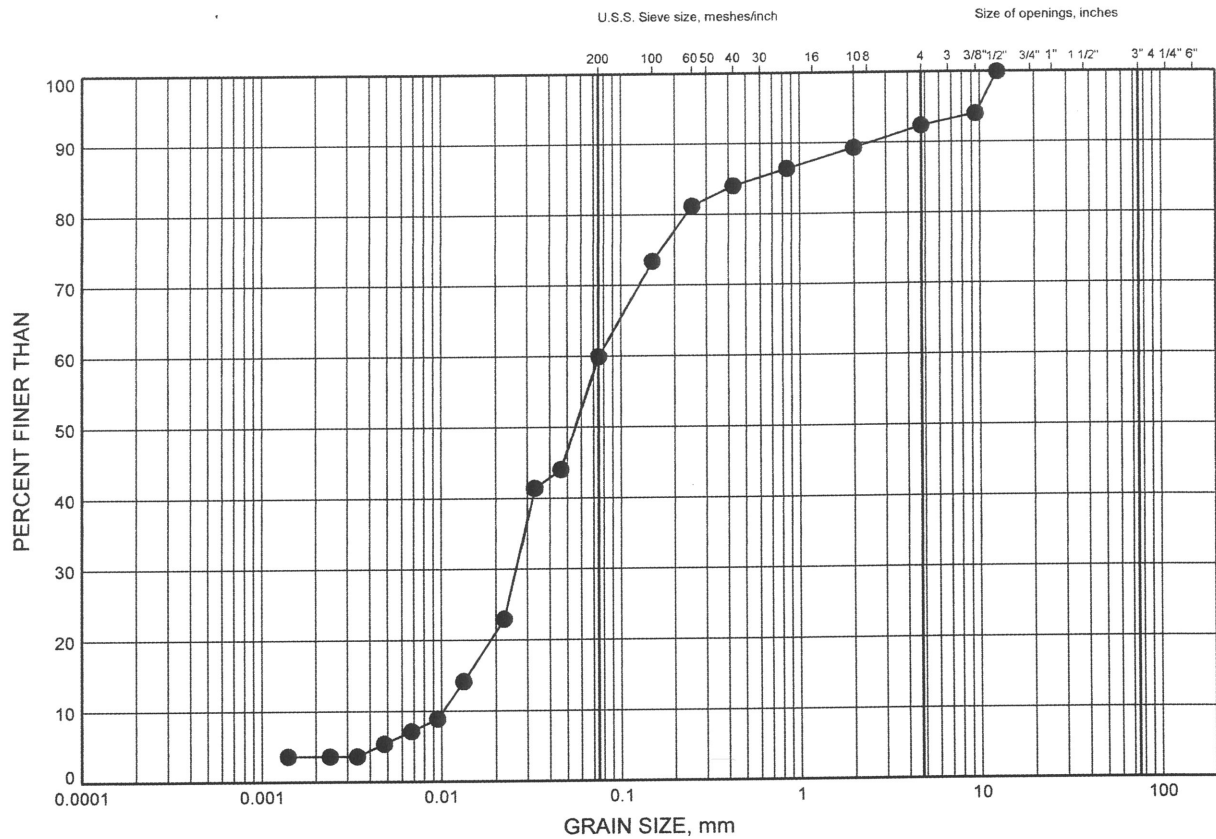


W.P.# 623-89-00
Prepared By AN
Checked By LRB

Grandview Creek Culvert - EBL GRAIN SIZE DISTRIBUTION

FIGURE B3

Sandy SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	GCE-4	1.83	238.67



W.P.# 623-89-00
Prepared By AN
Checked By LRB

Appendix C

Site Photographs



Photograph 1 – Grandview Creek EBL Culvert Inlet



Photograph 2 – Grandview Creek EBL Culvert Outlet

Appendix D

Foundation Comparison

COMPARISON OF FOUNDATION ALTERNATIVES

Footings on Native Soil	Footings on Rock Fill	Driven Steel Piles	Caissons (Drilled Shaft)
<p><i>Advantages:</i></p> <ul style="list-style-type: none"> i. Generally less costly construction than deep foundation elements. ii. Rock fill is not required. 	<p><i>Advantages:</i></p> <ul style="list-style-type: none"> i. Generally less costly construction than deep foundation elements. ii. Allows construction of footings above the groundwater level. iii. Higher geotechnical resistances compared to footings on native soil. iv. More uniform support than footings partially on native soil. v. Precast concrete footings may be employed 	<p><i>Advantages:</i></p> <ul style="list-style-type: none"> i. High geotechnical resistances can be achieved in dense to very dense soils. ii. Installation of piles could continue in freezing weather iii. Excavation below groundwater level may be reduced or eliminated. 	<p><i>Advantages:</i></p> <ul style="list-style-type: none"> i. High geotechnical resistances can be achieved in dense to very dense soils. ii. Installation of caissons could continue in freezing weather iii. Excavation below groundwater level may be reduced or eliminated.
<p><i>Disadvantages:</i></p> <ul style="list-style-type: none"> i. Subexcavation below the water level is required. ii. Footings must be placed using tremie concrete. iii. Greater excavation depths would be required for higher resistance values. iv. Potential disturbance of subgrade during excavation. 	<p><i>Disadvantages:</i></p> <ul style="list-style-type: none"> i. Subexcavation below the water level is required to place rock fill. ii. Additional cost of rock fill placement compared to footings on native soil. iii. Rock fill cannot be compacted under water. iv. Potential disturbance of subgrade during excavation. 	<p><i>Disadvantages:</i></p> <ul style="list-style-type: none"> i. Driven piles are expected to encounter refusal on cobbles and boulders at varying depths and often above the bedrock surface. ii. Predrilling through cobbles and boulders will be difficult. iii. Pile lengths will be inadequate at the outlet due to shallow bedrock. Socketing into the bedrock would be required. iii. Higher unit costs than footings. iv. Pile lengths may vary. 	<p><i>Disadvantages:</i></p> <ul style="list-style-type: none"> i. Augering and advancement of liner may be obstructed by cobbles and boulders and the very dense nature of the soils at site. ii. Higher cost than spread footings iii. Specialized installation measures such as temporary liners and drilling mud will be required to install caissons in cohesionless soils below the water table. iv. Potential difficulty in cleaning and inspecting bases.
FEASIBLE	RECOMMENDED	NOT RECOMMENDED	NOT 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 206
- OPSS 501
- OPSS 804
- OPSS 902

2 Suggested Text for NSSP on Foundation Excavation

The Contractor is advised that groundwater levels are high at this site and the soils consist of cohesionless silty to gravelly sands containing cobbles and boulders. Preparation of the founding surfaces for spread footings will require excavation below the groundwater level within these deposits.

Excavation sidewalls in the cohesionless deposits will generally be unstable and sloughing due to groundwater inflow must be anticipated. The presence of cobbles and boulders is likely to impede the use of driven sheet piles, and therefore installation of sheet pile shoring, dewatering of the excavation and construction of culvert footings in the dry will be difficult at this site.

In view of the site conditions, preparation of the founding surface is to entail subexcavation in the wet to the specified depths (compact to dense native soils) in short sections of about 2 m length followed by immediate backfilling with rock fill to above the groundwater level, followed by placement of clear stone to the design founding level as per the Contract Drawings.

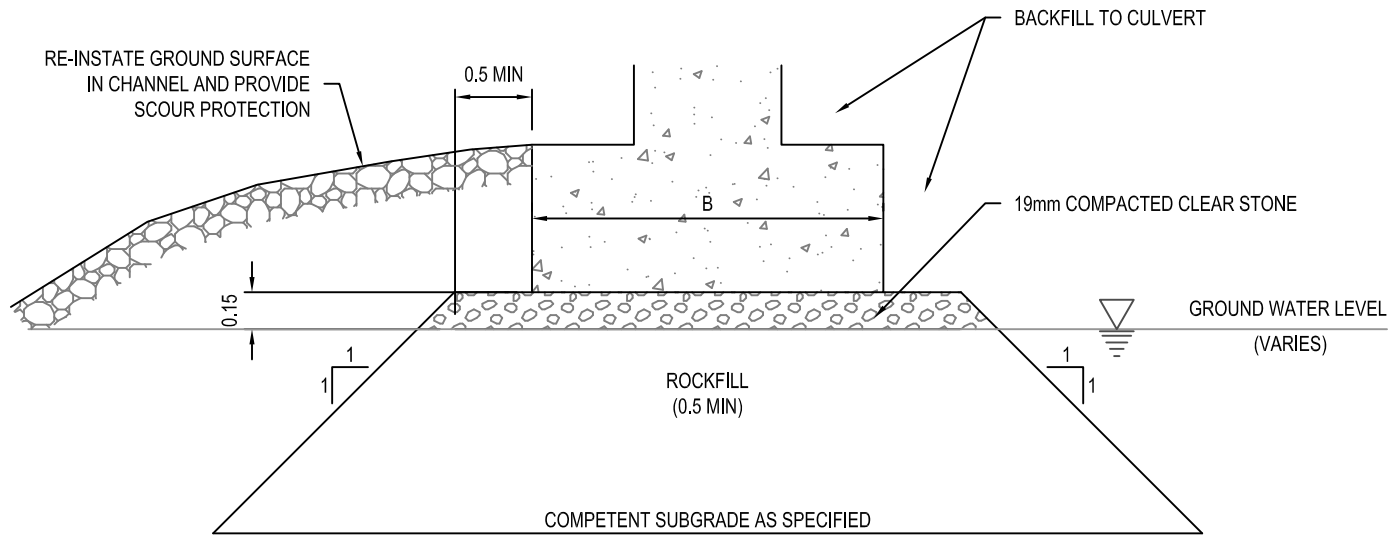
The contractor must carry out the work in a manner which minimizes disturbance to the excavation base and ensure that the excavation does not encroach into the creek by controlling the length of excavation open at any one time, use of shoring, or other suitable means.

Large boulders may be encountered within the excavation depth. Removal of these boulders will require appropriate excavating equipment, and may result in areas of over-excavation requiring additional rock fill to backfill.

Selection of the equipment and methodology to excavate and prepare the founding surface remains the responsibility of the Contractor, and should be based on his interpretation of the subsurface conditions presented in the Foundation Investigation Report as well as the surface conditions exposed at the site.

Appendix F

Figure F1 – Details of Footing on Rock Fill



CROSS-SECTION

NOTES:

1. REMOVE ANY TOPSOIL AND SOFT/LOOSE SUBSOIL UNDER AREA OF ROCKFILL TO COMPETENT SUBGRADE LEVEL AS SPECIFIED.
2. PLACE ROCKFILL TO ABOVE GROUNDWATER LEVEL. ROCKFILL TO HAVE PARTICLE SIZE NO GREATER THAN 150mm.
3. ROCKFILL SURFACE SHOULD BE COMPACTED WITH SEVERAL PASSES OF A DOZER/ROLLER AFTER ROCKFILL IS ABOVE WATER LEVEL.
4. PLACE CLEAR STONE TO BASE OF FOOTING LEVEL AND COMPACT THE CLEAR STONE.
5. PLACE CONCRETE FOOTING.
6. RE-INSTATE GROUND SURFACE IN CHANNEL AND PROVIDE SCOUR PROTECTION.

FOOTING ON ROCKFILL CORE



THURBER ENGINEERING LTD.

ENGINEER:	MRA	DRAWN:	MFA	APPROVED:	-
DATE:	SEPTEMBER 2012	SCALE:	N.T.S.	DRAWING No.	FIGURE F1

Appendix G

Borehole Locations and Soil Strata Drawing

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

CONT No 2012-6010
WP No 623-89-00

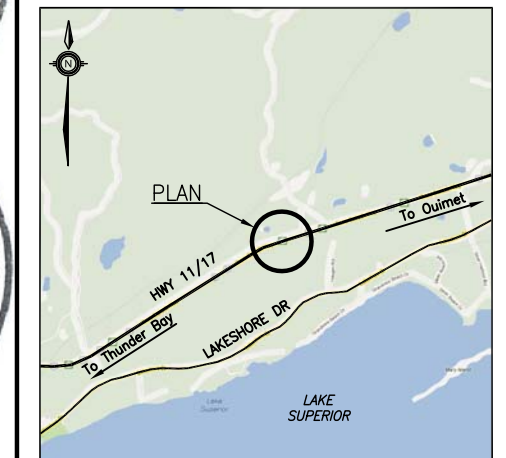
HIGHWAY 11/17
GRANDVIEW CREEK - EBL
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET
255

Hatch Mott
MacDonald

THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

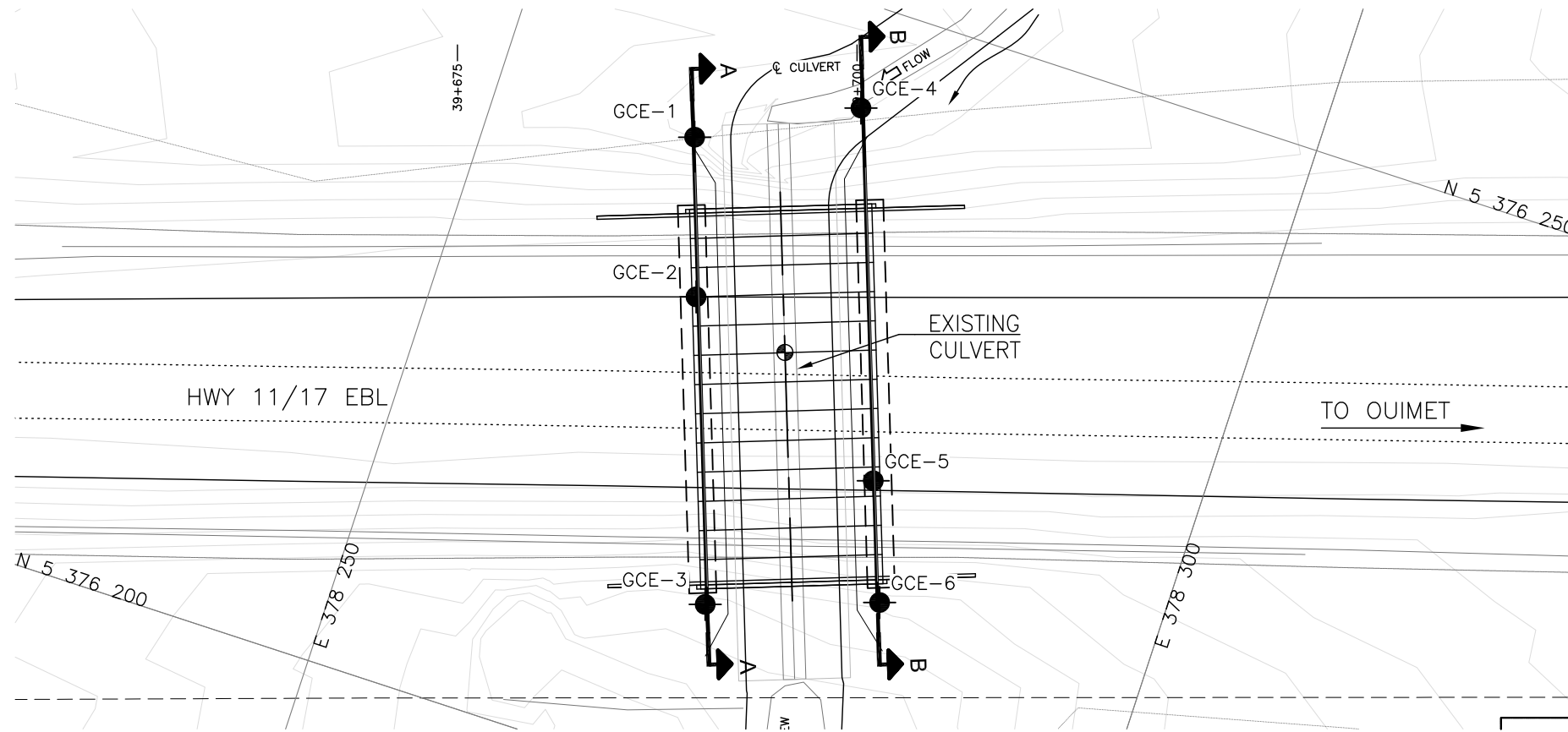
- Borehole
- Borehole and Cone
- N Blows /0.3m (Std Pen Test, 475J/blow)
- CONE Blows /0.3m (60' Cone, 475J/blow)
- PH Pressure, Hydraulic
- Water Level
- Head Artesian Water
- Piezometer
- 90% Rock Quality Designation (RQD)
- A/R Auger Refusal

NO	ELEVATION	NORTHING	EASTING
GCE-1	240.5	5 376 238.7	378 262.8
GCE-2	244.4	5 376 229.2	378 265.9
GCE-3	238.6	5 376 205.8	378 277.5
GCE-4	240.5	5 376 243.7	378 272.1
GCE-5	244.4	5 376 221.7	378 280.1
GCE-6	240.2	5 376 214.6	378 282.8

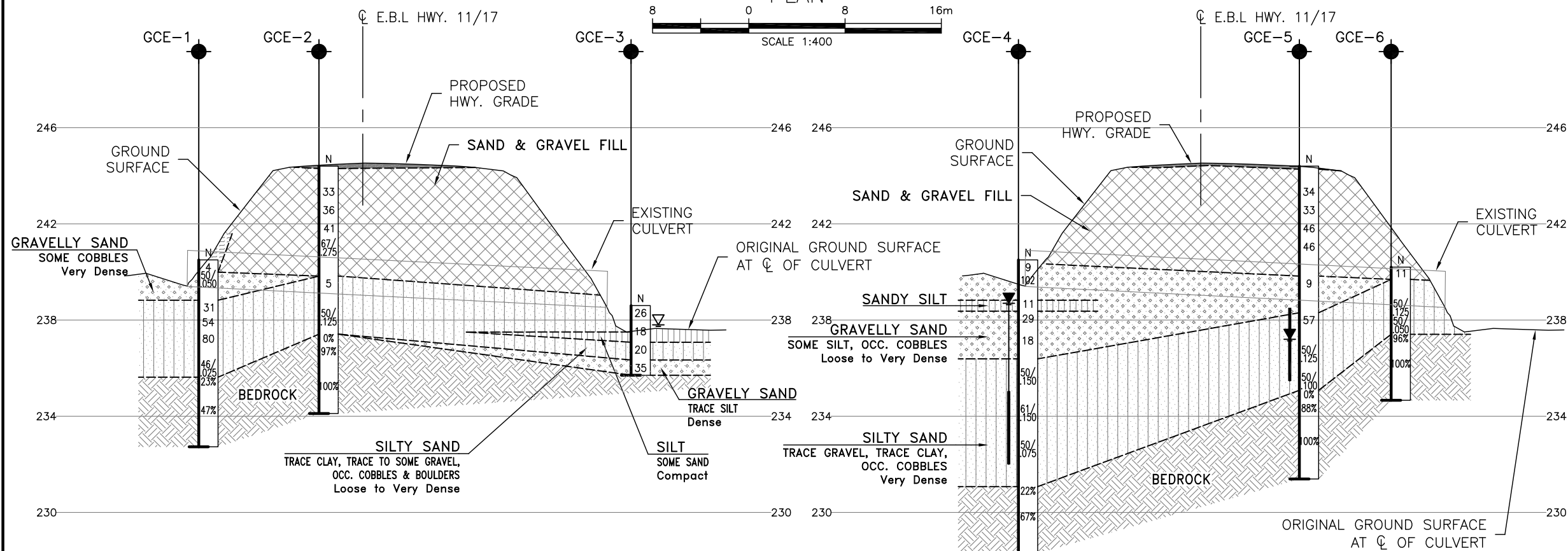
-NOTES-

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

GEOCRES No. 52A-157



PLAN



SECTION A-A

SECTION B-B

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	LRB	CHK LRB	CODE CAN/CSA S6-06[LOAD CL-625-ONT]
DRAWN	MFA	CHK AEG	SITE 48C-349/C1[STRUCT]