FOUNDATION INVESTIGATION AND DESIGN REPORT

BLIND CREEK EAST CULVERT – WBL

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-213/C2

Geocres Number: 52A-161

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 Blind Creek East culvert under the new westbound lanes of Highway 11/17 in the Township of MacGregor, District of Thunder Bay. The new 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 Blind Creek East culvert is located approximately 11 km east of Thunder Bay, Ontario and approximately 7.2 km east of Highway 527. The new culvert will be situated approximately 30 m north of the existing Highway 11/17 alignment. The existing roadway embankment is approximately 1.5 to 3.5 m in height.

Blind Creek East flows within a small bedrock channel at the proposed culvert location. Lands surrounding the culvert site consist of forested areas with bedrock outcrops.

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 is located near a boundary between mafic to intermediate metavolcanic bedrock and metasedimentary bedrock. Locally, the overburden consists of silt and sand overlying bedrock.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing for this project were carried out on November 7, 2011 and consisted of drilling and sampling two boreholes, identified as BCEW-1 and BCEW-2, as well as manual excavation at four borehole locations identified as BCEW-3 to BCEW-6.

Boreholes BCEW-1 and BCEW-4 were located near the proposed culvert inlet, Boreholes BCEW-2 and BCEW-5 were located near the centre, and Boreholes BCEW-3 and BCEW-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 F.

Boreholes BCEW-1 was advanced to refusal on bedrock at 1.2 m depth (elevation 232.8). Borehole BCEW-2 was drilled to bedrock at 1.2 m depth then advanced a further 3.5 m into bedrock to a total depth of 4.7 m (elevation 228.2) using rock coring equipment. Boreholes BCEW-3 to BCEW-6 were advanced by manual excavation to depths of 0.1 m to 1.2 m (elevations 233.3 to 230.7).

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 at this site and a combination of hollow-stem augers, casing and NQ coring techniques were used to advance the boreholes. Soil 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 upon completion of the drilling operations. The completion details of the boreholes are summarized in Table 3.1.

Table 3.1 – Borehole Completion Details

Borehole	Borehole Depth/ Elevation (m)	Completion Details
BCEW-1	1.2 / 232.8	Backfilled with bentonite holeplug and cuttings to surface.
BCEW-2	4.7 / 228.2	Backfilled with bentonite holeplug to surface.
BCEW-3	0.1 / 230.7	Backfilled with cuttings
BCEW-4	0.3 / 233.3	Backfilled with cuttings
BCEW-5	1.2 / 231.3	Backfilled with cuttings.
BCEW-6	0.1 / 231.8	Backfilled with cuttings.

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 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 site consisted of a layer of topsoil or silt and sand overlying bedrock. Bedrock is exposed along the creek channel. More detailed descriptions of the individual strata are presented below.

5.1 Topsoil

Topsoil was encountered at the ground surface at the locations of Boreholes BCEW-3, BCEW-4 and BCEW-6. The topsoil was described as black and silty to sandy. The thickness of the topsoil varied from 125 mm to 250 mm.

5.2 Silt and Sand

Native silt and sand was encountered at the ground surface in Boreholes BCEW-1, BCEW-2 and BCEW-5. The silt and sand was brown to reddish brown and contained trace to some gravel. Occasional cobbles and boulders were observed in Borehole BCEW-5.

The silt and sand layer was 1.2 m thick with a lower boundary on bedrock at elevation 232.8 to 231.3.

SPT N-values of 2 and 5 blows for 0.3 m penetration were recorded at the ground surface, indicating a very loose to loose condition. SPT N-values of 33 and 41 blows for 0.3 m penetration were obtained above the bedrock surface, indicating a dense condition.

The moisture content of three samples of the silt and sand ranged from 20% to 23%. A value of 8% was measured in one sample.

Selected samples of the silt and sand underwent laboratory gradation analysis, the results of which are summarized below. These results are also presented on the Record of Borehole sheets in Appendix A and the grain size distribution curves for these samples are plotted on Figure B1, Appendix B.

Gravel%	0 to 13
Sand%	41 to 44
Silt%	43 to 49
Clay%	3 to 7

5.3 Bedrock

Bedrock was encountered below the topsoil or silt and sand in all boreholes. The depths to bedrock proven by coring or exposed by manual excavation are summarized in Table 5.1.

Table 5.1 – Depth to Bedrock at Borehole Locations

Borehole	Depth to Bedrock (m)	Top of Bedrock Elevation (m)	Proving Method
BCEW-1	1.2	232.8	Auger Refusal
BCEW-2	1.2	231.7	Cored
BCEW-3	0.1	230.7	Manual excavation
BCEW-4	0.3	233.3	Manual excavation
BCEW-5	1.2	231.3	Manual excavation
BCEW-6	0.1	231.8	Manual excavation

The bedrock recovered in the core samples from Borehole BCEW-2 was described as a greenish grey metasedimentary rock. Total core recovery was between 95% and 100%. RQD values of 46% and 18% were recorded, indicating poor to very poor rock quality.

The Fracture Index (FI) of the rock, expressed as fractures per 0.3 m of core, ranged from 0 to 7.

Unconfined compressive strengths (UCS) of 63 and 116 MPa were assessed from the results of point load tests conducted on two rock core samples (average per run), indicating a strong to very strong intact rock. The UCS results are included on the borehole logs in Appendix A.

5.4 Water Levels

Water was observed seeping over the bedrock surface at the location of Borehole BCEW-4 at the time of the fieldwork. Water was not observed in the other boreholes during drilling or manual excavation.

At the time of drilling, a relatively small volume of water was observed flowing within the exposed bedrock channel forming the creek (Photograph 1 in Appendix C).

The above observations are short-term and seasonal fluctuations of the groundwater level and stream flow are to be expected. In particular, the flow may be greater after the spring snowmelt or after periods of heavy rainfall.

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.

The field program was supervised on a full time basis by 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. and Ms. Mei T. Cheong, M.Phil.

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 design of the new culvert carrying Blind Creek East under the new westbound lanes of Highway 11/17. The culvert installation 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 proposed culvert (as shown on the Preliminary General Arrangement drawing dated June 2012) consists of two parallel cast-in-place concrete walls poured directly on bedrock, capped with precast concrete panels to form the roof of the culvert. The new structure will have a span of 8.1 m (total panel length of 9.7 m) and a total length of 30.0 m. The concrete walls will be 0.8 m thick. 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 2.5 to 3.5 m with a proposed finished road grade at Elev. 236.1.

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 site generally consists of a bedrock outcrop partially overlain by deposits of topsoil or silt and sand. At the borehole locations, the bedrock was encountered at depths of 0.1 to 1.2 m (elevation 230.7 to 233.3). The creek flows within a small channel in the bedrock surface.

In view of the shallow and exposed bedrock at this site, it is recommended that the proposed culvert be supported on spread footings founded on bedrock. Recommendations for design of spread footings on bedrock are presented below.

A comparison of alternative foundation systems (steel piles, augered caissons, rock fill) based on advantages and disadvantages of each is included in Appendix D. No meaningful advantages were identified for alternative foundation types at this site, and these foundation options have not been developed.

8.1 Spread Footings on Bedrock

Spread footings must be founded on the bedrock below the level of all topsoil, sand and silt, surficial cobbles and boulders, and any loose, spalled or broken rock. The following geotechnical resistance is recommended for design of spread footings founded on bedrock:

Factored Geotechnical Resistance at ULS 2000 kPa

The SLS condition will not govern design of footings founded on bedrock.

The top of bedrock elevations encountered at the borehole locations are summarized in Table 8.1. Any depressions in the bedrock surface should be brought up to the design founding level using concrete of the same class as the footing concrete.

Table 8.1 – Top of Bedrock Elevations at Borehole Locations

Location		Borehole	Depth to Bedrock (m)	Top of Bedrock Elevation (m)
West Side	Inlet	BCEW-1	1.2	232.8
	Middle	BCEW-2	1.2	231.7
	Outlet	BCEW-3	0.1	230.7
East Side	Inlet	BCEW-4	0.3	233.3
	Middle	BCEW-5	1.2	231.3
	Outlet	BCEW-6	0.1	231.8

The geotechnical resistance is based on a minimum 0.8 m wide 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 lateral resistance of the footings may be computed using an unfactored friction coefficient of 0.7 for footings on bedrock. This value requires a degree of sliding movement to occur to fully mobilize the resistance.

To provide additional lateral/uplift resistance, the footings should be dowelled into the rock; a factored rock-grout bond stress of 500 kPa at ULS is recommended for dowel design (minimum 35 MPa grout). This value includes a geotechnical resistance factor of 0.4 as per Table 6.1 of the CHBDC. The rock dowels should extend a minimum 1.2 m into the bedrock.

8.2 Frost Cover

The depth of frost penetration at this site is 2.2 m. Footings founded on bedrock do not require earth cover as protection against frost action.

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.

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.

Table 9.1 – Earth Pressure Coefficients (K)

Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or Granular B Type II ϕ = 35°, γ = 22.8 kN/m^3		OPSS Granular B Type I or Type III ϕ = 32°, γ = 21.2 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.

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 protection should be provided for the culvert channel as well as at inlet and outlet areas not comprising exposed bedrock. Design of the 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.

11 EXCAVATION AND GROUNDWATER CONTROL

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

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

Seepage was observed along the bedrock surface at the location of Borehole BCEW-4 and should be anticipated at other locations, particularly after snowmelt or rainfall events. Diversion of seepage by such means as sandbagging and/or pumping from low areas in the bedrock may be required to enable placement of concrete on a dry bedrock surface.

Selection of the equipment and methodology to excavate and prepare the founding surface is the responsibility of the Contractor.

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 $\phi = 35°, \gamma = 22.8$ kN/m^3		OPSS Granular B Type I or Type III $\phi = 32°, \gamma = 21.2$ 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:

- The top of bedrock elevation may vary.
- Seepage may be encountered along the bedrock surface.

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.

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Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction

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

4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE

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

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

▼ Water Level

C_{pen} Shear Strength Determination by Pocket Penetrometer

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

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

UNIFIED SOILS CLASSIFICATION

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

EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

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

SYMBOLS

CLAYSTONE

SILTSTONE

SANDSTONE

COAL

Bedrock (general)

DISCONTINUITY SPACING

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

TERMS

Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a percentage of total core run length.
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen
Fracture Index: (FI)	Frequency of natural fractures per 0.3m of core run.

STRENGTH CLASSIFICATION

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No BCEW-1

METRIC

W.P. 623-89-00 | LOCATION N 5 374 713.3 E 375 311.2 Blind Creek East WBL | ORIGINATED BY RK

HWY 11/17 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY AN

DATUM Geodetic | DATE 2011.11.07 - 2011.11.07 | CHECKED BY LRB

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
234.0 / 0.0	**SILT** and **SAND**, trace to some clay, trace gravel Very Loose to Dense Brown Moist		1	SS	2		234		o (≈20)		0	44	49	7
			2	SS	33		233		o (≈20)					
232.8 / 1.2	END OF BOREHOLE AT 1.2m UPON AUGER REFUSAL ON PROBABLE BEDROCK. BOREHOLE DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.													

Legend: Dynamic cone penetration resistance plot scale 20, 40, 60, 80, 100. Shear strength kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; scale 20, 40, 60, 80, 100. Plastic limit w_P, natural moisture content w, liquid limit w_L; water content scale 20, 40, 60. Remarks & grain size distribution (%).

$+^3, \times^3$: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No BCEW-2

METRIC

W.P. 623-89-00 | LOCATION N 5 374 711.2 E 375 324.1 Blind Creek East WBL | ORIGINATED BY RK

HWY 11/17 | BOREHOLE TYPE Hollow Stem Augers/NQ Coring | COMPILED BY AN

DATUM Geodetic | DATE 2011.07.11 - 2011.07.11 | CHECKED BY LRB

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
232.9										
0.0	**SILT** and **SAND**, trace clay, some gravel Loose to Dense Reddish Brown to Brown Moist		1	SS	5			~20		
			2	SS	41		232	~14		13 41 43 3
231.7 / 1.2	**METASEDIMENTARY BEDROCK**, greenish grey, occasional vertical joints Rubble zone (50mm) at 1.8m		1	RUN					FI 3	
			2	RUN			231 230		1 0 2 1	RUN #2 TCR=95% SCR=48% RQD=46% UCS=63MPa (Average)
			3	RUN			229		7 1 0 0 0 4	RUN #3 TCR=100% SCR=83% RQD=18% UCS=116MPa (Average)
228.2 / 4.7	END OF BOREHOLE AT 4.7m. BOREHOLE DRY UPON COMPLETION OF HOLLOW STEM AUGERING. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.									

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

+3, ×3: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No BCEW-3

METRIC

W.P. 623-89-00
LOCATION N 5 374 705.1 E 375 345.6 Blind Creek East WBL
ORIGINATED BY RK

HWY 11/17
BOREHOLE TYPE Visual Assessment and Manual Excavation
COMPILED BY AN

DATUM Geodetic
DATE 2011.11.07 - 2011.11.07
CHECKED BY LRB

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: O 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
230.8											
0.0 / 0.1	**TOPSOIL**, sandy, occasional bedrock fragments: (125mm) Black Moist										
	END OF BOREHOLE AT 0.1m ON BEDROCK. BOREHOLE DRY UPON COMPLETION. EXCAVATION BACKFILLED WITH CUTTINGS.						230				

ONTMT4S 1182.GPJ 2/13/12

+ 3, × 3: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No BCEW-4

METRIC

G.W.P.	623-89-00	LOCATION	N 5 374 726.3 E 375 316.2 Blind Creek East WBL	ORIGINATED BY	RK
HWY	11/17	BOREHOLE TYPE	Visual Assessment and Manual Excavation	COMPILED BY	AN
DATUM	Geodetic	DATE	2011.11.07 - 2011.11.07	CHECKED BY	LRB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: O 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
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
233.6											
0.0 / 233.3 / 0.3	**TOPSOIL**, silty: (250mm) Black Wet										
	END OF BOREHOLE AT 0.3m ON BEDROCK. SEEPAGE OBSERVED ON BEDROCK SURFACE. EXCAVATION BACKFILLED WITH CUTTINGS.										

ONTMT4S 1182.GPJ 6/7/12

$+^3, \times^3$: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No BCEW-5

METRIC

W.P. 623-89-00 LOCATION N 5 374 720.3 E 375 338.1 Blind Creek East WBL ORIGINATED BY RK
HWY 11/17 BOREHOLE TYPE Visual Assessment and Manual Excavation COMPILED BY AN
DATUM Geodetic DATE 2011.11.07 - 2011.11.07 CHECKED BY LRB

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 (O 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
232.5											
0.0	**SILT** and **SAND**, some gravel, some cobbles/boulders Brown Moist						232				
231.3 1.2	END OF BOREHOLE AT 1.2m ON BEDROCK. BOREHOLE DRY UPON COMPLETION. EXCAVATION BACKFILLED WITH CUTTINGS.										

ONTMT4S 1182.GPJ 2/13/12

+³, ×³: Numbers refer to Sensitivity

15-⊕-5 (20 above, 10 below) (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No BCEW-6

METRIC

W.P. 623-89-00
LOCATION N 5 374 717.4 E 375 348.7 Blind Creek East WBL
ORIGINATED BY RK
HWY 11/17
BOREHOLE TYPE Visual Assessment and Manual Excavation
COMPILED BY AN
DATUM Geodetic
DATE 2011.11.07 - 2011.11.07
CHECKED BY LRB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (O 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
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
231.9											
0.0 / 0.1	**TOPSOIL**, sandy, rootlets: (125mm) Black Moist										
	END OF BOREHOLE AT 0.1m ON BEDROCK. EXCAVATION DRY UPON COMPLETION. EXCAVATION BACKFILLED WITH CUTTINGS.						231				

$+^3, \times^3$: Numbers refer to Sensitivity

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

Appendix B

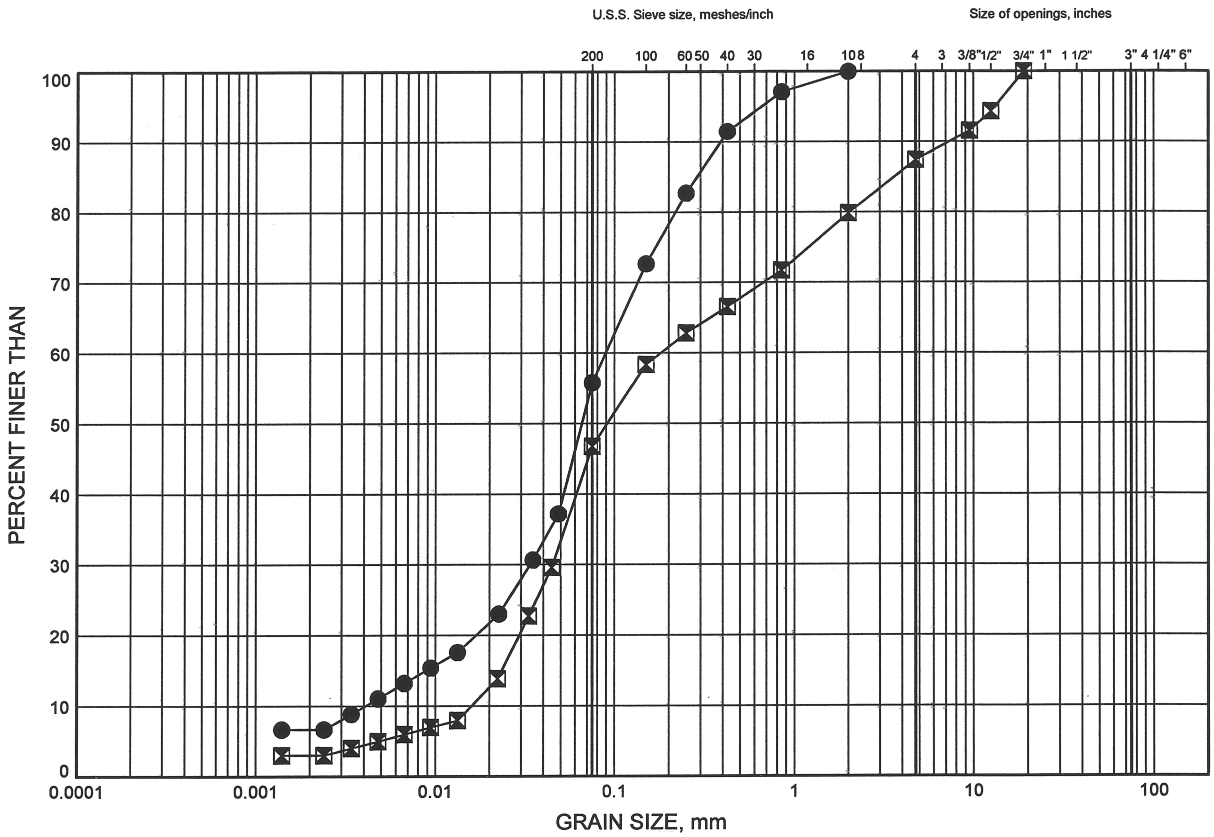
Laboratory Test Results

Hwy 17 - Hwy 527 easterly 12.6km

GRAIN SIZE DISTRIBUTION

FIGURE B1

SILT & SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BCEW-1	0.30	233.65
⊠	BCEW-2	0.91	232.02

W.P.# 623-89-00

Prepared By AN

Checked By LRB

THURBER

Appendix C

Site Photographs

Photograph 1 – Blind Creek East WBL looking north

Photograph 2 – Blind Creek East WBL looking south towards existing Highway 11/17

Appendix D

Foundation Comparison

COMPARISON OF FOUNDATION ALTERNATIVES

Footings on Native Soil	Footings on Rock Fill	Driven Steel Piles	Caissons (Drilled Shaft)
Advantages: i. Less costly construction than deep foundation elements. ii. High geotechnical resistance.	***Advantages:*** i. N/A	***Advantages:*** i. High geotechnical resistances can be achieved.	***Advantages:*** i. High geotechnical resistances can be achieved.
Disadvantages: i. Founding level will vary due to undulations in the bedrock surface. ii. Rock dowels may be required to provide additional lateral/uplift resistance.	***Disadvantages:*** i. Additional cost of rock fill. ii. Lower geotechnical resistance than bedrock.	***Disadvantages:*** i. Predrilling will be required to socket the piles into bedrock. iii. Higher unit costs than footings.	***Disadvantages:*** i. Coring into bedrock will be required to construct caissons. ii. Higher cost than spread footings.
RECOMMENDED	**NOT RECOMMENDED**	**NOT RECOMMENDED**	**NOT RECOMMENDED**

THURBER

Appendix E

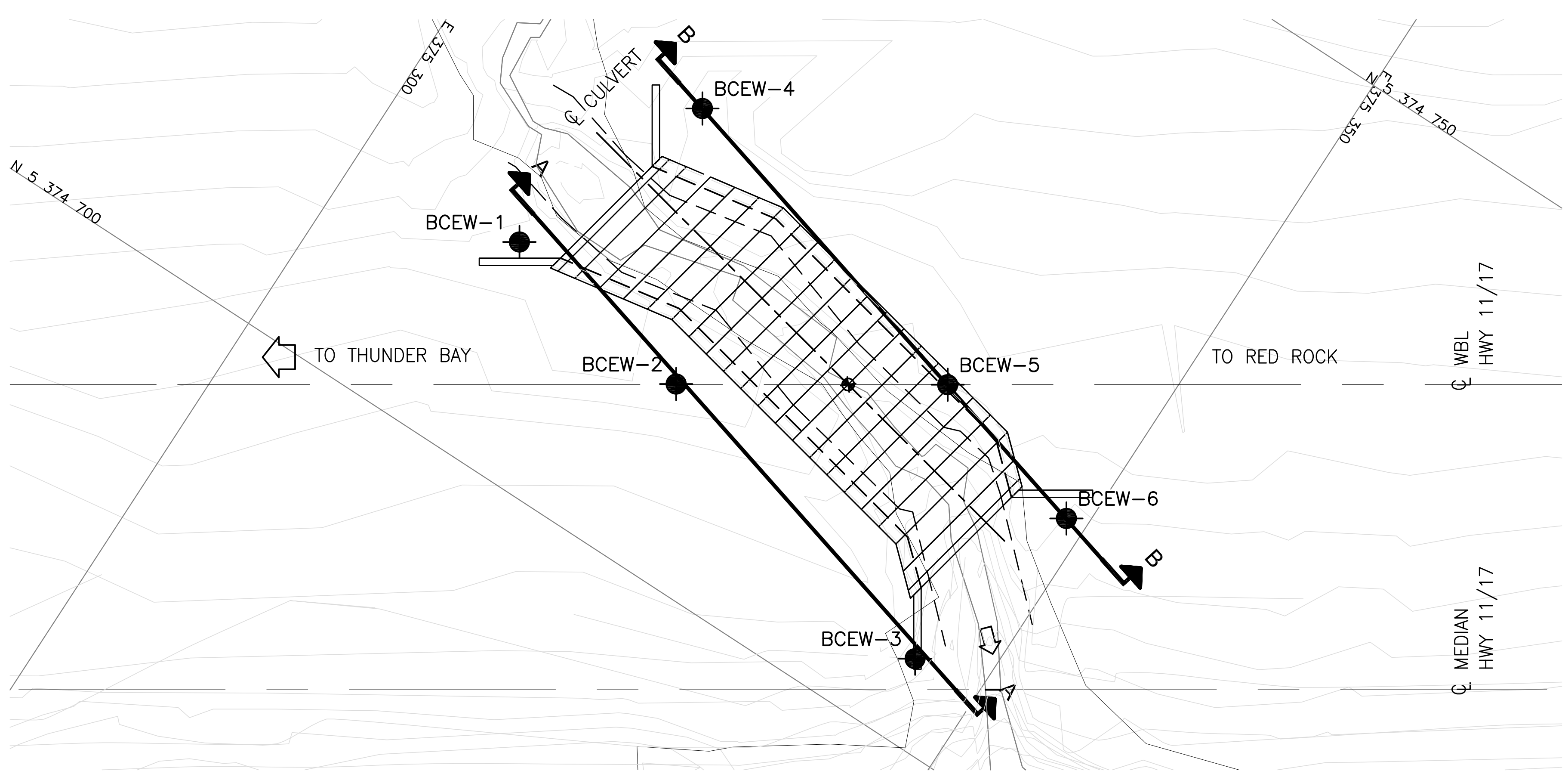
List of SPs and OPSS, and Suggested Text for Selected NSSP

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

- OPSS 501
- OPSS 804
- OPSS 902

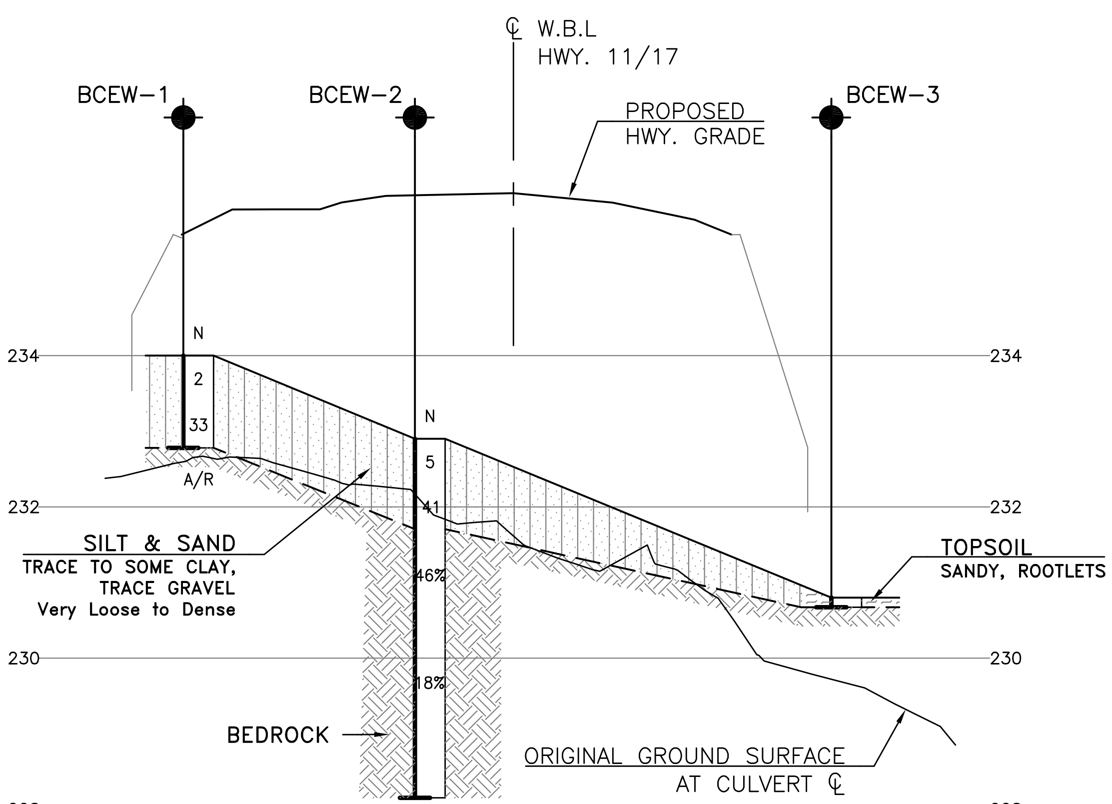
Appendix F

Borehole Locations and Soil Strata Drawing

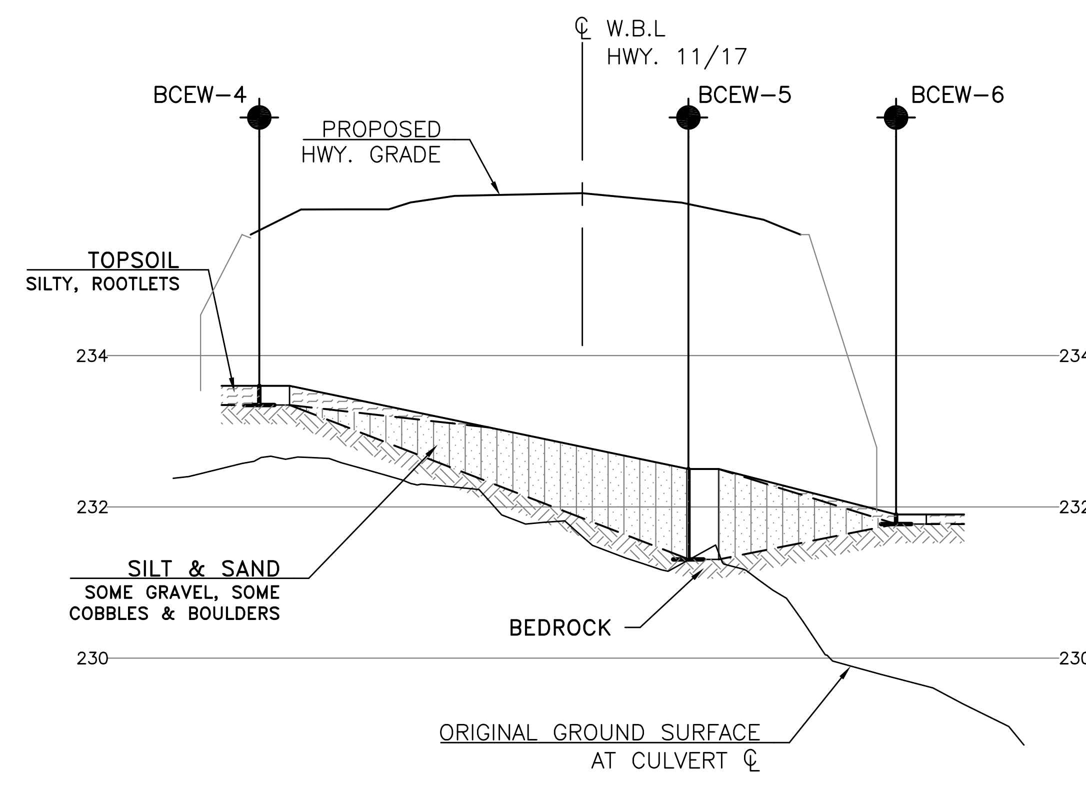


PLAN

8 0 8 16m
SCALE 1:400



SECTION A-A



SECTION B-B

8 0 8 16m H 1:400
2 0 2 4 V 1:100

METRIC

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

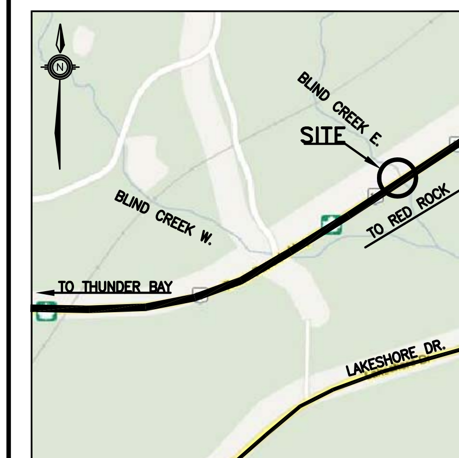
CONT No 2012-6010
WP No 623-89-00

HIGHWAY 11/17 FOUR LANING
BLIND CREEK EAST
CULVERT WESTBOUND LANES
BOREHOLE LOCATION AND SOIL STRATA

SHEET 246

MRC McCORMICK RANKIN A member of MMM GROUP

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
BCEW-1	234.0	5 374 713.3	375 311.2
BCEW-2	232.9	5 374 711.2	375 324.1
BCEW-3	230.8	5 374 705.1	375 345.6
BCEW-4	233.6	5 374 726.3	375 316.2
BCEW-5	232.5	5 374 720.3	375 338.1
BCEW-6	231.9	5 374 717.4	375 348.7

-NOTES-

1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCRES No. 52A-161

REVISIONS | DATE | BY | DESCRIPTION

DESIGN LRB | CHK LRB | CODE CAN/CSA S6-06 | LOAD CL-625-ONT | DATE JULY 2012
DRAWN AN | CHK LRB | SITE 48C-213/C2 | STRUCT | DWG 2

FILENAME: H:\Drafting\19\1351\182\ted1182-BlindCreekEast(WBL)Revise.dwg
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