

**FOUNDATION INVESTIGATION AND DESIGN REPORT
UNKNOWN CREEK (DRIFTWOOD) CULVERT REPLACEMENT
SITE NO. 39E-234
HIGHWAY 11
COCHRANE DISTRICT
G.W.P. No. 5193-13-00, W.P. No. 5198-12-01**

GEOCRES Number: 42H-55

Report to

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual data obtained from a foundation investigation conducted by Thurber Engineering Ltd. (Thurber) at the twin culverts which carry Unknown Creek (Driftwood) under Highway 11, located in the Township of Ottaway, Cochrane District. Ontario.

The purpose of this investigation was to obtain subsurface information at the location of the culverts and, based on the data obtained, to provide a borehole location plan, stratigraphic profiles, records of boreholes, laboratory test results, and a written description of the subsurface conditions.

Thurber was retained by URS Canada Inc. (URS) to carry out this foundation investigation under the MTO Agreement Number 5012-E-0033. The foundation terms of reference indicate that there is no record available of any previous foundation investigation carried out at, or near, the subject culvert.

2 SITE DESCRIPTION

The culvert site is located on Highway 11 in the Township of Ottaway, approximately 15.5 km north of Highway 11/579 in the Cochrane District. The culvert allows Unknown Creek (Driftwood) to flow from south to north under Highway 11.

The existing structure, constructed in 1950, consists of a combination of twin cell 2.1 m wide by 1.8 m high by 27 m long timber boxes, with twin 1.8 m diameter by 6 m long Corrugated Steel Pipe (CSP) extensions at the inlet (south end) area to accommodate the passing lane. The grade of the existing Highway 11 in the vicinity of the culvert is at approximate Elevation 266 m resulting in an embankment fill height above the culvert in the order of 2 m.

The site is located in a rural area with swamps, creeks and other watercourses nearby. The surrounding areas are covered by forests and low shrubs and bushes with no visible bedrock outcrops. Local topography is generally flat with some low hills. This site is adjacent to a turnaround point which provides access to a hiking path in the woods.

Based on published geological information, the general area of the project is covered by glacio-lacustrine sediments of clays and silts laid down by the Glacial Lake Barlow-Ojibway. These deposits are mostly varved clays, but massive clays are also present in some areas. Below the clays are glacial outwash deposits of silts, sands and gravel underlain by Early Precambrian metasedimentary rocks.

A selected photograph showing the existing conditions of the culvert area are included in Appendix E for reference.

3 SITE INVESTIGATION AND FIELD TESTING

This borehole investigation and field testing program was carried out on October 22, 23 and 30, 2013. The program consisted of drilling and sampling six boreholes (numbered UC13-01 through 13-06) to depths ranging from 6.4 to 18.9 m (Elevations 257.3 to 246.4 m) with Dynamic Cone Penetration Tests (DCPT's) continuing below the base of selected boreholes to depths ranging from 21.3 to 22.4 m (Elevations 244.6 to 243.1 m). Of the six boreholes, two were located in the vicinity of the inlets and outlets (UC13-01 and 13-06) and the remaining four boreholes (UC13-02 through 13-05) were located at the highway grade. The Record of Borehole sheets are included in Appendix A.

The borehole locations were marked in the field and utility clearances were obtained prior to commencement of drilling operations. The coordinates and elevations of the as-drilled boreholes were subsequently provided by Callon Dietz utilizing Digital Terrain Model (DTM), based on borehole location sketches prepared by Thurber. The approximate locations and elevations of the boreholes are shown on the attached Borehole Locations and Soil Strata Drawings included in Appendix C.

A truck-mounted drill rig was used to drill and sample the four boreholes advanced from the highway grade and a track-mounted drill rig was used to drill and sample the remaining two boreholes advanced in the vicinity of the culvert inlet and outlet. Hollow stem augers and NW casings were used to advance the boreholes. DCPT's were conducted below the last samples in Boreholes UC13-02 through 13-05 until practical refusal was reached.

Soil samples were obtained at select intervals using a 50 mm diameter split spoon sampler in conjunction with Standard Penetration Testing (SPT). Field vane testing was carried out using an MTO N-size vane to measure the in-situ, undrained shear strength of the cohesive soils at select locations. A number of relatively undisturbed samples were retrieved using 73 mm inside diameter, thin walled Shelby tubes at selected locations within the cohesive soils.

The drilling and sampling operations were supervised on a full time basis by an experienced member of Thurber's technical staff. The recovered soil samples were logged in the field and processed for transportation to Thurber's geotechnical laboratory in Oakville, Ontario for further examination and testing. Groundwater conditions in the open boreholes were observed throughout the drilling operations. The details of standpipe installations and borehole completion are summarized in Table 3-1.

Table 3-1 Borehole Completion and Standpipe Piezometer Installation Details

Borehole Number	Piezometer Tip Location		Completion Details
	Depth (m)	Elevation (m)	
UC13-01	6.1	257.6	Sand filter from 6.4 to 4.3 m, bentonite holeplug to surface
UC13-02	None Installed		Borehole backfilled with bentonite holeplug to 75 mm, granular backfill to surface
UC13-03	None Installed		Borehole backfilled with bentonite holeplug to 75 mm, granular backfill to surface
UC13-04	None Installed		Borehole backfilled with bentonite holeplug to 75 mm, granular backfill to surface
UC13-05	None Installed		Borehole backfilled with bentonite holeplug to 75 mm, granular backfill to surface
UC13-06	6.1	257.6	Sand filter from 7.0 to 4.3 m, bentonite holeplug to surface

4 LABORATORY TESTING

All recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected soil samples were subjected to grain size distribution analyses (sieve and hydrometer) and plasticity testing (Atterberg Limits). Based on the routine testing results and the initial assessment of the site conditions, a sample has been selected from a Shelby tube for laboratory consolidation (oedometer) testing. When the final results are available, they will be used to confirm the initial design recommendations. The results of this laboratory testing program are shown on the Record of Borehole sheets in Appendix A and on the figures in Appendix B.

A sample of surface water was submitted to AGAT Laboratories in Mississauga, a qualified analytical laboratory, for testing against selected corrosivity parameters.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

5.1 General

Reference is made to the Record of Borehole sheets in Appendix A and the Borehole Locations and Soil Strata Drawings in Appendix C for details of the soil stratigraphy encountered in the boreholes. An overall description of the stratigraphy, based on the conditions encountered in the boreholes, is given in the following paragraphs. However, the factual data presented in the Records of Boreholes governs any interpretation of the site conditions.

In general, the subsurface conditions encountered in the boreholes consist of embankment fill for the boreholes drilled from highway grade, or a layer of peat for the boreholes drilled near the inlet and outlet areas. The surficial soils are underlain by a deposit of silty clay which is

underlain by a layer of sand and silt to silty sand in the two deepest boreholes. More detailed descriptions of the soil strata encountered within the boreholes are presented below.

5.2 Peat

A 1.4 to 1.5 m thick layer of peat was encountered at the surface in Boreholes UC13-01 and 13-06. The base of the peat layer was at Elevation 262.2 m. The peat thickness may vary between and beyond the borehole locations and the limited data is not intended for the purpose of estimating quantities.

SPT N-values measured in the peat were between 1 and 2 blows per 0.3 m of penetration indicating a very loose state for the fibrous peat at Borehole UC13-01 and a soft consistency in Borehole UC13-06. The moisture content of the recovered samples ranged from 32% to 269%.

5.3 Sand to Gravelly Sand Fill

Embankment fill was encountered at the surface in Boreholes UC13-02 through 13-05. The upper portion of the fill typically consists of brown sand with some gravel to gravelly and trace silt. Where encountered, the underside of the sand fill extended to a depth of 1.4 to 3.0 m (Elevations 264.2 to 262.3 m).

SPT N-values measured in the sand to gravelly sand fill typically ranged from 10 to 37 blows per 0.3 m of penetration indicating compact to dense state. An N-value of 60 blows per 0.3 penetration was recorded for a frozen layer. The moisture contents of the recovered samples of this fill ranged from 5% to 21%.

Three laboratory grain size distribution analyses were performed on samples of the sand to gravelly sand fill. The results of these tests are presented on the corresponding Record of Borehole sheets in Appendix A and the grain size distribution curves are plotted in Figure B1 of Appendix B. The results are summarized in the following table.

Soil Particles	%
Gravel	21 to 55
Sand	43 to 73
Silt and Clay	2 to 16

5.4 Silty Clay Fill

Below the sand fill, a layer of silty clay fill with trace to some sand and some organics was encountered in Boreholes UC13-02, 13-04 and 13-05. This cohesive fill ranged from 1.4 to 3.5 m in thickness with an underside depth of 3.0 to 4.9 m (Elevations 262.7 to 260.3 m).

SPT N-values measured in the silty clay fill typically ranged from 3 to 14 blows per 300 mm of penetration, indicating soft to stiff consistency. An N-value as high as 22 blows per

0.3 mm of penetration was measured at the top surface of this fill. Measured moisture contents of the recovered samples of silty clay ranged from 3% to 31%.

Two laboratory grain size distribution analyses were performed on samples of the silty clay fill. The results of these tests are presented on the corresponding Record of Borehole sheets in Appendix A and the grain size distribution curves are plotted in Figure B2 of Appendix B. The results are summarized in the following table.

Soil Particles	%
Gravel	0 to 9
Sand	8 to 18
Silt	44 to 45
Clay	29 to 47

5.5 Silty Clay

A deposit of silty clay with trace to some sand and trace gravel was encountered below the peat or embankment fill in all boreholes. Boreholes UC13-01, 13-02, 13-05 and 13-06 terminated within the silty clay at depths of 6.4 to 15.8 m (Elevations 257.3 to 249.4 m). The silty clay was only fully penetrated in Boreholes UC13-03 and 04 with an underside depth of 18.3 to 18.4 m (Elevations 247.4 to 246.9 m).

SPT N-values measured in the silty clay typically ranged from 0 to 8 blows per 0.3 m penetration, and in conjunction with field vane shear strengths ranging between 10 and 35 kPa, indicate a generally stiff to firm crust becoming soft to occasionally very soft with depth. An occasional high N-value of 15 blows per 0.3 m of penetration was encountered in Borehole UC13-03 at about 5.8 m depth. The moisture contents of the recovered samples of silty clay ranged from 5% to 36%.

Ten laboratory grain size distribution analyses were performed on samples of silty clay. The results of these tests are presented on the corresponding Record of Borehole sheets in Appendix A and the grain size distribution curves are plotted on Figures B3 and B4 of Appendix B. The results are summarized in the following table.

Soil Particles	%
Gravel	0 to 23
Sand	0 to 12
Silt	27 to 64
Clay	36 to 60

The results of ten Atterberg Limits tests are plotted on Figures B6 and B7 of Appendix B and indicate that the silty clay has a typical intermediate plasticity with a group symbol of CI.

Results of an oedometer test were not available at the time of preparation of this report.

5.6 Silt and Sand to Silty Sand

A layer of silt and sand to silty sand with trace to some clay and trace gravel was encountered below the silty clay in Boreholes UC13-03 and 13-04. Sampling of the boreholes was discontinued after obtaining a sample in each of these two boreholes. Below the final sampled depth of 18.9 m (Elevations 246.8 to 246.4 m), DCPT's were carried out until practical refusal of the cone tip at 100 blows per 0.3 m penetration.

The SPT N-values measured for these soils ranged from 1 to 5 blows per 0.3 m of penetration indicating very loose to loose state. The moisture contents of the recovered samples ranged from 13% to 18%.

Two laboratory grain size distribution analyses were performed on samples of these soils. The results of these tests are presented on the corresponding Record of Borehole sheets in Appendix A and the grain size distribution curves are plotted on Figure B5 of Appendix B. The results are summarized in the following table.

Soil Particles	%
Gravel	3 to 9
Sand	38 to 47
Silt	28 to 41
Clay	16 to 18

5.7 Borehole Termination

Below the base level of the last sample, DCPT's were advanced to practical refusal taken as 100 blows per 0.3 m penetration. The depths and elevations of DCPT refusals are summarized below in Table 5-1.

Table 5-1. Depth and Elevation of DCPT Blow Count Refusal

Borehole	DCPT Refusal	
	Depth (m)	Elevation (m)
UC13-02	21.3	244.6
UC13-03	21.8	243.5
UC13-04	22.4	243.3
UC13-05	22.1	243.1

5.8 Groundwater Conditions

Water levels were observed in the open boreholes during and upon completion of drilling. Standpipe piezometers were installed in Boreholes UC13-01 and 13-06 to permit monitoring

of groundwater levels. The water levels observed in the open boreholes and measured in the piezometers are as follows:

Table 5-2. Groundwater Elevations

Borehole	Date of Reading	Water Level Depth (m)	Water Level Elevation (m)	Comments
UC13-01	Nov. 1, 2013	0.2	263.5	Standpipe
	Nov. 7, 2013	0.2	263.5	
UC13-02	Oct. 23, 2013	0.6	265.2	Open Borehole
UC13-03	Oct. 30, 2013	0.1	265.2	Open Borehole
UC13-04	Oct. 22, 2013	1.1	264.6	Open Borehole
UC13-05	Oct. 23, 2013	1.1	264.1	Open Borehole
UC13-06	Nov. 1, 2013	0.2	263.5	Standpipe
	Nov. 7, 2013	0.2	263.5	

Based on the above readings, the stabilized groundwater levels ranged between Elevations 264 and 265 m. Local high water levels, spring snowmelt and periods of significant and/or prolonged precipitation events will affect the groundwater level.

6 MISCELLANEOUS

Borehole locations were selected by Thurber. Callon Dietz provided the northing and easting coordinates and ground surface elevations for the as-drilled locations utilizing DTM, based on borehole location sketches provided by Thurber.

Eastern Ontario Diamond Drilling of Hawkesbury, Ontario supplied and operated a truck-mounted and track-mounted drill rig to carry out the drilling, sampling, in-situ testing operations and standpipe installations.

The drilling and sampling operations in the field were supervised on a full time basis by Mr. Joe Gurzanski and Ms. Eckie Siu of Thurber. Routine laboratory testing was carried out at Thurber's geotechnical laboratory in Oakville, Ontario.

A sample of creek water was submitted to AGAT Laboratories in Mississauga, Ontario for testing against corrosivity parameters.

Overall project management and direction of the field program was provided by Mr. Alastair Gorman, P.Eng. Interpretation of the field data and preparation of this report was completed by Stephen Peters, P.Eng. and Dr. Sydney Pang, P.Eng. The report was reviewed by Mr. Gorman 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 GENERAL

This report presents interpretation of the geotechnical data in the factual report and provides foundation recommendations for the replacement of the existing twin culverts and CSP extensions at Unknown Creek (Driftwood) on Highway 11, located approximately 15.5 km north of Highway 11/579 (Cochrane District) within the Township of Ottaway.

Based on the terms of reference, the existing structures, constructed in 1950, consists of twin timber cell culverts with each cell measuring 2.1 m wide by 1.8 m high by 27 m long with twin 1.8 m diameter by 6.0 m long Corrugated Steel Pipe (CSP) extensions at the inlet (south). The embankment height above the culvert is in the order of 2 m.

The discussions and recommendations presented in this report are based on information provided by URS and on the factual data obtained during the course of this investigation.

There is no record of any previous foundation information available for this site. A selected photograph showing the existing conditions of the culvert area are included in Appendix E for reference.

8 CULVERT FOUNDATIONS

8.1 General

The current project requirements involve replacement of the exiting twin cell timber culvert with twin concrete box culverts along the same alignment. It is understood that highway platform widening to both the north and south sides in the order of 2 m will be required during construction. No highway grade raise are currently planned. Physical dimension for the proposed culvert, obtained from URS, are presented in Table 8-1, below.

Table 8-1. Physical Data of Proposed Replacement Culverts

Culvert C09	Borehole Numbers	Approx. Invert Elevation (m)		Length (m)	Width (m)	Height (m)
		Inlet	Outlet			
East Culvert	UC13-06 near inlet UC13-02 to 13-05 through highway embankment adjacent to culverts UC13-01 near outlet	262.190	262.600	32.5	2.4	1.8
West Culvert		262.190	262.600	32.3	2.4	1.8

Note: All dimensions are preliminary and subject to change

8.2 Foundation Alternatives

This section presents discussions on alternate types of replacement culverts and foundation alternatives, and provides recommendations on feasible and/or preferred foundation option. Several common culvert and foundation types are listed below and a comparison of these alternatives, based on their respective advantages and disadvantages, is included in Appendix D.

Concrete, Open Footing Culvert

Concrete, open footing culverts are not considered a preferred option for this site from a foundation engineering perspective as the compressible silty clay subgrade will provide low geotechnical resistances and has potential for post construction settlement.

Circular Pipes (Concrete, Steel, HDPE)

From a foundation engineering standpoint, concrete, steel and HDPE pipes are technically feasible alternatives, provided that other design issues including flow capacity, hydraulic properties and durability can be satisfied.

Concrete Box (Closed) Culvert

Given the subsurface conditions and the anticipated construction sequencing, precast concrete box culvert is the preferred culvert replacement option from a foundation engineering standpoint. Precast sections, rather than cast-in-place construction, can be installed rapidly with less potential for disturbance of the founding soils during installation. Engineering granular fill pads may be used at locations where it is required to raise the subgrade to the desired invert elevations or where higher geotechnical resistances are required.

The report focuses on providing foundation recommendations on the design and construction of box culverts and the associated walls.

8.3 Foundation Design

The founding elevation of the culverts depends on factors including hydrologic, hydraulic and environmental considerations to be addressed by others. It is assumed that the replacement culverts will be founded at approximately the same level as the existing base of culverts.

8.3.1 Concrete Box Culvert

Since the replacement culverts are anticipated to be constructed on the same alignments as the existing culverts, the subgrade soils within the culvert footprint should not be subjected to any significant additional loading.

In order to provide a uniform foundation subgrade condition, a minimum 300 mm thick layer of bedding material conforming to OPSS 1010 Granular A requirements must be provided under the base of the box culvert as per OPSD 803.010. The bedding material must be placed on the approved subgrade as soon as practicable for protecting the subgrade from disturbance during construction following its inspection and approval. Construction equipment must not be allowed to travel on the bedding or the prepared subgrade.

The underside of the Granular A pad should be founded at or below Elevation 261.8 m on the undisturbed, firm to stiff silty clay. Any soft clays at the subgrade level must be sub-excavated and replaced with engineered fill as outlined below. The recommended geotechnical resistances for this founding elevation, under the existing culvert footprints, are as follows:

- Factored Geotechnical Resistance at ULS of 120 kPa
- Geotechnical Resistance at SLS (less than 25 mm settlement) of 80 kPa.

Resistance to lateral forces/sliding resistance between precast concrete and the underlying Granular A should be evaluated in accordance with the CHBDC (2010) assuming an ultimate coefficient of friction of 0.4.

It is recommended that culverts be designed to resist external loadings including frost forces, lateral earth pressure, hydrostatic pressure, weight of embankment fill, traffic loading and surcharge due to construction equipment and activities.

8.3.2 Retaining Walls

Preliminary design information provided by URS indicates that there will be no requirement for any retaining wall as part of this culvert replacement project.

8.3.3 Settlements

It is understood that there is no grade raise at this site. It is also understood that the culverts will be replaced along the same alignments as the existing culverts. Taking into consideration the proposed conceptual construction sequence, it is anticipated that the rebound of the subgrade after removal of the existing culverts will also be negligible.

It is anticipated that the concrete culverts are slightly heavier than the existing timber boxes. As such, the underlying firm to occasionally soft silty clay would be subjected to additional load resulting in some post construction consolidation settlements. It is estimated that settlement due to the slightly heavier weight for concrete is in the order of 5 to 10 mm within 10 years.

8.3.4 Subgrade Preparation

Boreholes UC13-06 and 13-01 located near the inlet and outlet areas, respectively, encountered surficial peat to 1.4 to 1.5 m depths. The presence of alluvial and other organic deposits should be expected in the vicinities of the existing culverts and watercourses.

After removal of the existing culverts and excavation to the design founding elevation, the exposed surface must be inspected to confirm that the subgrade is suitable and uniformly competent. Any remaining fill, topsoil, organics, soft creekbed deposits, soft/loose areas, disturbed soils and any deleterious materials within the culvert replacement and wall slab footprints must be further sub-excavated to undisturbed, competent firm native soils. The sub-excavated area should be replaced with well compacted granular fill consisting of OPSS 1010 Granular A or B Type II material as soon as practical for protecting the subgrade from disturbance during construction.

Culvert construction must be carried out in the dry.

8.3.5 Frost Depth

The frost penetration depth for this site is 2.6 m.

8.4 Construction Staging

Staged open cutting is proposed to be implemented to replace the culverts. The main features of the staged construction are as follows:

- Two lanes of traffic will be maintained at all times during construction
- Temporary widening of the highway platform will be carried out on both sides
- Cofferdams are installed at the inlet and outlet areas as part of the creek flow and surface water diversion
- Creek flow will be maintained through at least one culvert at all times
- Pumping from sumps is anticipated to be required inside the cofferdams during construction
- Roadway protection will be required during various stages of construction
- Excavation and removal of the existing culvert, installation of the new culvert and backfilling will be carried out within the protection systems
- All works to be carried out in the dry

Protection systems/temporary shoring, such as the use of interlocking steel sheetpiles, will be required to maintain movement of traffic during construction. Foundation recommendations

for the design of such a system are provided in Section 13. Sump pumping will be required to maintain the excavations in a dry condition.

9 CULVERT BACKFILL AND LATERAL EARTH PRESSURES

It is recommended that backfill to the culverts and walls consists of free-draining, non-frost susceptible granular materials such as Granular A or B Type II conforming to the requirements of OPSS 1010. Reference should be made to the backfill arrangements stipulated in OPSD 803.01 as appropriate.

All fills should be placed in regular lifts and be compacted in accordance with OPSS 501. The backfill should be placed and compacted in simultaneous lifts on both sides of a culvert, and the top of backfill elevation should be the same on both sides of the culvert at all times. Heavy compaction equipment must not be used adjacent to the walls and roofs of the culverts.

Earth pressures acting on the culvert walls may be assumed to impose a triangular distribution. For a fully drained backfill, the pressures should be computed in accordance with the CHBDC 2010 but are generally given by the expression:

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

where	p_h	=	horizontal pressure on the wall at depth h (kPa)
	K	=	earth pressure coefficient (see table below)
	γ	=	bulk unit weight of retained soil (see table below)
	h	=	depth below top of fill where pressure is computed (m)
	q	=	value of any surcharge (kPa)

If full drainage of the culvert backfill is not achievable, the culvert walls must be designed to withstand full hydrostatic pressure assuming a water level at least equal to the design creek water level.

Earth pressure coefficients for backfill to the retaining walls are dependent on the material used as backfill. Recommended unfactored values are shown in the following Table 9-1. The factors in Table 9-1 are “ultimate” values and require certain movements for the respective conditions to mobilize. The values to be used in design can be estimated from Figure C6.16 in the Commentary to the CHBDC.

Table 9-1. Earth Pressure Coefficients (K)

Wall Condition	Earth Pressure Coefficient (K)					
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ$; $\gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I (modified) $\phi = 32^\circ$; $\gamma = 21.2 \text{ kN/m}^3$		Embankment Fill $\phi = 30^\circ$; $\gamma = 20.0 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48	0.33	0.54
At rest (Restrained Wall)	0.43	0.62	0.47	0.70	0.50	0.76
Passive (Movement Towards Soil Mass)	3.7	-	3.3	-	3.0	-

For rigid structures such as concrete box culverts, it is recommended that at-rest horizontal earth pressures be used for design. Active pressures should be used for any headwalls or unrestrained wall.

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.

10 EMBANKMENT DESIGN AND CONSTRUCTION

10.1 Culvert Replacement

Embankment reconstruction, after culvert replacement, must be carried out in accordance with OPSS 206. The embankment material must consist of imported Granular A or B Type II material. Excavated granular fill may also be reused as backfill provided the following conditions are satisfied:

- There is sufficient space to stockpile the excavated fill on site and control the moisture content within acceptable limits for compaction
- No peat or organics are included in the fill
- Gradation and compaction characteristics meet the requirements prior to reuse as backfill

Slope stability analyses carried out based on slope profile information at the culvert provided by URS indicates that a Factor of Safety of 1.4 can be maintained for the existing slope inclination of 2.5H : 1V, or flatter.

Where applicable, benching the existing slope surface should be carried out as per OPSD 208.010 in order to enhance the keying in of the newly placed fill. Embankment reconstruction associated with the culvert replacement should be carried out in accordance with OPSS 206. The embankment material should consist of Granular A or B materials meeting the requirements of OPSS 1010.

10.2 Embankment widening for detour

Widening of the paved roadway on the north and south sides to accommodate temporary traffic detour lanes will require placement and compaction of granular fill. Slope stability analyses carried out based on slope profile information during staged construction at the culvert location provided by URS indicates that a global Factor of Safety of 1.2 can be maintained for an overall slope inclination of 2H : 1V. Stability analysis results for this condition is included in Appendix F. In order to achieve a Factor of Safety of 1.3 typically acceptable for short term conditions, the design has been revised to limit the new fill placement to essentially pavement widening. It is understood that the new fill will be removed before the end of construction. In the long term, a permanent slope inclination of 3H : 1V will remain stable.

As the new fill is placed on the existing embankment slope, it is anticipated that settlement due to elastic compression of the underlying native silty clay will take place. Due to the small quantity of new fill, it is anticipated that the resulting settlement would be negligible.

11 EROSION CONTROL

Erosion protection should be provided at the culvert inlet and outlet areas. Design of the erosion protection measures must consider hydrologic and hydraulic factors and should be carried out by specialists experienced in this field.

Typically, rock protection should be provided over all surfaces with which creek water is likely to be in contact. Treatment at the outlets should be in accordance with OPSD 810.010. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS 804.

It is recommended that a clay seal or a concrete cut-off wall be used to minimize the potential for piping through the backfill. The clay seal should extend a minimum of 0.3 m above the high water level and laterally for the width of the granular material, and have a minimum thickness of 0.5 m. The material requirements should be in accordance with OPSS 1205.

12 EXCAVATION AND GROUNDWATER CONTROL

12.1 General

All excavations must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the embankment fill and native silty clay at this site are classified as Type 3 soils above the water level and Type 4 soils below the water level. Peat and surficial alluvial deposits that are anticipated at the inlet and outlet areas are classified as Type 4 soils.

12.2 Excavations

Excavations for culvert replacement will typically be carried out through the existing embankment fill and extend into the underlying native silty clay soils. At locations where there is space restriction or where a slope has to be retained, the excavations will need to be carried out in conjunction with a protection system. Any roadway protection system must be designed by a licensed Professional Engineer experienced in such designs. OPSS 539 “Construction Specifications for Protection Systems” will have to be included in the contract documents. It is recommended that Performance Level 2, as per Clause 539.04.02.01 (maximum horizontal displacement of 25 mm), be specified for this culvert replacement site.

12.3 Control of Groundwater and Surface Water

Construction of the culvert must be carried out in the dry. Accordingly, it is recommended that surface water, e.g. water from the creek or swamp, be excluded from the construction area by means of a cofferdam. The cofferdam must be designed by the Contractor and while a sheet pile design may be the most effective, other designs such as sandbags may be used provided that they perform satisfactorily.

Accumulation of water from precipitation, surface runoff and seepage must be anticipated within the cofferdam. This may be removed by such means as pumping from sumps.

13 ROADWAY PROTECTION DESIGN

Roadway protection will be required during various stages of construction. The design of roadway protection is the responsibility of the Contractor and all shoring systems must be designed by a Professional Engineer experienced in such design. However, one option that is considered to be suitable for use at this site is steel interlocking sheetpile enclosures which are also anticipated to provide an effective groundwater cutoff.

It is anticipated that the sheetpiles will be extended into the firm silty clay to develop the required toe resistance. The designer of the roadway protection system should check whether the penetration depth is sufficiently deep to provide base fixity. It is anticipated that the shoring system may be stiffened by corner and cross bracings, where applicable. An interlocking sheetpiled wall may be designed using the parameters given below:

γ	=	20 kN/m ³
γ_w	=	10 kN/m ³
K_a	=	0.33 (highway embankment fill) 0.36 (silty clay)
K_p	=	2.8 (silty clay)

Typically, a triangular earth pressure distribution, as outlined in Section 9, should be used for a cantilevered sheetpiled wall. The actual pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall, and these factors must be considered when designing the shoring system. Full hydrostatic pressure should be considered assuming a water level at or above the design creek water level. In addition, the sheetpiled wall should be designed to incorporate traffic loading and surcharge loading due to construction equipment and operations.

14 CONSTRUCTION CONCERNS

During construction, the Contract Administrator should employ experienced geotechnical staff to observe construction activities related to foundation construction, and to inspect and approve the culvert subgrade.

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

- Impact of excavation on the existing pavement surface

Daily visual inspection of the pavement surface must be carried out in the vicinity of each culvert under construction. If cracks form in the pavement or settlement is observed to occur, these matters must immediately be brought to the attention of the C.A. for determining as to whether remedial action is required.

- removal of peat, organics, soft soils and alluvial deposits near creek and stream channels
- disturbance of the soil subgrade within the culvert foundation footprints
- confirmation that the culvert backfills and approach fills are adequately placed and compacted to specifications.

It is recommended that provision(s) be included in the contract requiring the QVE to confirm that the above issues are adequately addressed. Should there be any doubts about issues such as depth of sub-excavation, these provisions should require the QVE to alert the CA.

15 CLOSURE

Preparation of this foundation design report was carried out by Mr. Stephen Peters, P.Eng. and Dr. Sydney Pang, P.Eng. The report was reviewed by Mr. Alastair Gorman, P.Eng. and Dr. P.K. Chatterji, P.Eng.

THURBER ENGINEERING LTD.

Sydney Pang, P.Eng.
Senior Foundations Engineer



Alastair Gorman, P.Eng.
Project Manager, Senior Foundations Engineer



P.K. Chatterji, P.Eng.
Review Principal, Designated MTO Contact



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.

EXPLANATION OF ROCK LOGGING TERMS

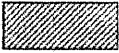




ROCK WEATHERING CLASSIFICATION

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

DISCONTINUITY SPACING

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

SYMBOLS

	CLAYSTONE
	SILTSTONE
	SANDSTONE
	COAL
	BEDROCK

STRENGTH CLASSIFICATION

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

TERMS

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

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
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

RECORD OF BOREHOLE No UC13-01 Site 39E-234 1 OF 1

METRIC

GWP# 5193-13-00 LOCATION HWY 11 - Driftwood Creek N 5 435 581.1 E 287 937.6 ORIGINATED BY JG
 HWY 11 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2013.10.22 - 2013.10.22 CHECKED BY SKP


SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	W _P W W _L	SHEAR STRENGTH kPa			WATER CONTENT (%)				GR	SA	SI	CL
263.7	GROUND SURFACE																			
0.0	PEAT, trace sand, trace silt, trace clay Very Loose Brown Moist		1	SS	1		263													
			2	SS	2															
262.2																				
1.5	Silty CLAY, trace gravel, trace sand, some organics Soft Grey Moist		3	SS	2		262													
			1	TW	PH		261													
			4	SS	0		260													
	Firm		5	SS	8		259												0 7 50 43	
						258														
257.3																				
6.4	END OF BOREHOLE AT 6.4m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) Nov. 1/13 0.2 263.5 Nov. 7/13 0.2 263.5																			

ONTMT4S 4069.GPJ 2012TEMPLATE(MTO).GDT 1/7/15

RECORD OF BOREHOLE No UC13-02 Site 39E-234 1 OF 3

METRIC

GWP# 5193-13-00 LOCATION HWY 11 - Driftwood Creek N 5 435 577.1 E 287 913.3 ORIGINATED BY ES
 HWY 11 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.10.23 - 2013.10.23 CHECKED BY SKP

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						
265.8	GROUND SURFACE							20 40 60 80 100						
0.0	Gravelly SAND , some silt Compact Brown Moist (FILL)		1	SS	24									35 49 16 (SI+CL)
			2	SS	27									
264.2														
1.6	Silty CLAY , trace to some sand, trace gravel Stiff Brown Moist (FILL)		3	SS	12									
			4	SS	6									
			5	SS	3									
			6	SS	7									
261.5														
4.4	Silty CLAY , trace sand, trace gravel Stiff to Very Soft Grey Moist		7	SS	12									
260.2														
5.6	Firm to Soft													
			8	SS	3									
			9	SS	1								0 0 64 36	
			10	SS	0									

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 (%) STRAIN AT FAILURE

METRIC

GWP#	5193-13-00	LOCATION	HWY 11 - Driftwood Creek N 5 435 577.1 E 287 913.3	ORIGINATED BY	ES
HWY	11	BOREHOLE TYPE	NW Casing	COMPILED BY	AN
DATUM	Geodetic	DATE	2013.10.23 - 2013.10.23	CHECKED BY	SKP

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RECORD OF BOREHOLE No UC13-02 Site 39E-234 3 OF 3

METRIC

GWP# 5193-13-00 LOCATION HWY 11 - Driftwood Creek N 5 435 577.1 E 287 913.3 ORIGINATED BY ES
 HWY 11 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.10.23 - 2013.10.23 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	WATER CONTENT (%)					
	Continued From Previous Page							20 40 60 80 100						
244.6							245							
21.3	END OF BOREHOLE AND DCPT AT 21.3m UPON DCPT REFUSAL. FREE WATER AT 6.3m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.1m, SAND AND GRAVEL TO SURFACE.													

RECORD OF BOREHOLE No UC13-03 Site 39E-234 1 OF 3

METRIC

GWP# 5193-13-00 LOCATION HWY 11 - Driftwood Creek N 5 435 573.5 E 287 942.4 ORIGINATED BY ES
 HWY 11 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.10.30 - 2013.10.30 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				GR	SA	SI	CL
								20	40	60	80	100	W _P	W		W _L			
265.3	GROUND SURFACE		1	SS	60/ 0.150														
0.0	SAND and GRAVEL to Gravelly SAND , trace silt Very Dense to Dense Brown Moist (FILL)		2	SS	32														
263.8																			
1.4	Compact		3	SS	15														
			4	SS	10														
262.3																			
3.0	Silty CLAY , trace sand, trace to some gravel Firm Brown Moist		5	SS	4														
			6	SS	3														
			1	TW	PH														
259.5																			
5.8	Stiff Grey		7	SS	15														
258.1																			
7.2	Firm to Soft		8	SS	8														
			2	TW	PH														

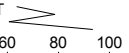



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RECORD OF BOREHOLE No UC13-03 Site 39E-234 2 OF 3

METRIC

GWP# 5193-13-00 LOCATION HWY 11 - Driftwood Creek N 5 435 573.5 E 287 942.4 ORIGINATED BY ES
 HWY 11 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.10.30 - 2013.10.30 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE																
Continued From Previous Page																
								WATER CONTENT (%)								
	Silty CLAY Firm to Soft Grey Moist		9	SS	0		255	2.0 +							0 0 49 51	
							254									
253.7							253									
11.6	Soft to Very Soft			10	SS	1		252	4.0 +							
							251									
				11	SS	0		250								
							249									
				12	SS	0		248								
							247									
	Occasional sand seams			13	SS	1		246	2.0 +							
246.9																
18.4	Silty SAND , some clay, trace gravel Very Loose Grey Moist			14	SS	1										9 47 28 16
246.4																
18.9	End of sampling at 18.9m and start of DCPT															

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(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No UC13-03 Site 39E-234 3 OF 3

METRIC

GWP# 5193-13-00 LOCATION HWY 11 - Driftwood Creek N 5 435 573.5 E 287 942.4 ORIGINATED BY ES
 HWY 11 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.10.30 - 2013.10.30 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE LIQUID CONTENT LIMIT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)			
	Continued From Previous Page							20 40 60 80 100	○ UNCONFINED + FIELD VANE	W _P W W _L			
								● QUICK TRIAXIAL × LAB VANE					
243.5							245						
21.8	END OF BOREHOLE AND DCPT AT 21.8m UPON DCPT REFUSAL. FREE WATER AT 0.1 m UPON COMPLETION. BORHEOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.1 m, SAND AND GRAVEL TO SURFACE. ARTESIAN CONDITIONS WHILE BACKFILLING THE BOREHOLE, AUGER DOWN TO 3.0m WITH HOLLOW STEM AUGERS TO PLUG THE BOREHOLE.						244						

RECORD OF BOREHOLE No UC13-04 Site 39E-234 1 OF 3

METRIC

GWP# 5193-13-00 LOCATION HWY 11 - Driftwood Creek N 5 435 559.0 E 287 920.4 ORIGINATED BY ES
 HWY 11 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.10.22 - 2013.10.22 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								20 40 60 80 100								
265.7	GROUND SURFACE															
0.0	SAND , some gravel to gravelly SAND Dense to Compact Brown Moist (FILL)		1	SS	37		265								21 73 6 (SI+CL)	
			2	SS	16		264									
264.1																
1.6	Silty CLAY , some sand, trace gravel, some organics Stiff to Firm Dark Brown Moist (FILL)		3	SS	9		263									no recovery
			4	SS	5											
262.7																
3.0	Silty CLAY , trace to some sand, trace gravel Stiff to Firm Brown to Grey Moist		5	SS	8		262									0 12 42 46
			6	SS	4											
	Occasional sand pockerts, occasional sand seams		7	SS	10		261									
260.1								260								
5.6																
	Grey Firm to Soft		8	SS	8		259									
							258	2.0 +						0 0 60 40		
			1	TW	PH		257	2.0 +								
			9	SS	1		256									

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RECORD OF BOREHOLE No UC13-04 Site 39E-234 2 OF 3

METRIC

GWP# 5193-13-00 LOCATION HWY 11 - Driftwood Creek N 5 435 559.0 E 287 920.4 ORIGINATED BY ES
 HWY 11 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.10.22 - 2013.10.22 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				GR	SA	SI	CL		
								20 40 60 80 100	○ UNCONFINED + FIELD VANE	W _P W W _L											
Continued From Previous Page							20 40 60 80 100	● QUICK TRIAXIAL × LAB VANE	WATER CONTENT (%)												
	Silty CLAY Soft Grey Moist							3.0 +													
			10	SS	0		255										0	0	49	51	
							254	2.0 +													
			11	SS	0		253														
							252	2.0 +													
			12	SS	0		251														
							250	2.0 +													
			2	TW	PH		249														
							248	2.0 +													
			13	SS	1		247														
247.4																					
18.3	SAND and SILT , trace to some clay, trace gravel Loose Grey Wet		14	SS	5		247											3	38	41	18
246.8																					
18.9	End of sampling at 18.9m and start of DCPT						246														

Continued Next Page

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Sensitivity

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(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No UC13-04 Site 39E-234 3 OF 3

METRIC

GWP# 5193-13-00 LOCATION HWY 11 - Driftwood Creek N 5 435 559.0 E 287 920.4 ORIGINATED BY ES
 HWY 11 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.10.22 - 2013.10.22 CHECKED BY SKP

SOIL PROFILE			SAMPLES				GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE LIQUID LIMIT CONTENT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	SHEAR STRENGTH kPa			WATER CONTENT (%)					
	Continued From Previous Page							<div><div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></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RECORD OF BOREHOLE No UC13-05 Site 39E-234 1 OF 3

METRIC

GWP# 5193-13-00 LOCATION HWY 11 - Driftwood Creek N 5 435 555.3 E 287 944.5 ORIGINATED BY ES
 HWY 11 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.10.23 - 2013.10.23 CHECKED BY SKP

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	REMARKS & GRAIN SIZE DISTRIBUTION (%)									
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80						100	20	40	60	3	GR	SA	SI	CL
SHEAR STRENGTH kPa											WATER CONTENT (%)														
○ UNCONFINED + FIELD VANE																									
● QUICK TRIAXIAL × LAB VANE																									
265.2	GROUND SURFACE					▽	265																		
0.0	Gravelly SAND Dense Dark Brown to Brown Moist (FILL)		1	SS	34																				
			2	SS	31																				
263.8							264																		
1.4	Silty CLAY , some sand, trace gravel Very Stiff to Firm Brown (FILL)		3	SS	22																				
			4	SS	8																				
			5	SS	5																				
			6	SS	14																				
			7	SS	3																				
260.3							261																		
4.9	Silty CLAY , trace sand Firm to Soft Grey Moist					260																			
			8	SS	2																				
			9	SS	1																				
			10	SS	0																				


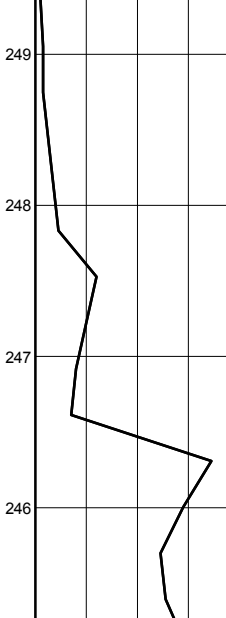
Continued Next Page

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

RECORD OF BOREHOLE No UC13-05 Site 39E-234 2 OF 3

METRIC

GWP# 5193-13-00 LOCATION HWY 11 - Driftwood Creek N 5 435 555.3 E 287 944.5 ORIGINATED BY ES
 HWY 11 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.10.23 - 2013.10.23 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			WATER CONTENT (%)								
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE											
Continued From Previous Page																			
249.4 15.8	Silty CLAY Soft Grey Moist						255	2.0 +								0 0 53 47			
			11	SS	0		254												
			12	SS	0		253	2.0 +											
			13	SS	2		252	2.0 +											
			251																
			250	2.0 +															
			14	SS	2														
End of sampling at 15.8m and start of DCPT																			

Continued Next Page

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

RECORD OF BOREHOLE No UC13-05 Site 39E-234 3 OF 3

METRIC

GWP# 5193-13-00 LOCATION HWY 11 - Driftwood Creek N 5 435 555.3 E 287 944.5 ORIGINATED BY ES
 HWY 11 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.10.23 - 2013.10.23 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE LIQUID LIMIT CONTENT		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		W P W W L			
	Continued From Previous Page							20 40 60 80 100	○ UNCONFINED + FIELD VANE	WATER CONTENT (%)			
								20 40 60 80 100	● QUICK TRIAXIAL × LAB VANE				
243.1							245						
22.1	END OF BOREHOLE AND DCPT AT 22.1m UPON DCPT REFUSAL. FREE WATER AT 1.1m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.1m, SAND AND GRAVEL TO SURFACE.						244						

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

RECORD OF BOREHOLE No UC13-06 Site 39E-234 1 OF 1

METRIC

GWP# 5193-13-00 LOCATION HWY 11 - Driftwood Creek N 5 435 550.6 E 287 918.0 ORIGINATED BY JG
 HWY 11 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2013.10.22 - 2013.10.22 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	W _P W W _L	GR	SA			SI
263.7	GROUND SURFACE														
0.0	PEAT, trace clay Soft Brown Moist		1	SS	2								263		
			2	SS	1								260		
262.2															
1.4	Silty CLAY, trace sand, some organics Soft to Very Soft Grey Moist		3	SS	0								108		
			4	SS	2										
			3	SS	2										
			1	TW											
256.7															
7.0	END OF BOREHOLE AT 6.7m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) Nov. 1/13 0.2 263.5 Nov. 7/13 0.2 263.5														

ONTMT4S 4069.GPJ 2012TEMPLATE(MTO).GDT 1/7/15

Appendix B

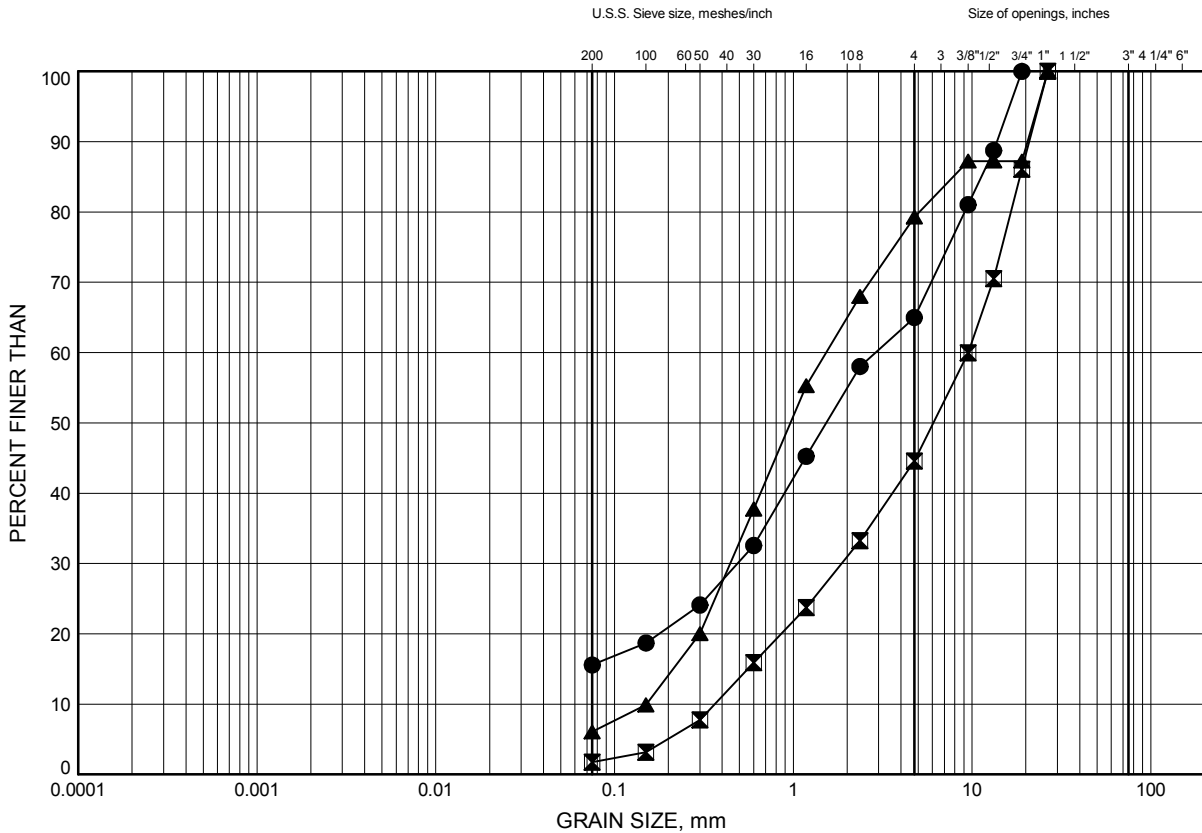
Laboratory Test Results

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B1

SAND FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UC13-02 Site 39E-234	0.30	265.53
⊠	UC13-03 Site 39E-234	1.07	264.22
▲	UC13-04 Site 39E-234	1.07	264.64

Date January 2015
GWP# 5193-13-00



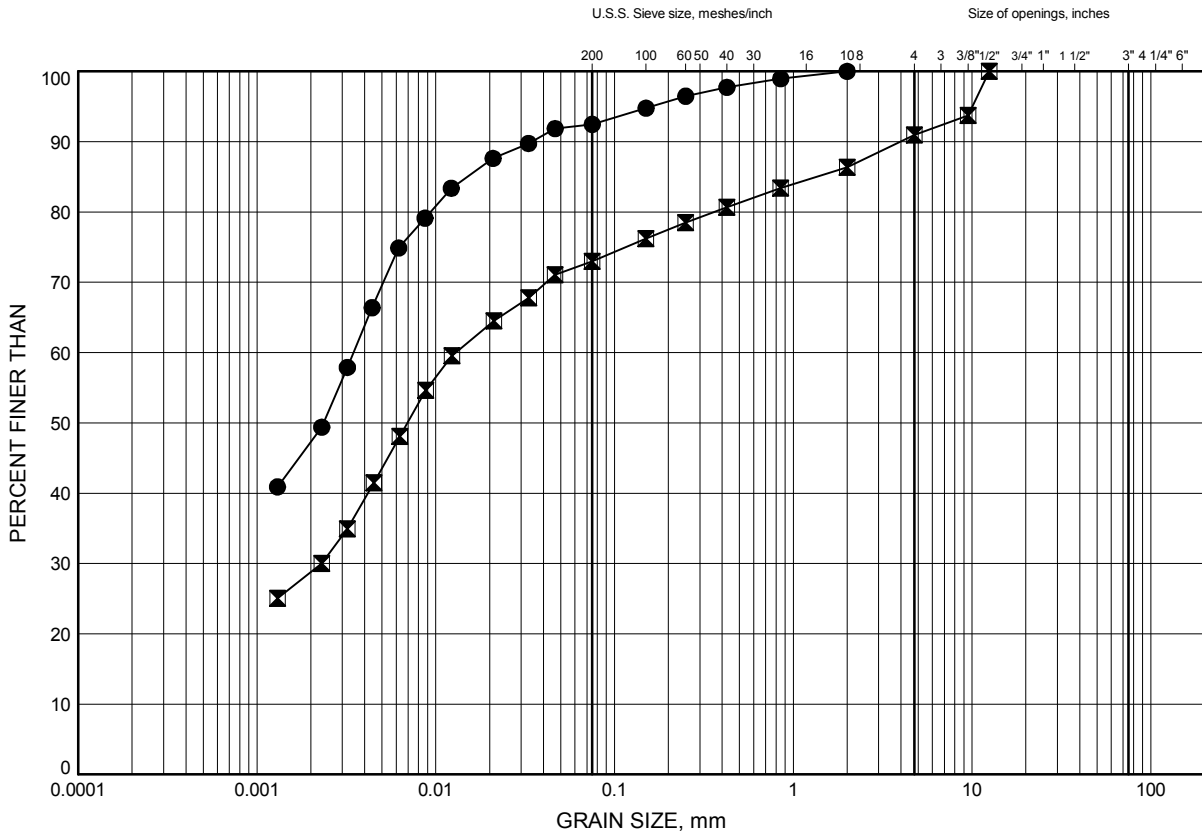
Prep'd AN
Chkd. SKP

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B2

SILTY CLAY FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UC13-02 Site 39E-234	4.11	261.72
⊠	UC13-05 Site 39E-234	1.83	263.38

Date January 2015
GWP# 5193-13-00

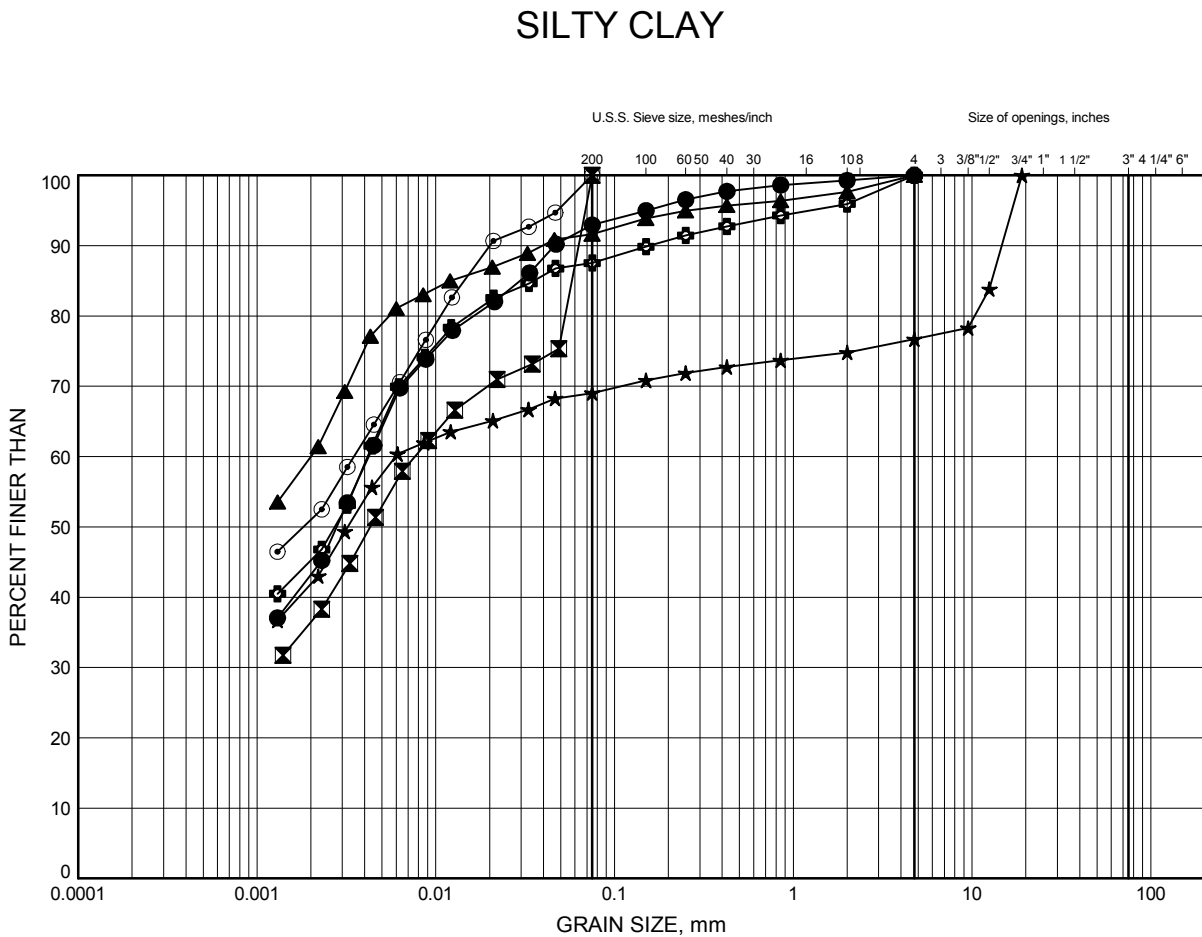


Prep'd AN
Chkd. SKP

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B3



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UC13-01 Site 39E-234	4.88	258.83
⊠	UC13-02 Site 39E-234	7.92	257.91
▲	UC13-02 Site 39E-234	12.50	253.34
★	UC13-03 Site 39E-234	3.35	261.93
⊙	UC13-03 Site 39E-234	10.97	254.31
⊕	UC13-04 Site 39E-234	3.35	262.35

Date January 2015

GWP# 5193-13-00



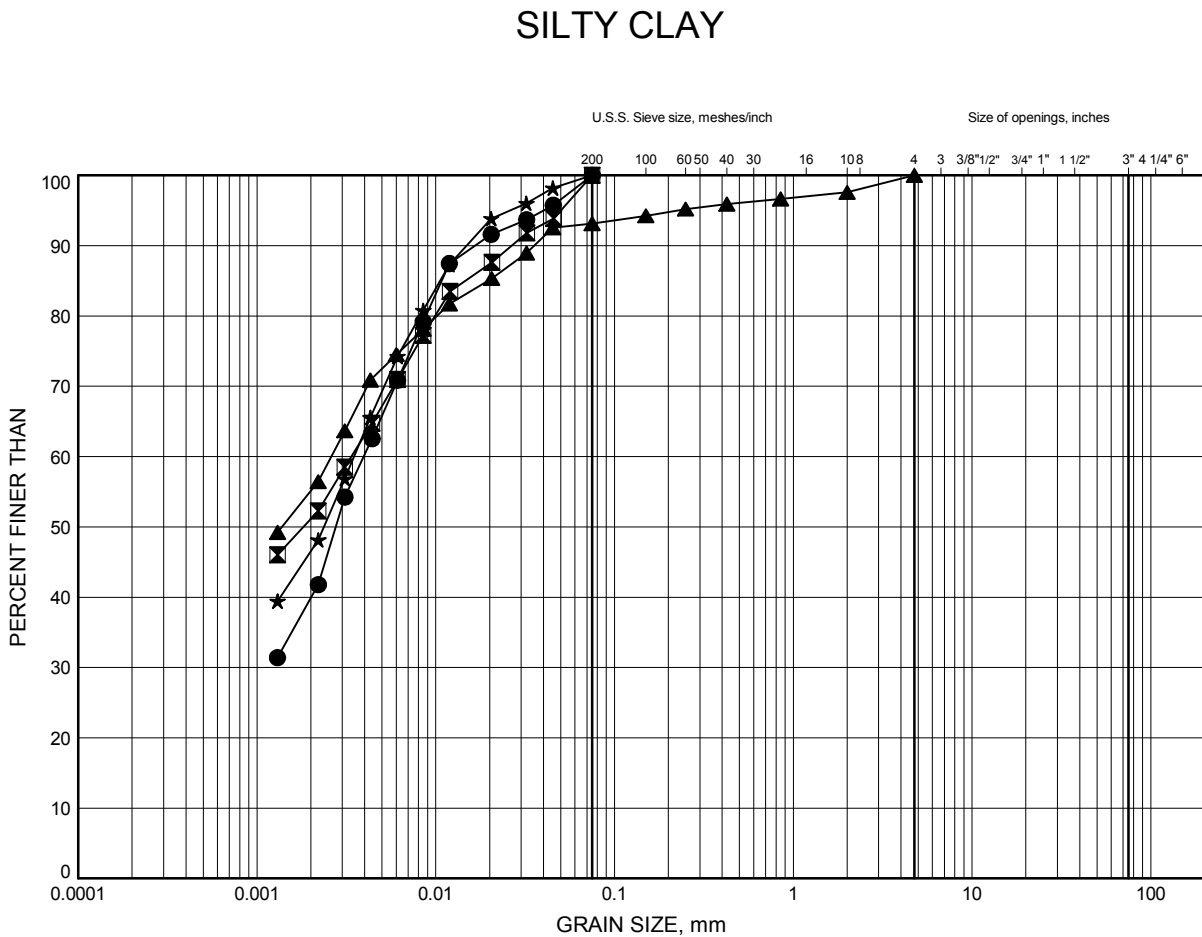
Prep'd AN

Chkd. SKP

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B4



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UC13-04 Site 39E-234	7.92	257.78
⊠	UC13-04 Site 39E-234	10.97	254.73
▲	UC13-05 Site 39E-234	6.40	258.81
★	UC13-05 Site 39E-234	14.02	251.19

Date January 2015
GWP# 5193-13-00



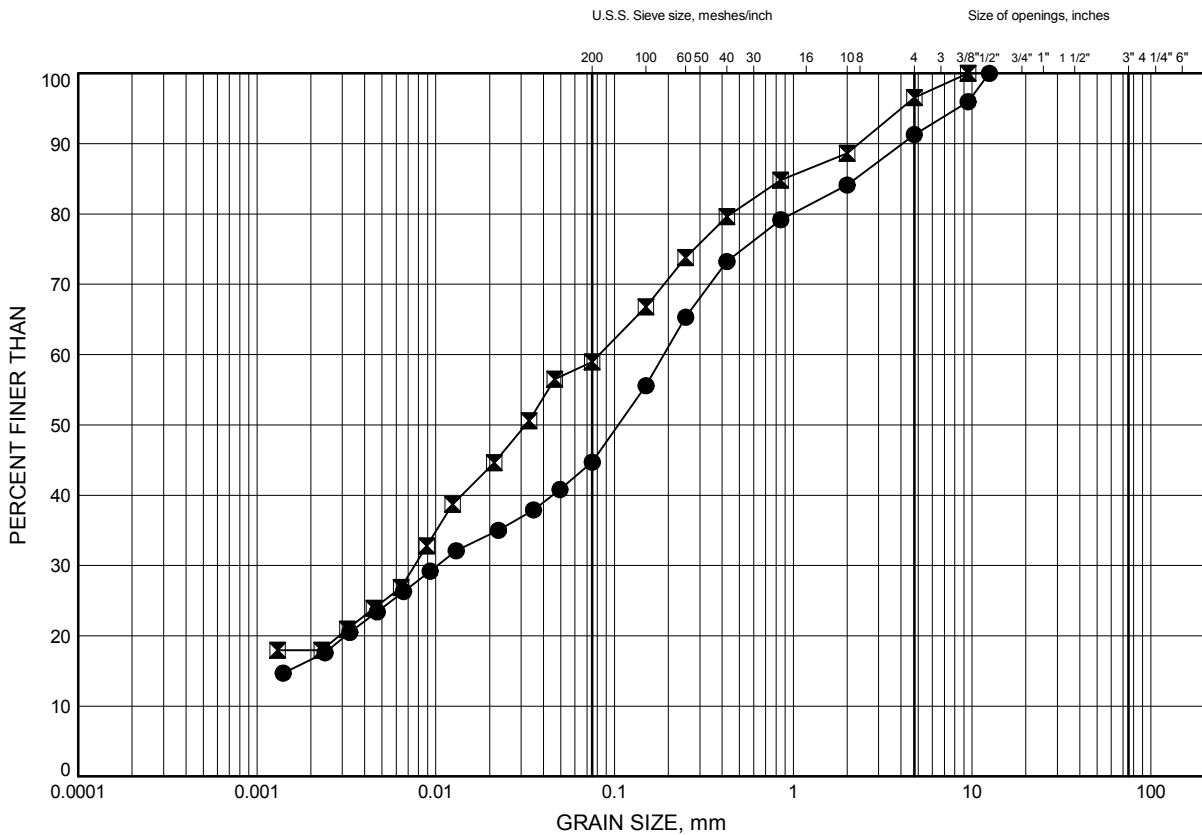
Prep'd AN
Chkd. SKP

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B5

SILT AND SAND TO SILTY SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UC13-03 Site 39E-234	18.59	246.69
⊠	UC13-04 Site 39E-234	18.59	247.11

Date January 2015
GWP# 5193-13-00



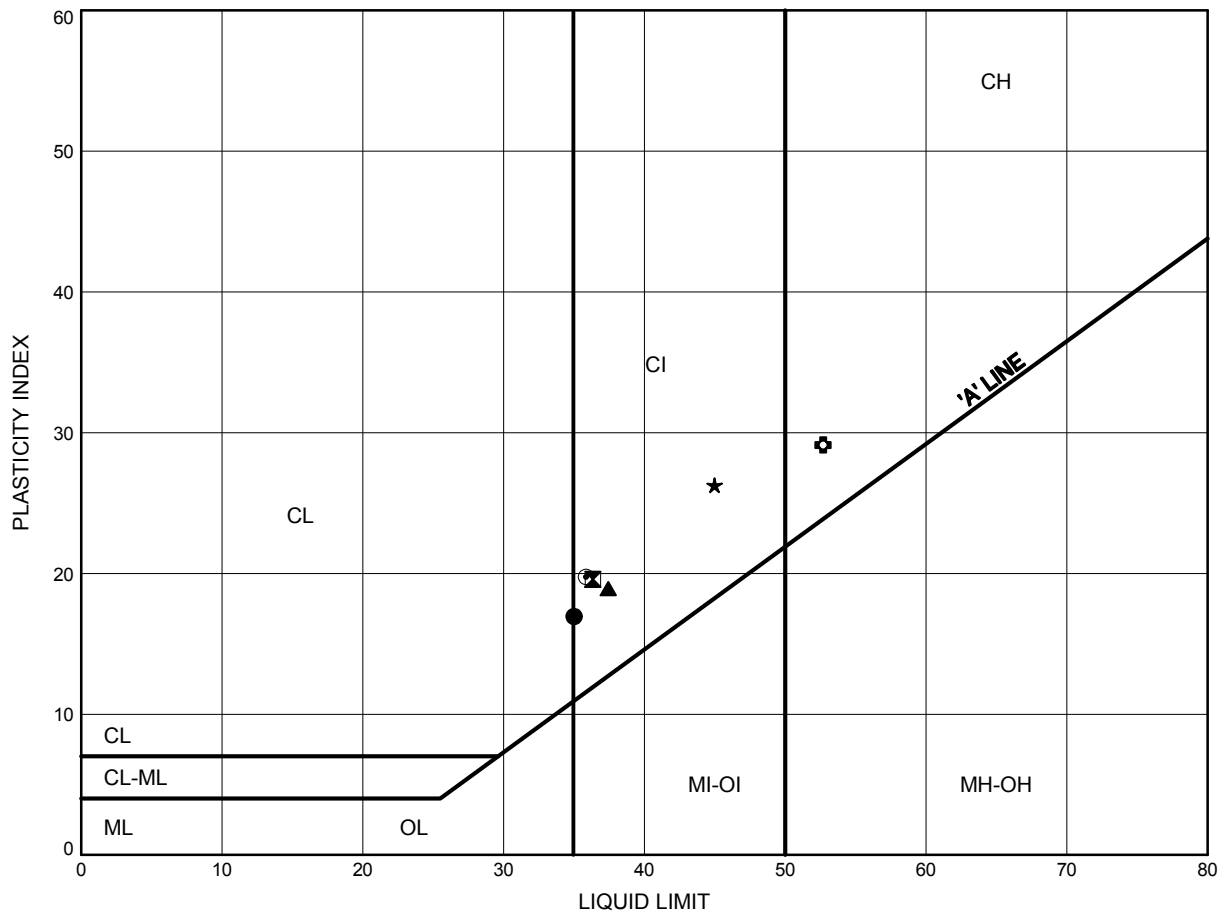
Prep'd AN
Chkd. SKP

Hwys 11, 583, 652 Culverts - Foundations

ATTERBERG LIMITS TEST RESULTS

FIGURE B6

SILTY CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UC13-01 Site 39E-234	4.88	258.83
⊠	UC13-02 Site 39E-234	7.92	257.91
▲	UC13-02 Site 39E-234	12.50	253.34
★	UC13-03 Site 39E-234	3.35	261.93
⊙	UC13-03 Site 39E-234	10.97	254.31
⊕	UC13-04 Site 39E-234	3.35	262.35

Date January 2015
GWP# 5193-13-00



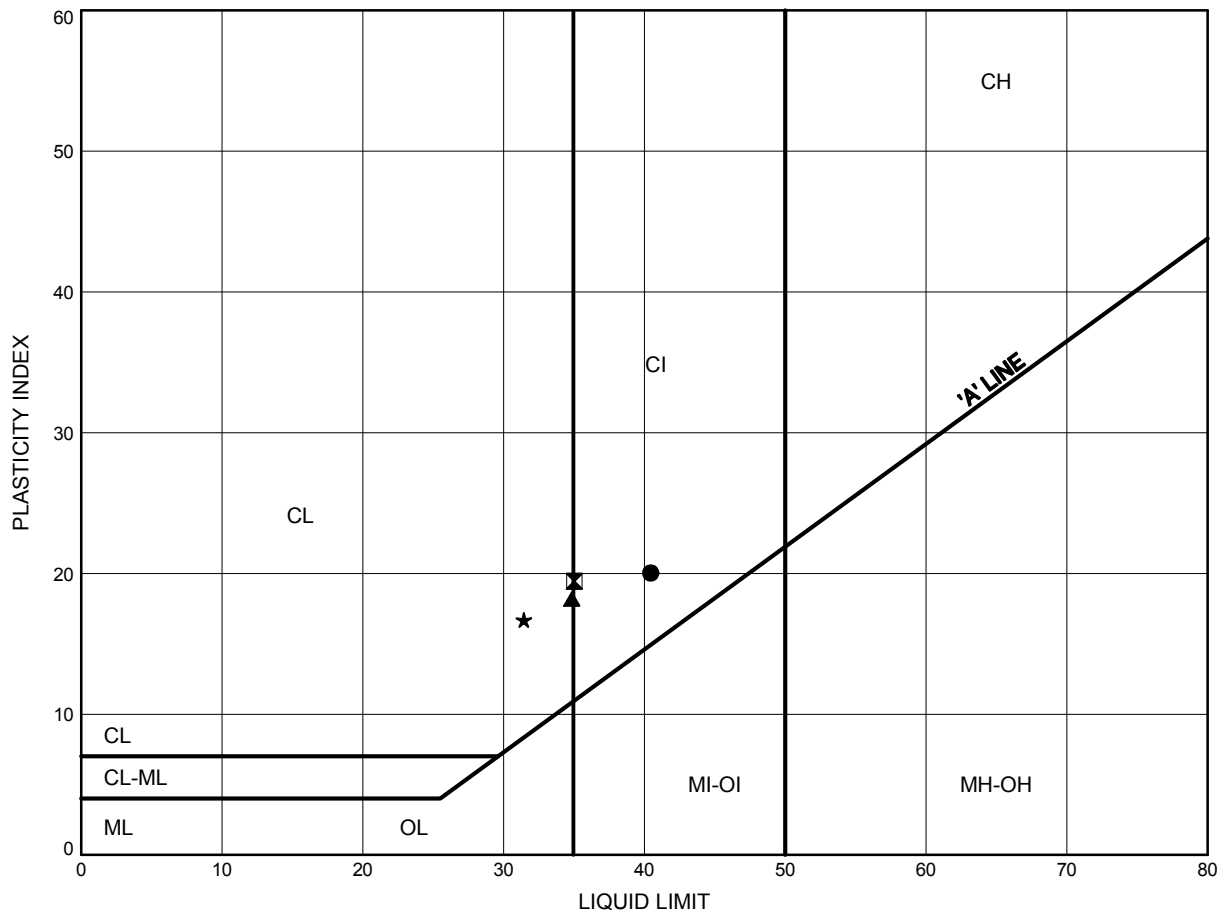
Prep'd AN
Chkd. SKP

Hwys 11, 583, 652 Culverts - Foundations

ATTERBERG LIMITS TEST RESULTS

FIGURE B7

SILTY CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UC13-04 Site 39E-234	9.45	256.26
⊠	UC13-04 Site 39E-234	10.97	254.73
▲	UC13-05 Site 39E-234	6.40	258.81
★	UC13-05 Site 39E-234	14.02	251.19

Date January 2015

GWP# 5193-13-00

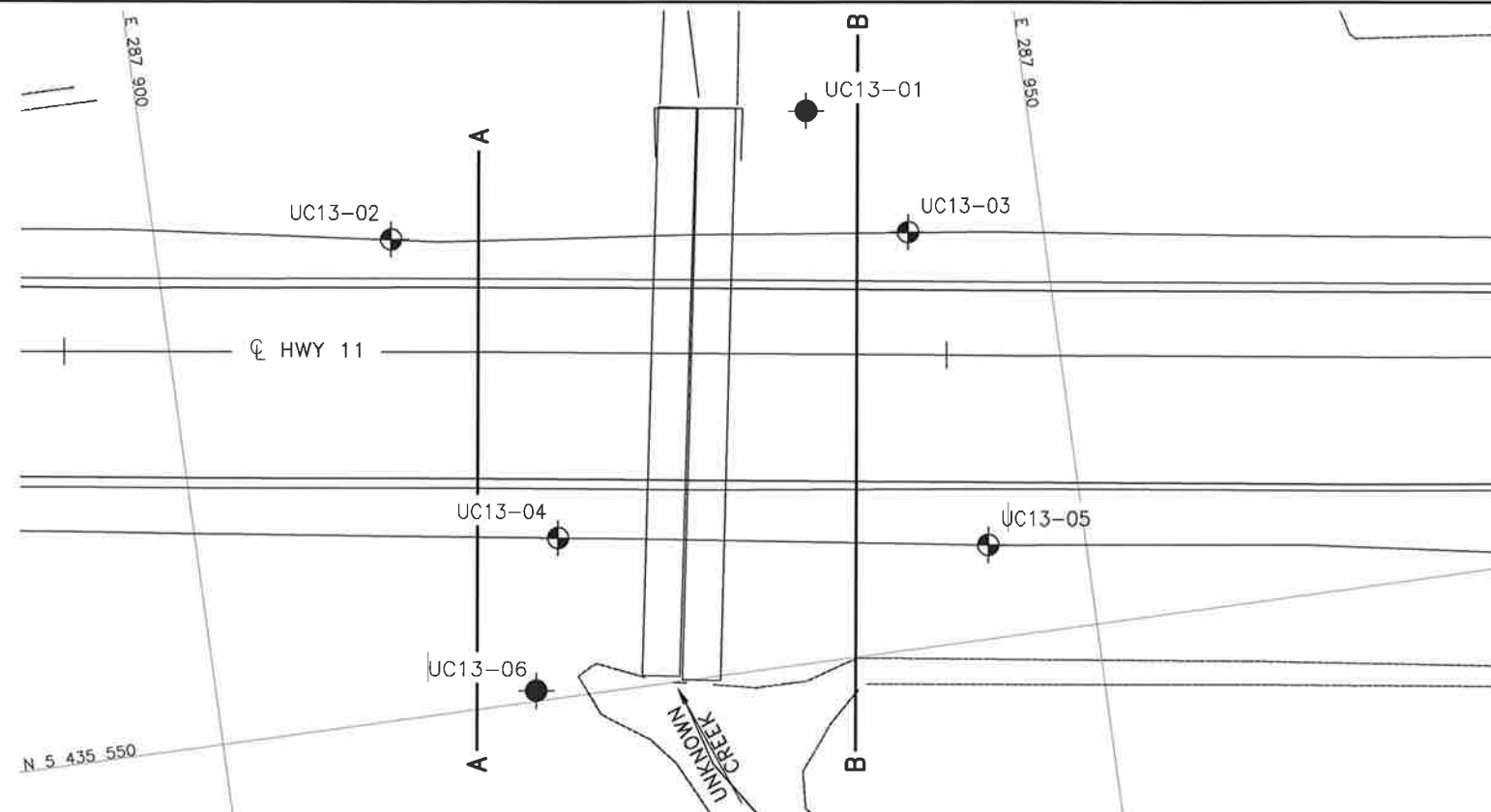


Prep'd AN

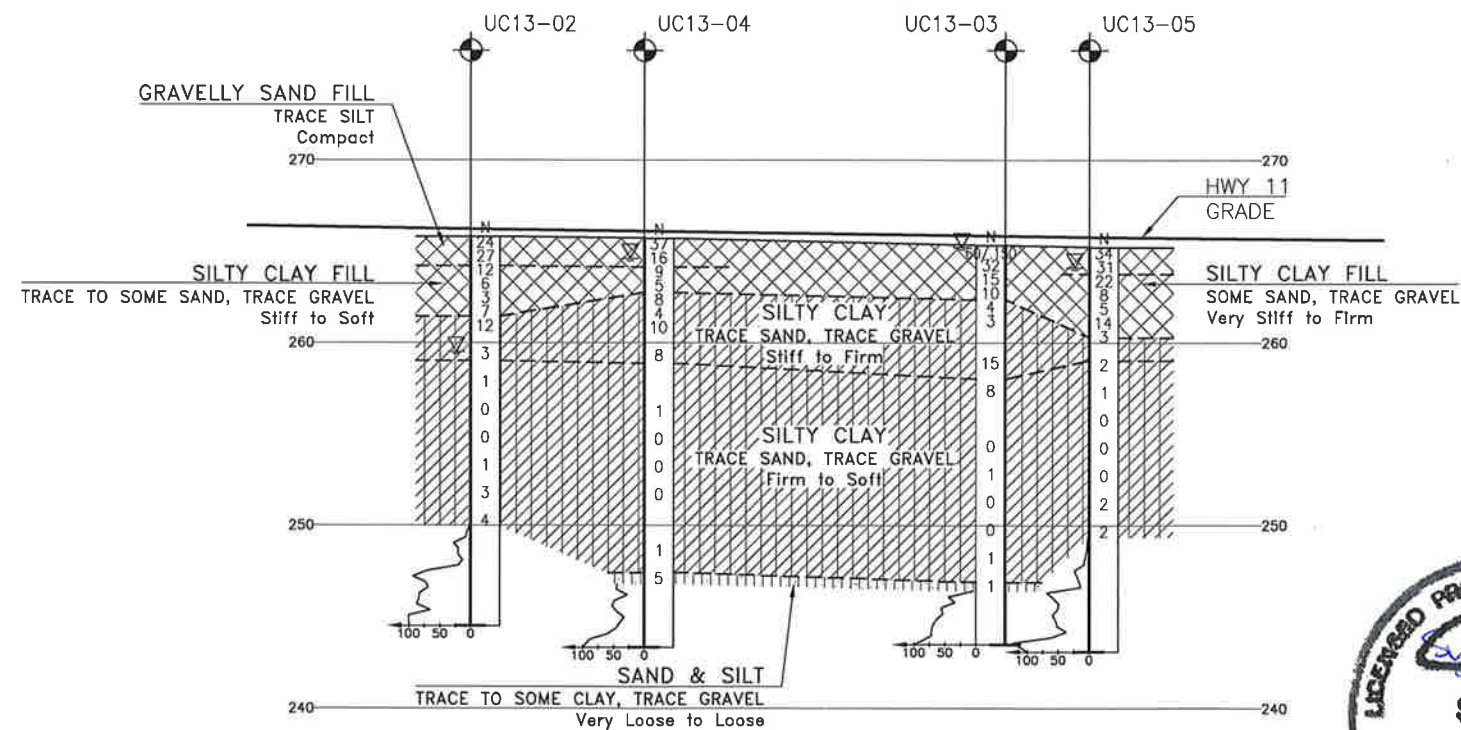
Chkd. SKP

Appendix C

Borehole Locations and Soil Strata Drawings



PLAN
SCALE 1:400



PROFILE ALONG C HWY 11
SCALE 1:400

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

CONT No
GWP No 5193-13-00



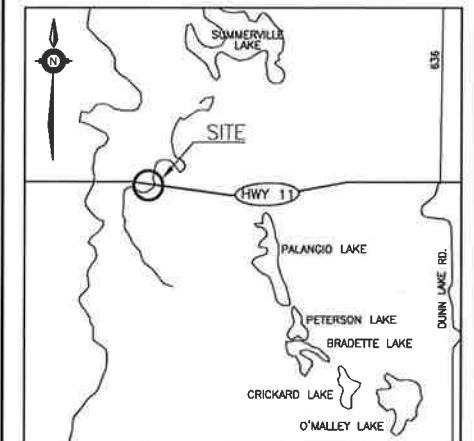
HIGHWAY 11
UNKNOWN CREEK (DRIFTWOOD)
CULVERT REPLACEMENT I
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

URS



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)
WH	Weight Hammer
PH	Pressure, Hydraulic
▽	Water Level
⬇	Head Artesian Water
⬇	Piezometer
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
UC13-01	263.7	5 435 581.1	287 937.6
UC13-02	265.8	5 435 577.1	287 913.3
UC13-03	265.3	5 435 573.5	287 942.4
UC13-04	265.7	5 435 559.0	287 920.4
UC13-05	265.2	5 435 555.3	287 944.5
UC13-06	263.7	5 435 550.6	287 918.0

-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. 42H-55

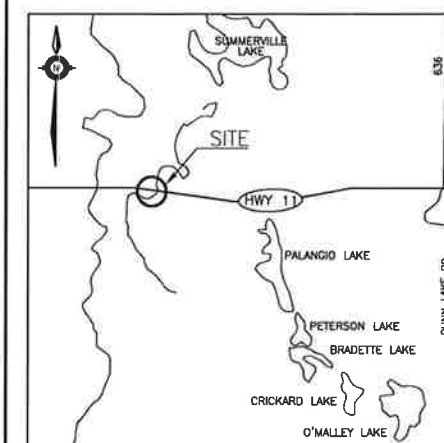


REVISIONS	DATE	BY	DESCRIPTION
DESIGN SKP	CHK SKP	CODE	LOAD
DRAWN AN	CHK AEG	SITE 39E-234C	STRUCT DWG 2

HIGHWAY 11
UNKNOWN CREEK (DRIFTWOOD)
CULVERT REPLACEMENT II
BOREHOLE LOCATIONS AND SOIL STRATA






URS

THURBER ENGINEERING LTD



KEYPLAN

LEGEND

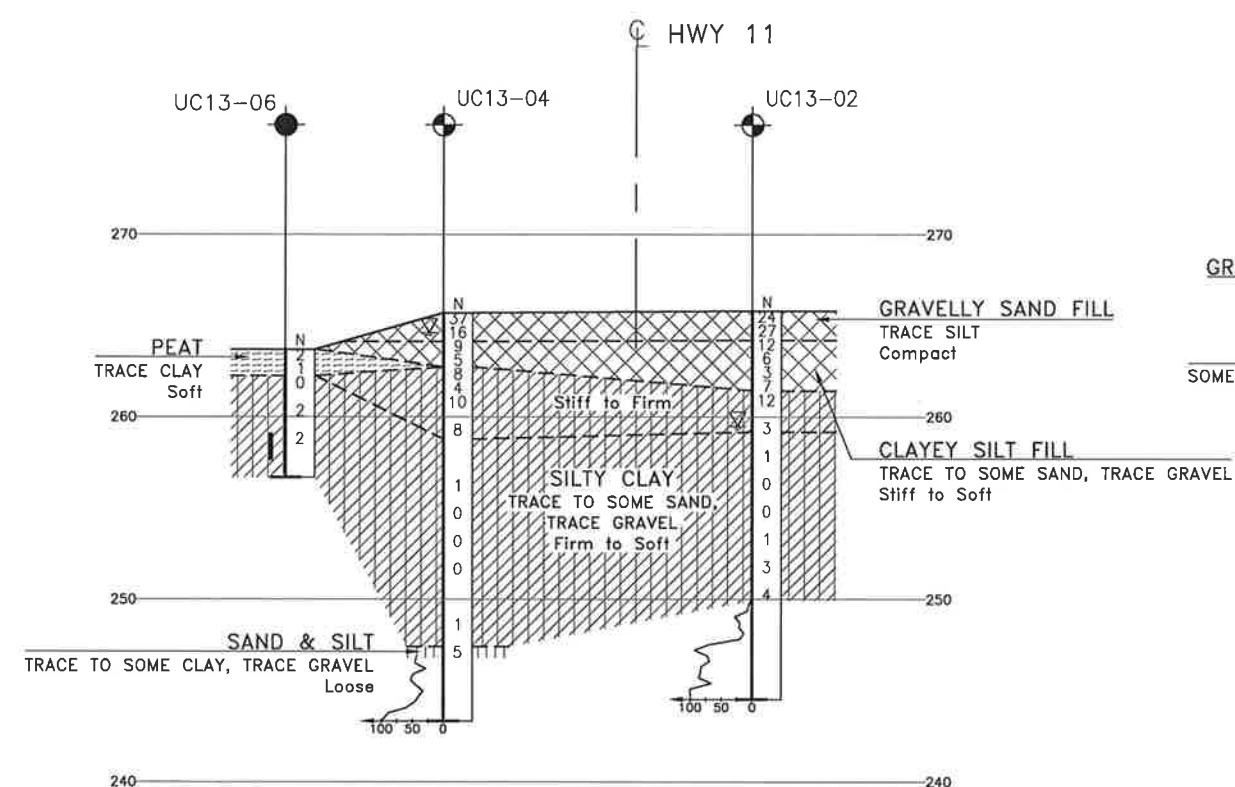
	Borehole
	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
WH	Weight Hammer
PH	Pressure, Hydraulic
	Water Level
	Head Artesian Water
	Piezometer
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
UC13-01	263.7	5 435 581.1	287 937.6
UC13-02	265.8	5 435 577.1	287 913.3
UC13-03	265.3	5 435 573.5	287 942.4
UC13-04	265.7	5 435 559.0	287 920.4
UC13-05	265.2	5 435 555.3	287 944.5
UC13-06	263.7	5 435 550.6	287 918.0

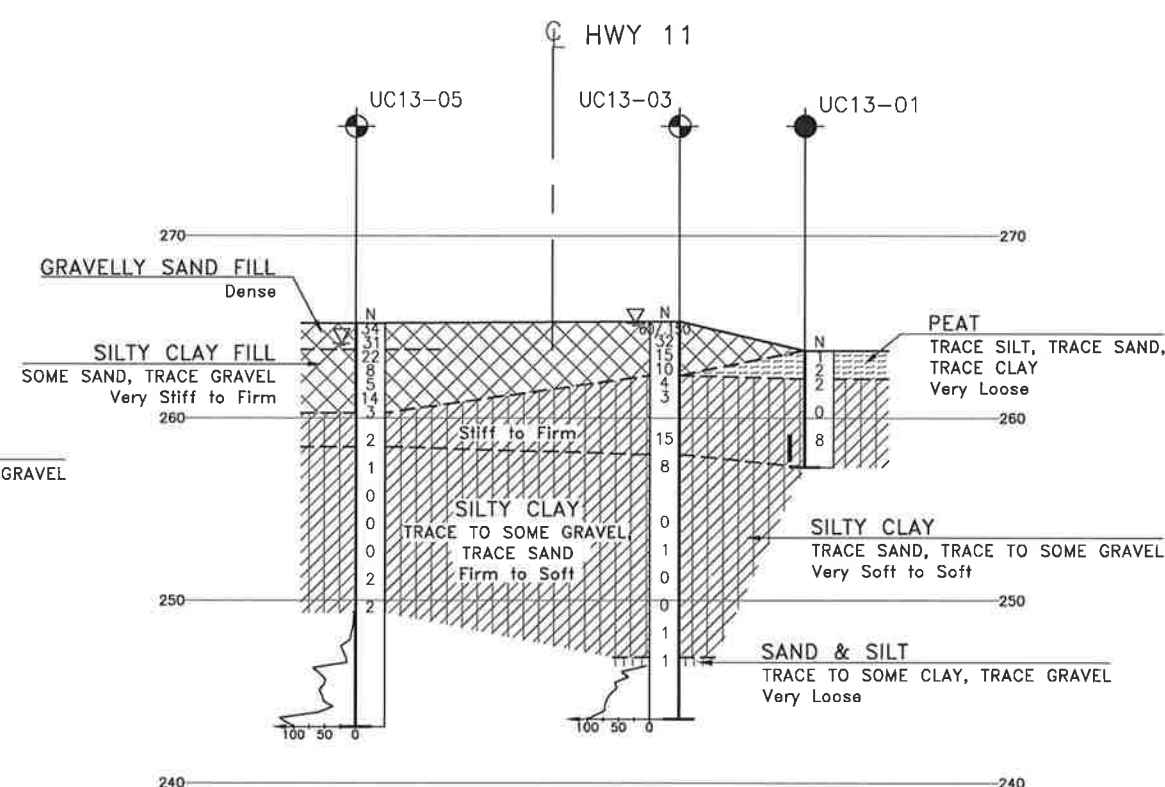
-NOTES-

- 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. 42H-55



SECTION ALONG A-A



SECTION ALONG B-B

[illegible]

FILENAME: H:\Drafting\19\4406\9\1ed4069-BoreholePlan&Profile(UnknownCreek DRIFTWOOD).dwg
DATE: 1/7/2015 1:17 PM

Appendix D

Foundation Alternatives Comparison

COMPARISON OF ALTERNATIVE CULVERT TYPES

Location	Concrete Open Footing Culvert	Concrete Rigid Box Culvert	Circular Pipe Culvert (concrete, CSP, HDPE)
Culvert Replacement	<p><i>Advantages:</i></p> <ul style="list-style-type: none"> i. Relatively expedient installation if precast units are used. <p><i>Disadvantages:</i></p> <ul style="list-style-type: none"> i. Compressible founding subgrade will provide low geotechnical resistances. ii. Potential for post construction settlement. <p style="text-align: center;">NOT RECOMMENDED</p>	<p><i>Advantages:</i></p> <ul style="list-style-type: none"> i. Smaller magnitude of settlement than open footing culvert due to lower bearing stress on subgrade. ii. Relatively expedient installation if precast units are used. <p><i>Disadvantages:</i></p> <ul style="list-style-type: none"> i. Requires compacted granular pad on subgrade. <p style="text-align: center;">RECOMMENDED</p>	<p><i>Advantages:</i></p> <ul style="list-style-type: none"> i. Can tolerate larger magnitude of settlement than concrete (rigid frame) culverts. ii. Lower cost than concrete (rigid frame) culverts. <p><i>Disadvantages:</i></p> <ul style="list-style-type: none"> i. CSP and HDPE pipes not as durable as concrete culverts. ii. Feasibility also depends on flow capacity and other hydraulic properties. <p style="text-align: center;">GENERALLY FEASIBLE</p>

Appendix E

Selected Photograph of Culvert Location

Unknown Creek (Driftwood) Culvert Replacement
Highway 11



Photo 1: Unknown Creek (Driftwood) culvert outlet

Appendix F

Selected Stability Analysis Results

Title: Driftwood Creek (39E-234)
 Name: Analysis 2
 Comments: Culvert Replacement Staging (Original)
 Last Edited By: Stephen Peters
 Last Solved Date: 2014-11-24, 1:19:04 PM

Method: Morgenstern-Price, Half-Sine
 Minimum Slip Surface Depth: 1 m
 Horz Seismic Load: 0

Cohesionless FILL	21 kN/m ³	0 kPa	30 °	1
Cohesive FILL	19 kN/m ³	0 kPa	28 °	1
CLAY 1 (ESA)	18 kN/m ³	0 kPa	27 °	1
CLAY 2 (ESA)	18 kN/m ³	0 kPa	27 °	1
CLAY 3 (ESA)	18 kN/m ³	0 kPa	27 °	1
Sand and Silt	19 kN/m ³	0 kPa	30 °	1
New FILL	21 kN/m ³	0 kPa	32 °	1

