

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
CULVERT REPLACEMENT AT UNKNOWN CREEK  
TRIBUTARY OF MONDOR CREEK  
SITE NO. 39E-314  
HIGHWAY 11  
COCHRANE DISTRICT, ONTARIO  
G.W.P. No. 5193-13-00**

**GEOCRES Number: 42H-56**

**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 location of a culvert where replacement is proposed along Highway 652 near Cochrane, Ontario.

The foundations terms of reference indicates that there is no record of any previous foundation investigation carried out at or near the subject culvert. A search in the Ministry of Transportation Ontario (MTO) GEOCRES Library did not reveal record of any previous foundation investigation carried out near the subject culverts.

The purpose of this investigation was to obtain subsurface information at the culvert location and, based on the data obtained, to provide a borehole location plan, a stratigraphic profile, cross sections, 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 Assignment Number 5012-E-0033.

**2 SITE DESCRIPTION**

The culvert site is located on Highway 11, 2.9 km south of Highways 11/579 junction in the Township of Calvert, Ontario. This culvert allows a tributary of Mondor Creek to flow under Highway 11.

The existing structure is a 3.9 m span by 2.4 m high by 30 m long steel plate pipe arch (SPPA). It is understood that the structure is in very poor condition.

The grade of the existing Highway 11 in the vicinity of the culvert ranges between approximate Elevations 262.9 and 263.3 m. The embankment fill height at the culvert is approximately 1.5 m.

Naturally low-lying, swampy areas are present near the inlet and outlet of the culvert, with vegetation consisting of tall grass and shrubs with occasional trees. Local topography is of low relief with no visible bedrock outcrops. Areas surrounding the properties are heavily forested. The area in the immediate vicinity of the culvert is undulating and generally sloping from the highway grade to the creek.

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. Due to the different rates of seasonal deposition during various periods of glaciation, the lower zones of the deposits display much thicker varves than in the upper zones. Below the varved clays are glacial outwash deposits of silts, sands and gravel underlain by Early Precambrian metasedimentary rocks.

### **3 SITE INVESTIGATION AND FIELD TESTING**

This borehole investigation and field testing program was carried out between October 24 and October 29, 2013. The program consisted of drilling and sampling 6 boreholes (number UC-01 to UC-06) to depths ranging from 6.4 to 18.9 m. Of these boreholes two were located at the culvert inlet and outlet (UC-02 and UC-05), and four were located on the highway (UC-01, UC-03 to UC-04, and UC-06).

Prior to the start of drilling, the borehole locations were marked/staked in the field and utility clearances were obtained. The co-ordinates and elevations of the as-drilled boreholes were subsequently provided by Callon Dietz obtained from the DTM, based on borehole location sketches provided by Thurber. The approximate borehole locations are shown on a Borehole Locations and Soil Strata drawing included in Appendix C.

A truck-mounted drill rig was used to drill and sample the boreholes on the highway and the shoulder, and a track-mounted drill rig was used to drill and sample the culvert inlet and outlet boreholes. Hollow stem augers and/or NW casing were used to advance the boreholes. Soil samples were obtained at selected intervals using a 50 mm diameter split spoon sampler in conjunction with Standard Penetration Testing (SPT). Field vane shear testing using an MTO “N” size vane were carried out in soft to firm cohesive soils. A limited number of thin walled Shelby tube (73 mm inside diameter) samples were obtained at selected locations. Below the last sample, dynamic cone penetration tests (DCPT) were conducted until refusal was reached in Boreholes UC-01, UC-03, UC-04 and UC-06. Standpipe piezometers were installed in Boreholes UC-02 and UC-05. Groundwater conditions in the open boreholes were observed throughout the drilling operations. The details of standpipe piezometer installations and borehole completion are summarized in Table 3.1.

**Table 3.1**  
**Borehole Completion and Standpipe Piezometer Installation Details**

Borehole Number	Standpipe Piezometer Installations				Completion Details
	Tip Location (Depth/Elev.)	Screen Depth (m)	Screen Elevation (m)	Filter Stratum	
UC-01		None Installed			Bentonite holeplug to 0.1 m, Sand and Gravel to Surface
UC-02	6.1 / 255.7	4.6 to 6.4	255.4 – 257.8	Silty Clay	Bentonite holeplug to surface
UC-03		None Installed			Bentonite holeplug to 0.05 m, Sand and Gravel to Surface
UC-04		None Installed			Bentonite holeplug to 0.1 m, Sand and Gravel to Surface
UC-05	6.1 / 256.3	4.2 to 6.7	255.7 – 258.2	Silty Clay	Bentonite holeplug to surface
UC-06		None Installed			Bentonite holeplug to 0.1 m, Sand and Gravel to Surface

Results of field drilling and sampling are presented on the Record of Borehole sheets in Appendix A.

A member of Thurber's technical staff supervised the drilling and sampling operations on a full time basis. The supervisor logged the boreholes, secured the recovered soil samples in labelled containers, and transported the samples to Thurber's laboratory for further examination and testing.

#### **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). One sample was selected from the Shelby tubes for laboratory consolidation (oedometer) testing. 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 creek water was submitted to 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 for details of the soil stratigraphy encountered in the boreholes. A stratigraphic profile and selected cross-sections for this culvert site are presented on the Borehole Locations and Soil Strata Drawings in Appendix C for illustrative purposes. An overall description of the stratigraphy is given in the

following paragraphs; however, the factual data presented in the record of boreholes governs any interpretation of the site conditions.

In general, the subsurface conditions encountered in the boreholes located on the highway shoulder consist of granular fill overlying an extensive deposit of silty clay. The silty clay underlies a thin veneer of topsoil or is exposed at ground surface beyond the highway. Groundwater levels are generally in the order of 0.4 to 3.8 m below original ground surface. More detailed descriptions of the individual stratum are presented below.

## 5.2 Topsoil

A layer of topsoil 75 mm in thickness was encountered at ground surface in Borehole UC-02 located off the roadway. The topsoil thickness may vary between and beyond the borehole locations, and the limited data is not suitable for estimating topsoil quantities.

## 5.3 Fill

Embankment fill was encountered at ground surface in Boreholes UC-01, UC-03, UC-04 and UC-06. This fill typically consists of brown sand with some gravel to sand and gravel, organic inclusions and rootlets at shallow depths. A layer of silty clay fill was encountered below the granular fill in Borehole UC-04. Where encountered, the embankment fill was found extending to 1.9 to 2.3 m depths (base Elevations from 261.5 to 260.4 m).

SPT N-values measured in the cohesionless fill ranged from 6 blows per 0.3 m penetration to 42 blows per 0.3 m penetration indicating a loose to dense state. Measured moisture contents of the recovered sand fill samples ranged between 3% and 43%, with the values increasing with higher depth. Grain size analyses conducted on samples of the cohesionless fill are presented on Figure B4 in Appendix B. These results are summarized in the following table.

Soil Particles	%
<u>Gravelly Sand Fill</u>	
Gravel	18 to 22
Sand	72 to 78
Silt and Clay	4 to 6
<u>Sand and Gravel, with Silty Clay Layer</u>	
Gravel	31
Sand	20
Silt	17
Clay	32

## 5.4 Silty Clay

Underlying the embankment fill and topsoil, silty clay was encountered in all six boreholes drilled at the site. This brown to grey soil typically contained layers of sand and gravel.

Boreholes UC-02 and UC-05 were terminated within the silty clay at depths of 6.4 to 6.7 m (base Elevations 255.4 to 255.7 m). In boreholes UC-01, UC-03, UC-04 and UC-06 Dynamic Cone Penetration Tests (DCPT) were conducted from depths of 15.8 to 18.9 m (base Elevations 247.3 to 244.0 m). DCPT's encountered refusal at depths of 25.7 to 28.5 m (base Elevations 237.6 to 234.6 m).

The weathered crust of the silty clay deposit is approximately 1 to 1.5 m thick. It has a relatively firm consistency and typically brown in colour. Within the crust, the SPT N-values ranged between 4 and 15 blows per 0.3 m of penetration. Measured field vane shear strengths ranging from 25 to 90 kPa, the silty clay crust was found to have a typically stiff to firm consistency.

Below the crust, the silty clay becomes grey with measured N-values of 0 to 29 blows per 0.3 m of penetration, with most values lying at 0 to 7 blows per 0.3 m of penetration. Higher SPT values were associated with sand and gravel layers within the silty clay. Field vane shear strengths ranged from 10 to 20 kPa and was found to have a very soft to soft consistency.

A 1.8 m thick layer of gravel was encountered in borehole UC-01 at a depth of 10.8 m (elevation 252.5 m). A sand layer 0.7 m thick was encountered in borehole UC-05 at a depth of 0.8 m (elevation 261.6 m). A grain size distribution for the sand layer in borehole UC-05 is presented in Figure B5 in Appendix B.

Oedometer test results are not available at the time of preparation of this report.

The measured water contents of samples recovered from these soils typically ranged from 20% to 60%. Grain size analyses conducted on samples of the silty clay are presented on Figures B1 to B2, and Atterberg Limits test results are presented in Figure B7 in Appendix B. Grain size analyses conducted on the silty clay with sand and gravel layer are presented on Figure B3 in Appendix B. The results are summarized in the following table.

Soil Type	Soil Particles	%
Silty Clay	Gravel	0
	Sand	0 to 8
	Silt	33 to 51
	Clay	47 to 67
	<b>Soil Property</b>	<b>%</b>
	Liquid Limit	36 to 58
	Plasticity Index	20 to 32
Silty Clay with Sand and Gravel Layer	Gravel	3 to 21
	Sand	17 to 30
	Silt	14 to 26
	Clay	31 to 56



The results of the Atterberg Limits tests indicate that the silty clay is typically of intermediate plasticity (CI) with occasional high plastic (CH) zones.

### 5.5 Groundwater Conditions

Free water was observed in most of the boreholes upon completion of drilling. Standpipe piezometers were installed in Boreholes UC-02 and UC-05 to permit groundwater monitoring. Water levels observed in the open boreholes and those measured in the two installed standpipes are presented below.

Borehole	Date of Reading	Water Level Depth (m)	Water Level Elevation (m)
UC-01	Oct. 29, 2013	0.5	262.8
UC-02	Nov. 1, 2013	3.2	258.6
	Nov. 7, 2013	3.1	258.7
UC-03	Oct. 24, 2013	2.4	260.7
UC-04	Oct. 29, 2013	0.6	262.8
UC-05	Nov. 1, 2013	3.8	258.6
	Nov 7, 2013	3.7	258.7
UC-06	Oct. 26, 2013	0.4	262.5

Where surface water is present, the groundwater level should be assumed to coincide with the local surface or creek water level. Based on the observations and measurements above, the groundwater level adjacent to the creek is at approximate Elevation 259.0 m. The groundwater levels are expected to vary seasonally and are subject to severe weather events such as rainstorms.

## 6 MISCELLANEOUS

Thurber staked and/or marked the borehole locations in the field and obtained utility clearances prior to drilling. Callon Dietz provided the northing and easting coordinates and ground surface elevations using their local DTM based on borehole location sketches provided by Thurber.

Downing Drilling of Hawkesbury, Ontario supplied and operated a truck-mounted drill rig and a track-mounted CME 55 drill rig to carry out the drilling, sampling and in-situ testing operations.

The drilling and sampling operations in the field were supervised on a full time basis by Ms. Eckie Siu and Mr. Joe Gurzanski of Thurber. Geotechnical laboratory testing was carried out by Thurber in its MTO-approved laboratory.

Overall project management was provided by Mr. Alastair Gorman, P.Eng. Direction of the field and laboratory program was provided by Dr. Sydney Pang, P.Eng. Interpretation of the field data and preparation of this report was completed by Mr. Lukasz Gilarski, 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., 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 design of the replacement of the existing culvert at Unknown Creek (Site No. 39E-314), a tributary of Mondor Creek. The culvert is located on Highway 11, 2.9 km South of Highway 11/579 in the Township of Calvert.

Based on the terms of reference, the existing structure is a 3.9 m span by 2.4 m high by 30 m long Steel Plate Pipe Arch (SPPA) culvert. It is understood that the structure is in very poor condition. The total embankment height at this location is up to 2.5 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.

An archived drawing shows the general topography of the subject area prior to construction of the culvert and the highway. Selected photographs of the culvert area are included in Appendix E for reference.

**8 CULVERT FOUNDATIONS**

**8.1 General**

Preliminary information from URS indicates that current project requirements involve replacement of the existing culvert with twin concrete box culverts. The new north culvert will be located along the existing culvert alignment while the new south culvert will be located immediately south of the current location. It is understood that embankment widening will be required on the east (approximately 4.5 m) and west (approximately 2.5 m) sides to accommodate the temporary traffic detour during construction. Approximate physical dimensions of the proposed culvert and other design information provided by URS are

presented in Table 8.1. Boreholes drilled at the culvert site are also identified in this table for reference.

**Table 8.1 Physical Data of Proposed Replacement Culverts**

Culvert #	Borehole Numbers	Approx. Invert Elevations (m)		Length (m)	Width (m)	Height (m)
		Inlet	Outlet			
C07	UC-02 and UC-05 near inlet/outlet					
	UC-01, UC-03, UC-04 and UC-06 through embankment within 10 to 15 m of existing culvert	259.650	259.480	29.8	2.8	2.2

Note: All dimensions are preliminary and subject to changes

## 8.2 Foundation Alternatives

This section presents discussions on available types of replacement culverts and foundation alternatives, and provides recommendations on a feasible and/or preferred foundation option. A comparison of these alternatives, based on their respective advantages and disadvantages, is included in Appendix D.

Several common culvert types that may be considered for this site are listed as follows:

- Concrete box (closed) culvert
- Concrete, open footing, culvert
- Circular pipes (concrete, steel, HDPE)

The existing culvert is an oval shaped Steel Plate Pipe Arch (SPPA). Preliminary design information indicates that consideration is being given to using precast twin box culverts as replacement. Given the subsurface conditions and anticipated construction sequencing, we consider this to be the preferred option from a foundation engineering standpoint. Precast sections can be installed rapidly with less potential for disturbance of the founding soils during installation.

Concrete, open footing, culverts are not considered suitable as the shallow foundation soils can only provide very low geotechnical resistances required to support strip footings of reasonable width. From a foundation engineering standpoint, concrete, steel and HDPE pipes are also technically feasible alternatives, provided that other design issues including flow capacity, hydraulic properties and durability can also be satisfied.

This report focuses on providing foundation recommendations on the design and construction of box culverts and the adjacent retaining walls. Recommendations for other culvert options will be provided upon request.

### **8.3 Foundation Design**

It is understood that the inverts of the replacement culverts are approximately the same as those of the existing culvert. Foundation design aspects for the replacement culverts include subgrade conditions, geotechnical resistances for the retaining walls, settlement of founding soils, lateral earth pressures, erosion control, protection system design and groundwater control, staged excavation, and stability of widening detour embankment.

#### **8.3.1 Concrete Box Culvert**

Since the new north culvert is anticipated to be constructed on the same alignment as the existing culvert, the subgrade soils within the culvert footprint will not be subjected to any significant additional loading. For the new south culvert that will be constructed immediately south of the existing culvert, excavation of the existing embankment will result in net unloading of the foundation soils.

In order to provide a more 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 culverts 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 must be founded at or below Elevation 261.0 m on the undisturbed, firm silty clay. Any soft soils must be sub-excavated and replaced with engineered fill as outlined below. The recommended geotechnical resistances for this founding elevation at the culvert footprints are as follows:

- Factored Geotechnical Resistance at ULS of 75 kPa
- Geotechnical Resistance at SLS (less than 25 mm settlement) of 50 kPa.

Resistance to lateral forces / sliding resistance between the 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 the culverts be designed to resist external loadings including frost forces, lateral earth pressures, hydrostatic pressure, weight of embankment fill, traffic loadings and surcharge due to construction equipment.

#### **8.3.2 Retaining Walls**

Retaining walls are required at all four quadrants adjacent to the new twin culverts. Consideration may be given to using Retained Soil Systems (RSS) walls and/or gabion walls.

Borehole information indicates that the founding condition at the likely wall locations generally consist of firm silty clay with some soft zones at depth.

### **8.3.2.1 RSS Walls**

The soil conditions encountered on site are generally suitable for the support of RSS walls. RSS walls should be specified as “Medium Performance” and “High Appearance”. The contract drawings should include information on the longitudinal alignment of the wall in plan, the top and base elevations of the wall in profile, cross-sectional space constraints and an NSSP for the RSS wall.

The performance of a RSS is dependent on, among other factors, the characteristics of its foundation. Failure to provide an adequate foundation may lead to settlement and distortion of the RSS and, in severe cases, to possible failure of the system. The foundation of the entire RSS mass must be considered, i.e. from the face of the wall to the furthest extent of the reinforcement.

To provide an acceptable foundation performance, the RSS mass should be founded at or below Elevation 261.0 m on the undisturbed, firm silty clay deposit. An RSS wall founded at these levels may be designed using a factored geotechnical resistance at ULS of 75 kPa and a geotechnical resistance at SLS of 50 kPa. The RSS may be founded on engineered fill resting on the silty clay subgrade. Engineered fill pads placed under the RSS mass must consist of OPSS Granular “A” compacted to 100% of its SPMDD at a moisture content within 2% of optimum. The engineered pad must laterally extend at least 500 mm beyond the limits of the RSS mass and levelling strip.

The geotechnical resistances provided above are for concentric, vertical loading. The effects of load inclination and eccentricity need to be taken into account according to the CHBDC (2010) Clauses 6.7.3 and 6.7.4.

The entire block of reinforced earth must be designed against various modes of failure including sliding and overturning. Sliding resistance along the base of the wall may be estimated using an ultimate friction coefficient of 0.55 for an engineered granular fill subgrade and 0.35 for a silty clay subgrade.

Topsoil, loose fill, and any soft/wet material must be stripped from the footprint of the RSS. The subgrade under the RSS foundation should be inspected and any soft spots sub-excavated and replaced with compacted granular materials prior to placing fill.

The proprietary RSS system must meet the Ministry’s specifications for performance and appearance. The RSS supplier/designer may specify more stringent criteria or other requirements related to the particular design. The internal stability of the RSS wall should be analyzed by the supplier/designer of the proprietary product selected for this site.

Global stability of the RSS walls will be analyzed by Thurber once the detailed configurations of the walls are known. A preliminary assessment indicates that a properly designed and constructed RSS retained embankment at this site would satisfy global stability requirements.

#### **8.3.2.2 Gabion Walls**

From a foundation standpoint, it is recommended that any gabion walls be supported on a pad of engineered fill that is itself resting on the firm silty clay at or below approximate Elevation 261.0 m. The walls should be founded as high as possible within the stiffer weathered crust of the silty clay in order to minimise stresses to be imposed on the underlying, more compressible silty clay. The pad is required to provide subgrade uniformity along the gabion wall alignments and should consist of a minimum 300 mm of compacted Granular A materials. For the recommended founding elevation, the geotechnical resistances recommended above for the RSS walls may be used for designing the gabion walls. Load inclination and eccentricity should also be taken into account as outlined above. The horizontal resistance against sliding between the base of the wall and the underlying engineered fill pad or undisturbed, native silty clay may be evaluated as recommended for the RSS walls above.

The gabion walls should be designed as a gravity wall which involves checking for internal stability, overturning stability and sliding resistance. Global stability of the gabion walls will be analyzed by Thurber once the detailed configurations of the walls are known. A preliminary assessment indicates that a properly designed and constructed gabion retained embankment would satisfy global stability requirements.

#### **8.3.3 Settlements**

It is understood that there is no grade raise at this site and embankment widening will be necessary during construction. The existing culvert will be replaced by a new north culvert and a new south culvert will be located immediately to its south.

Due to the slightly heavier weight of the concrete box compared to the SPPA, the firm silty clay subgrade soils at the north (existing) alignment would be subjected to additional load resulting in some post construction consolidation settlements. The estimated settlement due to the slightly heavier weight for concrete is in the order of 5 to 10 mm within 10 years. Some rebound of the subgrade at the south alignment after installation of the new south culvert should also be expected.

#### **8.3.4 Subgrade Preparation**

After the excavation and removal of the existing SPPA and surrounding soils are completed to the design founding elevation, any remaining fill, topsoil, creek bed deposits, disturbed soils and any deleterious materials within the culvert replacement footprint must be sub-excavated to undisturbed native firm silty clay at or below the desired founding elevations. The exposed surface must be inspected to confirm that the subgrade is suitable and uniformly competent. Any soft areas should be sub-excavated and replaced with well compacted granular fill consisting of compacted OPSS 1010 Granular A or B Type II material.



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 Considerations**

Staged open cutting will be employed to construct the replacement culvert at Unknown Creek (Tributary of Mondor Creek). The highway embankment will be widened to the east and west in order to maintain one lane of traffic during culvert replacement.

Construction sequencing proposed by URS is shown on staging plans. The main features outlined in these plans 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 required to be installed at the inlet and outlet areas as part of the creek flow and surface water diversions
- Creek flow will be maintained at all times
- Pumping from sumps is anticipated to be required
- Roadway protection will be required during 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 sheet piles will be required. Foundation recommendations for design of such a system are provided in Section 13 of this report. Foundation aspects of the detour embankment design and construction will be addressed in Section 10.2.

## **9 CULVERT BACKFILL AND LATERAL EARTH PRESSURES**

It is recommended that backfill to the culvert and wing walls consists of free-draining, non-frost susceptible granular materials such as Granular A or Granular 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. Excavated granular embankment fill may be considered for reuse (see section 12 below).

All fills must be placed in regular lifts and be compacted in accordance with OPSS 501. The backfill must 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)
	$\gamma$	=	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 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. This is applicable when the water level behind the culvert wall is higher than creek 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. Active pressures should be used for any wingwall or unrestrained wall.

For rigid structures such as concrete box culverts, it is recommended that at-rest horizontal earth pressures be used for design.

**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	-

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**

The existing highway embankment is up to 2.5 m in height at the culverts. It is understood that there is no planned grade raise at this site.

Embankment reconstruction after culvert replacement should be carried out in accordance with OPSS 206. The embankment material should consist of either the excavated granular fill discussed above, or imported Granular A or Granular B Type II material. Excavated granular fill may 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, organics, or clay is included in the fill
- Gradation and compaction characteristics meet the requirements prior to reuse as backfill

Information from URS indicates that consideration is being given to steepening the lower portion of the existing highway slope inclination from 3H : 1V to 2H : 1V between the top of the proposed culvert and the ground surface. Results of limit equilibrium stability analysis carried out for this proposed slope configuration indicates that the short term (undrained) and long term (drained) scenarios give factors of safety of 1.25 and 1.46, respectively (see Appendix F). Taking into consideration the relatively low embankment height, the results generally satisfy typical MTO criteria for global stability.

Where applicable, benching of the existing earth slope surface should be carried out as per OPSD 208.010 in order to enhance the keying in of the new fill.

In general, surface vegetation, peat, topsoil, organic deposits, disturbed material or otherwise loose/soft soils should be stripped from the areas around the culvert inlet and outlet, and within the culvert subgrade or embankment footprints. Inspection and approval of the foundation surfaces by qualified geotechnical personnel is recommended.

### **10.2 Embankment Widening for Detour**

Widening of the existing highway embankment on the east side to accommodate a temporary traffic detour lane will require placement and compaction of granular fill. It is recommended that a slope inclination of 2H : 1V be used to maintain embankment stability. All

requirements for keying in of new fill and subgrade preparation discussed in section 10.1 above must be followed.

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. The wedge of new fill (up to 0.5 m thick) for temporary detour widening (essentially pavement widening) would induce in the order of 5 mm of immediate (elastic) settlement during fill placement. This immediate settlement is expected to be completed by the end of embankment widening construction. Due to the relatively short duration of the construction, it is anticipated that foundation settlement due to time-dependent consolidation of the silty clay during the detour lane operation should be small.

## **11 EROSION CONTROL**

Erosion protection should be provided at the culvert inlet and/or 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, rip-rap 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 may be used to minimize the potential for piping around the culvert. The clay seal must extend to the order 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. A geo-synthetic clay liner may be used as a clay seal.

## **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 clays and clayey silts at this site are classified as Type 3 soils above the water level and Type 4 soils below the water level. Surficial alluvial deposits that are anticipated in the inlet and outlet areas are classified as Type 4 soils.

### **12.2 Foundations**

Excavation and backfilling for culvert construction must be carried out in accordance with OPSS 902.

Excavated gravelly sand to sand fill may be reused as backfill provided the following conditions are satisfied.

- There is sufficient space to stockpile on site and control the moisture content within acceptable limits for compaction
- Gradation and compaction characteristics are confirmed prior to reuse as backfill.

### **12.3 Excavations**

Excavations for culvert replacement will typically be carried out through the existing embankment fill and extended into the native silty clay deposits. The work will be carried out within a protection system.

Any protection system should be designed by licensed Professional Engineers experienced in such designs. OPSS 539 “Construction Specification 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.

### **12.4 Groundwater Control**

Groundwater perched within the embankment fill will seep into the excavations during culvert replacement. Surface runoff will also tend to accumulate in these excavations. The groundwater level is expected to be largely governed by the water level in the creek. As discussed in the previous section 8.4, a combination of the use of cofferdams at the inlet, creek water diversion, protection systems such as sheet piled enclosures and pumping from filtered sumps will be required to maintain dry excavations during the course of staged construction.

## **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. However, one option that is considered to be suitable for use at this site is steel interlocking sheet pile enclosures which are also anticipated to provide an effective groundwater cut off. It is anticipated that the sheet piles will need to be extended into the very stiff to firm weathered crust of the native silty clay to develop the required toe resistance.

An interlocking sheet piled wall may be designed using the parameters given below:

$\gamma$	=	20 kN/m <sup>3</sup>
$\gamma_w$	=	10 kN/m <sup>3</sup>
$K_a$	=	0.33 (road embankment fill)
	=	0.36 (silty clay)
$K_p$	=	2.8 (silty clay)

Full hydrostatic pressure should be considered assuming a water level at least equal to the design creek water level.

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. Typically, a triangular earth pressure distribution similar to the one used for culvert lateral pressure design should be used for a cantilevered sheet piled wall.

The designer of the roadway protection system should check whether the penetration depth is sufficiently deep to provide base fixity.

All shoring systems should be designed by a Professional Engineer experienced in such designs.

## **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 the culvert replacement. 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.

- effective dewatering of the temporary excavation for the installation of culvert;
- 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 Lukasz Gilarski, P.Eng and Dr. Sydney Pang, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng.

THURBER ENGINEERING LTD.

Lukasz Gilarski, P.Eng.  
Geotechnical Engineer



Sydney Pang, P.Eng.  
Associate, Senior Project Engineer



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



## **Appendix A**

### **Record of Borehole Sheets**

19-4406-9

## 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 <sup>(1)</sup> '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<sub>pen</sub>

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

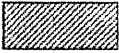




### ROCK WEATHERING CLASSIFICATION

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

### DISCONTINUITY SPACING

<b>Bedding</b>	<b>Bedding Plane Spacing</b>
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

<b>Rock Strength</b>	<b>Approximate Uniaxial Compressive Strength</b>		<b>Field Estimation of Hardness*</b>
	<b>(MPa)</b>	<b>(psi)</b>	
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	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

RECORD OF BOREHOLE No UC-01 Site 39E-314 1 OF 3

METRIC

GWP# 5193-13-00 LOCATION Unknown Creek N 5 432 734.1 E 302 596.5 ORIGINATED BY ES  
HWY 11 BOREHOLE TYPE NW Casing COMPILED BY AN  
DATUM Geodetic DATE 2013.10.29 - 2013.10.29 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa											
								20 40 60 80 100											
263.3	GROUND SURFACE																		
0.0	<b>SAND</b> , some gravel Dense to Compact Brown Moist (FILL)		1	SS	34		263												
			2	SS	26		262												
			3	SS	10														
261.3																			
2.0	Silty <b>CLAY</b> , trace organics, trace rootlets Firm to Very Soft Dark Brown							261											
					4		SS	7											
					5	SS	6		260										
					6	SS	1		259										
					1	TW			258										
							+												
			2	TW			257												
							+												
							256												
			7	SS	1														
							+												
							255												
			8	SS	0		254												
	Becoming grey																		

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15 10 5 0  
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No UC-01 Site 39E-314 2 OF 3

METRIC

GWP# 5193-13-00 LOCATION Unknown Creek N 5 432 734.1 E 302 596.5 ORIGINATED BY ES  
 HWY 11 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2013.10.29 - 2013.10.29 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	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						PLASTIC LIMIT w <sub>P</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>
Continued From Previous Page							20 40 60 80 100	20 40 60								
252.5							253	+								
10.8	GRAVEL, trace sand Compact Brown Wet		9	SS	11		252									
250.7			10	SS	11		251									
12.6	Silty CLAY, trace gravel Very Soft to Soft Grey						250									
			11	SS	1		249									
							248	+								
			12	SS	1		247									
							246									
	Occasional sand seams		13	SS	2		245									
244.4			14	SS	3		244									
18.9	End of sampling at 18.9m and start DCPT															

Continued Next Page

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

RECORD OF BOREHOLE No UC-01 Site 39E-314 3 OF 3

METRIC

GWP# 5193-13-00 LOCATION Unknown Creek N 5 432 734.1 E 302 596.5 ORIGINATED BY ES  
 HWY 11 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2013.10.29 - 2013.10.29 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT  $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				
	Continued From Previous Page							20 40 60 80 100	○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	PLASTIC LIMIT W <sub>P</sub> NATURAL MOISTURE CONTENT W LIQUID LIMIT W <sub>L</sub>		
								20 40 60 80 100		WATER CONTENT (%)		
		</										

RECORD OF BOREHOLE No UC-02 Site 39E-314 1 OF 1

METRIC

GWP# 5193-13-00 LOCATION Unknown Culvert N 5 432 730.2 E 302 576.5 ORIGINATED BY JG  
HWY 11 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
DATUM Geodetic DATE 2013.10.24 - 2013.10.24 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT  $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								○ UNCONFINED      + FIELD VANE								
								● QUICK TRIAXIAL      × LAB VANE								
							WATER CONTENT (%)									
							PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT									
							w <sub>p</sub> w      w <sub>L</sub>									
							20   40   60   80   100									
							20   40   60   80   100									
261.8	GROUND SURFACE															
0.0	TOPSOIL: (75mm)  Silty <b>CLAY</b> , some organics Firm to Very Soft Brown Moist          Becoming grey		1	SS	5											
0.1																
			2	SS	7											
			3	SS	8											
			4	SS	1											
			5	SS	0											
255.4																
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      3.2      258.6 Nov. 7/13      3.1      258.7															

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

## METRIC

[illegible]

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

## METRIC

[illegible]

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity



RECORD OF BOREHOLE No UC-03 Site 39E-314 3 OF 3

METRIC

GWP# 5193-13-00 LOCATION Unknown Creek N 5 432 739.7 E 302 585.4 ORIGINATED BY ES  
HWY 11 BOREHOLE TYPE NW Casing COMPILED BY AN  
DATUM Geodetic DATE 2013.10.24 - 2013.10.24 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100 PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W <sub>p</sub> W W <sub>L</sub> WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES					
	Continued From Previous Page									
234.6							243			
28.5	END OF BOREHOLE AND DCPT AT 28.5m UPON REFUSAL. WATER LEVEL AT 2.4m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.05m, SAND AND GRAVEL TO SURFACE.						235			

RECORD OF BOREHOLE No UC-04 Site 39E-314 1 OF 3

METRIC

GWP# 5193-13-00 LOCATION Unknown Creek N 5 432 705.2 E 302 595.5 ORIGINATED BY ES  
HWY 11 BOREHOLE TYPE NW Casing COMPILED BY AN  
DATUM Geodetic DATE 2013.10.28 - 2013.10.29 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  <b>γ</b>  kN/m <sup>3</sup>	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							
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE				WATER CONTENT (%)							
						20   40   60   80   100				20   40   60									
263.4	GROUND SURFACE					▽	263												
0.0	<b>SAND</b> , some gravel Dense Brown Frozen to Moist (FILL)		1	SS	42														
			2	SS	34														
261.5			3	SS	10														
1.9	Silty <b>CLAY</b> , some sand, trace gravel Stiff Brown																		
			4	SS	3														
260.4																			
3.0	Silty <b>CLAY</b> , trace sand Very Soft Brown to Grey		5	SS	1			260											
			6	SS	0														
			7	SS	0														
							258												
								+											
			8	SS	0		257												
							256												
			9	SS	0														
							255												
								+											
			10	SS	0		254												
	Sand layer																		


Continued Next Page

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

RECORD OF BOREHOLE No UC-04 Site 39E-314 2 OF 3

METRIC

GWP# 5193-13-00 LOCATION Unknown Creek N 5 432 705.2 E 302 595.5 ORIGINATED BY ES  
 HWY 11 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2013.10.28 - 2013.10.29 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 <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			WATER CONTENT (%)								
								20   40   60   80   100	W <sub>P</sub> W      W <sub>L</sub>										
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE											
	Continued From Previous Page							20   40   60   80   100											
247.6 15.8	Sand and gravel layer						253		+										
			11	SS	0														
			12	SS	29														
			13	SS	7														
							249												
							250												
							248												
	Sand and gravel layer		14	SS	5		248										21   17   14   48		
	End of sampling at 15.8m and start DCPT						247												
							246												
							245												
							244												

Continued Next Page

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

RECORD OF BOREHOLE No UC-04 Site 39E-314 3 OF 3

METRIC

GWP# 5193-13-00 LOCATION Unknown Creek N 5 432 705.2 E 302 595.5 ORIGINATED BY ES  
 HWY 11 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2013.10.28 - 2013.10.29 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	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										
	Continued From Previous Page							● QUICK TRIAXIAL      × LAB VANE										
									20 40 60 80 100	20 40 60								
							243											
							242											
							241											
							240											
							239											
							238											
							237											
236.1																		
27.3	END OF BOREHOLE AND DCPT AT 27.3m UPON REFUSAL. FREE WATER AT 0.6m UPON COMPLETION. BOREHOLE BACKFILLED WITH HOLEPLUG TO 0.1m, SAND AND GRAVEL TO SURFACE.																	

RECORD OF BOREHOLE No UC-05 Site 39E-314 1 OF 1

METRIC

GWP# 5193-13-00 LOCATION Unknown Creek N 5 432 715.6 E 302 606.0 ORIGINATED BY JG  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2013.10.24 - 2013.10.24 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
262.4	GROUND SURFACE							20	40	60	80	100					
0.0	Silty <b>CLAY</b> , some organics Firm Brown Moist		1	SS	6		262							○			
261.6																	
0.8	<b>SAND</b> , trace silt and clay, trace gravel Loose Brown Moist		2	SS	6		261							○		11 85 4 (SI+CL)	
260.9																	
1.5	Silty <b>CLAY</b> Firm to Very Soft Brown Moist		3	SS	8									○			
			4	SS	3		260							┌──○──┐		0 0 39 61	
							259	2.0 +									
	Becoming grey		5	SS	0		258										
			1	TW													
							257										
			6	SS	0		256							○			
255.7																	
6.7	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    3.8            258.6 Nov. 7/13    3.7            258.7																

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

RECORD OF BOREHOLE No UC-06 Site 39E-314 1 OF 3

METRIC

GWP# 5193-13-00 LOCATION Unknown Creek N 5 432 710.8 E 302 584.4 ORIGINATED BY ES  
 HWY 11 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2013.10.24 - 2013.10.25 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED    + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE									WATER CONTENT (%)
262.9	GROUND SURFACE					▽											
0.0	<b>SAND</b> , some gravel Dense to Compact Brown Moist (FILL)		1	SS	33										○		
			2	SS	17										○		
	Organics, rootlets Loose Dark Brown		3	SS	6										○		
260.6																	
2.3	Silty <b>CLAY</b> , trace sand Firm to Very Soft Brown		4	SS	7										○		
			5	SS	2									○			
	Occasional oxide staining		6	SS	2									— ○ —			
			1	TW										—			

Continued Next Page

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

## METRIC

[illegible]

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

RECORD OF BOREHOLE No UC-06 Site 39E-314 3 OF 3

METRIC

GWP# 5193-13-00 LOCATION Unknown Creek N 5 432 710.8 E 302 584.4 ORIGINATED BY ES  
 HWY 11 BOREHOLE TYPE NW Casing COMPILED BY AN  
 DATUM Geodetic DATE 2013.10.24 - 2013.10.25 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  $\gamma$  kN/m <sup>3</sup>	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			
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE	WATER CONTENT (%)							
	Continued From Previous Page							20 40 60 80 100		20 40 60							
235.0	END OF BOREHOLE AT 27.9m UPON REFUSAL. WATER LEVEL AT 0.4m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.1m, THEN SAND AND GRAVEL TO SURFACE.						242										
27.9							241										
							240										
							239										
							238										
							237										
							236										



## **Appendix B**

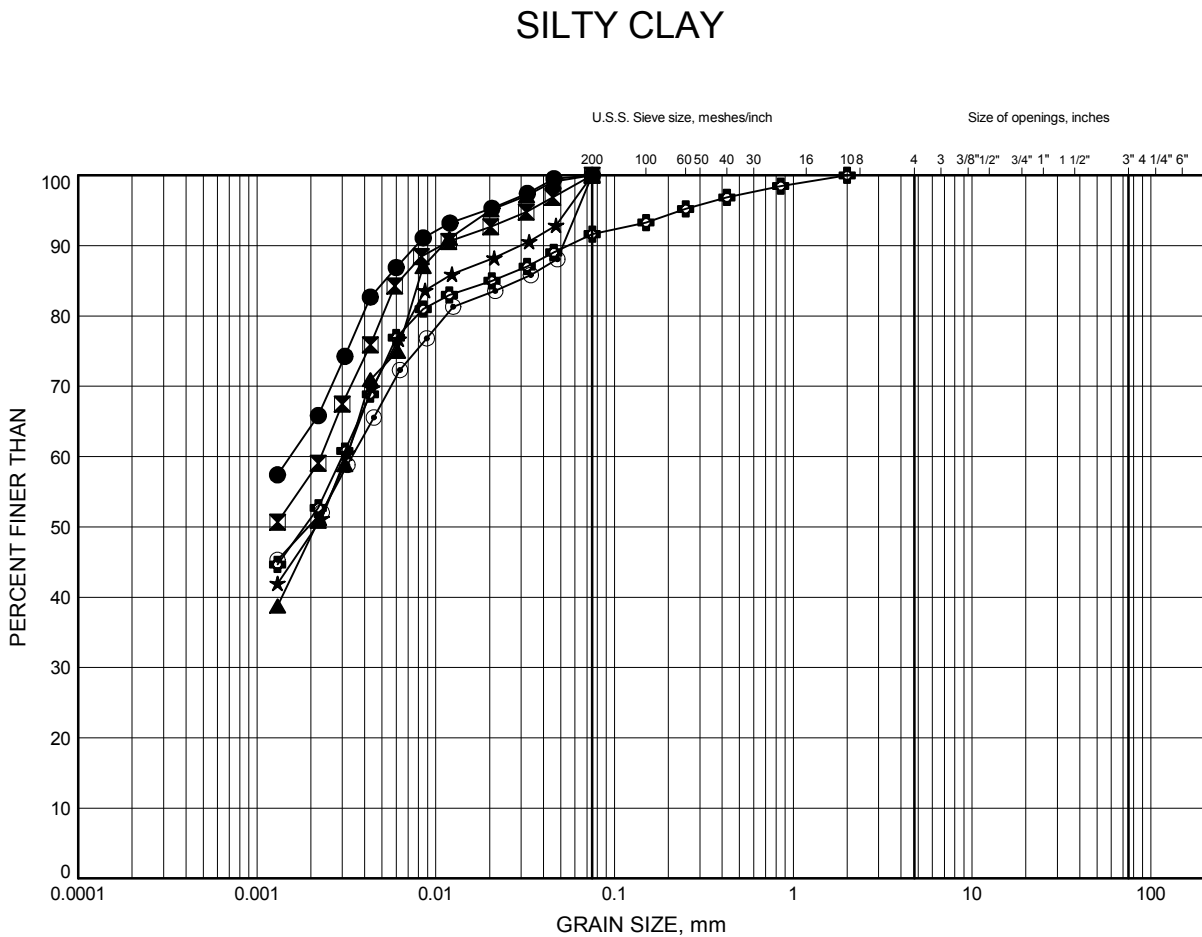
### **Laboratory Test Results**

19-4406-9

# Hwys 11, 583, 652 Culverts - Foundations

## GRAIN SIZE DISTRIBUTION

FIGURE B1



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UC-01 Site 39E-314	4.11	259.19
⊠	UC-01 Site 39E-314	15.54	247.76
▲	UC-02 Site 39E-314	1.83	259.97
★	UC-03 Site 39E-314	4.88	258.22
⊙	UC-04 Site 39E-314	3.35	260.05
⊕	UC-04 Site 39E-314	9.45	253.95

Date December 2013

GWP# 5193-13-00



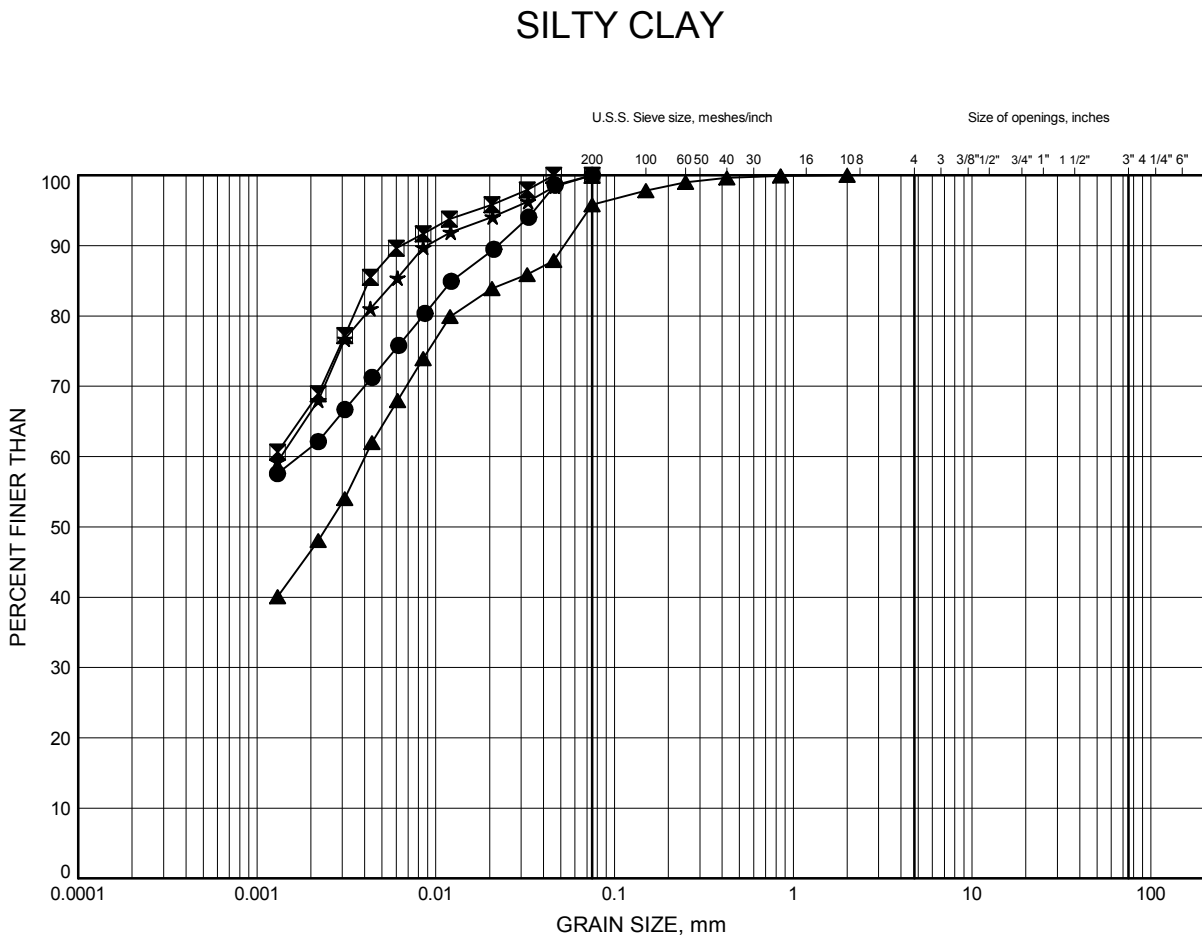
Prep'd AN

Chkd. LPG

# Hwys 11, 583, 652 Culverts - Foundations

## GRAIN SIZE DISTRIBUTION

FIGURE B2



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UC-05 Site 39E-314	2.59	259.81
⊠	UC-06 Site 39E-314	4.11	258.79
▲	UC-06 Site 39E-314	4.88	258.02
★	UC-06 Site 39E-314	18.59	244.31

Date December 2013

GWP# 5193-13-00



Prep'd AN

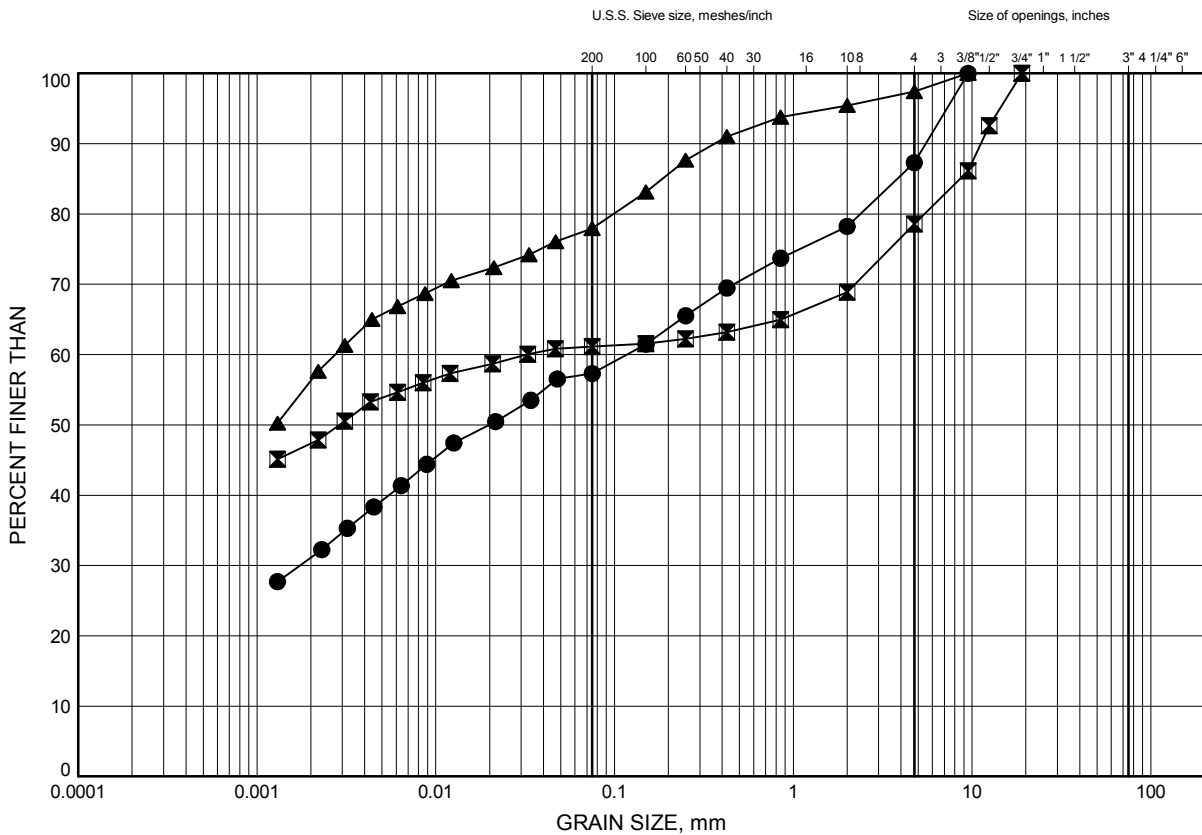
Chkd. LPG

# Hwys 11, 583, 652 Culverts - Foundations

## GRAIN SIZE DISTRIBUTION

FIGURE B3

### SILTY CLAY, With Sand & Gravel Layer



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UC-03 Site 39E-314	14.02	249.08
⊠	UC-04 Site 39E-314	15.54	247.86
▲	UC-06 Site 39E-314	12.50	250.40

Date December 2013

GWP# 5193-13-00



Prep'd AN

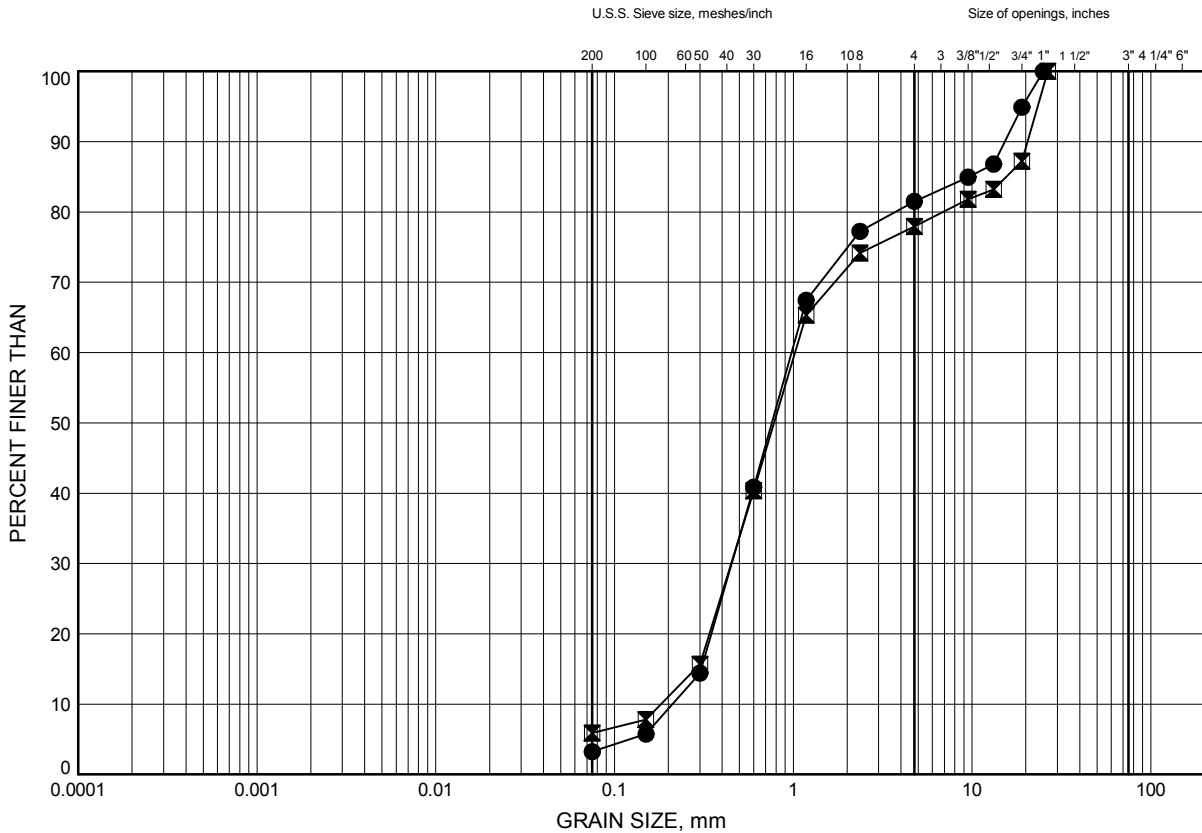
Chkd. LPG

# Hwys 11, 583, 652 Culverts - Foundations

## GRAIN SIZE DISTRIBUTION

FIGURE B4

### SAND (FILL), Some Gravel



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UC-04 Site 39E-314	1.07	262.33
⊠	UC-06 Site 39E-314	1.07	261.83

Date December 2013  
GWP# 5193-13-00



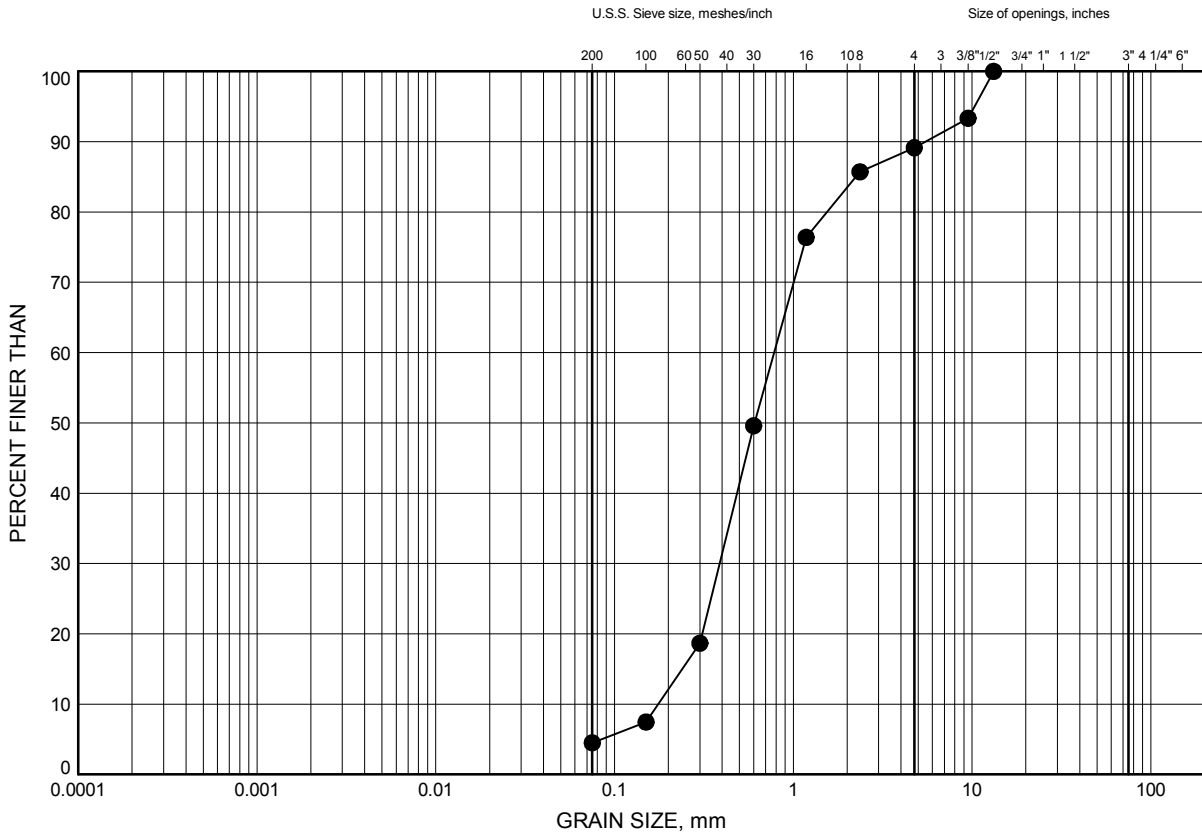
Prep'd AN  
Chkd. LPG

# Hwys 11, 583, 652 Culverts - Foundations

## GRAIN SIZE DISTRIBUTION

FIGURE B5

SAND, Some Gravel



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UC-05 Site 39E-314	1.07	261.33

Date December 2013

GWP# 5193-13-00



Prep'd AN

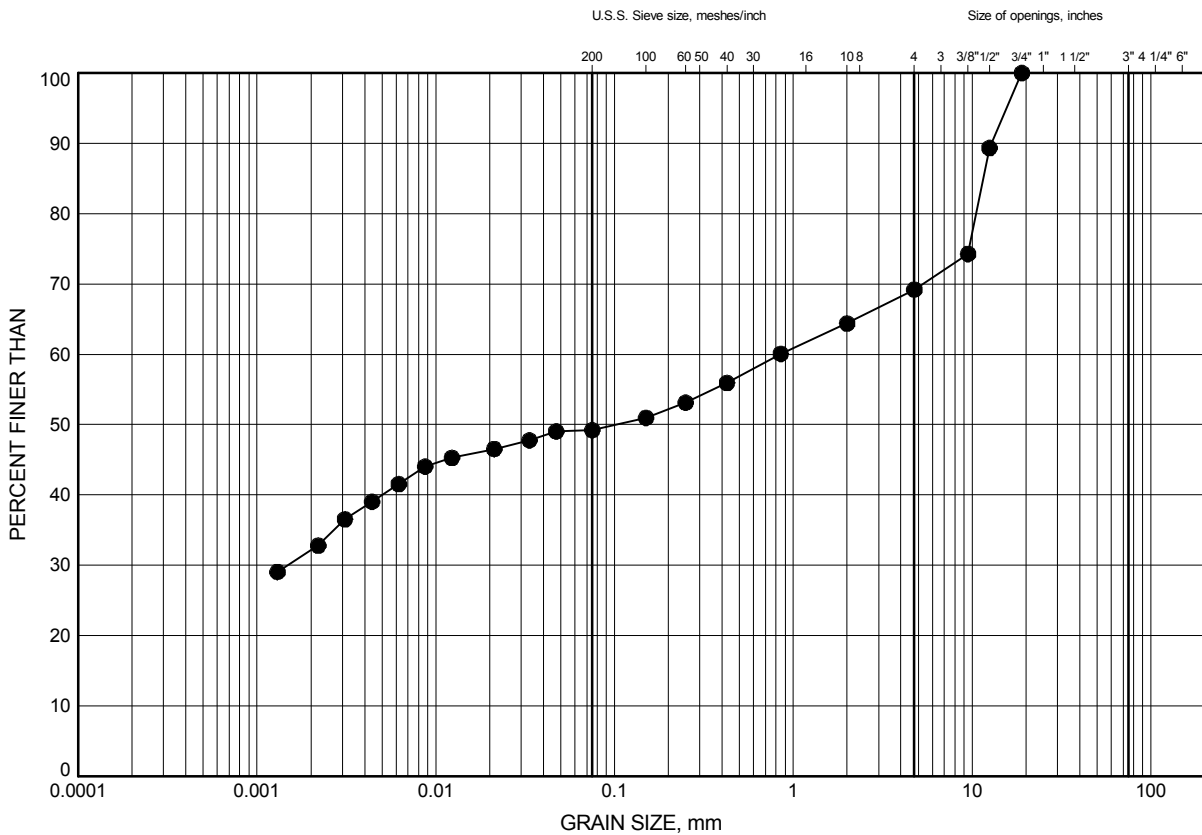
Chkd. LPG

# Hwys 11, 583, 652 Culverts - Foundations

## GRAIN SIZE DISTRIBUTION

FIGURE B6

### SAND & GRAVEL, With Silty Clay Layer (FILL)



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UC-03 Site 39E-314	1.07	262.03

Date December 2013  
GWP# 5193-13-00



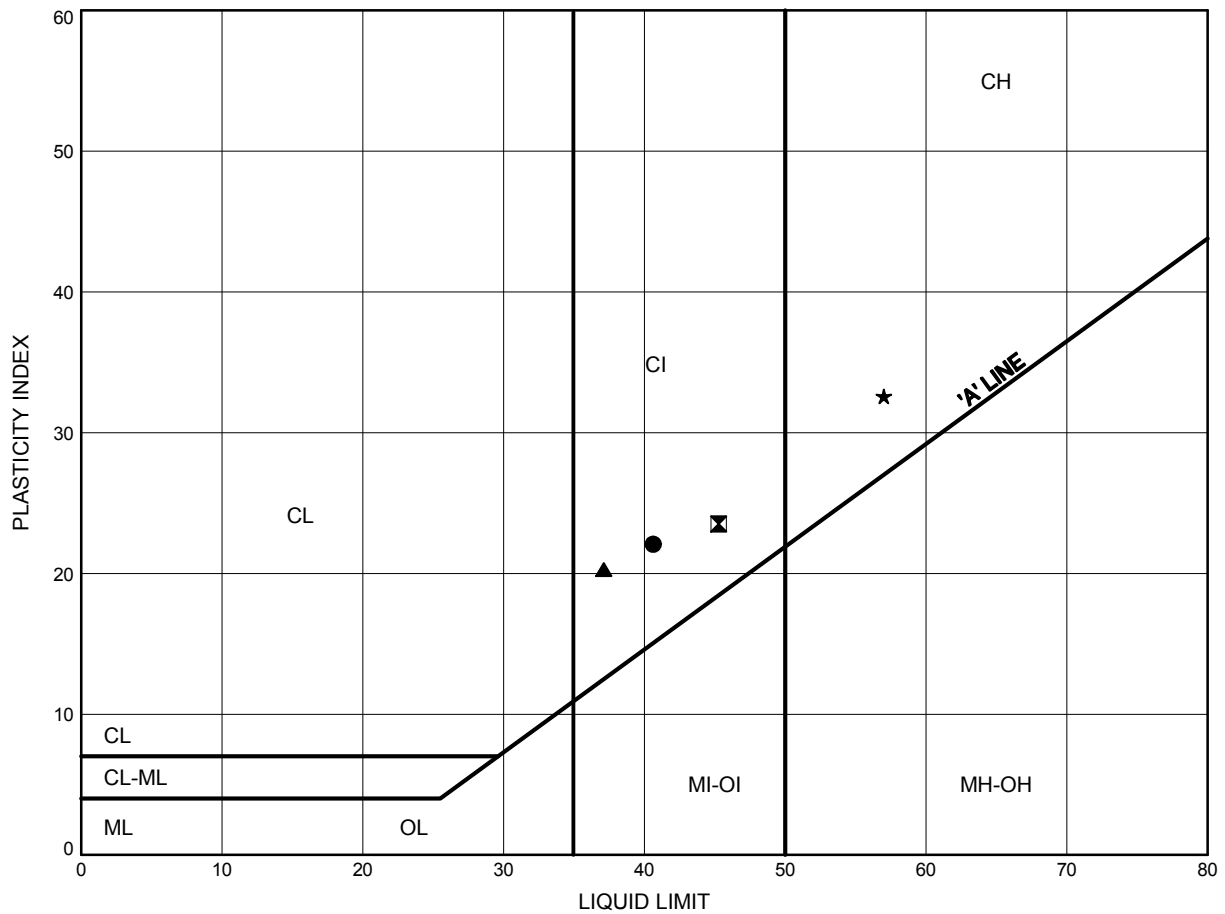
Prep'd AN  
Chkd. LPG

Hwys 11, 583, 652 Culverts - Foundations

# ATTERBERG LIMITS TEST RESULTS

FIGURE B7

## SILTY CLAY



### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	UC-01 Site 39E-314	4.11	259.19
⊠	UC-01 Site 39E-314	15.54	247.76
▲	UC-03 Site 39E-314	4.88	258.22
★	UC-05 Site 39E-314	2.59	259.81

Date December 2013

GWP# 5193-13-00



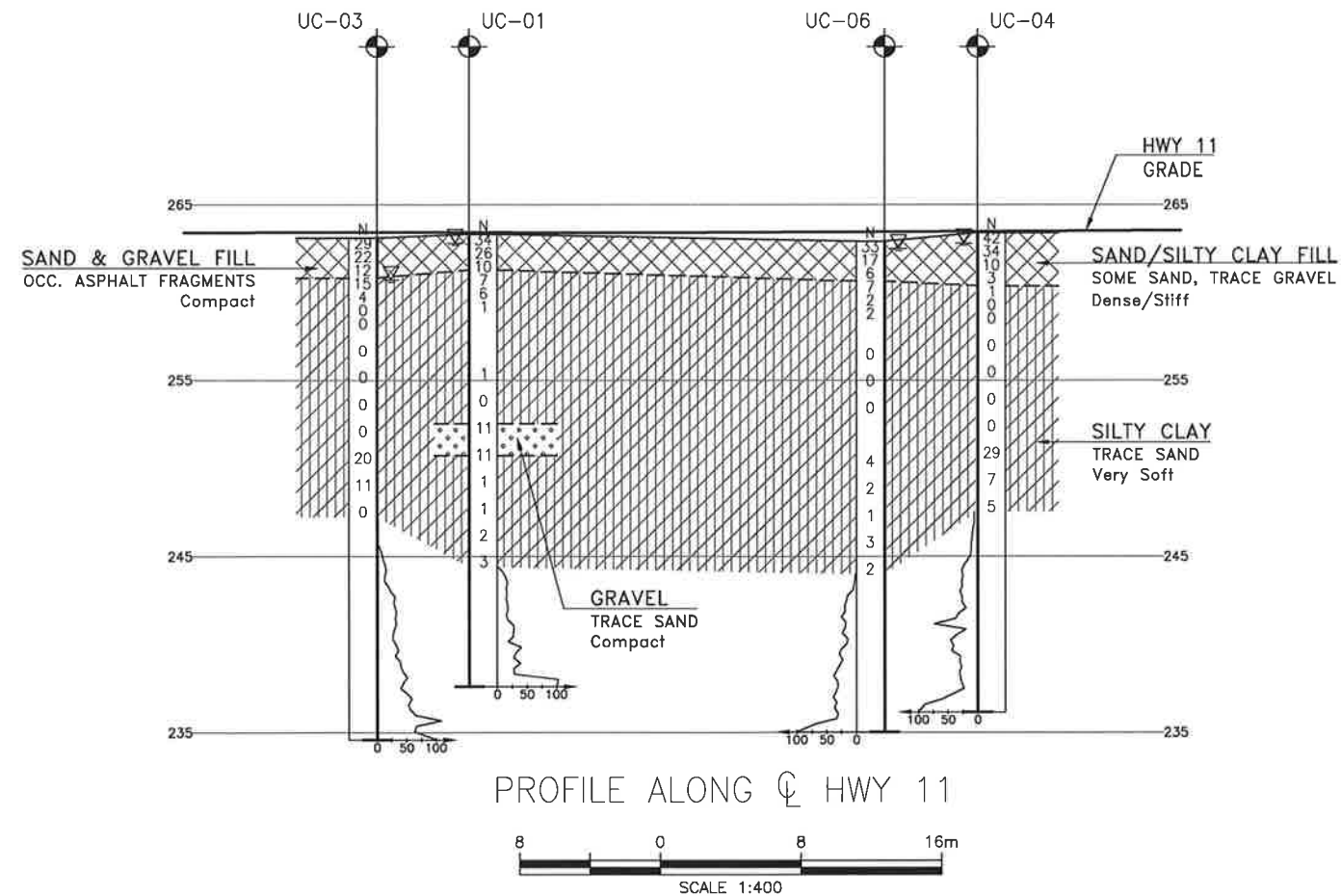
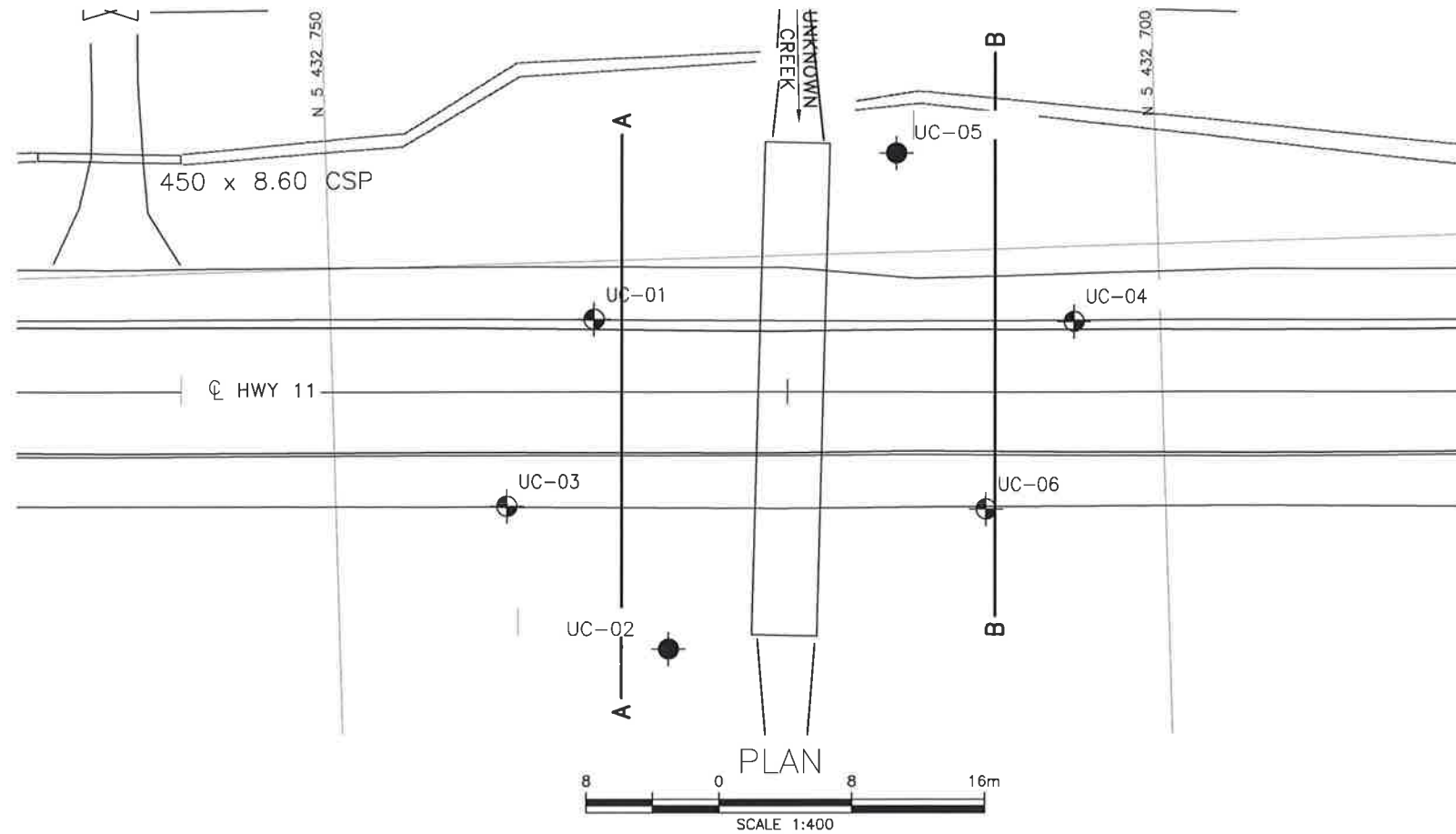
Prep'd AN

Chkd. LPG



## **Appendix C**

### **Borehole Locations and Soil Strata Drawings**



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



CONT No  
GWP No 5193-13-00

HWY 11 UNKNOWN CREEK  
(MONDOR CREEK TRIBUTARY)  
CULVERT REPLACEMENT I  
BOREHOLE LOCATIONS AND SOIL STRATA

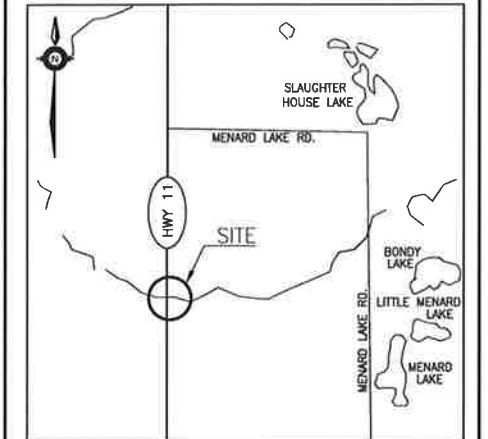


SHEET

**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
UC-01	263.3	5 432 734.1	302 596.5
UC-02	261.8	5 432 730.2	302 576.5
UC-03	263.1	5 432 739.7	302 585.4
UC-04	263.4	5 432 705.2	302 595.5
UC-05	262.4	5 432 715.6	302 606.0
UC-06	262.9	5 432 715.6	302 606.0

-NOTES-

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

GEOCRE No. 42H-56






DATE	BY	DESCRIPTION
DESIGN	SKP	CHK SKP
DRAWN	AN	CHK AEG
SITE	39E-314C	STRUCT
DATE	JAN 2015	PLDWG 2

HWY 11 UNKNOWN CREEK  
(MONDOR CREEK TRIBUTARY)  
CULVERT REPLACEMENT II  
BOREHOLE LOCATIONS AND SOIL STRATA

**URS**

A map of the study area. A north arrow is in the top left. Hwy 11 is a vertical line. Menard Lake Rd. is a horizontal line intersecting Hwy 11. The 'SITE' is marked with a circle at the intersection. To the north of the site is Slaughter House Lake. To the east are Bondy Lake, Little Menard Lake, and Menard Lake. A small lake is also shown to the north of Slaughter House Lake.

### 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                         |

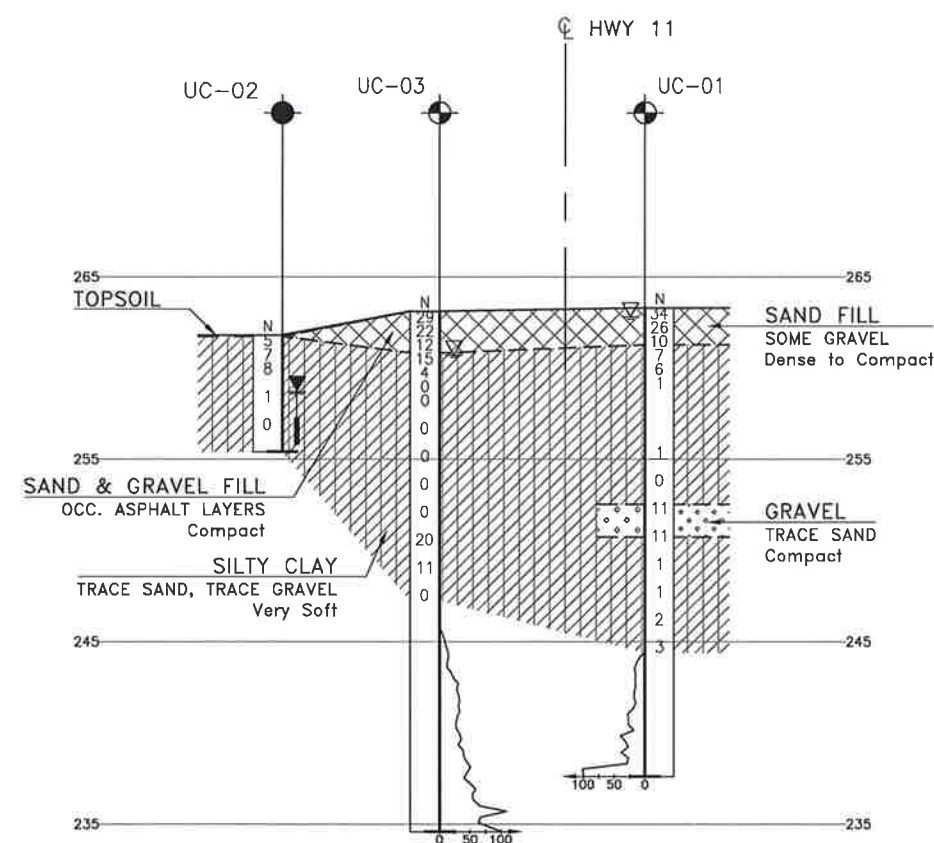
NO	ELEVATION	NORTHING	EASTING
UC-01	263.3	5 432 734.1	302 596.5
UC-02	261.8	5 432 730.2	302 576.5
UC-03	263.1	5 432 739.7	302 585.4
UC-04	263.4	5 432 705.2	302 595.5
UC-05	262.4	5 432 715.6	302 606.0
UC-06	262.9	5 432 715.6	302 606.0

**-NOTES-**

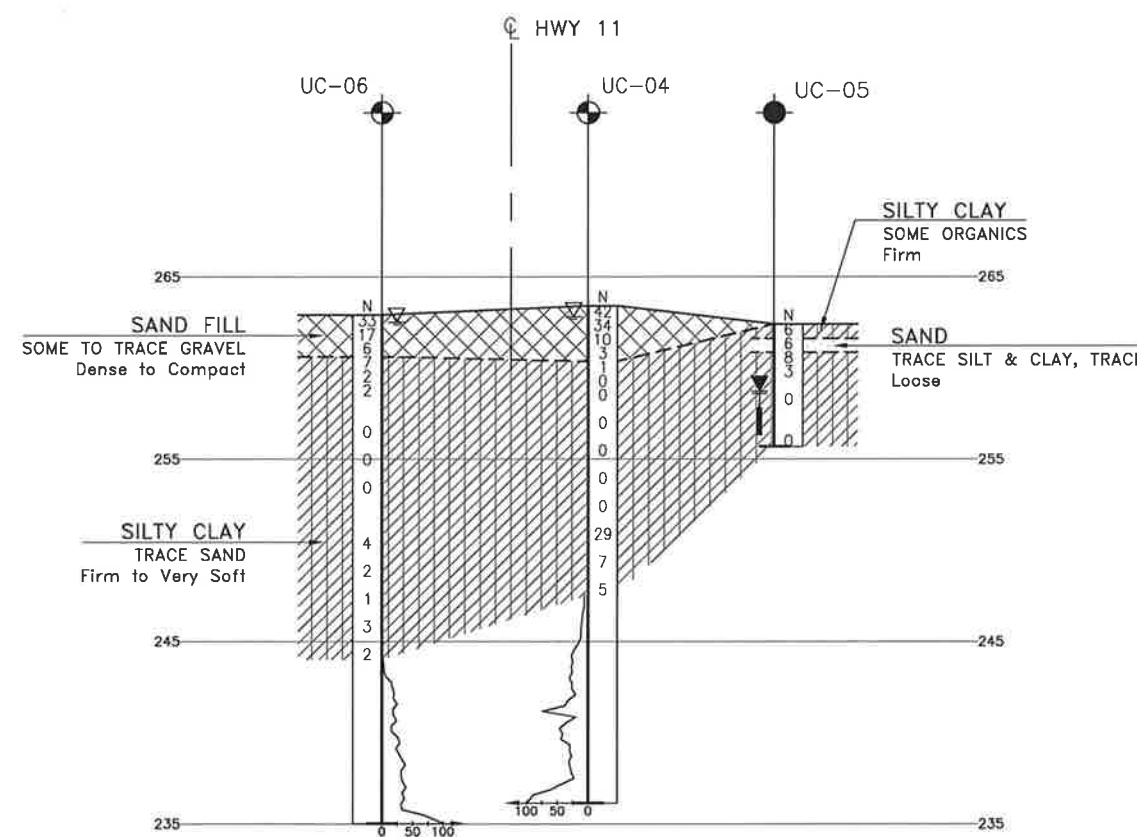
- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCRES No. 42H-56

REVISIONS							
	DATE	BY			DESCRIPTION		
DESIGN	SKP	CHK	SKP	CODE	LOAD	DATE	JAN 2015
DRAWN	AN	CHK	AEG	SITE	39E-314C	STRUCT	DWG 3



SECTION ALONG A-A



SECTION ALONG B-B



## **Appendix D**

### **Foundation Alternatives Comparison**

19-4406-9

**COMPARISON OF ALTERNATIVE CULVERT TYPES**

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

## **Appendix E**

### **Selected Photograph of Culvert Location**



Unknown Creek (Mondor Tributary) Culvert Replacement  
Highway 11



**Photo 1: Unknown Creek (Mondor Tributary) Culvert**

## **Appendix F**

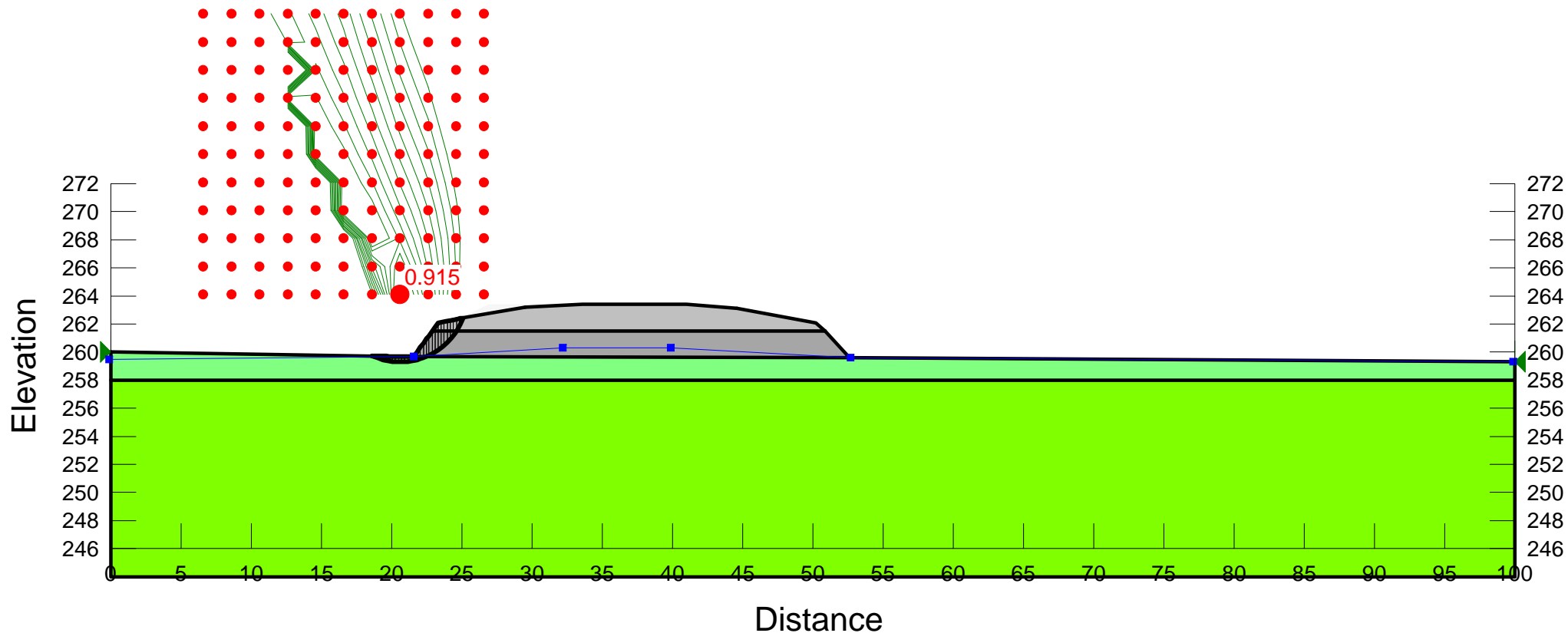
### **Selected Stability Analysis Results**

19-4406-9



Title: Cochrane Creek (39E-314)  
 Name: Analysis 1  
 Comments: Culvert Replacement Staging  
 Last Edited By: Stephen Peters  
 Last Solved Date: 12/19/2013, 2:35:45 PM  
 Method: Morgenstern-Price, Half-Sine  
 Minimum Slip Surface Depth: 1 m  
 Horz Seismic Load: 0

Cohesionless FILL	21 kN/m <sup>3</sup>	0 kPa	30 °	1
Cohesive FILL	19 kN/m <sup>3</sup>	0 kPa	28 °	1
CLAY 1 (ESA)	18 kN/m <sup>3</sup>	0 kPa	27 °	1
CLAY 2 (ESA)	18 kN/m <sup>3</sup>	0 kPa	27 °	1



Title: Cochrane Creek (39E-314)  
 Name: Analysis 2  
 Comments: Culvert Replacement Staging  
 Last Edited By: Stephen Peters  
 Last Solved Date: 12/19/2013, 2:35:52 PM  
 Method: Morgenstern-Price, Half-Sine  
 Minimum Slip Surface Depth: 1 m  
 Horz Seismic Load: 0

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

