

**FOUNDATION INVESTIGATION AND DESIGN REPORT
CULVERT REPLACEMENT AT ROY CREEK
SITE NO. 39E-221
HIGHWAY 652
COCHRANE DISTRICT, ONTARIO
G.W.P. No. 5169-10-00**

GEOCRES Number: 42H-58

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 twin culverts where replacement is proposed on Highway 652 over Roy Creek, located in the Township of Fox, Cochrane Area, 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.

The purpose of this investigation was to obtain subsurface information at the twin 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 652, 25.6 km north of Highway 579 in the Township of Fox. These culverts allow Roy Creek to flow, from south to north, under Highway 652.

The existing structure is a twin 3.0 m span by 23 m long steel plate pipe (SPP). The culverts were constructed in 1964. It is understood that the structures are in poor condition with deterioration of several elements.

The grade of the existing Highway 652 in the vicinity of the twin culverts is about Elevation 300.4 m. The embankment fill height above the culverts is up to 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 culverts 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 8 and October 16, 2013. The program consisted of drilling and sampling 9 boreholes (number RC13-01 to RC13-09) to depths ranging from 7.0 to 19.8 m. Of these boreholes, two were located at the culvert inlet (RC13-08 and RC13-09), two were located at the culvert outlet (RC13-01 and RC13-02), and five were located on the highway (RC13-03 to RC13-07).

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. In addition, a portable tripod drill rig was used to advance boreholes at locations of difficult access beyond the highway. 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 all but Boreholes RC13-01, RC13-02, RC13-08 and RC13-09. Standpipe piezometers were installed in Boreholes RC13-01 and RC13-08 for monitoring of groundwater levels. 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	
RC13-01	6.1 / 292.2	3.5 to 6.1	294.8 – 292.2	Silty Clay	Bentonite holeplug to surface
RC13-02		None Installed			Bentonite holeplug mixed with auger cuttings to surface
RC13-03		None Installed			Bentonite holeplug to 0.9 m, sand and asphalt cold patch to surface
RC13-04		None Installed			Bentonite holeplug to 0.3 m, and asphalt cold patch to surface
RC13-05		None Installed			Bentonite holeplug to 0.3 m, and asphalt cold patch to surface
RC13-06		None Installed			Bentonite holeplug to surface.
RC13-07		None Installed			Bentonite holeplug to 5.8 m, sand to surface
RC13-08	6.1 / 292.3	4.3 to 6.1	294.0 – 292.2	Silty Clay	Bentonite holeplug to surface
RC13-09		None Installed			Bentonite holeplug 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). 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.

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 with trace to some sand. 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 0.1 to 0.2 m below original ground surface. More detailed descriptions of the individual stratum are presented below.

5.2 Topsoil/Peat

A layer of topsoil 125 mm in thickness was encountered at ground surface in Borehole RC13-02 located near the culvert inlet and outlet areas. The topsoil thickness may vary between and beyond the borehole locations, and the limited data is not suitable for estimating topsoil quantities.

A 0.6 m thick layer of buried peat was noted below the embankment fill in Borehole RC13-07. The peat was very loose with an SPT N-value of 2 blows per 0.3 m of penetration and had a moisture content of 408%.

5.3 Fill

Embankment fill was encountered at ground surface in Boreholes RC13-03, RC13-04, RC13-05, RC13-06 and RC13-07. This fill typically consists of brown sand and gravel with trace silt and clay to brown sand with trace gravel. In Borehole RC13-04 a 15 mm thick layer of asphalt was encountered at ground surface. Where encountered, the embankment fill was found extending from 2.3 to 3.8 m depth (base Elevations from 298.0 to 296.5 m).

SPT N-values measured in the cohesionless fill ranged from 4 to 41 blows per 0.3 m penetration indicating a loose to dense state. Measured moisture contents of the recovered fill samples ranged between 2% and 23%. Grain size analyses conducted on samples of the embankment fill are presented on Figure B5 in Appendix B. These results are summarized in the following tables.

Soil Particles	%
Gravel	3 to 26
Sand	64 to 94
Silt and Clay	3 to 10

5.4 Silty Clay

Underlying the embankment fill and topsoil, silty clay was encountered in all nine boreholes drilled at the site. This brown to grey soil typically contained trace to some sand and trace gravel. Trace organics were noted near the surface of the clay. Boreholes RC13-01, RC13-02, RC13-08 and RC13-09 were terminated within the silty clay at depths of 7.0 to 7.1 m (base Elevations 291.7 to 291.1 m). In Borehole RC13-03 to RC13-07 the thickness of the clay layer was at least 13 to 16.8 m. In Boreholes RC13-03 to RC13-07 Dynamic Cone Penetration Tests (DCPT) were conducted from depths of 16.8 to 19.8 m (base Elevations 283.5 to 280.5 m). DCPT's encountered refusal at depths of 23.8 to 26.2 m (base Elevations 274.1 to 276.5 m).

SPT-N values measured in the silty clay ranged from 0 to 16 blows per 0.3 m of penetration. The silty clay was found to have a typically very soft to stiff consistency. A stiffer crust exists in the upper 1 to 1.5 m. Field vane shear strength measurements resulted in undrained shear strength values ranging from 10 to 45 kPa. The measured water contents of samples recovered from these soils typically ranged from 24 to 62%. Occasional values of greater than 60% at shallow depths are attributed to the organic contents in the soil. Grain size analyses conducted on samples of the silty clay are presented on Figures B1 to B4, and Atterberg Limits test results are presented in Figures B6 to B9 in Appendix B. The results are summarized in the following tables.

Soil Type	Soil Particles	%
Silty Clay	Gravel	0 to 2
	Sand	0 to 21
	Silt	23 to 65
	Clay	35 to 77
	Soil Property	%
	Liquid Limit	34 to 63
	Plasticity Index	18 to 35
Silty Clay with Sand, trace gravel Layer	Soil Particles	%
	Gravel	0 to 4
	Sand	9 to 25
	Silt	21 to 64
	Clay	21 to 52

	Soil Property	%
	Liquid Limit	31 to 48
	Plasticity Index	14 to 27

The results of the Atterberg Limits tests indicate that the silty clay is of intermediate to high plasticity (CI to CH). The silty clay with sand layers is of low to intermediate plasticity (CL to CI).

5.5 Groundwater Conditions

Standpipe piezometers were installed in Boreholes RC13-01 and RC13-08 to permit longer term monitoring. Water levels measured in the two installed standpipes are presented below.

Borehole	Date of Reading	Water Level Depth (m)	Water Level Elevation (m)
RC13-01	Nov. 1, 2013	0.1	298.2
	Nov. 7, 2013	0.1	298.2
RC13-08	Nov. 1, 2013	0.1	298.3
	Nov. 7, 2013	0.1	298.3

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 298.2 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, a track-mounted CME 55 drill rig, and a tri-pod 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. Katrina Young 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. 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 design of the replacement of the existing twin culverts at Roy Creek on Highway 652, located 25.6 km north of Highway 579.

Based on the terms of reference, the existing structure is a twin 3.0 m span by 23 m long Steel Plate Pipe (SPP) culverts. These twin culverts were constructed in 1964. It is understood that the culverts are in poor condition with deterioration of several elements. The total fill height above the culvert at this location is up to 1.3 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.

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 twin culverts with twin concrete box culverts along the same alignments. It is understood that embankment widening will be required on the south (approximately 1.5 m) and north (approximately 2.5 m) sides to accommodate temporary traffic detour during construction. Physical dimensions of the proposed culverts and other design information provided by URS are presented in the following 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)	Span (m)	Rise (m)
		Inlet	Outlet			
C06	RC13-08 and RC13-09 near inlet	296.070	296.002	22.7	3.0	3.0
	RC13-03 to RC13-07 through highway embankment adjacent to existing culvert					
	RC13-01 and RC13-02 near outlet					

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 twin culverts are Steel Plate Pipe (SPP). Preliminary design information indicates that consideration is being given to using precast twin concrete box culverts as replacements. Given the subsurface conditions and anticipated construction sequencing, we consider this as 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 will 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 associated wing 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 culverts. Foundation design aspects for the replacement culverts include subgrade conditions, geotechnical resistances for the wing 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 Culverts

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

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 should be provided under the base of the box culverts as per OPSD 803.010. The bedding material should 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 296.0 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, under the existing 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 296.0 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 296.0 m. 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. The existing twin cell SPP culverts are to be replaced with twin concrete box culverts along the same alignments. The opening sizes of the two culverts are similar. Taking into consideration the proposed conceptual construction sequencing for this site, it is anticipated that rebound of the subgrade after removal of the existing culvert and the surrounding fill will be negligible. Due to the slightly heavier weight of the concrete box compared to the SPP, the firm silty clay subgrade soils 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.

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, creekbed 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 Granular 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 culverts at Roy 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:

- One lane of traffic will be maintained at all times during construction
- 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 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)
	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 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 the 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 wing wall 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 3 m in height at the culverts. It is understood that 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 are included in the fill
- Gradation and compaction characteristics meet the requirements prior to reuse as backfill

Provided that the granular material is placed as recommended, it is anticipated that the existing highway embankment slope inclination of 3H : 1V or flatter should remain stable. 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.

Information from URS indicates that consideration is being given to steepening the slope inclination from 3H : 1V to 2H : 1V between the top of the proposed culvert and the ground surface, i.e. lower portion of slope. 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 1.42 and 1.45, respectively (see Appendix F). Taking into consideration the relatively low embankment height, the results generally satisfy typical MTO criteria for global stability.

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 and 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 and west sides to accommodate a temporary traffic detour lane will require placement and compaction of granular fill. It is recommended that the existing slope inclination 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.

The fill for temporary road widening during construction is to be placed on the upper slopes of the existing embankment. 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. It is anticipated that the wedges of new fill would induce in the order of 5 mm of settlement. 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 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 EMBANKMENT DESIGN AND CONSTRUCTION

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 and clayey silt 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 cutoff. It is anticipated that the sheet piles will need to be extended into the firm native silty clay to develop the required toe resistance.

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

γ	=	20 kN/m ³
γ_w	=	10 kN/m ³
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 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 Mr. Lukasz Gilarski, P.Eng. The report was reviewed by Mr. Alastair Gorman, P.Eng. and Dr. P.K. Chatterji, P.Eng.

THURBER ENGINEERING LTD.

Lukasz Gilarski, P.Eng.
Geotechnical Engineer



Sydney Pang, P.Eng.
Associate, 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

C_{pen}

Shear Strength Determination by Pocket Penetrometer

- (1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.
- (2) DCPT Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

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	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

RECORD OF BOREHOLE No RC13-01

1 OF 1

METRIC

GWP# 5193-13-00 LOCATION Roy Creek N 5 435 501.6 E 327 322.2 ORIGINATED BY KMY
 HWY 652 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2013.10.08 - 2013.10.08 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					
298.3	GROUND SURFACE							20 40 60 80 100	PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L		
0.0	Silty CLAY , trace to some sand, trace organics near surface Very Soft Dark Brown to Grey Wet		1	SS	1		298						0 3 47 50 Split spoon wet
			2	SS	1		297	2.0 +					
			3	SS	0		296						
			4	WH	0		295	2.0 +					
			5	WH	0		294	2.0 +					
			6	WH	0		293	+					
	Sand layer						292						0 13 40 47
291.3								+					
7.0	END OF BOREHOLE AT 7.0m. Monitoring well 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 0.1 298.2 Nov. 7/13 0.1 298.2												

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

RECORD OF BOREHOLE No RC13-02

1 OF 1

METRIC

GWP# 5193-13-00 LOCATION Roy Creek N 5 435 498.9 E 327 335.6 ORIGINATED BY KMY
 HWY 652 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2013.10.08 - 2013.10.08 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							WATER CONTENT (%)
								○ UNCONFINED		+ FIELD VANE		● QUICK TRIAXIAL			
298.7	GROUND SURFACE						20	40	60	80	100	PLASTIC LIMIT W P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W L	
0.0	TOPSOIL: (125mm)														
0.1	Silty CLAY , trace to some sand, roots and wood fragments near surface Very Soft Brown Wet 														


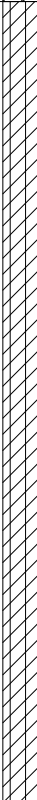
ONTMT4S 4069.GPJ 2012TEMPLATE(MTO).GDT 1/7/15

RECORD OF BOREHOLE No RC13-03

1 OF 3

METRIC

GWP# 5193-13-00 LOCATION Roy Creek N 5 435 489.3 E 327 338.9 ORIGINATED BY KMY
 HWY 652 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.10.10 - 2013.10.11 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 (%)											
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				w _P w w _L											
300.4	GROUND SURFACE							20	40	60	80	100					GR	SA	SI	CL			
0.0	SAND and GRAVEL , trace silt and clay Very Loose to Compact Light Brown Moist (FILL)		1	SS	9												26	68	6	(SI+CL)			
			2	SS	7																		
			3	SS	3																		
			4	SS	14																		
297.4																				Split spoon wet			
3.0	Silty CLAY , trace to some sand Firm to Very Soft Grey Wet		5	SS	7																		
			6	SS	3																		
			7	SS	WH																		
			8	SS	WH																		
	Sand layer		9	SS	WH															0	23	37	40
	Trace Gravel																						

Continued Next Page

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

RECORD OF BOREHOLE No RC13-03

2 OF 3

METRIC

GWP# 5193-13-00 LOCATION Roy Creek N 5 435 489.3 E 327 338.9 ORIGINATED BY KMY
 HWY 652 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.10.10 - 2013.10.11 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				w _P w w _L				
								20 40 60 80 100				20 40 60				
	Continued From Previous Page		10	SS	WH								○			
	Silty CLAY Very Soft Grey Wet						290	+								
			11	SS	WH		289						○			
								+								
							288									
			12	SS	WH		287							○		
								+								
							286									
			13	SS	WH		285							○		
								+								
							284									
			14	SS	WH		283									
								+								
							282									
								+								
							281							○		
			16	SS	WH											
								+								
280.6																
19.8	End of sampling at 19.8m and start of															
	Continued Next Page															

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

RECORD OF BOREHOLE No RC13-03

3 OF 3

METRIC

GWP# 5193-13-00 LOCATION Roy Creek N 5 435 489.3 E 327 338.9 ORIGINATED BY KMY
 HWY 652 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.10.10 - 2013.10.11 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				
	Continued From Previous Page							<div><div><div>20406080100</div><div>○ UNCONFINED + FIELD VANE</div><div>● QUICK TRIAXIAL × LAB VANE</div></div><div><div>PLASTIC LIMIT</div><div>NATURAL MOISTURE CONTENT</div><div>LIQUID LIMIT</div></div><div><div>W_P</div><div>W</div><div>W_L</div></div><div>WATER CONTENT (%)</div><div>204060</div></div>				
	DCPT											
							280					
							279					
							278					
							277					
							276					
274.8							275					
25.6	END OF BOREHOLE AND DCPT AT 25.6m UPON DCPT REFUSAL. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.9m, THEN SAND AND ASPHALT COLD PATCH TO SURFACE.											

RECORD OF BOREHOLE No RC13-04

1 OF 3

METRIC

GWP# 5193-13-00 LOCATION Roy Creek N 5 435 494.9 E 327 311.8 ORIGINATED BY KMY
 HWY 652 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.10.09 - 2013.10.10 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 (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)			
300.3	GROUND SURFACE							20	40	60	80	100					GR	SA	SI	CL
0.0	ASPHALT: (15 mm)		1	SS	16		300													
	SAND, trace gravel, trace silt and clay Compact to Loose Light Brown Moist (FILL)		2	SS	21		299													
			3	SS	6															
298.0							298													
2.3	Silty CLAY, trace organics Firm to Very Soft Dark Brown Moist		4	SS	5															
			5	SS	4		297													
			6	SS	2		296													
								2.0												
			7	SS	1		295													
								1.0												
							294													
			8	SS	WH		293													
	Sand, trace gravel layer																			
			9	SS	WH		292													
							291													

Continued Next Page

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

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No RC13-04

3 OF 3

METRIC

GWP# 5193-13-00 LOCATION Roy Creek N 5 435 494.9 E 327 311.8 ORIGINATED BY KMY
HWY 652 BOREHOLE TYPE NW Casing COMPILED BY AN
DATUM Geodetic DATE 2013.10.09 - 2013.10.10 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 (%)			
	Continued From Previous Page							20 40 60 80 100	20 40 60				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					
276.5							280						
279							279						
278							278						
277							277						
23.8	END OF BOREHOLE AND DCPT AT 23.8m UPON DCPT REFUSAL. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND ASPHALT COLD PATCH TO SURFACE.												

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No RC13-05

2 OF 3

METRIC

GWP# 5193-13-00 LOCATION Roy Creek N 5 435 485.6 E 327 314.1 ORIGINATED BY KMY
 HWY 652 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.10.11 - 2013.10.15 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL LIMIT 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		9	SS	WH			20 40 60 80 100		20 40 60					
	Silty CLAY Very Soft Grey Wet						290								
							+								
								289							
			10	SS	WH							○			
							+								
								288							
			11	SS	WH							— ○			
							+								
								286						○	
							+								
								285							
						13	SS	WH		284					○
							283								
			14	SS	WH		282					— ○			
							281						○		
280.5															
19.8	End of sampling at 19.8m and start of														

Continued Next Page

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

RECORD OF BOREHOLE No RC13-05

3 OF 3

METRIC

GWP# 5193-13-00 LOCATION Roy Creek N 5 435 485.6 E 327 314.1 ORIGINATED BY KMY
HWY 652 BOREHOLE TYPE NW Casing COMPILED BY AN
DATUM Geodetic DATE 2013.10.11 - 2013.10.15 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 DCPT						280 279 278 277	20 40 60 80 100 20 40 60 80 100						
276.5 23.8	END OF BOREHOLE AND DCPT AT 23.8m UPON DCPT REFUSAL. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND COLD PATCH TO SURFACE.													

RECORD OF BOREHOLE No RC13-06

1 OF 3

METRIC

GWP# 5193-13-00 LOCATION Roy Creek N 5 435 481.2 E 327 336.3 ORIGINATED BY KMY
 HWY 652 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2013.10.15 - 2013.10.16 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			SHEAR STRENGTH kPa									WATER CONTENT (%)			
300.3	GROUND SURFACE							20	40	60	80	100					GR	SA	SI	CL
0.0	SAND and GRAVEL Compact Light Brown to Brown Moist (FILL)		1	SS	15		300													
299.5																				
0.8	SAND , trace gravel, trace silt and clay Loose Light Brown Moist (FILL)		2	SS	6		299											3	94	3 (SI+CL)
			3	SS	5		298													Split spoon wet
			4	SS	4															
			5	SS	5		297													
296.5																				
3.8	Silty CLAY Firm to Very Soft Grey Wet		6	SS	4		296											0	0	48 52
								1.0												
			7	SS	WH		295													
								3.0												
							294													
			8	SS	WH		293													
								+												
							292													
			9	SS	WH															
								2.0												
							291													

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity


20
15 10 5 0
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No RC13-06

2 OF 3

METRIC

GWP# 5193-13-00 LOCATION Roy Creek N 5 435 481.2 E 327 336.3 ORIGINATED BY KMY
 HWY 652 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2013.10.15 - 2013.10.16 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 (%)						
								20 40 60 80 100	W _P W W _L							
Continued From Previous Page								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE								
	Silty CLAY , some sand Very Soft Grey Wet		10	SS	WH		290									
								+								
								289								
			11	SS	WH								○			
									+							
								288								
			12	SS	WH				287					┌───┐ ○		0 0 65 35
										+						
								286								
									285							
							+									
							284						○			
								+								
							283									
								+					┌───┐ ○	0 0 23 77		
							282									
							281						○			
								+								
280.5																
19.8	End of sampling at 19.8m and start of															
	Continued Next Page															

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

RECORD OF BOREHOLE No RC13-06

3 OF 3

METRIC

GWP# 5193-13-00 LOCATION Roy Creek N 5 435 481.2 E 327 336.3 ORIGINATED BY KMY
 HWY 652 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2013.10.15 - 2013.10.16 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							
	Continued From Previous Page							20 40 60 80 100	○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						
	DCPT							280							
								279							
								278							
								277							
								276							
275.3 25.0	END OF BOREHOLE AND DCPT AT 25.0m UPON DCPT REFUSAL. BOREHOLE OPEN TO 19.8m, BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.														

RECORD OF BOREHOLE No RC13-07

1 OF 3

METRIC

GWP# 5193-13-00 LOCATION Roy Creek N 5 435 480.3 E 327 340.2 ORIGINATED BY KMY
 HWY 652 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2013.10.16 - 2013.10.16 CHECKED BY LPG

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					
300.3	GROUND SURFACE						○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		
0.0	SAND and GRAVEL , trace silt and clay Dense to Loose Light Brown Moist (FILL)		1	SS	41						w _p w w _L		
			2	SS	32								
			3	SS	10								
298.0													
2.3	PEAT , wood fragments Very Loose Dark Brown Moist		4	SS	2								
297.4													
2.9	CLAY , with sand, some rootlets Firm Grey Wet		5	SS	5								
296.5													
3.8	Silty CLAY Soft Grey Wet		6	SS	3								
			1	TW	PH								
			7	SS	WH								
			2	TW	PH								

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity


20
15 10 5 0
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No RC13-07

2 OF 3

METRIC

GWP# 5193-13-00 LOCATION Roy Creek N 5 435 480.3 E 327 340.2 ORIGINATED BY KMY
 HWY 652 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2013.10.16 - 2013.10.16 CHECKED BY LPG

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		W P		W		W L								
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	WATER CONTENT (%)													
	Continued From Previous Page						20 40 60 80 100	20 40 60 80 100	20 40 60													
283.5 16.8	Silty CLAY Very Soft Grey Wet		8	SS	2		290											2	25	21	52	
									+													
									289													
			9	SS	WH																	
			10	SS	1				287													
							286															
			11	SS	WH																	
							285															
							284															
																			</			

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15 5
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No RC13-07

3 OF 3

METRIC

GWP# 5193-13-00 LOCATION Roy Creek N 5 435 480.3 E 327 340.2 ORIGINATED BY KMY
 HWY 652 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2013.10.16 - 2013.10.16 CHECKED BY LPG

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													
274.1														
26.2	END OF BOREHOLE AND DCPT AT 26.2m UPON DCPT REFUSAL. BOREHOLE OPEN TO 16.7m UPON COMPLETION AND WATER AT SURFACE. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 5.8m, SAND FROM 5.8m TO SURFACE.													

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

RECORD OF BOREHOLE No RC13-08

1 OF 1

METRIC

GWP# 5193-13-00 LOCATION Roy Creek N 5 435 475.9 E 327 317.3 ORIGINATED BY KMY
 HWY 652 BOREHOLE TYPE NW Casing with Tripod COMPILED BY AN
 DATUM Geodetic DATE 2013.10.06 - 2013.10.06 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 (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
298.4	GROUND SURFACE							20 40 60 80 100							GR SA SI CL
0.0	Silty CLAY Stiff to Very Soft Grey Wet		1	SS	3		298						163		Split spoon wet
			2	SS	2		297								
	Stiff		3	SS	11										
							296	6.0 +							
			4	SS	2		295								
								6.0 +							
							294								
			5	SS	2										
							293	1.0 +							
			6	SS	3		292								
291.4															
7.0	END OF BOREHOLE AT 7.0m. BOREHOLE CAVED TO 6.1m UPON COMPLETION. 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 0.1 298.3 Nov. 7/13 0.1 298.3														

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

RECORD OF BOREHOLE No RC13-09

1 OF 1

METRIC

GWP# 5193-13-00 LOCATION Roy Creek N 5 435 474.2 E 327 336.0 ORIGINATED BY KMY
 HWY 652 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.10.07 - 2013.10.07 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							
								○ UNCONFINED + FIELD VANE							
								● QUICK TRIAXIAL × LAB VANE							
						20	40	60	80	100	PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L		
298.2	GROUND SURFACE														
0.0	Silty SAND , with organics Loose Grey Brown Saturated		1	SS	4										
297.4															
0.8	Silty CLAY , some sand, trace rootlets Very Stiff to Very Soft Grey Wet		2	SS	11										Split spoon wet
															0 13 39 48
			3	SS	16										
	Sand layer		4	SS	3										0 9 45 46
			5	SS	4										
	Sand, trace gravel layer		6	SS	4										4 22 36 38
291.1															
7.1	END OF BOREHOLE AT 7.1m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.														

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

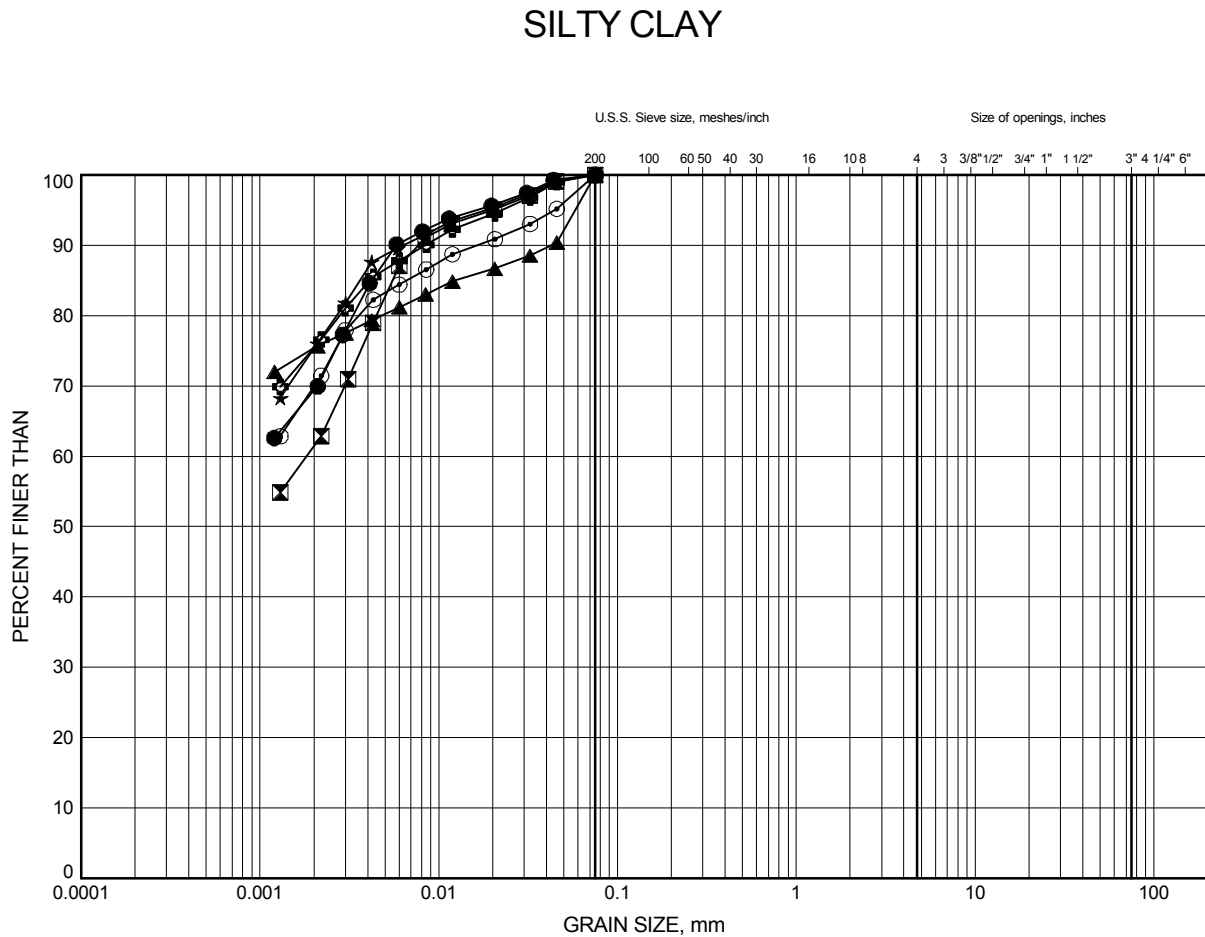
Appendix B

Laboratory Test Results

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B1



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	RC13-03	16.15	284.25
⊠	RC13-04	3.35	296.95
▲	RC13-04	14.63	285.67
★	RC13-05	3.35	296.95
⊙	RC13-05	13.11	287.19
⊕	RC13-05	17.68	282.62

Date December 2013

GWP# 5193-13-00



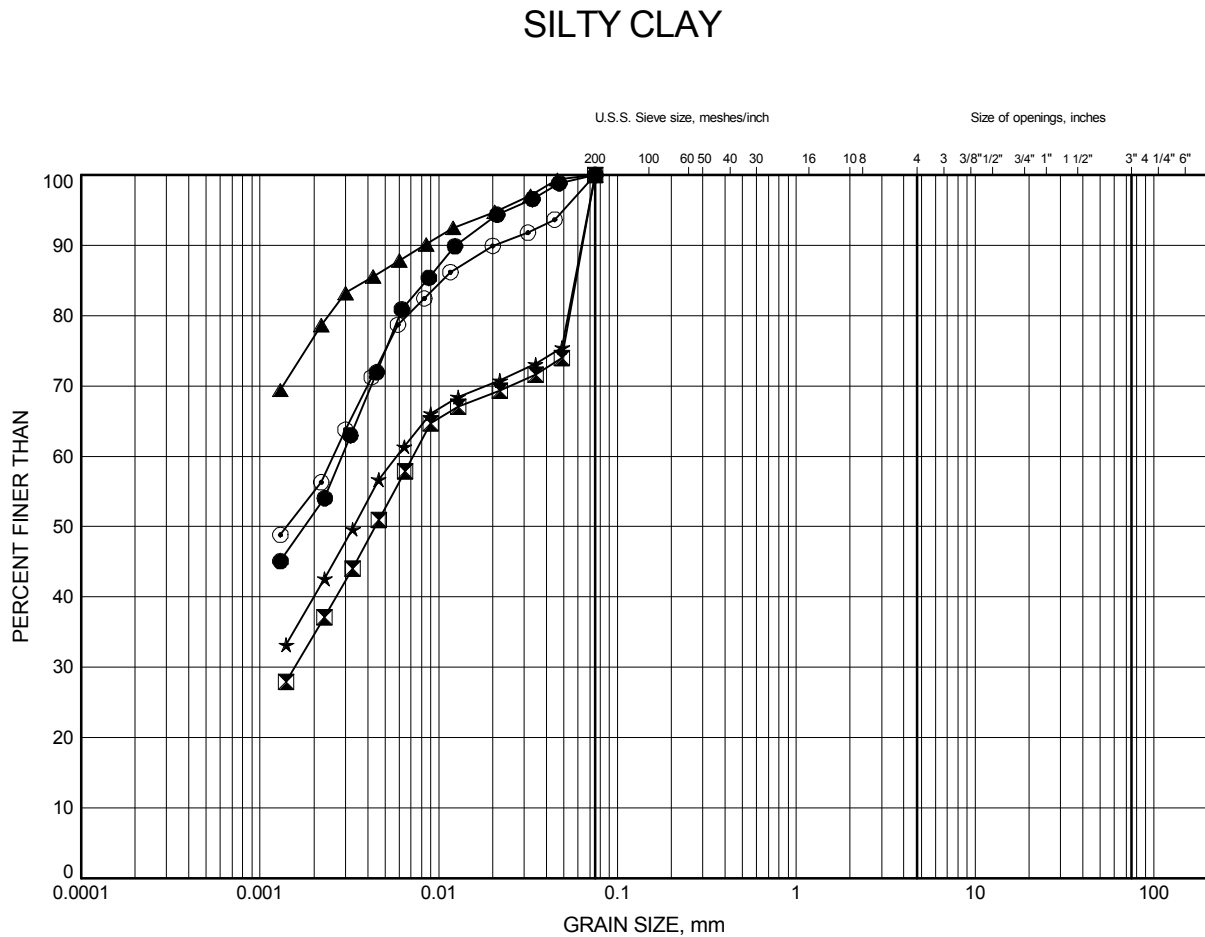
Prep'd AN

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)
●	RC13-06	4.11	296.19
⊠	RC13-06	13.11	287.19
▲	RC13-06	17.68	282.62
★	RC13-07	14.63	285.67
⊙	RC13-08	3.35	295.05

Date December 2013

GWP# 5193-13-00



Prep'd AN

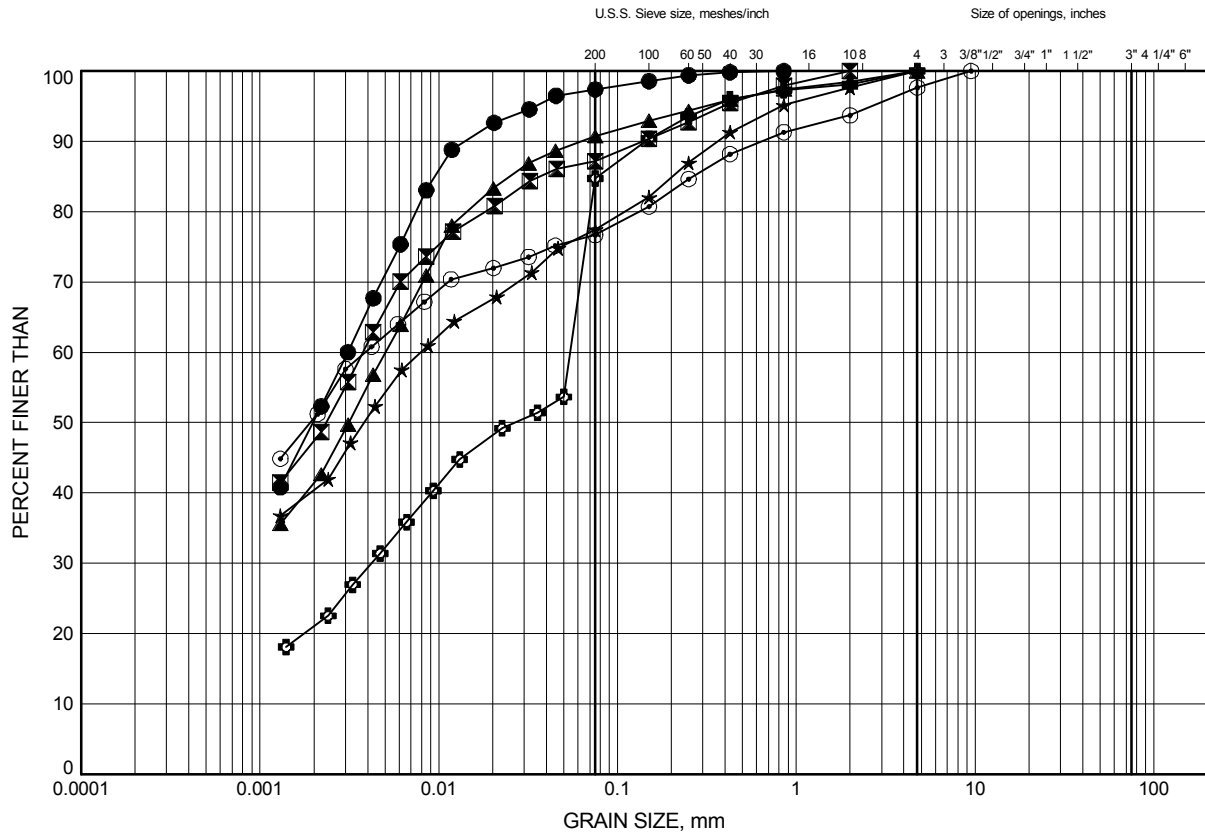
Chkd. LPG

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B3

SILTY CLAY, With Sand Layers



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	RC13-01	0.57	297.73
⊠	RC13-01	6.40	291.90
▲	RC13-02	5.49	293.21
★	RC13-03	8.53	291.87
⊙	RC13-04	7.01	293.29
⊕	RC13-05	7.16	293.14

Date December 2013

GWP# 5193-13-00



Prep'd AN

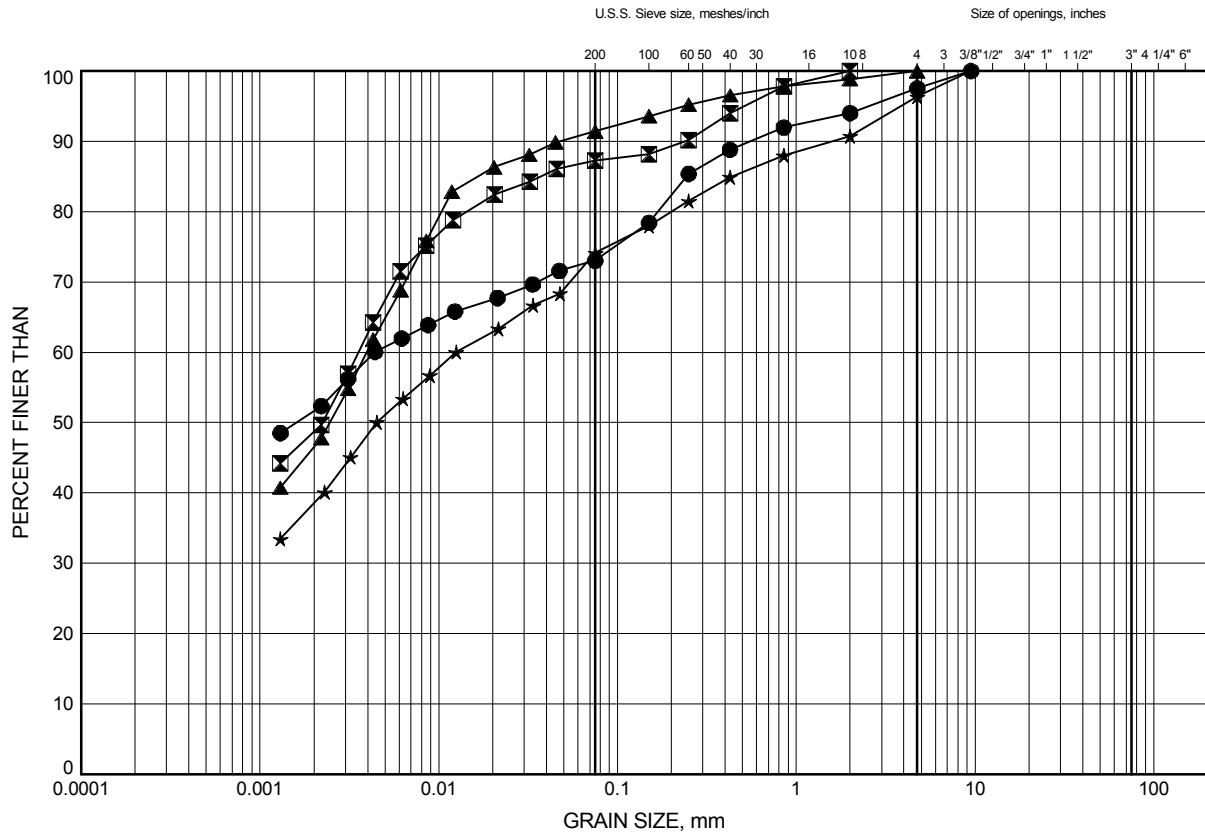
Chkd. LPG

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B4

SILTY CLAY, With Sand Layers



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	RC13-07	10.21	290.09
⊠	RC13-09	1.07	297.13
▲	RC13-09	3.35	294.85
★	RC13-09	6.40	291.80

Date December 2013

GWP# 5193-13-00



Prep'd AN

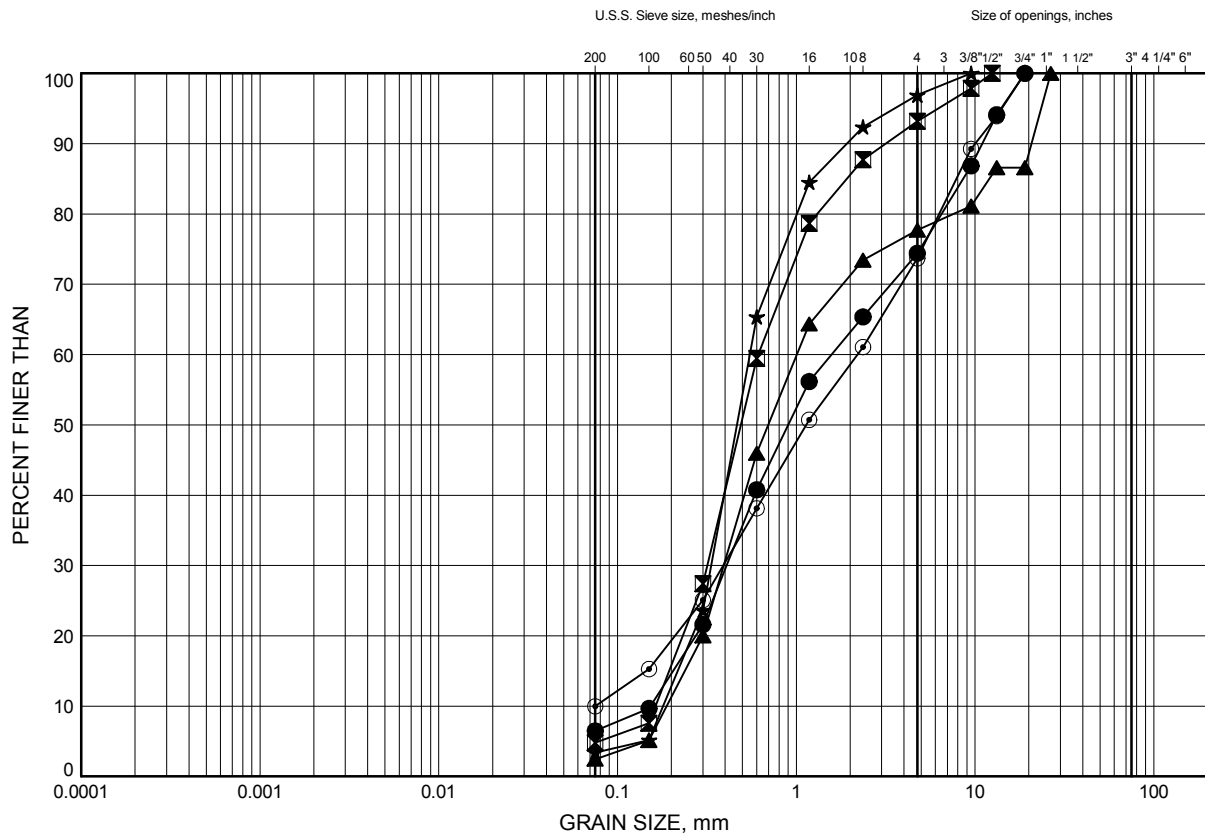
Chkd. LPG

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B5

SAND & GRAVEL FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	RC13-03	0.13	300.27
⊠	RC13-04	1.83	298.47
▲	RC13-05	1.07	299.23
★	RC13-06	1.07	299.23
⊙	RC13-07	0.30	300.00

Date December 2013

GWP# 5193-13-00



Prep'd AN

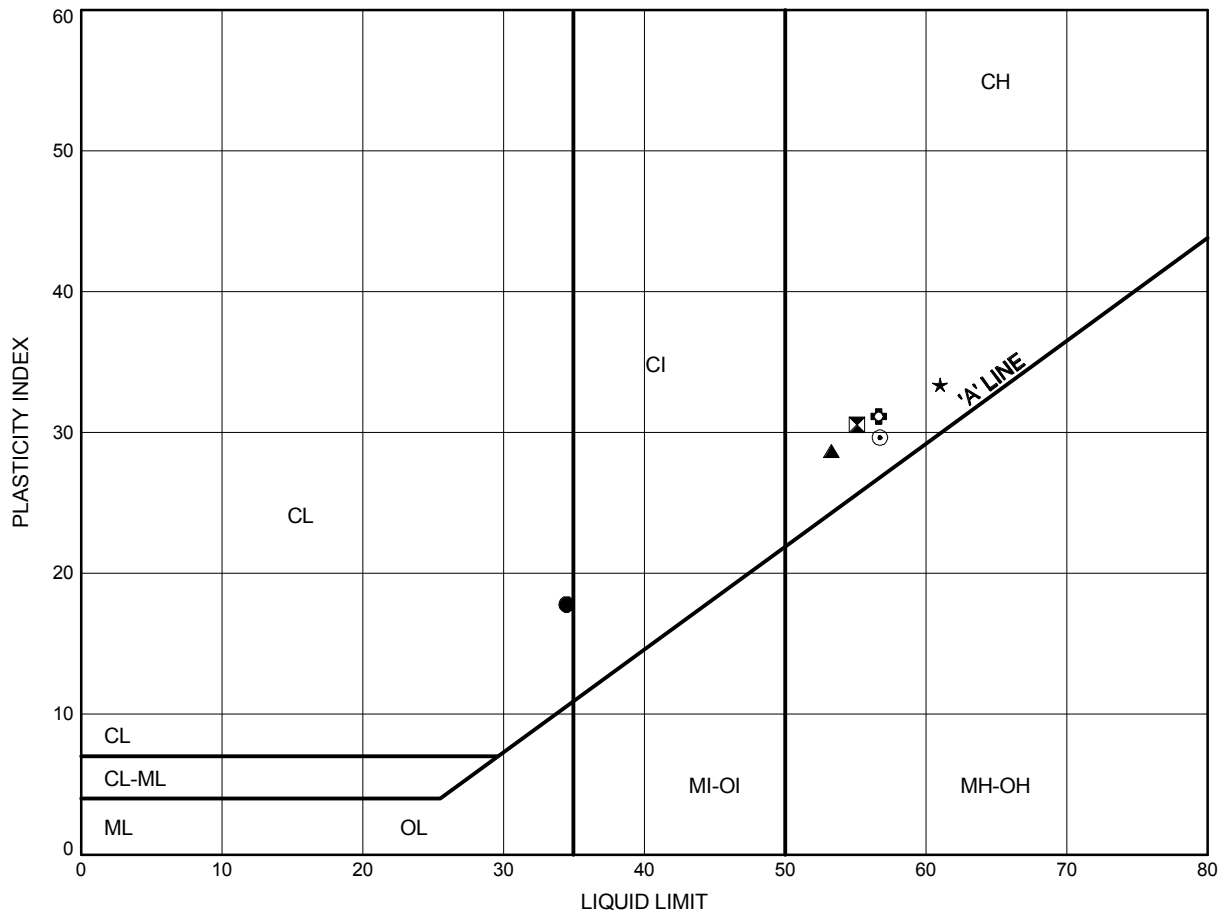
Chkd. LPG

Hwys 11, 583, 652 Culverts - Foundations

ATTERBERG LIMITS TEST RESULTS

FIGURE B6

SILTY CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	RC13-03	8.53	291.87
⊠	RC13-03	16.15	284.25
▲	RC13-04	3.35	296.95
★	RC13-04	14.63	285.67
⊙	RC13-05	13.11	287.19
⊕	RC13-05	17.68	282.62

Date December 2013

GWP# 5193-13-00



Prep'd AN

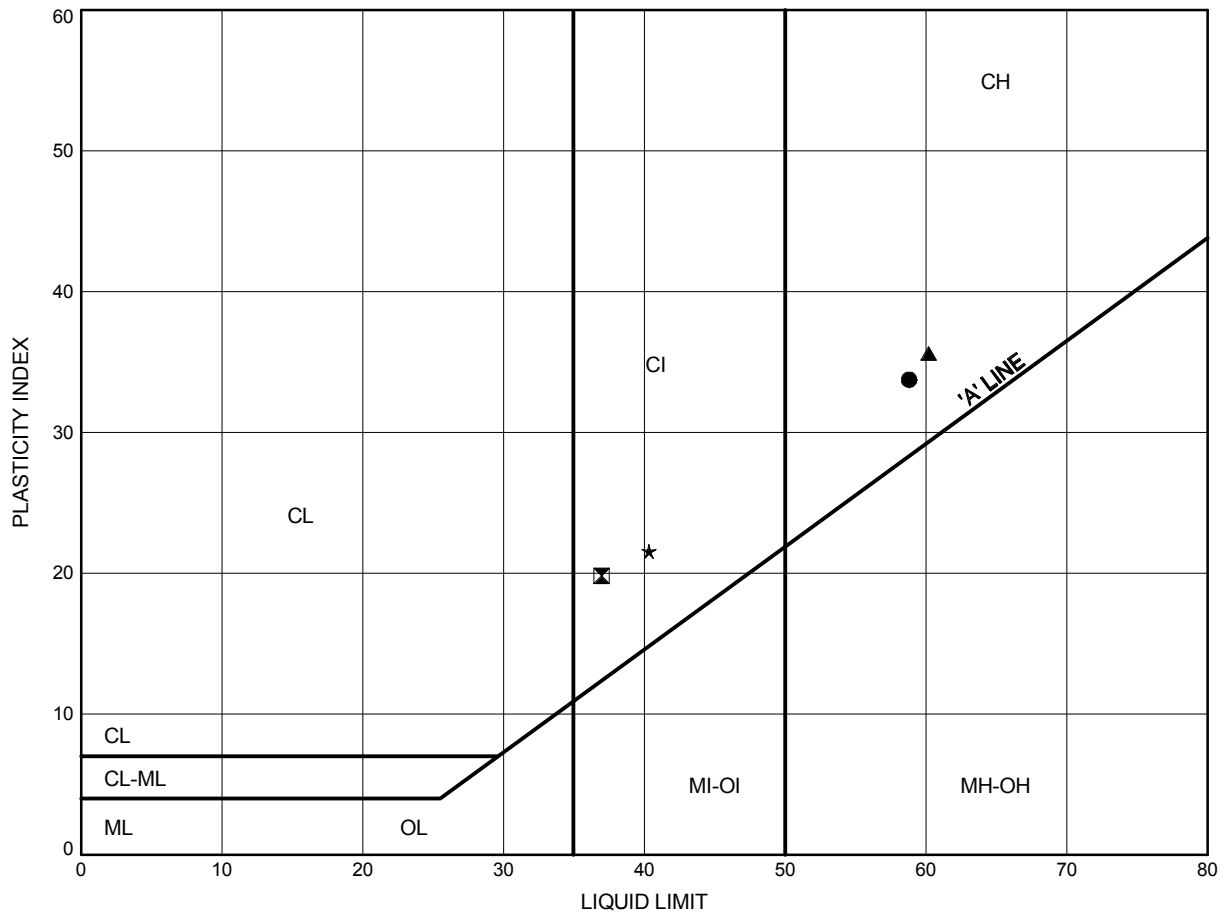
Chkd. LPG

Hwys 11, 583, 652 Culverts - Foundations

ATTERBERG LIMITS TEST RESULTS

FIGURE B7

SILTY CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	RC13-06	4.11	296.19
⊠	RC13-06	13.11	287.19
▲	RC13-06	17.68	282.62
★	RC13-08	3.35	295.05

Date December 2013

GWP# 5193-13-00



Prep'd AN

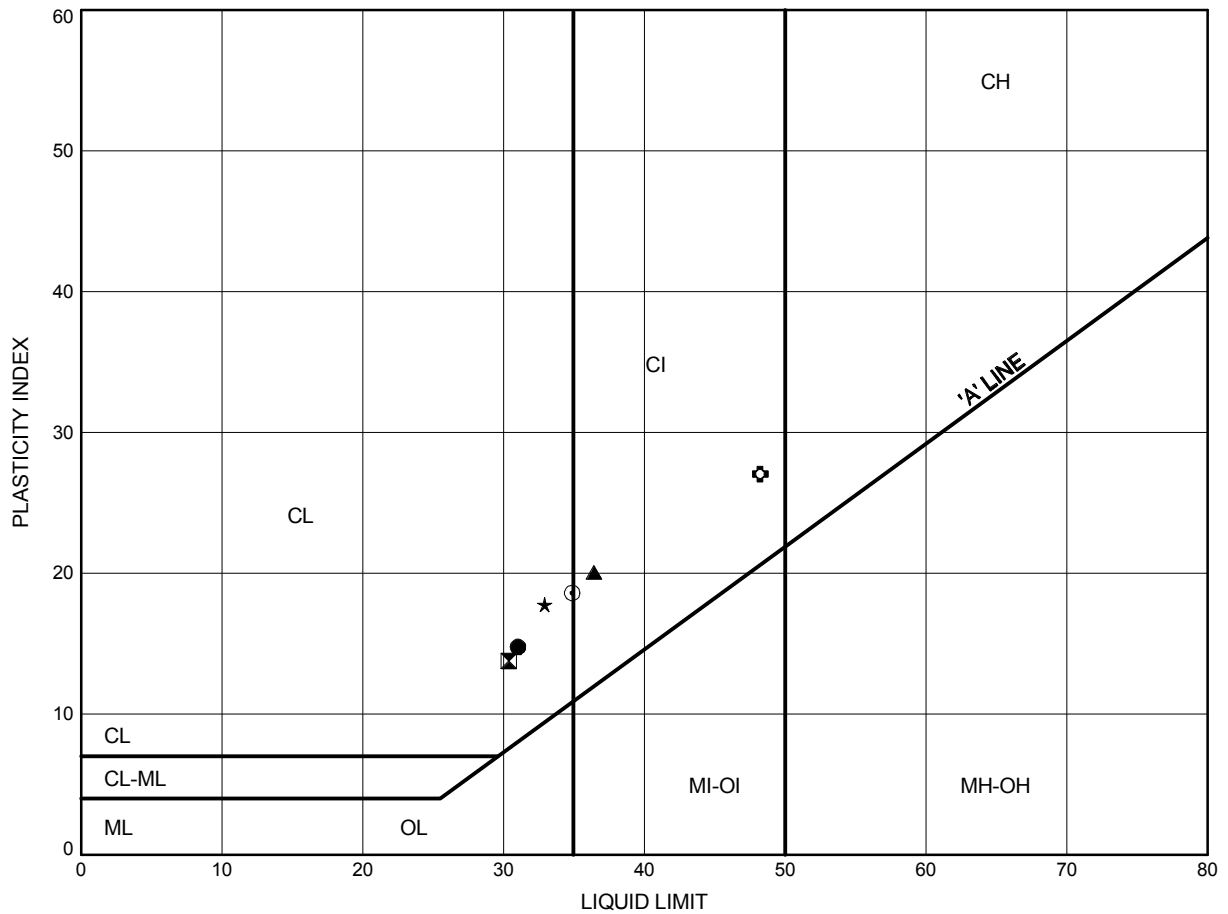
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Hwys 11, 583, 652 Culverts - Foundations

ATTERBERG LIMITS TEST RESULTS

FIGURE B8

SILTY CLAY, With Sand Layers



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	RC13-01	6.40	291.90
⊠	RC13-02	5.49	293.21
▲	RC13-04	7.01	293.29
★	RC13-05	7.16	293.14
⊙	RC13-07	10.21	290.09
⊕	RC13-09	1.07	297.13

Date December 2013
GWP# 5193-13-00



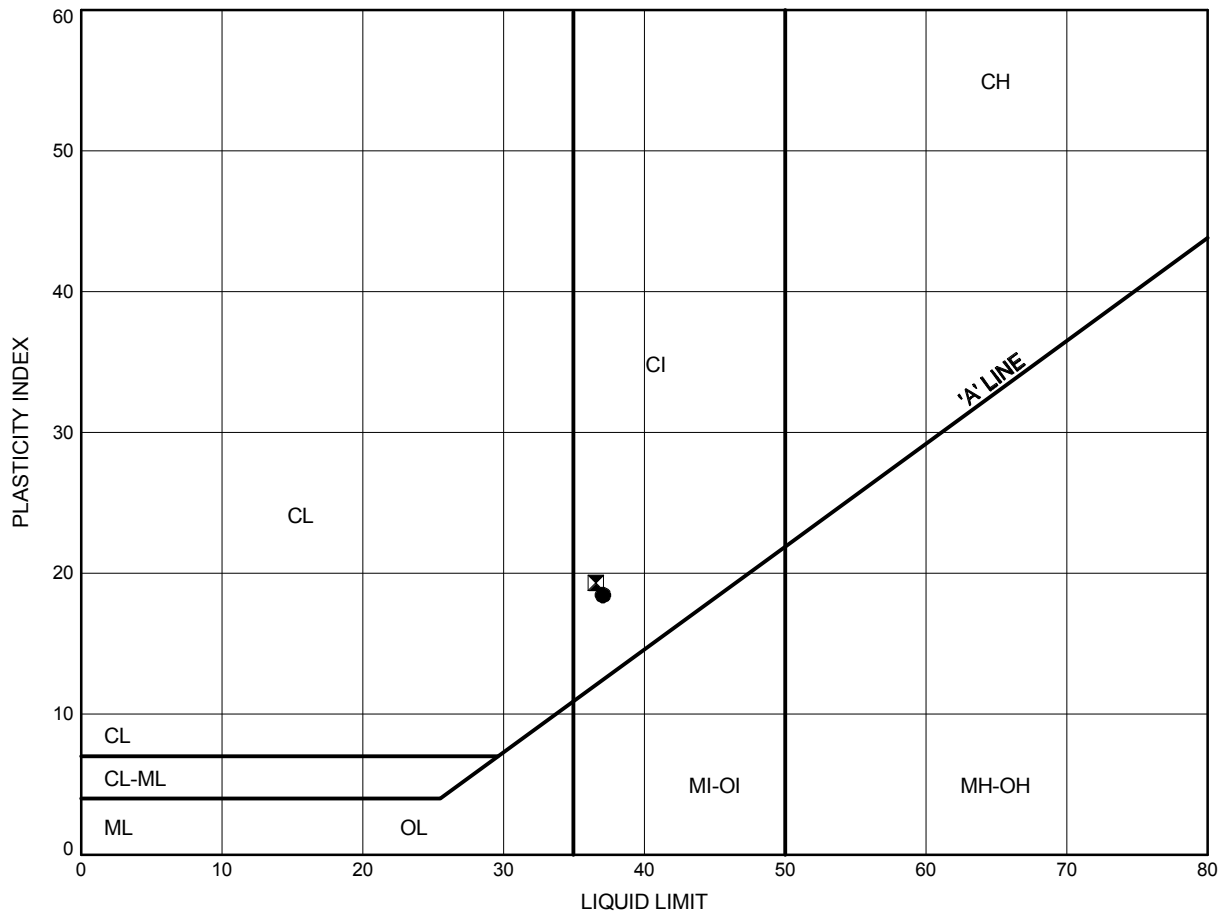
Prep'd AN
Chkd. LPG

Hwys 11, 583, 652 Culverts - Foundations

ATTERBERG LIMITS TEST RESULTS

FIGURE B9

SILTY CLAY, With Sand Layers



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	RC13-09	3.35	294.85
⊠	RC13-09	6.40	291.80

Date December 2013

GWP# 5193-13-00

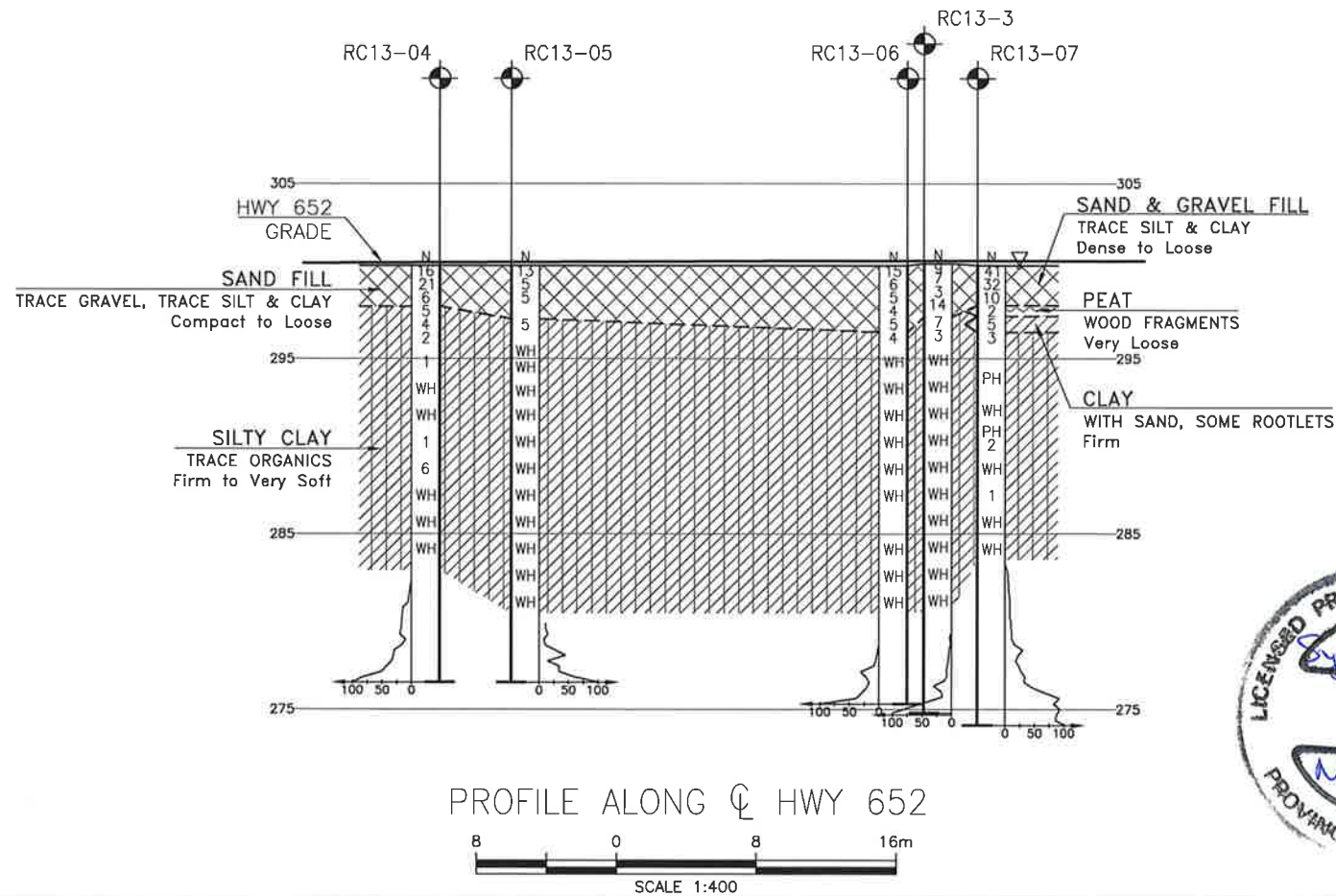
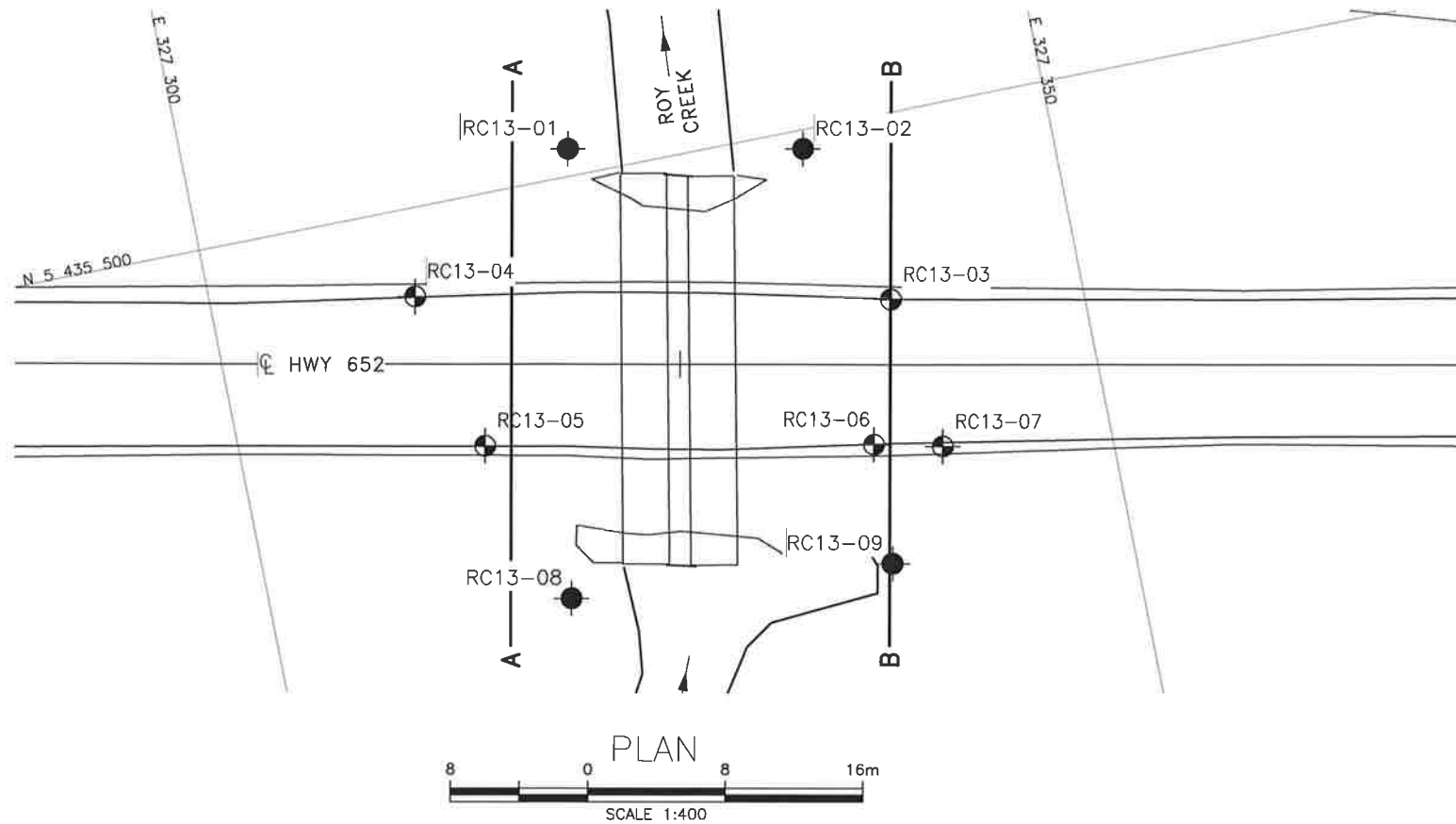


Prep'd AN

Chkd. LPG

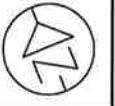
Appendix C

Borehole Locations and Soil Strata Drawings



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

CONT No
GWP No 5193-13-00



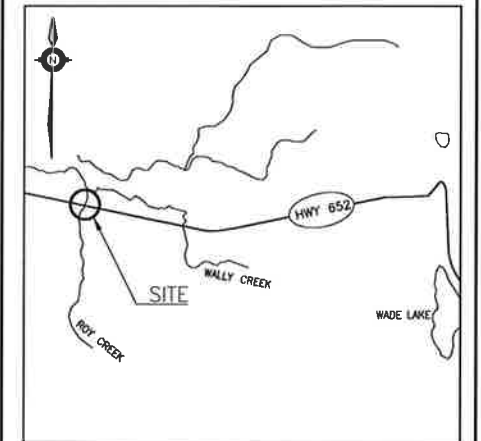
HIGHWAY 652
ROY CREEK
CULVERT REPLACEMENT I
BOREHOLE LOCATIONS AND SOIL STRATA

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
W	Water Level
W	Head Artesian Water
P	Piezometer
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
RC13-01	298.3	5 435 501.6	327 322.2
RC13-02	298.7	5 435 498.9	327 335.6
RC13-03	300.4	5 435 489.3	327 338.9
RC13-04	300.3	5 435 494.9	327 311.8
RC13-05	300.3	5 435 485.6	327 314.1
RC13-06	300.3	5 435 481.2	327 336.3
RC13-07	300.3	5 435 480.3	327 340.2
RC13-08	298.4	5 435 475.9	327 317.3
RC13-09	298.2	5 435 474.2	327 336.0

-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-58



REVISIONS	DATE	BY	DESCRIPTION
DESIGN	SKP	CHK	SKP
DRAWN	AN	CHK	AEG
DATE	NOV 2014		
FILENAME	H:\Drawing\19\408\19\408-13-00-09-BoreholePlan&Profile(RoyCreek).dwg		
PLTNAME	1/7/2015 11:55 AM		

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

CONT No
GWP No 5193-13-00

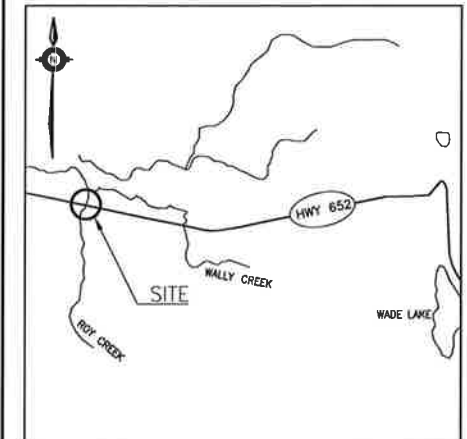
HIGHWAY 652
ROY CREEK
CULVERT REPLACEMENT II
BOREHOLE LOCATIONS AND SOIL STRATA

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

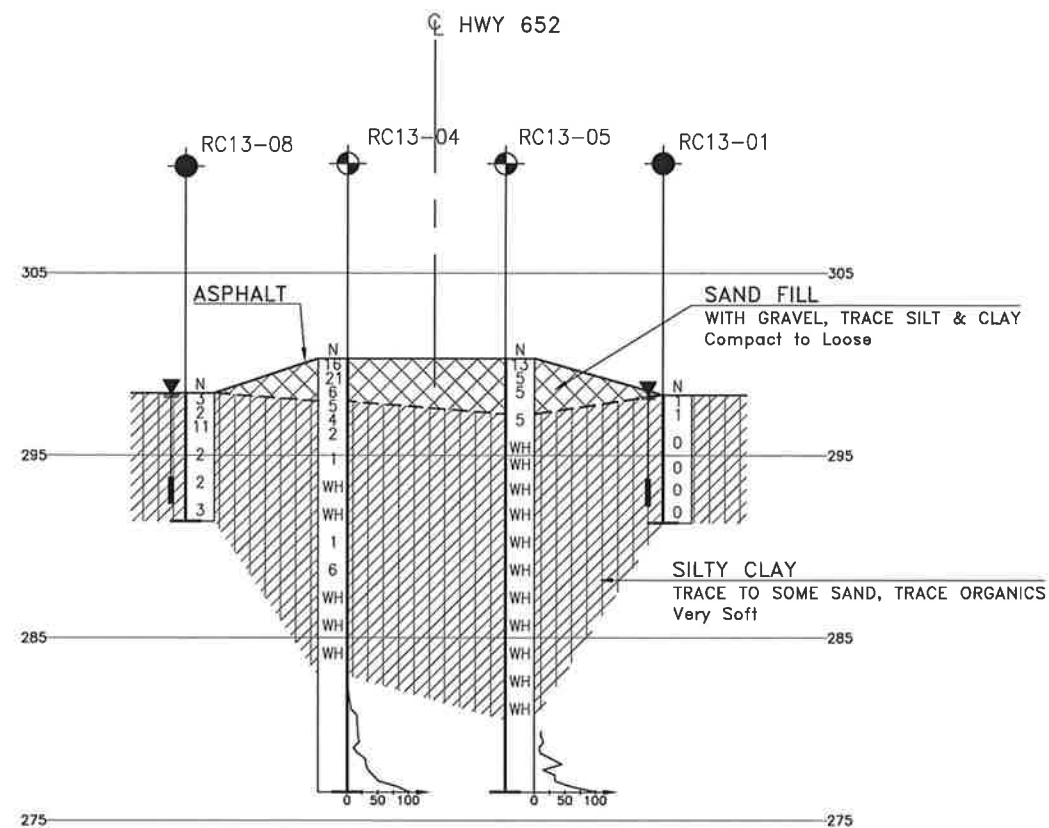
NO	ELEVATION	NORTHING	EASTING
RC13-01	298.3	5 435 501.6	327 322.2
RC13-02	298.7	5 435 498.9	327 335.6
RC13-03	300.4	5 435 489.3	327 338.9
RC13-04	300.3	5 435 494.9	327 311.8
RC13-05	300.3	5 435 485.6	327 314.1
RC13-06	300.3	5 435 481.2	327 336.3
RC13-07	300.3	5 435 480.3	327 340.2
RC13-08	298.4	5 435 475.9	327 317.3
RC13-09	298.2	5 435 474.2	327 336.0

-NOTES-

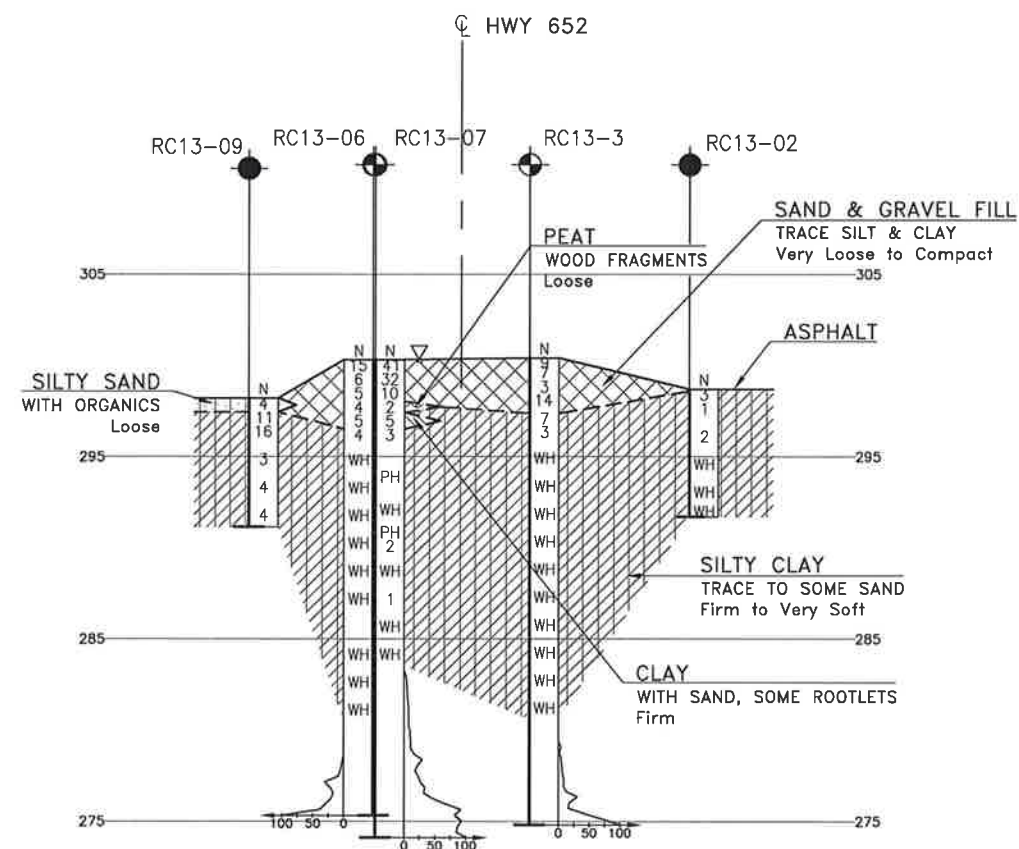
- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCRES No. 42H-58

DESIGN	SKP	CHK	SKP	CODE	LOAD	DATE	NOV 2014
DRAWN	AN	CHK	AEG	SITE	39E-221C(STRUCT)	DWG	3



SECTION ALONG A-A



SECTION ALONG B-B



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

Roy Creek Culvert Replacement
Highway 652



Photo 1: Roy Creek Embankment

Appendix F

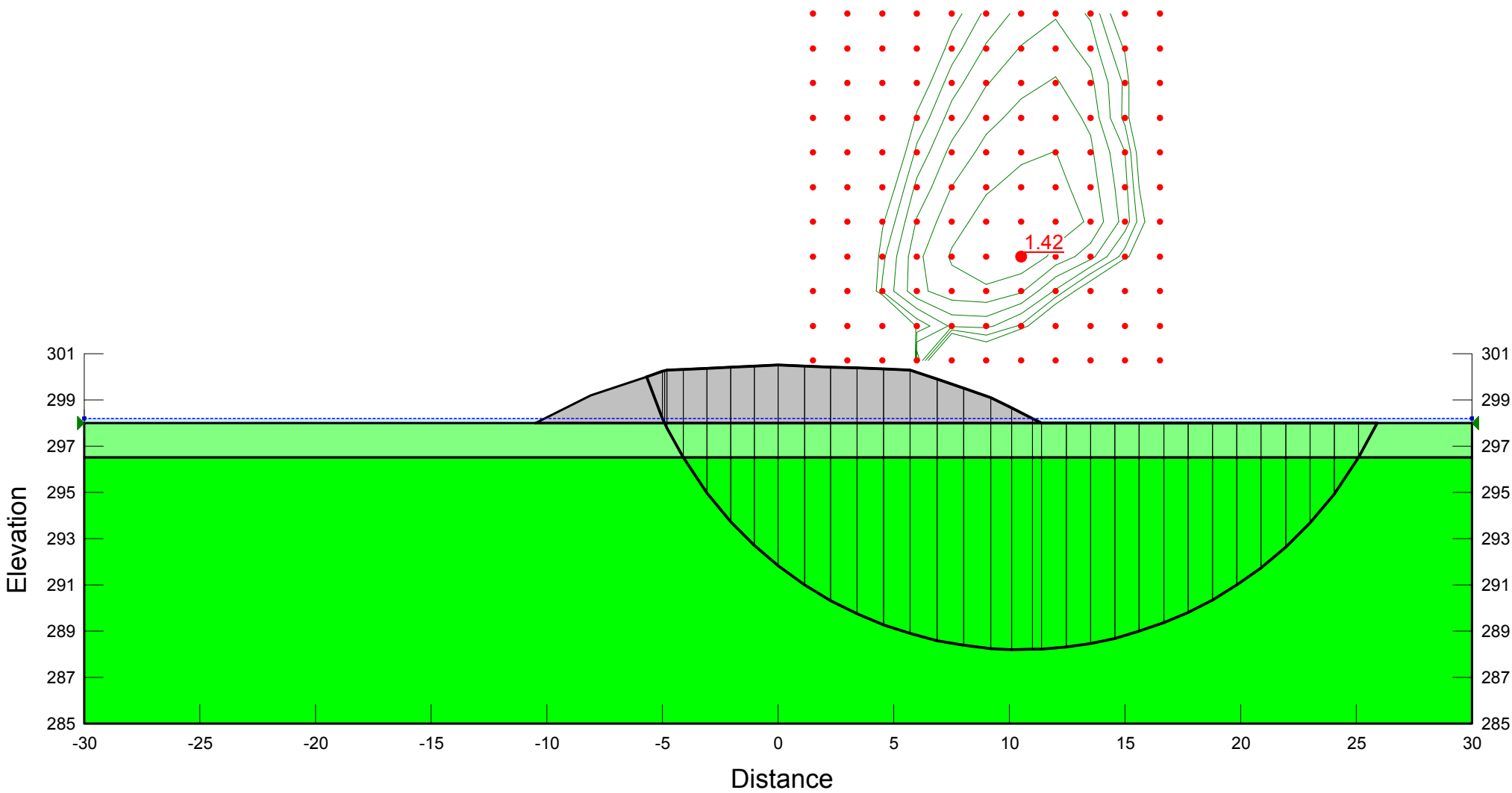
Selected Stability Analysis Results

19-4406-9

Title: Roy Creek Culvert
Comments: Highway 652, Township of Fox, Cochrane, Ontario
Name: Analysis 1

Method: GLE, Half-Sine
Minimum Slip Surface Depth: 1 m
Seismic: 0
Center: (10.5, 305.2) m

Embankment FILL	20 kN/m³	0 kPa	30 °	1
CLAY 1 (TSA)	17 kN/m³	30 kPa	0 °	1
CLAY 2 (TSA)	17 kN/m³	10 kPa	0 °	1

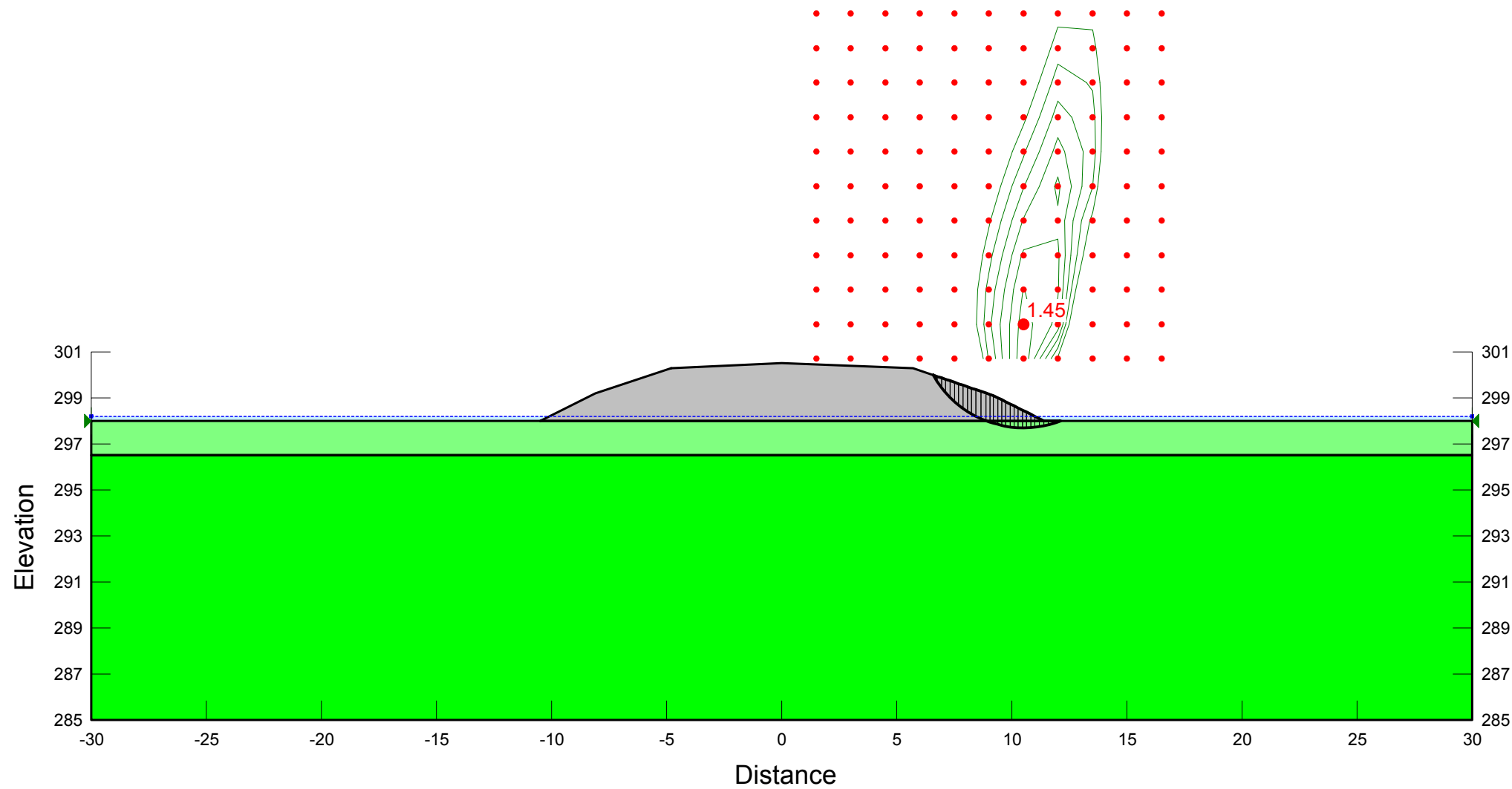


Figure

Title: Roy Creek Culvert
Comments: Highway 652, Township of Fox, Cochrane, Ontario
Name: Analysis 2

Method: GLE, Half-Sine
Minimum Slip Surface Depth: 1 m
Seismic: 0
Center: (10.5, 302.2) m

Embankment FILL	20 kN/m ³	0 kPa	30 °	1
CLAY 1 (ESA)	17 kN/m ³	0 kPa	29 °	1
CLAY 2 (ESA)	17 kN/m ³	0 kPa	26 °	1



Figure