FOUNDATION INVESTIGATION AND DESIGN REPORT
CULVERT REPLACEMENT AT BRADBURN CREEK
SITE NO. 39W-232
HIGHWAY 11
WEST OF HEARST, ONTARIO
G.W.P. No. 5194-13-00

GEOCRES Number: 42G-53

Report to

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual data obtained from a foundation investigation conducted by Thurber Engineering Ltd. (Thurber) at the twin culverts carrying Bradburn Creek under Highway 11, located in the Township of Hanlan, West of Hearst, Ontario.

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

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

2 SITE DESCRIPTION

The culvert site is located on Highway 11 in the Township of Hanlan, approximately 15.8 kilometres west of Highway 583 at Hearst, Ontario. The culvert allows Bradburn Creek to flow in a generally north-south orientation under Highway 11.

The existing structure, constructed in 1956, consists of twin timber box culverts each measuring 2.2 m wide by 1.8 m high by 18.5 m long. It is understood that the structure is showing signs of continuing movement and settlement, and there are concerns about its stability. The grade of the existing Highway 11 in the vicinity of the culvert is at approximate Elevation 242.8 m resulting in an embankment height above the culvert in the order of 1.5 to 2 m.

The site is located in a rural area with swamps, creeks and other watercourses nearby. The immediate surroundings of the culvert site are vegetated with grass, low shrubs, bushes and patches of trees. There is no visible bedrock outcrop. Local topography is typically flat with some low rolling hills at a distance. This site is adjacent to a turnaround point which provides access to a hiking path in the woods.

Based on published geological information, the general area of the project is covered by glacio-lacustrine sediments of clays and silts laid down by the Glacial Lake Barlow-Ojibway. These deposits are mostly varved clays, but massive clays are also present in some areas. 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 November 4th and 6th, 2013. The program consisted of drilling and sampling 8 boreholes (identified as BC13-01 through BC13-08) to depths ranging from 6.7 m to 15.8 m (elevations 234.6 to 226.8 m). Of the eight boreholes, two were located in the vicinity of the culvert inlet (BC13-01 and 13-02), two were located in the vicinity of the culvert outlet (BC13-07 and 13-08) and the remaining four boreholes (BC13-03 through 13-06) were located at the highway embankment elevation. The Record of Borehole sheets are included in Appendix A.

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

A truck mounted drill rig was used to drill and sample the four boreholes advanced from the highway elevation and a track mounted drill rig was used to drill and sample the remaining four boreholes located in the vicinity of the culvert inlet and outlet. Hollow stem augers and NW casing were used to advance the boreholes until the target depth was reached. Soil samples were obtained at select intervals using a 50 mm diameter split spoon sampler in conjunction with Standard Penetration Testing (SPT).

The drilling and sampling operations were supervised on a full time basis by an experienced member of Thurber's technical staff. The recovered soil samples were logged in the field and processed for transportation to Thurber's geotechnical laboratory in Oakville, Ontario for further examinations and testing.

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	Piezometer Tip Position		Borehole Completion and Piezometer Installation Details
	Depth (m)	Elev. (m)	
BC13-01	6.1	234.7	Sand filter from 6.7 to 4.0 m, bentonite holeplug to surface
BC13-02	None Installed		Borehole backfilled with bentonite holeplug to 3.0 m, then sand to surface
BC13-03	None Installed		Borehole backfilled with bentonite holeplug to 50 mm, then sand to surface
BC13-04	None Installed		Borehole backfilled with bentonite holeplug to 100 mm, then sand to surface
BC13-05	None Installed		Borehole backfilled with bentonite holeplug to 100 mm, then sand to surface
BC13-06	None Installed		Borehole backfilled with bentonite holeplug to 50 mm, then sand and gravel to surface
BC13-07	None Installed		Borehole backfilled with sand to 3.9 m, bentonite holeplug to 0.9 m and cuttings to surface
BC13-08	6.1	235.1	Sand filter from 6.7 to 4.3 m, bentonite holeplug to surface

4 LABORATORY TESTING

All recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected soil samples were subjected to grain size distribution analyses (sieve and hydrometer) and plasticity testing (Atterberg Limits). The results of this laboratory testing program are shown on the Record of Borehole sheets in Appendix A and on the figures in Appendix B.

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

5 DESCRIPTION OF SUBSURFACE CONDITIONS

5.1 General

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

In general, the subsurface conditions encountered in the boreholes consist of embankment fill, for boreholes drilled from the highway platform, or a surficial layer of peat or topsoil, for boreholes drilled beyond the toes of the embankment overlying a deposit of silty clay which is underlain by a layer of silt with some sand. These layers are underlain by a deposit of dense to very dense sandy silt till. More detailed descriptions of the individual stratum encountered within the boreholes are presented below.

5.2 Peat and Topsoil

Peat was encountered at ground surface in Borehole BC13-08 to 1.4 m depth (Elevation 239.7m). This amorphous peat was dark brown in colour, clayey and contains some sand with rootlets and twigs. SPT N-values of 6 and 3 blows per 0.3 m penetration indicated a firm to soft consistency. Measured moisture contents were 17% near the surface and 165% at about 1 m depth. The high value is typically indicative of the organic content.

Peat inclusions of about 0.3 m thick were encountered within the fill at 0.9 to 1 m depth in Boreholes BC13-03 and 13-04. The samples are silty and contained trace clay with wood fibres and trace rootlets. SPT N-values indicates that the peat was in a loose state. Measured moisture contents were in the order of 35% to 40%.

Topsoil of 75 to 100 mm in thickness was encountered surficially in Boreholes BC13-01, 13-02 and 13-07.

The thicknesses of peat and topsoil may vary between and beyond the borehole locations and the limited data is not intended for the purpose of estimating quantities.

5.3 Embankment Fill

Embankment fill was encountered at ground surface in Boreholes BC13-03 through 13-06. The upper portion of the fill (pavement granulars) typically consists of brown to dark brown gravelly sand to sand, some gravel, trace silt and trace clay. Underlying the gravelly sand to sand fill in Borehole BC13-05 and 13-06, and below an interlayer of peat in Boreholes BC13-03 and 13-04, was a layer of brown silt, clayey silt to silty clay fill, trace to some sand and trace gravel. Below the silt fill in Borehole BC13-06 was a localized layer of brown sandy gravel fill with trace silt. Where encountered, the embankment fill extended to depths of 2.3 to 3.0 m (Elevations 240.3 to 239.7 m)

SPT N-values measured in the upper gravelly sand to sand fill typically ranged from 25 to 29 blows per 0.3 m of penetration indicating a compact state. An N-value of 7 blows per 0.3 m of penetration encountered in the underlying sandy gravel fill in Borehole 13-06 indicated a loose state. The moisture contents of the recovered cohesionless fill samples ranged from 5 to 8%.

SPT N-values measured in the silt fill typically ranged from 9 to 11 blows per 0.3 m of penetration indicating loose to compact state. SPT N-values of 5 to 13 blows measured in the clayey silt to silty clay fill indicated a firm to stiff consistency. The moisture contents of the recovered samples of silt, clayey silt to silty clay fill ranged from 12 to 38%.

Four laboratory grain size distribution analyses were performed on samples of the fill. The results of these tests are presented on the corresponding Record of Borehole sheets in Appendix A and the grain size distribution curves are plotted in Figures B1 and B2 of Appendix B. The results are summarized in the following table.

Soil Particles	(%)	(%)
Gravel	26 to 77	0 to 4
Sand	21 to 55	11 to 16
Silt	2 to 19	40
Clay		44 to 45
	Sand/Gravel Fill	Silty Clay Fill

5.4 Silty Clay

A layer of brown silty clay with sand, or trace sand, was encountered below the fill, peat or topsoil in all boreholes. The silty clay ranged from 2.3 to 3.6 m in thickness with an underside depth of 3.7 to 5.6 m (Elevations 237.5 to 236.9 m).

The SPT N-values measured within the silty clay ranged from 1 to 8 blows per 0.3 m of penetration indicating a very soft to firm consistency. An N-Value of 10 blows per 0.3 m of penetration measured within the upper portion of the silty clay in Borehole BC13-06 indicated an occasional stiff zone. Measured moisture contents of the recovered silty clay samples typically ranged from 24% to 67%, with occasional values as high as 97% for a sample containing organics.

Nine laboratory grain size distribution analyses were performed on samples of the silty clay. The results of these tests are presented on the corresponding Record of Borehole sheets in Appendix A and the grain size distribution curves are plotted in Figures B3 and B4 of Appendix B. One set of Atterberg limits tests is plotted on Figure B8. The results are summarized in the following table.

Soil Particles	%
Gravel	0 to 5
Sand	0 to 40
Silt	26 to 70
Clay	28 to 61
Soil Property	**%**
Liquid Limit	21
Plasticity Index	9

The results of the limits testing indicate that the silty clay is of low plasticity with a group symbol of CL to CL-ML.

5.5 Silt

A layer of silt, some clay, trace sand was encountered below the silty clay in all boreholes. The silt ranged from 1.4 to 2.2 m in thickness with an underside depth of 5.6 to 7.8 m (Elevations 235.6 to 234.8 m)

The SPT N-values measured within the silt ranged from 4 to 19 blows per 0.3 m of penetration indicating a loose to compact state. The moisture contents of the recovered samples of silt ranged from 16 to 25%.

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

Soil Particles	(%)
Gravel	0
Sand	0 to 4
Silt	79 to 85
Clay	13 to 17

5.6 Sandy Silt Till

Sandy silt till with some clay to clayey and trace gravel was encountered below the silt layer in all boreholes. The till was brown to grey in colour. The investigated thickness of the sandy silt till ranged from 1.0 to 8.6 m, and all boreholes were terminated in this till at depths of 6.7 to 15.8 m (Elevations 234.1 to 226.8 m).

SPT N-values measured within the sandy silt till ranged from 16 to 79 blows per 0.3 m of penetration to as high as 50 blows for less than 0.3 m penetration, indicating a compact to very dense state. The higher values may be attributed to the presence of cobbles and/or boulders. It is noted that glacial tills inherently contain cobbles and boulders. The moisture contents of the recovered samples of the sandy silt till ranged from 9 to 20%.

Eleven laboratory grain size distribution analyses were performed on the samples of sandy silt till. The results of these tests are presented on the corresponding Record of Borehole sheets in Appendix A and the grain size distribution curves are plotted on Figures B6 and B7 of Appendix B. Results of Atterberg limits tests conducted on three selected samples are plotted on Figure B9 in Appendix B. The results are summarized in the following table.

Soil Particles	(%)
Gravel	0 to 10
Sand	8 to 34
Silt	42 to 65
Clay	10 to 27
Soil Property	**%**
Liquid Limit	18 to 21
Plasticity Index	6 to 8

Results of the three Atterberg Limits tests indicate that the sandy silt till is of low plasticity with a group symbol of CL-ML.

5.7 Groundwater Conditions

Water levels were observed in the open boreholes during and at the completion of drilling. Standpipe piezometers were installed in Boreholes BC13-01 and 13-08 to permit longer term water level monitoring. The water levels observed in the open boreholes and measured in the piezometers are as follows:

Table 5-1 Groundwater Elevations

Borehole	Date of Reading	Water Level Depth (m)	Water Level Elevation (m)	Comments
BC13-01	Nov. 7, 2013	0.5	240.3	Piezometer
BC13-03	Nov. 5, 2013	0.6	242.0	Open Borehole
BC13-04	Nov. 4, 2013	1.3	241.3	Open Borehole
BC13-06	Nov. 6, 2013	0.6	242.0	Open Borehole
BC13-08	Nov. 7, 2013	0.6	240.6	Piezometer

Where surface water is present, the groundwater level should be assumed to coincide with the local surface or creek water level. Local high water levels, spring snowmelt and periods of significant and/or prolonged precipitation events must be taken into consideration.

6 MISCELLANEOUS

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

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

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

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

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. Stephen Peters, P.Eng and Dr. Sydney Pang, P.Eng. The report was reviewed by Mr. Gorman and Dr. P.K. Chatterji, P.Eng, a Designated Principal Contact for MTO Foundations Projects.

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This report presents interpretation of the geotechnical data in the factual report and presents foundation recommendations for the replacement of the existing twin culverts at Bradburn Creek on Highway 11, located approximately 15.8 km west of Highway 583 at Hearst, within the Township of Hanlan, Ontario.

Based on the terms of reference, the existing structures, constructed in 1956, consists of twin timber box culvert with each box measuring 2.2 m wide by 1.8 m high by 18.5 m long. It is understood that the structures are showing signs of continuing movement and settlement, and there are concerns about its stability. The embankment height above the culvert is in the order of 1.5 to 2 m.

The discussions and recommendations presented in this report are based on preliminary 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 site area prior to construction of the culvert and the highway. A selected photograph showing the culvert inlet area is included in Appendix F for reference.

8 CULVERT FOUNDATION

8.1 General

The current project requirements involve replacement of the existing twin culverts with twin concrete box culverts that are to be installed along the same culvert alignments. It is understood that all works can be accommodated within the existing highway platform. Physical dimensions of the proposed twin culverts obtained from Table 3 Summary of Hydraulic Analysis Results – Proposed Conditions provided by URS are presented in Table 8-1.

Table 8-1. Physical Data of Proposed Replacement Culverts

Culvert #	Borehole Numbers	Approx. Invert Elevation (m)		Length (m)	Width (m)	Height (m)
		Inlet	Outlet			
C11	BC13-01/13-02 near inlet/outlet	239.632	239.475	19.52	2.4	1.8
	BC13-03 and 13-06 through highway embankment adjacent to culverts					
	BC13-04 and 13-05 through highway embankment further away from culverts					
	BC13-07/13-08 near inlet/outlet					

Note: All dimensions are preliminary and subject to changes.

8.2 Foundation Alternatives

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

Concrete, Open Footing Culvert

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

Circular Pipes (Concrete, Steel, HDPE)

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

Concrete Box (Closed) Culvert

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

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

8.3 Foundation Design

It is assumed that the replacement culverts will be founded at approximately the same level as the existing base of culverts.

8.3.1 Concrete Box Culverts

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

In order to provide a 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 culvert 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 239.5 m on the undisturbed, firm silty clay deposit. The recommended geotechnical resistances for this founding elevation, under the existing culvert footprints, are as follows:

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

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

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

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 overlying compact silt which is, in turn, underlain by dense to very dense sandy silt till.

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 239.5 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 120 kPa and a geotechnical resistance at SLS of 80 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 0.4 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 239.5 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. It is also understood that the culverts will be replaced along the same alignments as the existing culverts. Taking into consideration the proposed conceptual construction sequence, it is anticipated that the rebound of the subgrade after removal of the existing culverts will be negligible.

It is anticipated that the concrete culverts are slightly heavier than the existing timber boxes. As such, the underlying firm to occasionally soft silty clay would be subjected to additional load resulting in some post construction consolidation settlements. The estimated settlement due to the slightly heavier weight for concrete is in the order of 5 to 10 mm within 10 years. The terms of reference indicates that the existing timber culverts are undergoing settlement, but it is unclear if this is due to foundation compression or structural deterioration.

8.3.4 Subgrade Preparation

Borehole BC13-08 near the inlet/outlet encountered a surficial layer of peat up to 1.4 m depth. The presence of alluvial and organic deposits should be expected in the vicinities of the existing culverts and watercourses.

After removal of the existing culverts and excavation to the design founding elevation, the exposed surface must be inspected to confirm that the subgrade is suitable and uniformly competent. Any remaining fill, topsoil, organics, soft creekbed deposits, soft/loose areas, disturbed soils and any deleterious materials within the culvert replacement footprint must be further sub-excavated to undisturbed, competent native soils. The sub-excavated area should be replaced with well compacted granular fill consisting of OPSS 1010 Granular A or B

Type II material as soon as practical for protecting the subgrade from disturbance during construction.

It is anticipated that excavations for culvert replacement will be kept reasonably dry. In submerged areas, or where surficial ponding water prohibits adequate compaction of new fill, it is recommended that materials that do not require compaction, such as OPSS 1004 (clear crushed stone), be used as backfill to the sub-excavation. This work should be carried out in accordance with OPSS 902.

8.3.5 Frost Depth

The frost penetration depth for this site is 2.6 m.

8.4 Construction Considerations

Staged open cutting is proposed to be implemented to replace the culverts. The main features outlined in this plan 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 diversion of creek flow and surface water
- Creek flow will be maintained through at least one culvert at all times
- Pumping from sumps will be required during construction
- Roadway protection will be required during various stages of construction
- Excavation and removal of the existing culverts, installation of the new culverts and backfilling will be carried out within the protection systems
- All works to be carried out in the dry

Protection systems (temporary shoring) such as the use of interlocking steel sheetpiles will be required. Foundation recommendations for the design of such a system are provided in Section 13. Sump pumping will be required at all locations to maintain reasonably dry excavations. Unwatering methods such as temporary diversion of the creek and surface water using sandbag and/or sheetpile cofferdams may be required.

9 BACKFILL AND LATERAL EARTH PRESSURES

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

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

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

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

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

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

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

Table 9-1. Earth Pressure Coefficients (K)

Wall Condition	**Earth Pressure Coefficient (K)**					
	OPSS Granular A or OPSS Granular B Type II $\phi = 35°$; $\gamma = 22.8$ kN/m^3		OPSS Granular B Type I (modified) $\phi = 32°$; $\gamma = 21.2$ kN/m^3		Embankment Fill $\phi = 30°$; $\gamma = 20.0$ 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)	3.70	-	3.30	-	3.00	-

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

In accordance with Clause 6.9.3 of the CHBDC, a compaction surcharge should be added. The magnitude should be 12 kPa at the top of fill and decreasing to 0 kPa at a depth of 2.0 m for Granular B Type I, or at a depth of 1.7 m for Granular A or Granular B Type II.

10 EMBANKMENT DESIGN AND CONSTRUCTION

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

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

Where applicable, benching the existing slope surface should be carried out as per OPSD 208.010 in order to enhance the keying in of the newly placed fill. Provided that the subgrade is prepared as outlined in Section 8.3.4 and granular fill is placed as recommended in Section 9, it is anticipated that an embankment slope inclination of 2H : 1V, or flatter, should remain stable.

11 EROSION CONTROL

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

Typically, 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 erosion near the inlet area. The clay seal should extend a minimum of 0.3 m above the high water level and laterally for the width of the granular material, and have a minimum thickness of 0.5 m. The material requirements should be in accordance with OPSS 1205. A geosynthetic 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 clay 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 at the inlet and outlet areas are classified as Type 4 soils.

12.2 Excavations

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

Extreme care must be exercised to ensure that excavation and roadway protection installation operations will not result in the collapse of the deteriorated timber culverts. There must also be no stockpiling of materials on top of those culverts.

12.3 Groundwater Control

It is expected that groundwater and surface water will accumulate in the excavations during culvert construction. The groundwater level is expected to be largely governed by the water level in the creek and seasonal weather patterns. The Contractor must make provisions to control any groundwater seepage, surface runoff and ponding by measures including the use of sump pumps, cofferdams, creek diversion and protection systems such as sheetpiled enclosures to maintain dry excavations during the course of construction.

13 ROADWAY PROTECTION DESIGN

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

It is anticipated that the sheetpiles may need to be socketed into the typically dense to very dense sandy silt till to develop the required toe resistance. The designer of the roadway protection system should check whether the penetration depth is sufficiently deep to provide base fixity. Suggested wordings of an NSSP alerting the Contractor of potential obstructions such as cobbles and boulders in the fill and native glacial tills are included in Appendix E. It is anticipated that the shoring system may be stiffened by corner and cross bracings, where applicable. An interlocking sheetpiled wall may be designed using the parameters given below:

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

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

14 CONSTRUCTION CONCERNS

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

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

- Impact of excavation on the existing pavement surface

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

- removal of peat, organics, soft soils and alluvial deposits from the culvert subgrade near creek and stream channels,
- disturbance of the 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

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

THURBER ENGINEERING LTD.

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Appendix A

Record of Borehole Sheets

THURBER

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

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			

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No BC13-01

METRIC

GWP#	5194-13-00	LOCATION	Bradburn Creek N 5 509 647.0 E 313 792.6	ORIGINATED BY	JG
HWY	11	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2013.11.06 - 2013.11.06	CHECKED BY	SKP

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
240.8	GROUND SURFACE
0.0 / 0.1	**TOPSOIL:** (75mm)
	Silty **CLAY**, trace sand, organics Soft to Firm Brown Moist
237.1 / 3.7	**SILT**, some clay, trace sand Compact Brown Moist
235.2 / 5.6	Sandy **SILT**, some clay to clayey, trace gravel Compact to Dense Brown Moist (TILL)
234.1 / 6.7	END OF BOREHOLE AT 6.7m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.

DATE	DEPTH (m)	ELEV. (m)
Nov. 7/13	0.5	240.3

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	1				
2	SS	3	0	0	39	61
3	SS	3				
4	SS	4	0	7	63	30
5	SS	3				
6	SS	10	0	4	79	17
7	SS	14				
8	SS	30				

Elevation scale: 240, 239, 238, 237, 236, 235

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L

WATER CONTENT (%): 20 40 60 (sample 1 plotted at 97)

UNIT WEIGHT γ kN/m³

+³, ×³: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No BC13-02

METRIC

GWP#	5194-13-00	LOCATION	Bradburn Creek N 5 509 643.2 E 313 802.3	ORIGINATED BY	JG
HWY	11	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2013.11.06 - 2013.11.06	CHECKED BY	SKP

ELEV / DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
240.6	GROUND SURFACE					
0.0 / 0.1	**TOPSOIL:** (75mm)					
	Silty **CLAY**, trace to some sand, trace gravel, organics; Soft to Firm; Brown; Moist	1	SS	1		
		2	SS	4		
		2	SS	3		2 15 50 33
		4	SS	2		
		5	SS	3		4 12 56 28
236.9 / 3.7	**SILT**, some clay, trace sand; Loose to Compact; Brown; Moist	6	SS	7		
		7	SS	13		
234.9 / 5.7	Sandy **SILT**, some clay to clayey, trace gravel; Very Dense; Brown; Moist; (TILL)	8	SS	48		6 25 46 23
233.9 / 6.7	END OF BOREHOLE AT 6.7m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 3.0m, THEN SAND TO SURFACE.					

Elevation scale: 240, 239, 238, 237, 236, 235, 234

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE (20 40 60 80 100)

PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³

GROUND WATER CONDITIONS

+³, ×³: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No BC13-03

METRIC

GWP#	5194-13-00	LOCATION	Bradburn Creek N 5 509 642.4 E 313 787.7	ORIGINATED BY	ES
HWY	11	BOREHOLE TYPE	NW/NQ Casing	COMPILED BY	AN
DATUM	Geodetic	DATE	2013.11.05 - 2013.11.05	CHECKED BY	SKP

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
242.6	GROUND SURFACE							
0.0	Gravelly **SAND**, trace silt, trace clay Compact Brown Moist (FILL)	1	SS	25	▽	242	○	26 55 19 (SI+CL)
241.7 / 0.9	**PEAT**, trace clay, trace rootlets, wood fibres Loose Dark Brown Moist	2	SS	7		241	○	
241.4 / 1.2	**SILT**, some clay, trace sand, trace gravel Compact to Loose Brown (FILL) Occasional wood fibres	3	SS	11			○	
		4	SS	9		240	○	
239.7 / 3.0	Silty **CLAY**, trace sand, occasional wood fibres Firm to Soft Grey Moist	5	SS	8		239	○	0 0 45 55
		6	SS	2		238	○	
		7	SS	2			○	
237.0 / 5.6	**SILT**, some clay, trace sand Compact Grey Wet	8	SS	11		237, 236	○	
235.6 / 7.0	Sandy **SILT**, some clay to clayey, trace gravel Dense to Very Dense Grey Moist (TILL)	9	SS	44		235, 234	○ (with plastic/liquid limit range)	2 24 51 23
		10	SS	68		233	○	

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

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

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THURBER

RECORD OF BOREHOLE No BC13-03

METRIC

GWP#	5194-13-00	LOCATION	Bradburn Creek N 5 509 642.4 E 313 787.7	ORIGINATED BY	ES
HWY	11	BOREHOLE TYPE	NW/NQ Casing	COMPILED BY	AN
DATUM	Geodetic	DATE	2013.11.05 - 2013.11.05	CHECKED BY	SKP

Continued From Previous Page

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT kN/m3	GR	SA	SI	CL
	Sandy **SILT**, some clay to clayey, trace gravel Dense to Very Dense Grey Moist (TILL)					232						
		11	SS	72			○ (~5)					
						231						
		12	SS	46		230	○ (~5)		2	30	48	20
						229						
		13	SS	33			○ (~5)					
						228						
227.2	Occasional cobbles	14	SS	121/ 0.200			○ (~5)					
15.4	END OF BOREHOLE AT 16.1m. FREE WATER AT 0.6m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.05m, ASPHALT TO SURFACE.											

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100
PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L
REMARKS & GRAIN SIZE DISTRIBUTION (%)

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

RECORD OF BOREHOLE No BC13-04

METRIC

GWP# 5194-13-00	LOCATION Bradburn Creek N 5 509 636.9 E 313 809.4		ORIGINATED BY ES
HWY 11	BOREHOLE TYPE NW/NQ Coring		COMPILED BY AN
DATUM Geodetic	DATE 2013.11.04 - 2013.11.04		CHECKED BY SKP

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
242.6	GROUND SURFACE
0.0	**SAND**, some gravel to gravelly, trace silt, trace clay Compact Dark Brown to Brown Moist (FILL)
241.7 / 1.0	**PEAT**, silty, trace clay, trace rootlets Loose Dark Brown Moist
241.4 / 1.3	Silty **CLAY**, some sand, trace gravel Firm to Stiff Brown Moist (FILL) Occasional inferred cobbles
239.7 / 3.0	Silty **CLAY**, trace sand Soft to Firm Grey Moist
237.0 / 5.6	**SILT**, some clay, trace sand Compact Grey Moist
235.5 / 7.2	Sandy **SILT**, some clay to clayey, trace gravel Very Dense Grey Moist (TILL)

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	27				
2	SS	8				
3	SS	9				
4	SS	13				
5	SS	3				
6	SS	6	0	0	70	30
1	TW	PH				
7	SS	19				
8	SS	56/ 0.150				
9	SS	50/ 0.075	6	34	42	18

Grain size distribution at approx. elev. 241.3 (between samples 2 and 3): GR 0, SA 16, SI 40, CL 44.

GROUND WATER CONDITIONS: water level symbol at approx. elev. 241.5.

ELEVATION SCALE: 242, 241, 240, 239, 238, 237, 236, 235, 234, 233

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE — 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L

WATER CONTENT (%): 20 40 60

UNIT WEIGHT γ kN/m³

Continued Next Page

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No BC13-04

METRIC

GWP# 5194-13-00 | LOCATION Bradburn Creek N 5 509 636.9 E 313 809.4 | ORIGINATED BY ES

HWY 11 | BOREHOLE TYPE NW/NQ Coring | COMPILED BY AN

DATUM Geodetic | DATE 2013.11.04 - 2013.11.04 | CHECKED BY SKP

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Sandy SILT, some clay to clayey, trace gravel, Very Dense, Grey, Moist (TILL)				232		
		10	SS	75		○	
					231		
		11	SS	79	230	○	
229.4 / 13.3	Compact				229		
		12	SS	16		⊢○┤	3 29 47 21
227.9 / 14.8	Trace Sand, Very Dense				228		
		13	SS	74	227	○	0 8 65 27
226.8 / 15.8	END OF BOREHOLE AT 15.8m. FREE WATER AT 1.3m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND SAND TO 0.1m, SAND AND GRAVEL TO SURFACE.						

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; UNIT WEIGHT γ kN/m³

+3, ×3: Numbers refer to Sensitivity

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

RECORD OF BOREHOLE No BC13-05

METRIC

GWP#	5194-13-00	LOCATION	Bradburn Creek N 5 509 633.2 E 313 774.5	ORIGINATED BY	ES
HWY	11	BOREHOLE TYPE	NW/NQ Coring	COMPILED BY	AN
DATUM	Geodetic	DATE	2013.11.05 -	CHECKED BY	SKP

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%) (approx.)	GR	SA	SI	CL
242.6	GROUND SURFACE									
0.0	**SAND**, some gravel to gravelly, trace silt, Compact, Dark Brown, Moist (FILL)	1	SS	28	242	~7				
241.6 / 1.0	Silty **CLAY**, some sand, trace gravel, trace organics, Firm, Brown, Moist (FILL)	2	SS	12		~24	4	11	40	45
	Trace rootlets	3	SS	5	241	~38				
240.3 / 2.3	Silty **CLAY**, trace sand, trace rootlets, Firm, Brown, Moist	4	SS	6	240	~30				
		5	SS	7	239	~40				
	Occasional wood fibres	6	SS	6		~27 (with Wp–WL range)	0	9	47	44
		7	SS	4	238	~18				
237.0 / 5.6	**SILT**, some clay, trace sand, Compact, Grey, Moist	8	SS	15	237, 236	~24	0	2	85	13
235.4 / 7.2	Sandy **SILT**, some clay to clayey, trace gravel, Dense to Very Dense, Grey, Moist (TILL)	9	SS	31	235	~13 (with Wp–WL range)	10	20	46	24
	Occasional cobbles	10	SS	61/ 0.150	234, 233	~13				

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

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

RECORD OF BOREHOLE No BC13-05

METRIC

GWP# 5194-13-00	LOCATION Bradburn Creek N 5 509 633.2 E 313 774.5		ORIGINATED BY ES
HWY 11	BOREHOLE TYPE NW/NQ Coring		COMPILED BY AN
DATUM Geodetic	DATE 2013.11.05 -		CHECKED BY SKP

Continued From Previous Page

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
	Sandy **SILT**, some clay to clayey, trace gravel Compact to Dense Grey Moist (TILL)				232					
		11	SS	34		○				
					231					
		12	SS	17	230	○				
					229					
		13	SS	17		○	3	29	43	25
					228					
		14	SS	25	227	○				
226.8 15.8	END OF BOREHOLE AT 15.8m.									

Column headings: SOIL PROFILE (ELEV/DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); 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 w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20, 40, 60); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) (GR SA SI CL)

+ 3, × 3 : Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No BC13-06

METRIC

GWP# 5194-13-00	LOCATION Bradburn Creek N 5 509 626.3 E 313 800.0		ORIGINATED BY ES
HWY 11	BOREHOLE TYPE NW/NQ Casing		COMPILED BY AN
DATUM Geodetic	DATE 2013.11.06 - 2013.11.06		CHECKED BY SKP

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
242.6	GROUND SURFACE
0.0	Gravelly **SAND**, trace silt, Compact, Dark Brown to Brown, Moist (FILL)
241.7 / 0.9	Clayey **SILT**, occasional cobbles, Compact, Brown, Moist (FILL)
241.2 / 1.4	Sandy **GRAVEL**, trace silt, occasional cobbles, Loose, Brown, Moist (FILL)
240.3 / 2.3	Silty **CLAY**, trace sand, trace gravel, trace organics, occasional cobble, Firm to Stiff, Brown, Moist
237.0 / 5.6	**SILT**, some clay, trace sand, Compact, Brown, Wet
234.8 / 7.8	Sandy **SILT**, with sand, trace gravel, Very Dense, Grey, Moist (TILL)

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	29	
2	SS	11	
3	SS	7	77 21 2 (SI+CL)
4	SS	10	
5	SS	5	
6	SS	7	0 0 57 43
7	SS	8	
8	SS	16	
9	SS	58	
10	SS	97/0.150	4 32 54 10

GROUND WATER CONDITIONS: water level symbol at approx. elev. 242.2

ELEVATION SCALE: 242, 241, 240, 239, 238, 237, 236, 235, 234, 233

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L

WATER CONTENT (%): 20 40 60

UNIT WEIGHT γ kN/m³

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No BC13-06

METRIC

GWP# 5194-13-00 | LOCATION Bradburn Creek N 5 509 626.3 E 313 800.0 | ORIGINATED BY ES

HWY 11 | BOREHOLE TYPE NW/NQ Casing | COMPILED BY AN

DATUM Geodetic | DATE 2013.11.06 - 2013.11.06 | CHECKED BY SKP

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page						
	Sandy **SILT**, some clay to clayey, trace gravel Very Dense Grey Moist (TILL)				232		
		11	SS	61		○	
					231		
		12	SS	51	230	○	
229.4 13.3	Compact				229		
		13	SS	25		○ (with Wp–WL range)	1 28 48 23
227.8 14.8	Very Dense				228		
226.9		14	SS	52/ 0.150	227	○	
15.7	END OF BOREHOLE AT 15.7m. FREE WATER AT 0.6m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.05m, SAND AND GRAVEL TO SURFACE.						

Column headings also include: STRAT PLOT; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³.

+ 3, × 3: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No BC13-07

METRIC

GWP#	5194-13-00	LOCATION	Bradburn Creek N 5 509 626.0 E 313 784.4	ORIGINATED BY	JG
HWY	11	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2013.11.06 - 2013.11.06	CHECKED BY	SKP

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	NATURAL MOISTURE CONTENT (%) (approx.)	GR	SA	SI	CL
241.3	GROUND SURFACE								
0.0	**TOPSOIL:** (100mm)								
0.1	Silty **CLAY**, with sand, trace gravel Firm Brown Moist	1	SS	4		5	40	26	29
		2	SS	3					
	Trace sand, some organics Soft to Firm	3	SS	3	81				
		4	SS	7		3	8	59	30
		5	SS	5					
237.5 / 3.7	**SILT**, some clay, trace sand Compact to Loose Brown Moist	6	SS	11					
		7	SS	7		0	0	83	17
235.6 / 5.6	Sandy **SILT**, some clay to clayey, trace gravel Very Dense Brown/Grey Moist (TILL)	8	SS	68					
234.6 / 6.7	END OF BOREHOLE AT 6.7m. BOREHOLE BACKFILLED WITH SAND TO 3.9m, BENTONITE TO 0.9m, CUTTINGS TO SURFACE.								

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE (241, 240, 239, 238, 237, 236, 235); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20 40 60); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) (GR SA SI CL)

+³, ×³: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No BC13-08

METRIC

GWP# 5194-13-00	LOCATION Bradburn Creek N 5 509 622.2 E 313 794.1		ORIGINATED BY JG
HWY 11	BOREHOLE TYPE Solid Stem Augers		COMPILED BY AN
DATUM Geodetic	DATE 2013.11.04 - 2013.11.04		CHECKED BY SKP

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	GR	SA	SI	CL
241.2	GROUND SURFACE								
0.0	**PEAT** (amorphous), silty clay, trace sand, some organics Firm to Soft Dark Brown Moist to Wet	1	SS	6					
		2	SS	3	165				
239.7 / 1.4	Silty **CLAY**, trace sand, trace gravel, trace organics Firm Brown Moist	3	SS	4		0	5	42	53
		4	SS	6					
		5	SS	4					
237.4 / 3.7	**SILT**, some clay, trace sand Loose Brown Moist	6	SS	4		0	0	85	15
		7	SS	7					
235.5 / 5.6	Sandy **SILT**, some clay to clayey, trace gravel Very Dense Brown Moist (TILL)	8	SS	59		4	23	52	21
234.5 / 6.7	END OF BOREHOLE AT 6.7m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.								

Column headings: SOIL PROFILE; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (241, 240, 239, 238, 237, 236, 235); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L, WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m^3; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

DATE	DEPTH (m)	ELEV. (m)
Nov. 7/13	0.6	240.6

+ 3, × 3: Numbers refer to Sensitivity

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

Appendix B

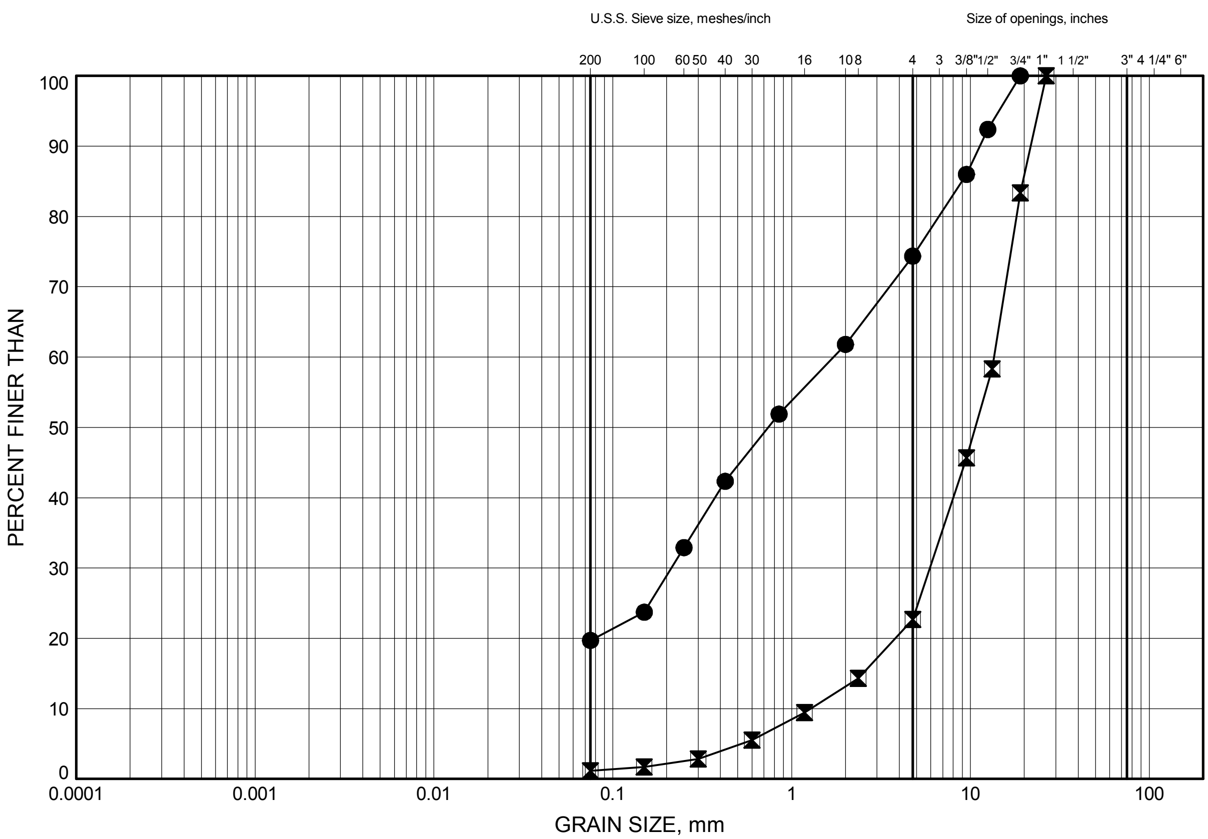
Laboratory Test Results

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B1

GRAVELLY SAND to SANDY GRAVEL FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BC13-03	0.30	242.33
⧗	BC13-06	1.83	240.79

Date January 2015

GWP# 5194-13-00

THURBER

Prep'd AN

Chkd. SKP

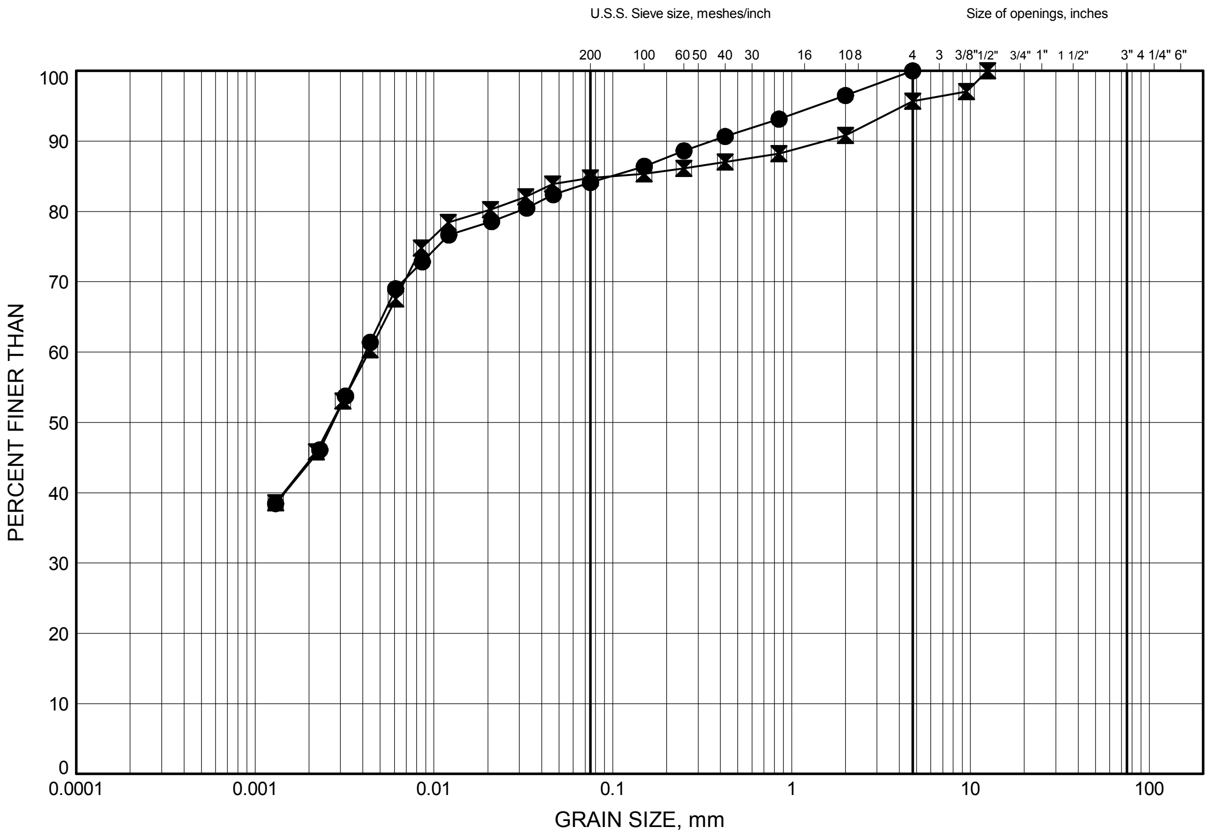
GRAIN SIZE DISTRIBUTION - THURBER 4069.GPJ 1/7/15

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B2

SILTY CLAY FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BC13-04	1.31	241.34
⧗	BC13-05	1.07	241.54

Date January 2015

GWP# 5194-13-00

THURBER

Prep'd AN

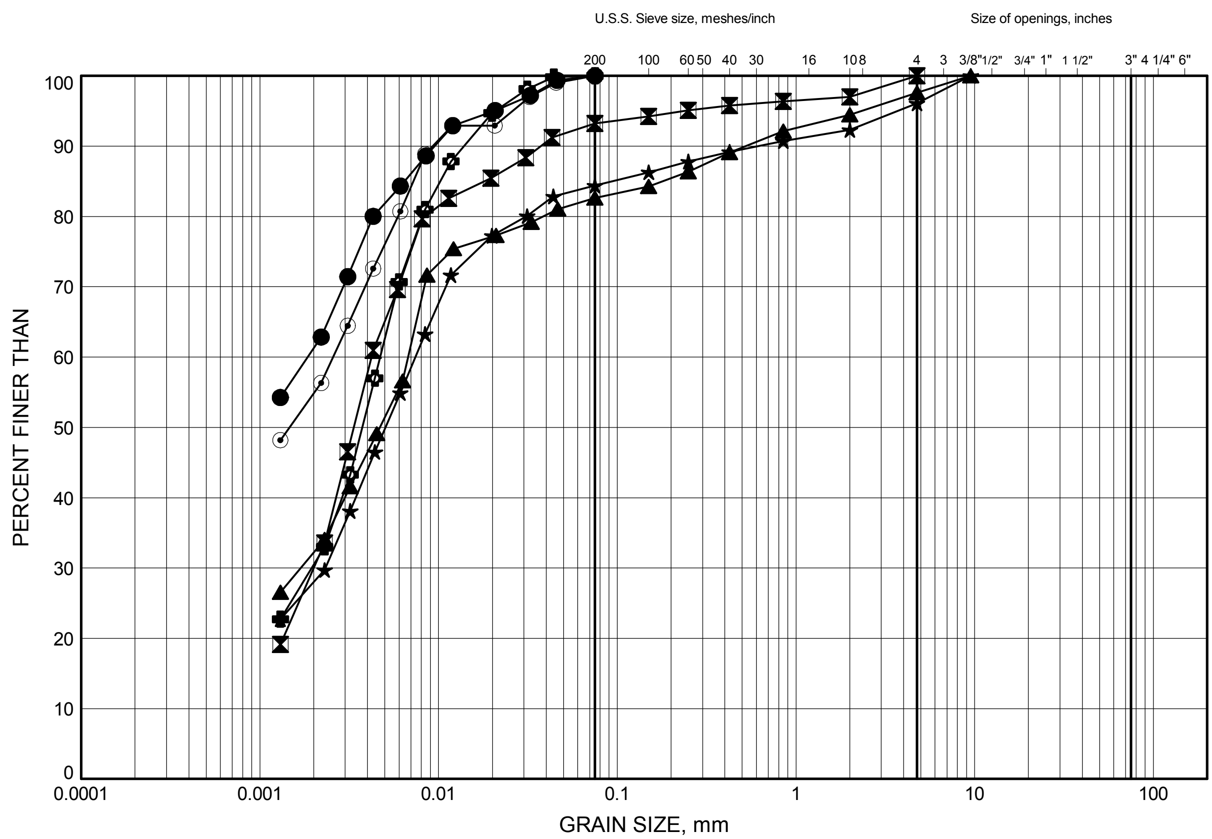
Chkd. SKP

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B3

SILTY CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BC13-01	1.07	239.77
⧗	BC13-01	2.59	238.25
▲	BC13-02	1.83	238.77
★	BC13-02	3.35	237.25
⊙	BC13-03	3.35	239.28
✤	BC13-04	4.11	238.53

Date January 2015

GWP# 5194-13-00

THURBER

Prep'd AN

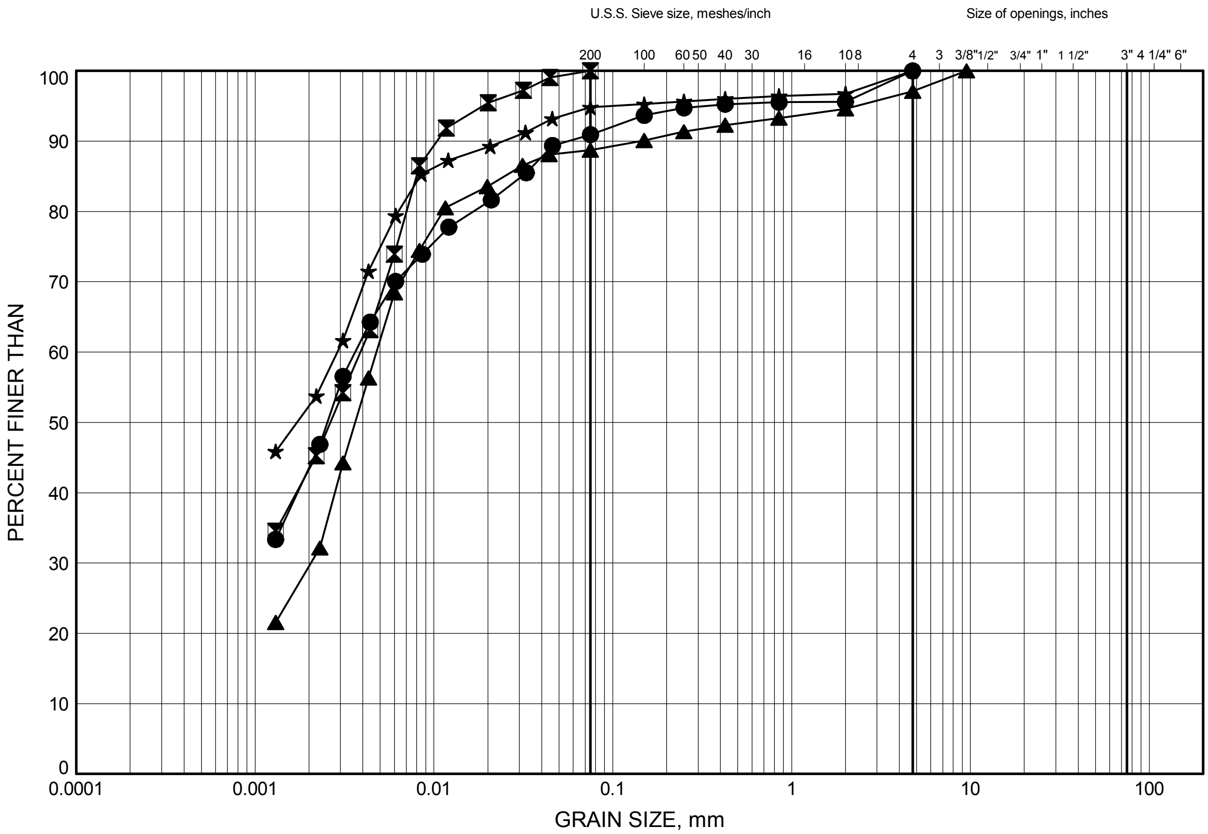
Chkd. SKP

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B4

SILTY CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BC13-05	4.11	238.49
⧗	BC13-06	4.11	238.50
▲	BC13-07	2.59	238.67
★	BC13-08	1.83	239.33

GRAIN SIZE DISTRIBUTION - THURBER 4069.GPJ 1/7/15

Date January 2015

GWP# 5194-13-00

THURBER

Prep'd AN

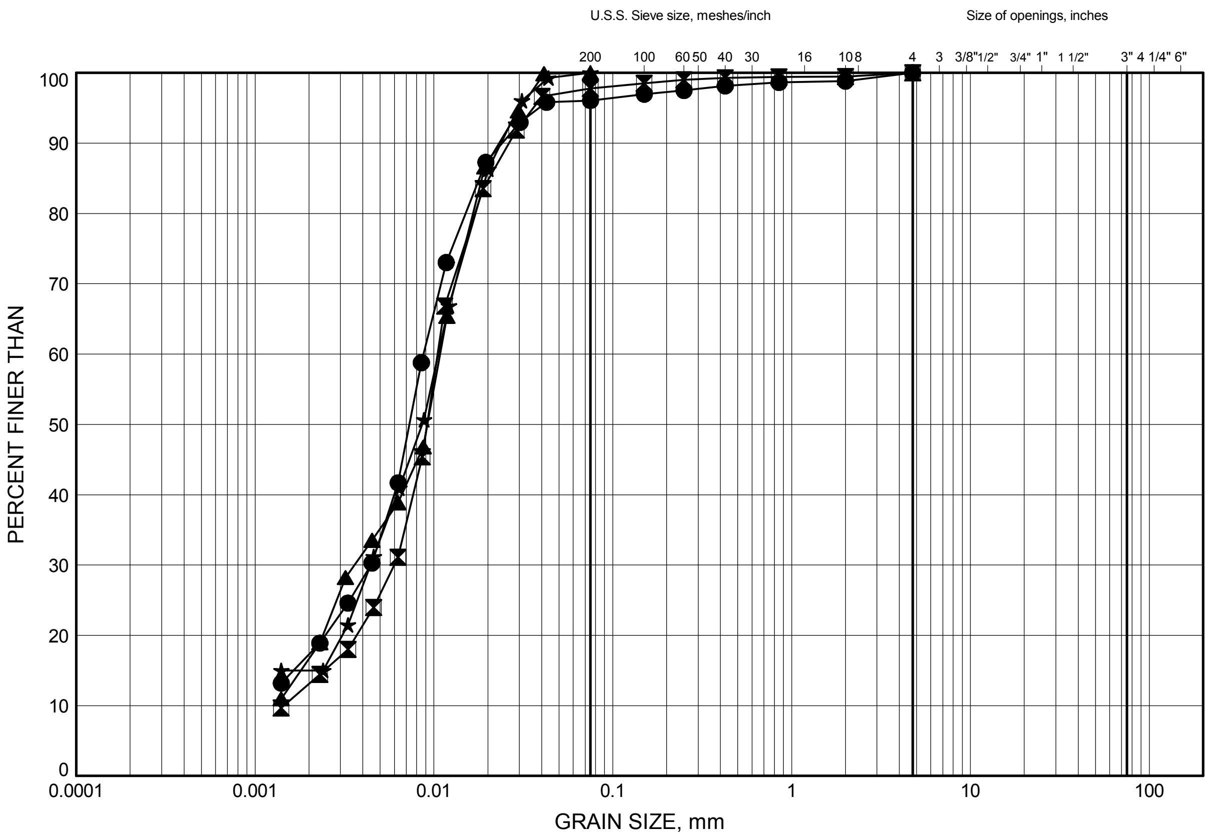
Chkd. SKP

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B5

SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BC13-01	4.11	236.73
⧗	BC13-05	6.40	236.20
▲	BC13-07	4.88	236.38
★	BC13-08	4.11	237.04

Date January 2015

GWP# 5194-13-00

THURBER

Prep'd AN

Chkd. SKP

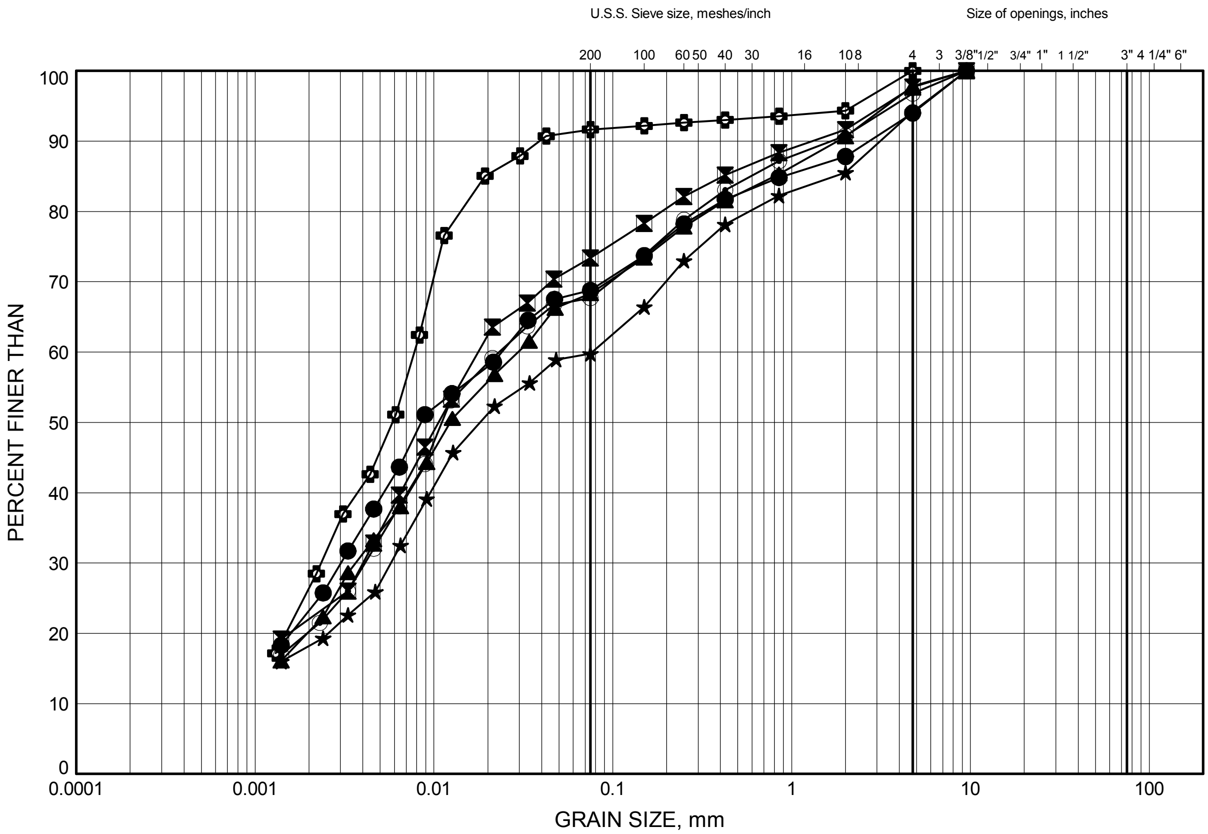
GRAIN SIZE DISTRIBUTION - THURBER 4069.GPJ 1/7/15

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B6

SANDY SILT TILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BC13-02	6.40	234.20
⧗	BC13-03	7.92	234.71
▲	BC13-03	12.50	230.14
★	BC13-04	9.33	233.31
⊙	BC13-04	14.02	228.62
✿	BC13-04	15.54	227.10

GRAIN SIZE DISTRIBUTION - THURBER 4069.GPJ 1/7/15

Date January 2015

GWP# 5194-13-00

THURBER

Prep'd AN

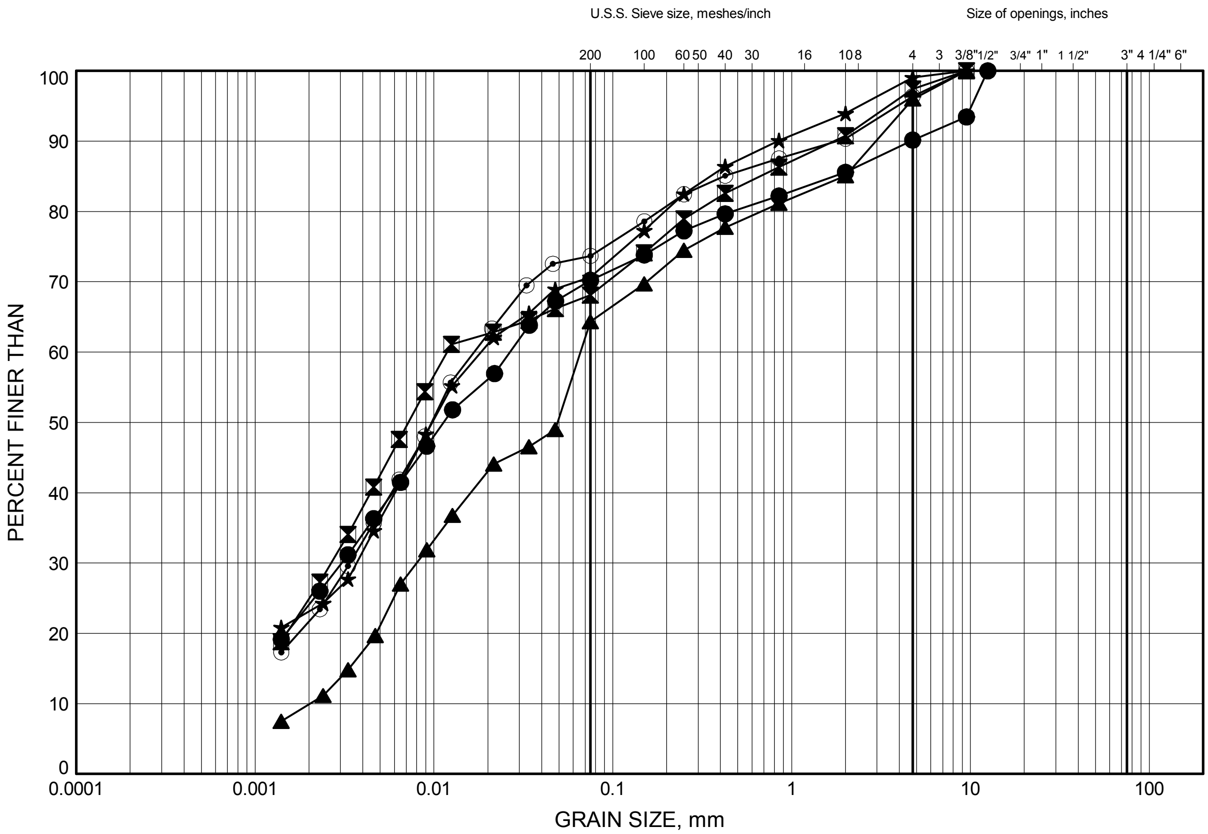
Chkd. SKP

Hwys 11, 583, 652 Culverts - Foundations

GRAIN SIZE DISTRIBUTION

FIGURE B7

SANDY SILT TILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BC13-05	7.92	234.68
⧗	BC13-05	14.02	228.58
▲	BC13-06	9.37	233.25
★	BC13-06	14.02	228.60
⊙	BC13-08	6.40	234.76

Date January 2015

GWP# 5194-13-00

THURBER

Prep'd AN

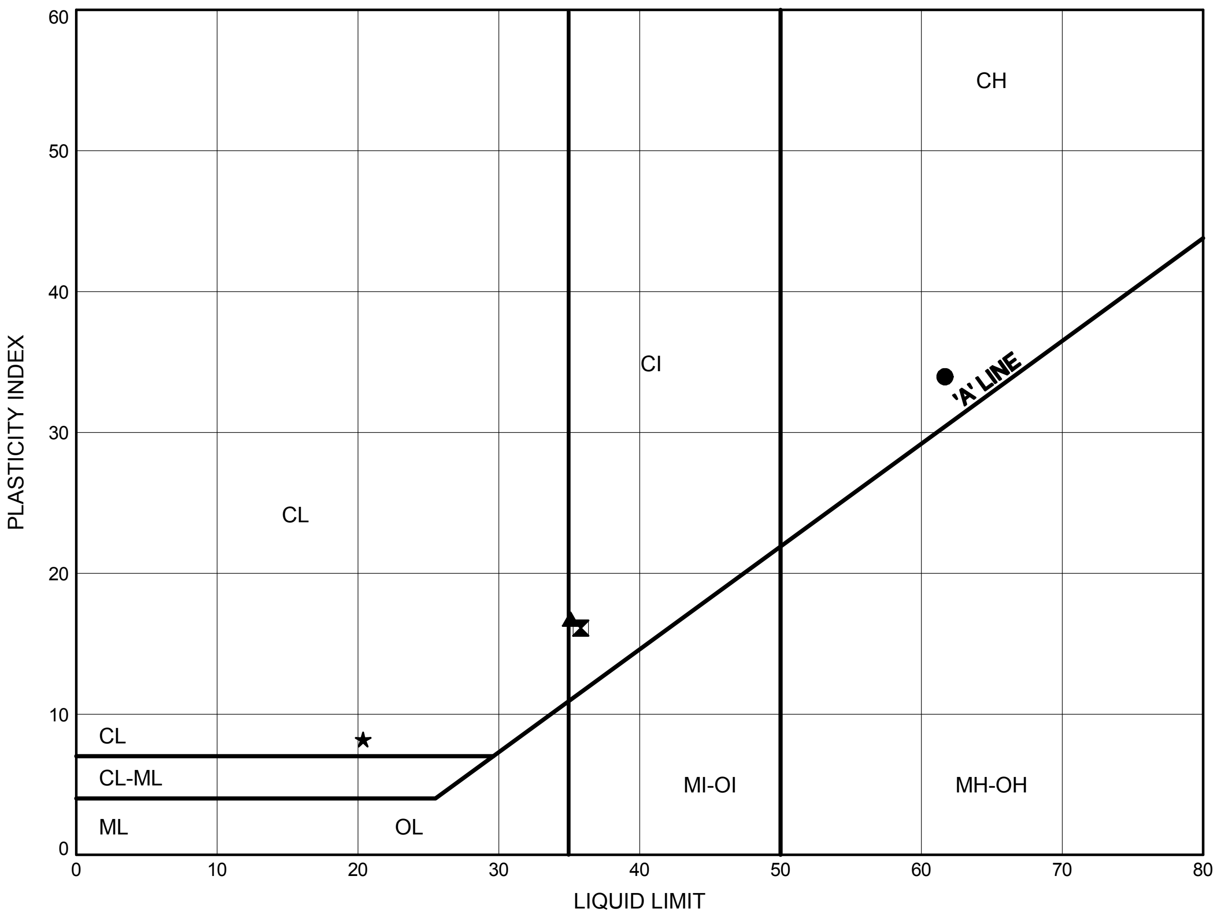
Chkd. SKP

Hwys 11, 583, 652 Culverts - Foundations

ATTERBERG LIMITS TEST RESULTS

FIGURE B8

SILTY CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BC13-01	1.07	239.77
⧗	BC13-02	1.83	238.77
▲	BC13-05	4.11	238.49
★	BC13-05	7.92	234.68

THURBALT 4069.GPJ 1/7/15

Date January 2015

GWP# 5194-13-00

THURBER

Prep'd AN

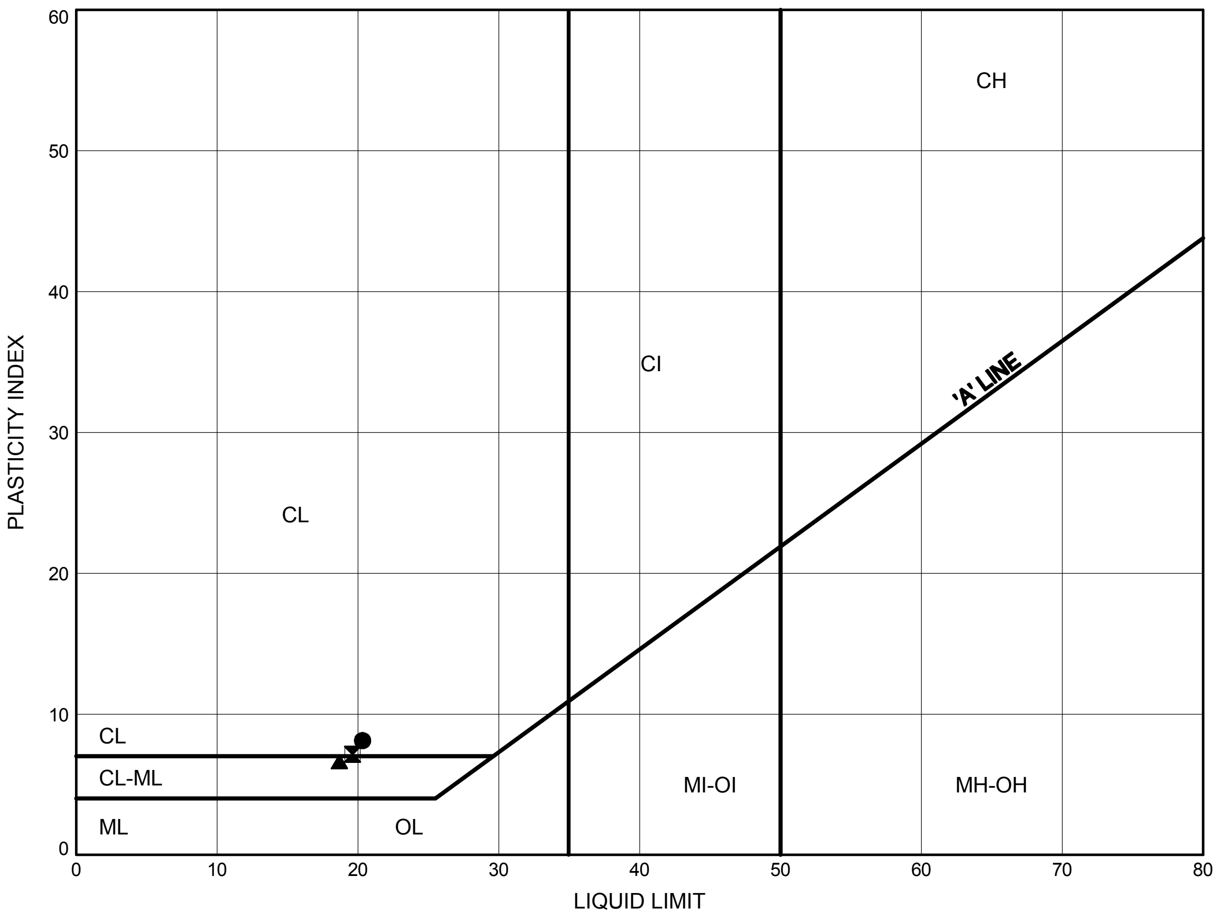
Chkd. SKP

Hwys 11, 583, 652 Culverts - Foundations

ATTERBERG LIMITS TEST RESULTS

FIGURE B9

SANDY SILT TILL



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BC13-03	7.92	234.71
⧗	BC13-04	14.02	228.62
▲	BC13-06	14.02	228.60

THURBALT 4069.GPJ 1/7/15

Date January 2015

GWP# 5194-13-00

THURBER

Prep'd AN

Chkd. SKP

Appendix C

Borehole Locations and Soil Strata Drawings

METRIC

DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

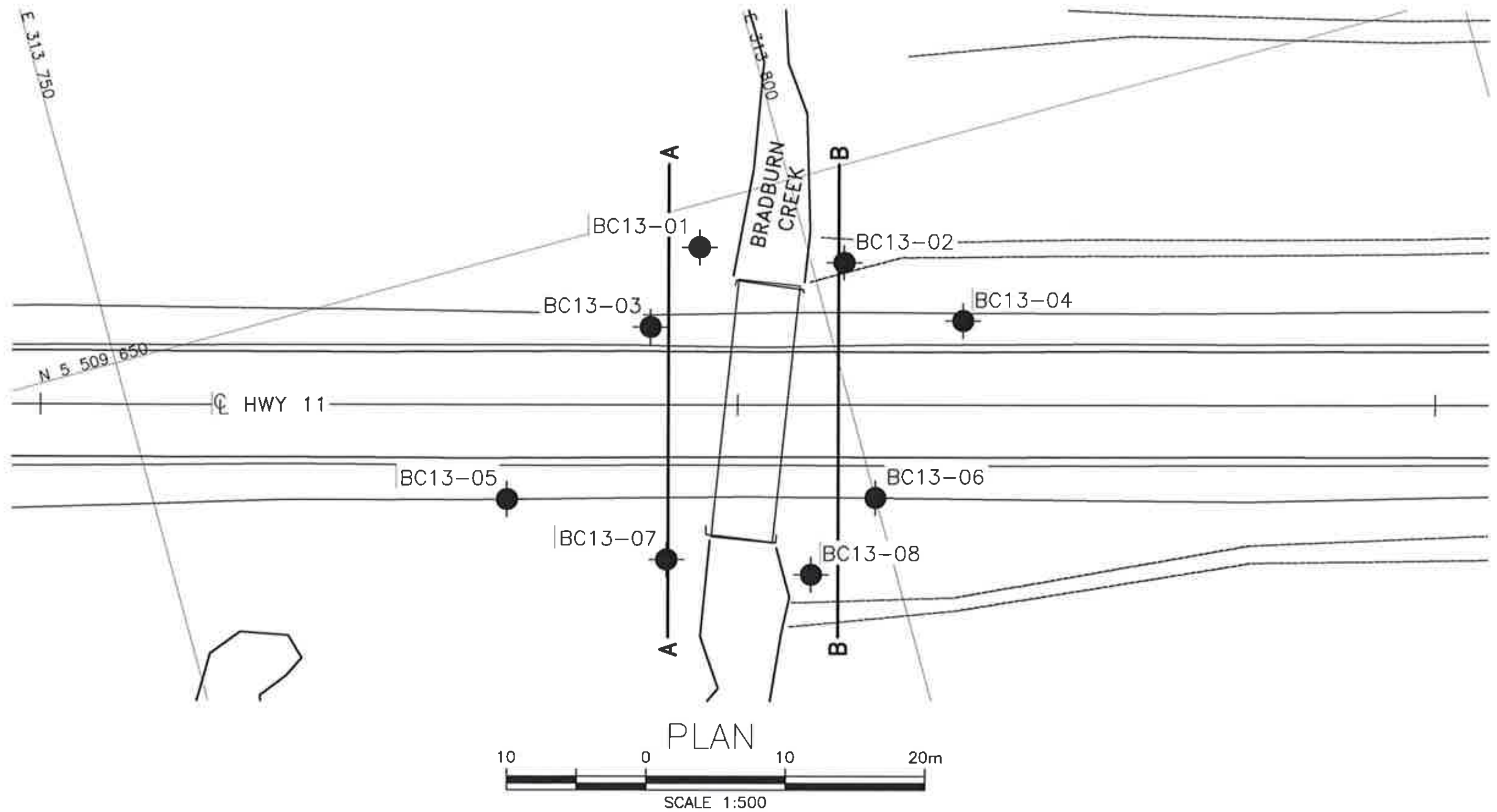
CONT No
GWP No 5194–13–00

HIGHWAY 11
BRADBURN CREEK
CULVERT REPLACEMENT I
BOREHOLE LOCATIONS AND SOIL STRATA

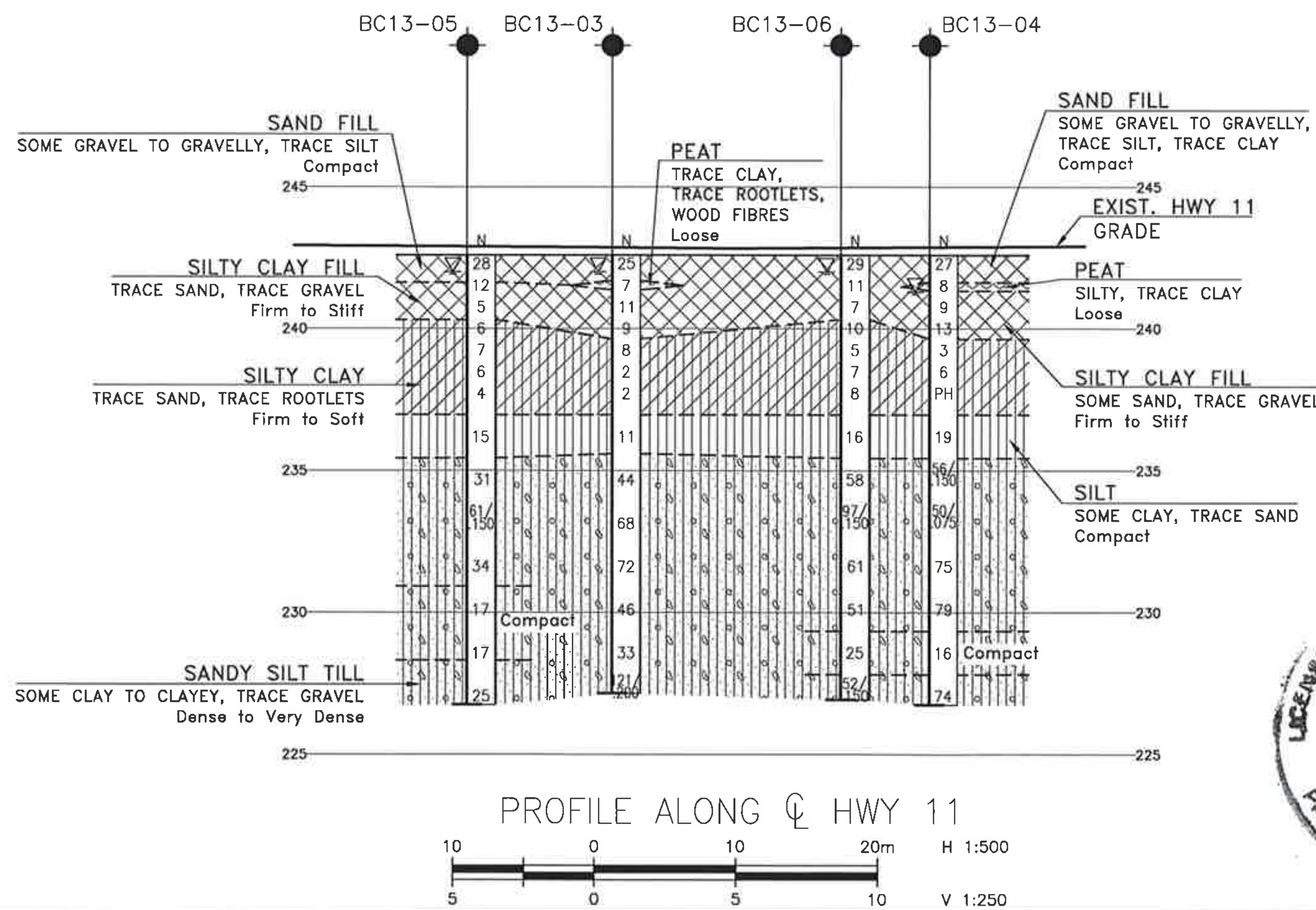
SHEET

URS

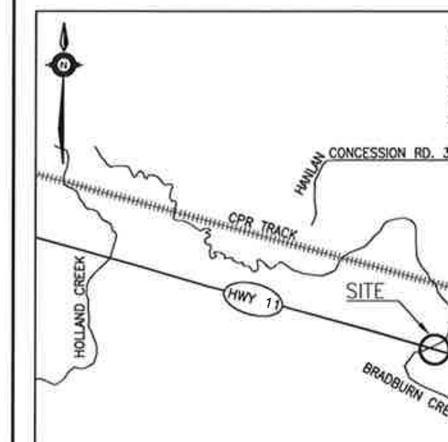
THURBER ENGINEERING LTD.



PLAN



PROFILE ALONG ℄ HWY 11



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
BC13–01	240.8	5 509 647.0	313 792.6
BC13–02	240.6	5 509 643.2	313 802.3
BC13–03	242.6	5 509 642.4	313 787.7
BC13–04	242.6	5 509 636.9	313 809.4
BC13–05	242.6	5 509 633.2	313 774.5
BC13–06	242.6	5 509 626.3	313 800.0
BC13–07	241.3	5 509 626.0	313 784.4
BC13–08	241.2	5 509 622.2	313 794.1

-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. 42G-53

REVISIONS	DATE	BY	DESCRIPTION		
DESIGN SKP	CHK SKP	CODE	LOAD	DATE NOV 2014	
DRAWN AN	CHK AEG	SITE 39W–232C	STRUCT	DWG 2	

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

CONT No
GWP No 5194-13-00

HIGHWAY 11
BRADBURN CREEK
CULVERT REPLACEMENT II
BOREHOLE LOCATIONS AND SOIL STRATA

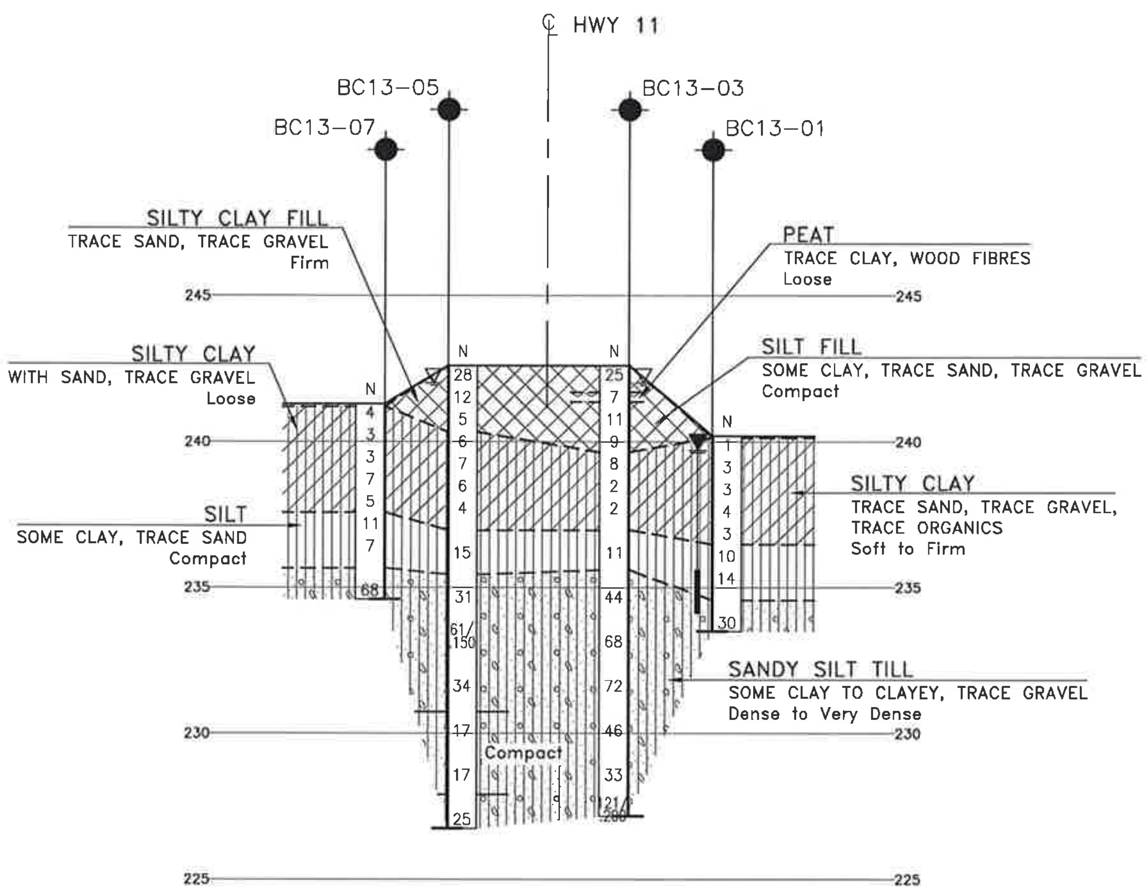
SHEET

URS

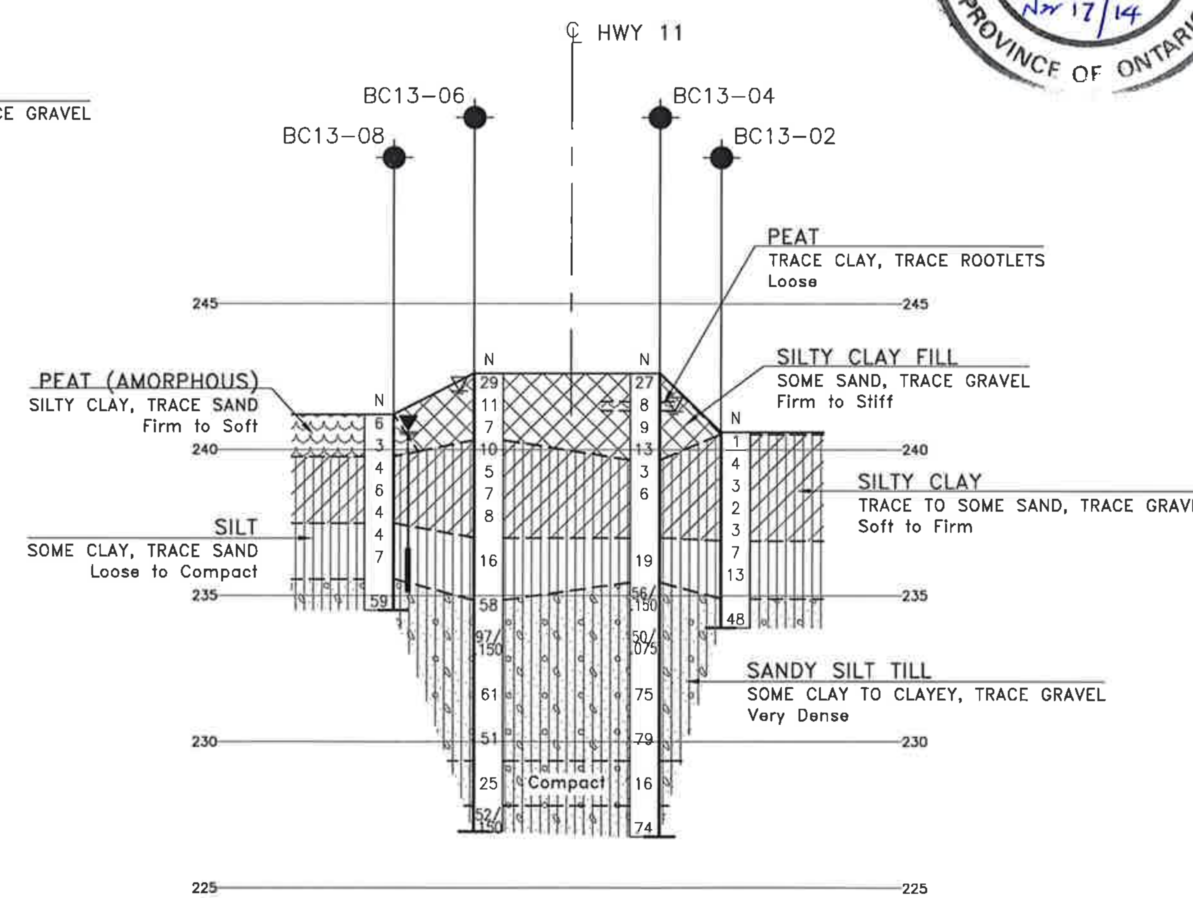
THURBER ENGINEERING LTD.

LICENSED PROFESSIONAL ENGINEER S. PANG Nov.17/14 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER P. K. CHATTERJI Nov 17/14 PROVINCE OF ONTARIO

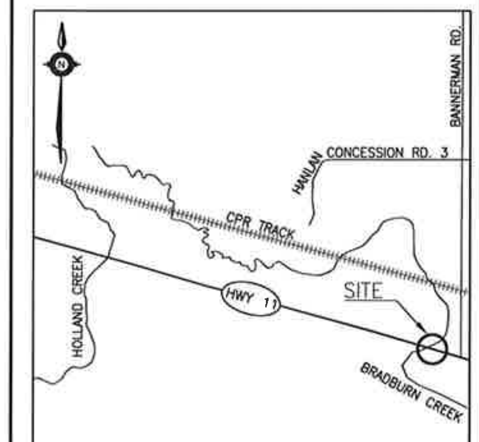


PROFILE ALONG A-A



PROFILE ALONG B-B

10 0 10 20m H 1:500
5 0 5 10 V 1:250



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
BC13-01	240.8	5 509 647.0	313 792.6
BC13-02	240.6	5 509 643.2	313 802.3
BC13-03	242.6	5 509 642.4	313 787.7
BC13-04	242.6	5 509 636.9	313 809.4
BC13-05	242.6	5 509 633.2	313 774.5
BC13-06	242.6	5 509 626.3	313 800.0
BC13-07	241.3	5 509 626.0	313 784.4
BC13-08	241.2	5 509 622.2	313 794.1

-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. 42G-53

REVISIONS | DATE | BY | DESCRIPTION

DESIGN SKP | CHK SKP | CODE | LOAD | DATE NOV 2014
DRAWN AN | CHK AEG | SITE 39W-232C | STRUCT | DWG 3

FILENAME: H:\Drafting\19\4406\9\tec4069-BoreholePlan&Profile(BradburnCreek).dwg
PLOTDATE: 1/7/2015 11:35 AM

Appendix D

Foundation Alternatives Comparisons

COMPARISON OF ALTERNATIVE CULVERT TYPES

Location	Concrete Open Footing Culvert	Concrete Rigid Box Culvert	Circular Pipe Culvert (concrete, CSP, HDPE)
Culvert Replacement	***Advantages:*** i. Relatively expedient installation if precast units are used. ***Disadvantages:*** i. Compressible founding subgrade will provide low geotechnical resistances. ii. Potential for post construction settlement. **NOT RECOMMENDED**	***Advantages:*** 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. ***Disadvantages:*** i. Requires compacted granular pad on subgrade. **RECOMMENDED**	***Advantages:*** i. Can tolerate larger magnitude of settlement than concrete (rigid frame) culverts. ii. Lower cost than concrete (rigid frame) culverts. ***Disadvantages:*** i. CSP and HDPE pipes not as durable as concrete culverts ii. Feasibility also depends on flow capacity and other hydraulic properties. **GENERALLY FEASIBLE**

Appendix E

Suggested Wording for NSSP

1. Suggested Text for NSSP on "Obstructions"

"Installation of roadway protection system could encounter obstructions such as cobbles and boulders embedded in the fill and native glacial tills. Such obstructions may impede sheetpile installation and prohibit the sheetpiles from reaching the design depth of installation. The Contractor shall be prepared to remove, drill through and/or penetrate these obstructions and extend the sheetpiles to the design depths."

Appendix F

Selected Photograph of Culvert Location

Photo 1: Bradburn Creek culvert inlet