

**FOUNDATION INVESTIGATION AND DESIGN REPORT
MARGUERATT ROAD CULVERT REPLACEMENT
NEW LISKEARD DISTRICT, ONTARIO**

G.W.P. No. 5032-14-00, SITE NO. 47-343

Geocres Number: 31M-110

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 culvert on Margueratt Road (Ingram Concession 3) over an unnamed creek, located in the Township of Ingram, New Liskeard District, Ontario.

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

Thurber was retained by MMM Group Limited to carry out this foundation investigation under the MTO Assignment Number 5014-E-0024.

2 SITE DESCRIPTION

The culvert site is located on Margueratt Road (Ingram Concession 3), 2.5 km east of Highway 569 in the Township of Ingram, New Liskeard District, Ontario. This culvert allows an unnamed creek to flow, from north to south, under Margueratt Road.

The existing structure is an 18 m long, twin 2.1 m diameter corrugated steel pipe (CSP) culvert with approximately 1 m of fill above the culverts. The embankment in the vicinity of the culvert was approximately 3 m in height. The year the structure was constructed is unknown. It is understood that the culverts are in poor condition with deterioration and deformation of the culvert barrels, and breakdown of the structural steel coatings. The twin culvert is proposed for full replacement.

Margueratt Road is a 2-lane gravel road with a grade level at the existing culvert at approximate Elevation 207 m.

The site is located approximately 18 km east of Englehart with residential properties nearby. Naturally low-lying, swampy areas are present near the inlet and outlet of the culvert, with vegetation consisting of tall grass and shrubs with frequent trees. Local topography is of low relief with no

visible bedrock outcrops. Areas surrounding the properties are heavily forested. The area in the immediate vicinity of the culvert is undulating and generally sloping downwards from the road grade to the creek.

Based on published geological information, the general area of the project is covered by glacioacustrine sediments of clays and silts deposited during the Pleisocene period. 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 Upper Ordovician shale, limestone, dolostone, and siltstone of the Liskeard Group.

3 SITE INVESTIGATION AND FIELD TESTING

This borehole investigation and field testing program was carried out in two segments. The first between May 23 and May 25, 2015 and the second between June 22 and June 26, 2015. The program consisted of drilling and sampling 6 boreholes (numbered MR-01 to MR-06) to depths ranging from 12.2 to 14.3 m, and extending two boreholes (MR-04 and MR-03) to 17.4 and 45.7 m by conducting Dynamic Cone Penetration Tests (DCPTs). Of these boreholes, two were located near the culvert inlet (MR-01 and MR-02), two were located near the culvert outlet (MR-05 and MR-06), and two were located on the shoulders of the road embankment (MR-03 and MR-04).

Prior to the start of drilling, the borehole locations were marked/staked in the field and utility clearances were obtained. The coordinates and ground surface elevations for the boreholes were derived from topographic plans provided to Thurber by MMM Group Limited. The approximate borehole locations are shown on the Borehole Locations and Soil Strata drawing included in Appendix C.

A track-mounted CME 45 hi-torque drill rig was used to advance boreholes MR-03 and MR-04 to the target depth using hollow stem augers and NW casing/wash boring techniques. A portable tripod drill rig was used to advance boreholes MR-01, MR-02, MR-05, and MR-06 due to difficult access for a conventional drill rig beyond the road embankment. 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 very soft to soft cohesive soils. Dynamic cone penetration tests (DCPT) were conducted below the last sample in boreholes MR-03 and MR-04 to specified depths. Groundwater conditions in the open boreholes were observed throughout the drilling operations. The details regarding borehole completion are summarized in Table 3.1.

Table 3.1 - Borehole Completion and Backfilling Details

Borehole	Borehole Depth/ Elevation (m)	Borehole Backfilling Details
MR-01	12.2/193.2	Bentonite holeplug and cuttings from 12.2 m to ground surface
MR-02	12.2/193.1	Bentonite holeplug and cuttings from 12.2 m to ground surface
MR-03	14.3/192.8	Bentonite holeplug and cuttings from 14.3 m to 0.2 m and granular to ground surface
MR-04	14.3/192.6	Bentonite holeplug and cuttings from 14.3 m to 0.2 m and granular to ground surface
MR-05	12.2/193.5	Bentonite holeplug and cuttings from 12.2 m to ground surface
MR-06	12.2/193.1	Bentonite holeplug and cuttings from 12.2 m to ground surface

The results of the 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.

In order to assess the potential for sulphate attack on concrete foundations, as well as the potential for corrosion on metal associated with the structure, a sample of the existing sandy silt embankment fill, and a sample of surface water from the creek upstream of the bridge were collected. The samples were submitted to AGAT Laboratories in Mississauga, Ontario for analytical testing of corrosivity parameters and sulphate. The results of the analytical testing are summarized in Section 6 below and are presented 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 road shoulder consist of granular fill overlying deposits of silty sand to sand, clayey silt, and an extensive layer of silty clay with occasional silt interlayers. At the culvert inlet and outlet beyond the road embankment, a layer of topsoil overlies the sand, clayey silt and clay layers. Groundwater levels are generally in the order of 0.4 to 2.4 m below original ground surface. More detailed descriptions of the individual stratum are presented below.

5.2 Topsoil

A layer of topsoil between 130 and 150 mm in thickness was encountered at the ground surface in Boreholes MR-01 and MR-05 located near the culvert inlet and outlet areas respectively. The topsoil thickness may vary between and beyond the borehole locations, and the limited data is not suitable for estimating topsoil quantities.

5.3 Embankment Fill

Embankment fill was encountered at ground surface in Boreholes MR-03 and MR-04. The upper part of the fill is brown to grey in colour and typically consists of a sand to sand and gravel with organic inclusions and rootlets at shallow depths. Where encountered, the embankment fill extended to depths of 1.4 to 1.7 m below the existing ground surface (base Elevation 205.7 to 205.2 m).

In Borehole MR-04, a 2.4 m sand fill layer underlies the upper sand and gravel fill with the inclusion of a 200 mm boulder at 2.1 m. This sand fill layer extends to a depth of 4.1 m (base Elevation 202.8 m). In Borehole MR-03, a sandy silt to silty sand fill layer 2.7 m in thickness underlies the upper sand and gravel fill with the inclusion of a 350 mm thick wood layer at 3.3 m. The lower boundary of the silty sand to sandy silt fill can be found at depths of 2.3 to 4.1 m respectively (base Elevations 204.8 and 203.0 m)

SPT N-values measured in the cohesionless fill ranged from 2 blows per 0.3 m penetration to 14 blows per 0.3 m penetration, but mostly between 7 and 11 blows per 0.3 m penetration indicating a typically loose to compact state.

Measured moisture contents of the recovered fill samples ranged between 2% and 310% in the wood layer, with most values ranging between 10% and 33%. No grain size analyses were conducted on samples of the gravelly sand to sand and gravel fill due to poor recoveries. The results of the grain size analysis conducted on the sand and sandy silt fill are presented on Figure B1 in Appendix B. These results are summarized in the following table.

Soil Particles	%
Gravel	0 to 1
Sand	68 to 84
Silt	20
Clay	12
Silt and Clay	15

5.4 Silty Sand to Sand

Sand to silty sand layers were found in boreholes MR-02 and MR-06 from surface, underlying the embankment fill in MR-03, beneath the silty clay layer in MR-01, and overlain by a layer of topsoil in MR-05. This brown to grey soil typically consists of trace gravel, trace to some clay, and occasional roots and rootlets at shallow depths. The thickness of the silty sand to sandy silt ranged from 1.5 to 2.4 m with a lower boundary at depths of 2.2 to 5.6 m (base Elevations 203.5 to 201.5 m).

SPT N-values measured in the silty sand to sandy silt ranged from 0 to 12 blows per 0.3 m penetration with most values between 3 and 9 blows per 0.3 m penetration indicating a typically loose to compact state.

Measured moisture contents of the recovered silty sand to sandy silt samples ranged between 15% and 53% with most values ranging between 17% and 40%. Grain size analyses conducted on samples of the silty sand to sand are presented in Figure B2. The results are summarized in the following table.

Soil Particles	%
Gravel	1 to 7
Sand	56 to 91
Silt	18 to 29
Clay	12 to 15
Silt and Clay	8 to 10

5.5 Clayey Silt

A clayey silt layer was encountered beneath the silty sand to sand layer in Boreholes MR-01, MR-02, MR-05, and MR-06, and underlying the sand fill in Borehole MR-04. The clayey silt ranged in composition from some sand to sandy. The thickness of the clayey silt ranged from 1.1 to 1.9 m with a lower boundary at depths of 4.1 to 5.6 m (base Elevations 201.6 to 201.2 m).

The measured N-values in the clayey silt ranged between 1 and 9 blows per 0.3 m penetration with most values between 1 and 3 blows per 0.3 m penetration indicating a typically very soft to soft consistency.

The measured water contents of samples recovered from this deposit typically ranged from 19% to 30%. Grain size analyses conducted on samples of the clayey silt are presented in Figure B3, and Atterberg Limits test results are presented in Figure B6 in Appendix B. The results are summarized in the following table.

Soil Particles	%
Gravel	0
Sand	19 to 38
Silt	32 to 60
Clay	19 to 30
Soil Property	%
Liquid Limit	34 to 38
Plasticity Index	8 to 13

The results of the Atterberg Limits tests indicate that the clayey silt is typically of low plasticity (ML) to intermediate plasticity (MI).

5.6 Silty Clay to Clay

A silty clay to clay layer was encountered in all six boreholes drilled at the site. All boreholes were terminated within the grey silty clay to clay with some silt at depths of 12.2 to 14.3 m (base Elevations 193.2 to 192.6 m).

The measured N-values in the silty clay range between 0 and 1 blows per 0.3 m penetration. In conjunction with measured field vane shear strengths ranging from 29 to 50 kPa, the silty clay to clay was found to have a typically firm consistency.

The measured water contents of samples recovered from these soils typically ranged from 43% to 79%. Grain size analyses conducted on samples of the silty clay are presented in Figure B4 and Figure B5, and Atterberg Limits test results are presented in Figure B7 and Figure B8 in Appendix B. The results are summarized in the following table.

Soil Particles	%
Gravel	0
Sand	0
Silt	16 to 44
Clay	56 to 84
Soil Property	%
Liquid Limit	60 to 65
Plasticity Index	31 to 38

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

Below the sampled depth in Borehole MR-03, a DCPT was carried out within the silty clay to a depth of 45.7 m (base Elevation 161.4 m). No practical refusal was encountered (100 blows per 0.3 m penetration).

5.7 Groundwater Conditions

Free water was observed in most of the boreholes upon completion of drilling and are presented below.

Table 5.1 – Water Level Measurements in Open Borehole

Borehole	Date of Reading	Water Level	
		Depth (m)	Elevation (m)
MR-01	June 04, 2015	0.7	204.7
MR-02	June 05, 2015	0.7	204.6
MR-03	May 25, 2015	11.3	195.8
MR-04	May 25, 2015	2.4	204.5
MR-05	June 07, 2015	0.4	205.3
MR-06	June 06, 2015	0.8	204.5

The groundwater level should be assumed to coincide with the local creek water level. Based on the observations and measurements above, the groundwater level adjacent to the creek is at approximate Elevation 205 m. The groundwater levels are expected to vary seasonally and are subject to severe weather events such as rainstorms.

6 CORROSIVITY AND SULPHATE TEST RESULTS

A sample of the existing silty sand embankment fill soil and a sample of the surface water from the creek were submitted for analytical testing of corrosivity parameters and sulphate. The results of the analytical tests are shown in Table 6.1. The laboratory certificates of analysis are presented in Appendix B.

Table 6.1 – Analytical Test Results

Parameter	Units (Soil)	Units (Water)	Test Results	
			MR-3 SS3/4A 5'-7'8"	Margueratt Road Culvert
			(Soil, 1.5-2.3 m deep)	(Creek Water)
Sulphide	%	mg/L	0.01	<0.05
Chloride	µg/g	mg/L	9	0.27
Sulphate	µg/g	mg/L	6	1.99
pH	pH Units	pH Units	6.87	6.87
Electrical Conductivity	mS/cm	µS/cm	0.083	49
Resistivity	ohm.cm	ohm.cm	12000	20400
Redox Potential	mV	mV	338	324
Langlier Index	-	-	-	-2.06
Total Hardness (as CaCO ₃)	-	mg/L	-	25.4
Total Dissolved Solids	-	mg/L	-	40
Alkalinity (as CaCO ₃)	-	mg/L	-	23

7 MISCELLANEOUS

Thurber staked and/or marked the borehole locations in the field and obtained utility clearances prior to drilling. Thurber obtained the northing and easting coordinates and ground surface elevations from measurements taken in the field relative to the topographic plans provided by MMM Group Limited.

Eastern Ontario Diamond Drilling of Hawkesbury, Ontario supplied and operated a track-mounted CME-45 hi-torque drill rig and a portable tripod drill rig to carry out the drilling, sampling and in-situ testing operations on the embankment shoulders and near the culvert inlet and outlet. The drilling and sampling operations in the field were supervised on a full time basis by Ms. Deanna Pizycki and Mr. Amir Fereidouni of Thurber. Geotechnical laboratory testing was carried out by Thurber in its MTO-approved laboratory.

A sample of creek water and a sample of embankment fill soil was submitted to AGAT Laboratories in Mississauga, Ontario for testing against selected corrosivity parameters.

Overall supervision of the field program, interpretation of the data, and preparation of the report were carried out by Mr. Stephane Loranger, CET, Ms. Deanna Pizycki, EIT and Mr. Mark Farrant P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

8 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 an unnamed creek on Margueratt Road, located 2.5 km east of Highways 569.

The existing culvert consists of twin 2.2 m diameter, 18.4 m long, corrugated steel pipe (CSP) culverts. The road embankment in the vicinity of the culvert is approximately 3 m in height. It is understood that the culverts are in poor condition with deterioration of several elements, including deterioration and deformation of the culvert barrels, and breakdown of the structural steel coatings. The twin culvert is therefore proposed for replacement.

The discussions and recommendations presented in this report are based on information provided by MMM Group Limited (MMM) and on the factual data obtained during the course of this investigation. It is understood that MMM are considering 3 options for the culvert replacement, including a 4.5 m by 2.5 m concrete box, twin 2.6 m diameter CSPs, and a 4.52 m by 2.77 m corrugated steel pipe arch (CSPA). Due to the existing embankment fill height of approximately 1 m above the existing culverts, it is not anticipated that a grade raise will be required to accommodate the replacement culvert options.

Selected photographs of the culvert area are included in Appendix F for reference.

9 CULVERT FOUNDATIONS

9.1 General

Based on the terms of reference, it is anticipated that the replacement twin culvert structure will be installed along the same alignment as the existing culverts. It is understood that staged construction should be assumed for the culvert replacement. Boreholes MR-01 and MR-02 were drilled near the existing culvert inlets, Boreholes MR-03 and MR-04 were drilled

through the existing embankment, and Boreholes MR-05 and MR-06 were drilled near the outlets.

9.2 Foundation Alternatives

This section presents discussions on available types of replacement culverts and foundation alternatives, and provides recommendations on a preferred foundation option.

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

- Concrete box (closed) culvert
- Concrete, open footing, culvert
- Corrugated steel pipes (circular) or single corrugated steel pipe arch

A comparison of the culvert types and foundation alternatives based on their respective advantages and disadvantages is included in Appendix D.

The existing culvert consists of twin CSPs. Given the subsurface conditions and anticipated construction sequencing, we consider the concrete box culvert, CSPs, or CSPA to be technically feasible alternatives.

A concrete, open footing culvert is not considered suitable as the shallow subgrade soils are relatively weak and are not likely to provide the geotechnical resistances required to support strip footings of reasonable width.

The report provides foundation recommendations for the design and construction of box culverts, CSPs and CSPA options.

9.3 Foundation Design for Culverts

It is anticipated that the invert of the replacement culverts will be approximately the same as that of the existing culverts. There is approximately 1 m of fill above the existing culverts. Foundation design aspects for the replacement culverts includes subgrade conditions, geotechnical resistances for the culverts and the wingwalls (if required), settlement of founding soils, lateral earth pressures, erosion control, protection system design and groundwater control, staged excavation, and stability and settlement of the roadway embankment.

9.3.1 Concrete Box Culvert

Since the replacement culvert will be constructed on the same alignment as the existing culverts with no anticipated grade raise of the road for the concrete box culvert option, it is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading, other than due to the weight of the concrete box structure. Associated settlement is discussed in Section 9.3.4.

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

A preliminary profile drawing from MMM indicates that the inverts of the existing culverts are at an approximate elevation of 204 m. Therefore, the underside of the granular pad should be founded below elevation of 203.5 m or lower, which based on the borehole logs is to be founded on predominantly loose native sand to silty sand and embankment sand fill. The native sand and embankment fill are underlain by typically firm silty clay to clay. 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 the concrete slab and the underlying Granular A or B Type II should be calculated assuming an ultimate coefficient of friction of 0.4.

It is recommended that the culvert 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.

Foundation design for any wingwalls associated with the box culvert option are discussed in the following sub-section 9.3.3.

9.3.2 Corrugated Steel Pipe (Circular) or Steel Pipe Arch Culvert

Replacement of the culverts with CSPs or a CSPA on the same alignments as the existing culverts is not anticipated to require a grade raise due to the existing cover of approximately 1 m. Therefore, it is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading.

The CSPs or CSPA should be placed on a minimum 300 mm thick layer of bedding material conforming to OPSS PROV 1010 Granular A or Granular B Type II requirements, as per OPSD 802.010 or 802.020 respectively. The bedding material must be placed on the approved subgrade as soon as practicable following its inspection and approval. Construction equipment must not be allowed to travel on the bedding or the prepared subgrade, which must be protected from disturbance during construction.

The underside of the bedding layer should be placed at an approximate elevation of 203.7 m or lower, which corresponds to loose sand to silty sand subgrade.

Resistance to lateral forces / sliding resistance between the steel pipes and the underlying Granular A or B Type II should be calculated assuming an ultimate coefficient of friction of 0.4.

9.3.3 Retaining Walls

If retaining walls are required, consideration may be given to using Retained Soil Systems (RSS) walls or cantilevered concrete walls. However, RSS is recommended as it may be more tolerant of settlement.

Borehole information indicates that the founding conditions at the wall locations generally consist of loose sand to silty sand.

9.3.3.1 RSS Walls

According to the MTO RSS manual, RSS walls at this site may be specified as “Low Performance” and “Low Appearance”. The Ministry may wish to specify a higher performance and appearance level. 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 on a 500 mm thick engineered fill pad resting on the loose sand to silty sand subgrade at an approximate elevation of 203.7 m or lower. An RSS wall founded on this material may be designed using a factored geotechnical resistance at ULS of 120 kPa and a geotechnical reaction at SLS of 80 kPa. Engineered fill pads placed under the RSS mass must consist of OPSS PROV Granular A or Granular B Type II compacted to 100% of its SPMDD at a moisture content within 2% of optimum. The engineered pad must be at least 500 mm beyond the limits of the RSS mass and levelling strip.

If these geotechnical resistances are not adequate to support the proposed RSS walls, Thurber should be contacted for additional assessment of alternate measures to accommodate an RSS system.

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 0.4 for an engineered granular fill 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 must be analyzed by the supplier/designer of the proprietary product selected for this site.

Global stability of the RSS walls must be analyzed once the detailed configurations of the walls are known.

9.3.3.2 Foundation for Concrete Retaining Walls

From a foundation standpoint, concrete retaining walls may be supported on spread footings founded on the loose sand to silty sand subgrade. For founding at Elevation 203.7 m or lower, the geotechnical resistances recommended above for the box culverts may be used for design. A granular levelling pad should be considered below the footing. Load inclination and eccentricity should also be taken into account as outlined above.

Resistance to lateral forces / sliding resistance between precast concrete and the underlying soil should be evaluated in accordance with the CHBDC (2010) assuming an ultimate coefficient of friction of 0.3 for loose sand to silty sand or 0.4 for engineered fill.

9.3.4 Settlements

It is anticipated that the replacement culverts will have approximately the same alignments and opening sizes as the existing twin CSP culverts with no grade raise. Taking into consideration the anticipated staged construction approach 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 concrete boxes compared to the existing CSPs, the loose sand to silty sand and underlying firm silty clay to clay subgrade soils would be subjected to additional load resulting in some post construction consolidation settlements. The estimated post construction settlement is in the order of 10 to 15 mm within 10 years.

If staged construction is used, and the box culvert or CSPA options are selected, it is anticipated that one existing CSP barrel may be left in place for diverting creek flow (likely the smaller, 3 m diameter barrel). At a later stage, the abandonment of the remaining barrel may result in settlement of the embankment foundation in the order of 25 mm due to the backfill required to fill the void left by the barrel.

The RSS walls will be founded on an engineered fill pad over soft to firm clay. For a 1.5 to 2 m high RSS wall, the settlement under the wall is estimated to be in the order of 25 mm. The RSS wall must be designed to accommodate this settlement.

Resurfacing or regrading of the granular roadway may be required after settlement is complete.

9.3.5 Subgrade Preparation

After the excavation reaches the design subgrade elevation, the exposed surface must be inspected to confirm that the subgrade is suitable and uniformly competent. Any remaining topsoil, creek bed deposits, disturbed soils and any deleterious materials within the culvert replacement footprint must be removed and replaced with well compacted bedding.

This work must be carried out in accordance with OPSS PROV 902 and construction must be carried out in the dry.

9.4 Construction Considerations

Detailed construction sequencing was not available at the time of preparation of this report. However, it is anticipated that one lane of traffic must be maintained, which requires staged construction.

Staged construction sequencing will likely require the following:

- Diversion of the creek will be required for construction. It is anticipated that one barrel of the culvert will be maintained for creek flow. Cofferdams may be required at the inlet and outlet areas as part of the creek diversion, as well as pumping from sumps
- Roadway protection may be required during all stages of construction
- Excavation and removal of the existing culvert, installation of the new culvert and backfilling should be carried out within the protection systems if utilized
- All culvert subgrade preparation and foundation preparation for retaining walls must be carried out in the dry.

Protection systems (temporary shoring) such as the use of interlocking steel sheetpiles may be utilized. Foundation recommendations for design of such a system are provided in a subsequent section of this report. Sump pumping will be required to maintain reasonably dry excavations. Unwatering methods such as temporary diversion of the creek and surface water using sandbags and/or sheetpile cofferdams may also be required.

Since the excavation and culvert installations will be conducted within the existing creek channel, it is recommended that all works be carried out within a water-tight, sheetpile enclosure.

10 CULVERT 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 PROV 1010. Reference should be made to the backfill arrangements stipulated in OPSD 803.01, 802.010, or 802.020 as appropriate.

All fills must be placed in regular lifts and be compacted in accordance with OPSS PROV 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 roof of the culvert.

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

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)

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 10.1. Active pressures should be used for any unrestrained wall.

Table 10.1
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.

11 EMBANKMENT DESIGN AND CONSTRUCTION

The existing highway embankment is up to 3 m in height at the culvert locations. It is anticipated that that there will be no grade raise at this site for the culvert replacement. Temporary widening of the embankment may however be required to accommodate staged construction.

Embankment reconstruction after culvert replacement should be carried out in accordance with OPSS PROV 206. The embankment material should consist of imported Granular A or B Type II material.

Provided that the granular material is placed as recommended and at the same slope inclination as the existing embankment, i.e., at an inclination 2H:1V or shallower, it is anticipated that the embankment slope will remain stable.

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

In widened embankment areas, the settlement is estimated to be 50 mm.

12 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, rock protection should be provided over all surfaces with which creek water is likely to be in contact, which includes toe protection for the wingwalls. 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 PROV 804.

A clay seal or a concrete cut-off wall should be used to minimize the potential for erosion or 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 PROV 1205. A geosynthetic clay liner may be used in place of a compacted clay seal.

13 EXCAVATION AND GROUNDWATER CONTROL

13.1 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, native sand, silt, 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 in the inlet and outlet areas are classified as Type 4 soils.

13.2 Foundations

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

13.3 Excavations

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

Any protection system must be designed by licensed Professional Engineers experienced in such designs. OPSS PROV 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.

13.4 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 9.4, a combination of the use of cofferdams at the inlets and outlets, creek water diversion, protection systems such as sheetpiled enclosures and pumping from filtered sumps will be required to maintain dry excavations during the course of staged construction. A water-tight, sheetpile enclosure is recommended since all excavation and culvert installation works will be conducted within the existing creek channel.

14 ROADWAY PROTECTION DESIGN

Roadway protection may 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 sheetpile enclosures which are also anticipated to provide an effective groundwater cutoff. It is anticipated that the sheetpiles will need to be driven into

the firm native silty clay below the sand to develop the required toe resistance and cutoff groundwater seepage. 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	=	21 kN/m ³ (fill and native soils)
γ_w	=	10 kN/m ³
K_a	=	0.33 (road embankment fill)
	=	0.35 (sand, silty sand, sandy silt)
	=	0.36 (clayey silt, 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 sheetpiled wall.

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

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

15 CORROSION AND SULPHATE ATTACK POTENTIAL

The results of the corrosivity and sulphate analytical tests conducted on the embankment fill soil and the creek water indicate the following:

- The potential for sulphate attack on concrete foundations from the surrounding soil or surface water is considered to be negligible due to the low concentration of sulphate in the samples tested.
- The potential for soil or water corrosion on metal is considered to be mild to moderate.
- If metal structural elements are used, appropriate corrosion protection measures must be provided.

16 CONSTRUCTION CONCERNS

During construction, the Contract Administrator must employ experienced geotechnical staff to provide advice on construction activities related to foundation construction.

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

- Impact of excavation on the existing roadway surface – resurfacing or regrading of the granular roadway surface may be required after construction and settlement is complete
- Impact on the culverts being protected during construction must be addressed by an adequately designed and installed protection system
- Removal of peat, organics, soft soils and alluvial deposits near the creek channel
- Disturbance of the soil subgrade within the culvert and wingwall foundation footprints; inspection and approval is required
- All subgrade and foundation preparation works for the replacement culvert and any retaining walls must be done in the dry
- 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.

17 CLOSURE

Preparation of this foundation design report was carried out by Mr. Mark Farrant, P.Eng. The report was reviewed by Mr. Alastair Gorman, P.Eng. and Dr. P.K. Chatterji, P.Eng.

THURBER ENGINEERING LTD.

Mark Farrant, P.Eng.
Geotechnical Engineer



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Project Manager, Senior Foundations Engineer



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



Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction

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


4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

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

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

 Water Level
 Shear Strength Determination by Pocket Penetrometer

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

EXPLANATION OF ROCK LOGGING TERMS


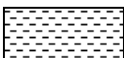



ROCK WEATHERING CLASSIFICATION

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

DISCONTINUITY SPACING

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

SYMBOLS

	CLAYSTONE
	SILTSTONE
	SANDSTONE
	COAL
	BEDROCK

STRENGTH CLASSIFICATION

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

TERMS

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

UNIFIED SOILS CLASSIFICATION

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

RECORD OF BOREHOLE No MR-01

1 OF 2

METRIC

GWP# 5032-14-00 LOCATION Margueratt Road Culvert N 5 296 315.0 E 405 041.6 ORIGINATED BY AHF
 HWY BOREHOLE TYPE Tripod COMPILED BY MFA
 DATUM Geodetic DATE 2015.06.25 - 2015.06.25 CHECKED BY MEF

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					
205.4	GROUND SURFACE												
0.0	TOPSOIL: (130mm)						○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	WATER CONTENT (%)					
0.1	Silty CLAY , some roots and rootlets, trace sand		1	SS	4								
204.7	Soft Brown												
0.7	Wet												
	SAND , trace silt, trace gravel, trace to some clay, occasional roots and rootlets		2	SS	5								
	Loose												
	Grey		3	SS	9								
	Wet												
			4	SS	6								
202.4													
3.0	Clayey SILT , sandy Very Soft Grey		5	SS	1								
201.3													
4.1	CLAY , some silt Firm Grey		6	SS	1								
			7	SS	1								
			8	SS	1								
			9	SS	1								

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

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(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No MR-01

2 OF 2

METRIC

GWP# 5032-14-00 LOCATION Margueratt Road Culvert N 5 296 315.0 E 405 041.6 ORIGINATED BY AHF
 HWY BOREHOLE TYPE Tripod COMPILED BY MFA
 DATUM Geodetic DATE 2015.06.25 - 2015.06.25 CHECKED BY MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE LIQUID CONTENT LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE								
	Continued From Previous Page							20	40	60	80	100	W _p	W	W _L	
193.2							195		6.5 +							
			10	SS	1										○	
							194		6.7 +							
12.2	END OF BOREHOLE AT 12.2m. BOREHOLE OPEN TO 10.2m AND WATER LEVEL AT 0.7m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.															

RECORD OF BOREHOLE No MR-02

1 OF 2

METRIC

GWP# 5032-14-00 LOCATION Margueratt Road Culvert N 5 296 315.1 E 405 051.1 ORIGINATED BY AHF
 HWY BOREHOLE TYPE Tripod COMPILED BY MFA
 DATUM Geodetic DATE 2015.06.24 - 2015.06.24 CHECKED BY MEF

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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE								
205.3	GROUND SURFACE															
0.0	SAND , some silt, some clay, trace gravel, occasional roots and rootlets Loose Grey Moist		1	SS	5		205									
			2	SS	4		204									0 70 18 12
	Compact Wet		3	SS	12		203									
203.1							203									
2.2	Clayey SILT , sandy Very Soft Grey		4	SS	2		202									0 38 32 30
			5	SS	1		201									
201.2							200									
4.1	CLAY , some silt Firm Grey		6	SS	1		199									0 0 18 82
			7	SS	1		198									
			8	SS	1		197									
			9	SS	0		196									

Continued Next Page

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 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No MR-02

2 OF 2

METRIC

GWP# 5032-14-00 LOCATION Margueratt Road Culvert N 5 296 315.1 E 405 051.1 ORIGINATED BY AHF
 HWY BOREHOLE TYPE Tripod COMPILED BY MFA
 DATUM Geodetic DATE 2015.06.24 - 2015.06.24 CHECKED BY MEF

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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					WATER CONTENT (%)				
							20	40	60	80	100	W _p	W	W _L			
	Continued From Previous Page																
			10	SS	1		195										
							194										
193.1																	
12.2	END OF BOREHOLE AT 12.2m. WATER LEVEL AT 0.7m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																

RECORD OF BOREHOLE No MR-03

1 OF 5

METRIC

GWP# 5032-14-00 LOCATION Margueratt Road Culvert N 5 296 306.7 E 405 051.4 ORIGINATED BY DJP
 HWY BOREHOLE TYPE Hollow Stem Augers/Casing/Dynamic Cone Penetration Test COMPILED BY MFA
 DATUM Geodetic DATE 2015.05.23 - 2015.05.25 CHECKED BY MEF

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 (%)					
								20 40 60 80 100	20 40 60	w _p w w _L					
						○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
207.1	GROUND SURFACE							20 40 60 80 100	20 40 60					GR SA SI CL	
0.0	SAND , trace to some gravel, trace organics Loose to Compact Brown Dry to Moist (FILL)		1	SS	4		207							0 68 20 12	
			2	SS	13		206								
205.7															
1.4	SILT , sandy to some sand, trace to some clay Compact Brown Moist to Wet (FILL)	3	SS	11		205									
204.8	sand layer (50mm) at 1.7m														
2.3	Silty SAND , some clay, trace gravel Loose Grey Wet to Moist (FILL) wood (350mm) at 3.3m	4	SS	2		204									
		5	SS	8								310			
203.0						203									
4.1	SAND , some silt Loose Grey Wet	6	SS	7		202									
201.5															
5.6	Silty CLAY Firm Grey		7	SS	0		201						0 0 21 79		
							200								
			8	SS	1		199								
							198								
			9	SS	0										

Continued Next Page

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

RECORD OF BOREHOLE No MR-03

2 OF 5

METRIC

GWP# 5032-14-00 LOCATION Margueratt Road Culvert N 5 296 306.7 E 405 051.4 ORIGINATED BY DJP
 HWY BOREHOLE TYPE Hollow Stem Augers/Casing/Dynamic Cone Penetration Test COMPILED BY MFA
 DATUM Geodetic DATE 2015.05.23 - 2015.05.25 CHECKED BY MEF

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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	W _p W W _L	WATER CONTENT (%)				
	Continued From Previous Page						197							
			10	SS	0		196	32						
							195							
			11	SS	0		194							
							193							
192.8			12	SS	0		193							0 0 41 59
14.3	End of sampling at 14.3m and start of DCPT.						192							
							191							
							190							
							189							
							188							

Continued Next Page

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

RECORD OF BOREHOLE No MR-03

3 OF 5

METRIC

GWP# 5032-14-00 LOCATION Margueratt Road Culvert N 5 296 306.7 E 405 051.4 ORIGINATED BY DJP
 HWY BOREHOLE TYPE Hollow Stem Augers/Casing/Dynamic Cone Penetration Test COMPILED BY MFA
 DATUM Geodetic DATE 2015.05.23 - 2015.05.25 CHECKED BY MEF

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			20 40 60 80 100	20 40 60	W _p W W _L				
	Continued From Previous Page						187							
							186							
							185							
							184							
							183							
							182							
							181							
							180							
							179							
							178							

Continued Next Page

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

RECORD OF BOREHOLE No MR-03

4 OF 5

METRIC

GWP# 5032-14-00 LOCATION Margueratt Road Culvert N 5 296 306.7 E 405 051.4 ORIGINATED BY DJP
 HWY BOREHOLE TYPE Hollow Stem Augers/Casing/Dynamic Cone Penetration Test COMPILED BY MFA
 DATUM Geodetic DATE 2015.05.23 - 2015.05.25 CHECKED BY MEF

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						177							
							176							
							175							
							174							
							173							
							172							
							171							
							170							
							169							
							168							

Continued Next Page

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

RECORD OF BOREHOLE No MR-03

5 OF 5

METRIC

GWP# 5032-14-00 LOCATION Margueratt Road Culvert N 5 296 306.7 E 405 051.4 ORIGINATED BY DJP
 HWY BOREHOLE TYPE Hollow Stem Augers/Casing/Dynamic Cone Penetration Test COMPILED BY MFA
 DATUM Geodetic DATE 2015.05.23 - 2015.05.25 CHECKED BY MEF

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						167	20	40	60	80	100					
							166										
							165										
							164										
							163										
							162										
161.4																	
45.7	END OF BOREHOLE AND DCPT AT 45.7m. WATER LEVEL AT 11.3m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																

ONTMT4S 19-5161-252.GPJ 2015TEMPLATE(MTO).GDT 10/22/15

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No MR-04

2 OF 2

METRIC

GWP# 5032-14-00 LOCATION Margueratt Road Culvert N 5 296 299.7 E 405 041.1 ORIGINATED BY DJP
 HWY BOREHOLE TYPE Casing/Hollow Stem Augers/Dynamic Cone Penetration Test COMPILED BY MFA
 DATUM Geodetic DATE 2015.05.25 - 2015.05.25 CHECKED BY MEF

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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
	Continued From Previous Page																
	occasional silt seams		9	SS	0		196										
								195									
			10	SS	0			194	53								
192.6			11	SS	0			193									
14.3	End of sampling at 14.3m and start of DCPT. All DCPT resistances recorded as 0 blows/0.3m.						192										
							191										
							190										
189.5																	
17.4	END OF BOREHOLE AND DCPT AT 17.4m. WATER LEVEL AT 2.4m UPON COMPLETION.																





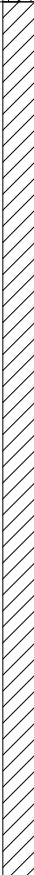
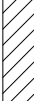
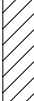
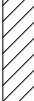
+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No MR-05

1 OF 2

METRIC

GWP# 5032-14-00 LOCATION Margueratt Road Culvert N 5 296 291.8 E 405 052.4 ORIGINATED BY AHF
 HWY BOREHOLE TYPE Tripod COMPILED BY MFA
 DATUM Geodetic DATE 2015.06.25 - 2015.06.26 CHECKED BY MEF

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											
205.7	GROUND SURFACE							20	40	60	80	100							
0.0	TOPSOIL: (150mm)																		
0.2	Silty SAND , some clay, occasional roots and rootlets Very Loose Brown to Grey Moist Loose Wet		1	SS	0		205										0 56 29 15		
			2	SS	5														
204	trace gravel		3	SS	3			204											
203.5	Clayey SILT , some sand Soft to Very Soft Grey		4	SS	3				203										0 19 60 21
			5	SS	1														
201.6	CLAY , some silt Firm Grey									202									
			6	SS	1														
197	6.7					197													
			7	SS	1														
198	7.0						198												
			8	SS	0														
196	6.0							196											
			9	SS	1														

Continued Next Page

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

RECORD OF BOREHOLE No MR-05

2 OF 2

METRIC

GWP# 5032-14-00 LOCATION Margueratt Road Culvert N 5 296 291.8 E 405 052.4 ORIGINATED BY AHF
 HWY BOREHOLE TYPE Tripod COMPILED BY MFA
 DATUM Geodetic DATE 2015.06.25 - 2015.06.26 CHECKED BY MEF

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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
	Continued From Previous Page																
			10	SS	1		195										
							194										
193.5																	
12.2	END OF BOREHOLE AT 12.2m. BOREHOLE OPEN TO 9.0m AND WATER LEVEL AT 0.4m UPON COMPLETION.																

RECORD OF BOREHOLE No MR-06

1 OF 2

METRIC

GWP# 5032-14-00 LOCATION Margueratt Road Culvert N 5 296 292.1 E 405 041.7 ORIGINATED BY AHF
 HWY BOREHOLE TYPE Tripod COMPILED BY MFA
 DATUM Geodetic DATE 2015.06.23 - 2015.06.23 CHECKED BY MEF

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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%) w _P w w _L				GR	SA	SI	CL
205.3	GROUND SURFACE							20	40	60	80	100							
0.0	Silty SAND , trace gravel, trace clay, occasional roots and rootlets Loose Brown Moist Very Loose		1	SS	4		205								○				
			2	SS	2		204								○				
	becoming trace silt becoming Grey Wet		3	SS	9										○				1 91 8 (SI+CL)
202.9							203								○				
2.4	Clayey SILT , sandy Stiff to Very Soft Grey		4	SS	9										○				
			5	SS	1		202								○				0 34 47 19
201.2																			
4.1	CLAY , some silt Firm Grey		6	SS	1		201			4.7 +									
							200			4.5 +									
			7	SS	1	199									○				
						198			6.5 +										
			8	SS	0										○				
						197			4.7 +										
			9	SS	1	196								○					

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No MR-06

2 OF 2

METRIC

GWP# 5032-14-00 LOCATION Margueratt Road Culvert N 5 296 292.1 E 405 041.7 ORIGINATED BY AHF
 HWY BOREHOLE TYPE Tripod COMPILED BY MFA
 DATUM Geodetic DATE 2015.06.23 - 2015.06.23 CHECKED BY MEF

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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
	Continued From Previous Page																
	silty						195										
			10	SS	1												
193.1							194										
12.2	END OF BOREHOLE AT 12.2m. BOREHOLE OPEN TO 9.9m AND WATER LEVEL AT 0.8m UPON COMPLETION.																

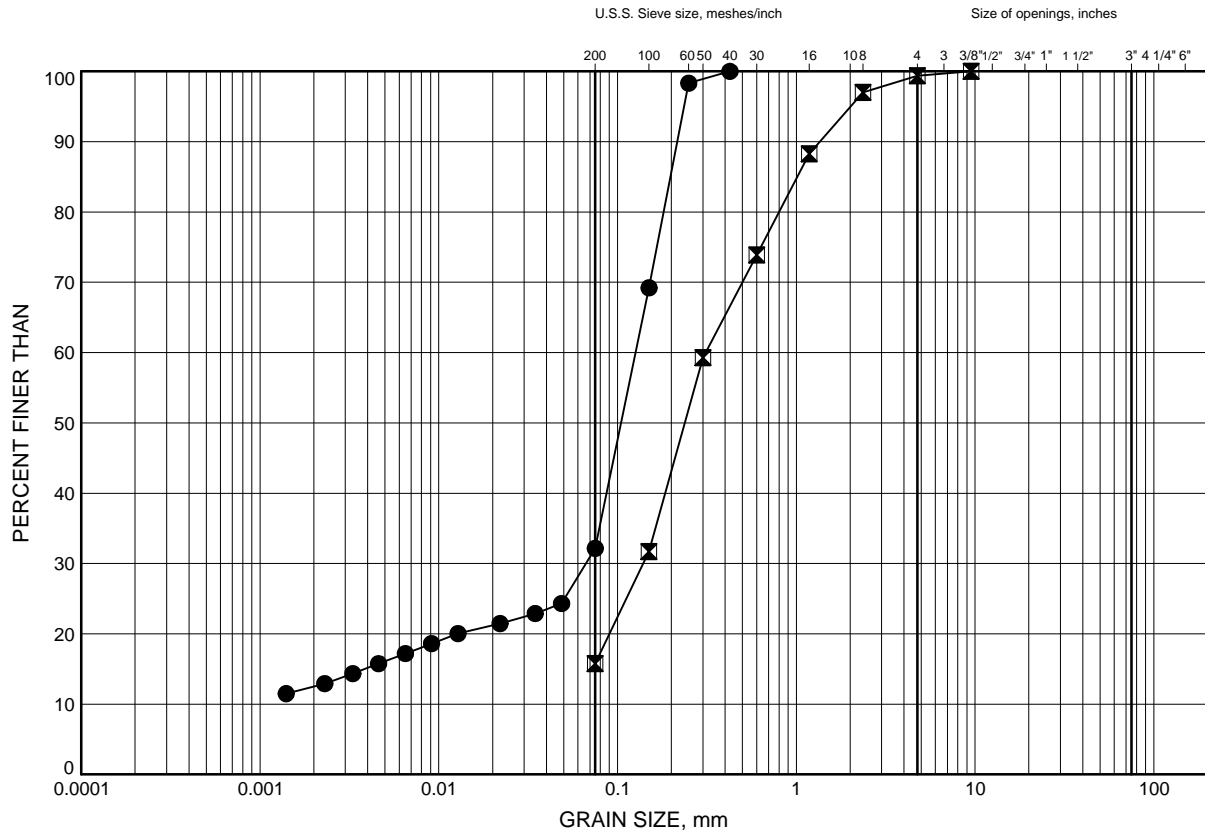
Appendix B

Geotechnical and Analytical Laboratory Test Results

Margueratt Road Culvert
GRAIN SIZE DISTRIBUTION

FIGURE B1

Embankment FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MR-03	2.62	204.48
⊠	MR-04	2.59	204.31

Date ..October 2015.....
GWP# ..5032-14-00.....

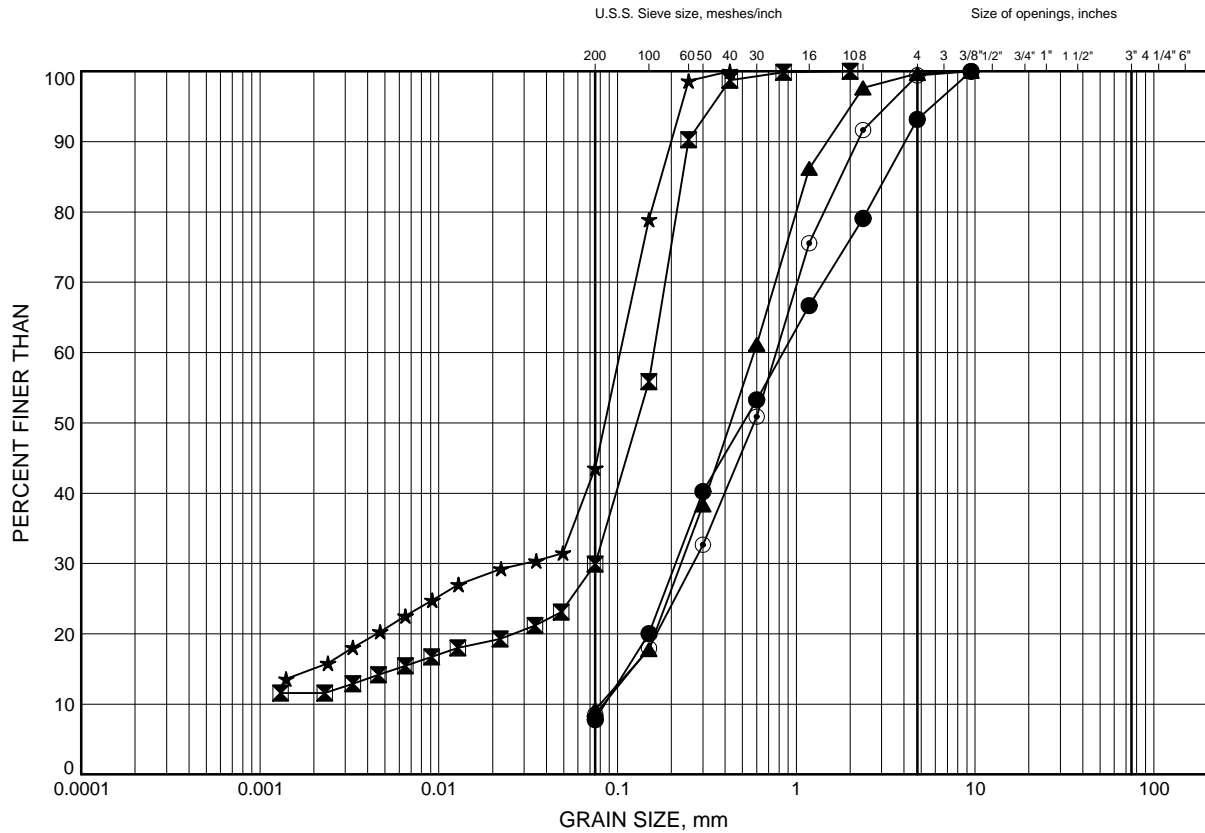


Prep'dAN.....
Chkd.AMP.....

Margueratt Road Culvert GRAIN SIZE DISTRIBUTION

FIGURE B2

Silty SAND to SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MR-01	1.83	203.57
⊠	MR-02	1.07	204.23
▲	MR-03	4.88	202.22
★	MR-05	0.30	205.40
⊙	MR-06	1.83	203.47

Date ..October 2015.....

GWP# ..5032-14-00.....



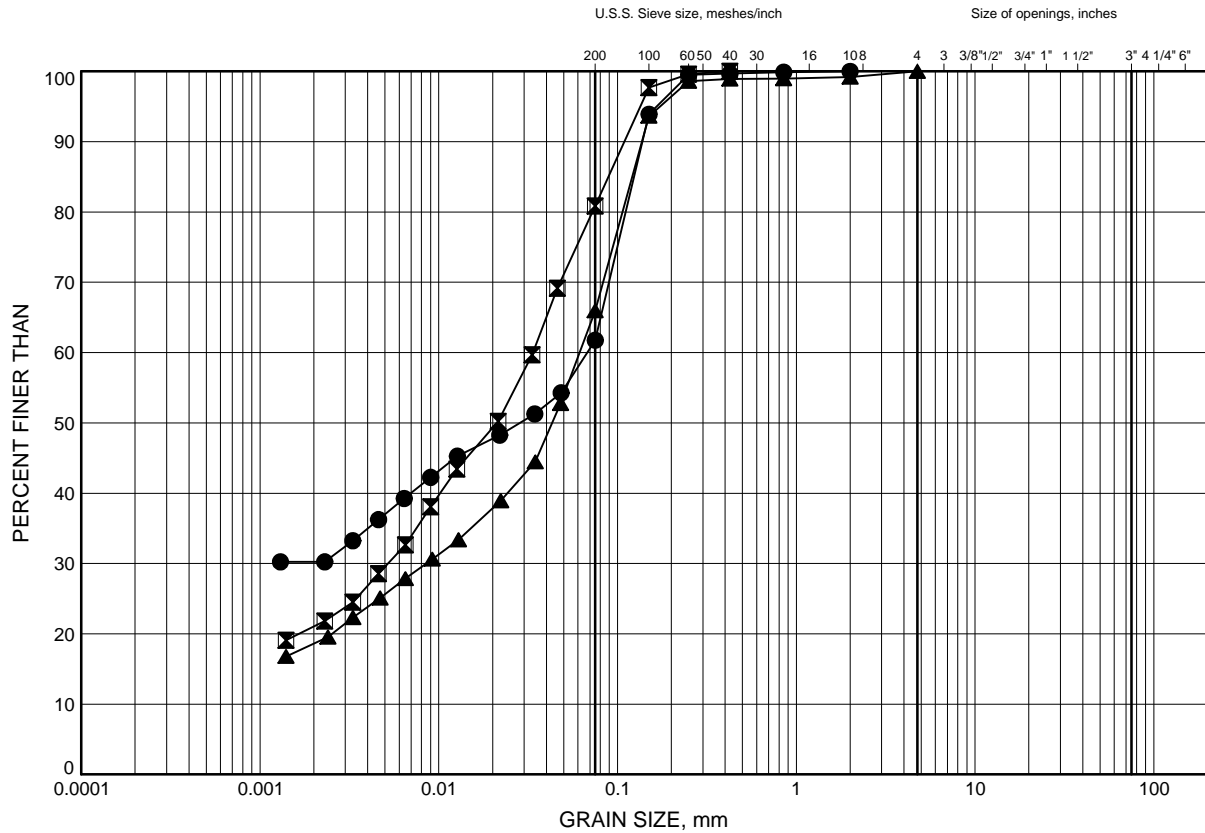
Prep'dAN.....

Chkd.AMP.....

Margueratt Road Culvert GRAIN SIZE DISTRIBUTION

FIGURE B3

Clayey SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MR-02	3.35	201.95
⊠	MR-05	2.59	203.11
▲	MR-06	3.35	201.95

Date ..October 2015.....

GWP# ..5032-14-00.....

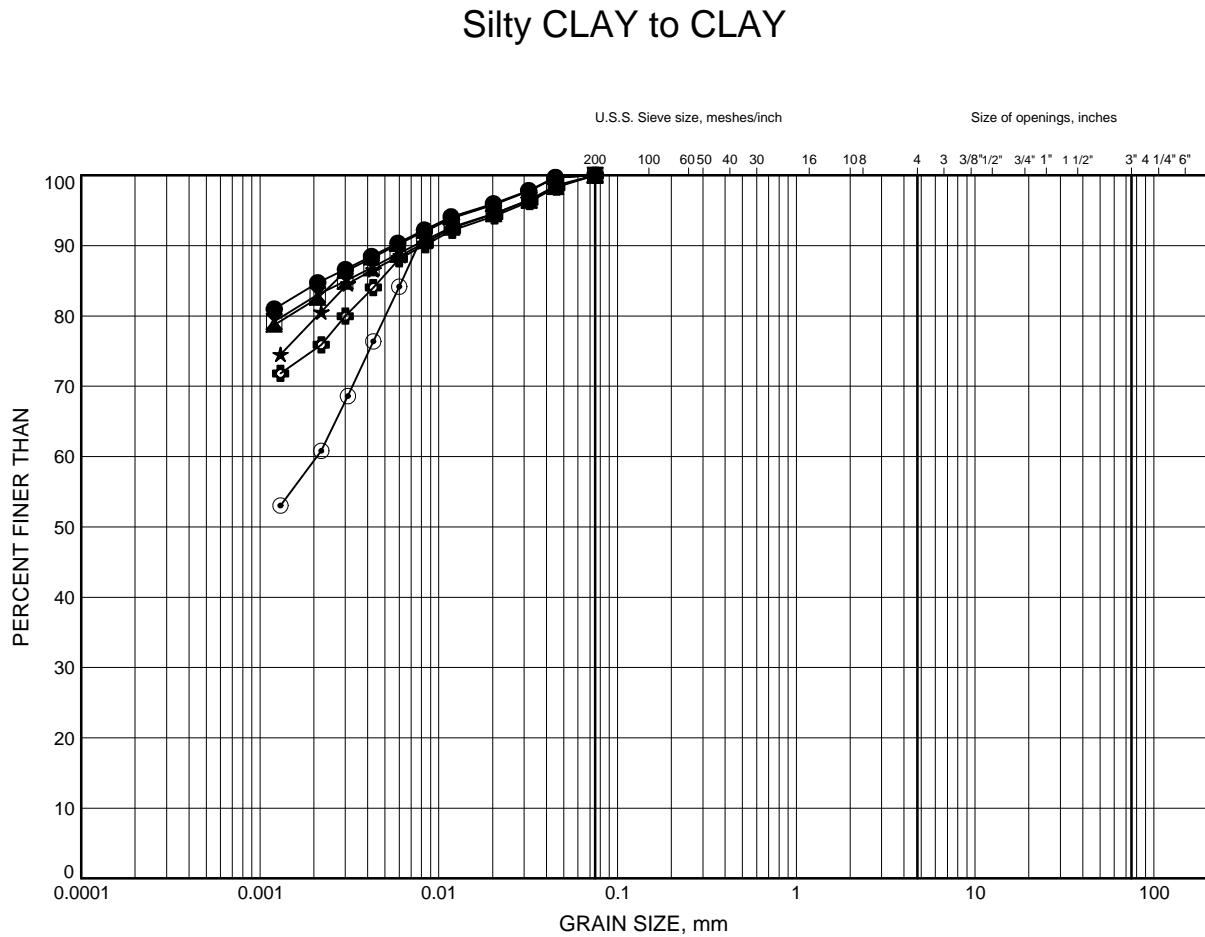


Prep'dAN.....

Chkd.AMP.....

Margueratt Road Culvert GRAIN SIZE DISTRIBUTION

FIGURE B4



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MR-01	4.88	200.52
⊠	MR-01	9.45	195.95
▲	MR-02	6.40	198.90
★	MR-03	7.92	199.18
⊙	MR-03	14.02	193.08
⊕	MR-04	7.92	198.98

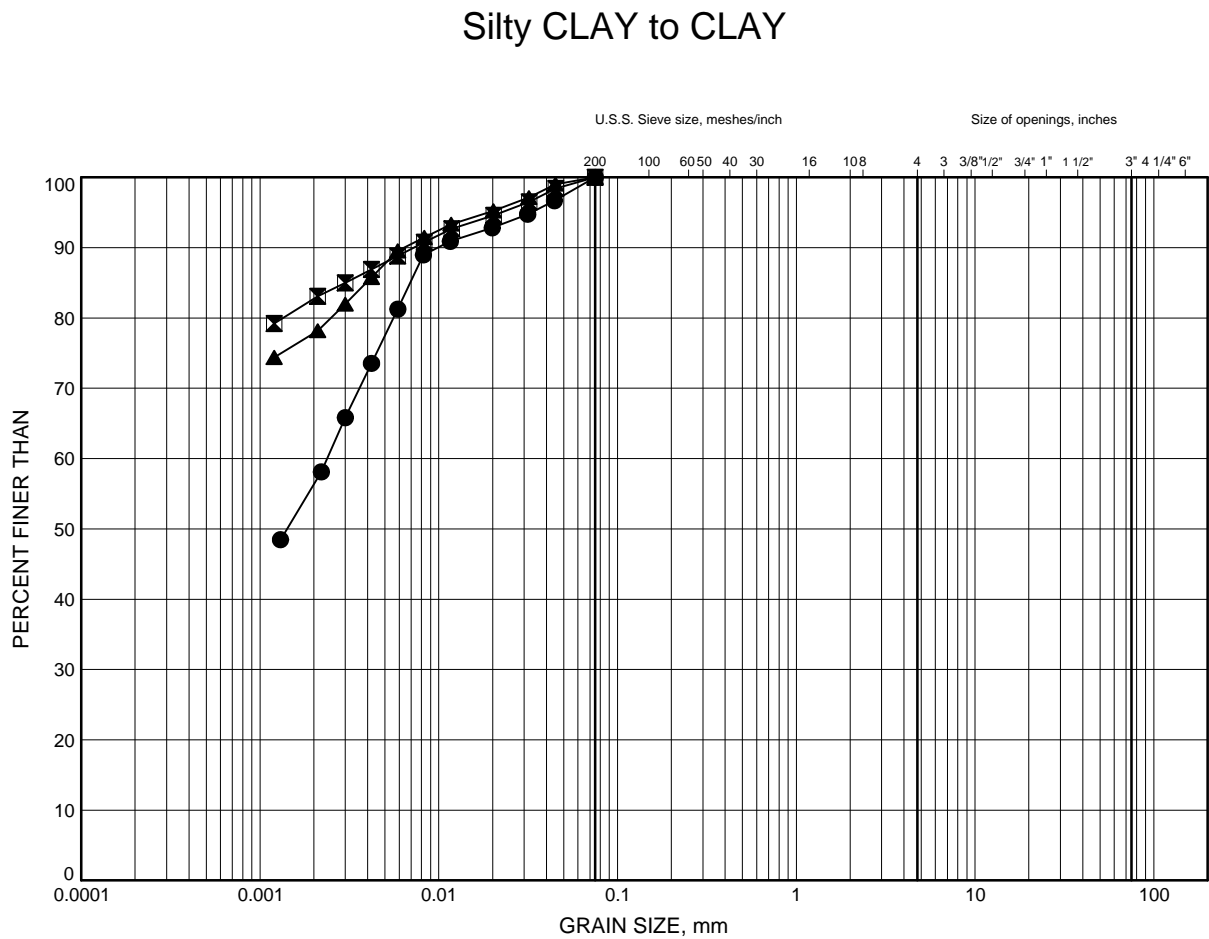
Date October 2015
GWP# 5032-14-00



Prep'd AN
Chkd. AMP

Margueratt Road Culvert
GRAIN SIZE DISTRIBUTION

FIGURE B5



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MR-04	14.02	192.88
⊠	MR-05	7.92	197.78
▲	MR-06	10.97	194.33

Date ..October 2015.....
GWP# ..5032-14-00.....

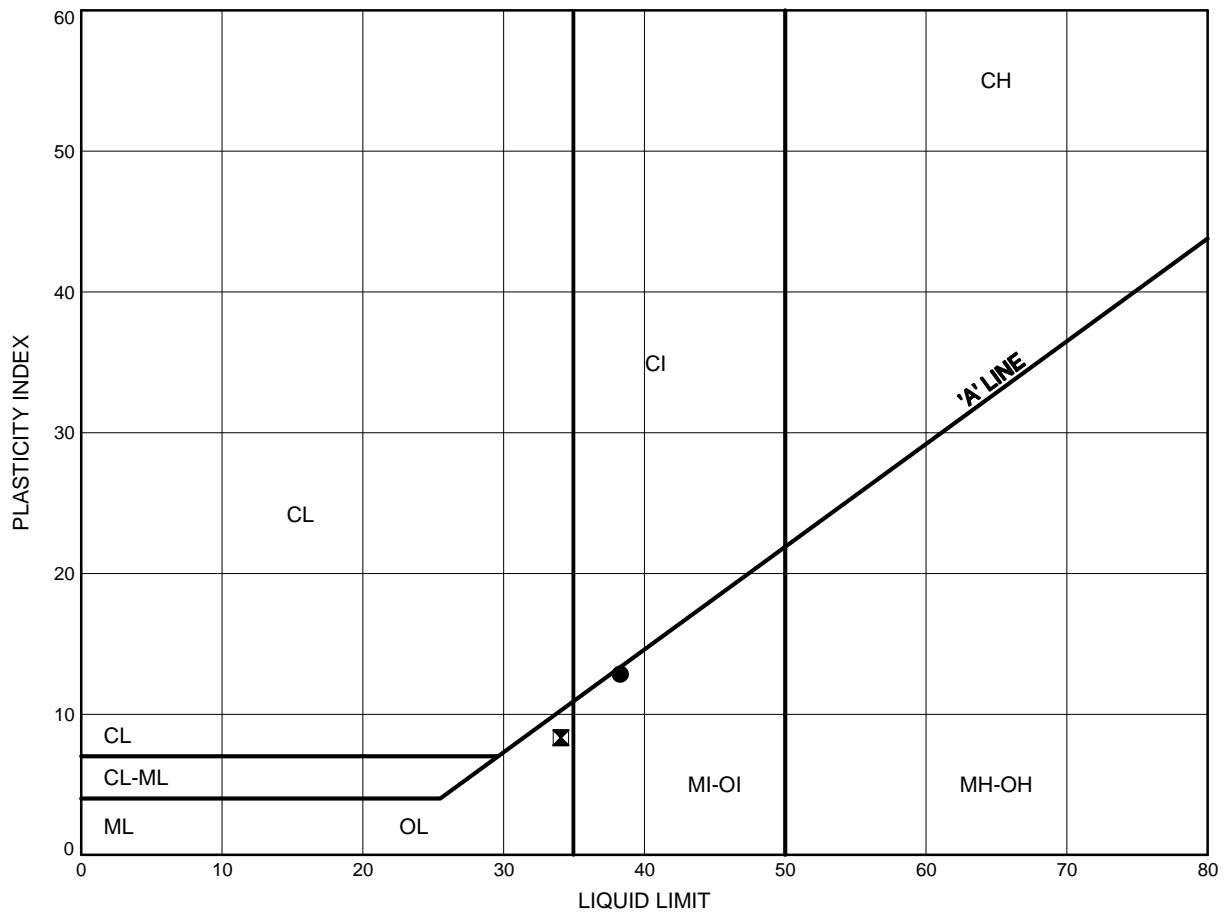


Prep'dAN.....
Chkd.AMP.....

Margueratt Road Culvert
ATTERBERG LIMITS TEST RESULTS

FIGURE B6

Clayey SILT



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MR-02	3.35	201.95
⊠	MR-06	3.35	201.95

Date October 2015
 GWP# 5032-14-00

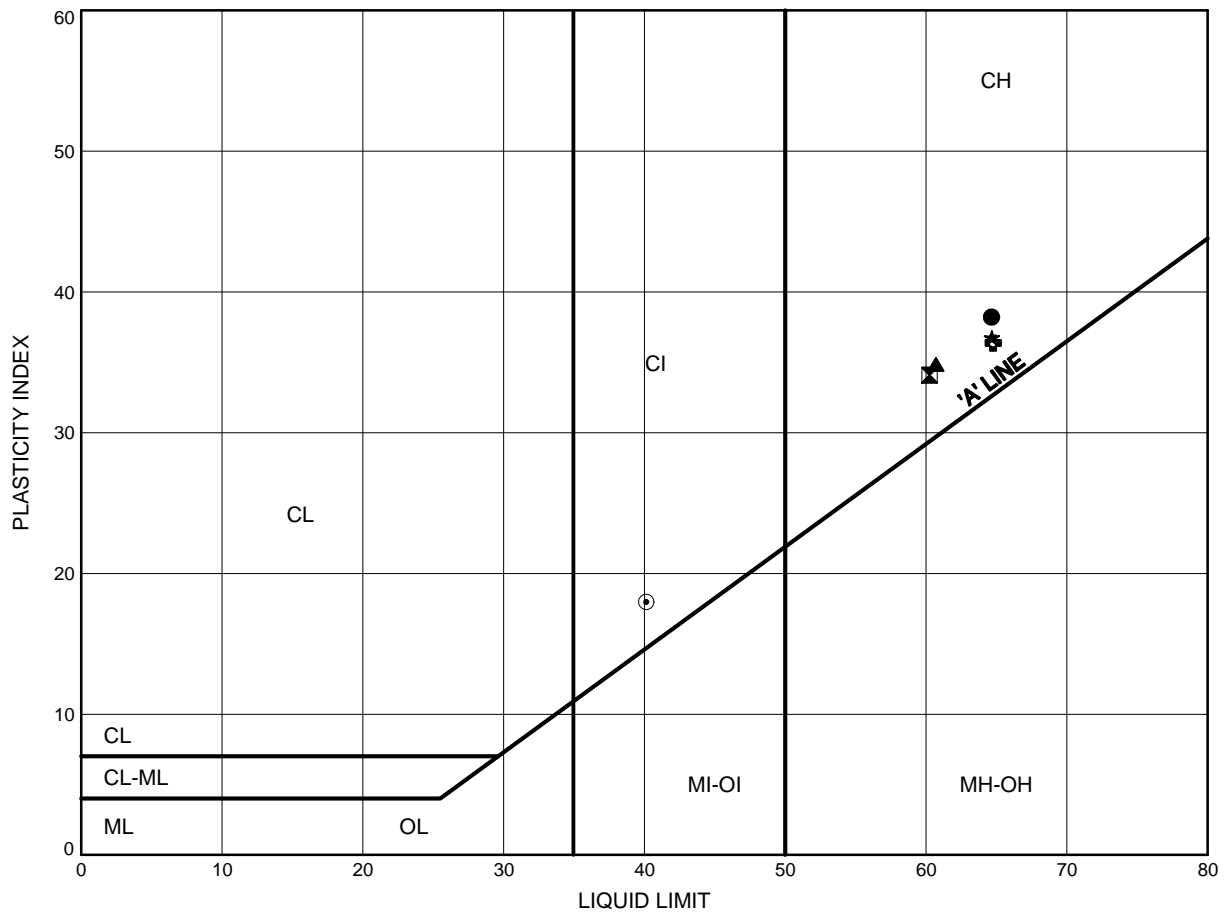


Prep'd AN
 Chkd. AMP

Margueratt Road Culvert
ATTERBERG LIMITS TEST RESULTS

FIGURE B7

Silty CLAY to CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MR-01	4.88	200.52
⊠	MR-01	9.45	195.95
▲	MR-02	6.40	198.90
★	MR-03	7.92	199.18
⊙	MR-03	14.02	193.08
⊕	MR-04	7.92	198.98

Date ..October 2015.....
 GWP# ..5032-14-00.....

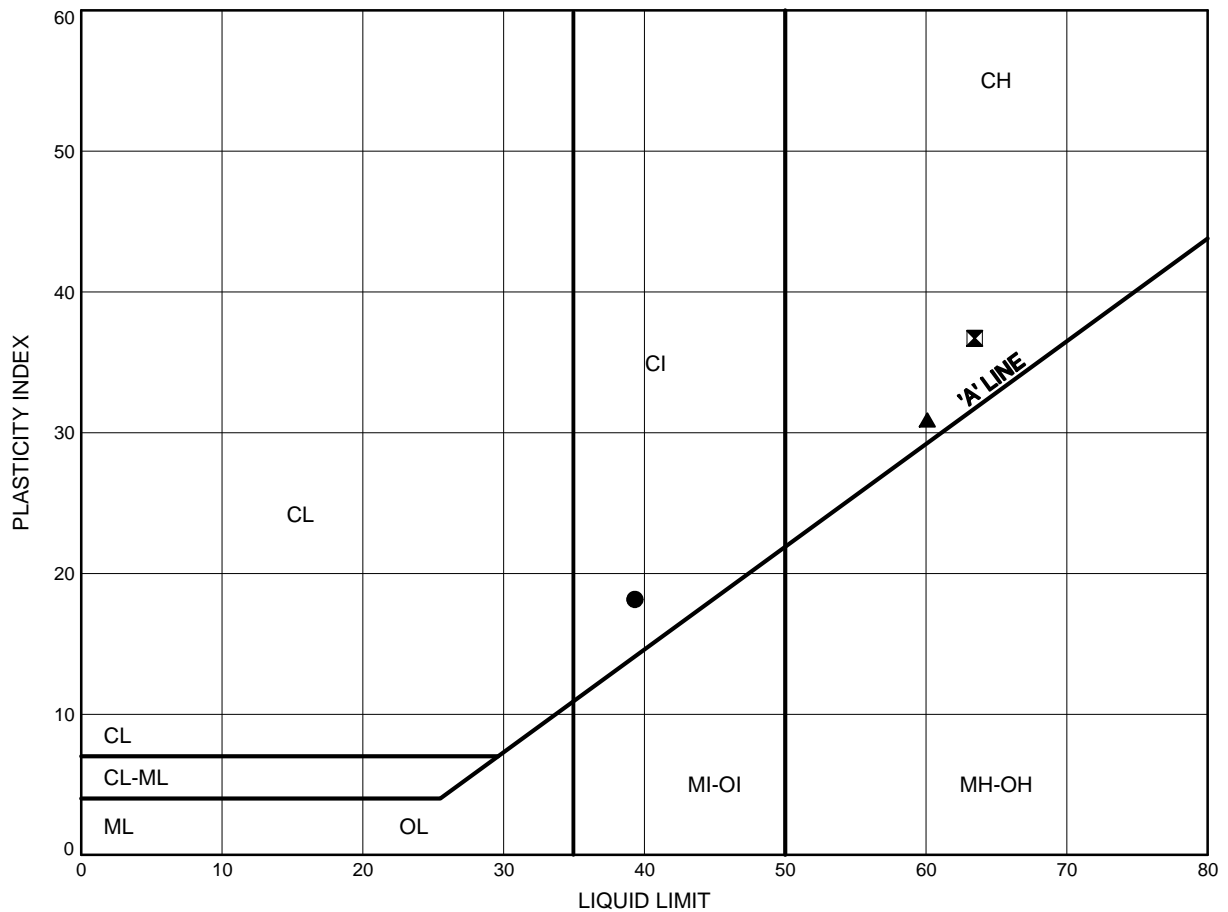


Prep'dAN.....
 Chkd.AMP.....

Margueratt Road Culvert
ATTERBERG LIMITS TEST RESULTS

FIGURE B8

Silty CLAY to CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MR-04	14.02	192.88
⊠	MR-05	7.92	197.78
▲	MR-06	10.97	194.33

Date October 2015
 GWP# 5032-14-00



Prep'd AN
 Chkd. AMP

Certificate of Analysis

CLIENT NAME: THURBER ENGINEERING LTD

PROJECT: 19-5161-252

SAMPLING SITE:

AGAT WORK ORDER: 15T980955

ATTENTION TO: MARK FARRANT

SAMPLED BY:

Corrosivity Package							
SAMPLE TYPE: Soil		SAMPLE ID: 6615973			DATE RECEIVED: Jun 04, 2015		
DATE SAMPLED: May 23, 2015				DATE REPORTED: Jun 09, 2015			
SAMPLE DESCRIPTION: MR-3 SS3/4A 5'-7'8"							
PARAMETER	UNIT	RESULT	G / S	RDL	DATE ANALYZED	INITIAL	DATE PREPARED
Sulfide	%	0.01		0.01	Jun 09, 2015	FM	Jun 08, 2015
Chloride (2:1)	µg/g	9		2	Jun 09, 2015	WZ	Jun 09, 2015
Sulphate (2:1)	µg/g	6		2	Jun 09, 2015	WZ	Jun 09, 2015
pH (2:1)	pH Units	6.87		NA		BG	Jun 09, 2015
Electrical Conductivity (2:1)	mS/cm	0.083		0.005	Jun 09, 2015	TM	Jun 09, 2015
Resistivity (2:1)	ohm.cm	12000		1	Jun 09, 2015	SYS	Jun 09, 2015
Redox Potential (2:1)	mV	338		5	Jun 09, 2015	TM	Jun 09, 2015

COMMENTS:

RDL - Reported Detection Limit; G / S - Guideline / Standard
* Sulphide analysis was performed at AGAT Laboratories Vancouver.

EC/Resistivity, pH, Chloride, Sulphate and Redox Potential were determined on the extract obtained from the 2:1 leaching procedure (2 parts DI water: 1 part soil).

Certified By:



Certificate of Analysis

CLIENT NAME: THURBER ENGINEERING LTD

PROJECT: 19-5161-252

SAMPLING SITE:

AGAT WORK ORDER: 15T990314

ATTENTION TO: MARK FARRANT

SAMPLED BY:

Inorganic Chemistry (Water)							
SAMPLE TYPE: Water		SAMPLE ID: 6698925			DATE RECEIVED: Jun 29, 2015		
DATE SAMPLED: Jun 26, 2015				DATE REPORTED: Jul 07, 2015			
SAMPLE DESCRIPTION: Margueratt Road Culvert							
PARAMETER	UNIT	RESULT	G / S	RDL	DATE ANALYZED	INITIAL	DATE PREPARED
Electrical Conductivity	uS/cm	49		2	Jul 03, 2015	JC	Jul 03, 2015
pH	pH Units	6.87		NA	Jul 03, 2015	JC	Jul 03, 2015
Langelier Index		-2.06			Jul 06, 2015	SYS	Jul 06, 2015
Total Hardness (as CaCO3)	mg/L	25.4		0.5	Jul 03, 2015	SYS	Jul 03, 2015
Total Dissolved Solids	mg/L	40		20	Jul 06, 2015	AP	Jul 03, 2015
Alkalinity (as CaCO3)	mg/L	23		5	Jul 03, 2015	JC	Jul 03, 2015
Chloride	mg/L	0.27		0.10	Jul 03, 2015	WZ	Jul 03, 2015
Sulphate	mg/L	1.99		0.10	Jul 03, 2015	WZ	Jul 03, 2015
Calcium	mg/L	6.18		0.05	Jul 03, 2015	PB	Jul 03, 2015
Magnesium	mg/L	2.42		0.05	Jul 03, 2015	PB	Jul 03, 2015
Resistivity	ohms.cm	20400			Jul 03, 2015	SYS	Jul 03, 2015
Sulphide	mg/L	<0.05		0.05	Jul 02, 2015	SN	Jul 02, 2015
Redox Potential	mV	324		5	Jul 06, 2015	BG	Jul 06, 2015

COMMENTS:

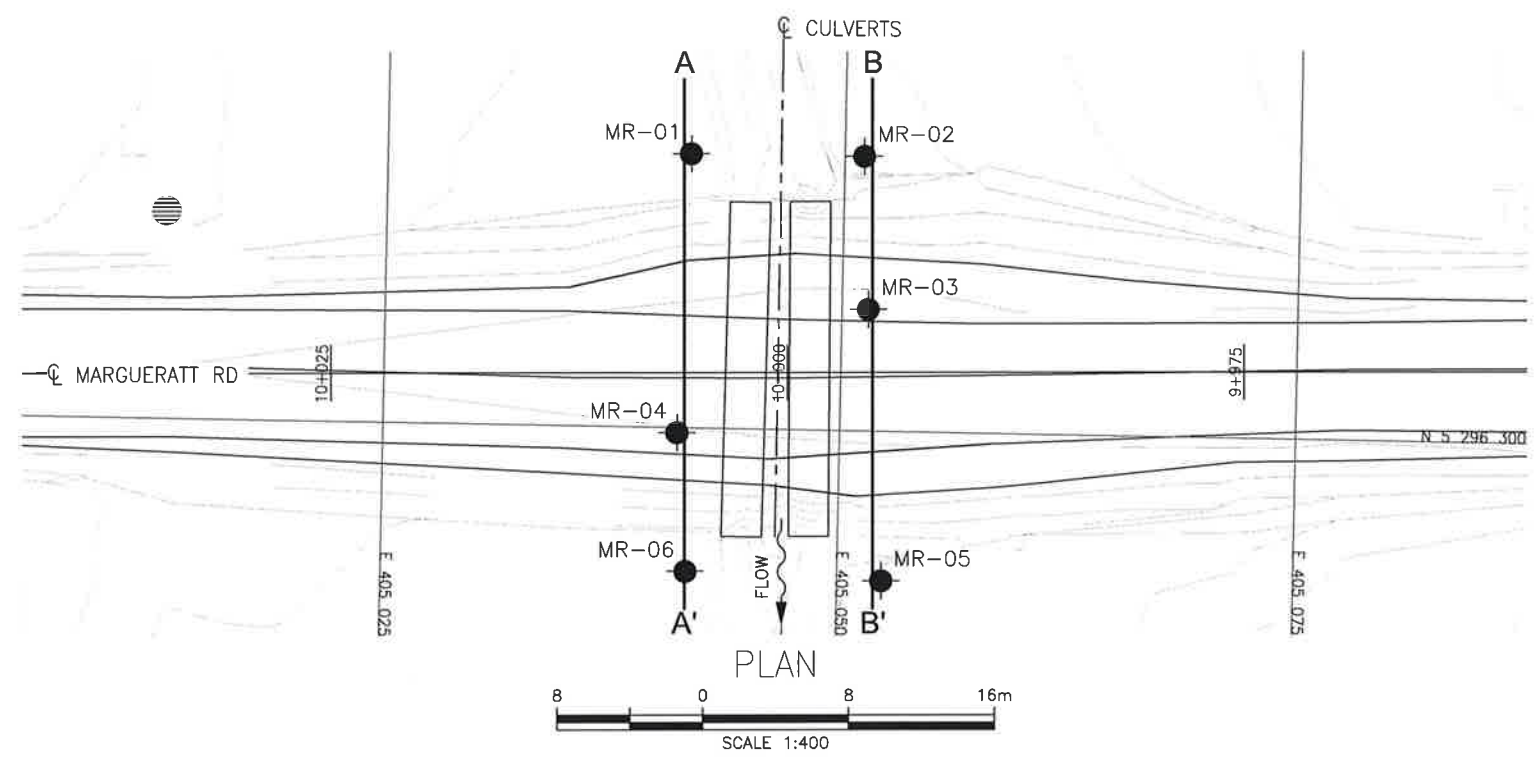
RDL - Reported Detection Limit; G / S - Guideline / Standard

Certified By:



Appendix C

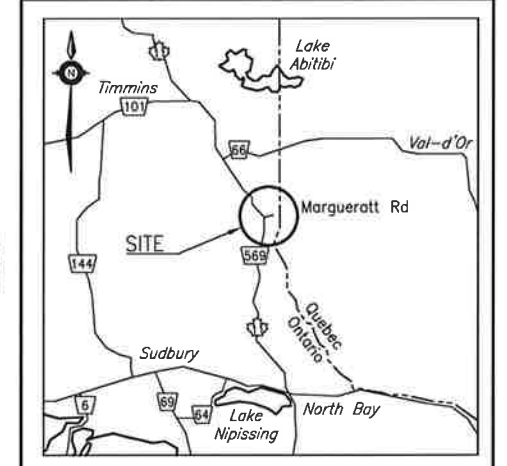
Borehole Locations and Soil Strata Drawings



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



CONT No GWP No 5032-14-00	SHEET
MARGUERATT ROAD CULVERT REPLACEMENT BOREHOLE LOCATIONS AND SOIL STRATA	



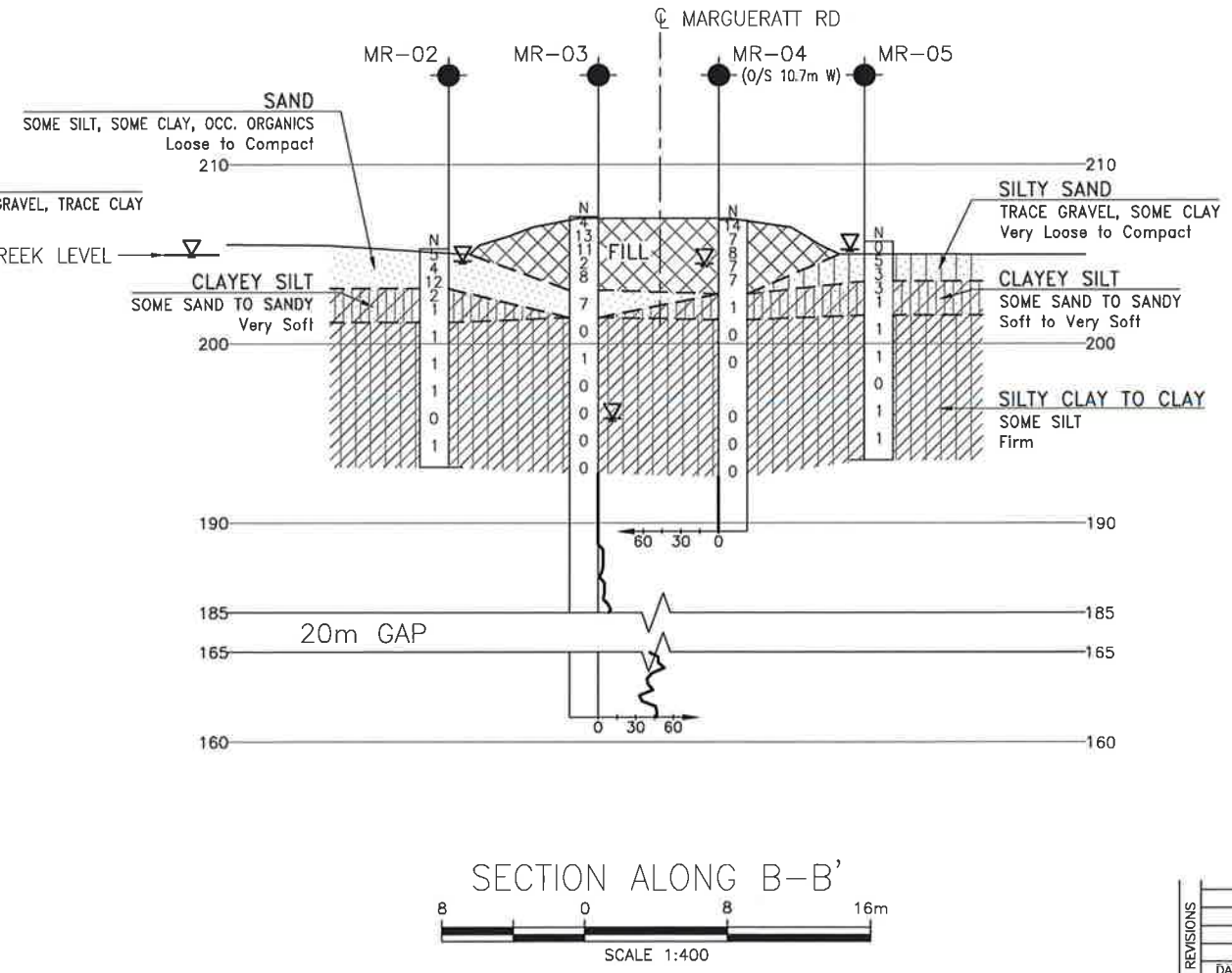
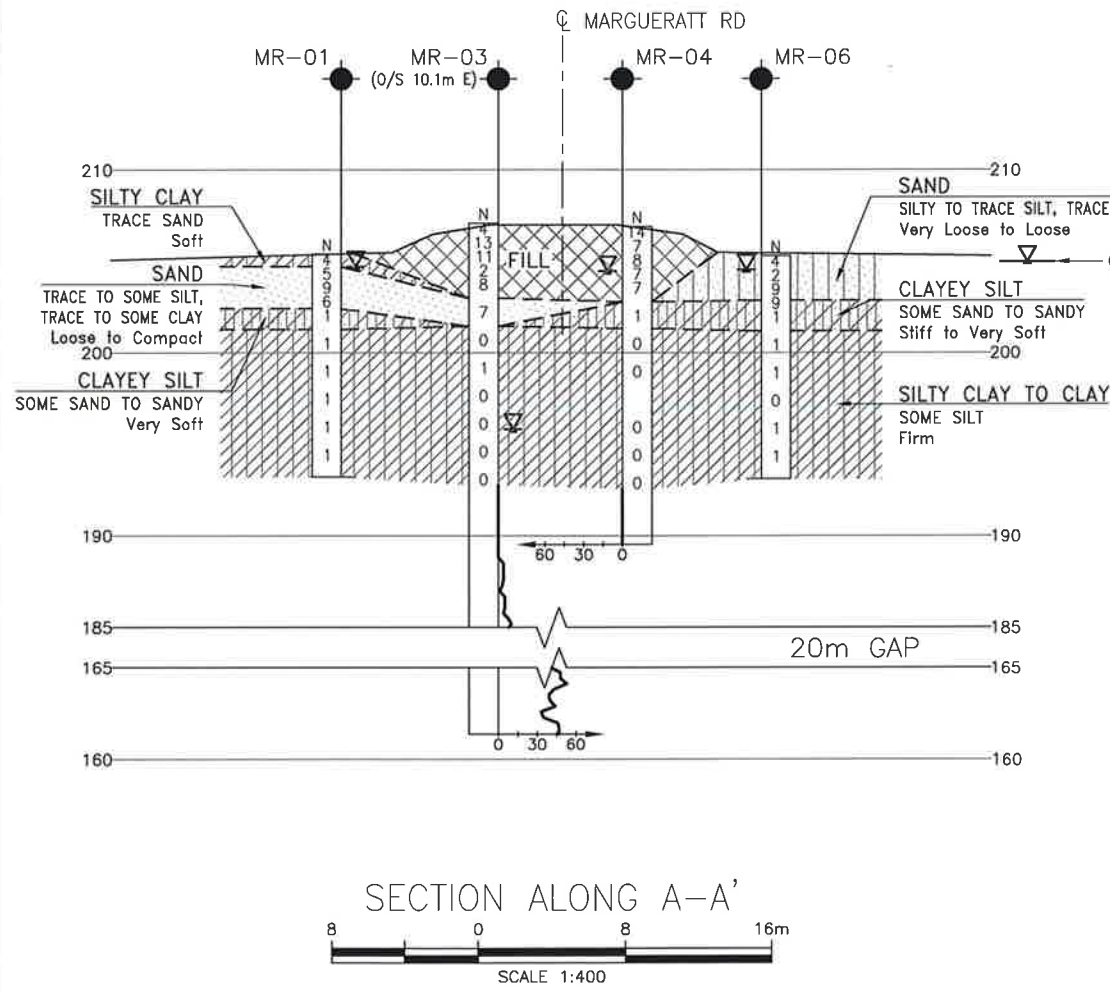
LEGEND

●	Borehole
⊕	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
▽	Water Level
⊕	Head Artesian Water
⊕	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
MR-01	205.4	5 296 315.1	405 041.6
MR-02	205.3	5 296 315.1	405 051.1
MR-03	207.1	5 296 306.7	405 051.4
MR-04	206.9	5 296 299.7	405 041.1
MR-05	205.7	5 296 291.8	405 052.4
MR-06	205.3	5 296 292.1	405 041.7

- 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. 31M-110



REVISIONS	DATE	BY	DESCRIPTION
DESIGN	DJP	CHK MEF	CODE
DRAWN	MFA	CHK DJP	SITE 47-343/C/STRUCT
DATE	OCT 2015		DWG 1

Appendix D

Foundation Alternatives Comparisons

COMPARISON OF ALTERNATIVE CULVERT TYPES

Proposed Works	Concrete Box (Closed) Culvert	Concrete Open Footing Culvert	Twin Corrugated Steel Pipes or Steel Pipe Arch Culvert
Culvert Replacement	<p><i>Advantages:</i></p> <ul style="list-style-type: none"> i. Relatively rapid installation and less disturbance to subgrade soils if precast units are used. ii. Less requirement for soil geotechnical resistances as loading is spread over a larger width. <p><i>Disadvantages:</i></p> <ul style="list-style-type: none"> i. More expensive than CSP or CSPA alternatives. 	<p><i>Advantages:</i></p> <ul style="list-style-type: none"> i. Relatively rapid installation if precast units are used. ii. May have less environmental issues such as those involving spawning fish species. <p><i>Disadvantages:</i></p> <ul style="list-style-type: none"> i. Requires higher soil geotechnical resistances to support strip footings. ii. Requires deeper excavation for strip footing construction. iii. Potentially more difficult unwatering requirements. 	<p><i>Advantages:</i></p> <ul style="list-style-type: none"> i. Steel pipes or pipe arches may be more cost effective than concrete box or open footing culverts. <p><i>Disadvantages:</i></p> <ul style="list-style-type: none"> i. May require grade raise to provide sufficient cover above the culvert

RECOMMENDED

NOT RECOMMENDED

RECOMMENDED

Appendix E

List of OPS Specifications

1. List of OPSS Documents Relevant this Project

- OPSS 206
- OPSS 209
- OPSS 404
- OPSS 422
- OPSS 501
- OPSS 517
- OPSS 518
- OPSS 539
- OPSS 804
- OPSS 902
- OPSS 1010
- OPSS 1205
- OPSD 803.01
- OPSD 810.01

Appendix F

Selected Photographs of Culvert Location

Margueratt Road Culvert Replacement
Margueratt Road, Site No. 47-343



Photo 1: Margueratt Road Culvert Inlet



Photo 2: Margueratt Road Culvert Outlet

Margueratt Road Culvert Replacement
Margueratt Road, Site No. 47-343



Photo 3: Erosion of Watercourse at North East Inlet



Photo 4: Beaver Dam at North East Inlet



Photo 5: Road Surface Looking West