

**FOUNDATION INVESTIGATION AND DESIGN REPORT
LAWRENCE WAY CULVERT REPLACEMENT
NEW LISKEARD DISTRICT, ONTARIO**

G.W.P. No. 5029-14-00, SITE NO. 47-342/C

GEOCRES Number: 31M-111

Report to

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TABLE OF CONTENTS

SECTION	PAGE
PART 1 FACTUAL INFORMATION	
1 INTRODUCTION	1
2 SITE DESCRIPTION.....	1
3 SITE INVESTIGATION AND FIELD TESTING	2
4 LABORATORY TESTING	3
5 DESCRIPTION OF SUBSURFACE CONDITIONS	3
5.1 General.....	3
5.2 Fill.....	4
5.3 Peat	4
5.4 Silty Clay	4
5.5 Silt.....	5
5.6 Sand to Sand and Gravel.....	6
5.7 Groundwater Conditions.....	6
6 CORROSIVITY AND SULPHATE TEST RESULTS	7
7 MISCELLANEOUS.....	8
PART 2 ENGINEERING DISCUSSION AND RECOMMENDATIONS	
8 GENERAL	9
9 CULVERT FOUNDATIONS	9
9.1 General.....	9
9.2 Foundation Alternatives.....	10
9.3 Foundation Design for Culverts.....	10
9.3.1 Concrete Box Culvert.....	10
9.3.2 Corrugated Steel Pipe (Circular) or Steel Pipe Arch Culvert.....	11
9.3.3 Retaining Walls	12
9.3.4 Settlements	13
9.3.5 Subgrade Preparation	14
9.4 Construction Considerations.....	14
10 CULVERT BACKFILL AND LATERAL EARTH PRESSURES	14
11 EMBANKMENT DESIGN AND CONSTRUCTION	16
12 EROSION CONTROL.....	16
13 EXCAVATION AND GROUNDWATER CONTROL	17
13.1 General.....	17

13.2 Foundations..... 17

13.3 Excavations..... 17

13.4 Groundwater Control..... 17

14 ROADWAY PROTECTION DESIGN..... 17

15 CORROSION AND SULPHATE ATTACK POTENTIAL..... 18

16 CONSTRUCTION CONCERNS..... 18

17 CLOSURE..... 19

Appendices

Appendix A	Record of Borehole Sheets
Appendix B	Geotechnical and Analytical Laboratory Test Results
Appendix C	Borehole Locations and Soil Strata Drawings
Appendix D	Foundation Alternatives Comparison
Appendix E	List of OPS Specifications
Appendix F	Selected Photographs of Culvert Location

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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 Lawrence Way (Ingram Concession Road 5) 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 a borehole location plan, stratigraphic profile, 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 Lawrence Way (Ingram Concession Road 5), 6.7 km north 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 Lawrence Way.

The existing structure is a 21.3 m long, 3.3 m diameter corrugated steel pipe (CSP) culvert, with approximately 0.3 m of fill above the culvert. The structure was constructed in 1968. It is understood that the structure is in fair condition with minor deterioration of several elements with more significant deterioration of the structural steel coatings. The culvert is proposed for full replacement.

Lawrence Way is a 2-lane gravel road with a grade level at the existing culvert at approximate Elevation 231 m.

The site is located approximately 18 km east of Englehart with residential and agricultural properties nearby. An access driveway leading to a property on the northeast side of the culvert is located adjacent to the road embankment. Naturally low-lying, swampy areas are present near the inlet and outlet of the culvert, with vegetation consisting of tall grass and shrubs with occasional trees. Local topography is of low relief with no visible bedrock outcrops. Areas surrounding the properties are heavily forested. The area in the immediate vicinity of the culvert is undulating and generally sloping downwards from the highway grade to the creek.

Based on published geological information, the general area of the project is covered by glaciolacustrine deposits of clays and silts deposited during the Pleisocene period. These deposits are mostly varved clays. 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 Middle Precambrian mafic intrusive bedrock.

3 SITE INVESTIGATION AND FIELD TESTING

This borehole investigation and field testing program was carried out between May 21 and May 23, 2015. The program consisted of drilling and sampling 4 boreholes (numbered SL-01 to SL-04) to depths ranging from 9.4 to 12.8 m. Of these boreholes, one was located near the culvert inlet (SL-01), one was located near the culvert outlet (SL-04), and two were located on the shoulders of the road embankment (SL-02 and SL-03) near the culvert alignment.

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 SL-01, SL-02, and SL-04 to the target depth using hollow stem augers. Borehole SL-03 was advanced using NW casing/wash boring techniques. 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. 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
SL-01	9.4 / 221.2	Bentonite holeplug and cuttings from 9.4 m to ground surface.
SL-02	10.4 / 220.4	Bentonite holeplug and cuttings from 10.4 m to 0.2 m and granular to ground surface.
SL-03	12.8 / 218.0	Bentonite holeplug and cuttings from 12.8 m to 0.2 m and granular to ground surface.
SL-04	9.8 / 219.8	Bentonite holeplug and cuttings from 9.8 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 associated with the structure, a sample of the existing native soil, and a sample of surface water from the creek upstream of the existing culvert were collected. The samples were submitted to AGAT Laboratories in Mississauga, Ontario for analytical testing of corrosivity parameters and sulphate content. 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 Drawing 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 and the inlet (located on the adjacent driveway) consist of granular fill overlying a deposit of clay which is further underlain by a silt layer with clay and sand seams. The above layers are underlain by a sand and gravel layer. A peat layer was encountered below the granular fill in Borehole SL-02. Groundwater levels are generally in the order of 0.8 to 4.7 m below original ground surface. More detailed descriptions of the individual stratum are presented below.

5.2 Fill

Embankment fill was encountered at the ground surface in Boreholes SL-01, SL-02, and SL-03. This fill typically consists of brown sand to sand and gravel with trace silt, trace organic inclusions and rootlets at shallow depth. Where encountered, the thickness of the embankment fill ranged from 2.2 to 4.1 m with a lower boundary at depths of 2.2 to 4.1 m (base Elevations 228.6 to 226.7 m).

SPT N-values measured in the cohesionless fill ranged from 2 to 25 blows per 0.3 m penetration, but mostly between 4 and 15 blows per 0.3 m penetration indicating a typically loose to compact state. Measured moisture contents of the recovered fill samples ranged between 4% and 19%. Grain size analyses conducted on samples of the gravelly sand fill are presented in Figure B1 in Appendix B. These results are summarized in the following table.

Soil Particles	%
Gravel	36 to 77
Sand	20 to 60
Silt and Clay	3 to 4

5.3 Peat

A layer of peat that was silty with some sand was encountered below the granular fill in Borehole SL-02. The thickness of the peat was approximately 0.7 m with a lower boundary at a depth of 2.9 m (base Elevation of 227.9 m).

An SPT performed in this layer gave an N-value of 2 blows per 0.3 m of penetration, indicating a very loose state. A moisture content of 150% was measured in this deposit.

5.4 Silty Clay

Silty clay was encountered in all four boreholes drilled at the site. The thickness of the silty clay ranged from 3.7 to 7.2 m with a lower boundary at a depth of 6.7 to 8.7 m (base Elevations 223.9 to 222.1 m).

A 2.3 m thick weathered crust of the silty clay deposit was encountered at the ground surface in Borehole SL-04 (base Elevation of 227.3 m). The crust had a firm consistency and was brown to grey in colour and contained some sand and gravel. Within the crust, the SPT N-values ranged between 4 and 7 blows per 0.3 m penetration.

Below the crust in Borehole SL-04 and the embankment fill in Boreholes SL-01 to SL-03, the silty clay was grey with measured SPT N-values ranging between 0 and 2 blows per 0.3 m penetration. In conjunction with in situ field vane tests, which measured undrained shear strengths ranging from 33 to 65 kPa, the lower portion of the silty clay was found to have a typically firm to stiff consistency.

A 0.1 m thick seam of gravelly sand was encountered in Borehole SL-01 at a depth of 4.6 m (base Elevation of 226.0 m).

The measured water contents of samples recovered from the silty clay typically ranged from 37% to 68%. Values of between 27% and 34% were observed at shallow depths in the weathered crust. Grain size analyses conducted on samples of the silty clay are presented in Figure B2, and Atterberg Limits test results are presented in Figure B5 in Appendix B. The results are summarized in the following table.

Soil Particles	%
Gravel	0 to 10
Sand	0 to 13
Silt	22 to 47
Clay	53 to 67
Soil Property	%
Liquid Limit	34 to 52
Plasticity Limit	20 to 24

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

5.5 Silt

A layer of silt was encountered beneath the silty clay in all of the boreholes. The silt was grey in colour and ranged in composition from some clay to clayey with trace sand and occasional sandy seams.

Borehole SL-04 was terminated within the silt layer at a depth of 9.8 m (base Elevation 219.8 m). Where the silt was fully penetrated in Boreholes SL-01 to SL-03, the thickness of the silt ranged from 0.3 to 1.5 m with the lower boundary at depths of 7.0 to 10.2 m (base

Elevations 223.6 to 220.6 m). SPT N-values measured within the silt varied between 6 and 8 blows per 0.3 m penetration indicating a firm consistency.

Measured water contents of samples recovered from the silt ranged from 21% to 39%. Grain size analyses conducted on samples of the silt are presented in Figure B3 in Appendix B. The results are summarized in the following table.

Soil Particles	%
Gravel	0
Sand	0 to 8
Silt	74 to 78
Clay	18 to 22

5.6 Sand to Sand and Gravel

Boreholes SL-01 to SL-03 were terminated in a deposit of sand ranging to sand and gravel at depths from 9.4 to 12.8 m (base Elevations of 221.2 to 218.0 m). The sand deposit also contained trace silt and cobbles. SPT N-values measured within the sand layer varied between 7 and 49 blows per 0.3 m penetration, typically 16 to 32 blows per 0.3 m penetration, indicating that the deposit is compact to dense. Boreholes SL-01 and SL-02 were terminated at depths of 9.4 and 10.4 m respectively (base Elevations of 221.2 and 220.4 m) in the sandy gravel to sand and gravel layer due to heaving sand and auger refusal.

Measured water contents of samples recovered from the sand deposit ranged from 8% to 30%. Grain size analyses conducted on samples of the sand to sand and gravel are presented in Figure B4 in Appendix B. The results are summarized in the following table.

Soil Particles	%
Gravel	29 to 43
Sand	52 to 60
Silt and Clay	5 to 11

5.7 Groundwater Conditions

Free water was observed in the boreholes upon completion of drilling and the water level measurements are presented in Table 5.1 below. Wash boring methods were used to advance Borehole SL-03 and therefore the water level recorded during or upon completion of drilling may not reflect natural groundwater levels. In addition, water was introduced in Boreholes SL-01 and SL-2 to reduce the effects of heaving sand and may also not reflect natural groundwater levels.

Table 5.1 – Water Level Measurements in Open Boreholes

Borehole	Date of Reading	Water Level	
		Depth (m)	Elevation (m)
SL-01	May 21, 2015	4.0	226.6
SL-02	May 21, 2015	0.9	229.9
SL-03	May 21, 2015	1.6	229.2
SL-04	May 21, 2015	4.7	224.9

The observed water level in the creek was measured at 1.5 m from the road surface (Elevation 229.3). The groundwater level should be assumed to coincide with the local creek water level. 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 native 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	
			SL-2 SS4, 7'6"-9'6"	Lawrence Way Culvert
			(Soil, 2.3-2.9 m deep)	(Creek Water)
Sulphide	%	mg/L	0.08	<0.05
Chloride	µg/g	mg/L	10	0.28
Sulphate	µg/g	mg/L	21	2.38
pH	pH Units	pH Units	7.03	6.81
Electrical Conductivity	mS/cm	µS/cm	0.374	35
Resistivity	ohm.cm	ohm.cm	2670	28600
Redox Potential	mV	mV	297	354
Langlier Index	-	-	-	-2.61
Total Hardness (as CaCO ₃)	-	mg/L	-	15.8
Total Dissolved Solids	-	mg/L	-	34
Alkalinity (as CaCO ₃)	-	mg/L	-	12

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 drill rig to carry out the drilling, sampling and in-situ testing operations. The drilling and sampling operations in the field were supervised on a full time basis by Ms. Deanna Pizycki, EIT of Thurber. Geotechnical laboratory testing was carried out by Thurber in its MTO-approved laboratory.

A sample of creek water and a sample of native soil was submitted to AGAT Laboratories in Mississauga, Ontario for testing of 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 Mr. Alastair Gorman, P.Eng. and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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**FOUNDATION INVESTIGATION AND DESIGN REPORT
LAWRENCE WAY CULVERT REPLACEMENT
LAWRENCE WAY (INGRAM CONCESSION ROAD 5)
NEW LISKEARD DISTRICT, ONTARIO**

G.W.P. No. 5029-14-00, SITE NO. 47-342/C

GEOCRES Number: 31M-111

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 Lawrence Way Culvert on Lawrence Way, located 6.7 km north of Highway 569 in the Township of Ingram, Ontario.

Based on the terms of reference, the existing structure is a 3.3 m diameter corrugated steel pipe (CSP) culvert, which was constructed in 1968. It is understood that the culvert is in poor condition, with deformation of the barrel, sagging at several locations, gaps at sagging splice locations, and breakdown of coating. The culvert therefore is 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, a 3.3 m diameter corrugated steel pipe (CSP), and a 4.05 m by 2.85 m corrugated steel pipe arch (CSPA). The CSP and CSPA culvert options may require a grade raise of up to 1 m.

The depth of frost penetration at this site is estimated to be 2.3 m based on OPSD 3090.100.

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 culvert will be installed along the same alignment as the existing culvert. It is understood that staged construction

should be assumed for the culvert replacement. Boreholes SL-01 and SL-02 were drilled near the existing culvert inlet, and Boreholes SL-03 and SL-04 were drilled near the outlet.

9.2 Foundation Alternatives

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

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 pipe (circular) or 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 is a circular CSP. Given the subsurface conditions and anticipated construction sequencing, we consider the box culvert, circular CSP, or CSPA to be technically feasible alternatives from a foundation engineering standpoint.

A concrete, open footing culvert is not considered suitable as the shallow subgrade soils are incapable of providing the geotechnical resistances required to support strip footings of reasonable width.

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

9.3 Foundation Design for Culverts

It is anticipated that the invert of the replacement culvert will be approximately the same as that of the existing culvert. There is approximately 0.3 m of fill above the existing culvert. Foundation design aspects for the replacement culvert include subgrade conditions, geotechnical resistances for the culvert and the wingwalls (if required), settlement of founding soils, lateral earth pressures, erosion control, roadway 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 culvert with no anticipated grade raise of the road for concrete box 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, 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 invert of the existing culvert is at an approximate elevation of 227 m. Therefore, the underside of the granular pad should be founded below elevation 226.5 m or lower, which based on the borehole logs is to be founded on firm silty clay. The recommended geotechnical resistances for this founding elevation, under the existing culvert footprint, are as follows:

- Factored Geotechnical Resistance at ULS of 130 kPa
- Geotechnical Resistance at SLS (less than 25 mm settlement) of 90 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 culvert with a CSP or CSPA on the same alignment as the existing culvert is anticipated to require a grade raise to provide sufficient cover above the culvert. We understand that the grade raise may be up to 1 m. The additional embankment loading associated with this grade raise may result in settlement of the foundation in the order of 25 mm, as discussed in Section 9.3.4. The culvert should be designed to accommodate this settlement.

The CSP or CSPA culvert 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 practical 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 226.7 or lower, which corresponds to firm silty clay subgrade.

Resistance to lateral forces / sliding resistance between the steel pipe 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 condition at the wall locations generally consist of the firm silty clay deposit.

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 firm silty clay subgrade at an approximate elevation of 226.5 m or lower. An RSS wall founded on this material may be designed using a factored geotechnical resistance at ULS of 130 kPa and a geotechnical reaction at SLS of 90 kPa (for less than 25 mm of settlements). 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 firm silty clay subgrade. For founding at Elevation 227.0 m or lower, the geotechnical resistances recommended above for the culvert may be used for design. A granular levelling pad should be placed 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 firm silty clay or 0.4 for engineered fill.

9.3.4 Settlements

It is anticipated that the replacement culvert will have approximately the same alignment and opening size as the existing CSP culvert. For the box culvert option, it is anticipated that there will be no grade raise at this site, however the CSP or CSPA options may result in a grade raise of up to 1 m. Taking into consideration that staged construction approach will probably be 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 a concrete box compared to the existing CSP, the firm silty 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 5 to 10 mm within 10 years. For the CSP or CSPA options, the additional load from the fill required to raise the grade is estimated to result in settlement of approximately 25 mm.

The RSS walls will be founded on an engineered fill pad over firm silty 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 the 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 fill, topsoil, creekbed deposits, disturbed soils and any deleterious materials within the culvert replacement footprint must be removed and replaced with well compacted bedding. The buried peat layer found in Borehole SL-02 should be removed.

This work must be carried out in accordance with OPSS 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. 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 utilized during 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. It is anticipated that there is no planned grade raise at this site for the concrete box culvert option, or up to 1 m grade raise for the CSP or CSPA options. Widening of the embankment may also be required to accommodate the grade raise.

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., not steeper than 2H:1V, it is anticipated that the embankment slope should 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 inlet and outlet, and within the embankment footprints. The buried peat layer found in Borehole SL-02 should be removed. Inspection and approval of the foundation surfaces by qualified geotechnical personnel is recommended.

The settlement due to grade raise (if required) is estimated to be in the order of 25 mm. In widened embankment areas, the settlement is estimated to be in the order of 50 mm. The differential settlement up to 25 mm should be expected along the original embankment shoulder and the end of the culvert.

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 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 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 silty clay deposit. The work may 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 inlet and outlet, 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 to develop the required toe resistance. 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:

$$\begin{aligned}\gamma &= 21 \text{ kN/m}^3 \text{ (embankment fill);} \\ &= 17 \text{ kN/m}^3 \text{ (silty clay)} \\ \gamma_w &= 10 \text{ kN/m}^3 \\ K_a &= 0.33 \text{ (road embankment fill)} \\ &= 0.36 \text{ (silty clay)} \\ K_p &= 2.8 \text{ (silty clay)}\end{aligned}$$

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 native 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 metal corrosion on metal is considered to be 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 culvert 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



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



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



Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction

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


4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

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

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

 Water Level
 Shear Strength Determination by Pocket Penetrometer

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

EXPLANATION OF ROCK LOGGING TERMS


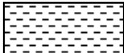



ROCK WEATHERING CLASSIFICATION

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

DISCONTINUITY SPACING

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

SYMBOLS

	CLAYSTONE
	SILTSTONE
	SANDSTONE
	COAL
	BEDROCK

STRENGTH CLASSIFICATION

Rock Strength	Approximate Uniaxial Compressive Strength (MPa)	Approximate Uniaxial Compressive Strength (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			

RECORD OF BOREHOLE No SL-01

1 OF 2

METRIC

GWP# 5029-14-00 LOCATION Lawrence Way Culvert N 5 299 558.5 E 406 063.8 ORIGINATED BY DJP
 HWY BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2015.05.23 - 2015.05.23 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				WATER CONTENT (%)						
230.6	GROUND SURFACE							20	40	60	80	100						
0.0	SAND , some organics (roots), trace gravel Loose Brown Dry to Moist (FILL)		1	SS	7		230								○			
	trace silt and clay		2	SS	9		229											
229.2																		
1.4	SAND and GRAVEL , trace silt Loose to Very Loose Brown Wet (FILL)		3	SS	4		229								○			36 60 4 (SI+CL)
			4	SS	2		228								○			
227.6																		
3.0	Silty CLAY Firm Grey		5	SS	1			227								┌───┐ ○		0 0 33 67
	gravelly sand seam at 4.6m		6	SS	0			226								○		
223.9			7	SS	0	224											○	
6.7	SILT , some clay to clayey, trace sand Grey														○			
223.6																		
7.0	Gravelly SAND , some silt, trace cobbles Compact Grey Wet		8	SS	16	223									○ ○		29 60 11 (SI+CL)	
	cobbles																	
	Dense		9	SS	36	222									○			
221.2																		
9.4	END OF BOREHOLE AT 9.4m UPON AUGER REFUSAL. WATER LEVEL AT 4.0m UPON																	

Continued Next Page

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

RECORD OF BOREHOLE No SL-01

2 OF 2

METRIC

GWP# 5029-14-00 LOCATION Lawrence Way Culvert N 5 299 558.5 E 406 063.8 ORIGINATED BY DJP
 HWY BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2015.05.23 - 2015.05.23 CHECKED BY MEF






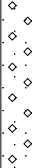
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH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

RECORD OF BOREHOLE No SL-02

1 OF 2

METRIC

GWP# 5029-14-00 LOCATION Lawrence Way Culvert N 5 299 552.7 E 406 056.2 ORIGINATED BY DJP
 HWY BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2015.05.22 - 2015.05.23 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							
230.8	GROUND SURFACE							20 40 60 80 100							
0.0	SAND , trace gravel, trace silt, trace organics (roots) Loose Brown (FILL)		1	SS	8		230								44 52 4 (SI+CL)
230.1	SAND and GRAVEL , trace silt Loose Brown Moist to Wet (FILL) trace clay		2	SS	4		229								
0.7			3	SS	4										
228.6	Silty PEAT , some sand, trace gravel, trace roots and wood fragments Very Loose Brown		4	SS	2		228								
227.9	Silty CLAY Firm Grey		5	SS	2		227	7.0							
	becoming Very Soft		6	SS	0		226								0 0 41 59
			7	SS	1		225								
			8	SS	8		224	9.0							
			9	SS	49		223								
223.6	SILT , some clay to clayey, trace sand Firm Grey						222								
7.2	SAND and GRAVEL , trace silt Dense Grey Wet 1.8m of sand heaving in augers						221								
222.1															
8.7															

Continued Next Page

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

RECORD OF BOREHOLE No SL-02

2 OF 2

METRIC

GWP# 5029-14-00 LOCATION Lawrence Way Culvert N 5 299 552.7 E 406 056.2 ORIGINATED BY DJP
 HWY BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2015.05.22 - 2015.05.23 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									
	Continued From Previous Page							20	40	60	80	100					
220.4 10.4	END OF BOREHOLE AT 10.4m UPON AUGER REFUSAL. BOREHOLE CAVED TO 4.7m AND WATER LEVEL AT 0.9m UPON COMPLETION. WATER INTRODUCED DURING DRILLING; UNCHARACTERISTIC FREE WATER OBSERVED. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.2m AND GRANULAR TO SURFACE.																

RECORD OF BOREHOLE No SL-03

1 OF 2

METRIC

GWP# 5029-14-00 LOCATION Lawrence Way Culvert N 5 299 544.2 E 406 073.6 ORIGINATED BY DJP
 HWY BOREHOLE TYPE Casing COMPILED BY AN
 DATUM Geodetic DATE 2015.05.21 - 2015.05.21 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 (%)				GR	SA	SI	CL
								20	40	60	80	100	W _P	W	W _L					
230.8	GROUND SURFACE																			
0.0	SAND and GRAVEL , trace silt, trace clay Compact Brown Moist (FILL) some gravel		1	SS	10		230								○					
			2	SS	15												○			
			3	SS	25												○			
	becoming sandy gravel		4	SS	12												○			
			5	SS	17												○			
226.7																				
4.1	Silty CLAY Firm Grey		6	SS	0			226									▬			
	trace sand		7	SS	0												○			
	Stiff		1	SH																
222.1																				
8.7	SILT , some clay to clayey, trace sand Firm Grey					222														
	sandy seam (25mm) at 9.3m		8	SS	8											○				
							221													

Continued Next Page

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

RECORD OF BOREHOLE No SL-03

2 OF 2

METRIC

GWP# 5029-14-00 LOCATION Lawrence Way Culvert N 5 299 544.2 E 406 073.6 ORIGINATED BY DJP
 HWY BOREHOLE TYPE Casing COMPILED BY AN
 DATUM Geodetic DATE 2015.05.21 - 2015.05.21 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 (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								20	40	60	80	100			PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L
Continued From Previous Page																	
220.6																	
10.2	SAND Dense to Loose Brown Wet		9	SS	32		220										
							219										
			10	SS	7												
218.0							218										
12.8	END OF BOREHOLE AT 12.8m. WATER LEVEL AT 1.6m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.2m AND GRANULAR TO SURFACE. WATER LEVEL IN OPEN BOREHOLE AT 2.2m ON 2015.05.22.																








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

RECORD OF BOREHOLE No SL-04

1 OF 2

METRIC

GWP# 5029-14-00 LOCATION Lawrence Way Culvert N 5 299 537.5 E 406 064.8 ORIGINATED BY DJP
 HWY BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2015.05.22 - 2015.05.22 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					WATER CONTENT (%)							
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					w _p w w _L							
229.6	GROUND SURFACE						20	40	60	80	100	20	40	60						
0.0	Silty CLAY , some sand, some gravel, some organics (roots) Soft Brown		1	SS	7		229													
			2	SS	7															
becoming Grey																				
	3	SS	4																	
227.3																				
2.3	Silty CLAY Stiff to Firm Grey		4	SS	1				227											
			5	SS	1															
trace gravel																				
	6	SS	0																	
			7	SS	0		225													
222.4																				
7.2	SILT , some clay to clayey Firm Grey		8	SS	7		224													
sandy seam (25mm) at 9.4m																				
	9	SS	6																	
219.8																				
9.8	END OF BOREHOLE AT 9.8m.																			

Continued Next Page

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

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

RECORD OF BOREHOLE No SL-04

2 OF 2

METRIC

GWP# 5029-14-00 LOCATION Lawrence Way Culvert N 5 299 537.5 E 406 064.8 ORIGINATED BY DJP
 HWY _____ BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2015.05.22 - 2015.05.22 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																
	BOREHOLE CAVE TO 8.3m AND WATER LEVEL AT 4.7m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																

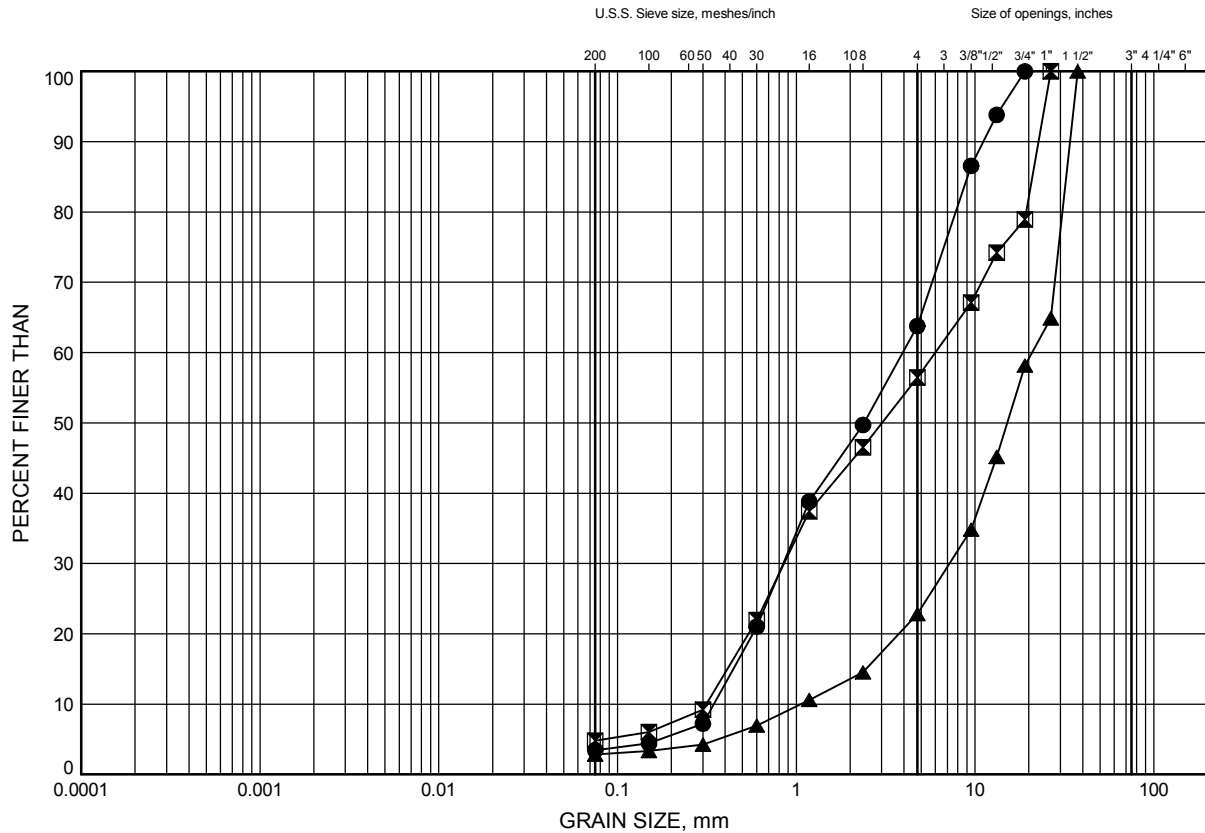
Appendix B

Laboratory Test Results

Lawrence Way 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)
●	SL-01	1.83	228.77
⊠	SL-02	1.07	229.73
▲	SL-03	3.35	227.45

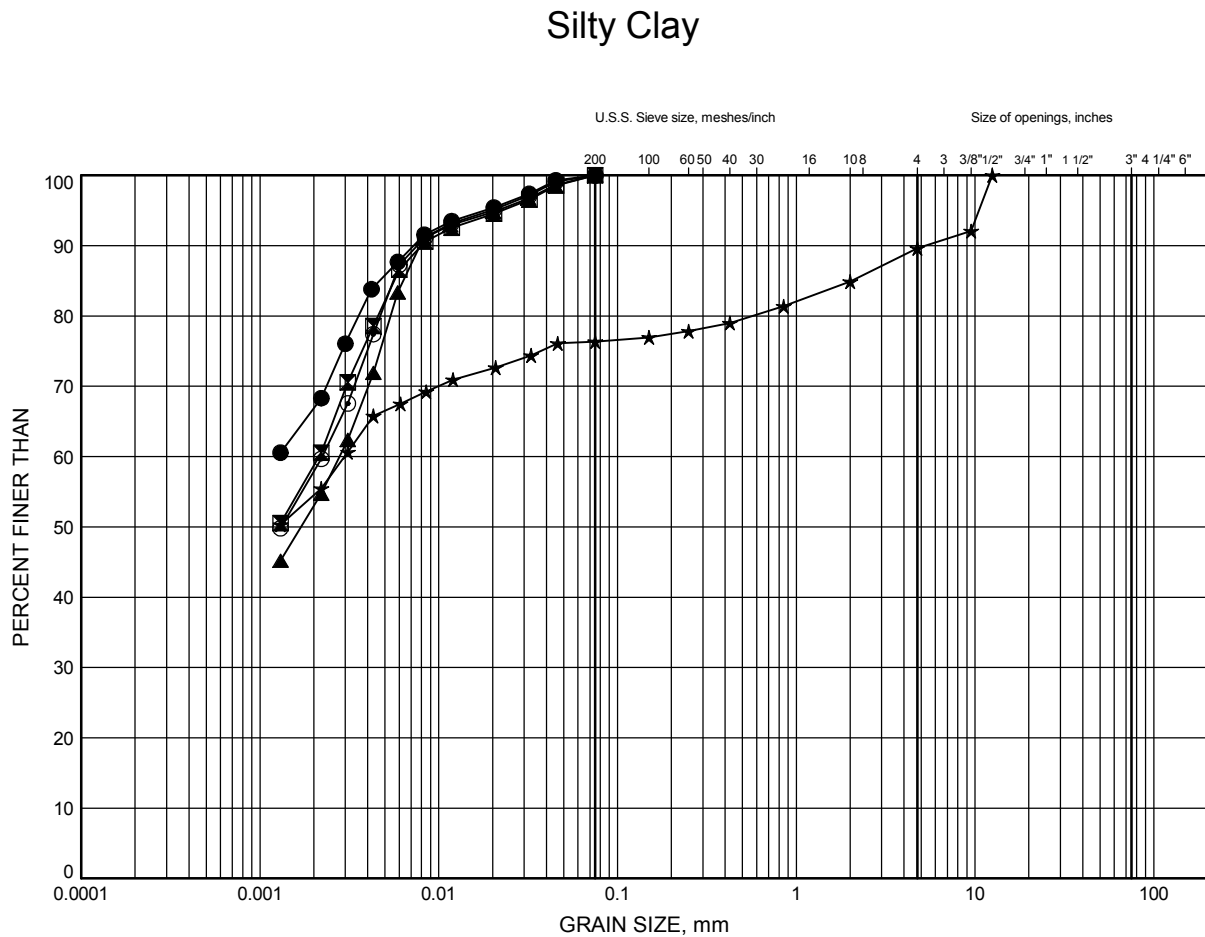
Date June 2015
GWP# 5029-14-00



Prep'd MFA
Chkd. DJP

Lawrence Way Culvert GRAIN SIZE DISTRIBUTION

FIGURE B2



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SL-01	3.35	227.25
⊠	SL-02	4.88	225.92
▲	SL-03	4.88	225.92
★	SL-04	1.83	227.77
⊙	SL-04	4.88	224.72

Date June 2015

GWP# 5029-14-00

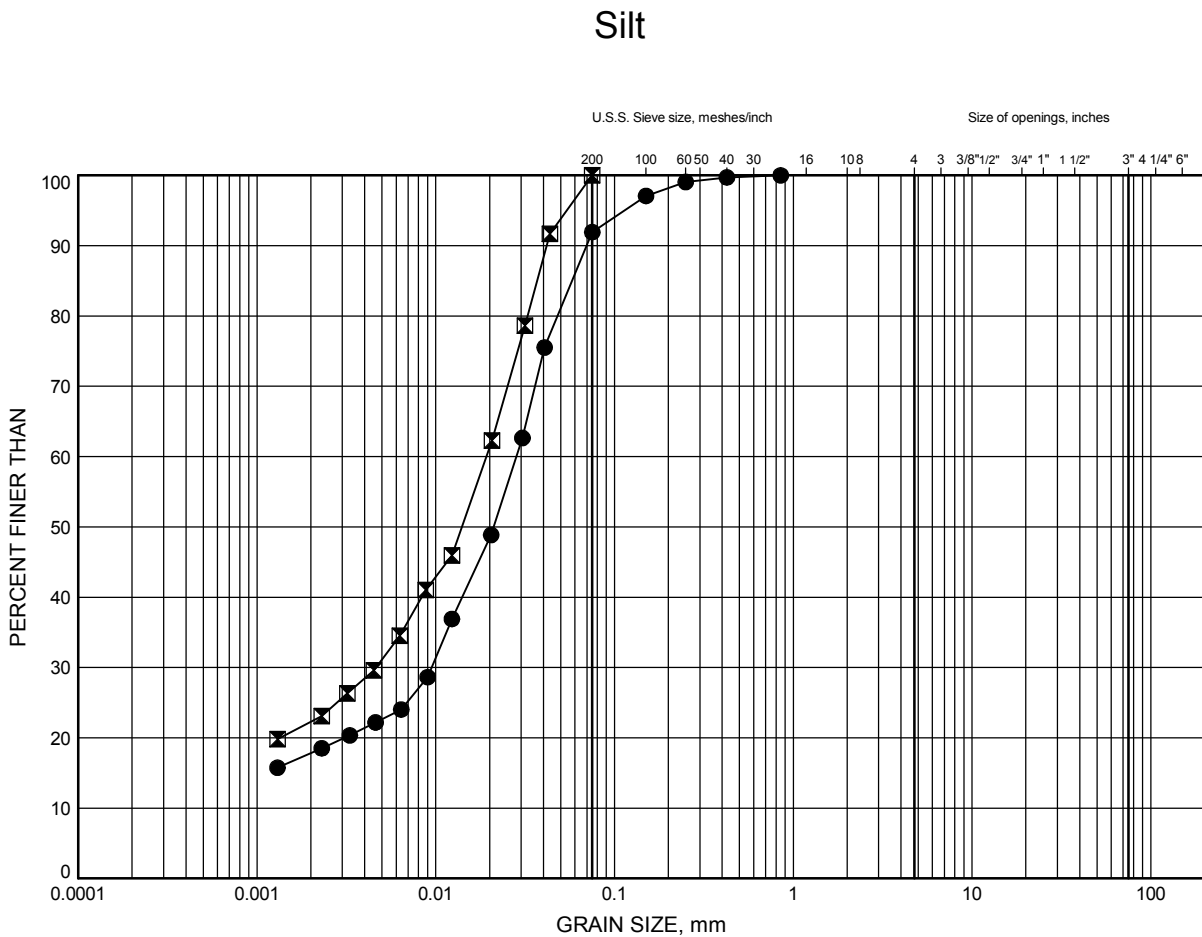


Prep'd MFA

Chkd. DJP

Lawrence Way Culvert GRAIN SIZE DISTRIBUTION

FIGURE B3



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SL-03	9.45	221.35
⊠	SL-04	9.45	220.15

Date June 2015
GWP# 5029-14-00

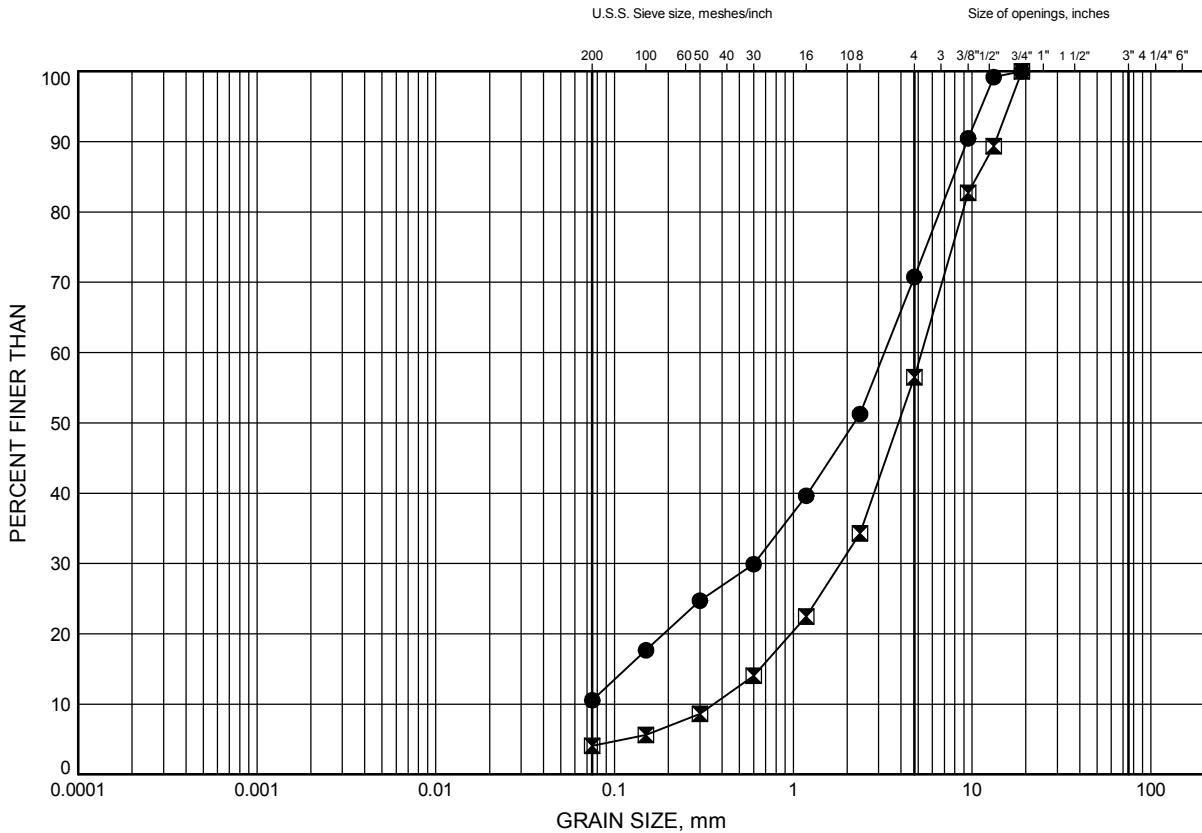


Prep'd MFA
Chkd. DJP

Lawrence Way Culvert
GRAIN SIZE DISTRIBUTION

FIGURE B4

Sand to Sand and Gravel



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SL-01	7.92	222.68
⊠	SL-02	9.45	221.35

Date June 2015
GWP# 5029-14-00

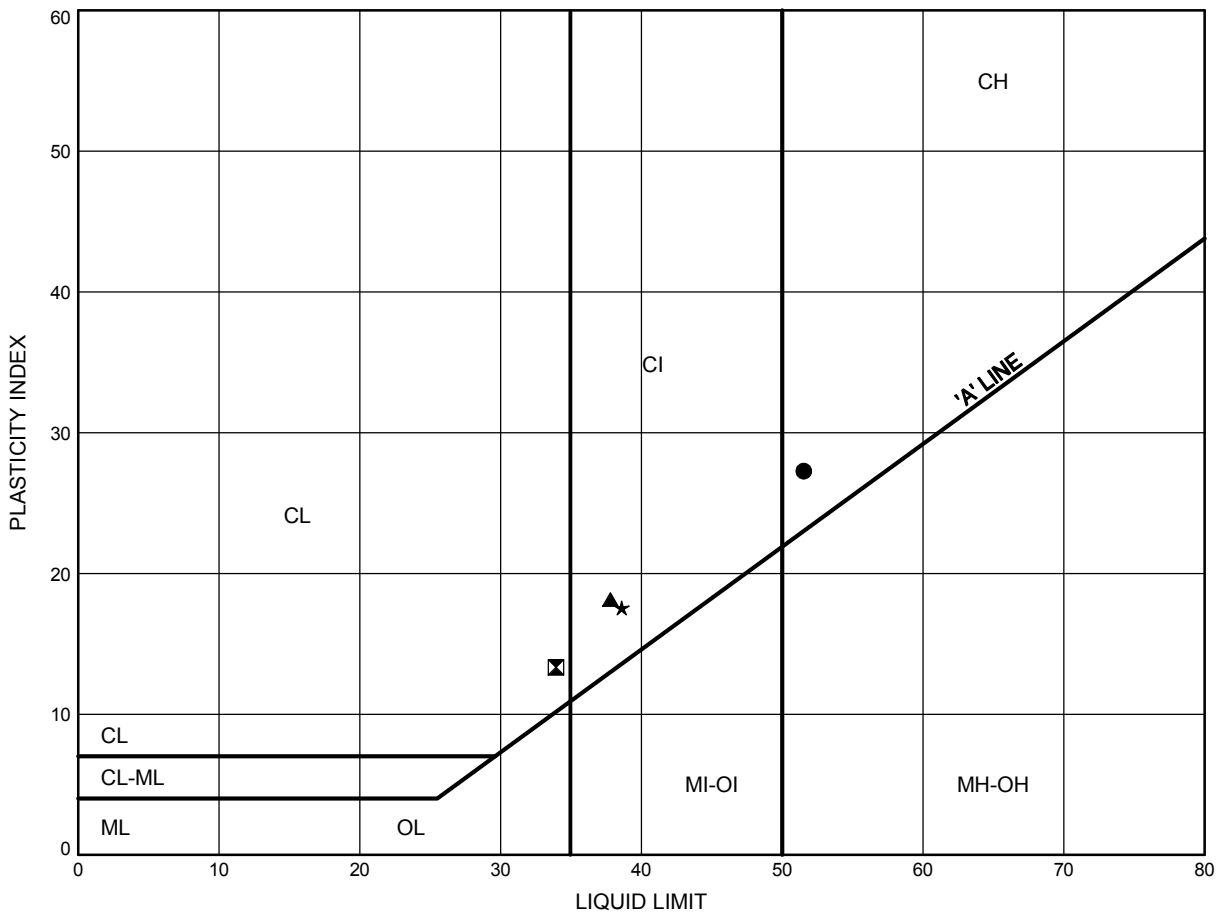


Prep'd MFA
Chkd. DJP

Lawrence Way Culvert
ATTERBERG LIMITS TEST RESULTS

FIGURE B5

Silty Clay



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SL-01	3.35	227.25
⊠	SL-02	4.88	225.92
▲	SL-03	4.88	225.92
★	SL-04	4.88	224.72

Date June 2015
 GWP# 5029-14-00



Prep'd MFA
 Chkd. DJP

Certificate of Analysis

CLIENT NAME: THURBER ENGINEERING LTD

PROJECT: 19-5161-252

SAMPLING SITE:

AGAT WORK ORDER: 15T980838

ATTENTION TO: MARK FARRANT

SAMPLED BY:

Corrosivity Package							
SAMPLE TYPE: Soil		SAMPLE ID: 6615987			DATE RECEIVED: Jun 03, 2015		
DATE SAMPLED: May 27, 2015				DATE REPORTED: Jun 09, 2015			
SAMPLE DESCRIPTION: SL-2, SS4, 7'6"-9'6"							
PARAMETER	UNIT	RESULT	G / S	RDL	DATE ANALYZED	INITIAL	DATE PREPARED
Sulfide	%	0.08		0.01	Jun 09, 2015	FM	Jun 08, 2015
Chloride (2:1)	µg/g	10		2	Jun 08, 2015	WZ	Jun 08, 2015
Sulphate (2:1)	µg/g	21		2	Jun 08, 2015	WZ	Jun 08, 2015
pH (2:1)	pH Units	7.03		NA		BG	Jun 08, 2015
Electrical Conductivity (2:1)	mS/cm	0.374		0.005	Jun 08, 2015	TM	Jun 08, 2015
Resistivity (2:1)	ohm.cm	2670		1	Jun 08, 2015	SYS	Jun 08, 2015
Redox Potential (2:1)	mV	297		5	Jun 08, 2015	TM	Jun 08, 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: 15T981461

ATTENTION TO: MARK FARRANT

SAMPLED BY: DP

Inorganic Chemistry (Water)							
SAMPLE TYPE: Water		SAMPLE ID: 6621906			DATE RECEIVED: Jun 05, 2015		
DATE SAMPLED: Jun 03, 2015				DATE REPORTED: Jun 10, 2015			
SAMPLE DESCRIPTION: Lawrence Way Culvert							
PARAMETER	UNIT	RESULT	G / S	RDL	DATE ANALYZED	INITIAL	DATE PREPARED
Electrical Conductivity	uS/cm	35		2	Jun 08, 2015	JC	Jun 08, 2015
pH	pH Units	6.81		NA	Jun 08, 2015	JC	Jun 08, 2015
Langelier Index		-2.61			Jun 09, 2015	SYS	Jun 09, 2015
Total Hardness (as CaCO3)	mg/L	15.8		0.5	Jun 09, 2015	SYS	Jun 09, 2015
Total Dissolved Solids	mg/L	34		20	Jun 08, 2015	BP	Jun 08, 2015
Alkalinity (as CaCO3)	mg/L	12		5	Jun 08, 2015	JC	Jun 08, 2015
Resistivity	ohms.cm	28600			Jun 08, 2015	SYS	Jun 08, 2015
Redox Potential	mV	354		5	Jun 10, 2015	TM	Jun 10, 2015
Chloride	mg/L	0.28		0.10	Jun 08, 2015	WZ	Jun 08, 2015
Sulphate	mg/L	2.38		0.10	Jun 08, 2015	WZ	Jun 08, 2015
Sulphide	mg/L	<0.05		0.05	Jun 10, 2015	SN	Jun 10, 2015

COMMENTS:

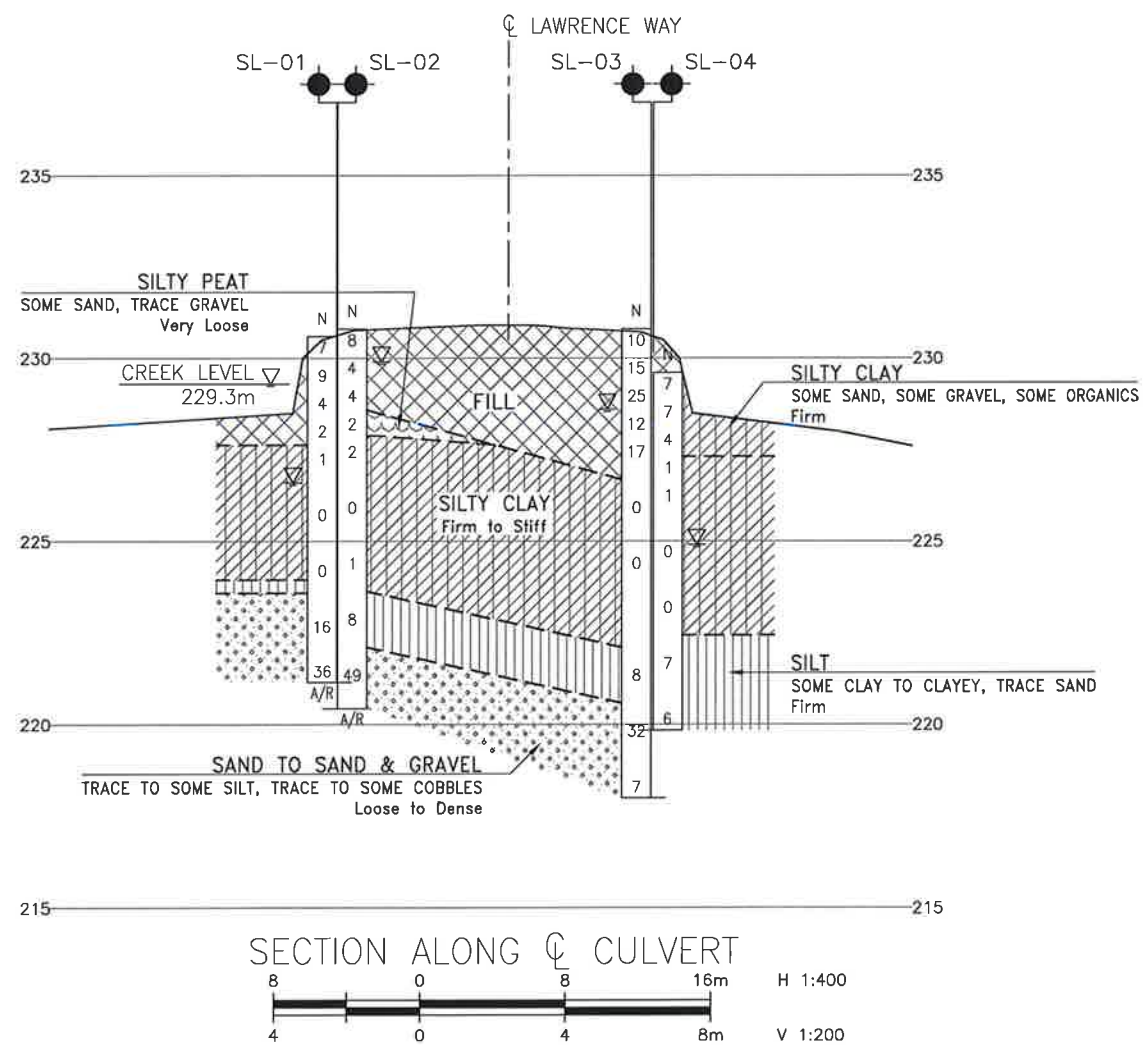
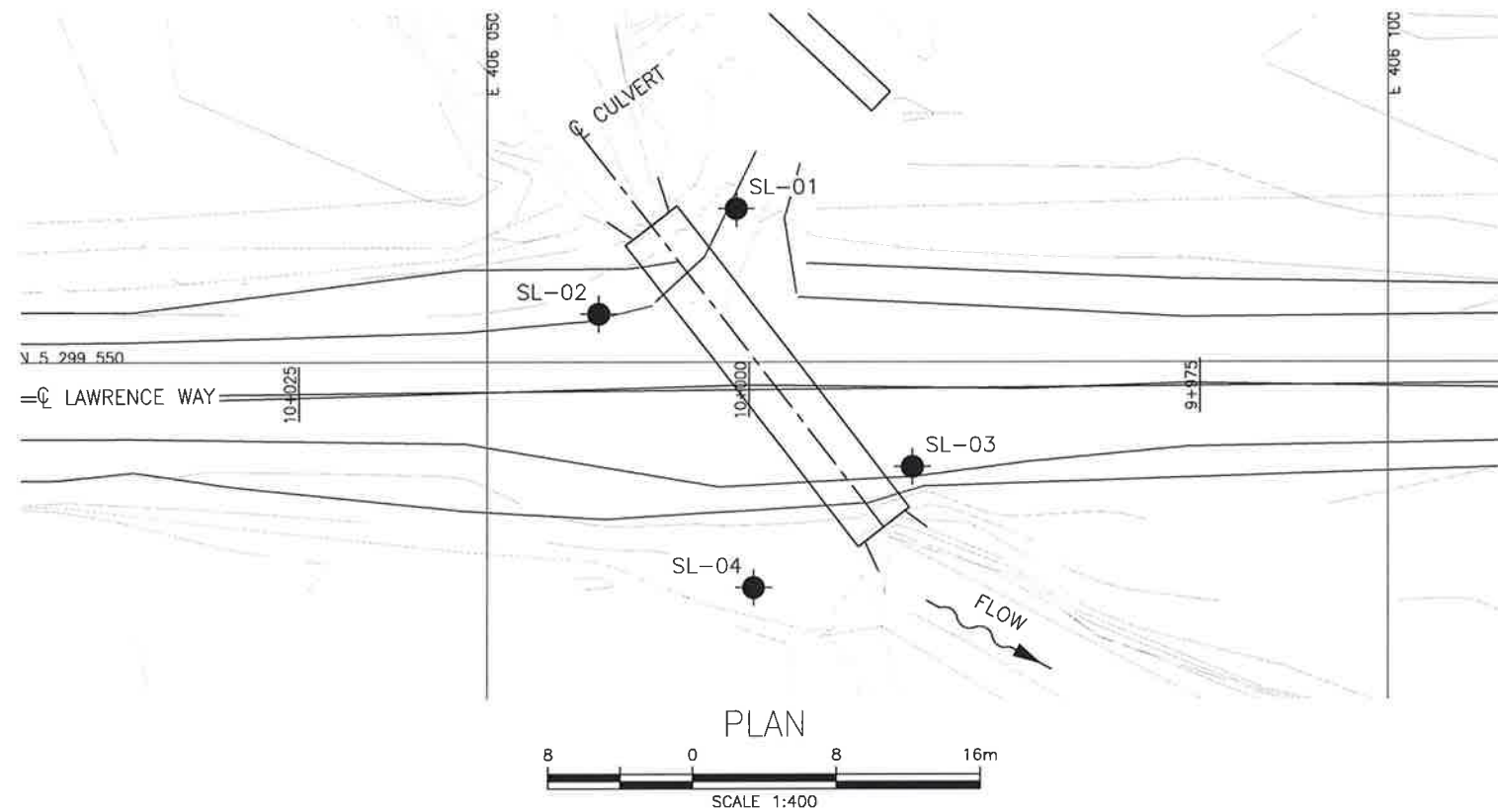
RDL - Reported Detection Limit; G / S - Guideline / Standard

Certified By:



Appendix C

Borehole Locations and Soil Strata Drawings



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

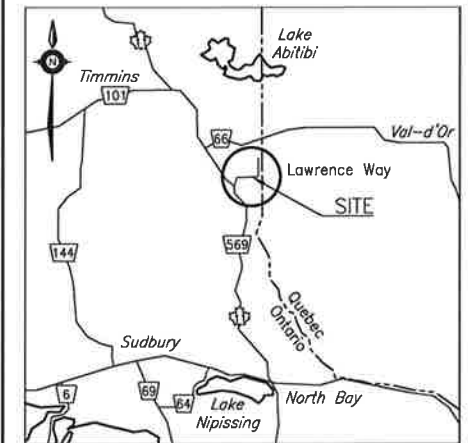


CONT No
GWP No 5029-14-00

LAWRENCE WAY
CULVERT
REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET



KEYPLAN

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
SL-01	230.6	5 299 558.5	406 063.8
SL-02	230.8	5 299 552.7	406 056.2
SL-03	230.8	5 299 544.2	406 073.6
SL-04	229.6	5 299 537.5	406 064.8

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-111

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	DJP	CHK	MEF
DRAWN	AN/MEIK	DJP	SITE 47-342/C/STRUCT
DATE	OCT 2015		

Appendix D

Foundation Alternatives Comparisons

COMPARISON OF ALTERNATIVE CULVERT TYPES

Proposed Works	Concrete Box (Closed) Culvert	Concrete Open Footing Culvert	Corrugated Steel Pipe 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 OPS Documents Relevant to 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 802.010
- OPSD 802.020
- OPSD 803.010
- OPSD 810.01

Appendix F

Selected Photographs of Culvert Location



Photo 1: Lawrence Way Culvert Inlet



Photo 2: Lawrence Way Culvert Outlet



Photo 3: Driveway Adjacent to Lawrence Way Culvert Inlet



Photo 4: Road Surface Looking East