



April 6, 2017

## FOUNDATION INVESTIGATION AND DESIGN REPORT

**Centreline Culvert Replacement - Highway 112  
STA 27+691, Township of Teck  
Ministry of Transportation, Ontario  
G.W.P. 5105-12-00; W.P. 5428-15-01**

**Submitted to:**

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REPORT





## Table of Contents

### **PART A – FOUNDATION INVESTIGATION REPORT**

<b>1.0 INTRODUCTION.....</b>	<b>1</b>
<b>2.0 SITE DESCRIPTION.....</b>	<b>1</b>
<b>3.0 INVESTIGATION PROCEDURES .....</b>	<b>1</b>
<b>4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS .....</b>	<b>4</b>
4.1 Regional Geology .....	4
4.2 General Overview of Local Subsurface Conditions.....	4
4.3 Culvert at STA 27+691 .....	5
4.3.1 Asphalt.....	5
4.3.2 Silty Peat.....	5
4.3.3 Embankment Fill .....	5
4.3.4 Gravelly Silty Sand to Sand and Gravel.....	5
4.3.5 Sandy Silt to Silt and Sand to Silty Sand.....	6
4.3.6 Silty Clay.....	6
4.3.7 Cobbles.....	6
4.3.8 Bedrock / Refusal.....	7
4.3.9 Groundwater Conditions .....	7
4.3.10 Analytical Testing of Creek Water.....	7
<b>5.0 CLOSURE.....</b>	<b>8</b>

### **PART B – FOUNDATION DESIGN REPORT**

<b>6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS.....</b>	<b>9</b>
6.1 General.....	9
6.2 Consequence and Site Understanding Classification .....	9
6.3 Foundations for Culvert Replacement .....	10
6.3.1 Foundation Options.....	10
6.3.2 Founding Elevations and Frost Protection Requirements .....	10
6.3.2.1 Corrugated Steel Pipe Culvert Replacement.....	10
6.3.2.2 Concrete Pipe Culvert Replacement.....	10



## FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 27+691

6.3.2.3	Precast Box Culvert Replacement .....	10
6.3.2.4	Open Footing Culvert Replacement.....	10
6.3.3	Factored Geotechnical Resistances.....	11
6.3.3.1	Corrugated Steel Pipe (CSP) Culvert Replacement .....	11
6.3.3.2	Concrete Pipe Culvert Replacement.....	11
6.3.3.3	Precast Box Culvert Replacement.....	11
6.3.3.4	Open Footing Culvert Replacement.....	12
6.3.4	Resistance to Lateral Loads / Sliding Resistance .....	12
6.4	Embankment Stability and Settlement .....	12
6.4.1	Stability .....	13
6.4.1.1	Methods.....	13
6.4.1.2	Parameter Selection .....	13
6.4.1.3	Results of Analysis .....	13
6.4.2	Settlement.....	14
6.4.2.1	Methods.....	14
6.4.2.2	Parameter Selection .....	14
6.4.2.3	Results of Analysis .....	14
6.5	Lateral Earth Pressures for Design.....	15
6.6	Construction Considerations.....	15
6.6.1	Temporary Roadway Protection and Cofferdams .....	15
6.6.2	Temporary Excavation .....	16
6.6.3	Sub-Excavation and Replacement below Culvert Bedding .....	17
6.6.4	Sloughing of Temporary Side Slopes.....	17
6.6.5	Embankment Fill Placement .....	17
6.6.6	Culvert Bedding and Backfill .....	18
6.6.6.1	Corrugated Steel Pipe Culvert .....	18
6.6.6.2	Concrete Pipe Culvert.....	19
6.6.6.3	Precast Box Culvert.....	19
6.6.6.4	Open Footing Culvert.....	19
6.6.7	Erosion Protection.....	19
6.6.8	Temporary Culvert .....	20



## FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 27+691

6.6.9	Surface Water and Groundwater Control .....	20
6.6.10	Recommendations for Construction Materials Based on Analytical Testing .....	21
6.6.10.1	Potential for Sulphate Attack .....	21
6.6.10.2	Potential for Corrosion .....	21
<b>7.0</b>	<b>CLOSURE.....</b>	<b>22</b>

### REFERENCES

### TABLES

Table 1	Summary of Existing Culvert Details
Table 2	Comparison of Foundation Alternatives for Culvert Replacement
Table 3	Factored Ultimate and Serviceability Geotechnical Resistances for Culvert Replacement Options
Table 4	Resistance to Lateral Loads/Sliding Resistance for Culvert Replacement Options
Table 5	Summary of Foundation Engineering Parameters
Table 6	Summary of Stability Analysis
Table 7	Summary of Settlement Analysis

### FIGURES

Figures 1A and 1B	Site Photographs
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### DRAWINGS

Drawing 1	Borehole Locations and Soil Strata
Drawing 2	Soil Strata

### APPENDICES

#### **Appendix A**                      **Record of Boreholes**

List of Symbols and Abbreviations	
Lithological and Geotechnical Rock Description Terminology	
Record of Boreholes	C4-1 to C4-6B
Record of Drillholes	C4-2, C4-4, C4-5 and C4-6A
Record of DCPTs	C4-DCPT-1 to C4-DCPT-9

#### **Appendix B**                      **Geotechnical Laboratory Test Results**

Table B1	Summary of Point Load Tests on Rock Samples
Figure B1	Grain Size Distribution –Silty Sand and Gravelly Sand (FILL)
Figure B2	Grain Size Distribution – Gravelly Silty Sand and Sand and Gravel
Figure B3	Grain Size Distribution – Silt and Sand
Figure B4	Grain Size Distribution – Silty Clay
Figure B5	Plasticity Chart – Silty Clay
Figure B6	Bedrock Core Photographs
Figure B7	Unconfined Compression Test (UC) – Borehole C4-2, Run No. 3

#### **Appendix C**                      **Analytical Test Results**



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## FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 27+691

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### **Appendix D**

#### **Stability Analysis Figures**

Figure D1	Stability Analysis: Median/Internal Side Slopes with 4.5 m Embankment Widening (East Slope)
Figure D2	Stability Analysis: Median/Internal Side Slopes with 4.5 m Embankment Widening (West Slope)
Figure D3	Stability Analysis: Median/Internal Side Slopes with Grade Lowering (East Slope)
Figure D4	Stability Analysis: Median/Internal Side Slopes with Grade Lowering (West Slope)
Figure D5	Stability Analysis: Final Embankment

### **Appendix E**

#### **Non-Standard Special Provisions**

NSSP	Obstructions
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# **PART A**

**FOUNDATION INVESTIGATION REPORT  
CENTRELINE CULVERT REPLACEMENT – HIGHWAY 112  
STA 27+691, TOWNSHIP OF TECK  
MINISTRY OF TRANSPORTATION, ONTARIO  
G.W.P. 5105-12-00; W.P. 5428-15-01**



## FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 27+691

### 1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by MMM Group Limited (MMM) on behalf of Ministry of Transportation, Ontario (MTO) to provide Foundation Engineering services for the replacement of the centreline culvert at STA 27+691 on Highway 112 in the Township of Teck, approximately 3 km south of Kirkland Lake, Ontario.

The Terms of Reference and the Scope of Work for the foundation investigation are outlined in MTO's Work Order / Assignment #2, dated March 2016. Golder's proposal for the foundation engineering services associated with the various culverts is contained in Golder's letter addressed to MMM, dated April 13, 2016. The work has been carried out in accordance with Golder's Supplementary Specialty Plan for foundation engineering services for this project, dated May 25, 2016.

This report addresses the investigation carried out for the culvert at STA 27+691 on Highway 112 which has been identified for replacement. The foundation investigation and design associated with the other culverts for Work Order / Assignment #2 are presented in separate reports.

### 2.0 SITE DESCRIPTION

The centreline culvert requiring replacement is located at approximately STA 27+691 on Highway 112 in the Township of Teck, approximately 3 km south of Kirkland Lake, Ontario. The existing culvert is buried and the dimensions of it are unknown. The highway embankment at the approximate culvert location is about 2.5 m and 5.0 m high on the east side and west side of the highway, respectively. Details of the culvert and associated foundation investigation are summarized in Table 1 following the text of this report.

In general, the topography in the area of the culvert consists of rolling surface topography with sparsely to densely populated treed areas and numerous bedrock outcrops separated by valleys which generally contain agricultural land or swamps containing slow flowing to standing water, various types of vegetation and organic soils. The developed area directly adjacent to Highway 112 is primarily used for residential purposes and agriculture. The ground surface at the boreholes and DCPT locations advanced for the culvert investigation, including through the existing Highway 112 embankment, varies between Elevation 314.2 m and 319.7 m, referenced to Geodetic datum. Figure 1A and 1B contains photographs of the culvert location.

### 3.0 INVESTIGATION PROCEDURES

The fieldwork for the foundation investigation associated with the culvert at STA 27+691 was carried out between June 6 and 10, 2016, during which time a total of seven boreholes and nine Dynamic Cone Penetration Test (DCPT) were advanced at, or in the immediate vicinity of the culvert alignment, as summarized in Table 1 and as shown on Drawing 1.

The field investigation was carried out using a truck-mounted CME55 drill rig and portable drilling equipment which were supplied and operated by Landcore Drilling of Sudbury, Ontario.

The boreholes drilled by the truck-mounted CME55 drill rig were advanced through the overburden using 152 mm diameter solid stem augers and wash boring techniques. The boreholes completed by the portable equipment were advanced through the overburden using NQ and HQ sized casing with wash boring techniques. Boreholes that were completed with rock coring were advanced using NW size casing and NQ size core barrel. In general,





## FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 27+691

soil samples were obtained at intervals of depth of about 0.75 m and 1.5 m using a 50 mm outside diameter (O.D.) split-spoon sampler operated by an automatic hammer on the drill rig, performed in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586). Boreholes advanced using portable equipment employed a full-weight hammer lifted manually and dropped from the SPT height.

The groundwater conditions and water levels in the open boreholes were observed during the drilling operations and are described on the Record of Borehole sheets in Appendix A. Boreholes were backfilled with bentonite upon completion in accordance with R.R.O 1990, Regulation 903 (Wells) (as amended).

A sample of creek water was obtained on June 12, 2016 at the culvert location, and submitted to an accredited analytical laboratory under chain of custody procedures for testing for a suite of parameters, including pH, resistivity, conductivity, sulphates and chlorides. The results of the analytical testing are included in Appendix C.

The fieldwork was observed by members of Golder's engineering and technical staff, who located the boreholes, arranged for the clearance of underground services, observed the drilling, sampling and in situ testing operations, logged the boreholes, and examined the soil samples. The soil and bedrock core samples were identified in the field, placed in appropriate containers, labelled and transported to Golder's Mississauga geotechnical laboratory where the samples underwent further visual examination and laboratory testing. All of the laboratory tests were carried out to MTO Laboratory Standards and/or ASTM Standards, as appropriate. Classification testing (water content, Atterberg limits and grain size distribution) was carried out on selected soil samples. Point load tests (PLT) and unconfined compression (UC) tests were carried out on selected specimens of the rock core samples. The results of the laboratory testing are summarized on the Record of Borehole and Drillhole sheets in Appendix A and presented on the laboratory test figures in Appendix B.

Classification of the rock mass quality of the bedrock with respect to the Rock Quality Designation (RQD) is described based on Table 3.10 of the Canadian Foundation Engineering Manual (CFEM)<sup>1</sup>. Classification of the bedrock core samples with respect to strength from point load tests and unconfined compression test is described based on Table 3.5 of CFEM<sup>1</sup>. The degree of weathering of the bedrock samples (i.e. fresh to slightly weathered – W1 to W2) and the strength classification of the intact rock mass based on field identification (i.e. strong – R4) are described in accordance with the International Society for Rock mechanics (ISRM)<sup>2</sup> standard classification system.

Borehole locations were surveyed in the field relative to fixed markers on site. The as-drilled borehole locations, in stations and offsets, were measured in reference to the applicable markers and from existing site features and were subsequently converted into MTM NAD 83 (Zone 12) coordinates in AutoCAD. Borehole elevations were surveyed by a member of our technical staff in reference to the centreline of Highway 112 and the existing culvert and were subsequently converted to Geodetic elevations using topographic information, provided by MTO. The borehole locations, ground surface elevations and depths drilled are as follows:

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<sup>1</sup> Canadian Geotechnical Society. (2006). Canadian Foundation Engineering Manual, 4<sup>th</sup> Edition.

<sup>2</sup> International Society for Rock Mechanics Commission on test Methods. (1985). Int. J. Rock Mech. Min. Sci & Geomech. Abstr. Vol 22, No. 2, pp.51-60.





## FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 27+691

Culvert Location	Borehole / DCPT	Location		Ground Surface Elevation (m)	Depth of Borehole / DCPT (m)
		Northing (m) / Latitude (°)	Easting (m) / Longitude (°)		
STA 27+691 (Township of Teck)	C4-1	5,330,640.9 / 48.110835	374,470.0 / -80.064304	314.7	2.7
	C4-2	5,330,648.9 / 48.110906	374,477.6 / -80.064201	319.7	10.5*
	C4-3	5,330,676.4 / 48.111153	374,475.0 / -80.064230	317.4	3.2
	C4-4	5,330,654.7 / 48.110960	374,454.1 / -80.064515	316.9	3.2*
	C4-5	5,330,662.5 / 48.111030	374,460.3 / -80.064430	319.7	5.1*
	C4-6A	5,330,636.5 / 48.110793	374,493.3 / -80.063992	319.3	5.6*
	C4-6B	5,330,628.1 / 48.110718	374,487.8 / -80.064066	315.0	2.8
	C4-DCPT-1	5,330,682.3 / 48.111207	374,470.8 / -80.064287	317.1	0.6
	C4-DCPT-2	5,330,679.2 / 48.111179	374,481.1 / -80.064148	317.2	1.2
	C4-DCPT-3	5,330,672.1 / 48.111114	374,480.5 / -80.064157	317.5	1.3
	C4-DCPT-4	5,330,643.2 / 48.110856	374,465.4 / -80.064364	314.2	1.1
	C4-DCPT-5	5,330,634.5 / 48.110777	374,470.0 / -80.064304	314.2	1.9
	C4-DCPT-6	5,330,636.4 / 48.110794	374,474.1 / -80.064250	314.2	0.9
	C4-DCPT-7	5,330,627.1 / 48.110709	374,485.8 / -80.064094	315.0	2.0
	C4-DCPT-8	5,330,625.6 / 48.110695	374,490.9 / -80.064025	315.0	1.7
	C4-DCPT-9	5,330,631.2 / 48.110746	374,483.9 / -80.064118	315.0	1.3

Note: \* Includes between 2.0 m and 3.8 m length of bedrock coring.



## **4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS**

### **4.1 Regional Geology**

Highway 112 is located in the Abitibi Uplands physiographic region, within the Canadian Shield as delineated by the *Geomorphic Systems of North America*<sup>3</sup>. The Abitibi Uplands generally slopes down towards Hudson Bay and is typically characterized by low broad hills with gently sloping, rolling or undulating topography and subdued relief. This region is underlain by massive, mainly crystalline rocks covered by Quaternary glaciolacustrine, glaciofluvial, and till deposits, as well as more recent organic deposits within the depressions between bedrock knobs<sup>4</sup>.

Highway 112 crosses four main assemblages, or batholiths associated with the southern Abitibi Greenstone Belt: Round Lake Batholith; Catharine-Pacaud assemblage; Boston assemblage and Temiskaming assemblage<sup>5</sup>. The southern end of the highway, where it meets the TransCanada Highway is located within the granodioritic Round Lake Batholith. The highway trends north passing through the Catharine-Pacaud and Boston assemblages which are characterized by mafic to intermediate grey to green basalt flows with felsic to silicious banding and plagioclase phenocrysts and metavolcanic to metasedimentary basalts, cherts and conglomerates, respectively. The northern end of Highway 112 in the area of the culvert south of Swastika contains the Temiskaming assemblage, characterized by clastic metasedimentary rocks, primarily cherts (jasper) and sandstones. This area contains multiple faults and deformations associated within the Larder-Cadillac shear zone which generally runs along Highway 11 in the area where it intersects with Highway 112.

### **4.2 General Overview of Local Subsurface Conditions**

The detailed subsurface soil and groundwater conditions as encountered in the boreholes advanced during this investigation, together with the results of the laboratory tests carried out on selected soil and bedrock samples, are presented on the Record of Borehole sheets and the laboratory test sheets in Appendices A and B, respectively. The results of the in situ field testing (i.e. SPT 'N' values) as presented in the Record of Borehole sheets and in Section 4.3 are uncorrected. The stratigraphic boundaries shown on the Record of Boreholes sheets are inferred from non-continuous sampling, observations of drilling progress and in situ testing and are approximate. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Further, subsurface conditions will vary between and beyond the borehole locations.

The stratigraphy at the borehole locations at the culvert site consists of surficial layers of asphalt, silty sand to sand to gravelly sand fill (at boreholes drilled through the highway embankment) and very loose to loose silt and sand or firm silty clay. The embankment fill is underlain by very loose to dense gravelly silty sand, sand and gravel and silty sand in places. The overburden deposits generally contain some cobbles and are underlain in places by zones of cobbles, in turn underlain by andesite or granite bedrock. A detailed description of the subsurface conditions at the culvert crossing is provided in the following section of this report. Where relatively significant thicknesses of overburden were encountered, the various soil types are described in detail for each main deposit or stratum.

<sup>3</sup> Graf, W. L. (1987). *Geomorphic systems of North America*. Geological Society of America, Inc.: Boulder, Colorado.

<sup>4</sup> Ministry of Northern Development and Mines, Ontario (MNDMO). (2016). *OGSEarth: Quaternary Geology* [Electronic Map]. 1:1,000,000. Retrieved July 28, 2016 from OGSEarth. Queen's Printer for Ontario, 2016.

<sup>5</sup> Jackson, S. L. and Fyon, J. A. (1991). The western Abitibi subprovince in Ontario; in *Geology of Ontario*, Ontario Geological Survey, Special Volume 4, Part 1, p.405-482.



### **4.3 Culvert at STA 27+691**

The plan and profile along the centreline of the existing culvert at STA 27+691 showing the borehole locations and interpreted stratigraphy are shown on Drawing 1. Profiles along the west toe and centerline of the embankment and cross sections of the roadway embankment, with interpreted stratigraphy are shown on Drawings 1 and 2. The height of the embankment at the culvert location is about 2.5 m on the east side of the highway and 5.0 m on the west side of the highway. The existing culvert dimensions are unknown. A total of seven boreholes and nine DCPT were completed to investigate the subsurface conditions at the culvert location: two boreholes (Borehole C4-1 and C4-3) and six DCPTs (C4-DCPT-1 to C4-DCPT-6) were advanced near the ends of the existing culvert; one borehole (Borehole C4-2) was advanced through the Highway 112 southbound lane roadway embankment, south of the existing culvert alignment; and four boreholes (Borehole C4-4, C4-5, C4-6A and C4-6B) and three DCPTs (C4-DCPT-7 to C4-DCPT-9) were advanced north and south of the culvert through the crest of the embankment and at the west toe of the embankment.

#### **4.3.1 Asphalt**

An approximately 100 mm layer of asphalt was encountered at ground surface in Boreholes C4-2, C4-5 and C4-6A.

#### **4.3.2 Silty Peat**

A 0.2 m thick deposit of silty peat was encountered at ground surface in Borehole C4-4.

#### **4.3.3 Embankment Fill**

An approximately 1.7 m to 4.5 m thick deposit of embankment fill was encountered below the asphalt in Boreholes C4-2, C4-5 and C4-6A between Elevations 319.6 m and 319.2 m. The embankment fill consists of an upper 0.4 m to 2.0 m thick layer of gravelly sand containing some cobbles and a lower 1.3 m and 2.5 m thick deposit of silty sand and sand, trace to some gravel, containing some cobbles encountered in Boreholes C4-2 and C4-5.

The SPT 'N'-values measured within the embankment fill deposit range between 7 blows and 51 blows per 0.3 m of penetration, indicating a loose to very dense relative density.

The natural water content measured on three samples of the non-cohesive fill range from about 3 per cent to 9 per cent.

The results of grain size distribution tests completed on two samples of the silty sand and gravelly sand fill are shown on Figure B1, in Appendix B.

#### **4.3.4 Gravelly Silty Sand to Sand and Gravel**

A 2.1 m thick deposit of gravelly silty sand to sand and gravel, some silt, trace clay was encountered at Elevation 315.1 m below the non-cohesive fill in Borehole C4-2.



The SPT 'N'-values measured within the gravelly silty sand to sand and gravel deposit are 13 blows and 43 blows per 0.3 m of penetration, indicating a compact to dense relative density.

The natural water content measured on two samples of the gravelly silty sand and sand and gravel deposit is about 11 per cent and 20 per cent.

The results of grain size distribution tests completed on two samples of the gravelly silty sand to sand and gravel deposit are shown on Figure B2.

### 4.3.5 Sandy Silt to Silt and Sand to Silty Sand

A 0.5 m to 1.2 m thick deposit of various layers of silt and sand was encountered at ground surface in Boreholes C4-1 and C4-3, and below the surficial silty peat and the embankment fill in Boreholes C4-4 and C4-5, respectively between Elevations 317.9 m and 314.7 m.

The SPT 'N'-values measured within the sandy silt to silt and sand deposit range from 1 blow to 9 blows per 0.3 m of penetration, indicating a very loose to loose relative density.

The natural water content measured on two samples of the silty sand is about 8 per cent and 17 per cent.

The result of a grain size distribution test completed on a sample of silt and sand layer of the deposit is shown on Figure B3.

An Atterberg limits test carried out on a sample of the silt and sand layer of the deposit indicates that the material is non-plastic.

### 4.3.6 Silty Clay

A 2.2 m thick deposit of silty clay, trace to some sand, some gravel and trace organics was encountered at ground surface in Borehole C4-6B, at Elevation 315.0.

The measured SPT 'N'-values within the silty clay deposit range from 6 blows to 16 blows per 0.3 m of penetration suggesting that the deposit has a firm to very stiff consistency.

The natural water content measured on two samples of the silty clay deposit is about 29 per cent and 37 per cent.

The result of a grain size distribution test completed on a sample of silty clay is shown on Figure B4.

An Atterberg limits test was carried out on a sample of silty clay and measured a liquid limit of 37 per cent and a plastic limit of 19 per cent, corresponding to a plasticity index of 18 per cent. The test result, which is plotted on a plasticity chart on Figure B5 on in Appendix B, indicates that the material tested is a silty clay of intermediate plasticity.

### 4.3.7 Cobbles

An approximately 2.2 m and 2.5 m thick deposit of cobbles, generally between 50 mm and 250 mm diameter in size, was encountered below the surficial sandy silt to silt and sand and the sand deposits in Boreholes C4-1 and C4-3, respectively, at Elevations 314.2 m and 316.7 m. These two boreholes were terminated on the cobbles as



## FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 27+691

a result of jamming of the core barrel. A 200 mm thick layer of cobbles, generally 80 mm diameter in size, was encountered between the gravelly sand fill and the bedrock in Borehole C4-6A at Elevation 317.3 m.

### 4.3.8 Bedrock / Refusal

Bedrock was encountered in Boreholes C4-2, C4-4, C4-5 and C4-6A at depths between 1.2 m and 6.7 m below ground surface between Elevations 317.1 m and 313.0 m. DCPT Refusal was encountered in the Borehole C4-6B and in C4-DCPT-1 to C4-DCPT-9 at depths of 0.6 m to 2.8 m, corresponding to Elevations 316.5 m to 312.2 m.

Based on review of the bedrock core samples, the bedrock consists of grey, fine grained, non-porous, crystalline andesite and pink, medium grained, non-porous, crystalline granite. The bedrock is fresh to moderately weathered. The bedrock descriptions are shown on the Record of Drillhole sheets in Appendix A and the rock core samples are shown on the photographs on Figure B6 in Appendix B.

The Total Core Recovery (TCR) and Solid Core Recovery (SCR) of samples recovered range between 40 per cent and 100 per cent and between 0 per cent and 100 per cent, respectively. The Rock Quality Designation (RQD) of the bedrock core samples from the boreholes on the south side of the culvert ranges from 0 per cent to 85 per cent, indicating a rock mass of very poor to good quality as per Table 3.10 of the Canadian Foundation Engineering Manual (CFEM, 2006). The RQD of the bedrock core samples from the boreholes on the north side of the culvert ranges from 33 per cent to 100 per cent, indicating a rock mass of poor to excellent quality.

Point load strength index tests were carried out on a selected sample of the granite bedrock core from Borehole C4-4 and a core sample of the andesite bedrock from Borehole C4-6A. The corrected point load strength index values ( $Is_{50}$ ) are presented on the Record of Drillhole sheets and in Table B1 in Appendices A and B, respectively, and are 7 MPa and 4 MPa for the axial and diametral tests, respectively on granite core sample; and 9 MPa for the diametral test on the andesite core sample. An Unconfined Compression (UC) test performed on a core sample of the granite bedrock from Borehole C4-2 measured a uniaxial compressive strength (UCS) of 12.9 MPa. The UC test result is presented on Figure B7 in Appendix B. Based on the laboratory point load strength index tests and the UC test, the bedrock is classified as weak ( $R_2$ ,  $5 \text{ MPa} < \text{UCS} < 25 \text{ MPa}$ ).

### 4.3.9 Groundwater Conditions

The water level was measured in Boreholes C4-1 to C4-5 and C4-6B upon completion of drilling operations at depths between 0.0 m and 5.4 m below ground surface, ranging from Elevations 317.2 m to 314.3 m. The water level at the site is expected to fluctuate seasonally in response to changes in precipitation and snow melt, and is expected to be higher during the spring and periods of precipitation.

### 4.3.10 Analytical Testing of Creek Water

Analytical testing was carried out on a sample of creek water taken from the culvert site to assess the corrosivity and concrete degradation potential from the creek water/groundwater for the new culvert structure. The results from the specialist analytical laboratory are presented in Appendix C and are summarised below:



## FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 27+691

Parameter	Test Result
Water Resistivity	7,000 ohm-cm
Water Conductivity	140 $\mu$ mho/cm
Sulphate Concentration	Less than 1.0 mg/L
Chloride Concentration	15 mg/L
Water pH	7.46

### 5.0 CLOSURE

Messrs. Shane Albert and Dave Marmor, EIT, supervised the borehole investigation program. This report was prepared by Ms. Marzieh Kamranzadeh, M.Sc., EIT., and was reviewed by Mr. Christopher Ng, P.Eng., a senior geotechnical engineer and an Associate of Golder. Mr. Jorge M. A. Costa, P.Eng., a Senior Consultant with Golder and Designated MTO Foundations Contact conducted an independent quality control review of this report.



## FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 27+691

### Report Signature Page

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# **PART B**

**FOUNDATION DESIGN REPORT  
CENTRELINE CULVERT REPLACEMENT – HIGHWAY 112  
STA 27+691, TOWNSHIP OF TECK  
MINISTRY OF TRANSPORTATION, ONTARIO  
G.W.P. 5105-12-00; W.P. 5428-15-01**



## **6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS**

This section of the report provides foundation design recommendations for the proposed replacement of the buried culvert at about STA 27+691 on Highway 112. These recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the investigation. The discussion and recommendations presented are intended to provide the designer with sufficient information to assess the feasible foundation alternatives and carry out the design of the culvert foundations. The foundation investigation report, discussion and recommendations are intended for the use of the Ministry of Transportation, Ontario (MTO) and shall not be used or relied upon for any other purpose or by any other parties, including the construction or design-build contractor. The contractor must make their own interpretation based on the factual data in Part A of the report. Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project and for which special provisions may be required in the Contract Documents. Those requiring information on the aspects of construction must make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

### **6.1 General**

Golder Associates Ltd. (Golder) was retained by MMM Group Limited (MMM) on behalf of the MTO to provide recommendations on the foundation aspects of the detail design for the replacement of the existing centerline culvert at STA 27+691 on Highway 112 in the Township of Teck.

This report presents geotechnical resistances for design of the replacement culvert as well as the results of stability and settlement analyses associated with the temporary embankments required for staged construction, and provides recommendations for stable embankment geometry and embankment fill materials that may be required as a means to reduce culvert settlements and to improve embankment stability (if necessary). The report also addresses potential construction concerns and geotechnical issues associated with the culvert replacement and temporary embankments associated with staged construction and placement of new fill materials.

It is understood that the replacement culvert is planned to be either a 750 mm diameter concrete pipe or a 910 mm wide by 910 mm high open footing constructed at upstream (east end) and downstream (west end) invert at about Elevation 317.1 m and 315.1 m. In addition, it is understood that replacement of the existing culvert by staged construction will require either a temporary embankment widening up to about 4.5 m on the west side of the existing embankment or an approximately 0.9 m grade lowering and stage construction to facilitate the culvert replacement. There are no permanent embankment widening or grade raise as part of the culvert replacement.

### **6.2 Consequence and Site Understanding Classification**

In accordance with Section 6.5 of the 2014 Canadian Highway Bridge Design Code and its Commentary (CHBDC, S6-14, 2014), the proposed culvert and its foundation system is considered to be classified as having a “typical consequence level” associated with exceeding limits states design. In addition, given the level of foundation investigation completed to date in comparison to the degree of site understanding in Section 6.5 of CHBDC (2014), the level of confidence for design is considered to be a “typical degree of site and prediction model understanding.” Accordingly, the appropriate corresponding ULS and SLS consequence factor,  $\Psi$ , from Table 6.1 and geotechnical resistance factors,  $\phi_{gu}$  and  $\phi_{gs}$ , from Table 6.2 of the CHBDC (2014) have been used for design, as indicated in Sections 6.3 and 6.4 below.



## **6.3 Foundations for Culvert Replacement**

### **6.3.1 Foundation Options**

A CSP culvert, concrete pipe culvert, precast box culvert, and cast-in-place open footing culvert are all feasible alternatives for the replacement of the existing culvert. Foundation recommendations have been provided for these various culvert alternatives although it is understood that the proposed replacement culvert will be either a 750 mm diameter concrete pipe culvert or a 910 mm wide open footing culvert.

The advantages and disadvantages associated with replacing the existing culvert with the various culvert alternatives are summarized in Table 2, following the text of this report. Recommendations for replacement of the existing culvert with a CSP, concrete pipe, precast box as well as cast-in-place open footing structure are provided in the following sections. From a foundation perspective, a concrete pipe culvert is considered to be the preferred replacement alternative.

### **6.3.2 Founding Elevations and Frost Protection Requirements**

#### **6.3.2.1 Corrugated Steel Pipe Culvert Replacement**

It is not necessary to found the CSP culvert replacement at or below the standard depth of frost penetration for frost protection purposes, as CSP culverts are tolerant of small magnitudes of movement related to freeze-thaw cycles, should these occur. Table 3, following the text of this report, provides recommended founding elevations and founding conditions for a CSP replacement culvert, assuming a 0.3 m thick combined bedding layer and culvert bottom thickness.

#### **6.3.2.2 Concrete Pipe Culvert Replacement**

It is not necessary to found the concrete pipe culvert replacement at or below the standard depth of frost penetration for frost protection purposes, as concrete pipes are tolerant of small magnitudes of movement related to freeze-thaw cycles, should these occur. Table 3, following the text of this report, provides recommended founding elevations and founding conditions for a concrete pipe replacement culvert, assuming a 0.3 m thick combined bedding layer and culvert bottom thickness.

#### **6.3.2.3 Precast Box Culvert Replacement**

It is not necessary to found the precast box culvert replacement at or below the standard depth of frost penetration for frost protection purposes, as precast box structures are tolerant of small magnitudes of movement related to freeze-thaw cycles, should these occur. Table 3, following the text of this report, provides recommended founding elevations and founding conditions for a precast box replacement culvert, assuming a 0.3 m thick combined bedding layer, levelling layer and culvert bottom thickness.

#### **6.3.2.4 Open Footing Culvert Replacement**

The strip footings for an open footing culvert replacement should be founded at a minimum depth of 2.4 m below the lowest surrounding grade to provide adequate protection against frost penetration, as per OPSD 3090.100



(Foundation, Frost Penetration Depths for Northern Ontario). Table 3, following the text of this report, provides recommended founding elevations and founding conditions for an open footing replacement culvert.

### 6.3.3 Factored Geotechnical Resistances

#### 6.3.3.1 Corrugated Steel Pipe (CSP) Culvert Replacement

A CSP culvert placed on the properly prepared subgrade (compacted granular fill on the native sandy silt to gravelly silty sand deposits), at the founding elevation recommended in Table 3, should be designed based on the recommended factored ultimate geotechnical resistance at Ultimate Limit State (ULS) and the factored serviceability geotechnical resistance at Serviceability Limit State (SLS) for 25 mm of settlement, as given in Table 3. These recommendations are based on constructing a 750 mm or 910 mm diameter CSP culvert.

The factored ultimate geotechnical resistance at ULS and the factored serviceability geotechnical resistance at SLS for 25 mm of settlement are dependent on the culvert diameter and founding elevation and as such, the geotechnical resistances should be reviewed if the culvert diameter or founding elevation differs from those given in Table 3.

The factored ultimate geotechnical resistance provided in Table 3 is based on loading applied perpendicular to the top surface of the culvert. Where the load is not applied perpendicular to the top surface of the culvert, inclination of the load should be taken into account in accordance with Section 6.10.4 and Section C6.10.4 of the CHBDC (2014) and its *Commentary*.

#### 6.3.3.2 Concrete Pipe Culvert Replacement

A concrete pipe culvert placed on the properly prepared subgrade (compacted granular fill on the native sandy silt to gravelly silty sand deposits), at the founding elevation recommended in Table 3, should be designed based on the recommended factored ultimate geotechnical resistance at ULS and the factored serviceability geotechnical resistance at SLS for 25 mm of settlement, as given in Table 3. These recommendations are based on a 750 mm and 910 mm diameter concrete pipe culvert.

The factored ultimate geotechnical resistance at ULS and the factored serviceability geotechnical resistance at SLS for 25 mm of settlement are dependent on the culvert diameter and founding elevation and as such, the geotechnical resistances should be reviewed if the culvert diameter or founding elevation differs from those given in Table 3.

The factored ultimate geotechnical resistance provided in Table 3 is based on loading applied perpendicular to the top surface of the culvert. Where the load is not applied perpendicular to the top surface of the culvert, inclination of the load should be taken into account in accordance with Section 6.10.4 and Section C6.10.4 of the CHBDC (2014) and its *Commentary*.

#### 6.3.3.3 Precast Box Culvert Replacement

A precast box culvert placed on the properly prepared subgrade (compacted granular fill or leveling pad over sandy silt to gravelly silty sand deposits), at the founding elevation recommended in Table 3, should be designed based on the recommended factored ultimate geotechnical resistance at ULS and the factored serviceability



## FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 27+691

geotechnical resistance at SLS for 25 mm of settlement, as given in Table 3. These recommendations are based on a 750 mm or 910 mm wide box culvert.

The factored ultimate geotechnical resistance at ULS and the factored serviceability geotechnical resistance at SLS for 25 mm of settlement are dependent on the culvert width and founding elevation and as such, the geotechnical resistances should be reviewed if the culvert width or founding elevation differs from those given in Table 3.

The factored ultimate geotechnical resistance provided in Table 3 is based on loading applied perpendicular to the top surface slab of the culvert. Where the load is not applied perpendicular to the top surface slab of the culvert, inclination of the load should be taken into account in accordance with Section 6.10.4 and Section C6.10.4 of the CHBDC (2014) and its *Commentary*.

### 6.3.3.4 Open Footing Culvert Replacement

Strip footings placed on the properly prepared subgrade (sand and gravel/cobble deposits), at the founding elevation recommended in Table 3, should be designed based on the factored ultimate geotechnical resistance at ULS and the factored serviceability geotechnical resistance at SLS for 25 mm of settlement, as given in Table 3. These recommendations are based on an assumed footing width of 0.6 m and 1.2 m which are applicable to both a 750 mm and 910 mm wide culvert. Where cobbles are present at the founding level, it is recommended that a 75 mm thick levelling pad of Granular B Type II be incorporated below the footings; this is discussed further in Section 6.6.6.4.

The factored ultimate geotechnical resistance at ULS and factored serviceability geotechnical resistance at SLS for 25 mm of settlement are dependent on the culvert footing and founding elevation and as such, the geotechnical resistances should be reviewed if the culvert strip footing width differs from 0.6 m or 1.2 m or the founding elevation differs from that given in Table 3.

The factored ultimate geotechnical resistance provided in Table 3 is based on loading applied perpendicular to the surface of the footings. Where the load is not applied perpendicular to the surface of the footings, inclination of the load should be taken into account in accordance with Section 6.10.4 and Section C6.10.4 of the CHBDC (2014) and its *Commentary*.

### 6.3.4 Resistance to Lateral Loads / Sliding Resistance

Resistance to lateral forces / sliding resistance between the base of the CSP, concrete pipe or box culvert, or strip footings for the open footing culverts, and the subgrade should be calculated in accordance with Section 6.10.5 of the CHBDC (2014). Table 4, following the text of this report, provides the coefficients of friction ( $\tan \delta$ ) between the base of the culvert/footing and potential interface materials.

## 6.4 Embankment Stability and Settlement

It is understood that there are no changes to the final grade and embankment geometry of Highway 112 associated with this culvert replacement and that either a temporary embankment widening up to 4.5 m on the west side of Highway 112 or an approximately 1 m grade lowering are being evaluated for staged construction. The purpose



of the temporary embankment widening and/or grade lowering is to maintain traffic on the existing roadway during the replacement works without the need for temporary roadway protection systems.

The results of stability and settlement analysis for the temporary and final embankment geometry are presented in the following sections.

### 6.4.1 Stability

#### 6.4.1.1 Methods

Limit equilibrium slope stability analyses for the temporary and permanent embankments were carried out using the commercially available program Slide (version 6.0), developed by Rocscience Inc., employing the Morgenstern-Price method of analysis. For all analyses, the Factors of Safety (FoS) of numerous potential failure surfaces were computed for the critical embankment cross-section at STA 27+691 in order to establish the minimum FoS. The FoS is defined as the ratio of the forces tending to resist failure to the driving forces tending to cause failure. For the purpose of the stability analysis, the FoS is equal to the inverse of the product of the consequence factor,  $\Psi$ , and the geotechnical resistance factor,  $\phi_{gu}$ . (i.e.  $FoS = 1/(\Psi \cdot \phi_{gu})$ ). Accordingly, target minimum factors of safety of 1.3 and 1.5 have been used for the design of the embankment slopes for temporary and permanent conditions against deep-seated global failures, respectively, as per Table 6.2 of CHBDC (2014). The stability analyses assume that all organics and other deleterious materials are removed prior to constructing the approach embankments.

#### 6.4.1.2 Parameter Selection

For the non-cohesive soils present at this site, the effective stress parameters employed in the analysis were estimated from empirical correlations based on the results of the in situ Standard Penetration Tests (SPT). The correlations proposed by Peck et al. (1974) and U.S. Navy (1986) were employed and the results were adjusted by engineering judgment based on precedent experience in similar soils. The parameters used in the analysis are summarized in Table 5, following the text of this report.

For the purpose of the stability analysis, the groundwater level at each site was assumed to be at ground surface at the toes of the embankment, consistent with the level at which it was encountered in boreholes advanced during the site investigation and observations of surface water on site.

Table 5 presents the simplified stratigraphy and the associated strengths and unit weights employed for the existing and new fill material as well as the native overburden deposits encountered.

#### 6.4.1.3 Results of Analysis

The results of the stability analysis for the temporary excavation and final embankment geometry are summarized in Table 6 and shown in Figures D1 to D5. At this site, the minimum FoS for deep-seated global failure of the temporary embankment widening and for the grade lowering geometry of the temporary stage embankment, as well as for the final embankment geometry, is equal to or greater than 1.3 in short-term conditions, and 1.5 in long-term conditions.



## **6.4.2 Settlement**

### **6.4.2.1 Methods**

To estimate the magnitude of expected settlement of the temporary embankment widening and final embankment, analysis was carried out at the critical section, corresponding to the thickest soil deposits at STA 27+691. Settlement analyses were carried out using the commercially available program *Settle<sup>3D</sup>* (version 4.0), developed by Rocscience Inc. The settlement analyses assume that all organics and other deleterious materials (i.e. peat, and rootlets) are removed prior to constructing the temporary embankment widening.

### **6.4.2.2 Parameter Selection**

The simplified stratigraphy and the associated unit weights and strengths employed for the estimation of settlement of the foundation soils of the temporary widening and final embankment are presented in Table 5. The immediate compression of the non-cohesive overburden soils were modelled by estimating an elastic modulus of deformation based on the SPT 'N'-values and using correlations proposed by Bowles (1984) and Kulhawy and Mayne (1990). These estimated values were compared with the typical range of expected values for similar soil types, as outlined in *CHBDC* (2014) and adjusted, as appropriate. The consolidation settlement parameters of the cohesive deposits was assessed using empirical correlations proposed in literature by Koppula (1986), Terzaghi and Peck (1967), Kulhawy and Mayne (1990) and Azzouz et al. (1976).

For the purpose of the settlement analysis, the groundwater level was assumed to be at ground surface at the toe of the embankment, which is consistent with the level at which it was encountered in boreholes advanced during the site investigation and observations of surface water on site.

### **6.4.2.3 Results of Analysis**

Based on the settlement analysis, the total factored settlement of the foundation soils due to the 4.5 m temporary embankment widening on the west side of the existing embankment is estimated to be about 25 mm. This settlement is estimated to be comprised of about 5 mm of factored immediate settlement due to the compression of the non-cohesive deposits and about 20 mm of factored primary settlement within the cohesive deposit, as encountered in Borehole C4-6B. Based on the average coefficient of consolidation ( $c_v$ ) of about  $2 \times 10^{-3} \text{ cm}^2/\text{s}$  estimated for the cohesive deposit and the imposed loading conditions, and assuming a two way drainage of approximately 2.8 m thick cohesive deposit, it is estimated that about 90 per cent of the factored primary consolidation settlement will be completed in about 10 days.

Given that there is no grade raise or permanent platform widening of the final embankment, the existing fill below the existing culvert invert level as well as native overburden is not expected to experience additional load as a result of the culvert replacement and as such, the settlement of the foundation soils below the culvert is estimated to be less than 25 mm.

The results of the foundation soil settlement analysis for the temporary widening, grade lowering and final embankment are summarized in Table 7.





## 6.5 Lateral Earth Pressures for Design

The lateral earth pressures acting on the walls of the culvert will depend on the type and method of placement of the backfill material, the nature of the soils/embankment fill behind the backfill, the magnitude of surcharge including construction loadings, the freedom of lateral movement of the structure, and the drainage conditions behind the walls.

The following recommendations are made concerning the design of the culvert walls. These design recommendations and parameters assume level backfill and ground surface behind the walls. Where there is sloping ground behind the walls, the coefficient of lateral earth pressure must be adjusted to account for the slope.

- Select, free draining granular fill meeting the specifications of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II should be used as backfill behind the culvert walls, and on top of the culvert for a thickness of not less than 300 mm. Backfill should be placed in a maximum of 200 mm loose lift thickness and nominally compacted. Compaction (including type of equipment, target densities, etc.) should be carried out in accordance with OPSS.PROV 501 (Compacting).
- For restrained walls in box culvert design, granular fill should be placed in a zone with the width equal to at least 2.4 m behind the back of the wall (in accordance with Figure C6.20(a) of the *Commentary* to the *CHBDC (2014)*). For unrestrained walls in open footing culvert design, fill should be placed within the wedge-shaped zone defined by a line drawn at 1.5 horizontal to 1 vertical (1.5H:1V) extending up and back from the rear face of the footing (in accordance with Figure C6.20(b) of the *Commentary* to the *CHBDC (2014)*). The pressures are based on the proposed embankment fill material and the following parameters (unfactored) may be used:

Fill Type	Soil Unit Weight	Coefficients of Static Lateral Earth Pressure	
		At-Rest, $K_o$	Active, $K_a$
Granular 'A'	22 kN/m <sup>3</sup>	0.43	0.27
Granular 'B' Type II	21 kN/m <sup>3</sup>	0.43	0.27

If the culvert structure does not allow lateral yielding, at-rest earth pressures should be assumed for the foundation design. If the culvert structure allows for lateral yielding, active earth pressures should be used in the foundation design. The movement required to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure for design, should be calculated in accordance with Section C6.12.1 and Table C6.6 of the *Commentary* to the *CHBDC (2014)*.

## 6.6 Construction Considerations

### 6.6.1 Temporary Roadway Protection and Cofferdams

The temporary excavations for the culvert replacement will be made through the existing embankment fill, comprised of silty sand and gravelly sand, and into native overburden soils, which typically are comprised of compact to dense gravelly silty sand to sand and gravel, very loose to loose sandy silt to silt and sand to sand, and cobbles, over bedrock. Excavation works must be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act (OHSA) and Regulations for Construction Projects. According to OHSA, the existing fill and native overburden soils would be classified as Type 3 soils. Provided that proper groundwater



## FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 27+691

control is in place, temporary open-cut excavations through the embankment fill and native overburden soils should be made with side slopes inclined no steeper than 1H:1V.

Given the presence of cobbles in the embankment fill, a cobble deposit below the embankment and relatively shallow depth to bedrock, it will not be possible to install sheet pile shoring. A soldier pile and lagging system may be used for support of the excavation, but may require pre-drilling to facilitate installation of the soldier piles. In addition, where bedrock is present at shallow depth below ground surface, if the soil cover does not have sufficient depth to provide lateral resistance, the use of rakers and tie-backs will be required to provide lateral support, or the soldier piles would have to be socketed into bedrock. The Contractor should be alerted to the presence of these obstructions; an example Non-Standard Special Provision (NSSP) to be included in the Contract Documents is presented in Appendix E.

It is understood that a cofferdam may be required to maintain a dry excavation during construction. Given the relatively shallow depth to the cobble deposit and bedrock it will be difficult to install sheet pile shoring. Cofferdams comprised of sand bags and/or a bladder cofferdam system could be considered as an alternative; however, additional pumping will likely be required to maintain a dry excavation as groundwater seepage through the relatively permeable granular embankment fill materials (i.e. silty sand fill), the sandy silt to sand and gravel subgrade and the cobbles and/or fractured bedrock (near surface bedrock with a low RQD). The Contractor should be alerted to the presence of these obstructions; an example NSSP to be included in the Contract Documents is presented in Appendix E.

Where required, all temporary protection systems and cofferdams should be designed and constructed in accordance with OPSS.PROV 539 (Temporary Protection Systems). The lateral movement of the temporary shoring and cofferdams should meet Performance Level 2 as specified in OPSS.PROV 539.

The selection and design of the protection systems and cofferdams is the responsibility of the Contractor. The support systems may be designed using the parameters provided in Table 5.

The temporary protection system and cofferdams should be assessed for both the drained ( $\phi$ ) and undrained cases ( $s_u$ ), based on the more conservative earth pressure conditions. The earth pressure coefficients noted in Section 6.5 and Table 5 are based on a horizontal surface adjacent to the excavation. If sloped surfaces are present, the coefficient of earth pressure should be adjusted accordingly.

Design of the temporary support system, including cofferdams, should include an evaluation of base stability, soil squeezing stability and the hydraulic uplift stability as defined in the Canadian Foundation Engineering Manual (CFEM 2006).

Consideration could be given to either partial or full removal of the temporary protection system upon completion of construction or each stage of construction (as required). Where possible, full removal of the temporary protection system should be considered to mitigate potential impediments to future rehabilitation/reconstruction work at the culvert site.

### 6.6.2 Temporary Excavation

Given that the internal friction angles for embankment fill is variable and may be less than the side slope angles proposed (1H:1V, 45°) sloughing/surficial failures may occur during construction. If sloughing occurs during construction, consideration could be given to the placement of a surficial layer of granular fill on the temporary



embankment slope to prevent further sloughing. Alternatively, consideration could be given to using temporary side slopes of 1.5H:1V to reduce the potential for sloughing during construction.

### 6.6.3 Sub-Excavation and Replacement below Culvert Bedding

Prior to the placement of any bedding material or granular fill, all organic soils should be stripped from the plan limits of the proposed works. Given the proposed culvert founding elevations of the replacement culvert summarized in Table 3, excavation of the embankment fill, organic material and native overburden soils up to about 4.6 m below existing ground surface will be required. Where excavation below the proposed culvert foundation level is required to remove disturbed/unsuitable material or the existing culvert footings, replacement backfill should consist of OPSS.PROV 1010 Granular 'B' Type II material.

The culvert subgrade, if comprised of native material, or the excavation base following sub-excavation, should be inspected to ensure that all organic soils or other unsuitable materials have been removed, in accordance with OPSS.PROV 421 (Pipe Culvert Installation in Open Cut) for a concrete pipe or CSP culvert, OPSS 422 (Precast Reinforced Concrete Box Culverts) for a precast box culvert and OPSS 902 (Excavating and Backfilling Structures) for a cast-in-place open footing culvert. Following inspection, any sub-excavated area should be backfilled with granular material meeting OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II and placed and compacted in accordance with OPSS.PROV 501 (Compacting) to at least 98 per cent of the Standard Proctor maximum dry density of the material.

All excavations should be carried out in accordance with OPSS 902 (Excavating and Backfilling – Structures) and must be carried out in accordance with Ontario Regulation 213 Ontario Occupational Health and Safety Act for Construction Projects (as amended).

### 6.6.4 Sloughing of Temporary Side Slopes

Given that the embankment fill is heterogeneous in composition and the angle of internal friction of the material(s) is variable, sloughing of the temporary 1 horizontal to 1 vertical (1H:1V) embankment slopes may occur during construction. If sloughing of the surficial/near surface slope material(s) should occur, consideration could be given to the placement of a surficial layer of granular fill on the temporary embankment slope to prevent further sloughing. Alternatively, consideration could also be given to flattening the temporary side slopes to 1.5 horizontal to 1 vertical (1.5H:1V) to reduce the potential for sloughing of the temporary slopes during construction. Barriers along the temporary 1H:1V embankment slopes should be positioned to provide as much separation distance as practical from the edge of the embankment crest. Further, visual monitoring of the embankment side slopes for signs of sloughing/instability should be carried out on a regular basis.

### 6.6.5 Embankment Fill Placement

Prior to the placement of any granular fill for the embankment widening, all organic soils should be stripped from the plan limits of the proposed works. Placement of granular fill for the construction of embankment widening and final embankment should be carried out in accordance with OPSS.PROV 206 (Grading) and compaction of the granular fill should be in accordance with OPSS.PROV 501 (Compacting), with inspection during construction to confirm that appropriate materials are used and that adequate levels of compaction are achieved. The granular



## FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 27+691

fill used in embankment construction should be compacted to not less than 95 per cent of the materials standard proctor maximum dry density (SPDMDD).

The up to 4 m high staged embankment, which will be incorporated into the final construction of permanent embankment, may be constructed at a 1 horizontal to 1 vertical (1H:1V) median/internal side slope. The final embankment should be constructed with permanent side slopes no steeper than 2 horizontal to 1 vertical (2H:1V).

Where granular fill is placed on an embankment side slope, benching of the embankment side slopes should be carried out in accordance with OPSD 208.010 (Benching of Earth Slopes) to integrate the new fill into the existing embankment fill.

### 6.6.6 Culvert Bedding and Backfill

Culvert construction, including placement of bedding, cover and backfill should be placed in accordance with the following standards associated with each culvert type:

Culvert Type	Bedding, Cover Material and Backfill	Culvert Construction
Corrugated Steel Pipe	OPSD 802.010 – Flexible Pipe Embedment and Backfill, Earth Excavation	OPSS.PROV 421 – Pipe Culvert Installation in Open Cut
Concrete Pipe	OPSD 802.031 – Rigid Pipe Bedding, Cover, And Backfill, Type 3 Soil - Earth Excavation	OPSS.PROV 421 – Pipe Culvert Installation in Open Cut
Precast Box	OPSD 803.010 – Backfill and Cover for Concrete Culverts	OPSS 422 – Precast Reinforced Concrete Box Culverts
Open Footing	OPSD 803.010 – Backfill and Cover for Concrete Culverts	OPSS 902 – Excavating And Backfilling – Structures

Culvert bedding should be placed on a properly prepared subgrade, whether comprised of native material or sub-excavation backfill. The bedding, cover and backfill should be placed in lifts not exceeding 200 mm in loose thickness, and compacted to at least 95 per cent of the Standard Proctor maximum dry density of the material.

The backfill behind the culvert walls should consist of granular fill meeting the specifications for OPSS.PROV 1010 Granular 'A' or Granular 'B' Type II. The granular backfill should be placed and compacted in accordance with OPSS.PROV 501 (Compacting). Backfill placement for reconstruction of the highway embankments along and over the culvert should be carried out as per OPSD 208.010 (Benching of Earth Slopes) to integrate the new fill into the existing embankment fill along the cut faces.

Inspection and field density testing should be carried out during all engineered fill placement operations to ensure that appropriate materials are used, and that adequate levels of compaction have been achieved.

Additional requirements/recommendations for culvert construction are provided below for each culvert option.

#### 6.6.6.1 Corrugated Steel Pipe Culvert

It is important that the backfill at the haunches be well compacted. The circular culvert should be constructed on a minimum 300 mm thick layer of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II material for



bedding and be covered with a minimum 300 mm above the pipe for cover purposes, while Granular 'B' Type I may be used as backfill above the cover.

Backfill should be placed concurrently on both sides of the culvert walls, ensuring that the backfill depth on one side does not exceed the other side by more than 200 mm as per OPSS.PROV 401 (Trenching, Backfilling and Compacting).

### 6.6.6.2 Concrete Pipe Culvert

It is important that the backfill at the haunches be well compacted. The circular culvert should be constructed on a 300 mm thick layer of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II material for bedding and be covered with a minimum 300 mm above the pipe for cover purposes, while Granular 'B' Type I may be used as backfill above the cover.

Backfill should be placed concurrently on both sides of the culvert walls, ensuring that the backfill depth on one side does not exceed the other side by more than 200 mm as per OPSS.PROV 401 (Trenching, Backfilling and Compacting).

### 6.6.6.3 Precast Box Culvert

It is recommended that at least 300 mm of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II material be used for bedding purposes. In addition, a minimum 75 mm thick uncompacted levelling layer consisting of OPSS.PROV 1010 Granular 'A' or concrete fine aggregate meeting the gradation requirements specified in OPSS.PROV 1002 (Aggregates – Concrete) should be provided as shown on OPSS 803.010 (Backfill and Cover for Concrete Culverts) for culvert construction.

Backfill should be placed concurrently on both sides of the culvert walls, ensuring that the backfill depth on one side does not exceed the other side by more than 400 mm as per OPSS 422 (Precast Reinforced Concrete Box Culverts).

### 6.6.6.4 Open Footing Culvert

Where cobbles are encountered at the founding elevation, it is recommended that a 75 mm thick levelling pad of OPSS.PROV 1010 Granular 'B' Type II be placed below the footings to create a level surface on which to place pre-cast footing elements or construct cast-in-place footings.

Backfill should be placed concurrently on both sides of the culvert walls, ensuring that the backfill depth on one side does not exceed the other side by more than 500 mm as per OPSS 902 (Excavating and Backfilling – Structures).

### 6.6.7 Erosion Protection

Provision should be made for scour and erosion protection at the culvert location. In order to prevent surface water from flowing either beneath the culvert (potentially causing undermining and scouring), or around the culvert (creating seepage through the embankment fill, and potentially causing erosion and loss of fine soil particles), a



## FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 27+691

clay seal or concrete cut-off wall should be provided at the upstream and downstream ends of the CSP, concrete pipe and precast box culvert. If a clay seal is adopted, the clay material should meet the requirements of OPSS.PROV 1205 (Clay Seal), and the seal should be a minimum 1 m thick if constructed of natural clay or soil-bentonite mix and extend from a depth of 1 m below the scour level for a CSP, concrete pipe or precast box culvert, and from the ground surface immediately adjacent to an open footing culvert, to a minimum horizontal distance of 2 m on either side of the culvert inlet opening, and to a minimum vertical height equivalent to the high water level, including along the embankment slopes.

The requirements for and design of erosion protection measures for the inlet and outlet of the culvert should be assessed by the hydraulics design engineer. As a minimum, rip-rap treatment for the outlet of the culvert should be consistent with the standard presented in OPSD 810.010 (Rip-Rap Treatment for Sewer and Culvert Outlets). Erosion protection for the inlet of the culvert should generally follow the standard presented in OPSD 810.010, with the rip-rap placed up to the toe of slope level, in combination with the cut-off measures noted above, including over the full extent of the clay seal on the embankment slope.

### 6.6.8 Temporary Culvert

A temporary culvert extension will be required to provide surface water passage/drainage below the temporary embankment widening. The temporary culvert extension may consist of a precast concrete culvert (box or pipe) or corrugated steel pipe (CPS) culvert. Bedding recommendations for the temporary culvert extension should be in accordance with the corresponding OPSS and/or OPSD, as outlined in Section 6.6.6, depending on the type of temporary culvert extension chosen.

Settlement of the temporary culvert extension below the temporary embankment will occur concurrently with and be of the same magnitude as the settlement of the temporary embankment. The anticipated magnitude of settlement of the temporary embankment, and therefore the temporary culvert extension, is provided in Table 7. The selection of the temporary culvert extension should take into account the anticipated settlement and should be sized such that it may still perform its intended function for the duration that the temporary embankment widening will be in place.

### 6.6.9 Surface Water and Groundwater Control

Groundwater control will be required as the foundation excavation will extend below the existing ground surface for the removal of existing fill and overburden soils prior to placement of the culvert, and for installation of the cast-in-place culvert footings. For excavations extending to or below the groundwater level at the time of construction, groundwater inflows should be expected due to the relatively permeable adjacent identified/inferred granular embankment fill materials (i.e. silty sand fill), the sandy silt to sand and gravel subgrade and the cobbles and/or fractured bedrock (near surface bedrock with relatively low RQD). Therefore, control of groundwater will be necessary to allow for construction to be carried out in dry conditions. Surface water should be directed away from the excavation areas to prevent ponding of water that could result in disturbance and weakening of the foundation subgrade. Dewatering of all excavations should be carried out in accordance with OPSS 517 (Dewatering).

If required, temporary shoring and groundwater control could be in the form of a cofferdam advanced to an appropriate depth to control groundwater inflow and to prevent base heaving of the foundation subgrade. As noted in Section 6.6.1, due to the presence of a cobble deposit and the shallow depth to bedrock at the culvert site, sheet





pile installation may not be feasible. Alternatively, a sand bag and/or bladder cofferdam system could be considered; however, additional pumping may be required to maintain a dry excavation as groundwater seepage may occur through the relatively permeable embankment fill, sandy silt to sand and gravel subgrade and the cobbles and/or fractured bedrock.

Depending on the surface water level and flow conditions and groundwater levels at the time of construction, water flow could be diverted and/or pumped from behind a cofferdam. However, if construction dewatering pumping volumes are anticipated to exceed 50 m<sup>3</sup>/day, an Environmental Activity Section Registry (EASR) will be required as per the Environmental Protection Act by the Ontario Ministry of the Environment and Climate Change (MOECC). A permit to take water (PTTW) would be required if construction dewatering pumping volumes exceed 400 m<sup>3</sup>/day.

### 6.6.10 Recommendations for Construction Materials Based on Analytical Testing

The results of an analytical test on one sample of creek water are summarized in Section 4.3.9 and presented in Appendix C. The potential for deterioration of concrete due to sulphate attack and corrosion of steel elements are discussed in the following sections. It is the responsibility of the designer to determine the appropriate construction materials, including the exposure class and ensuring that all aspects of CSA A23.1-14 Section 4.1.1 "Durability Requirements" are followed when designing concrete components and protection of steel elements.

#### 6.6.10.1 Potential for Sulphate Attack

The analytical test results were compared to CSA A23.1-14 Table 3 ("*Additional requirements for concrete subjected to sulphate attack*") for the potential sulphate attack on concrete. The sulphate concentration measured in the creek water sample is less than 0.0001 per cent (<1 mg/L), which is below the exposure class of S-3 (Moderate). Therefore, based on the single sample of creek water tested, when the designer is selecting the exposure class for the structure, the effects of sulphates from within the creek water around the culvert may not need to be considered.

#### 6.6.10.2 Potential for Corrosion

The water sample tested exhibited a pH of 7.46 and a resistivity of 7,000 ohm-cm. According to the MTO Gravity Pipe Design Guidelines (2014), the pH is not considered detrimental to culvert durability as it is less than 8.0. The resistivity is greater than 6,000 ohm-cm, which indicates that the soil corrosiveness is very low (10,000 > R > 2,000 ohm-cm), as per Table 3.2 of the MTO Gravity Pipe Design Guidelines (2014). However, the culvert will be located under the roadway shoulder and will be exposed to de-icing salt. Therefore, concrete should be designed for a "C" type exposure class as defined by CSA A23.1-14 Table 1 and consideration should be given to providing corrosion protection to reinforcing elements. All culverts should be designed with consideration given to Table 7.1 of the MTO Gravity Pipe Design Guidelines (2014).





## **7.0 CLOSURE**

This Foundation Design Report was prepared by Ms. Madison Kennedy, B.A.Sc., a member of the geotechnical engineering group. The technical aspects were reviewed by Mr. Christopher Ng, P.Eng., a geotechnical engineer and an Associate of Golder. Mr. Jorge M. A. Costa, P.Eng., a Senior Consultant with Golder and Designated MTO Foundations Contact conducted an independent quality control review of this report.



## FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 27+691

### Report Signature Page

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## FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 27+691

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## FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 27+691

### Ontario Water Resources Act:

Ontario Regulation 331/13 Amendment to Revised Regulations of Ontario 1990, Regulation 903

### Ontario Occupational Health and Safety Act:

Ontario Regulation 213/91 Construction Projects as amended by O. Reg. 443/09

### Ontario Provincial Standard Drawing:

OPSD 208.010	Benching of Earth Slopes
OPSD 802.010	Flexible Pipe Embedment and Backfill
OPSD 802.031	Rigid Pipe Bedding, Cover and Backfill, Type 3 Soil – Earth Excavation
OPSD 803.010	Backfill and Cover for Concrete Culverts with Spans Less Than or Equal to 3.0 m
OPSD 810.010	Rip-Rap Treatment for Sewer and Culvert Outlets
OPSD 3090.100	Foundation, Frost Penetration Depths for Northern Ontario

### Ontario Provincial Standard Specification:

OPSS.PROV 206	Construction Specification for Grading
OPSS.PROV 401	Construction Specifications for Trenching, Backfilling and Compacting
OPSS.PROV 421	Construction Specifications for Pipe Culvert Installation in Open Cut
OPSS 422	Construction Specifications for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS.PROV 501	Construction Specifications for Compacting
OPSS 517	Construction Specifications for Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS.PROV 539	Construction Specifications for Temporary Protection Systems
OPSS 902	Construction Specifications for Excavating and Backfilling – Structures
OPSS.PROV 1002	Material Specifications for Aggregates - Concrete
OPSS.PROV 1010	Material Specifications for Aggregates – Base, Subbase, Select Subgrade, Backfill Material
OPSS.PROV 1205	Material Specification for Clay Seal

### Commercial Software:

Slide (Version 6.0) by Rocscience Inc

Settle<sup>3D</sup> (Version 4.0) by Rocscience Inc



# **TABLES**



## FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 27+691

Table 1: Summary of Existing Culvert Details

Culvert Location (Township)	Culvert ID	Approximate Height of Embankment <sup>1</sup>	Existing Culvert			Approximate Invert Elevation <sup>2</sup>		Boreholes	Dynamic Cone Penetration Tests
			Type	Approximate Dimension	Approximate Length	Upstream	Downstream		
STA 27+691 (Teck)	C4	Up to about 5 m	Unknown	Unknown	Unknown	316.8 m (East End)	315.2 m (West End)	7 Boreholes (C4-1 to C4-6A and C4-6B)	9 DCPTs (C4-DCPT-1 to C4-DCPT-9)

Notes:

1. Embankment height is relative to existing ground surface level at the toe of embankment adjacent to the culvert.
2. Culvert invert elevations are estimated based on the top of culvert surveys and culvert dimensions provided by MTO.

Prepared By: MK  
Checked By: CN  
Reviewed By: JMAC



## FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 27+691

**Table 2: Comparison of Foundation Alternatives for Culvert Replacement**

Replacement Alternatives	Advantages	Disadvantages	Risks/Consequences
Corrugated Steel Pipe (CSP) Culvert	<ul style="list-style-type: none"> <li>Minimizes the depth of excavation, excavation support and dewatering requirements compared to cast-in-place open footing culvert.</li> <li>Culvert construction using CSP pipes is expected to be the fastest, resulting in the shortest duration for dewatering and surface water pumping, where required.</li> <li>More tolerant of total and differential settlement if embankment widening or a grade raise is required, at the culvert site than precast and cast-in-place open footing culverts.</li> </ul>	<ul style="list-style-type: none"> <li>Dewatering is required to carry out construction in-the-dry to allow for placement and compaction of backfill around the culvert.</li> <li>Cut-off wall or clay blanket may be required at inlet/outlet ends to mitigate potential for scour around/under the culvert.</li> <li>Proper compaction of backfill material under the haunches and to the springline is difficult.</li> <li>Will have a shorter lifespan than a concrete structure (concrete pipe, precast box or open footing culvert).</li> <li>Much larger structure(s) may be required to accommodate design flows as compared to a box or open footing culvert of similar span width and height.</li> </ul>	<ul style="list-style-type: none"> <li>Some risk of disturbance of the very loose to compact sandy silt to gravelly silty sand to sand deposit under the culvert during construction.</li> </ul>
Concrete Pipe Culvert	<ul style="list-style-type: none"> <li>Minimizes the depth of excavation, excavation support and dewatering requirements compared to cast-in-place open footing culvert.</li> <li>Compared to cast-in-place open footings, the use of concrete pipe segments is expected to allow for faster construction, resulting in shorter duration for dewatering and surface water pumping, where required.</li> <li>More tolerant of total and differential settlement if embankment widening or a grade raise is required, at the culvert site than a cast-in-place open footing culvert.</li> <li>Will have a longer lifespan than a culvert of CSP construction.</li> </ul>	<ul style="list-style-type: none"> <li>A concrete pipe culvert will require slightly longer duration for construction as compared to the construction of a CSP culvert.</li> <li>Dewatering is required to carry out construction in-the-dry to allow for placement and compaction of backfill around the culvert.</li> <li>Cut-off wall or clay blanket may be required at inlet/outlet ends to mitigate potential for scour around/under the culvert.</li> <li>Proper compaction of backfill material under the haunches and to the springline is difficult.</li> <li>Much larger structure(s) may be required to accommodate design flows as compared to a box or open footing culvert of similar span width and height.</li> </ul>	<ul style="list-style-type: none"> <li>Some risk of disturbance of the very loose to compact sandy silt to gravelly silty sand to sand deposit under the culvert during construction.</li> </ul>





## FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 27+691

**Table 2: Comparison of Foundation Alternatives for Culvert Replacement**

Replacement Alternatives	Advantages	Disadvantages	Risks/Consequences
Precast Box Culvert	<ul style="list-style-type: none"> <li>Minimizes the depth of excavation, excavation support and dewatering requirements compared to cast-in-place open footing culvert.</li> <li>Compared to cast-in-place open footings, the use of precast box segments is expected to allow for faster construction, resulting in shorter duration for dewatering and surface water pumping.</li> <li>More tolerant of total and differential settlement if embankment widening or a grade raise is required, at the culvert site than a cast-in-place open footing culvert.</li> <li>Will have a longer lifespan than a culvert of CSP construction.</li> <li>Easier to place/compact backfill compared to a pipe culvert.</li> <li>Box culvert of similar span width and height as a CSP or concrete pipe culvert can accommodate higher flows.</li> </ul>	<ul style="list-style-type: none"> <li>A precast box culvert will require longer duration for construction than a CSP and a concrete pipe culvert.</li> <li>Cut-off wall or clay blanket may be required at inlet/outlet ends to mitigate potential for scour around/under the culvert.</li> </ul>	<ul style="list-style-type: none"> <li>Some risk of disturbance of the very loose to compact sandy silt to gravelly silty sand to sand deposit under the culvert during construction.</li> </ul>
Cast-In-Place Open Footing Culvert	<ul style="list-style-type: none"> <li>Provides a relatively higher bearing capacity due to the depth of embedment of footings and /or the footings being founded on the cobble deposit.</li> <li>Will have a longer lifespan than a culvert of CSP construction.</li> <li>Open footing culvert of similar span width and height as a CSP or concrete pipe culvert can accommodate higher flows.</li> </ul>	<ul style="list-style-type: none"> <li>Deeper excavations, excavation support and dewatering requirements compared to other culvert types;</li> <li>Additional time will be required to implement a dewatering system for the construction of footings in-the-dry.</li> <li>A cast-in-place open footing culvert is less tolerant of total and differential settlement.</li> <li>May require excavation of cobbles layer and placement of a granular levelling pad to accommodate strip footing construction.</li> </ul>	<ul style="list-style-type: none"> <li>High risk of disturbance of the dense sand and gravel deposit under the culvert during construction.</li> <li>Culvert joints may be required to accommodate total and differential settlement (if applicable)</li> </ul>

Prepared By: MCK  
Checked By: CN  
Reviewed By: JMAC



## FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 27+691

**Table 3: Factored Ultimate and Serviceability Geotechnical Resistances for Culvert Replacement Options**

Culvert Location (Township)	Proposed Invert Elevation <sup>1</sup> (Upstream / Downstream)	Culvert Type	Approximate Founding Elevation (Upstream / Downstream) <sup>1</sup>	Founding Condition	Culvert Dimensions <sup>1</sup>	Factored Geotechnical Axial Resistance at ULS <sup>2</sup>	Factored Serviceability Geotechnical Resistance at SLS for 25 mm of Settlement
STA 21+845 (Otto)	317.1 m / 315.1 m (East / West)	Corrugated Steel Pipe (CSP)	316.8 m / 314.8 m (East / West)	Compacted Granular Fill over Sandy Silt to Silt and Sand to Sand	750 mm diameter by 37 m long	550 kPa	500 kPa
					910 mm diameter by 37 m long	550 kPa	350 kPa
		Concrete Pipe Culvert	316.8 m / 314.8 m (East / West)	Compacted Granular Fill over Sandy Silt to Silt and Sand to Sand	750 mm diameter by 37 m long	550 kPa	200 kPa
					910 mm diameter by 37 m long	550 kPa	150 kPa
		Precast Box	316.8 m / 314.8 m (East / West)	Compacted Granular Fill over Sandy Silt to Silt and Sand to Sand	750 mm wide by 750 mm high by 37 m long	550 kPa	200 kPa
					910 mm wide by 910 mm high by 37 m long	550 kPa	150 kPa
		Cast-In-Place Open Footing	314.7 m / 312.7 m (East / West)	Sand and Gravel / Granular 'B' Type II over Cobbles	0.6 m wide footings / 37 m long	800 kPa	N/A <sup>3</sup>
			314.7 m / 312.7 m (East / West)	Sand and Gravel / Granular 'B' Type II over Cobbles	1.2 m wide footings / 37 m long	850 kPa	N/A <sup>3</sup>

- Notes:
1. Culvert invert elevations and length are based on the Drainage and Hydrology Report for the Replacement of Four Centreline Culverts on Highway 112 and Highway 650, W.P. 5427-15-01, prepared by MMM, dated November 2016
  2. The factored ultimate geotechnical resistance at ULS and factored serviceability geotechnical resistance at SLS for 25 mm of settlement are estimated based on the assumed culvert dimensions. The geotechnical resistance should be reviewed if the founding elevation and/or the footing/base width differ from those given above.
  3. The factored serviceability geotechnical resistance at SLS for 25 mm of settlement will be greater than the factored ultimate geotechnical resistance at ULS and as a result, the SLS condition does not apply; the estimated settlement for the factored ULS resistance is less than 25 mm.

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Reviewed By: JMAC



## FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 27+691

**Table 4: Resistance to Lateral Loads/Sliding Resistance for Culvert Replacement Options**

Culvert Type	Interface Material	Coefficient of Friction ( $\tan \delta$ )
Corrugated Steel Pipe Culvert (CSP)	Compacted Granular Fill (Bedding)	0.35
Concrete Pipe Culvert	Compacted Granular Fill (Bedding)	0.40
Precast Box Culvert	Compacted Granular Fill (Bedding)	0.40
Cast-In-Place Open Footing Culvert	Dense Sand and Gravel and Cobbles	0.50

Prepared By: MCK  
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FOUNDATION REPORT - CENTRELINE CULVERT  
REPLACEMENT - HIGHWAY 112 STA 27+691

Table 5: Summary of Foundation Engineering Parameters

Culvert Designation	Culvert Location (Township)	Stratigraphic Unit	Top Elevation (m)	Thickness (m)	$\gamma'$ (kN/m <sup>3</sup> )	$\phi'$ (°)	$c'$ (kPa)	$S_u$ (kPa)	$\sigma_p'$ (kPa)	$e_o$	$C_c$	$C_r$	$m_v$ (kPa <sup>-1</sup> )	$E'$ (MPa)	$c_v$ (cm <sup>2</sup> /s)	Coefficient of Earth Pressure		
																Active, $K_a$	At Rest, $K_o$	Passive, $K_p$
C4	Highway 112 STA 27+691 (Teck)	New Granular Embankment Fill	-	-	21	35	-	-	-	-	-	-	-	150	-	0.27	0.43	3.69
		Existing Compact to Very Dense Gravelly Sand Fill	319.6 – 319.2	0.4 – 2.0	21	32	-	-	-	-	-	-	-	40	-	0.31	0.47	3.25
		Existing Loose to Compact Silty Sand Fill	319.2 – 317.6	1.3 – 2.5	20	30								20	-	0.33	0.50	3.00
		Compact to Dense Gravelly Silty Sand to Sand and Gravel	~ 315.1	~ 2.1	21	32	-	-	-	-	-	-	-	10 - 40	-	0.31	0.47	3.25
		Very Loose to Loose Sandy Silt to Silt and Sand to Sand	317.9 – 314.7	0.5 – 1.2	20	30	-	-	-	-	-	-	-	5	-	0.33	0.50	3.00
		Firm to Very Stiff Silty Clay	~ 315.0	~ 2.2	19	30	-	50	-	-	-	-	1 x 10 <sup>-4</sup>	-	2 x 10 <sup>-3</sup>	0.33	0.50	3.00
		Cobble	316.7 – 314.2	2.2 – 2.5	20	40	-	-	-	-	-	-	-	150	-	0.21	0.36	4.60

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## FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 27+691

**Table 6: Summary of Stability Analysis**

Culvert ID Culvert Location (Township)	Stability Analysis <sup>1</sup>					Figure Number
	Condition	Embankment	Slope Profile	Embankment Height at Culvert Location	Minimum Factor of Safety <sup>2</sup>	
C4 STA 27+691 (Teck)	4.5 m Embankment Widening – West Side (Temporary) <sup>3</sup>	West Slope	1.5H:1V	5 m	≥ 1.3	D2
	Median/Internal Side Slopes with 4.5 m Embankment Widening – West Side (Temporary)	East Slope	1H:1V <sup>4</sup>	Up to 4 m	≥ 1.3	D1
		West Slope	1H:1V <sup>4</sup>	Up to 4 m	≥ 1.3	D2
	Median/Internal Side Slopes with Grade Lowering (Temporary)	East Slope	1H:1V <sup>4</sup>	Up to 3 m	≥ 1.3	D3
		West Slope	1H:1V <sup>4</sup>	Up to 3 m	≥ 1.3	D4
	Final Embankment	East Slope	2H:1V	3 m	≥ 1.5	D5
		West Slope	2H:1V	5 m	≥ 1.5	D5

- Note:
1. Stability analysis was carried out using total stress (undrained) parameters for cohesive deposits and Mohr-Coulomb (drained) parameters for non-cohesive deposits.
  2. The minimum FoS is based on a deep seated, global trial failure surface that would impact the operation of the highway.
  3. Where embankment widening is required, benching of the existing embankment side slope should be carried out in accordance with OPSD 208.010 (Benching of Earth Slopes).
  4. For temporary 1H:1V side slopes, surficial sloughing may occur which may require maintenance. If sloughing occurs during construction, consideration could be given to the placement of a surficial layer of granular fill on the temporary embankment slope to mitigate further sloughing.

Prepared By: MCK  
 Checked By: CN  
 Reviewed By: JMAC



## FOUNDATION REPORT - CENTRELINE CULVERT REPLACEMENT - HIGHWAY 112 STA 27+691

Table 7: Summary of Settlement Analysis

Culvert ID Culvert Location (Township)	Construction Stage	Estimated Factored Immediate Settlement of Foundation Soils	Estimated Factored Consolidation Settlement of Foundation Soils <sup>1</sup>	Estimated Total Factored Settlement
C4 STA 27+691 (Teck)	4.5 m Embankment Widening – West Side (Temporary)	< 5 mm	20 mm	< 25 mm
	Final Embankment	< 5 mm	< 5 mm	< 10 mm

Notes: 1. About 90 per cent of the factored primary consolidation settlement is estimated to be completed in about 10 days.

Prepared By: MCK  
Checked By: CN  
Reviewed By: JMAC



# FIGURES






West side of Highway 112 at STA 27+691 (Township of Teck) Culvert, looking west. May 31, 2016.



West side of Highway 112 at STA 27+691 (Township of Teck) Culvert, looking northeast. May 31, 2016.

REVISION DATE: February 3, 2017 BY: MCK Project: 1531057

PROJECT		<b>Detail Design for Replacement of 3 Centreline Culverts – Highway 112</b>			
		<b>GWP 5105-12-00; WP 5428-15-01</b>			
TITLE		<b>Site Photographs</b>			
		<b>Culvert STA 27+691 (Township of Teck)</b>			
		<b>Highway 112</b>			
		PROJECT No. 1530157		FILE No. ----	
		DESIGN	MCK	Aug16	SCALE NTS
		CADD	-- --		REV.
		CHECK	CN	Aug 16	<b>FIGURE 1A</b>
		REVIEW	JMAC	Aug 16	





East side of Highway 112 at STA 27+691 (Township of Teck) Culvert, looking southwest. June 1, 2016.

REVISION DATE: February 3, 2017 BY: MCK Project: 1531057

PROJECT		<b>Detail Design for Replacement of 3 Centreline Culverts – Highway 112</b> <b>GWP 5105-12-00; WP 5428-15-01</b>			
TITLE		<b>Site Photographs</b> <b>Culvert STA 27+691 (Township of Teck)</b> <b>Highway 112</b>			
		PROJECT No. 1530157		FILE No. ----	
		DESIGN	MCK	Aug16	SCALE NTS REV.
		CADD	-- --		
		CHECK	CN	Aug 16	
		REVIEW	JMAC	Aug 16	
					<b>FIGURE 1B</b>

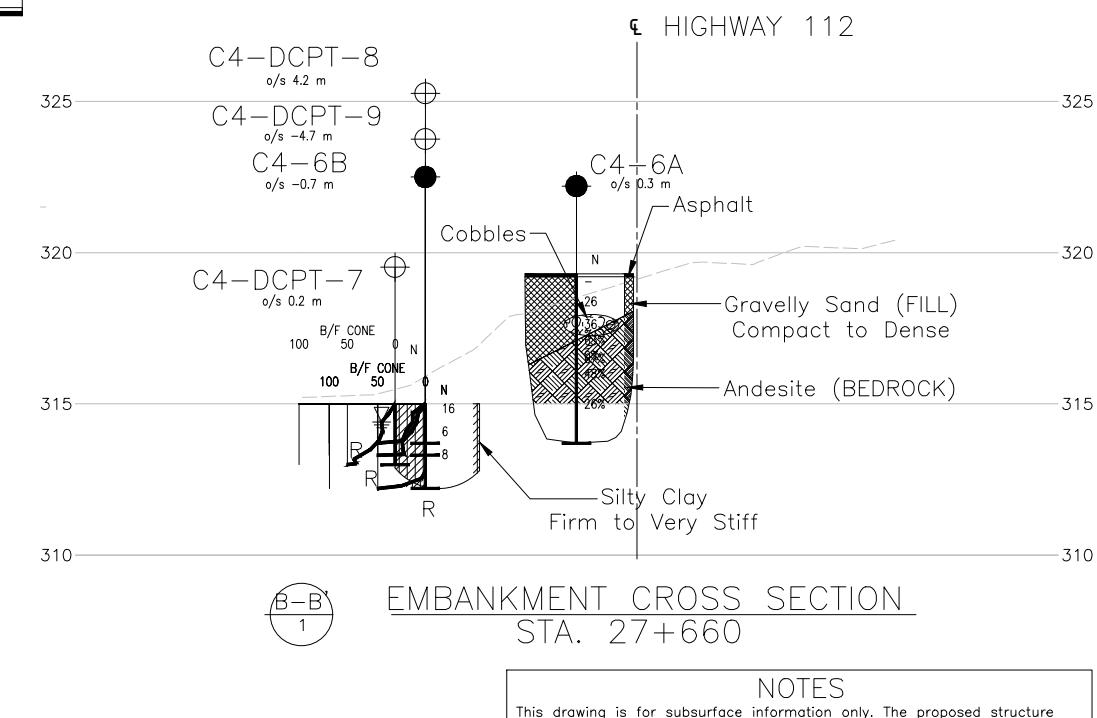
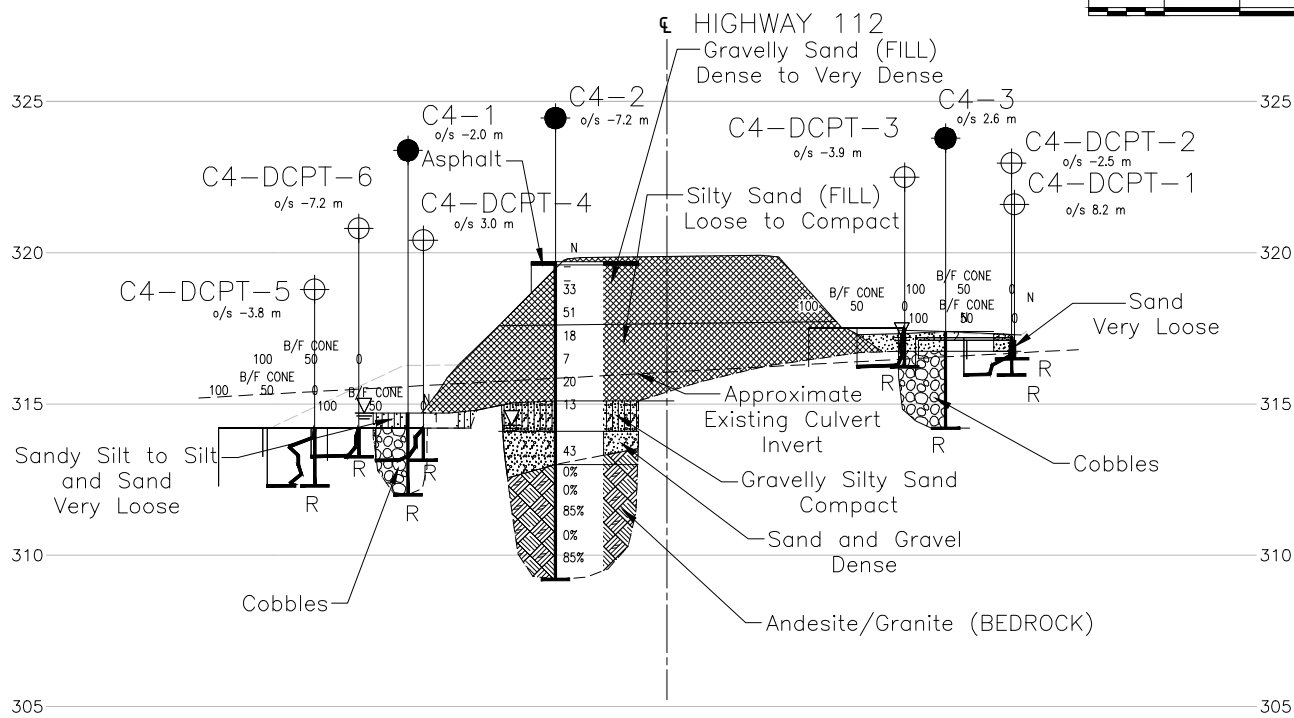
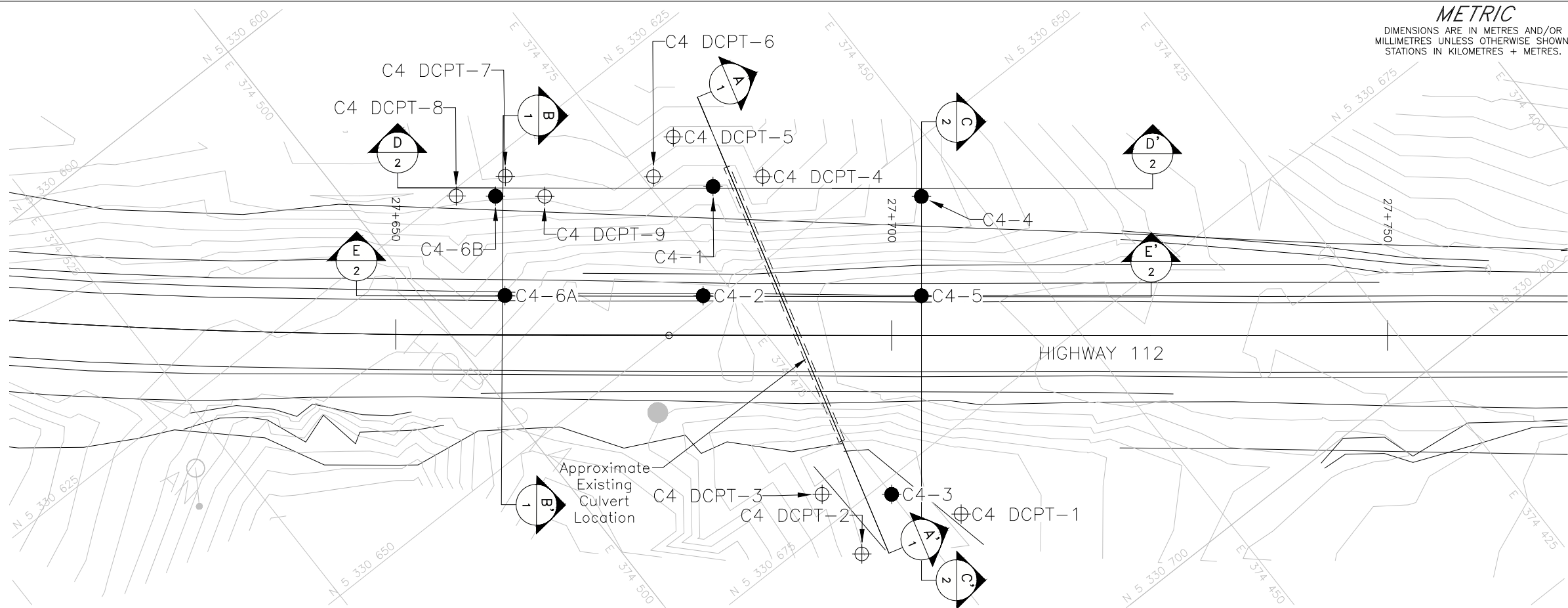


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**FOUNDATION REPORT - CENTRELINE CULVERT  
REPLACEMENT - HIGHWAY 112 STA 27+691**

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# DRAWINGS



**NOTES**

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

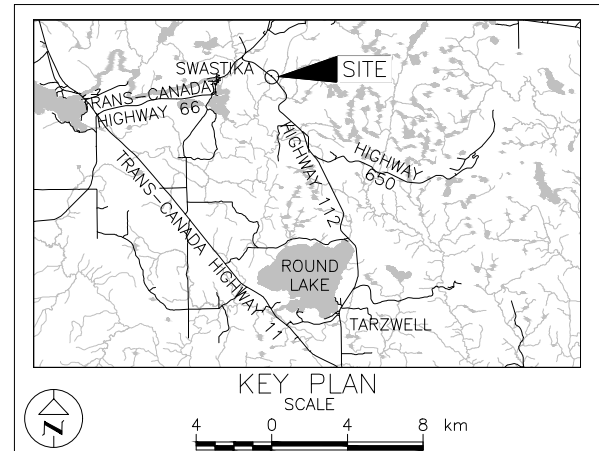
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

**METRIC**  
DIMENSIONS ARE IN METRES AND/OR  
MILLIMETRES UNLESS OTHERWISE SHOWN.  
STATIONS IN KILOMETRES + METRES.

CONT No. \_\_\_\_\_  
WP No. 5428-15-01

HIGHWAY 112  
CULVERT STA. 27+691

BOREHOLE LOCATIONS AND  
SOIL STRATA



**LEGEND**

- Borehole - Current Investigation
- ⊕ Dynamic Cone Penetration Test
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% Rock Quality Designation (RQD)
- ≡ WL upon completion of drilling
- R Refusal

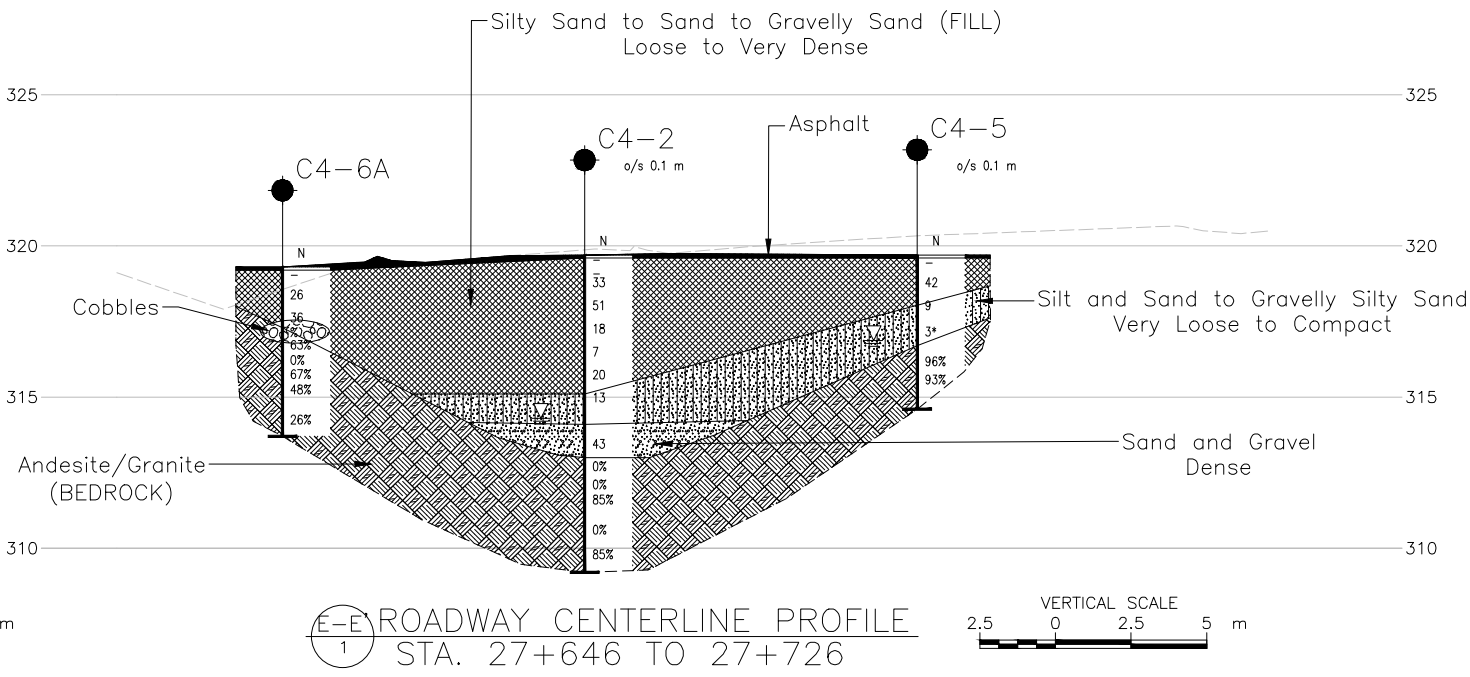
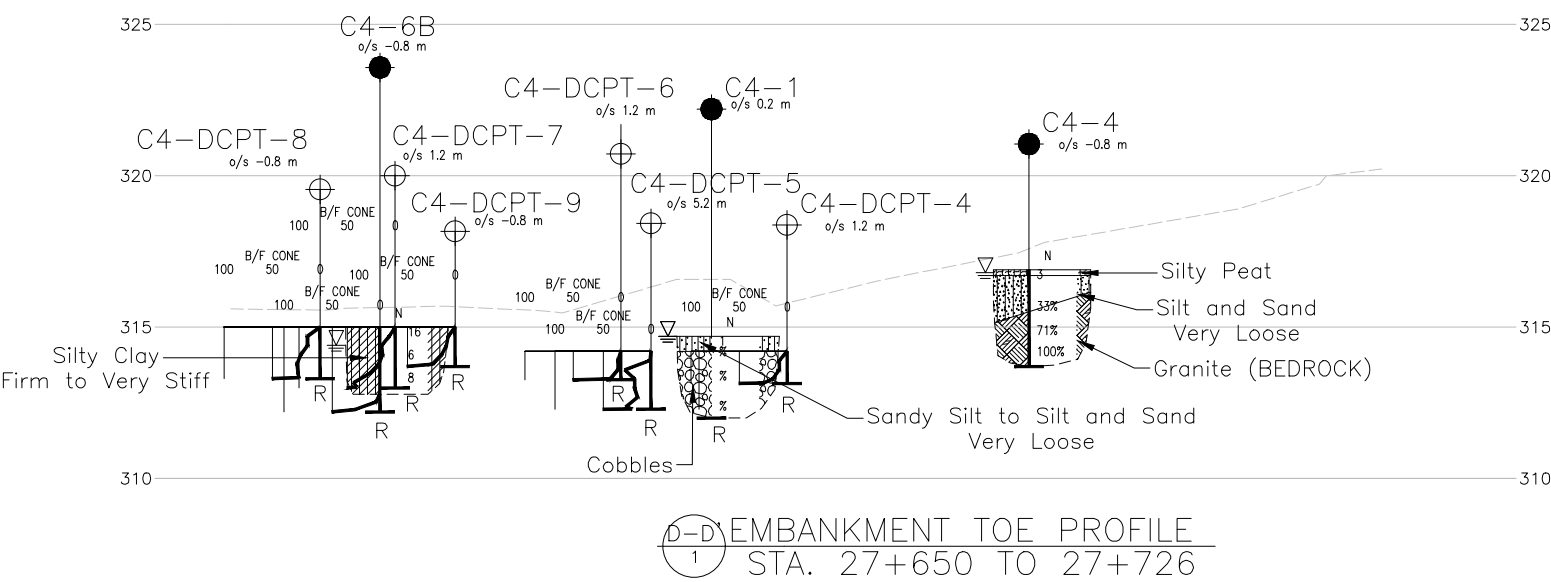
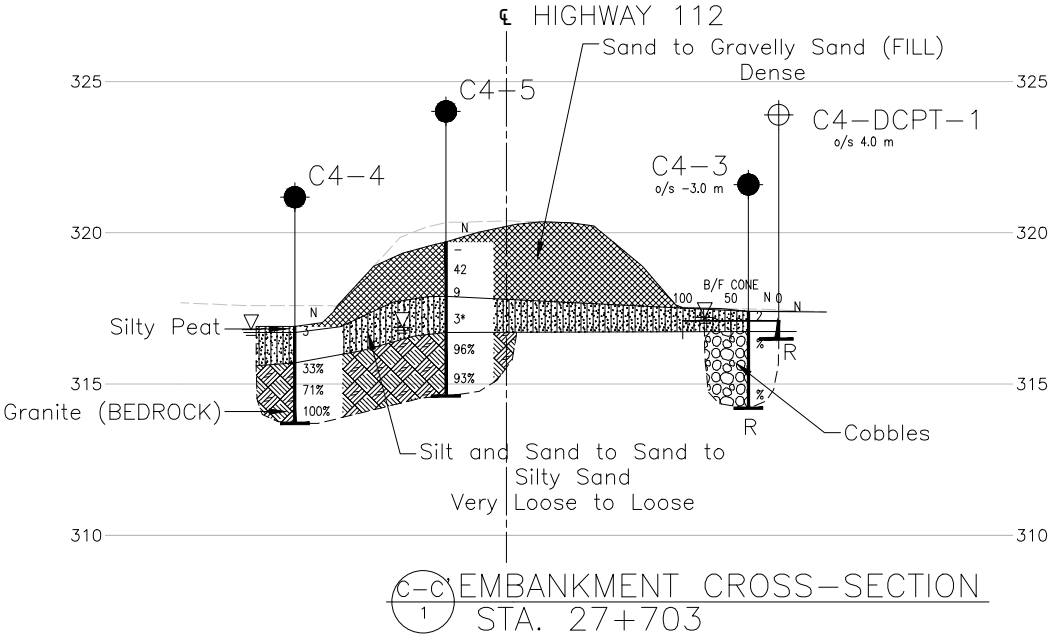
BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
C4-1	314.7	5330640.9	374470.0
C4-2	319.7	5330648.9	374477.6
C4-3	317.4	5330676.4	374475.0
C4-4	316.9	5330654.7	374454.1
C4-5	319.7	5330662.5	374460.3
C4-6A	319.3	5330636.5	374493.3
C4-6B	315.0	5330628.1	374487.8
C4 DCPT-1	317.1	5330682.3	374470.8
C4 DCPT-2	317.2	5330679.2	374481.1
C4 DCPT-3	317.5	5330672.1	374480.5
C4 DCPT-4	314.2	5330643.2	374465.4
C4 DCPT-5	314.2	5330634.5	374470.0
C4 DCPT-6	314.2	5330636.4	374474.1
C4 DCPT-7	315.0	5330627.1	374485.8
C4 DCPT-8	315.0	5330625.6	374490.9
C4 DCPT-9	315.0	5330631.2	374483.9

**REFERENCE**

Base plan, culvert section and surface data provided in digital format by MTO, drawing file no. "b07590112001.dwg", dated May, 2016, received June 29, 2016.

NO.	DATE	BY	REVISION
Geocres No. 42A-114			
HWY. 112	PROJECT NO. 1531057		DIST. .
SUBM'D. MK	CHKD. MCK	DATE: 4/4/2017	SITE: .
DRAWN: MR	CHKD. MCK	APPD. JMAC	DWG. 1





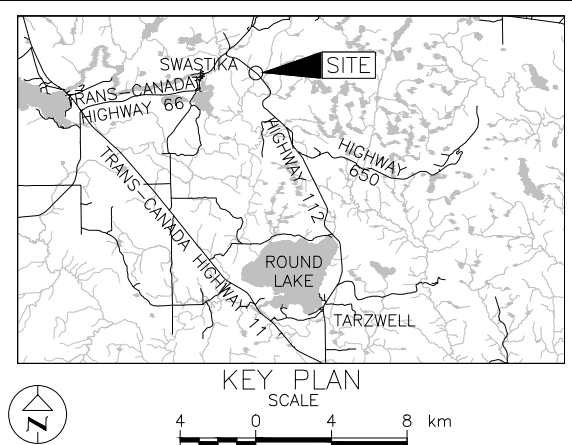
**METRIC**  
DIMENSIONS ARE IN METRES AND/OR  
MILLIMETRES UNLESS OTHERWISE SHOWN.  
STATIONS IN KILOMETRES + METRES.

CONT No. WP No. 5428-15-01

HIGHWAY 112  
CULVERT STA. 27+691

SOIL STRATA

SHEET



- LEGEND**
- Borehole - Current Investigation
  - ⊕ Dynamic Cone Penetration Test
  - N Standard Penetration Test Value
  - 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
  - 100% Rock Quality Designation (RQD)
  - WL upon completion of drilling
  - R Refusal

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
C4-1	314.7	5330640.9	374470.0
C4-2	319.7	5330648.9	374477.6
C4-3	317.4	5330676.4	374475.0
C4-4	316.9	5330654.7	374454.1
C4-5	319.7	5330662.5	374460.3
C4-6A	319.3	5330636.5	374493.3
C4-6B	315.0	5330628.1	374487.8
C4 DCPT-1	317.1	5330682.3	374470.8
C4 DCPT-4	314.2	5330643.2	374465.4
C4 DCPT-5	314.2	5330634.5	374470.0
C4 DCPT-6	314.2	5330636.4	374474.1
C4 DCPT-7	315.0	5330627.1	374485.8
C4 DCPT-8	315.0	5330625.6	374490.9
C4 DCPT-9	315.0	5330631.2	374483.9

**NOTES**

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The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

**REFERENCE**

Base plan, culvert section and surface data provided in digital format by MTO, drawing file no. "b07590112001.dwg", dated May, 2016, received June 29, 2016.



NO.	DATE	BY	REVISION
Geocres No. 42A-114			
HWY. 112	PROJECT NO. 1531057	DIST. .	
SUBM'D. MK	CHKD. MCK	DATE: 4/4/2017	SITE: .
DRAWN: MR	CHKD. MCK	APPD. JMAC	DWG. 2





# **APPENDIX A**

## **Record of Boreholes**



## LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

### I. GENERAL

$\pi$	3.1416
$\ln x$ ,	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
FoS	factor of safety

### II. STRESS AND STRAIN

$\gamma$	shear strain
$\Delta$	change in, e.g. in stress: $\Delta \sigma$
$\varepsilon$	linear strain
$\varepsilon_v$	volumetric strain
$\eta$	coefficient of viscosity
$\nu$	Poisson's ratio
$\sigma$	total stress
$\sigma'$	effective stress ( $\sigma' = \sigma - u$ )
$\sigma'_{vo}$	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
$\sigma_{oct}$	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
$\tau$	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

### III. SOIL PROPERTIES

#### (a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
$\gamma'$	unit weight of submerged soil ( $\gamma' = \gamma - \gamma_w$ )
$D_R$	relative density (specific gravity) of solid particles ( $D_R = \rho_s / \rho_w$ ) (formerly $G_s$ )
e	void ratio
n	porosity
S	degree of saturation

\* Density symbol is  $\rho$ . Unit weight symbol is  $\gamma$  where  $\gamma = \rho g$  (i.e. mass density multiplied by acceleration due to gravity)

#### (a) Index Properties (continued)

w	water content
$w_l$ or LL	liquid limit
$w_p$ or PL	plastic limit
$I_p$ or PI	plasticity index = $(w_l - w_p)$
$w_s$	shrinkage limit
$I_L$	liquidity index = $(w - w_p) / I_p$
$I_C$	consistency index = $(w_l - w) / I_p$
$e_{max}$	void ratio in loosest state
$e_{min}$	void ratio in densest state
$I_D$	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

#### (b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

#### (c) Consolidation (one-dimensional)

$C_c$	compression index (normally consolidated range)
$C_r$	recompression index (over-consolidated range)
$C_s$	swelling index
$C_{\alpha}$	secondary compression index
$m_v$	coefficient of volume change
$C_v$	coefficient of consolidation (vertical direction)
$C_h$	coefficient of consolidation (horizontal direction)
$T_v$	time factor (vertical direction)
U	degree of consolidation
$\sigma'_p$	pre-consolidation stress
OCR	over-consolidation ratio = $\sigma'_p / \sigma'_{vo}$

#### (d) Shear Strength

$\tau_p, \tau_r$	peak and residual shear strength
$\phi'$	effective angle of internal friction
$\delta$	angle of interface friction
$\mu$	coefficient of friction = $\tan \delta$
$c'$	effective cohesion
$c_u, s_u$	undrained shear strength ( $\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
$p'$	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
$q_u$	compressive strength $(\sigma_1 - \sigma_3)$
$S_t$	sensitivity

Notes: 1  
2

$\tau = c' + \sigma' \tan \phi'$   
shear strength = (compressive strength)/2





## LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

### I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split-spoon
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

### II. PENETRATION RESISTANCE

#### Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

#### Dynamic Cone Penetration Resistance; $N_d$ :

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

**PH:** Sampler advanced by hydraulic pressure

**PM:** Sampler advanced by manual pressure

**WH:** Sampler advanced by static weight of hammer

**WR:** Sampler advanced by weight of sampler and rod

#### Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm<sup>2</sup> pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance ( $Q_t$ ), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

### III. SOIL DESCRIPTION

#### (a) Non-Cohesive Soils

Density Index	N
Relative Density	Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

#### (b) Cohesive Soils Consistency

	kPa	Cu, Su	psf
Very soft	0 to 12		0 to 250
Soft	12 to 25		250 to 500
Firm	25 to 50		500 to 1,000
Stiff	50 to 100		1,000 to 2,000
Very stiff	100 to 200		2,000 to 4,000
Hard	over 200		over 4,000

### IV. SOIL TESTS

w	water content
w <sub>p</sub>	plastic limit
w <sub>l</sub>	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test <sup>1</sup>
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement <sup>1</sup>
D <sub>R</sub>	relative density (specific gravity, G <sub>s</sub> )
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO <sub>4</sub>	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

**Note: 1** Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

### V. MINOR SOIL CONSTITUENTS

#### Per cent by Weight

Modifier	
0 to 5	Trace
5 to 12	Trace to Some (or Little)
12 to 20	Some
20 to 30	(ey) or (y)
over 30	And (non-cohesive (cohesionless)) or With (cohesive)

#### Example

Trace sand  
Trace to some sand  
Some sand  
Sandy  
Sand and Gravel  
Silty Clay with sand / Clayey Silt with sand



## LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

### WEATHERING STATE

**Fresh:** no visible sign of weathering

**Faintly weathered:** weathering limited to the surface of major discontinuities.

**Slightly weathered:** penetrative weathering developed on open discontinuity surfaces but only slight weathering of rock material.

**Moderately weathered:** weathering extends throughout the rock mass but the rock material is not friable.

**Highly weathered:** weathering extends throughout rock mass and the rock material is partly friable.

**Completely weathered:** rock is wholly decomposed and in a friable condition but the rock and structure are preserved.

### BEDDING THICKNESS

<u>Description</u>	<u>Bedding Plane Spacing</u>
Very thickly bedded	Greater than 2 m
Thickly bedded	0.6 m to 2 m
Medium bedded	0.2 m to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 mm to 60 mm
Laminated	6 mm to 20 mm
Thinly laminated	Less than 6 mm

### JOINT OR FOLIATION SPACING

<u>Description</u>	<u>Spacing</u>
Very wide	Greater than 3 m
Wide	1 m to 3 m
Moderately close	0.3 m to 1 m
Close	50 mm to 300 mm
Very close	Less than 50 mm

### GRAIN SIZE

<u>Term</u>	<u>Size*</u>
Very Coarse Grained	Greater than 60 mm
Coarse Grained	2 mm to 60 mm
Medium Grained	60 microns to 2 mm
Fine Grained	2 microns to 60 microns
Very Fine Grained	Less than 2 microns

Note: \* Grains greater than 60 microns diameter are visible to the naked eye.

### CORE CONDITION

#### Total Core Recovery (TCR)

The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

#### Solid Core Recovery (SCR)

The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

#### Rock Quality Designation (RQD)

The percentage of solid drill core, greater than 100 mm length, recovered at full diameter, measured relative to the length of the total core run. RQD varied from 0% for completely broken core to 100% for core in solid sticks.

### DISCONTINUITY DATA

#### Fracture Index

A count of the number of discontinuities (physical separations) in the rock core, including both naturally occurring fractures and mechanically induced breaks caused by drilling.

#### Dip with Respect to Core Axis

The angle of the discontinuity relative to the axis (length) of the core. In a vertical borehole a discontinuity with a 90° angle is horizontal.

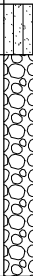
#### Description and Notes

An abbreviation description of the discontinuities, whether naturally occurring separations such as fractures, bedding planes and foliation planes, or mechanically induced features caused by drilling such as ground or shattered core and mechanically separated bedding or foliation surfaces. Additional information concerning the nature of fracture surfaces and infillings are also noted.

#### Abbreviations

JN Joint	PL Planar
FLT Fault	CU Curved
SH Shear	UN Undulating
VN Vein	IR Irregular
FR Fracture	K Slickensided
SY Stylolite	PO Polished
BD Bedding	SM Smooth
FO Foliation	SR Slightly Rough
CO Contact	RO Rough
AXJ Axial Joint	VR Very Rough
KV Karstic Void	
MB Mechanical Break	

PROJECT <u>1531057</u>	<b>RECORD OF BOREHOLE No C4-1</b>	SHEET 1 OF 1	<b>METRIC</b>
W.P. <u>5428-15-01</u>	LOCATION <u>N 5330640.9; E 374470.0 MTM ZONE</u>	ORIGINATED BY <u>SA</u>	
DIST <u>          </u> HWY <u>112</u>	BOREHOLE TYPE <u>Portable Equipment, HQ Casing, NQ Coring (Manual Hammer)</u>	COMPILED BY <u>MR</u>	
DATUM <u>Geodetic</u>	DATE <u>June 9, 2016</u>	CHECKED BY <u>MK</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)							
								20	40	60	80	100	W <sub>P</sub>	W	W <sub>L</sub>					
314.7	GROUND SURFACE		1A	SS	1															
0.0	Sandy SILT to SILT and SAND, trace gravel, trace to some clay, trace organics and rootlets		1B																	
314.2	Loose Brown Wet COBBLES		2	RC	REC 29%															
0.5			3	RC	REC 49%															
			4	RC	REC 0%															
312.0	END OF BOREHOLE CORE BARREL JAMMED																			
2.7	NOTES:  1. Water level at ground surface upon completion of drilling.  2. Geographic Coordinates:  Latitude: 48.110835 Longitude: -80.064304																			


PROJECT 1531057		RECORD OF BOREHOLE No C4-2				SHEET 1 OF 1		METRIC								
W.P. 5428-15-01		LOCATION N 5330648.9; E 374477.6 MTM ZONE				ORIGINATED BY DM										
DIST _____ HWY 112		BOREHOLE TYPE CME 55, 152 mm O.D. Solid Stem Augers				COMPILED BY MR										
DATUM Geodetic		DATE June 6, 2016				CHECKED BY MK										
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
319.7	GROUND SURFACE															
0.9	ASPHALT (100 mm)		1	AS	-											
	Gravelly sand, some silt, containing cobbles (FILL) Dense to very dense Brown Moist		2	AS	-											
			3	SS	33											
			4A	SS	51											
317.6			4B													
2.1	Silty sand, trace to some gravel, trace clay, containing cobbles (FILL) Loose to compact Brown to light brown Moist		5	SS	18											
			6	SS	7											
			7	SS	20											
315.1																
4.6	Gravelly Silty SAND, trace clay, containing cobbles Compact Light brown Wet		8	SS	13											
314.1																
5.6	SAND and GRAVEL, some silt, trace clay Dense Brown Wet		9	SS	43											
313.0																
6.7	ANDESITE/GRANITE (BEDROCK)		1	RC	REC 40%											
	Bedrock cored from depths of 6.7 m to 10.5 m.		2	RC	REC 71%											
	For bedrock coring details refer to Record of Drillhole C4-2.		3	RC	REC 100%											
			4	RC	REC 100%											
			5	RC	REC 100%											
309.2																
10.5	END OF BOREHOLE															
	NOTES:  1. Water level in open borehole at a depth of 5.4 m below ground surface (Elev. 314.3 m) upon completion of drilling.  2. Geographic Coordinates:  Latitude: 48.110906 Longitude: -80.064201															



SHEET 1 OF 1

DATUM: Geodetic

DRILLING CONTRACTOR: Landcore Drilling Inc.

CHECKED: MK

PROJECT		1531057		RECORD OF BOREHOLE No C4-3				SHEET 1 OF 1		METRIC							
W.P.		5428-15-01		LOCATION		N 5330676.4; E 374475.0 MTM ZONE				ORIGINATED BY SA							
DIST		HWY 112		BOREHOLE TYPE		Portable Equipment, HQ Casing, NQ Coring (Manual Hammer)				COMPILED BY MR							
DATUM		Geodetic		DATE		June 7, 2016				CHECKED BY MK							
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
317.4	GROUND SURFACE																
0.0	SAND, some gravel, trace silt, trace organics and rootlets Very loose Brown		1	SS	2	▽	317										
316.7	Wet COBBLES between 50 mm and 250 mm in diameter		2	RC	REC 48%		316										
0.7			3	RC	REC 0%		315										
314.2	END OF BOREHOLE CORE BARREL JAMMED																
3.2	NOTES:  1. Water level in open borehole at a depth of 0.2 m below ground surface (Elev. 317.2 m) upon completion of drilling.  2. Geographic Coordinates:  Latitude: 48.111153 Longitude: -80.064230																

PROJECT		1531057		RECORD OF BOREHOLE No C4-4				SHEET 1 OF 1		METRIC									
W.P.		5428-15-01		LOCATION		N 5330654.7; E 374454.1 MTM ZONE		ORIGINATED BY		SA									
DIST		HWY 112		BOREHOLE TYPE		Portable Equipment, HQ Casing (Manual Hammer)		COMPILED BY		MR									
DATUM		Geodetic		DATE		June 9, 2016		CHECKED BY		MK									
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)	
316.9	GROUND SURFACE																		
0.0	Silty PEAT, some sand, trace clay		1	SS	3		316												
0.2	Dark brown Moist																		
315.7	SILT and SAND, some gravel, trace to some clay, trace organics and rootlets, containing cobbles Very loose Brown to grey Wet		1	RC	REC 90%			315											RQD = 33%
1.2	GRANITE (BEDROCK)																		
	Bedrock cored from depths of 1.2 m to 3.2 m.  For bedrock coring details refer to Record of Drillhole C4-4.	2	RC	REC 100%															
			3	RC	REC 100%		314											RQD = 100%	
313.7	END OF BOREHOLE																		
3.2	NOTES:  1. Water level in open borehole at a depth of 0.1 m below ground surface (Elev. 316.8 m) upon completion of drilling.  2. Geographic Coordinates:  Latitude: 48.110960 Longitude: -80.064515																		



SHEET 1 OF 1

DATUM: Geodetic

DRILLING CONTRACTOR: Landcore Drilling Inc.

CHECKED: MK

PROJECT <u>1531057</u>		<b>RECORD OF BOREHOLE No C4-5</b>		SHEET 1 OF 1		<b>METRIC</b>	
W.P. <u>5428-15-01</u>		LOCATION <u>N 5330662.5; E 374460.3 MTM ZONE</u>		ORIGINATED BY <u>DM</u>			
DIST <u>          </u> HWY <u>112</u>		BOREHOLE TYPE <u>CME 55, 152 mm O.D. Solid Stem Augers</u>		COMPILED BY <u>MR</u>			
DATUM <u>Geodetic</u>		DATE <u>June 6 to 9, 2016</u>		CHECKED BY <u>MK</u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT   NATURAL MOISTURE   LIQUID CONTENT   LIMIT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
								○ UNCONFINED   + FIELD VANE ● QUICK TRIAXIAL   × REMOULDED					w <sub>p</sub> w   w <sub>L</sub>				
							20	40	60	80	100		20	40	60		
319.7	GROUND SURFACE																
0.0	ASPHALT (100 mm)		1	AS	-												
319.2	Gravelly sand, some slit, some crushed asphalt pieces (FILL) Brown Moist																
0.5	Sand, some gravel, trace to some silt, containing cobbles (FILL) Dense Brown Moist		2	SS	42												
317.9	SILT and SAND, some gravel, trace to some clay, trace organics and cobbles Very loose to loose Brown to light brown Wet		3	SS	9								○				
1.8																	
316.7			4	SS	3*								○				
3.0	GRANITE (BEDROCK)		1	RC	REC 100%												11 57 31 1
	Bedrock cored from depths of 3 m to 5.1 m.																RQD = 96%
	For bedrock coring details refer to Record of Drillhole C4-5.		2	RC	REC 100%												RQD = 93%
314.6	END OF BOREHOLE																
5.1	NOTES:  1. Water level in open borehole at a depth of 2.8 m below ground surface (Elev. 316.9 m) upon completion of drilling.  * Split-Spoon Bouncing  2. Geographic Coordinates:  Latitude: 48.111030 Longitude: -80.064430																

PROJECT: 1531057

**RECORD OF DRILLHOLE: C4-5**

SHEET 1 OF 1

LOCATION: N 5330662.5 ;E 374460.3

DRILLING DATE: June 9, 2016

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: —

DRILL RIG: CME 55

DRILLING CONTRACTOR: Landcore Drilling Inc.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	FLUSH	JN - Joint FLT - Fault SH - Shear VN - Vein CJ - Conjugate BD - Bedding FO - Foliation CO - Contact OR - Orthogonal CL - Cleavage PL - Planar CU - Curved UN - Undulating ST - Stepped IR - Irregular PO - Polished K - Slickensided SM - Smooth RO - Rough VR - Very Rough MB - Mechanical Break BR - Broken Rock <b>NOTE:</b> For additional abbreviations refer to list of abbreviations & symbols.										NOTES			
								RECOVERY		R.Q.D. %	FRACT. INDEX PER 0.25 m	DISCONTINUITY DATA					HYDRAULIC CONDUCTIVITY K, cm/sec		Diametral Point Load Index (MPa)	RMC -Q AVG	
								TOTAL CORE %	SOLID CORE %			B Angle	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja					Jn
								80 60 40 20 0	80 60 40 20 0												
3	NQ RC June 9, 2016	GROUND SURFACE		316.70																	
		Fresh, crystalline, pink with white banding, medium grained, non-porous, weak to strong GRANITE		3.00	1																
4					2																
5		END OF DRILLHOLE		314.60																	
6																					
7																					
8																					
9																					
10																					
11																					
12																					
13																					

DEPTH SCALE

1 : 50



LOGGED: DM

CHECKED: MK

PROJECT		1531057		RECORD OF BOREHOLE No C4-6A				SHEET 1 OF 1		METRIC							
W.P.		5428-15-01		LOCATION		N 5330636.5; E 374493.3 MTM ZONE		ORIGINATED BY		DM							
DIST		HWY 112		BOREHOLE TYPE		CME 55, 152 mm O.D. Solid Stem Augers		COMPILED BY		MR							
DATUM		Geodetic		DATE		June 9, 2016		CHECKED BY		MK							
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
319.3	GROUND SURFACE																
0.0	ASPHALT (100 mm)		1	AS	-												
	Gravelly sand, some silt, trace clay, containing cobbles (FILL) Compact to dense Brown Moist		2	SS	26												28 58 12 2
317.3	COBBLES 80 mm in diameter		3	SS	36												
2.2	ANDESITE (BEDROCK)		4	RC	REC 50%												RQD = 63%
	Bedrock cored from depths of 2 m to 5.6 m.		1	RC	REC 95%												RQD = 0%
	For bedrock coring details refer to Record of Drillhole C4-6A.		2	RC	REC 100%												RQD = 67%
			3	RC	REC 100%												RQD = 48%
			4	RC	REC 100%												
			5	RC	REC 100%												RQD = 26%
313.7	END OF BOREHOLE																
5.6	NOTE: 1. Geographic Coordinates: Latitude: 48.110793 Longitude: -80.063992																

PROJECT: 1531057

**RECORD OF DRILLHOLE: C4-6A**

SHEET 1 OF 1

LOCATION: N 5330636.5 ;E 374493.3

DRILLING DATE: June 9, 2016



DATUM: Geodetic

INCLINATION: -90° AZIMUTH: —

DRILL RIG: CME 55

DRILLING CONTRACTOR: Landcore Drilling Inc.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	FLUSH	RECOVERY				FRACT. INDEX PER 0.25 m	DISCONTINUITY DATA				HYDRAULIC CONDUCTIVITY K, cm/sec	Diametral Point Load Index (MPa)	RMC -Q AVG	NOTES	
								TOTAL CORE %	SOLID CORE %	R.Q.D. %	B Angle		DIP w.r.t CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja					Jn
2		GROUND SURFACE		317.30																	
	NQ RC June 9, 2016	COBBLES		2.00 317.10	4																
		Moderately weathered, crystalline, pink and white inclusions, fine grained, non-porous, weak ANDESITE		2.20	1													9 MPa			
					2																
3					3																
4					4																
5					5																
		END OF DRILLHOLE		313.70 5.60																	
6																					
7																					
8																					
9																					
10																					
11																					
12																					

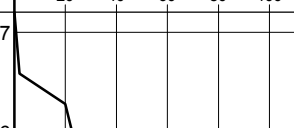
PROJECT		1531057		RECORD OF BOREHOLE No C4-6B		SHEET 1 OF 1		METRIC						
W.P.		5428-15-01		LOCATION		N 5330628.1; E 374487.8 MTM ZONE		ORIGINATED BY SA						
DIST		HWY 112		BOREHOLE TYPE		Portable Equipment, HQ Casing (Manual Hammer)		COMPILED BY MR						
DATUM		Geodetic		DATE		June 10, 2016		CHECKED BY MK						
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
315.0	GROUND SURFACE													
0.0	SILTY CLAY, some sand, some gravel, trace organics, wood fragments and rootlets		1	SS	16		314							0 3 51 46
314.4	Very stiff													
0.6	Brown to grey Moist		2	SS	6									
	SILTY CLAY, trace sand Firm Brown Wet		3	SS	8		313							
312.8	Dynamic Cone Penetration Test (DCPT)													
2.2														
312.2	END OF DCPT REFUSAL TO FURTHER PENETRATION (50 Blows / 0.08 m) (HAMMER BOUNCING)													
2.8	NOTES:  1. Water level in open borehole at a depth of 0.6 m below ground surface (Elev. 314.4 m) upon completion of drilling.  2. Geographic Coordinates: Latitude: 48.110718 Longitude: -80.064066													

PROJECT <u>1531057</u>		<b>RECORD OF DCPT No C4-DCPT-1</b>		SHEET 1 OF 1		<b>METRIC</b>	
W.P. <u>5428-15-01</u>		LOCATION <u>N 5330682.3; E 374470.8 MTM ZONE</u>		ORIGINATED BY <u>SA</u>			
DIST <u>          </u> HWY <u>112</u>		BOREHOLE TYPE <u>Portable Equipment, Dynamic Cone Penetration Test (Manual Hammer)</u>		COMPILED BY <u>MR</u>			
DATUM <u>Geodetic</u>		DATE <u>June 8, 2016</u>		CHECKED BY <u>MK</u>			


SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT   NATURAL MOISTURE   LIQUID CONTENT   LIMIT			UNIT WEIGHT  γ  kN/m³	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 <sub>p</sub>	W	W <sub>L</sub>					
317.1	GROUND SURFACE																			
0.0	Dynamic Cone Penetration Test (DCPT)						317													
316.5	END OF DCPT REFUSAL TO FURTHER PENETRATION (20 Blows / 0.01 m) (HAMMER BOUNCING)																			
0.6	NOTE:  1. Geographic Coordinates:  Latitude: 48.111207 Longitude: -80.064287																			

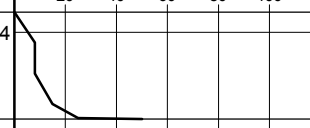
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PROJECT <u>1531057</u>		<b>RECORD OF DCPT No C4-DCPT-2</b>				SHEET 1 OF 1		<b>METRIC</b>											
W.P. <u>5428-15-01</u>		LOCATION <u>N 5330679.2; E 374481.1 MTM ZONE</u>				ORIGINATED BY <u>SA</u>													
DIST <u>          </u> HWY <u>112</u>		BOREHOLE TYPE <u>Portable Equipment, Dynamic Cone Penetration Test (Manual Hammer)</u>				COMPILED BY <u>MR</u>													
DATUM <u>Geodetic</u>		DATE <u>June 8, 2016</u>				CHECKED BY <u>MK</u>													
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa											
317.2	GROUND SURFACE						<div style="display: flex; justify-content: space-between;"> <span>20 40 60 80 100</span> <span>20 40 60 80 100</span> </div> <div style="display: flex; justify-content: space-between;"> <span>○ UNCONFINED</span> <span>+ FIELD VANE</span> </div> <div style="display: flex; justify-content: space-between;"> <span>● QUICK TRIAXIAL</span> <span>× REMOULDED</span> </div>												
0.0	Dynamic Cone Penetration Test (DCPT)					317													
316.0						316													
1.2	END OF DCPT REFUSAL TO FURTHER PENETRATION (50 Blows / 0.02 m) (HAMMER BOUNCING)  NOTE:  1. Geographic Coordinates:  Latitude: 48.111179 Longitude: -80.064148																		

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PROJECT <u>1531057</u>		<b>RECORD OF DCPT No C4-DCPT-3</b>				SHEET 1 OF 1		<b>METRIC</b>											
W.P. <u>5428-15-01</u>		LOCATION <u>N 5330672.1; E 374480.5 MTM ZONE</u>				ORIGINATED BY <u>SA</u>													
DIST <u>          </u> HWY <u>112</u>		BOREHOLE TYPE <u>Portable Equipment, Dynamic Cone Penetration Test (Manual Hammer)</u>				COMPILED BY <u>MR</u>													
DATUM <u>Geodetic</u>		DATE <u>June 8, 2016</u>				CHECKED BY <u>MK</u>													
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa											
317.5	GROUND SURFACE						<div style="display: flex; justify-content: space-between;"> <span>20 40 60 80 100</span> <span>20 40 60 80 100</span> </div> <div style="display: flex; justify-content: space-between;"> <span>○ UNCONFINED</span> <span>+ FIELD VANE</span> </div> <div style="display: flex; justify-content: space-between;"> <span>● QUICK TRIAXIAL</span> <span>× REMOULDED</span> </div>												
0.0	Dynamic Cone Penetration Test (DCPT)					317													
316.2	END OF DCPT REFUSAL TO FURTHER PENETRATION (50 Blows / 0.05 m) (HAMMER BOUNCING)																		
1.3	NOTE:  1. Geographic Coordinates:  Latitude: 48.111114 Longitude: -80.064157																		

PROJECT <u>1531057</u>		<b>RECORD OF DCPT No C4-DCPT-4</b>				SHEET 1 OF 1		<b>METRIC</b>											
W.P. <u>5428-15-01</u>		LOCATION <u>N 5330643.2; E 374465.4 MTM ZONE</u>				ORIGINATED BY <u>SA</u>													
DIST <u>          </u> HWY <u>112</u>		BOREHOLE TYPE <u>Portable Equipment, Dynamic Cone Penetration Test (Manual Hammer)</u>				COMPILED BY <u>MR</u>													
DATUM <u>Geodetic</u>		DATE <u>June 9, 2016</u>				CHECKED BY <u>MK</u>													
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa											
314.2	GROUND SURFACE						<div style="display: flex; justify-content: space-between;"> <span>20 40 60 80 100</span> <span>20 40 60 80 100</span> </div> <div style="display: flex; justify-content: space-between;"> <span>○ UNCONFINED</span> <span>+ FIELD VANE</span> </div> <div style="display: flex; justify-content: space-between;"> <span>● QUICK TRIAXIAL</span> <span>× REMOULDED</span> </div>												
0.0	Dynamic Cone Penetration Test (DCPT)					314													
313.1	END OF DCPT REFUSAL TO FURTHER PENETRATION (50 Blows / 0.01 m) (HAMMER BOUNCING)																		
1.1	NOTE:  1. Geographic Coordinates:  Latitude: 48.110856 Longitude: -80.064364																		

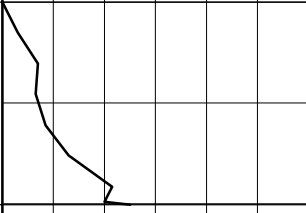
PROJECT <u>1531057</u>		<b>RECORD OF DCPT No C4-DCPT-5</b>		SHEET 1 OF 1		<b>METRIC</b>	
W.P. <u>5428-15-01</u>		LOCATION <u>N 5330634.5; E 374470.0 MTM ZONE</u>		ORIGINATED BY <u>SA</u>			
DIST <u>          </u> HWY <u>112</u>		BOREHOLE TYPE <u>Portable Equipment, Dynamic Cone Penetration Test (Manual Hammer)</u>		COMPILED BY <u>MR</u>			
DATUM <u>Geodetic</u>		DATE <u>June 9, 2016</u>		CHECKED BY <u>MK</u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			WATER CONTENT (%)				GR	SA	SI	CL
								20	40	60	80	100	W <sub>p</sub>		W	W <sub>L</sub>		
314.2	GROUND SURFACE																	
0.0	Dynamic Cone Penetration Test (DCPT)						314											
							313											
312.3																		
1.9	END OF DCPT REFUSAL TO FURTHER PENETRATION (50 Blows / 0.01 m) (HAMMER BOUNCING)  NOTE:  1. Geographic Coordinates:  Latitude: 48.110777 Longitude: -80.064304																	


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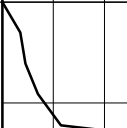
PROJECT 1531057		<b>RECORD OF DCPT No C4-DCPT-6</b>				SHEET 1 OF 1		<b>METRIC</b>									
W.P. 5428-15-01		LOCATION N 5330636.4; E 374474.1 MTM ZONE				ORIGINATED BY SA											
DIST _____ HWY 112		BOREHOLE TYPE Portable Equipment, Dynamic Cone Penetration Test (Manual Hammer)				COMPILED BY MR											
DATUM Geodetic		DATE June 9, 2016				CHECKED BY MK											
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa									WATER CONTENT (%)
314.2	GROUND SURFACE						<div style="display: flex; justify-content: space-between;"> <span>20 40 60 80 100</span> <span>20 40 60 80 100</span> </div> <div style="display: flex; justify-content: space-between;"> <span>○ UNCONFINED + FIELD VANE</span> <span>● QUICK TRIAXIAL × REMOULDED</span> </div>										
0.0	Dynamic Cone Penetration Test (DCPT)					314											
313.3	END OF DCPT REFUSAL TO FURTHER PENETRATION (50 Blows / 0.02 m) (HAMMER BOUNCING)																
0.9	NOTE:  1. Geographic Coordinates:  Latitude: 48.110794 Longitude: -80.064250																

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PROJECT <u>1531057</u>		<b>RECORD OF DCPT No C4-DCPT-7</b>				SHEET 1 OF 1		<b>METRIC</b>										
W.P. <u>5428-15-01</u>		LOCATION <u>N 5330627.1; E 374485.8 MTM ZONE</u>				ORIGINATED BY <u>SA</u>												
DIST <u>          </u> HWY <u>112</u>		BOREHOLE TYPE <u>Portable Equipment, Dynamic Cone Penetration Test (Manual Hammer)</u>				COMPILED BY <u>MR</u>												
DATUM <u>Geodetic</u>		DATE <u>June 9, 2016</u>				CHECKED BY <u>MK</u>												
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa										
315.0	GROUND SURFACE						<div style="display: flex; justify-content: space-between;"> <span>20 40 60 80 100</span> <span>20 40 60 80 100</span> </div> <div style="display: flex; justify-content: space-between;"> <span>○ UNCONFINED</span> <span>+ FIELD VANE</span> </div> <div style="display: flex; justify-content: space-between;"> <span>● QUICK TRIAXIAL</span> <span>× REMOULDED</span> </div>											
0.0	Dynamic Cone Penetration Test (DCPT)																	
313.0	END OF DCPT REFUSAL TO FURTHER PENETRATION (50 Blows / 0.02 m) (HAMMER BOUNCING)																	
2.0	NOTE:  1. Geographic Coordinates:  Latitude: 48.110709 Longitude: -80.064094																	

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PROJECT <u>1531057</u>										RECORD OF DCPT No <b>C4-DCPT-8</b>										SHEET 1 OF 1										<b>METRIC</b>																													
W.P. <u>5428-15-01</u>										LOCATION <u>N 5330625.6; E 374490.9 MTM ZONE</u>										ORIGINATED BY <u>SA</u>																																							
DIST <u>          </u> HWY <u>112</u>										BOREHOLE TYPE <u>Portable Equipment, Dynamic Cone Penetration Test (Manual Hammer)</u>										COMPILED BY <u>MR</u>																																							
DATUM <u>Geodetic</u>										DATE <u>June 9, 2016</u>										CHECKED BY <u>MK</u>																																							
SOIL PROFILE										SAMPLES										DYNAMIC CONE PENETRATION RESISTANCE PLOT										PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT										UNIT WEIGHT										REMARKS & GRAIN SIZE DISTRIBUTION (%)									
ELEV DEPTH	DESCRIPTION									STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)					γ					GR SA SI CL																												
315.0	GROUND SURFACE															20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					W <sub>p</sub> — W — W <sub>L</sub> 20 40 60					kN/m <sup>3</sup>																																	
0.0	Dynamic Cone Penetration Test (DCPT)														314																																												
313.3	END OF DCPT REFUSAL TO FURTHER PENETRATION (50 Blows / 0.02 m) (HAMMER BOUNCING)																																																										
1.7	NOTE:  1. Geographic Coordinates:  Latitude: 48.110695 Longitude: -80.064025																																																										

PROJECT 1531057		<b>RECORD OF DCPT No C4-DCPT-9</b>				SHEET 1 OF 1		<b>METRIC</b>												
W.P. 5428-15-01		LOCATION N 5330631.2; E 374483.9 MTM ZONE				ORIGINATED BY SA														
DIST _____ HWY 112		BOREHOLE TYPE Portable Equipment, Dynamic Cone Penetration Test (Manual Hammer)				COMPILED BY MR														
DATUM Geodetic		DATE June 9, 2016				CHECKED BY MK														
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa									WATER CONTENT (%)			
315.0	GROUND SURFACE						<div style="display: flex; justify-content: space-between;"> <span>20 40 60 80 100</span> <span>20 40 60 80 100</span> </div> <div style="display: flex; justify-content: space-between;"> <span>○ UNCONFINED</span> <span>+ FIELD VANE</span> </div> <div style="display: flex; justify-content: space-between;"> <span>● QUICK TRIAXIAL</span> <span>× REMOULDED</span> </div>													
0.0	Dynamic Cone Penetration Test (DCPT)																			
313.7	END OF DCPT REFUSAL TO FURTHER PENETRATION (50 Blows / 0.08 m) (HAMMER BOUNCING)																			
1.3	NOTE:  1. Geographic Coordinates:  Latitude: 48.110746 Longitude: -80.064118																			





# **APPENDIX B**

## **Geotechnical Laboratory Test Results**

**TABLE B1**  
**SUMMARY OF POINT LOAD TESTS ON ROCK SAMPLES**

PROJECT NO. 1531057						
DATE July, 2016						
Borehole Number	Run Number	Sample Depth (m)	Sample Elevation (m)	Bedrock Description	Test Type	Is (50mm) (MPa)
C4-4	2	1.8	313.1	Granite	Diametral	4.0
C4-4	2	1.7	313.2	Granite	Axial	7.1
C4-6A	1	2.7	316.6	Andesite	Diametral	8.9

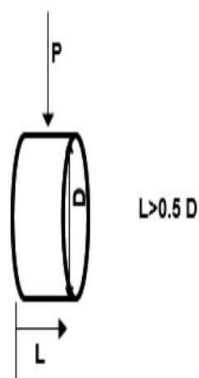
<sup>(1)</sup>  $Is_{50} \times C$  (actual value will have to be confirmed by UCS testing), from ISRM ("Suggested Methods for Determining Point Load Strength", International Society for Rock Mechanics Commission on Testing Methods, Int. J. Rock. Mech. Min. Sci. and Geomechanical Abstr., Vol 22, No. 2 1985, pp. 51-60.

<sup>(2)</sup> Actual distance between point load cones at time of failure.

#### DIAMETRAL SPECIMEN SHAPE REQUIREMENTS

note: Diametral tests are perpendicular to core axis

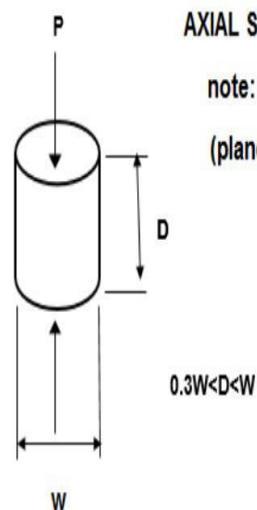
(planes of weakness)



#### AXIAL SPECIMEN SHAPE REQUIREMENTS

note: Axial tests are parallel to core axis

(planes of weakness)

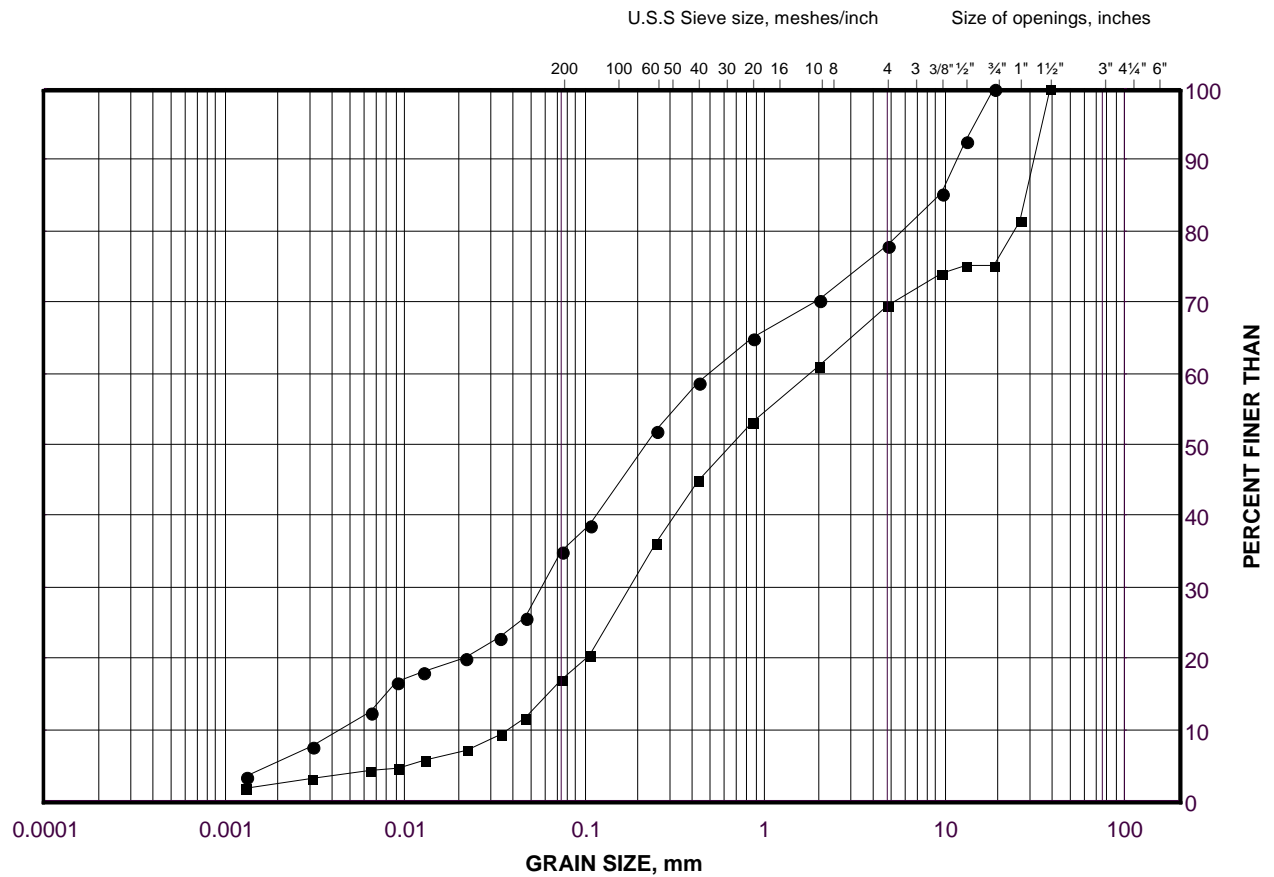




# GRAIN SIZE DISTRIBUTION

Gravelly Silty Sand and Sand and Gravel

FIGURE B2



SILT AND CLAY SIZES		FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED		SAND SIZE			GRAVEL SIZE		

## LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	C4-2	8	314.8
■	C4-2	9	313.3

Project Number: 1531057

Checked By: CN

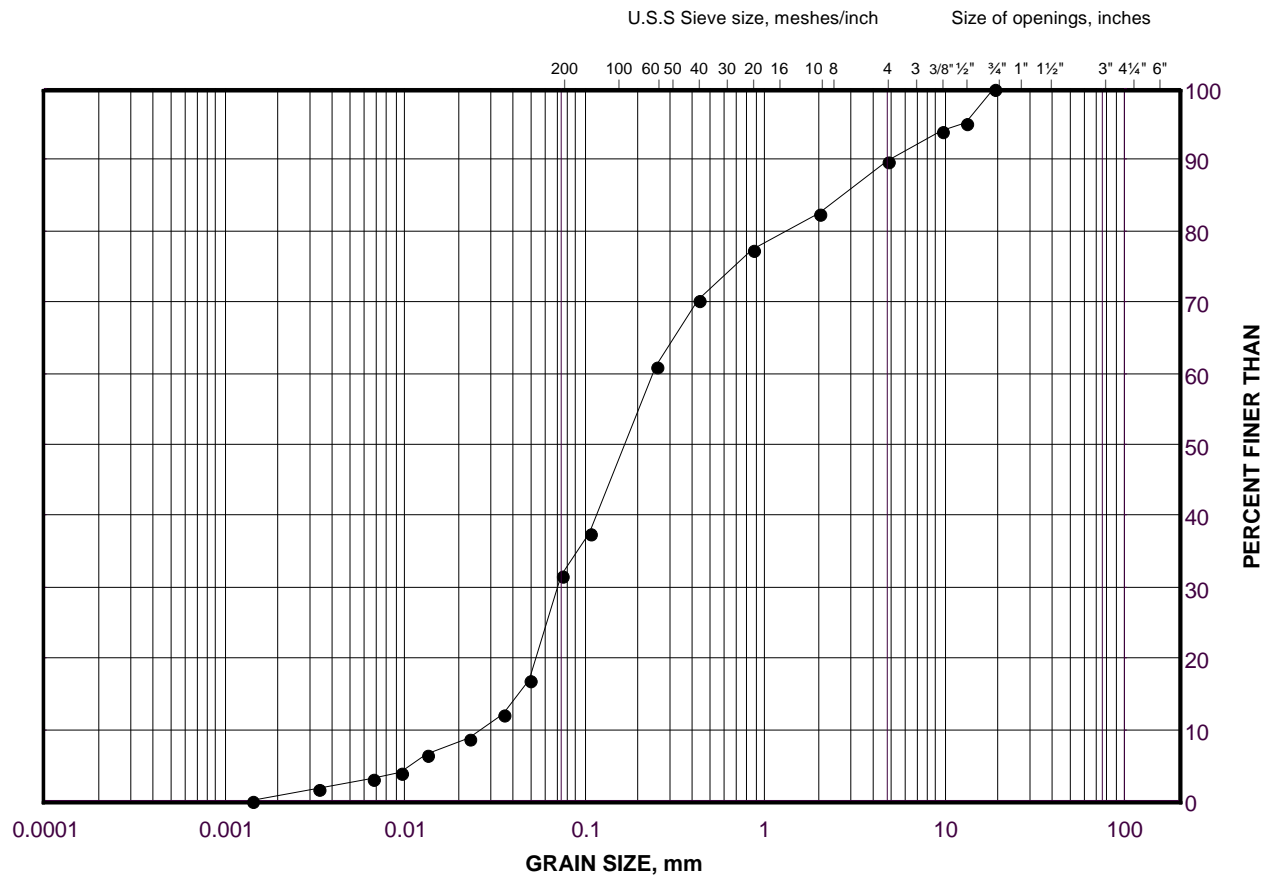
**Golder Associates**

Date: 03-Feb-17

# GRAIN SIZE DISTRIBUTION

Silt and Sand

FIGURE B3



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		SIZE

## LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	C4-5	4	317.0

Project Number: 1531057

Checked By: CN

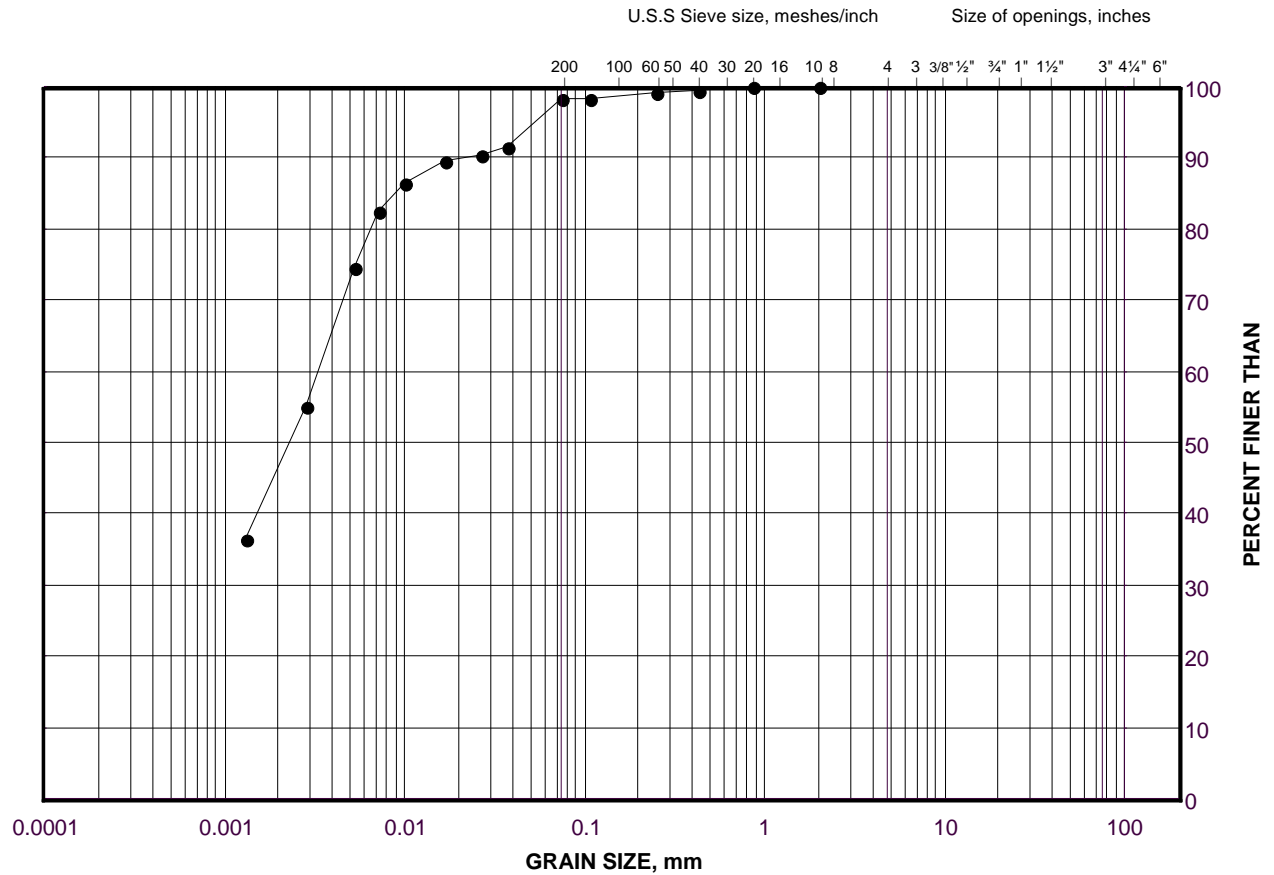
**Golder Associates**

Date: 03-Feb-17

# GRAIN SIZE DISTRIBUTION

Silty Clay

FIGURE B4



SILT AND CLAY SIZES				FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED				SAND SIZE			GRAVEL SIZE		SIZE

## LEGEND

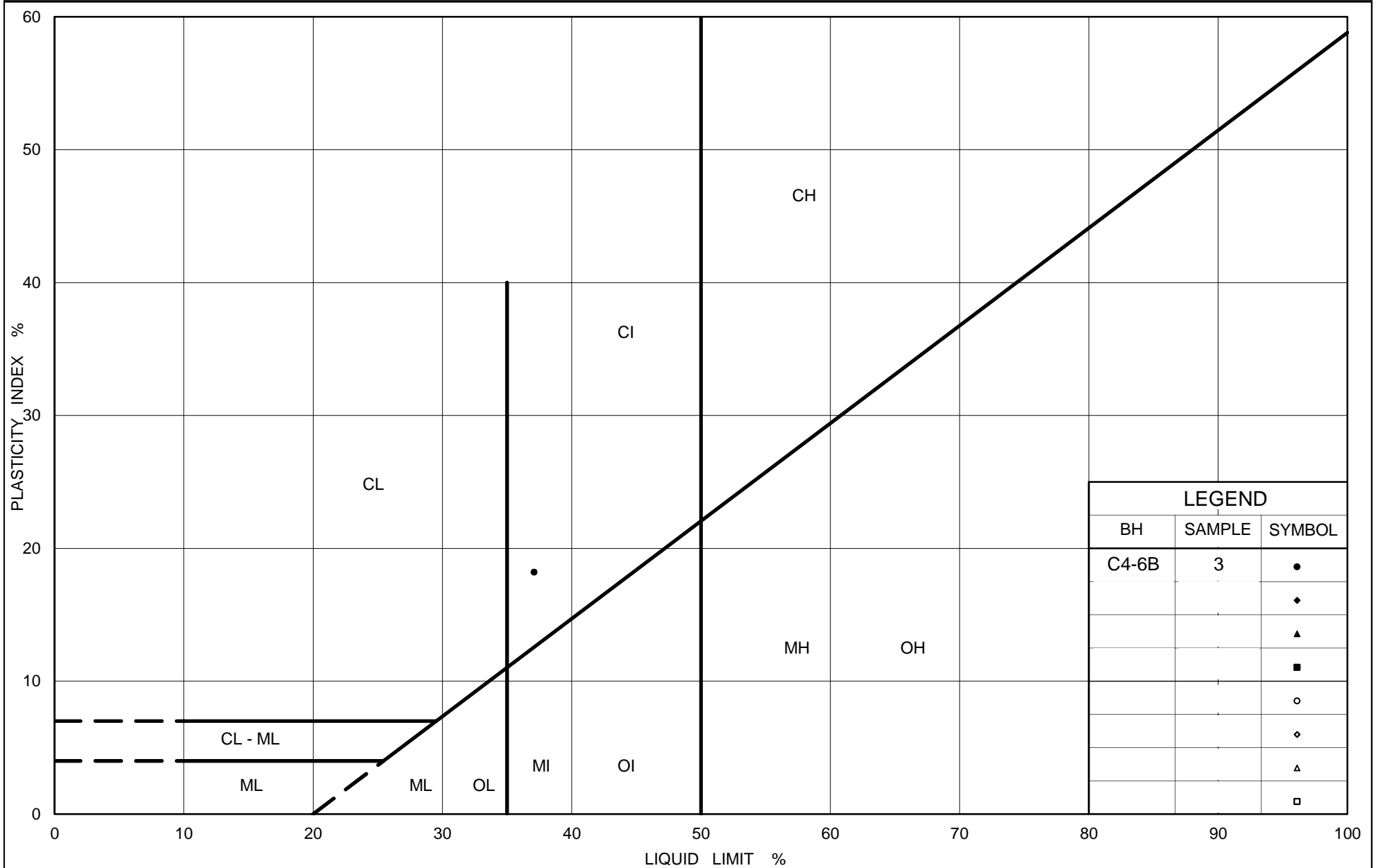
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	C4-6B	3	313.2

Project Number: 1531057

Checked By: CN

**Golder Associates**

Date: 03-Feb-17



Ministry of Transportation

Ontario

## PLASTICITY CHART

### Silty Clay

Figure No. B5

Project No. 1531057

Checked By: CN

### Borehole C4-2



Box 1: 6.70 m – 10.50 m

### Borehole C4-4



Box 1: 1.20 m – 3.20 m

### Borehole C4-5



Box 1: 3.0 m – 5.10 m

### Borehole C4-6A



Box 1: 2.0 m – 5.60 m

0 m	0.25 m	0.5 m	0.75 m	1.0 m	1.25 m	1.5 m
0 ft	1 ft	2 ft	3 ft	4 ft	5 ft	

Scale

PROJECT					
Detail Design for Replacement of Centreline Culvert– Highway 112 WP 5428-15-01					
TITLE					
Bedrock Core Photographs – Highway 112 Boreholes C4-2 and C4-4 to C4-6A					
PROJECT No. 1531057			FILE No. ----		
DESIGN	MK	AUG 16	SCALE	NTS	REV.
CADD	--		FIGURE B6		
CHECK	CN	AUG 16			
REVIEW	JMAC	AUG 16			





**UNCONFINED COMPRESSION TEST (UC)****Figure B7****ASTM D7012**

SAMPLE IDENTIFICATION			
PROJECT NUMBER	1531057	SAMPLE NUMBER	Run 3
PROJECT NAME	MMM/5015-E-0003/LV Retainer NE	SAMPLE DEPTH, m	8.64-8.79
BOREHOLE NUMBER	C4-2	DATE:	2016-07-19

TEST CONDITIONS			
MACHINE SPEED, mm/min	N/A	TYPE OF SPECIMEN	Rock Core
DURATION OF TEST,min	>2 <15	L/D	2.06

SPECIMEN INFORMATION			
SAMPLE HEIGHT, cm	9.74	WATER CONTENT, (specimen) %	0.09
SAMPLE DIAMETER, cm	4.73	UNIT WEIGHT, kN/m <sup>3</sup>	26.79
SAMPLE AREA, cm <sup>2</sup>	17.55	DRY UNIT WT., kN/m <sup>3</sup>	26.77
SAMPLE VOLUME, cm <sup>3</sup>	170.84	SPECIFIC GRAVITY	-
WET WEIGHT, g	466.90	VOID RATIO	-
DRY WEIGHT, g	466.48		

**VISUAL INSPECTION****FAILURE SKETCH**

TEST RESULTS			
STRAIN AT FAILURE, %	N/A	COMPRESSIVE STRENGTH, MPa	12.9

REMARKS:

Checked By: CN

**Golder Associates**



# **APPENDIX C**

## **Analytical Test Results**

Your Project #: 1531057  
Site Location: LV RETAINER NER ASSIGN#2, HWY 112  
Your C.O.C. #: 565300-01-01

**Attention:Chris Ng**

Golder Associates Ltd  
Mississauga - Standing Offer  
6925 Century Ave  
Suite 100  
Mississauga, ON  
CANADA L5N 7K2

**Report Date: 2016/06/20**  
Report #: R4035051  
Version: 1 - Final

**CERTIFICATE OF ANALYSIS**

**MAXXAM JOB #: B6C1265**

**Received: 2016/06/13, 11:35**

Sample Matrix: Water  
# Samples Received: 4

Analyses	Date		Date Analyzed	Laboratory Method	Reference
	Quantity	Extracted			
Chloride by Automated Colourimetry	4	N/A	2016/06/16	CAM SOP-00463	EPA 325.2 m
Conductivity	4	N/A	2016/06/16	CAM SOP-00414	SM 22 2510 m
pH	4	N/A	2016/06/16	CAM SOP-00413	SM 4500H+ B m
Resistivity of Water	4	2016/06/14	2016/06/17	CAM SOP-00414	SM 22 2510 m
Sulphate by Automated Colourimetry	4	N/A	2016/06/16	CAM SOP-00464	EPA 375.4 m

**Remarks:**

Maxxam Analytics has performed all analytical testing herein in accordance with ISO 17025 and the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act. All methodologies comply with this document and are validated for use in the laboratory. The methods and techniques employed in this analysis conform to the performance criteria (detection limits, accuracy and precision) as outlined in the Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act.

Maxxam Analytics is accredited for all specific parameters as required by Ontario Regulation 153/04. Maxxam Analytics is limited in liability to the actual cost of analysis unless otherwise agreed in writing. There is no other warranty expressed or implied. Samples will be retained at Maxxam Analytics for three weeks from receipt of data or as per contract.

Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.

**Encryption Key**

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Ema Gitej, Senior Project Manager

Email: EGitej@maxxam.ca

Phone# (905)817-5829

=====

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

### RESULTS OF ANALYSES OF WATER

Maxxam ID		CNJ774	CNJ775	CNJ776	CNJ777			
Sampling Date		2016/06/12 11:00	2016/06/12 10:45	2016/06/12 07:45	2016/06/12 07:40			
COC Number		565300-01-01	565300-01-01	565300-01-01	565300-01-01			
	UNITS	C1	C2	C3	C4	RDL	QC Batch	MDL
<b>Calculated Parameters</b>								
Resistivity	ohm-cm	21000	7900	28000	7000		4538726	
<b>Inorganics</b>								
Conductivity	umho/cm	48	130	36	140	1.0	4541542	0.20
pH	pH	6.72	7.11	7.16	7.46		4541543	
Dissolved Sulphate (SO <sub>4</sub> )	mg/L	<1.0	<1.0	<1.0	<1.0	1.0	4541170	0.10
Dissolved Chloride (Cl)	mg/L	2.0	24	1.3	15	1.0	4541163	0.30
RDL = Reportable Detection Limit								
QC Batch = Quality Control Batch								

## TEST SUMMARY

**Maxxam ID:** CNJ774  
**Sample ID:** C1  
**Matrix:** Water

**Collected:** 2016/06/12  
**Shipped:**  
**Received:** 2016/06/13

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride by Automated Colourimetry	KONE	4541163	N/A	2016/06/16	Alina Dobreanu
Conductivity	AT	4541542	N/A	2016/06/16	Yogesh Patel
pH	AT	4541543	N/A	2016/06/16	Yogesh Patel
Resistivity of Water		4538726	2016/06/17	2016/06/17	Automated Statchk
Sulphate by Automated Colourimetry	KONE	4541170	N/A	2016/06/16	Deonarine Ramnarine

**Maxxam ID:** CNJ775  
**Sample ID:** C2  
**Matrix:** Water

**Collected:** 2016/06/12  
**Shipped:**  
**Received:** 2016/06/13

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride by Automated Colourimetry	KONE	4541163	N/A	2016/06/16	Alina Dobreanu
Conductivity	AT	4541542	N/A	2016/06/16	Yogesh Patel
pH	AT	4541543	N/A	2016/06/16	Yogesh Patel
Resistivity of Water		4538726	2016/06/17	2016/06/17	Automated Statchk
Sulphate by Automated Colourimetry	KONE	4541170	N/A	2016/06/16	Deonarine Ramnarine

**Maxxam ID:** CNJ776  
**Sample ID:** C3  
**Matrix:** Water

**Collected:** 2016/06/12  
**Shipped:**  
**Received:** 2016/06/13

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride by Automated Colourimetry	KONE	4541163	N/A	2016/06/16	Alina Dobreanu
Conductivity	AT	4541542	N/A	2016/06/16	Yogesh Patel
pH	AT	4541543	N/A	2016/06/16	Yogesh Patel
Resistivity of Water		4538726	2016/06/17	2016/06/17	Automated Statchk
Sulphate by Automated Colourimetry	KONE	4541170	N/A	2016/06/16	Deonarine Ramnarine

**Maxxam ID:** CNJ777  
**Sample ID:** C4  
**Matrix:** Water

**Collected:** 2016/06/12  
**Shipped:**  
**Received:** 2016/06/13

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride by Automated Colourimetry	KONE	4541163	N/A	2016/06/16	Alina Dobreanu
Conductivity	AT	4541542	N/A	2016/06/16	Yogesh Patel
pH	AT	4541543	N/A	2016/06/16	Yogesh Patel
Resistivity of Water		4538726	2016/06/17	2016/06/17	Automated Statchk
Sulphate by Automated Colourimetry	KONE	4541170	N/A	2016/06/16	Deonarine Ramnarine

Maxxam Job #: B6C1265  
Report Date: 2016/06/20

Golder Associates Ltd  
Client Project #: 1531057  
Site Location: LV RETAINER NER ASSIGN#2, HWY 112  
Sampler Initials: SA

#### GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	9.3°C
-----------	-------

**Results relate only to the items tested.**

## QUALITY ASSURANCE REPORT

Golder Associates Ltd  
Client Project #: 1531057  
Site Location: LV RETAINER NER ASSIGN#2, HWY 112  
Sampler Initials: SA

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
4541163	Dissolved Chloride (Cl)	2016/06/16	NC	80 - 120	101	80 - 120	<1.0	mg/L	0.024	20
4541170	Dissolved Sulphate (SO4)	2016/06/16	NC	75 - 125	104	80 - 120	<1.0	mg/L	4.3	20
4541542	Conductivity	2016/06/16			102	85 - 115	<1.0	umho/cm	1.9	25
4541543	pH	2016/06/16			101	98 - 103			1.2	N/A

N/A = Not Applicable

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spiked amount was too small to permit a reliable recovery calculation (matrix spike concentration was less than 2x that of the native sample concentration).

### VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

*Cristina Carriere*

---

Cristina Carriere, Scientific Services

---

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.



<div style="display: flex; justify-content: space-between;"> <div> <b>Maxxam</b>  <small>A Maxxam Analytics International Corporation o/a Maxxam Analytics</small>  <small>6740 Campbell Road, Mississauga, Ontario Canada L5N 2L8 Tel (905) 817-5700 Toll-Free (800) 563-6266 Fax (905) 817-5777 www.maxxam.ca</small> </div> <div> <b>CHAIN OF CUSTODY RECORD</b> </div> </div>										Page / of /				
<b>INVOICE TO:</b> Company Name: #1326 Golder Associates Ltd Attention: Central Acct: 1112, 1113, 1118 Address: 6925 Century Ave Suite 100 Mississauga ON L5N 7K2 Tel: (905) 567-4444 Fax: (905) 567-6561 Email: Catherine_Guido@golder.com, Rachel_Benjamin@gol			<b>REPORT TO:</b> Company Name: _____ Attention: _____ Address: _____ Tel: _____ Fax: _____ Email: _____			<b>PROJECT INFORMATION:</b> Quotation #: B52596 P.O. #: _____ Project: 1531057 Project Name: LV Retainer NER Assign #2 Site #: HWY 112 Sampled By: S.A. + D.M.			<b>Laboratory Use Only:</b> Maxxam Job #: _____ Bottle Order #: _____ COC #: _____ Project Manager: _____ Ema Gitej					
<b>MOE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE MAXXAM DRINKING WATER CHAIN OF CUSTODY</b>						<b>ANALYSIS REQUESTED (PLEASE BE SPECIFIC)</b>								
<b>Regulation 153 (2011)</b> <input type="checkbox"/> Table 1 <input type="checkbox"/> Res/Park <input type="checkbox"/> Medium/Fine <input type="checkbox"/> Table 2 <input type="checkbox"/> Ind/Comm <input type="checkbox"/> Coarse <input type="checkbox"/> Table 3 <input type="checkbox"/> Agri/Other <input type="checkbox"/> For RSC <input type="checkbox"/> Table _____			<b>Other Regulations</b> <input type="checkbox"/> CCME <input type="checkbox"/> Sanitary Sewer Bylaw <input type="checkbox"/> Reg 558 <input type="checkbox"/> Storm Sewer Bylaw <input type="checkbox"/> MISA Municipality _____ <input type="checkbox"/> PWQO <input type="checkbox"/> Other _____			<b>Special Instructions</b> _____			<b>Field Filtered (please circle):</b> Metals / Hg / Cr-VI Chloride & Sulphate Conductivity, Resistivity and pH			<b>Turnaround Time (TAT) Required:</b> Please provide advance notice for rush projects <b>Regular (Standard) TAT:</b> (will be applied if Rush TAT is not specified) Standard TAT = 5-7 Working days for most tests. Please note: Standard TAT for certain tests such as BOD and Dioxins/Furans are > 5 days - contact your Project Manager for details. <input checked="" type="checkbox"/>		
<b>Include Criteria on Certificate of Analysis (Y/N)?</b> _____						<b>Job Specific Rush TAT (if applies to entire submission)</b> Date Required: _____ Time Required: _____ Rush Confirmation Number: _____ (call lab for #)								
Sample Barcode Label	Sample (Location) Identification	Date Sampled	Time Sampled	Matrix								# of Bottles	Comments	
1	C1	June 12/16	11:00AM	Surface Water								1	*small puddle (~3" deep) NOT Flowing	
2	C2	June 12/16	10:45AM	"								1		
3	C3	June 12/16	7:50AM	"								1		
4	C4	June 12/16	7:40AM	"								1		
5														
6														
7														
8														
9														
10														

Received in Sudbury

13-Jun-16 11:35  
 Ema Gitej  
  
 B6C1265  
 GK1 ENV-1107

* RELINQUISHED BY: (Signature/Print)		Date: (YY/MM/DD)	Time	RECEIVED BY: (Signature/Print)		Date: (YY/MM/DD)	Time	# jars used and not submitted	<b>Laboratory Use Only</b> Time Sensitive Temperature (°C) on Receipt: 9, 10, 9°C Custody Seal: Present <input type="checkbox"/> Intact <input type="checkbox"/> Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>		
Shane Albert		16/06/13	11:35am	Bradley Frappier YLR KUSPAT NAZ		16/06/13	11:35				
						24/6/14	11:00				

\* IT IS THE RESPONSIBILITY OF THE RELINQUISHER TO ENSURE THE ACCURACY OF THE CHAIN OF CUSTODY RECORD. AN INCOMPLETE CHAIN OF CUSTODY MAY RESULT IN ANALYTICAL TAT DELAYS.

Maxxam Analytics International Corporation o/a Maxxam Analytics

2/5/14



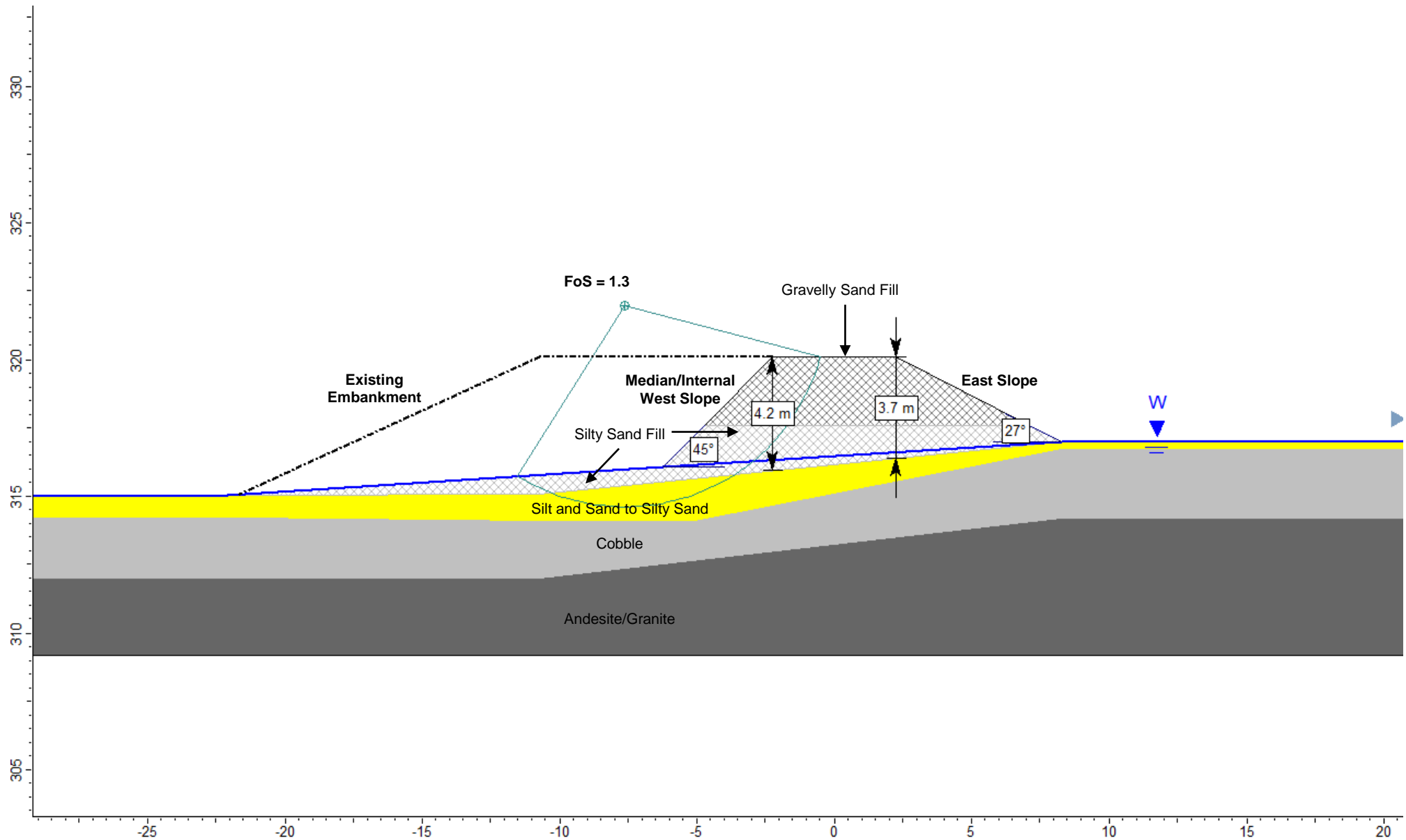
# **APPENDIX D**

## **Stability Analysis Figures**



## Stability Analysis: Median/Internal Side Slopes with 4.5 m Embankment Widening (East Slope)

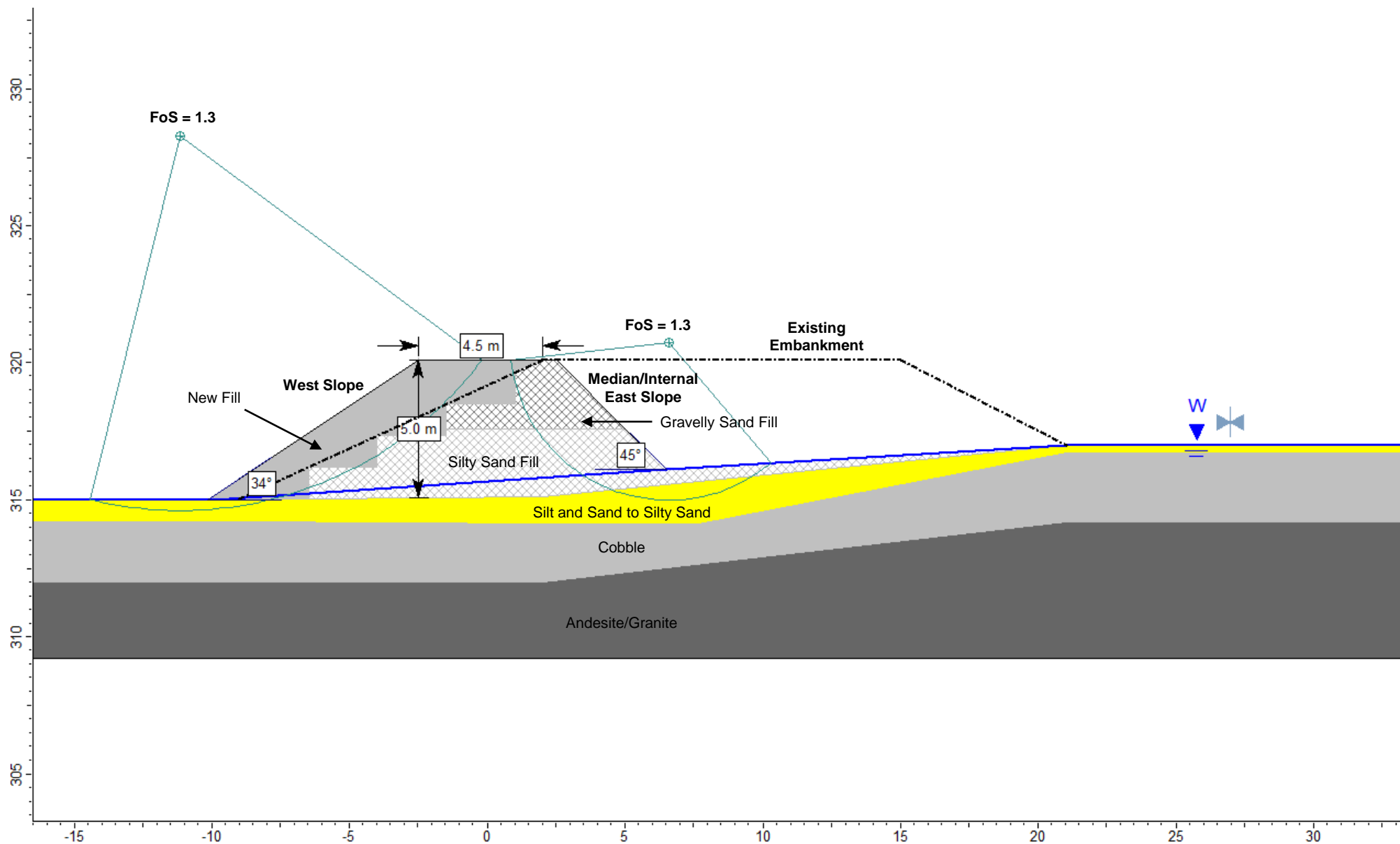
Figure D1





## Stability Analysis: Median/Internal Side Slopes with 4.5 m Embankment Widening (West Slope)

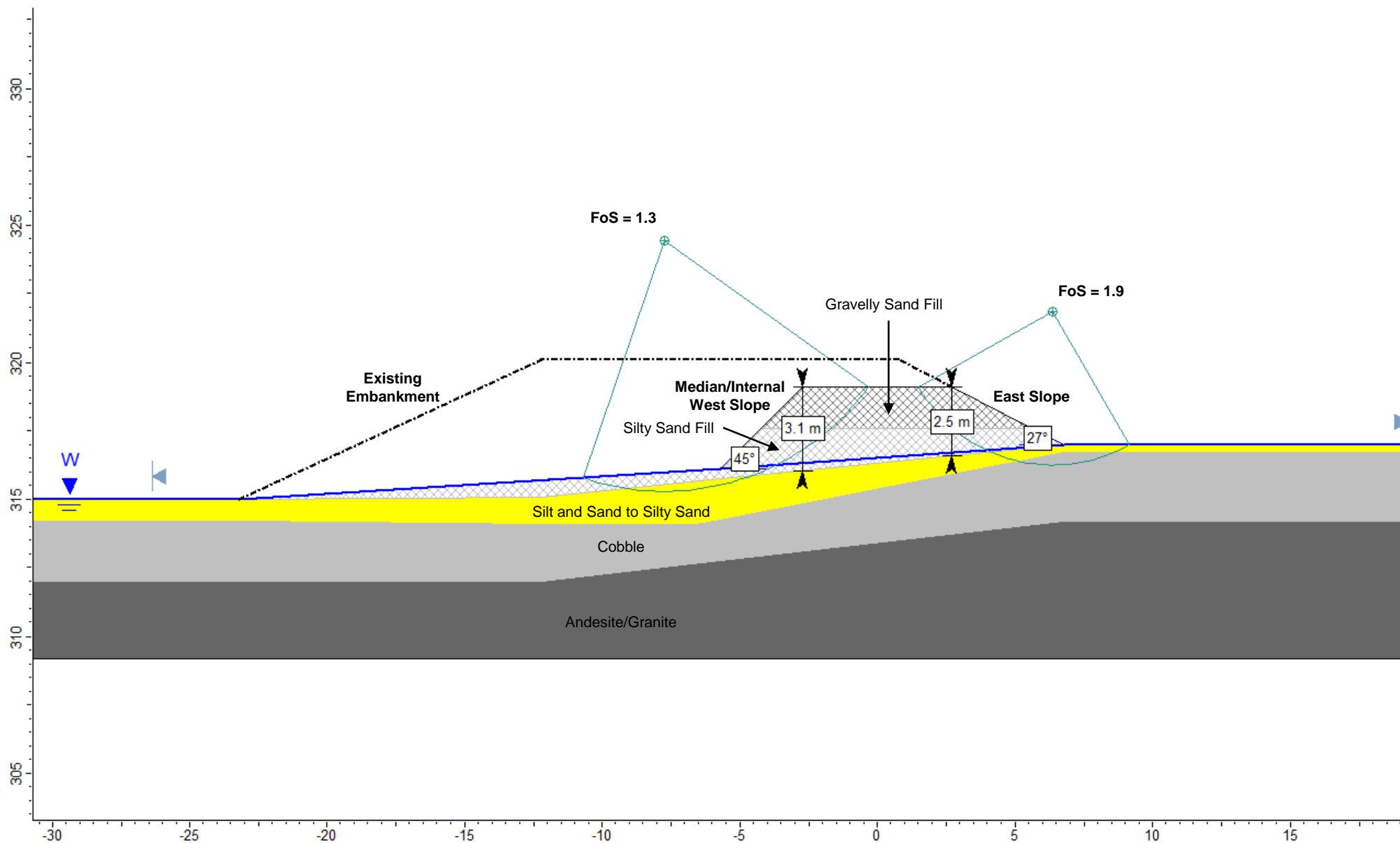
Figure D2





## Stability Analysis: Median/Internal Side Slopes with Grade Lowering (East Slope)

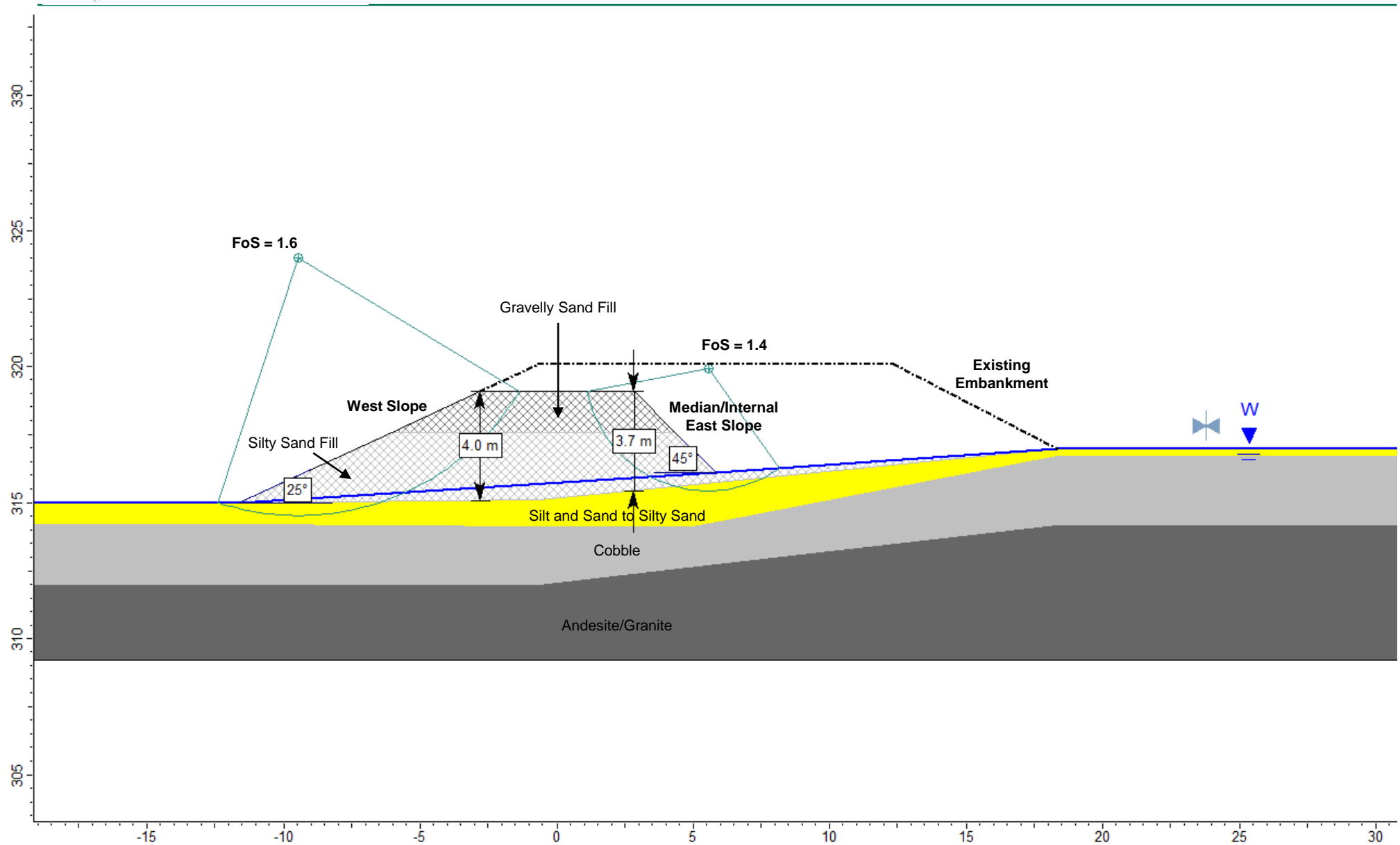
Figure D3





## Stability Analysis: Median/Internal Side Slopes with Grade Lowering (West Slope)

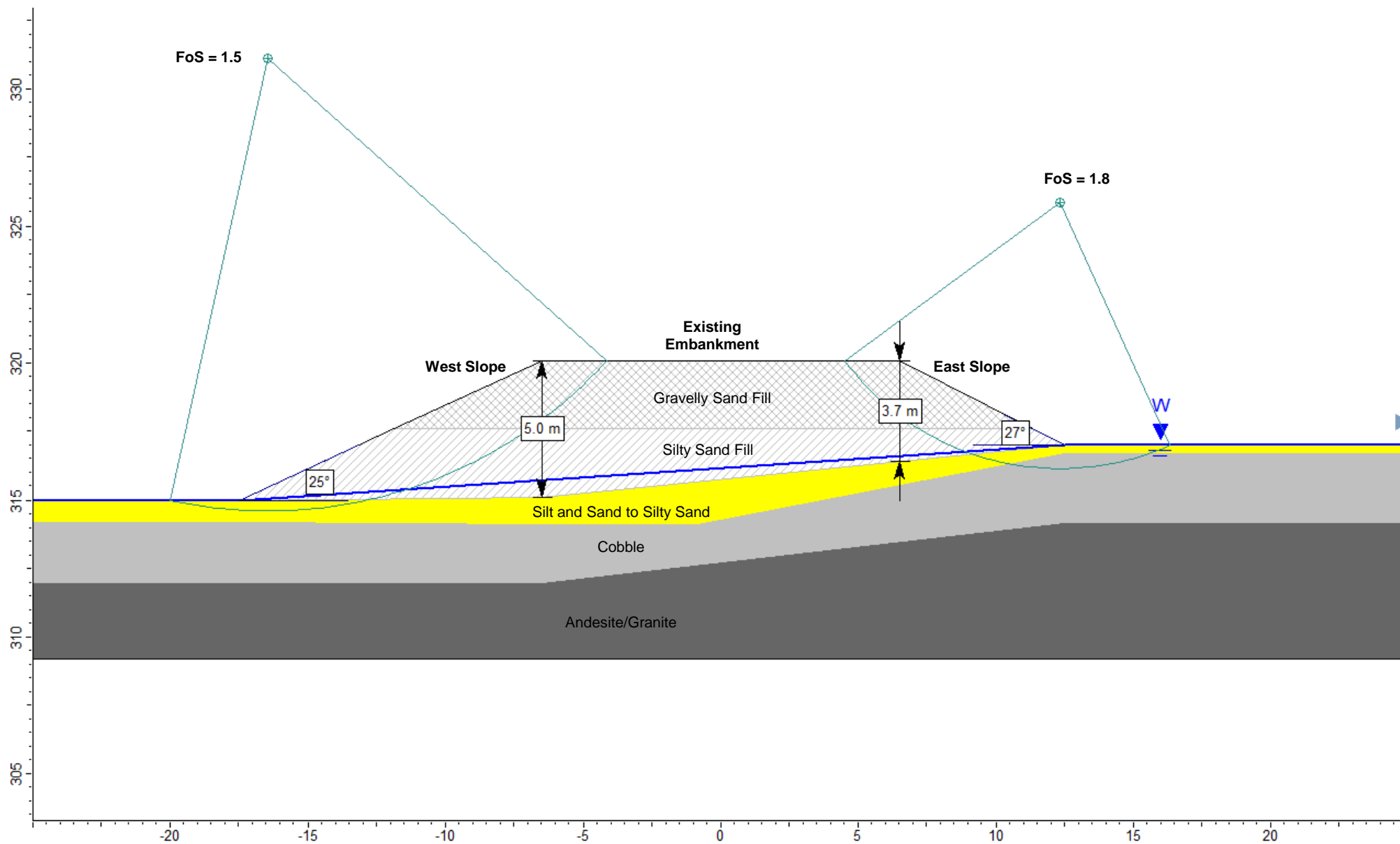
Figure D4





## Stability Analysis: Final Embankment

Figure D5





# **APPENDIX E**

## **Non-Standard Special Provisions**



**OBSTRUCTIONS - Item No.**

---

Non-Standard Special Provision

---

At Culvert C4 (STA 26+675, Township of Teck), a deposit of cobbles was encountered below the embankment between Elevation 316.7 m and 314.2 m. In addition, bedrock was encountered between Elevations 317.1 m and 313.0 m at or in the vicinity of the culvert. Consideration of the presence of these obstructions must be made in the selection of the appropriate equipment and procedures for sub-excavation, and installation of temporary roadway protection systems and cofferdams through this material for culvert construction.

**BASIS OF PAYMENT**

Payment at the lump sum contract price for this tender item shall be full compensation for all labour, equipment and materials for completion of the work.

END OF SECTION

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

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Australasia	+ 61 3 8862 3500
Europe	+ 44 1628 851851
North America	+ 1 800 275 3281
South America	+ 56 2 2616 2000

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[www.golder.com](http://www.golder.com)

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**Mississauga, Ontario, L5N 7K2**  
**Canada**  
**T: +1 (905) 567 4444**

