

**FOUNDATION INVESTIGATION AND DESIGN REPORT
MUNRO RIVER BRIDGE REPLACEMENT
HIGHWAY 613
TOWNSHIP OF DANCE, DISTRICT OF THUNDER BAY, ONTARIO**

G.W.P. 494-00-00, SITE NO. 45-50

Geocres Number: 52C-33

Report to

Hatch Mott MacDonald

Thurber Engineering Ltd.
2010 Winston Park Drive, Suite 103
Oakville, Ontario
L6H 5R7
Phone: (905) 829 8666
Fax: (905) 829 1166

August 8, 2014
File: 19-1605-121

H:\19\1605\121 Bridge & Culvert Rehabs NWR\Reports & Memos\
Munro River Bridge\03 FINAL FIDR\Munro River Bridge FINAL FIDR.doc

TABLE OF CONTENTS

PART 1: FACTUAL INFORMATION

1	INTRODUCTION	1
2	SITE DESCRIPTION	1
3	SITE INVESTIGATION AND FIELD TESTING.....	2
4	LABORATORY TESTING	3
5	DESCRIPTION OF SUBSURFACE CONDITIONS	3
5.1	Asphalt Pavement	3
5.2	Gravelly Sand Fill	3
5.3	Silty Clay Fill.....	4
5.4	Peat.....	4
5.5	Silty Clay	4
5.6	Silty Sand Till	5
5.7	Cobbles and Boulders	5
5.8	Silt.....	5
5.9	Groundwater Conditions	5
6	MISCELLANEOUS	6

PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7	GENERAL.....	7
8	STRUCTURE FOUNDATIONS.....	7
8.1	Spread Footings on Native Soil or Engineered Fill	8
8.2	Driven Steel H-Piles.....	8
8.2.1	Axial Resistance	8
8.2.2	Downdrag	8
8.2.3	Pile Tips.....	9
8.2.4	Pile Installation	9
8.2.5	Lateral Pile Resistance.....	9
8.3	Caissons (Drilled Shafts)	11
8.4	Recommended Foundation	11
8.5	Frost Cover.....	11
8.6	Impact on Existing Foundations	11
9	EXCAVATION AND DEWATERING	11
10	SHEET PILE WALLS.....	12
11	APPROACH EMBANKMENTS	13
12	SCOUR AND EROSION PROTECTION	14
13	LATERAL EARTH PRESSURES.....	14

14	SEISMIC CONSIDERATIONS	15
15	CONSTRUCTION CONCERNS	15
16	CLOSURE	16

Appendices

Appendix A	Record of Borehole Sheets
Appendix B	Laboratory Test Results
Appendix C	Site Photographs
Appendix D	Foundation Comparison
Appendix E	List of Standard Specifications and Special Provisions
Appendix F	Select Runs of Slope Stability Analysis
Appendix G	Borehole Locations and Soil Strata Drawing

**FOUNDATION INVESTIGATION AND DESIGN REPORT
MUNRO RIVER BRIDGE REPLACEMENT
HIGHWAY 613
TOWNSHIP OF DANCE, DISTRICT OF THUNDER BAY, ONTARIO**

G.W.P. 494-00-00, SITE NO. 45-50

Geocres Number: 52C-33

PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted for the proposed replacement of the Munro River Bridge on Highway 613, located approximately 700 m north of Dance Hall Road in the Township of Dance, District of Thunder Bay, Ontario.

The purpose of the investigation was to explore the subsurface conditions at the site, and based on the data obtained, to provide a borehole location plan, record of borehole sheets, a stratigraphic profile, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions was developed from the data obtained in the course of the investigation.

Thurber carried out the investigation as a sub-consultant to Hatch Mott MacDonald, under the Ministry of Transportation Ontario (MTO) Assignment Number 6010-E-0010.

2 SITE DESCRIPTION

The bridge site is located on Highway 613 approximately 700 m north of the Town of Dance, Ontario. The Munro River meanders easterly from Abbott Lake to Rainy Lake. At present, Highway 613 crosses the Munro River on a three span structure with a total length of approximately 18 m.

The area surrounding the site is gently undulating and heavily treed with low-lying swamps in the river flood plain. Photographs of the bridge and surrounding area are presented in Appendix C.

The site lies within the physiographical area of Canadian Shield, which is characterized by Pre-Cambrian igneous and metamorphic bedrock typically occurring as rounded knobs and ridges where exposed. Based on the data from the Ontario Geological Survey, the bedrock at this site generally consists of massive granodiorite to granite. The bedrock is typically overlain by thick glaciolacustrine clay deposit and a discontinuous cover of fine-grained granular till deposit.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing for this project were carried out during the period of November 15 to 21, 2013. A total of four boreholes, identified as MRB-01, MRB-02, MRB-05 and MRB-06, were advanced from the existing pavement level to depths ranging from 11.3 m to 43.3 m. Boreholes MRB-03 and MRB-04 were planned as the second borehole at each abutment. However, since Boreholes MRB-02 and MRB-05 were drilled well beyond 30 m depth without encountering refusal, Boreholes MRB-03 and MRB-04 were not drilled. Details of the borehole locations and drilling depths were summarized as follows:

Table 3.1 – Borehole Summary

Location	Boreholes	Drilling Depth (m)
South Approach	MRB-01	11.3
South Abutment	MRB-02	40.8
North Abutment	MRB-05	43.3
North Approach	MRB-06	11.3

The approximate locations of the boreholes are shown on the Borehole Locations and Soil Strata Drawings included in Appendix G.

All boreholes were drilled using a CME75 truck-mounted drill rig in combination with hollow stem augers and NW casing methods to advance the boreholes in the native soils. Samples of the fill and native soils were obtained from the boreholes at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). Bedrock coring was not carried out as bedrock was not encountered within the depth of drilling.

Groundwater conditions in the open boreholes were observed during the drilling operations. No standpipe piezometer was installed due to the artesian pressure encountered in the silty sand and silt underlying the silty clay deposit. Observations on artesian head were noted in the drill casing.

The drilling and sampling operations were supervised on a full time basis by a member of Thurber's technical staff. The supervisor logged the boreholes and processed the recovered soil samples for transport to Thurber's laboratory for further examination and testing. Borehole completion details are summarized in Table 3.2.

Table 3.2 – Borehole Completion Details

Borehole	Piezometer Tip		Completion Details
	Depth (m)	Elevation (m)	
MRB-01	None Installed		Borehole backfilled with soil cuttings mixed with bentonite holeplug to 0.1 m, then cold patch asphalt to surface
MRB-02	None Installed		Borehole backfilled with bentonite gel and holeplug to 0.3 m, then filter sand to 0.1 m and cold patch asphalt to surface
MRB-05	None Installed		Borehole backfilled with bentonite holeplug to 29.5 m, then peltonite to 25.9 m, bentonite holeplug and gel to 0.5 m, granular fill to 0.1 m and cold patch asphalt to surface

Borehole	Piezometer Tip		Completion Details
	Depth (m)	Elevation (m)	
MRB-06	None Installed		Borehole backfilled with bentonite holeplug to 1.9 m, then soil cutting to 0.1 m and cold patch asphalt to surface

4 LABORATORY TESTING

The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. The results of this testing are shown on the Record of Borehole sheets included in Appendix A. Selected samples were also subjected to gradation analysis. The results of this testing program are summarized on the Record of Borehole sheets in Appendix A and shown on the figures included in Appendix B.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets included in Appendix A. Details of the encountered soil stratigraphy are presented in this appendix and on the “Borehole Locations and Soil Strata” drawing in Appendix G. An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole sheets governs any interpretation of the site conditions.

The subsurface stratigraphy encountered at the site generally consists of embankment fill overlying a layer of fibrous to amorphous peat, which in turn overlies a thick silty clay deposit. Below the silty clay deposit, a layer of silty sand till was encountered at the south abutment before encountering cobbles and boulders, and a silt deposit at the north abutment, respectively. More detailed descriptions of individual strata are presented below.

5.1 Asphalt Pavement

Asphalt pavement was encountered in all boreholes. Thickness of the asphalt ranged from 25 to 50 mm.

5.2 Gravelly Sand Fill

Gravelly sand fill containing occasional cobbles was encountered in all boreholes below the asphalt pavement. Thickness of the brown cohesionless fill ranged from 1.4 to 1.7 m with the base elevations ranging from 359.6 to 360.0 m.

SPT ‘N’ values recorded in the gravelly sand fill ranged from 15 to 58 blows per 0.3 m penetration, indicating a compact to very dense relative density. The measured moisture contents of the cohesionless fill samples ranged from 5 to 9%.

The results of grain size analyses conducted on the gravelly sand fill samples are provided on the Record of Borehole sheets in Appendix A and illustrated on Figure B1a of Appendix B. Grain size distribution analyses carried out on three fill samples indicated that the fill contains 26 to 34% gravel, 55 to 57% sand and 9 to 19% fines.

5.3 Silty Clay Fill

Brown to dark brown silty clay fill containing organics, some sand and trace gravel was encountered below the cohesionless fill in all boreholes except in MRB-02 where peat was encountered directly beneath the cohesionless fill. Thickness of the cohesive fill ranged from 0.6 to 1.5 m with the base elevations from 358.2 to 359.3 m.

SPT 'N' values recorded in the silty clay fill ranged from 4 to 13 blows per 0.3 m penetration, indicating a firm to stiff consistency. The measured moisture contents of the cohesive fill samples ranged from 25 to 65% with the upper bound moisture content likely representing organic content.

One grain size distribution analysis conducted on the silty clay fill sample is provided on the Record of Borehole sheets in Appendix A and illustrated on Figure B1b of Appendix B. The result of grain size distribution analysis indicated that the fill contains 3% gravel, 14% sand, 31% silt and 52% clay.

5.4 Peat

A layer of amorphous to fibrous peat was encountered beneath the fill. The peat contained wood fragments and some clay. Thickness of the peat ranged from 1.5 to 2.0 m with the base of the layer at elevations varying from 356.6 to 357.9 m.

SPT 'N' values recorded in the peat ranged typically from 3 to 9 blows per 0.3 m penetration, indicating a soft to stiff consistency. Two SPT tests recorded 'N' values of 41 and 32 blows per 0.3 m penetration, indicating the presence of wood fragments. The measured moisture contents of the peat samples ranged from 55 to 378%.

5.5 Silty Clay

A layer of silty clay with trace to some sand and some organic matter in the upper 1 to 2 m was encountered below the peat in all boreholes. MRB-01 and MRB-06 were terminated within the silty clay at elevations 350.2 m and 349.8 m, respectively. The silty clay layer was penetrated in MRB-02 and MRB-05. Where penetrated, the thickness of the layer ranged from 33.0 to 37.2 m with the base of the layer at elevations varying from 319.4 to 324.6 m.

SPT 'N' values recorded in the silty clay ranged from 3 to 21 blows per 0.3 m penetration, indicating a soft to very stiff consistency which generally increases with depth. The measured moisture contents of the silty clay samples ranged from 22 to 56% with typical values varying from 35 to 43%.

The results of Atterberg Limits tests conducted on the silty clay samples are provided on the Record of Borehole sheets in Appendix A and illustrated on Figures B6a and B6b of Appendix B. The results indicated that the deposit has plastic limits ranging from 23 to 30% and liquid limits ranging from 58 to 75%, indicating high plasticity (CH).

The results of grain size distribution analyses conducted on the silty clay samples are

provided on the Record of Borehole sheets in Appendix A and illustrated in Figures B2, B3a and B3b of Appendix B. The results are summarized as follows:

Gravel %	0
Sand %	5 to 20
Silt %	21 to 49
Clay %	43 to 71

5.6 Silty Sand Till

A relatively thin layer of grey silty sand till with trace clay and gravel was encountered beneath the silty clay in MRB-02. Thickness of the layer was 2.6 m with the base of the layer at elevation 322.0 m.

One SPT 'N' value recorded in the till was 100 blows for 0.225 m of penetration, indicating a very dense relative density. Measured moisture content was in the order of 17%.

The result of grain size distribution analysis conducted on the till sample is provided on the Record of Borehole sheets in Appendix A and illustrated in Figure B4 of Appendix B. The result indicated that the till contains 3% gravel, 68% sand, 21% silt and 8% clay.

5.7 Cobbles and Boulders

MRB-02 was terminated within a layer of cobbles and boulders encountered below the silty sand till. The cobbles and boulders layer was cored for 1.5 m.

5.8 Silt

A grey silt layer with some clay and trace sand was encountered beneath the silty clay in MRB-05. Soil sampling in MRB-05 was terminated within the silt layer at 43.3 m depth or elevation 317.9 m. Dynamic cone penetration test (DCPT) was carried out from the base of the sampled borehole and encountered refusal at elevation 314.0 m, where 'N' value of 100 blows for 0.225 m of penetration was recorded.

One SPT 'N' value recorded in the silt was 13 blows per 0.3 m of penetration, indicating a compact relative density. Measured moisture content was in the order of 27%.

The result of grain size distribution analysis conducted on the silt sample is provided on the Record of Borehole sheets in Appendix A and illustrated in Figure B5 of Appendix B. The result indicated that the silt contains 0% gravel, 7% sand, 78% silt and 15% clay.

5.9 Groundwater Conditions

Artesian conditions were encountered in the cobbles and boulders/silt layer underlying the silty clay at the base of the boreholes upon completion of drilling in MRB02 and MRB-05. Artesian heads observed in the casings ranged from 2.9 to 3.0 m (elevation 364.2) above the ground surface. Standpipe piezometers were therefore not installed and the boreholes were carefully sealed.

Based on the General Arrangement drawing provided by HMM, the river level was at elevation 359.7 m on October 16, 2013, or about 1.5 m below the existing road grade.

6 MISCELLANEOUS

Eastern Ontario Diamond Drilling of Hawkesbury, Ontario supplied a truck mounted CME75 drill rig and conducted the drilling, sampling and in-situ testing operations.

The drilling and sampling operations were supervised in the field by Mr. Stephane Loranger of Thurber. Mr. Mark E. Farrant, P.Eng. directed the field operations.

The report was prepared by Mr. Keli Shi, P.Eng. and Mr. Murray Anderson, P.Eng., and reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations projects.

THURBER ENGINEERING LTD.

Keli Shi, P.Eng.
Geotechnical Engineer



Murray R. Anderson, P.Eng.
Associate, Senior Foundation Engineer



P.K. Chatterji, P.Eng.
Review Principal



FOUNDATION INVESTIGATION AND DESIGN REPORT
MUNRO RIVER BRIDGE REPLACEMENT
HIGHWAY 613
TOWNSHIP OF DANCE, DISTRICT OF THUNDER BAY, ONTARIO

G.W.P. 494-00-00, SITE NO. 45-50

Geocres Number: 52C-33

PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This report presents interpretation of the geotechnical data in the factual report and provides geotechnical recommendations to assist the design team in selecting and designing a suitable foundation system for the proposed replacement bridge.

At present, Highway 613 crosses the Munro River on an 18 m long three-span structure carrying a bridge deck which is approximately 8 m wide. The existing road grade on the bridge varies from elevations 361.2 to 361.3 m. The existing approach fills range in thickness from 1.7 to 3.0 m. The approach fills were placed in a swampy environment directly over peat which is currently 1.5 to 2.0 m in thickness. Based on the existing bridge drawings, the existing abutments and piers are each supported by a single row of five timber piles.

The General Arrangement drawing indicates that the replacement bridge will be constructed in two stages with half of the bridge operational during each stage. The replacement bridge will be a 19.5 m long single-span bridge carrying an approximately 11.5 m wide bridge deck. The finished road grade will be approximately 0.5 m higher than the existing grade at the centreline. Steel sheet pile walls will be installed at both abutments for retaining the approach embankments. At the embankment centreline, fill heights above the existing ground will be up to about 2.4 m at the South Abutment and 2.2 m at the North Abutment, respectively.

The discussion and recommendations presented in this report are based on information provided by Hatch Mott MacDonald and on the factual data obtained in the course of this investigation.

8 STRUCTURE FOUNDATIONS

In general, the soil stratigraphy below the existing embankment fill consists of a peat layer underlain by a thick deposit of silty clay, which is underlain by silt at the North Abutment and silty sand till and cobbles & boulders at the South Abutment. Bedrock was not encountered within the depth of

drilling.

The water level in the river was at approximately elevation 359.7 m on October 16, 2013, or 1.5 m below the existing road grade. Artesian conditions were encountered in the cobbles and boulders/silt layer underlying the silty clay at the base of the boreholes upon completion of drilling in MRB02 and MRB-05.

Foundation alternatives are presented in the following sections together with the corresponding geotechnical design parameters. A preferred foundation scheme from a geotechnical perspective is recommended.

A comparison of the technical advantages and disadvantages of alternative foundation schemes is presented in Appendix D. Initial consideration was given to spread footings on native soil or engineered fill, driven steel H-piles, and caissons (drilled shafts).

8.1 Spread Footings on Native Soil or Engineered Fill

The use of spread footings founded on native soil to support the abutments is not recommended given the relatively low geotechnical resistance available and potential large consolidation settlement of the foundation soils. Similarly, supporting the abutments on spread footings founded on engineered fill is not feasible.

8.2 Driven Steel H-Piles

8.2.1 Axial Resistance

The ground conditions at the site are considered to be suitable for the support of abutments on steel H-piles driven in the silty clay deposit.

In view of the significant depth to refusal soil ranging from 40 to 50 m at the abutments and the presence of artesian conditions below the silty clay layer, floating H-piles with pile tips terminated within the silty clay should be considered. Steel piles HP 310x110 founded in the silty clay deposit with varying pile lengths may be designed using the geotechnical resistances presented in Table 8.1.

Table 8.1 – Geotechnical Resistances for H-Piles Founded in Silty Clay

Approximate Pile Length (m)	Pile Tip Elevation (m)	Factored Geotechnical Resistance at ULS (kN)	Geotechnical Resistance at SLS (kN)
25	335.0	500	400
30	330.0	600	500
35	325.0	725	600

8.2.2 Downdrag

Downdrag forces will develop along the length of abutment piles embedded in the embankment fill, peat and silty clay due to consolidation of the peat and silty clay under the weight of new approach fill placed behind the abutments.

As the piles will not be driven to unyielding materials (floating piles), the downdrag forces will be alleviated by downward movement of the piles. Consequently, the combined dead load and downdrag load will not exceed the structural capacity of the pile section, and a check in this regard is not required.

8.2.3 Pile Tips

For floating H-piles founded in the silty clay, pile tip protection should not be used.

8.2.4 Pile Installation

Pile installation should be in accordance with OPSS 903.

There is evidence of artesian conditions below the silty clay layer. The design pile tip elevation should be located above the source of artesian pressure. In addition, the significant thickness of high plastic clays around the piles should minimize any upward flow of water around the pile shafts.

Pile driving must be controlled in accordance with Standard Drawing SS103-11 (Hiley Formula) and an ultimate pile resistance should be specified by the designer. The Hiley formula need not be used until the piles are within 2.0 m of the design tip elevation. The appropriate pile driving note is “Piles to be driven in accordance with Standard SS 103-11 using an ultimate resistance of “R” kN per pile. “R” must have a minimum value of twice the design load at ULS.

Oversize materials (e.g. greater than 75 mm nominal diameter) must not be used in any fills through which the piles will be driven.

8.2.5 Lateral Pile Resistance

The geotechnical lateral resistance acting on a pile in cohesionless soils may be calculated using a value for the coefficient of horizontal subgrade reaction (k_s) and ultimate lateral resistance (p_{ult}) as follows:

$$k_s = n_h \cdot z / D \quad (\text{kN/m}^3)$$

$$p_{ult} = 3 \cdot \gamma' \cdot z \cdot K_p \quad (\text{kPa})$$

Where z = depth of embedment of pile (metre)

D = pile width or diameter (metre)

n_h = coefficient related to soil density (kN/m^3)

γ' = effective unit weight (kN/m^3)

K_p = coefficient of passive earth pressure

The geotechnical lateral resistance acting on a pile in cohesive soils may be calculated using a value for the coefficient of horizontal subgrade reaction (k_s) and ultimate lateral resistance (p_{ult}) as follows:

$$k_s = 67 \cdot S_u / D \quad (\text{kN/m}^3)$$

$$p_{ult} = 9 \cdot S_u \quad (\text{kPa})$$

Where S_u = undrained shear strength (kPa)

D = pile width or diameter (metre)

The above equations and recommended parameters in Table 8.2 below may be used to analyze the interaction between a pile and the surrounding soil. The lateral pressures obtained from the analysis must not exceed the ultimate lateral resistance.

Table 8.2 – Soil Parameters for Lateral Pile Resistance

Soil Unit	Elevation (m)		γ' (kN/m ³)	n _h (kN/m ³)	K _p	S _u (kPa)
	Top	Bottom				
South Abutment (Borehole MRB-02)						
Fill	360.7	359.6	11	3,000	3.0	-
Peat	359.6	357.6	4	-	-	-
Upper Silty Clay	357.6	336.5	9	-	-	50
Lower Silty Clay	336.5	324.6	10	-	-	65
North Abutment (Borehole MRB-05)						
Fill	360.5	358.2	11	2,500	2.8	-
Peat	358.2	356.6	4	-	-	-
Upper Silty Clay	356.6	342.0	9	-	-	50
Lower Silty Clay	342.0	319.4	10	-	-	65

The spring constant, K_s , for analysis may be obtained by the expression, $K_s = k_s \times L \times D$ (kN/m), where k_s is the coefficient of horizontal subgrade reaction (kN/m³), D is the pile width (m) and L is the length (m) of the pile segment or element used in the analysis. The ultimate lateral resistance, P_{ult} , may be obtained from the expression, $P_{ult} = p_{ult} \times L \times D$. This represents the ultimate load at which the pile fails and will not support any additional load at greater displacements. It is recommended, however, that the total lateral resistance assumed in one pile be limited to no more than 120 kN at ULS and 35 kN at SLS.

The coefficient of subgrade reaction and ultimate lateral resistance may have to be reduced, based on the pile spacing. The reduction factors to be used for a pile group oriented perpendicular or parallel to the direction of loading are provided in Table 8.3. Intermediate values may be obtained by linear interpolation.

Table 8.3 – Subgrade Reaction Reduction Factors for Pile Spacing

Condition	Pile Spacing Centre to Centre	Reduction Factor
Pile group oriented <i>perpendicular</i> to direction of loading	4D	1.0
	1D	0.5
Pile group oriented <i>parallel</i> to direction of loading	8D	1.0
	6D	0.7
	4D	0.4
	3D	0.25

8.3 Caissons (Drilled Shafts)

In view of the fact that bedrock was not encountered within the depth of drilling greater than 40 m, the use of caissons or drilled shafts is not considered to be a cost-effective option and has not been developed herein.

8.4 Recommended Foundation

From a geotechnical perspective and based on the subsurface conditions, steel H-piles developing resistance through adhesion within the thick silty clay deposit are considered to be the most cost effective foundation option at this site.

8.5 Frost Cover

The depth of frost penetration at this site is approximately 2.4 m. The base of footings and pile caps must be provided with a minimum of 2.4 m of earth cover as protection against frost action.

8.6 Impact on Existing Foundations

Piles will be driven adjacent to the existing bridge for construction of the replacement bridge.

The existing timber piles are likely frictional piles founded in the silty clay deposit. Potential for settlement exists for the existing bridge due to excess pore pressure generation and dissipation in the silty clay in response to the pile driving.

Therefore, it is recommended that the structural designer select appropriate settlement monitoring points on the existing structure and specify a monitoring program for the duration of pile driving. Based on results of the monitoring program, the Contractor should be prepared with appropriate equipment on site to maintain the grade of the existing bridge in operation, which includes but is not limited to lifting and shimming the bridge.

9 EXCAVATION AND DEWATERING

It is recommended that all excavation for construction of pile caps or footings at the abutments be maintained above the river level, approximately elevation 359.7 m on October 16, 2013. Excavation above this level will be carried out primarily within the existing gravelly sand fill.

All excavations must be carried out in accordance with the requirements of the Occupational Health and Safety Act (OHSA) and in accordance with OPSS 902. For the purposes of the OHSA, the approach fill within the depth of excavation may be classified as Type 3 soil above the groundwater level and Type 4 soil below the groundwater level. Flatter slopes may be required at locations where water seepage affects surficial stability.

The selection of the method of excavation is the responsibility of the Contractor and must be based on his equipment, experience and interpretation of the site conditions. It is anticipated that a hydraulic excavator will be suitable. Provision must be made for the handling of pavement materials, potential obstructions in the fill, and cobbles and boulders.

Roadway protection will be required for the staged construction at this site. Sheet piles or soldier pile & lagging walls are two options for roadway protection. The Contractor should select the wall type and design taking into account the soil conditions encountered in the boreholes and the lateral earth pressure parameters given in later sections of this report.

The roadway protection should be designed and constructed in accordance with OPSS 539. In general, the lateral movement of the temporary shoring system should meet Performance Level 2 as specified in OPSS 539. The design of roadway protection is the responsibility of the Contractor, and the shoring system must be designed by a Professional Engineer.

10 SHEET PILE WALLS

The current design proposes the installation of steel sheet pile walls adjacent to the pile foundations in lieu of conventional abutment walls. The sheet piles will provide containment and resistance to lateral earth pressures from the approach fill. The alignment of the proposed sheet pile walls should be carefully selected to avoid existing timber bents and piles.

Lateral stability of the sheet pile walls should be checked by the wall designer using the parameters presented in Table 10.1. The coefficients of passive earth pressure (K_p) are provided for horizontal ground surface in front of the sheet pile wall. For sloping ground in front of the sheet pile wall, the recommended values for the coefficients of passive earth pressure (K_p) should be reduced.

Table 10.1 – Soil Parameters for Sheet Pile Analysis

Foundation Element	Soil Unit	Elevation (m)		γ' (kN/m ³)	K_a	K_p
		Top	Bottom			
South Abutment (Borehole MRB-02)	Fill	362.0*	359.6	21	0.33	3.0
	Peat	359.6	357.6	4	0.40	—**
	Silty Clay	357.6	324.6	9	0.39	2.6
North Abutment (Borehole MRB-05)	Fill	362.0*	359.6	21	0.33	3.0
	Fill (Submerged)	359.6	358.2	10	0.35	2.9
	Peat	358.2	356.6	4	0.40	—**
	Silty Clay	356.6	319.4	9	0.39	2.6

* Top of sheet pile elevation varies.

** Passive resistance in the peat has been ignored.

Driving of the sheet pile through the existing approach fill may encounter cobbles. Removal of any such obstructions may be required to install the sheeting. Any visible obstructions such as boulders and rock protection along the sides of the embankment should be removed prior to driving the sheet piles. No tip protections are required for these sheet piles.

Design of the permanent sheet pile walls must consider environmental conditions such as road salts or fluctuating water levels that may cause corrosion and reduce the service life of the structure. The native soils in front of the sheet piles should be protected from river erosion so that the sheet piles do not lose lateral support.

Backfill to the sheet pile walls should be in accordance with OPSS 902 and should consist of Granular A, Granular B Type II or Granular B Type III material. All granular material should meet the specifications of OPSS.PROV 1010. Compaction equipment to be used adjacent to retaining structures should be restricted in accordance with OPSS 501.

11 APPROACH EMBANKMENTS

Based on the latest GA drawing, a grade raise of 0.5 m is proposed at both approach embankments. The new approach embankments will be retained by sheet pile walls to approximately 6 m behind the abutment walls. The foundation soils governing stability of the approach embankments consist of compressed peat and firm to stiff silty clay.

Global stability analyses were carried out to assess the stability of the forward slopes with the proposed sheet pile wall configuration. The stability analyses were carried out using the commercially available slope stability program GEO-SLOPE, applying the Morgenstern-Price method. The geotechnical model and results of the analyses are shown on Figures 1 to 4 in Appendix F. The computed factors of safety are summarized in Table 11.1.

The computed factors of safety generally meet or exceed the minimum values of 1.3 and 1.5 normally accepted for this type of analysis under short and long term conditions, respectively, provided the sheet piles are driven to or below Elev. 356.5 m. In all cases, however, it is recommended that the sheet piles be driven to Elev. 354 m at both abutments. The depth of penetration may need to be greater to provide lateral stability.

Table 11.1 - Computed Factors of Safety for Approach Embankments

Abutment	Condition	Factor of Safety	Figure (Appendix F)
South	Short term - undrained	2.32	1
	Long term - drained	1.51	2
North	Short term - undrained	2.04	3
	Long term - drained	1.55	4

Settlement induced by the additional embankment fill is expected to be up to about 90 mm at the south abutment and 130 mm at the north abutment. About 50% of the settlement is anticipated to have occurred in about three months after the embankments have reached the proposed grade and the remainder will gradually take place within 2 to 3 years following the construction. Preloading of the foundation soils associated with the grade raise for 6 months is recommended to reduce the post-construction settlement to 25 to 30 mm. If foundation preloading cannot be accommodated, regular settlement monitoring and maintenance of pavement using granular padding / re-grading of the approach embankments will be necessary to compensate for the post-construction settlement.

Embankment construction should be in accordance with OPSS.PROV 206. It is recommended that embankment fill consist of granular materials. All granular material should meet the specifications of OPSS.PROV 1010. Compaction equipment to be used adjacent to retaining structures should be restricted in accordance with OPSS 501. The backfill to the abutment walls should be in accordance

with OPSS 902. Granular backfill should be placed to the extents shown in OPSD 3101.150.

12 SCOUR AND EROSION PROTECTION

Erosion protection should be provided along any soil surfaces that may be in contact with the river flow. In particular, erosion protection must be provided in front of the sheet pile walls to prevent undermining of the sheet pile walls at the abutments.

A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion, in general accordance with OPSS 804.

13 LATERAL EARTH PRESSURES

Earth pressures acting on the structure may be assumed to be distributed triangularly and to be governed by the characteristics of the abutment backfill. For a fully drained condition, the pressures should be computed in accordance with the CHBDC but generally are given by the expression:

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

Where: p_h = horizontal pressure on the wall at depth h (kPa)

K = coefficient of lateral earth pressure (see Table 13.1)

γ = unit weight of retained soil (see Table 13.1)

h = depth below top of fill where pressure is computed (m)

q = value of any surcharge (kPa)

Earth pressure coefficients for backfill to the abutment wall are dependent on the material used as backfill. Typical values are given in Table 13.1.

The use of a material with a high friction angle and low active pressure coefficient (e.g. Granular A, Granular B Type II) is preferred as it results in lower earth pressures acting on the wall.

The factors in Table 13.1 are “ultimate” values and require certain movements for the respective conditions to be mobilized. The values to use in design can be estimated from Figure C6.16 in the Commentary to the Canadian Highway Bridge Design Code.

Table 13.1 – Coefficients of Lateral Earth Pressure (K)

Conditions	OPSS Granular A or Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I or Type III $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)
Active (Unrestrained Wall)	0.27	0.38*	0.31	0.46*
At-rest (Restrained Wall)	0.43	-	0.47	-
Passive	3.7	-	3.3	-

* For wing walls.

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

14 SEISMIC CONSIDERATIONS

The following seismic parameters should be used for design:

- Velocity Related Seismic Zone 0
- Zonal Velocity Ratio 0.00
- Acceleration Related Seismic Zone 0
- Zonal Acceleration Ratio 0.00
- Peak Ground Acceleration 0.036 g

The soil profile type at this site has been classified as Type II. Therefore, according to Table 4.4 of the CHBDC, a Site Coefficient “S” (ground motion amplification factor) of 1.2 should be used in seismic design.

The foundation soils at the site are assessed as not being prone to liquefaction.

In accordance with Clause 4.6.4 of the CHBDC, retaining structures should be designed using active (K_{AE}) and passive (K_{PE}) earth pressure coefficients that incorporate the effects of earthquake loading.

For the design of retaining walls under seismic loading, the coefficients of horizontal earth pressure in Table 14.1 may be used:

Table 14.1 – Earth Pressure Coefficient for Earthquake Loading

Conditions	Granular A or Granular B Type II $\phi = 35^\circ$; $\gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I or Type III $\phi = 32^\circ$; $\gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)
Active (K_{AE})*	0.28	0.42	0.32	0.51
Passive (K_{PE})	3.6	-	3.2	-
At Rest (K_{OE})**	0.47	-	0.52	-

* After Mononobe & Okabe, passive case assumes a horizontal surface in front of the wall.

** After Woods (1973).

15 CONSTRUCTION CONCERNS

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

- There is a risk that pile driving for the replacement bridge may cause settlement of the existing bridge. It is recommended that settlement monitoring of the existing bridge be carried out for the duration of pile driving. The Contractor should be prepared with appropriate equipment on site to

maintain the grade of the existing bridge within acceptable tolerances.

- Installation of the sheet piles retaining approach embankments may encounter resistance in the fill due to the presence of cobbles and in the peat due to the presence of wood fragments. Under these circumstances, the Contractor must allow for removing any such obstructions.
- The Contractor's selection of construction equipment and methodology must include assessment of the capability of the clay subgrade to support the proposed construction equipment and any temporary structures or fill (i.e. as a pad for crane support). Site conditions may limit the type of equipment suitable for use. The design and safety of any temporary works is the responsibility of the Contractor.

16 CLOSURE

Engineering analysis and preparation of the foundation design report were carried out by Mr. Keli Shi, P.Eng. and Mr. Murray Anderson, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

THURBER ENGINEERING LTD.

Keli Shi, P.Eng., M.Eng.
Geotechnical Engineer



Murray R. Anderson, P.Eng., M.Eng.
Associate, Senior Foundation Engineer



P.K. Chatterji, P.Eng., Ph.D.
Review Principal



Appendix A

Record of Borehole Sheets

RECORD OF BOREHOLE No MRB-01

1 OF 2

METRIC

WP# 494-00-00 LOCATION Munro River Bridge ORIGINATED BY SLL
 HWY 613 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2013.11.21 - 2013.11.21 CHECKED BY MC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				
361.5								20 40 60 80 100				
0.0								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				
	ASPHALT: (50mm)						PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT w _p w w _L WATER CONTENT (%)					
360.0	Gravelly SAND, some silt Brown Moist (FILL)		1	SS	34							26 55 19 (SI+CL)
359.3	Silty CLAY, with organic matters Stiff Brown Moist (FILL)		2	SS	10							
357.9	PEAT, fibrous Stiff to Firm Brown to Black Moist		3	SS	9							
355.8			4	SS	5							
354.0	Silty CLAY, some sand, with organic matters Stiff Dark Brown Moist		5	SS	11							0 20 35 45
352.0			6	SS	7							
350.0	Silty CLAY, trace sand Firm Dark grey Moist		7	SS	7							0 8 21 71
348.0			8	SS	5							

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No MRB-01

2 OF 2

METRIC

WP# 494-00-00 LOCATION Munro River Bridge ORIGINATED BY SLL
HWY 613 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
DATUM Geodetic DATE 2013.11.21 - 2013.11.21 CHECKED BY MC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	Continued From Previous Page																
350.2			9	SS	8		351										
11.3	END OF BOREHOLE AT 11.3m. BOREHOLE OPEN AND DRY. BOREHOLE BACKFILLED WITH CUTTINGS MIXED WITH BENTONITE HOLEPLUG TO 0.1m, THEN ASPHALT TO SURFACE.																

RECORD OF BOREHOLE No MRB-02

1 OF 5

METRIC

WP# 494-00-00 LOCATION Munro River Bridge ORIGINATED BY SLL
HWY 613 BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY AN
DATUM Geodetic DATE 2013.11.19 - 2013.11.20 CHECKED BY MC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE							
361.3							20	40	60	80	100	PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	
0.0	ASPHALT: (50mm)						20	40	60	80	100	W _P	W	W _L	
	Gravelly SAND, some silt		1	SS	49							○			34 55 11 (SI+CL)
	Dense		2	SS	32								○		
	Brown														
	Moist														
	(FILL)														
359.6															
1.7	PEAT, fibrous		3	SS	8									○	
	Firm														
	Black														
	Moist														
	Wood fragment	4	SS	41										○	
	No recovery, possible timber														
		5	SS	5											
357.6															
3.7	Silty CLAY, some sand, topsoil stained														
	Stiff														
	Dark Brown														
	Moist	6	SS	9										○	0 11 46 43
355.7															
5.6	Silty CLAY, trace sand														
	Firm														
	Dark Grey														
	Moist	7	SS	6										○	
		8	SS	5										○	

Continued Next Page

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

RECORD OF BOREHOLE No MRB-02

2 OF 5

METRIC

WP# 494-00-00 LOCATION Munro River Bridge ORIGINATED BY SLL
HWY 613 BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY AN
DATUM Geodetic DATE 2013.11.19 - 2013.11.20 CHECKED BY MC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)	
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE										
								20 40 60 80 100	20 40 60									
	Continued From Previous Page						351											
	Silty CLAY , trace sand Firm to Stiff Dark Grey Moist		10	SS	6													
							350											
							349											
			11	SS	6													
							348											
							347											
			12	SS	15													
							346											
			13	SS	7													
							345											
							344											
			14	SS	7													
							343											
			15	SS	7													
							342											

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No MRB-02

3 OF 5

METRIC

WP# 494-00-00 LOCATION Munro River Bridge ORIGINATED BY SLL
 HWY 613 BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.11.19 - 2013.11.20 CHECKED BY MC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				w _P w w _L				
								20 40 60 80 100					20 40 60			
	Continued From Previous Page		16	SS	5		341									
							340									
							339									
			17	SS	6		338									
							337									
							336									
			18	SS	12		335								0 7 37 56	
							334									
							333									
			19	SS	9		332									

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15 5
10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No MRB-02

4 OF 5

METRIC

WP# 494-00-00 LOCATION Munro River Bridge ORIGINATED BY SLL
HWY 613 BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY AN
DATUM Geodetic DATE 2013.11.19 - 2013.11.20 CHECKED BY MC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE			W P W W L				
								● QUICK TRIAXIAL × LAB VANE							
	Continued From Previous Page							20 40 60 80 100							
	Silty CLAY , trace sand Stiff to Hard Dark Grey Moist						331								
							330								
			20	SS	13		329								
							328								
							327								
			21	SS	21		326								
							325								
324.6															
36.7	Silty SAND , trace clay and gravel Very Dense Grey Moist (TILL)						324								
			22	SS	100/ 0.225		323							3 68 21 8	
322.0	End of sampling and start coring at 39.3m						322								
39.3	BOULDERS and COBBLES													RUN #1 TCR=60% SCR=47% RQD=28%	

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15 10 5 0
(%) STRAIN AT FAILURE

ONTMT4S 5121.GPJ 2012TEMPLATE(MTO).GDT 7/14/14

RECORD OF BOREHOLE No MRB-02

5 OF 5

METRIC

WP# 494-00-00 LOCATION Munro River Bridge ORIGINATED BY SLL
 HWY 613 BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.11.19 - 2013.11.20 CHECKED BY MC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
							20	40	60	80	100	W _p	W	W _L			
	Continued From Previous Page		1	RUN													
320.5																	
40.8	END OF BOREHOLE AT 40.8m. 2.9m OF ARTESIAN PRESSURE OBSERVED IN CASING. BOREHOLE BACKFILLED WITH BENTONITE GEL AND BENTONITE HOLEPLUG TO 0.3m, FILTER SAND TO 0.1m, THEN ASPHALT TO SURFACE.																

RECORD OF BOREHOLE No MRB-05

1 OF 5

METRIC

WP# 494-00-00 LOCATION Munro River Bridge ORIGINATED BY SLL
 HWY 613 BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2013.11.15 - 2013.11.17 CHECKED BY MC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				GR	SA	SI	CL	
								20	40	60	80	100	W _p	W		W _L				
361.2																				
0.0	ASPHALT: (25mm)																			
	Gravelly SAND , trace silt Dense to Very Dense Brown Moist (FILL)		1	SS	35							○								
	Occasional cobbles		2	SS	58							○						34 57 9 (SI+CL)		
359.7																				
1.5	Silty CLAY , with organic matters Stiff Dark Brown Moist (FILL)		3	SS	13							○								
			4	SS	11							○								
358.2																				
3.0	PEAT , fibrous, with wood fragments Soft Black Moist		5	SS	3															
356.6																				
4.6	Silty CLAY , trace sand, with organic matters Firm Dark Brown Moist		6	SS	3									○						
355.1																				
6.1	Silty CLAY , trace sand Stiff Grey Moist		7	SS	8								○							
	Trace gravel		8	SS	4									┌─○─┐				0 5 49 46		
			9	SS	8							○								

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No MRB-05

2 OF 5

METRIC

WP# 494-00-00 LOCATION Munro River Bridge ORIGINATED BY SLL
HWY 613 BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY AN
DATUM Geodetic DATE 2013.11.15 - 2013.11.17 CHECKED BY MC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
							20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				W _p	W	W _L			
	Continued From Previous Page						351									
	Silty CLAY , trace sand Stiff to Firm Grey Moist		10	SS	13		350									
							349									0 7 42 51
			11	SS	6		348									
							347									
			12	SS	7		346									
							345									
			13	SS	6		344									0 7 34 59
							343									
			14	SS	6		342									
			15	SS	5											

Continued Next Page

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

RECORD OF BOREHOLE No MRB-05

3 OF 5

METRIC

WP# 494-00-00 LOCATION Munro River Bridge ORIGINATED BY SLL
HWY 613 BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY AN
DATUM Geodetic DATE 2013.11.15 - 2013.11.17 CHECKED BY MC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE								
	Continued From Previous Page															
	Silty CLAY , trace sand Stiff Grey Moist		16	SS	10		341									
							340									
							339									
			17	SS	11		338									
							337									
							336									
			18	SS	9		335									0 9 39 52
							334									
							333									
			19	SS	10		332									

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
5
0
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No MRB-05

4 OF 5

METRIC

WP# 494-00-00 LOCATION Munro River Bridge ORIGINATED BY SLL
HWY 613 BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY AN
DATUM Geodetic DATE 2013.11.15 - 2013.11.17 CHECKED BY MC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)								
								20 40 60 80 100				w _p w w _L								
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE												
	Continued From Previous Page																			
	Silty CLAY , trace sand Firm to Very Stiff Grey Moist						331													
							330													
							329						○							
	Sand layers between 28.9m and 32.0m		20	SS	6									○						
							328													
							327													
							326													
	Silty sand layer at 35m. Artesian pressure to 20.1m						325													
							324								○					
							323													
						322														
			22	SS	20								○							

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15 10 5 0
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No MRB-05

5 OF 5

METRIC

WP# 494-00-00 LOCATION Munro River Bridge ORIGINATED BY SLL
HWY 613 BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY AN
DATUM Geodetic DATE 2013.11.15 - 2013.11.17 CHECKED BY MC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				
	Continued From Previous Page											
319.4	Silty CLAY , trace sand Very Stiff Grey Moist						321					
41.8	SILT , some clay, trace sand Compact Grey Moist to Wet						320					
317.9			23	SS	13		319					
43.3	End of sampling and start DCPT						318					0 7 78 15
							317					
							316					
							315					
314.0												
47.2	END OF BOREHOLE AT 47.2m. PIEZOMETER NOT INSTALL DUE TO ARTESIAN PRESSURE UP TO 3.0m. BOREHOLE CAVED TO 31.4m AFTER REMOVING CASING TO 28.9m BELOW GROUND SURFACE. BOREHOLE BACKFILLED WITH HOLEPLUG BENTONITE FROM 31.3m TO 29.5m, BENTONITE PELLETS HOLEPLUG FROM 29.5m TO 25.9m, BENTONITE HOLEPLUG TO 18.2m, HOLEPLUG GEL TO 0.9m, BENTONITE HOLEPLUG TO 0.5m, GRANULAR FILL TO 0.1m, THEN ASPHALT TO SURFACE											

ONTMT4S 5121.GPJ 2012TEMPLATE(MTO).GDT 7/14/14

RECORD OF BOREHOLE No MRB-06

1 OF 2

METRIC

WP# 494-00-00 LOCATION Munro River Bridge ORIGINATED BY SLL
 HWY 613 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2013.11.15 - 2013.11.15 CHECKED BY MC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)								
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				GR	SA	SI	CL					
								○ UNCONFINED + FIELD VANE	● QUICK TRIAXIAL × LAB VANE													
361.1	0.0	ASPHALT: (25mm)					361															
		Gravelly SAND Compact Brown Moist (FILL)		1	SS	15																
				2	SS	18																
359.6																						
1.4		Silty CLAY , some sand, trace gravel Soft to Firm Dark Brown Moist (FILL)		3	SS	4											3	14	31	52		
358.9																						
2.1		PEAT , amorphous, mixed with clay Soft Black Moist Wood fragments		4	SS	32																
				5	SS	3																
357.5																						
3.6		Silty CLAY , with organic matters Firm Dark Brown Moist																				
356.6																						
4.4		Silty CLAY , trace sand Stiff Dark Grey Moist		6	SS	8												0	7	24	69	
				8	SS	9																
				9	SS	8													0	6	27	67

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No MRB-06

2 OF 2

METRIC

WP# 494-00-00 LOCATION Munro River Bridge ORIGINATED BY SLL
 HWY 613 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2013.11.15 - 2013.11.15 CHECKED BY MC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	WATER CONTENT (%)								
	Continued From Previous Page						351	20	40	60	80	100					
	Silty CLAY , trace sand Stiff Dark Grey Moist		10	SS	10		350										
349.8																	
11.3	END OF BOREHOLE AT 11.3m. BOREHOLE OPEN AND DRY. BOREHOLE BACKFILLED WITH HOLEPLUG BENTONITE TO 1.9m, CUTTINGS TO 0.1m, THEN ASPHALT TO SURFACE.																

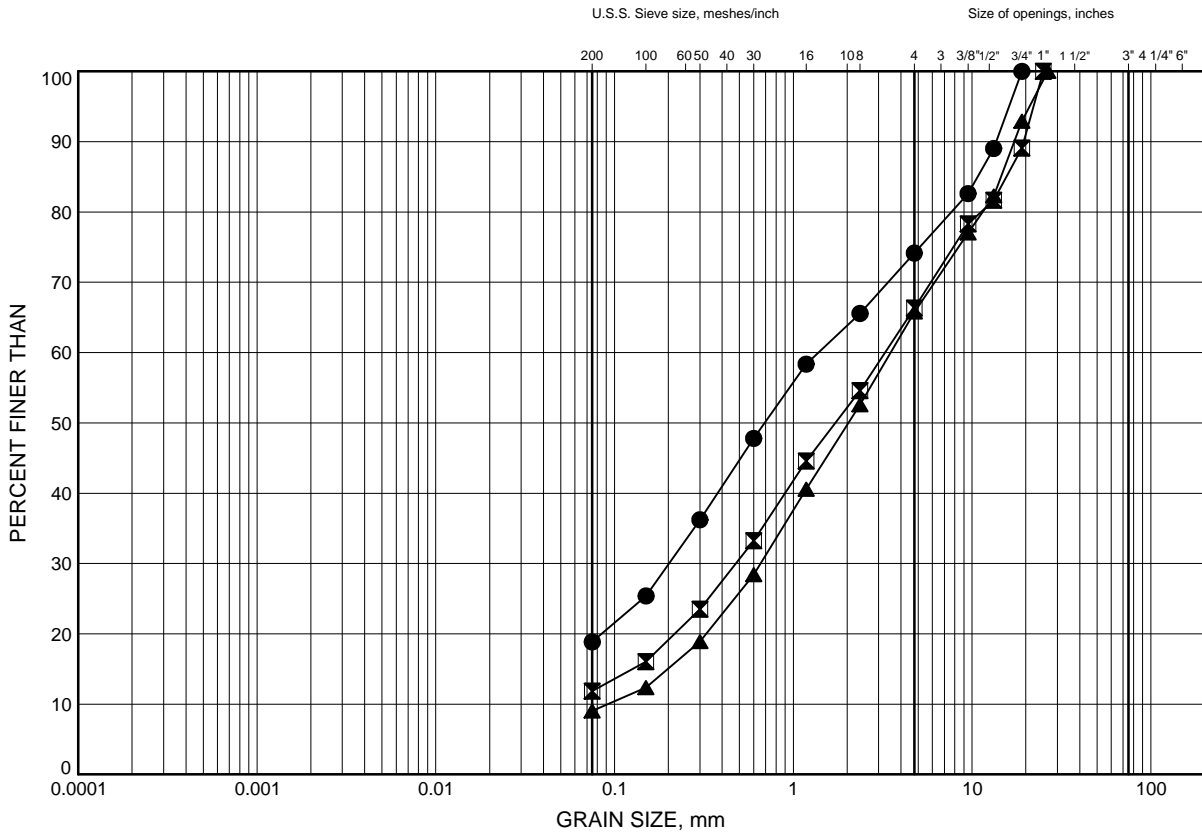
Appendix B

Laboratory Test Results

Munro River Bridge GRAIN SIZE DISTRIBUTION

FIGURE B1a

GRAVELLY SAND FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MRB-01	1.07	360.41
⊠	MRB-02	0.38	360.92
▲	MRB-05	1.07	360.13

Date July 2014
WP# 494-00-00

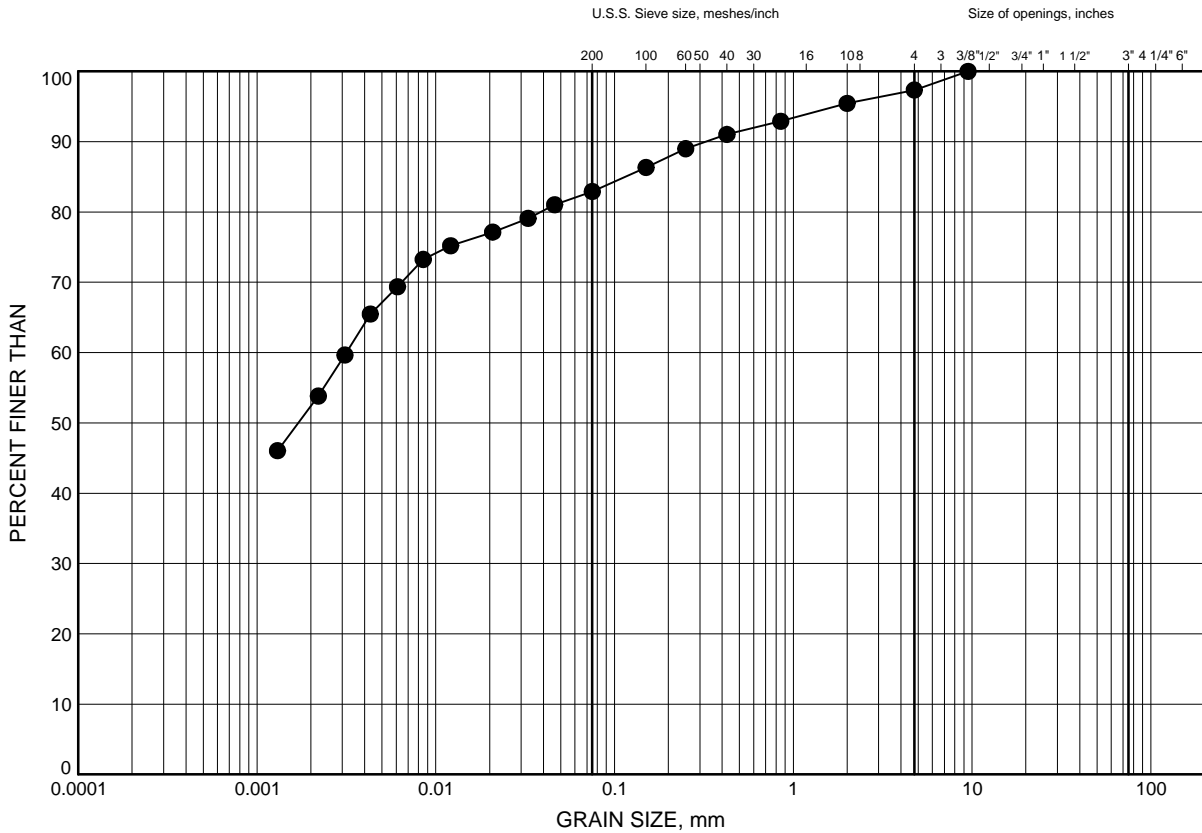


Prep'd AN
Chkd. KS

Munro River Bridge GRAIN SIZE DISTRIBUTION

FIGURE B1b

SILTY CLAY FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MRB-06	1.83	359.22

Date July 2014
WP# 494-00-00

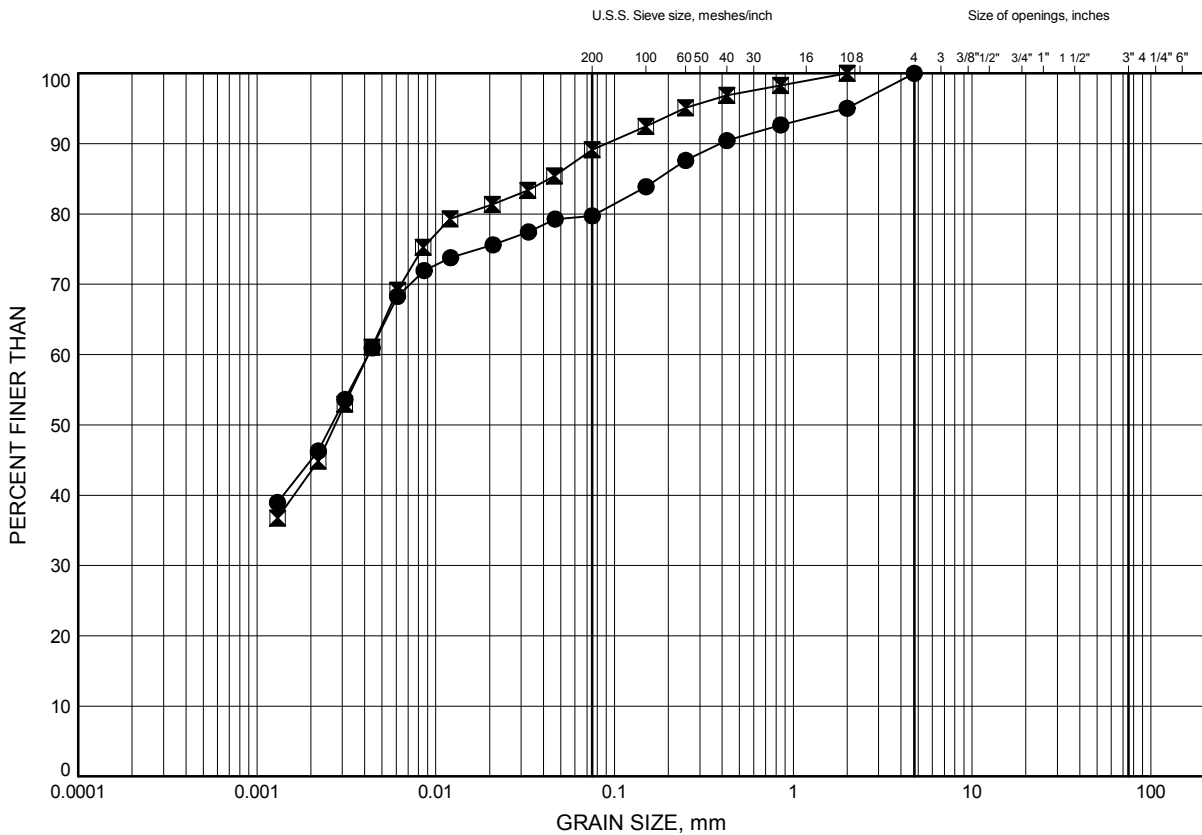


Prep'd AN
Chkd. KS

Munro River Bridge GRAIN SIZE DISTRIBUTION

FIGURE B2

SILTY CLAY, Some Sand



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MRB-01	3.63	357.85
⊠	MRB-02	4.88	356.42

Date July 2014
WP# 494-00-00



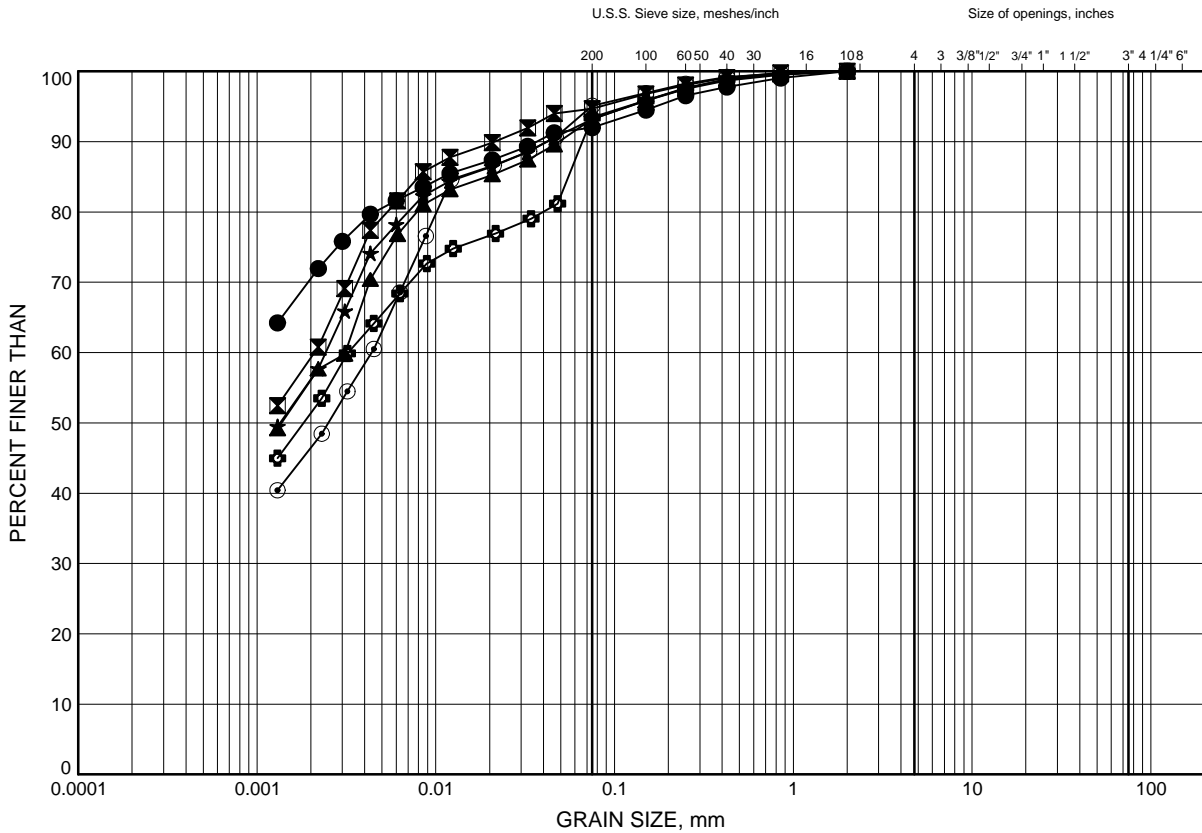
Prep'd AN
Chkd. KS

Munro River Bridge

GRAIN SIZE DISTRIBUTION

FIGURE B3a

SILTY CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MRB-01	6.40	355.08
⊠	MRB-02	9.45	351.85
▲	MRB-02	15.54	345.76
★	MRB-02	26.21	335.09
⊙	MRB-05	7.92	353.28
⊕	MRB-05	12.50	348.70

Date July 2014
WP# 494-00-00

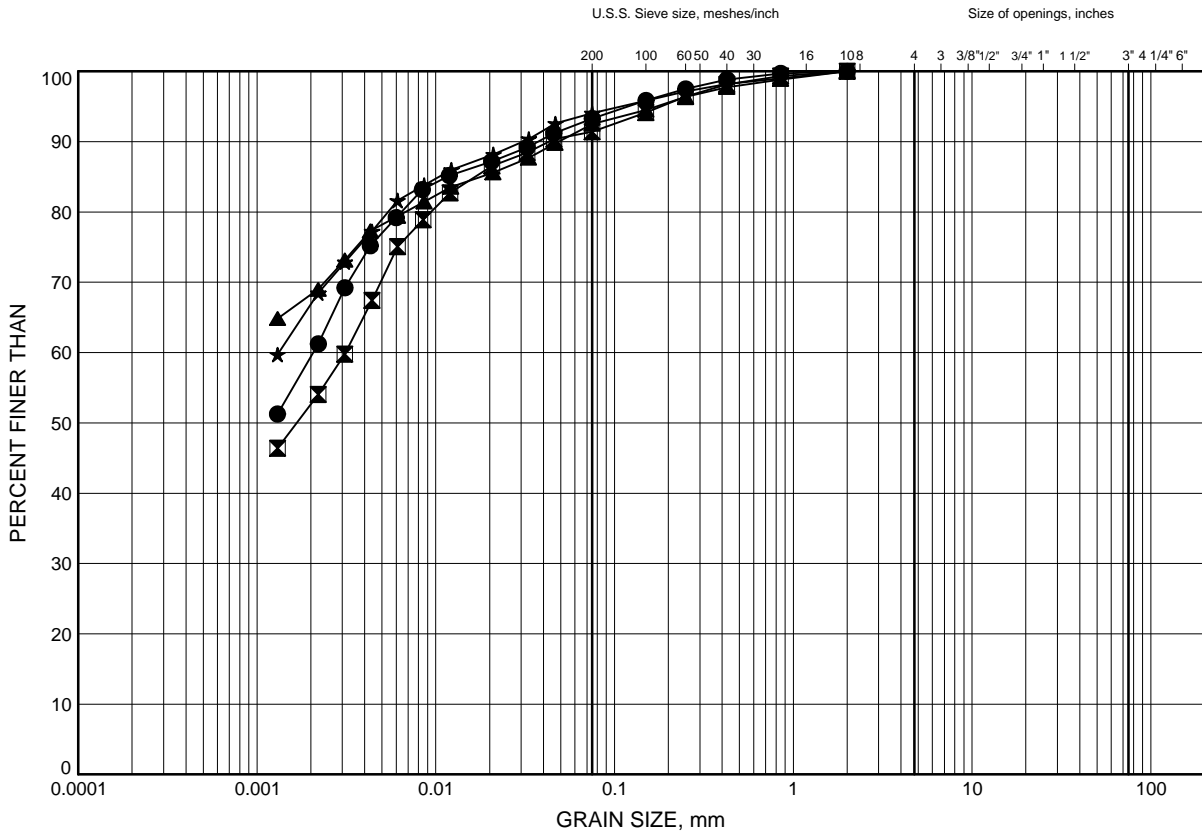


Prep'd AN
Chkd. KS

Munro River Bridge GRAIN SIZE DISTRIBUTION

FIGURE B3b

SILTY CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MRB-05	17.07	344.13
⊠	MRB-05	26.21	334.99
▲	MRB-06	4.88	356.17
★	MRB-06	9.45	351.60

Date July 2014
WP# 494-00-00

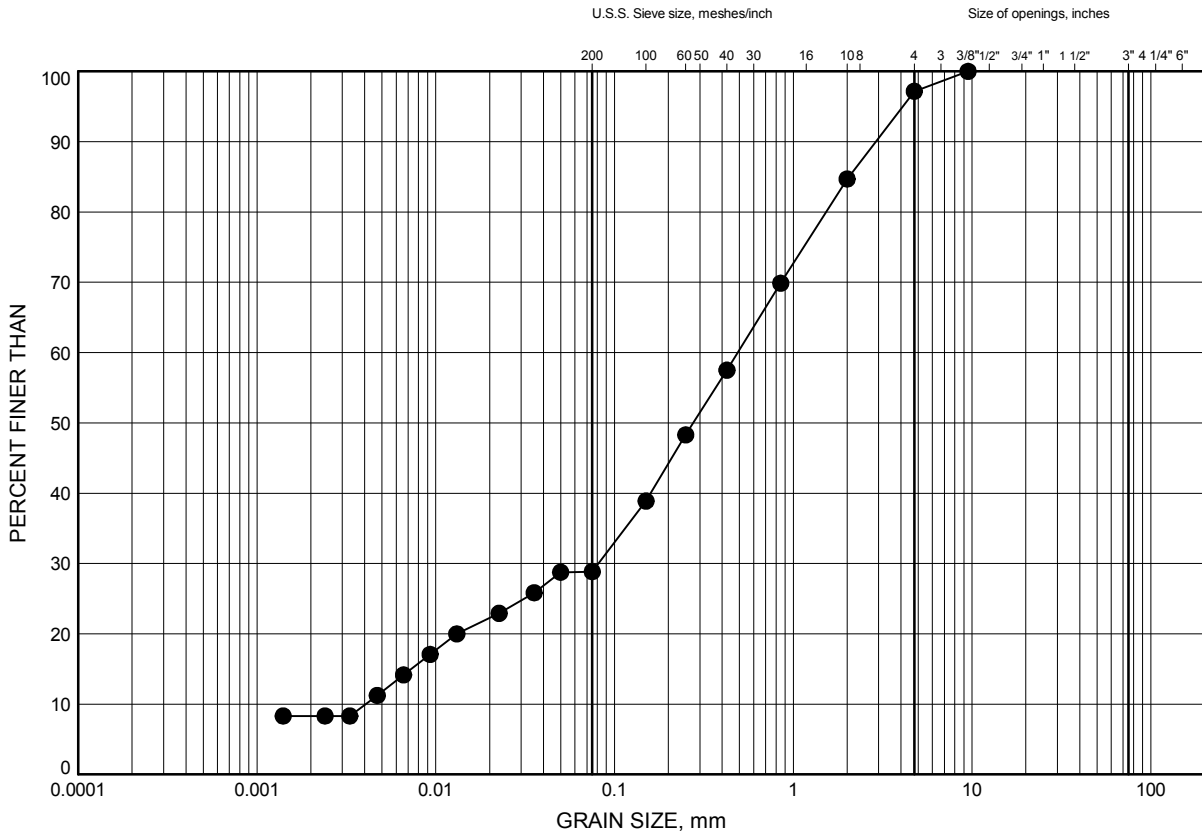


Prep'd AN
Chkd. KS

Munro River Bridge GRAIN SIZE DISTRIBUTION

FIGURE B4

SILTY SAND TILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MRB-02	38.29	323.01

Date July 2014
WP# 494-00-00

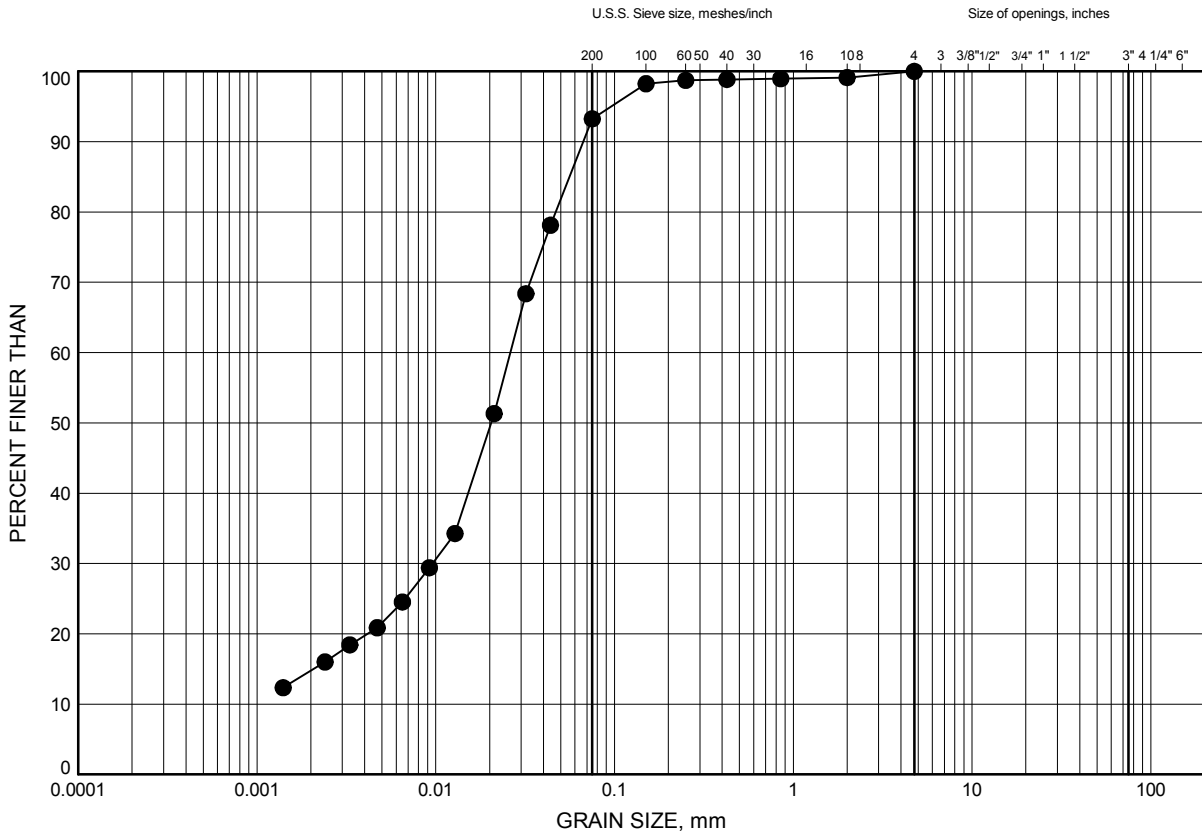


Prep'd AN
Chkd. KS

Munro River Bridge GRAIN SIZE DISTRIBUTION

FIGURE B5

SILT, Some Clay



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MRB-05	42.98	318.22

Date July 2014
WP# 494-00-00

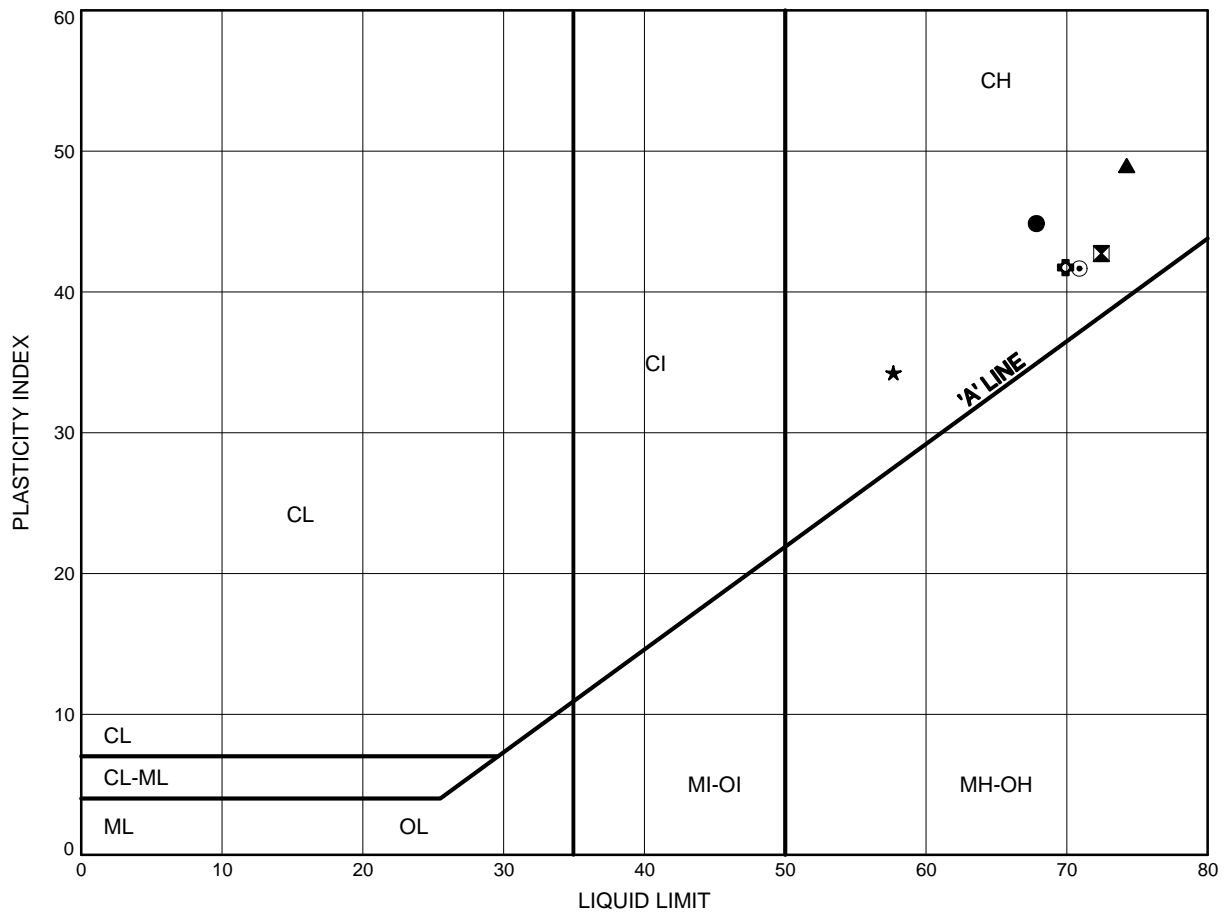


Prep'd AN
Chkd. KS

Munro River Bridge
ATTERBERG LIMITS TEST RESULTS

FIGURE B6a

SILTY CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MRB-01	6.40	355.08
⊠	MRB-02	9.45	351.85
▲	MRB-02	15.54	345.76
★	MRB-05	7.92	353.28
⊙	MRB-05	12.50	348.70
⊕	MRB-05	17.07	344.13

Date July 2014
 WP# 494-00-00

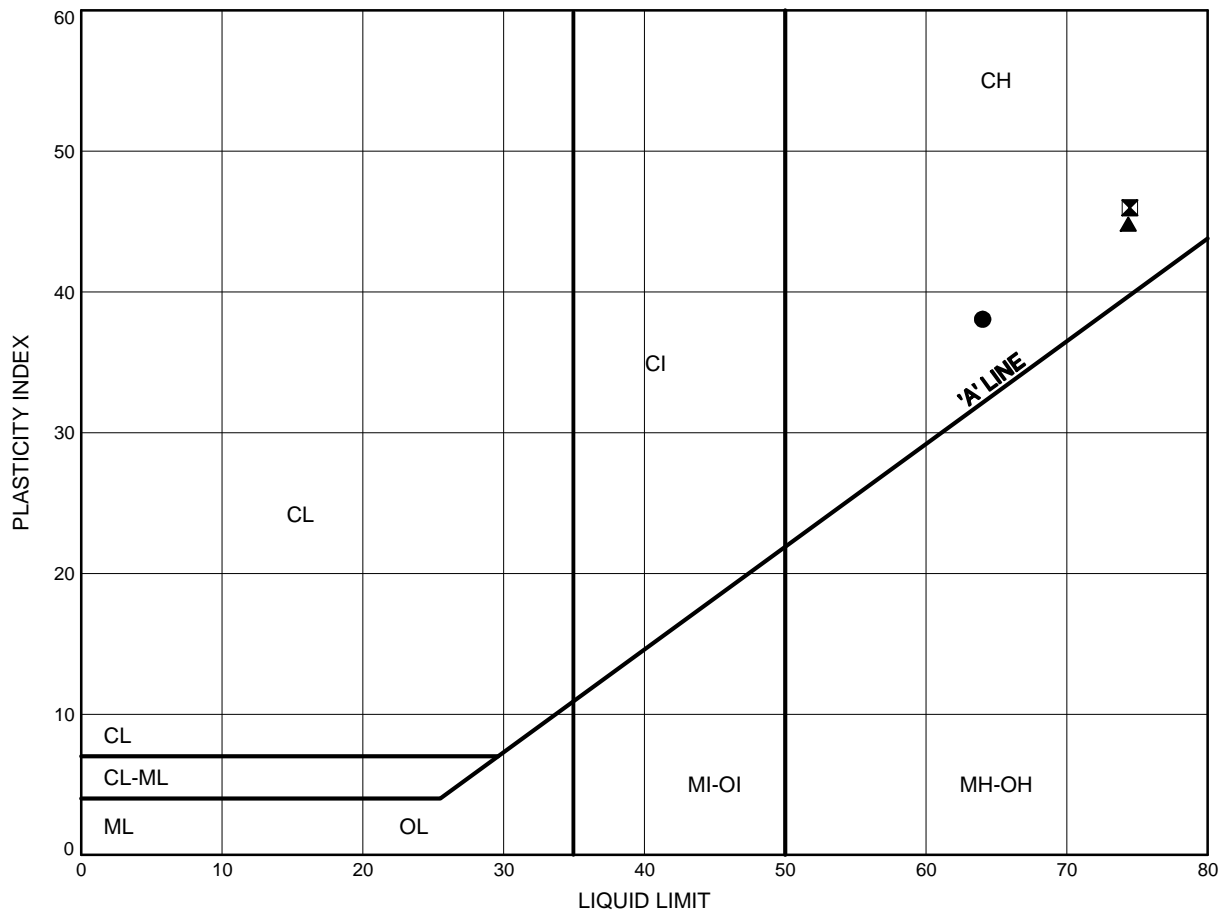


Prep'd AN
 Chkd. KS

Munro River Bridge
ATTERBERG LIMITS TEST RESULTS

FIGURE B6b

SILTY CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	MRB-05	26.21	334.99
⊠	MRB-06	4.88	356.17
▲	MRB-06	9.45	351.60

Date July 2014
 WP# 494-00-00



Prep'd AN
 Chkd. KS

Appendix C

Site Photographs



Looking North From South Abutment



Looking South from North Approach



Looking West (Upstream)

Appendix D

Foundation Comparison

COMPARISON OF FOUNDATION ALTERNATIVES FOR EACH FOUNDATION ELEMENT

Footings on Native Soil	Footings on Engineered Fill	Driven H-Piles	Caissons (Drilled Shaft)
<p>Advantages</p> <ul style="list-style-type: none"> i. Ease of construction. ii. Lower cost than deep foundations. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Relatively low geotechnical resistance is likely to be inadequate. ii. Large consolidation settlement likely due to the presence of deep compressible deposit. iii. Dewatering may be required, depending on depth of excavation and groundwater level at time of construction. <p>NOT RECOMMENDED</p>	<p>Advantages:</p> <ul style="list-style-type: none"> i. Generally less costly than deep foundation elements. ii. Allows use of perched abutments. iii. Higher geotechnical resistance than on native soil. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Cost of engineered fill placement. ii. Not feasible due to thick clay deposit overlying competent granular soil. iii. Dewatering may be required, depending on depth of excavation and groundwater level at time of construction. <p>NOT RECOMMENDED</p>	<p>Advantages:</p> <ul style="list-style-type: none"> i. Higher geotechnical resistance than footings. ii. Installation of piles could continue in freezing weather. iii. Allows integral abutment design. iv. Foundation construction may require less volume of excavation than footings. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Higher unit costs than footings. ii. Bedrock elevation unknown at this site. iii. Piles may need to be driven to elevations deeper than design tip elevations to achieve required capacity. <p>RECOMMENDED</p>	<p>Advantages:</p> <ul style="list-style-type: none"> i. High resistance is available for caissons founded on bedrock. ii. Construction of caissons could continue in freezing weather. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Higher cost than spread footings. ii. Bedrock elevation unknown at this site and depth to competent stratum. iii. Possibility of cobbles and boulders being encountered during augering. iv. Difficulty in cleaning and inspecting bases. <p>NOT RECOMMENDED</p>

Appendix E

List of Standard Specifications and Special Provisions

- 1) The following Standard Specifications and Special Provisions are referenced in this report:

OPSS.PROV 206
OPSS 501
OPSS 539
OPSS 804
OPSS 902
OPSS 903
OPSS.PROV 1010

OPSD 3101.150

Appendix F

Select Runs of Slope Stability Analysis

Title: Highway 613, Munro River Bridge
Comments: Abutment Stability Assessment
Name: South Abutment.TSA

New FILL	21 kN/m ³	0 kPa	32 °	1
Existing FILL	20 kN/m ³	0 kPa	30 °	1
PEAT (TSA)	14 kN/m ³	10 kPa	0 °	1
CLAY2 (TSA)	18 kN/m ³	30 kPa	0 °	1

Method: GLE, Half-Sine
Minimum Slip Surface Depth: 1 m
Seismic: 0
Center: (-9, 364.403) m

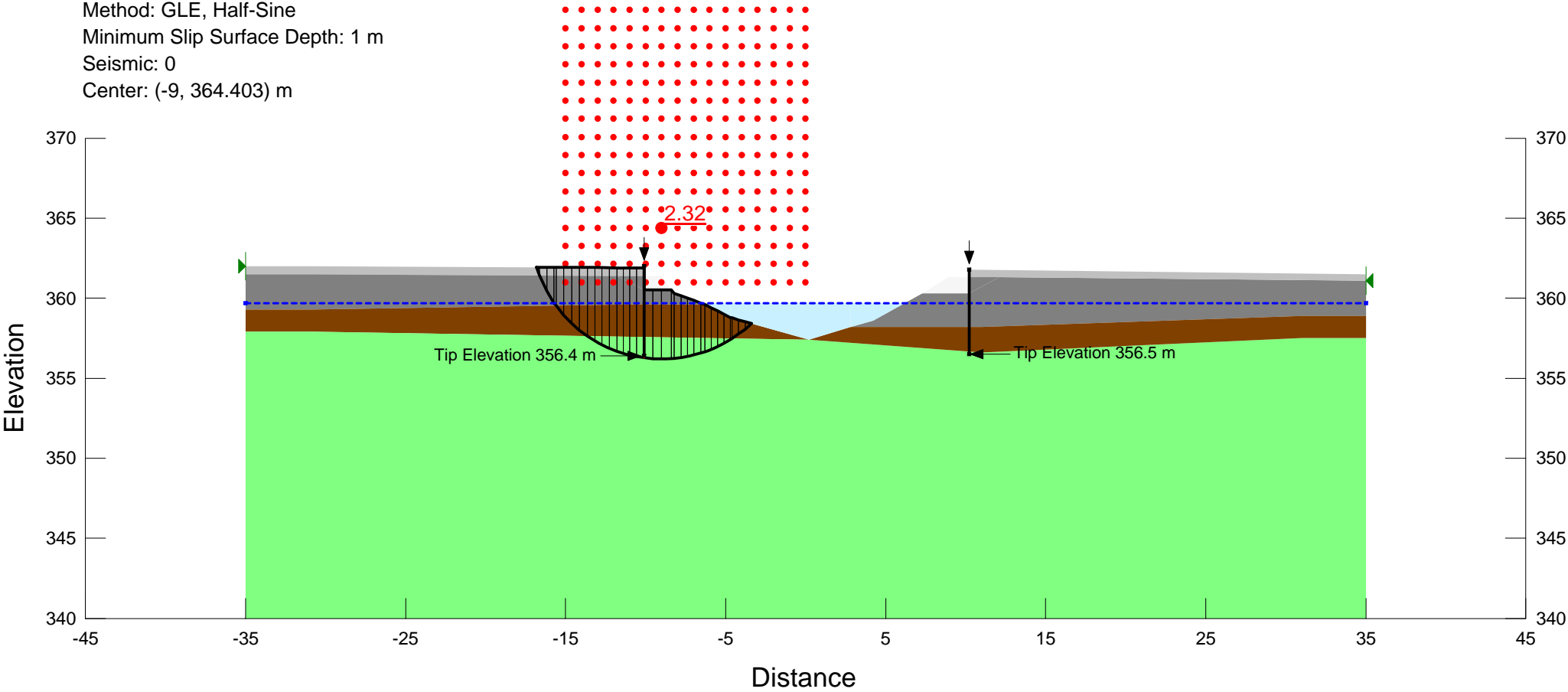


Figure 1

Title: Highway 613, Munro River Bridge
Comments: Abutment Stability Assessment
Name: South Abutment.ESA

New FILL	21 kN/m ³	0 kPa	32 °	1
Existing FILL	20 kN/m ³	0 kPa	30 °	1
PEAT (ESA)	14 kN/m ³	2 kPa	25 °	1
CLAY1 (ESA)	18 kN/m ³	0 kPa	27 °	1

Method: GLE, Half-Sine
Minimum Slip Surface Depth: 1 m
Seismic: 0
Center: (-6, 367.202) m

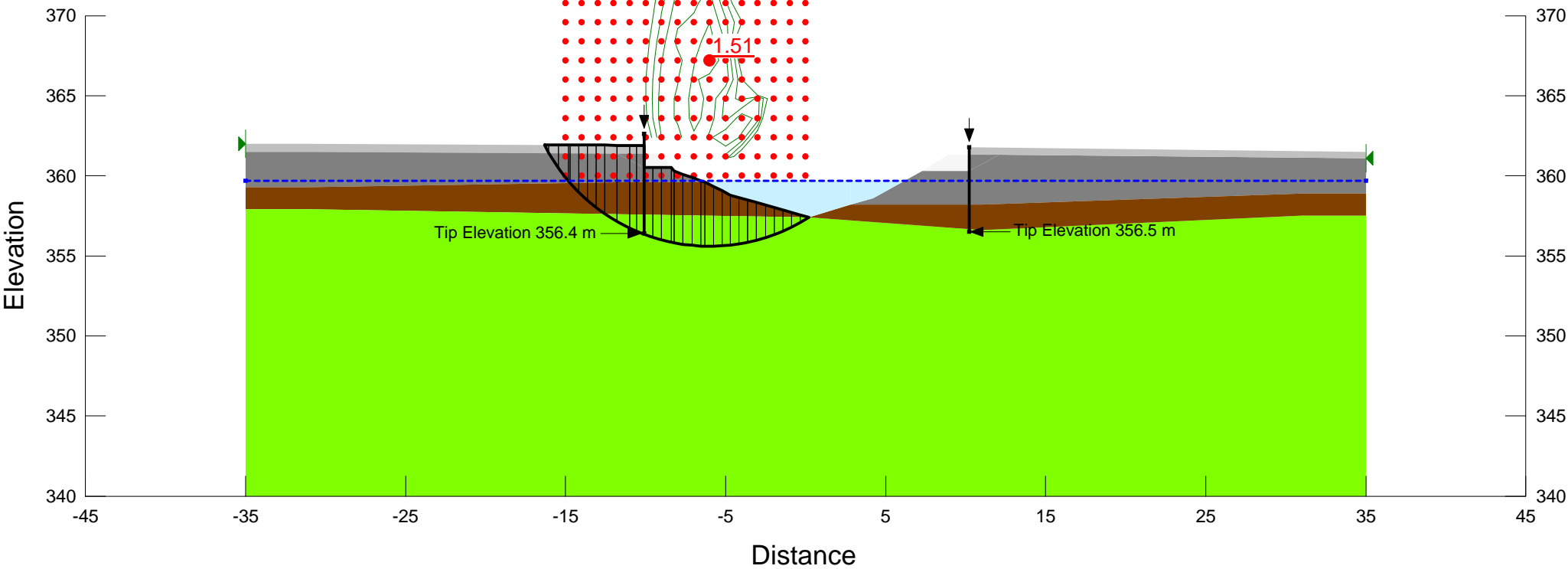


Figure 2

Title: Highway 613, Munro River Bridge
Comments: Abutment Stability Assessment
Name: North Abutment.TSA

New FILL	21 kN/m ³	0 kPa	32 °	1
Existing FILL	20 kN/m ³	0 kPa	30 °	1
PEAT (TSA)	14 kN/m ³	10 kPa	0 °	1
CLAY2 (TSA)	18 kN/m ³	30 kPa	0 °	1

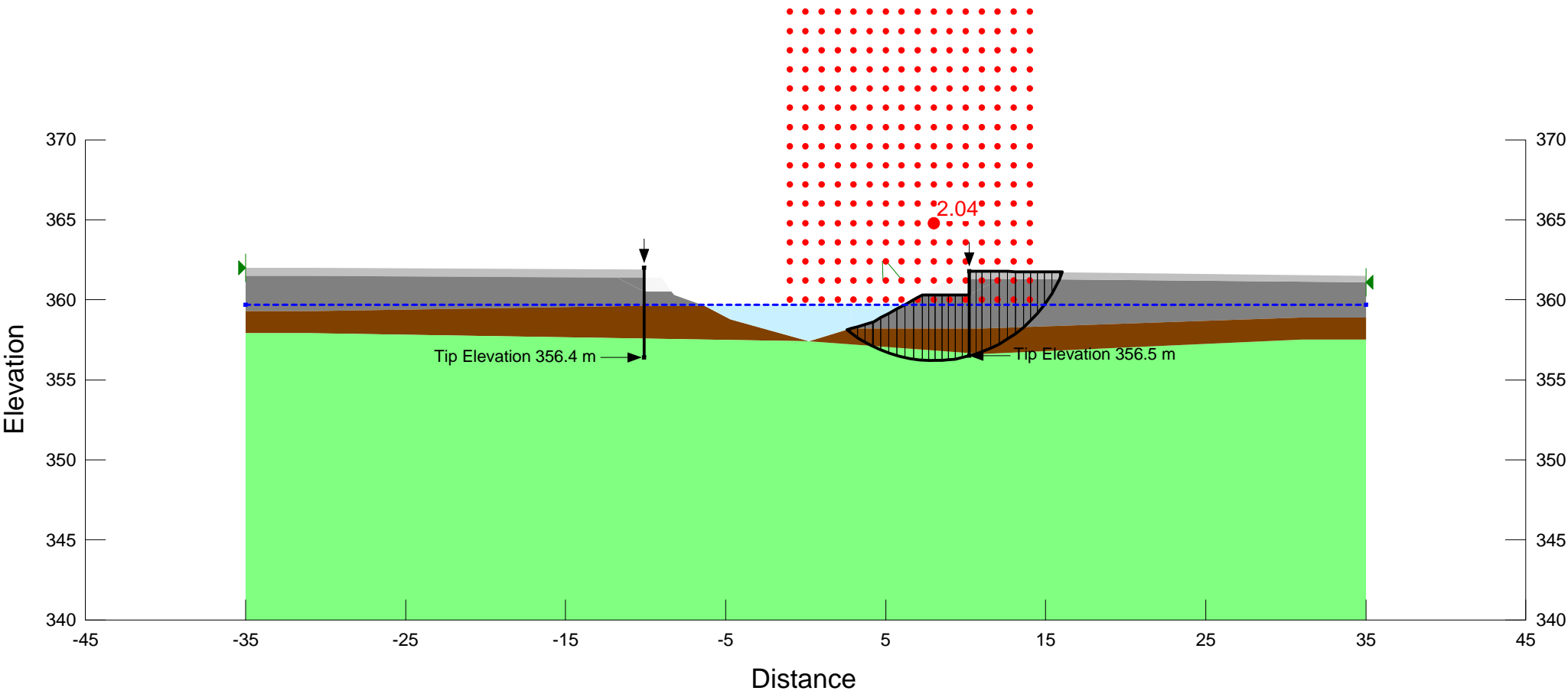


Figure 3

Title: Highway 613, Munro River Bridge
Comments: Abutment Stability Assessment
Name: North Abutment.ESA

New FILL	21 kN/m ³	0 kPa	32 °	1
Existing FILL	20 kN/m ³	0 kPa	30 °	1
PEAT (ESA)	14 kN/m ³	2 kPa	25 °	1
CLAY1 (ESA)	18 kN/m ³	0 kPa	27 °	1

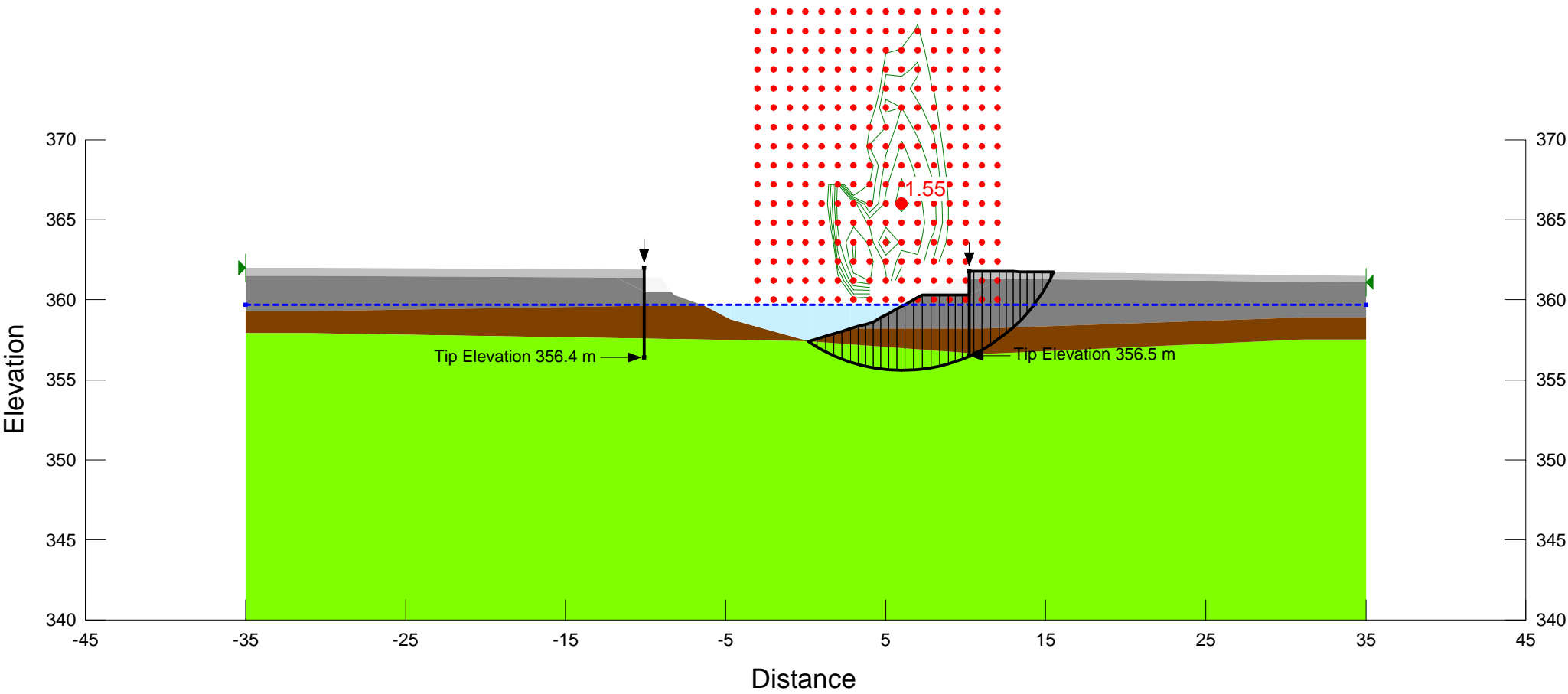
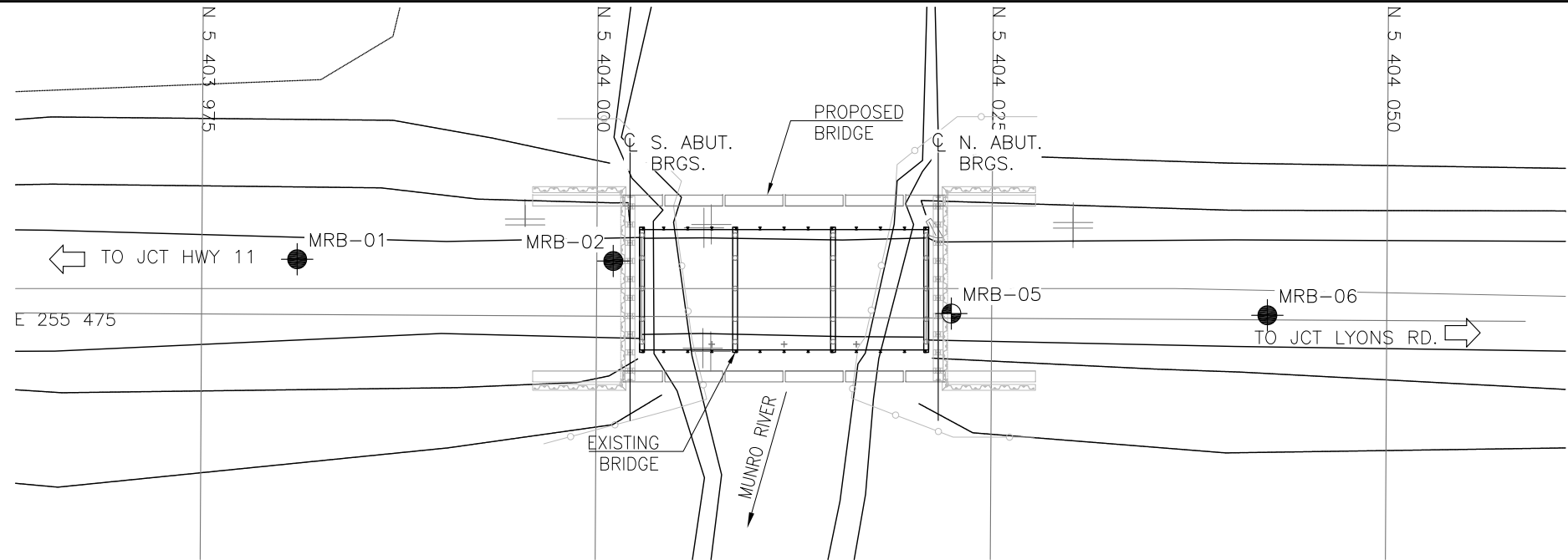


Figure 4

Appendix G

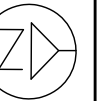
Borehole Locations and Soil Strata Drawing



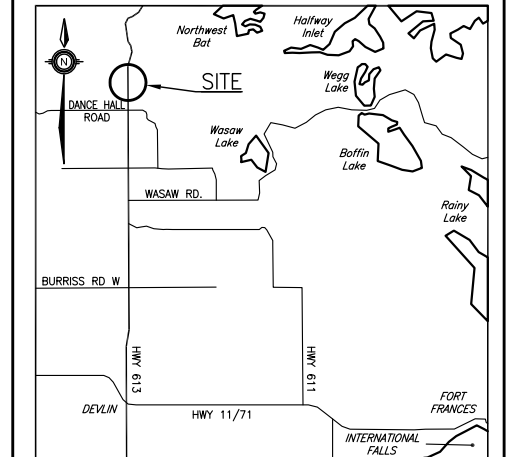
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No
WP No 495-00-01

HIGHWAY 613
MUNRO RIVER BRIDGE
STRUCTURAL REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET
9



KEYPLAN

LEGEND

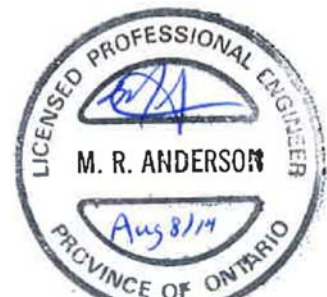
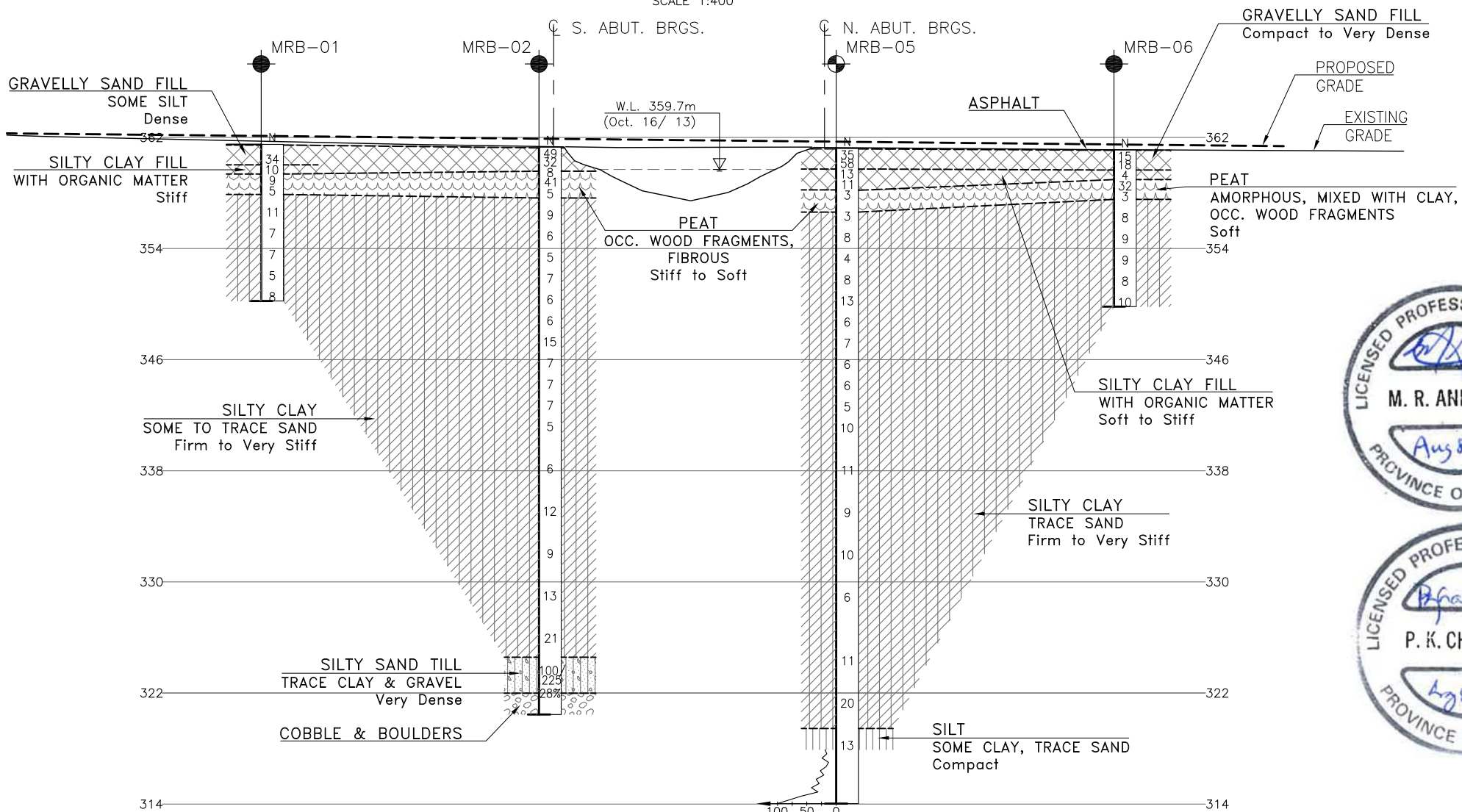
●	Borehole
⊕	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
≡	Water Level
⌋	Head Artesian Water
⌋	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
MRB-01	361.5	5 403 981.0	255 471.5
MRB-02	361.3	5 404 001.0	255 471.5
MRB-05	361.2	5 404 022.4	255 474.7
MRB-06	361.1	5 404 042.4	255 474.7

-NOTES-

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

GEOCRES No. 52C-33



REVISIONS	DATE	BY	DESCRIPTION
DESIGN	KS	CHK PKC	CODE CAN/CSA S6-06 [LOAD CL-626-ONT] DATE AUG 2014
DRAWN	AN	CHK KS	SITE 45-50 [STRUCT] DWG 2