

**FOUNDATION INVESTIGATION AND DESIGN REPORT
OFF LAKE BRIDGE REPLACEMENT
HIGHWAY 615
TOWNSHIP OF CHAPPLE, ONTARIO
RAINY RIVER DISTRICT**

G.W.P. 6092-10-01, SITE No. 45-13

Geocres Number: 52C-30

Report to

GENIVAR

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted at the location of the Off Lake Bridge along Highway 615 in the Township of Chapple, Rainy River District, Ontario.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide a borehole location plan, records of boreholes, stratigraphic profile and sections, laboratory test results and written descriptions 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 GENIVAR, under the Ministry of Transportation Ontario (MTO) Agreement Number 6092-10-00.

2 SITE DESCRIPTION

The Off Lake Bridge is located on Highway 615 between French Road and Fleming Road, approximately 45 km northwest of Fort Frances and 30 km northeast of the intersection of Highways 11 and 71. The bridge is located at the west end of Off Lake and spans the west inlet.

The lands immediately surrounding the bridge site consist of forested and low-lying swamp areas. There are several private residences to the north and south of the bridge site, off Highway 615.

The existing bridge comprises a seven-span timber-concrete composite structure supported on six pier bents and two abutments, each carried by five timber piles. The bridge is approximately 32 m long and 7 m wide. The existing approach embankments are in the order of 1.5 m to 2.0 m high.

Photographs in Appendix C show the general nature of the site.

The site lies within the physiographic region known as the Wabigoon Subprovince of the Superior Province of the Canadian Shield. The soil deposits in the area comprise glaciolacustrine deposits of sand, silt and clay locally overlain by alluvial and organic deposits in low lying areas. Bedrock at depth is formed of felsic to intermediate metavolcanic rock.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing for this project were carried out between August 23 and October 14, 2011 and consisted of drilling and sampling six boreholes, identified as OFF-01 to OFF-06. The approximate borehole locations are shown on the attached Borehole Locations and Soil Strata Drawing included in Appendix G.

Boreholes OFF-02 to OFF-05 were drilled to depths of 29.8 to 37.4 m adjacent to the existing bridge abutments. Boreholes OFF-01 and OFF-06 were drilled to 11.3 m depth through the approaches. A 2.8 m length of bedrock core was recovered from Borehole OFF-05. Borehole OFF-04 was terminated upon refusal in the dense sand and gravel layer containing cobbles and boulders above the bedrock.

The borehole locations were marked in the field and utility clearances were obtained prior to drilling.

Drilling was carried out using a truck-mounted CME 75 drill rig. The boreholes were advanced using a combination of hollow-stem augers and wash-boring/NW casing. Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT).

NQ coring techniques were used to penetrate cobbles and boulders in the sand and gravel layer above the bedrock and to recover bedrock core samples. All rock cores were logged, and the Total Core Recovery (TCR), Rock Quality Designation (RQD) and the Fracture Indices (FI) were determined.

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 and bedrock samples for transport to Thurber's laboratory for further examination and testing.

Groundwater conditions in the open boreholes were observed during the drilling operations. Groundwater levels observed after completion of wash-boring and coring operations were not representative of site conditions as water was introduced into the borehole. Standpipe piezometers were installed in two boreholes to monitor groundwater levels at the site. Completion details of the piezometers and boreholes are summarized in Table 3.1. The piezometers were decommissioned in general accordance with MOE Regulation 903 at the end of October 2012.

Table 3.1 – Borehole Completion Details

Location	Borehole	Piezometer Tip Depth/ Elevation (m)	Completion Details
North Approach	OFF-01	None installed	Backfilled with bentonite holeplug from 11.3m to 3.0m, cuttings from 3.0m to 0.1m, then asphalt cold patch to surface.
North Abutment	OFF-02	34.1 / 65.8	Piezometer with 3.1m slotted screen installed with sand filter to 30.6m, bentonite from 30.6m to 0.6m, cement mix from 0.6m to 0.1m, then asphalt cold patch to surface.
	OFF-03	None installed	Borehole caved to 11.3m, borehole backfilled with bentonite holeplug and grout from 11.3m to 1.2m, cuttings from 1.2m to 0.15m, then asphalt cold patch to surface.
South Abutment	OFF-04	None installed	Grouted with bentonite holeplug from 29.8m to 2.9m, backfilled with cuttings from 2.9m to 0.3m, then asphalt cold patch to surface.
	OFF-05	30.4 / 69.5	Piezometer with 1.5m slotted screen installed with sand filter to 27.0m, bentonite and grout from 27.0m to 2.5m, sand from 2.5m to 0.4m, cement mix from 0.4m to surface.
South Approach	OFF-06	None installed	Backfilled with bentonite from 11.3m to 3.1m, cuttings from 3.1m to 0.1m, then asphalt cold patch to surface.

4 LABORATORY TESTING

All recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected samples were also subjected to gradation analysis (sieve and hydrometer) and Atterberg Limits testing, where appropriate. The results of these tests are summarized on the Record of Borehole sheets included in Appendix A and on the figures presented in Appendix B.

Point load tests were carried out on selected samples of intact bedrock in the laboratory to evaluate the unconfined compressive strength (UCS) of the bedrock. The UCS values of the rock samples assessed from the point load test data are included on the borehole logs presented in Appendix A.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets included in Appendix A. Details of the encountered soil and rock stratigraphy are presented in these sheets and on the “Borehole Locations and Soil Strata” drawing included 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 conditions at the site typically consist of existing sand to sand and gravel embankment fill overlying a discontinuous layer of peat and marl, underlain by very loose to compact native sand to silt and sand, which in turn is underlain by typically firm to stiff silty clay.

Beneath the silty clay deposit is a layer of silt or clayey silt till, and a deposit of very dense sand and gravel with cobbles and boulders which overlies bedrock.

More detailed descriptions of the individual strata are presented below.

5.1 Asphalt

An approximate 25mm to 50mm thick layer of asphalt was encountered surficially in all boreholes drilled through the Highway 615 pavement.

5.2 Embankment Fill

Brown granular fill consisting of sand to sand and gravel was encountered below the asphalt in all boreholes. The fill contained trace to some silt (locally silty) and occasional cobbles, boulders and rock fragments. A 200 mm thick layer of silty clay was encountered at 1.2 m depth locally within the fill in Borehole OFF-01. The fill thickness ranged from 2.3 m to 3.4 m, with the lower boundary at Elev. 96.5 to 97.6.

SPT N-values ranged from 10 blows for 0.3 m penetration to 50 blows for no penetration, indicating a compact to very dense relative density. The fill is typically compact and the high recorded N-values are believed to be due to the sampler encountering cobbles and boulders within the fill. The moisture content of samples of the sand and gravel fill typically ranged from 2% to 15%.

Laboratory grain size analysis testing was undertaken on three samples of the fill and the results of the testing are summarized below. The results are also presented on the Record of Borehole sheets included in Appendix A. The grain size distribution curves for these samples are shown in Figure B1 of Appendix B.

Gravel %	6 to 47
Sand %	40 to 87
Silt and Clay %	6 to 29

5.3 Peat and Marl

A layer of dark brown to black peat was encountered below the granular embankment fill in all boreholes except for Borehole OFF-05. The peat was typically silty and contained wood fragments. The peat layer was 0.5 m thick in all boreholes except Borehole OFF-02 where it was 1.2 m thick. The lower boundary was encountered at depths of 3.4 m to 3.7 m (Elev. 96.5 to 96.2).

In Boreholes OFF-01, OFF-02 and OFF-06, the peat was underlain by grey silty marl containing shell fragments. This layer was 0.5 m to 0.6 m thick, with a lower boundary at 4.1 m depth (Elev. 95.8).

SPT N-values recorded in the peat layer ranged from 2 to 6 blows for 0.3 m penetration, indicating a very loose to loose condition. Moisture contents of the peat and marl ranged from 120% to 217%.

5.4 Sand

A layer of native grey sand with trace to some silt and gravel was encountered beneath the fill, peat and marl in all boreholes. The thickness of the sand layer ranged from 1.9 m to 4.5 m. The lower boundary of this deposit was at depths of 5.3 m to 8.2 m (Elev. 94.6 to 91.7).

SPT N-values recorded in the sand layer ranged from 2 to 29 blows for 0.3 m penetration, indicating a very loose to compact relative density. Moisture contents ranged from 11% to 20%.

The results of grain size analysis testing conducted on samples of the sand are presented on the Record of Borehole sheets included in Appendix A and the grain size distribution curves plotted on Figure B2 of Appendix B. The results are summarized as follows:

Gravel %	1 to 4
Sand %	77 to 95
Silt and Clay %	2 to 22

5.5 Silty Sand to Sandy Silt

Below the sand layer, a cohesionless deposit grading from sandy silt to silty sand with trace to some clay was encountered. Borehole OFF-01 was terminated within this deposit at 11.3 m depth (Elev. 88.6). In the remaining boreholes, the thickness of this layer ranged from 2.7 m to 6.6 m. The lower boundary was at depths of 9.4 m to 14.2 m (Elev. 90.5 to 85.7).

SPT N-values recorded in the silty sand to sandy silt layer ranged from 1 to 12 blows for 0.3 m penetration, indicating a very loose to compact relative density. Moisture contents ranged from 14% to 32%.

The results of grain size analysis testing conducted on samples of the sand/silt are presented on the Record of Borehole sheets included in Appendix A and the grain size distribution curves plotted on Figures B3 and B4, Appendix B. The results are summarized as follows:

Gravel %	0 to 5
Sand %	23 to 76
Silt %	22 to 58
Clay %	2 to 19

5.6 Silt

A 1.4 m thick layer of silt with some clay and trace of sand was encountered below the sand/silt locally in Borehole OFF-02. The lower boundary was at 15.2 m depth (Elev. 84.7). An SPT N-value of 4 blows for 0.3 m was recorded in the silt, indicating a loose condition. A moisture content of 23% was measured.

The results of a grain size analysis conducted on the silt are presented on the Record of Borehole sheets in Appendix A and summarized below. The grain size curve is shown on Figure B5, Appendix B.

Gravel %	0
Sand %	7
Silt %	79
Clay %	14

5.7 Silty Clay

Grey silty clay with occasional silt and sand seams was encountered below the sand and silt deposits in all boreholes except for Borehole OFF-01. Borehole OFF-06 was terminated within this layer at 11.3 m depth (Elev. 88.6). The thickness of the clay layer in the remaining boreholes varied from 10.5 m to 14.7 m, with the lower boundary at depths of 24.1 m to 26.1 m (Elev. 75.8 to 73.8).

SPT N-values recorded in the clay ranged from 3 to 19 blows for 0.3 m of penetration, indicating a very soft to very stiff consistency, typically firm to stiff. Moisture contents ranged from 22% to 49%, generally less than 30%.

Grain size distribution curves from ten samples are presented on the Record of Borehole sheets included in Appendix A and on Figures B6 and B7 of Appendix B. Atterberg Limits test results are presented on Figure B8. The results are summarized below:

Gravel %	0 to 1
Sand %	1 to 13*
Silt %	25 to 71
Clay %	22 to 72

* 23% in one sample with sand seams

Liquid Limit	27 to 69
Plastic Limit	15 to 21

The results indicate that the silty clay is typically of low to intermediate plasticity with a group symbol of CL to CI. One sample from Borehole OFF-02 exhibited high plasticity (CH).

5.8 Silt

A layer of silt with some clay was encountered below the silty clay in Boreholes OFF-02 and OFF-03. The silt layer was 2.6 to 3.0 m thick with a lower boundary at depths of 27.1 and 28.7 m (Elev. 72.8 and 71.2). SPT N-values of 12 and 15 blows for 0.3 m were recorded in the silt, indicating a compact condition. Moisture contents of 23% and 24% were measured.

The results of grain size analyses conducted on the silt are presented on the Record of Borehole sheets in Appendix A and summarized below. The grain size curves are shown on Figure B5, Appendix B.

Gravel %	0 to 2
Sand %	0 to 9
Silt %	73 to 87
Clay %	13 to 16

5.9 Clayey Silt Till

A layer of clayey silt till with occasional cobbles and boulders was encountered below the silty clay in Boreholes OFF-04 and OFF-05. The till layer was 2.7 m to 3.0 m thick with a lower boundary at depths of 27.4 and 27.7 m (Elev. 72.5 and 72.2).

SPT N-values of 100 for 0.075 m and 38 blows for 0.3 m of penetration were recorded in the till, indicating a hard consistency. The higher N-value may indicate the presence of a cobble however. Moisture contents of 27% and 29% were measured.

5.10 Sand and Gravel with Cobbles and Boulders

A layer of sand and gravel with cobbles and boulders was encountered below the silt and clayey silt till layers in Boreholes OFF-02 to OFF-05. In Boreholes OFF-02 and OFF-05, rock coring procedures were required to penetrate the cobbles and boulders in this deposit. Cobble and boulder sizes of 100 mm to 680 mm were noted in the recovered core runs.

Boreholes OFF-02 and OFF-03 were terminated within this deposit at 37.4 m depth (Elev. 62.5), indicating a layer thickness of at least 8.7 to 10.3 m. Borehole OFF-04 was terminated upon auger refusal on probable boulders at 29.8 m depth (Elev. 70.1). Bedrock was contacted below the sand and gravel at 31.3 m depth (Elev. 68.6) in Borehole OFF-05, for a layer thickness of 3.6 m.

SPT N-values recorded in the sand and gravel typically ranged from 52 blows for 0.3 m to 100 blows for 0.025 m of penetration, indicating a very dense condition and/or the presence of cobble and boulders. Locally at depths of 31.5 and 33.0 m (Elev. 68.4 and

66.9) in Borehole OFF-03, N-values of 26 and 28 blows per 0.3 m of penetration were recorded, indicating a compact zone.

One moisture content of 14% was measured in the sand and gravel.

5.11 Bedrock

Bedrock was contacted below the layer of sand and gravel in Borehole OFF-05 at 31.3 m depth (Elev. 68.6), and a 2.8 m length of rock core was recovered. The bedrock recovered in the core was described as grey intermediate metavolcanic rock.

Total core recovery in the bedrock was 100% except for the final core run where recovery was 44%. The Rock Quality Designation (RQD) varied from 0% to 46%, indicating very poor to poor rock quality. The Fracture Index (FI) of the rock, expressed as fractures per 0.3 m of core, ranged from 5 to 15.

The unconfined compressive strength estimated from the results of point load tests conducted on the rock cores ranged from 155 MPa to 346 MPa, indicating a very strong to extremely strong rock.

5.12 Water Levels

Water levels were monitored in the open boreholes during drilling where possible. Wash boring and rock coring methods were used to advance Boreholes OFF-02 to OFF-05 and therefore water levels in these boreholes were not representative of the groundwater conditions. Piezometers were installed in Boreholes OFF-02 and OFF-05 upon completion of drilling.

The water levels recorded in the boreholes during drilling and subsequently in the piezometers are summarized in Table 5.1.

The GA drawing provided by GENIVAR indicates that the water level at the inlet to Off Lake was at Elev. 98.3 when measured in May 2011.

The above values are short-term readings and seasonal fluctuations of the lake and groundwater level are to be expected. In particular, the lake and groundwater level may be at a higher elevation after the spring snowmelt or after periods of heavy rainfall.

Table 5.1 – Water Level Measurements

Borehole	Date	Water Level (m)		Comment
		Depth	Elevation	
OFF-01	Aug. 23, 2011	2.7	97.2	Open borehole
OFF-02	Oct. 02, 2011	4.1	95.8	In piezometer
	Oct. 04, 2011	3.9	96.0	
	Oct. 13, 2011	3.9	96.0	
	Oct. 20, 2011	3.8	96.1	
	Oct. 27, 2012	1.4	98.5	
OFF-03	Oct. 14, 2013	2.4	97.5	Open borehole
OFF-05	Oct. 02, 2011	0.9	99.0	In piezometer
	Oct. 04, 2011	0.9	99.0	
	Oct. 13, 2011	0.9	99.0	
	Oct. 20, 2011	0.9	99.0	
	Oct. 27, 2012	1.4	98.5	
OFF-06	Aug. 23, 2011	3.3	96.6	Open borehole

6 MISCELLANEOUS

Borehole locations were selected in the field by Thurber Engineering Ltd. The coordinates and ground surface elevations for the boreholes were established based on topographic surface information provided by GENIVAR.

Thurber obtained utility clearances for the borehole locations prior to drilling.

Eastern Ontario Diamond Drilling of Hawkesbury, Ontario supplied a truck mounted CME-75 drill rig and conducted the drilling, sampling and in-situ testing operations. The field program was supervised by Ms Eckie Siu, Mr George Azzopardi, Mr Jason Mei, and Mr Stephane Loranger, C.E.T. of Thurber.

Overall supervision of the field program was conducted by Mr. Mark Farrant, P.Eng. Interpretation of the data and preparation of this report were carried out by Ms. Rocio Palomeque Reyna, P.Eng. and Ms. Mei T. Cheong, P.Eng.

The report was reviewed by Mr. Murray R. Anderson, P.Eng. and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This report presents interpretation of the geotechnical data provided in the factual report and provides geotechnical recommendations for design of a new bridge to replace the existing bridge on Highway 615 at Off Lake in the Township of Chapple, Rainy River District, Ontario.

The existing Off Lake Bridge was constructed in 1973. The bridge comprises a seven-span timber-concrete composite structure supported on six pier bents and two abutments, each carried by five timber piles. Information on the length of the timber piles was not available. The existing bridge is approximately 32 m long and 7 m wide. The existing approach embankments are in the order of 1.5 m to 2.0 m high.

The preliminary General Arrangement drawing provided by GENIVAR indicates that the proposed replacement bridge will be a single span modular structure supported on steel H-piles. The new bridge will be approximately 30.5 m long and 9.4 m wide. The current foundation configuration calls for three permanent supports and one temporary support at each abutment, with two HP 310 x 110 piles at each support. The permanent support piles will carry design loads of 860 kN at factored ULS and 500 kN at SLS per pile.

Structural ramps supported on sleeper slabs will be placed at each end of the bridge. Road grades will be raised by almost 600 mm, and sheet pile wingwalls will be installed along the northwest and southeast sides of the approaches.

The discussions and recommendations presented in this report are based on the factual data obtained during the course of the investigation. The plans and profiles used for preparation of this report were provided by GENIVAR.

8 STRUCTURE FOUNDATIONS

The subsurface conditions at the site consist of 2.3 m to 3.4 m of existing sand to sand and gravel embankment fill overlying a discontinuous layer of peat and marl, underlain by very loose to compact native sand to silt and sand, which in turn is underlain by typically firm to stiff silty clay. Beneath the silty clay deposit is a layer of silt or clayey silt till, and a deposit of very dense sand and gravel with cobbles and boulders which overlies bedrock.

The latest piezometer measurements indicate groundwater levels at a depth of 1.4 m below the road surface (Elev. 98.5). The groundwater level is slightly above the water level measured in Off Lake, which was reported to be at Elev. 98.3 in May 2011.

Consideration was given to the following foundation types based on the existing site conditions:

- Spread footings on native soils
- Augered caissons (drilled shafts)
- Driven steel H-piles

A comparison of the foundation alternatives based on advantages and disadvantages of each is included in Appendix D.

8.1 Spread Footings on Native Soils

Consideration was given to supporting the structure on spread footings founded on native soils. However, this option is not recommended due to the following:

- The geotechnical resistance available in the native loose to compact sand to silt and sand underlying the existing embankment fill is relatively low.
- Construction of footings on native soils would require excavation below the lake and groundwater levels within cohesionless embankment fill and native soil. Temporary shoring (i.e. sheet pile cofferdam) and dewatering would be required under these conditions.
- Footing construction would require temporary excavation which may have an environmental impact on the lake.
- Scour protection will be required for the footings.

Based on the above issues, the spread footing option was not further developed.

8.2 Augered Caissons (Drilled Shafts)

Caissons supporting the structure at this site would need to be extended to the very dense sand and gravel deposit or the underlying bedrock. Construction of caissons through the cohesionless sands and silts below the groundwater table would require use of a steel liner to support the caisson sidewalls. Advancing the steel liner into the deposit of sand and gravel with cobbles and boulders would be difficult, and the potential exists for construction/hydraulic disturbance of the materials at the caisson base. For caissons extended to bedrock, a proper seal of the caisson base would be difficult to achieve.

For these reasons, the use of caisson foundations is not recommended.

8.3 Driven Steel H-piles

The use of driven steel H-piles is considered suitable to support the bridge structure. Considering the design abutment loads, it is recommended that the piles be driven to the deposit of sand and gravel with cobbles and boulders encountered at depths of 27.1 to 28.7 m (Elev. 72.8 to 71.2) in the boreholes.

The geotechnical resistance values recommended for HP 310 x 110 steel H-piles driven to a tip elevation of 71.0 in the very dense sand and gravel with cobbles and boulders are as follows:

Factored Geotechnical Resistance at ULS = 1,000 kN

Geotechnical Reaction at SLS = 800 kN

The pile tip elevations are presented for estimating purposes only and may vary along the abutment locations. The actual pile tip elevations will be controlled by the Hiley Formula as described in the next section. Some piles may achieve the required capacity or encounter refusal on cobbles and boulders in the sand and gravel above the recommended founding level.

If higher resistance values are required, the H-piles could be driven to refusal in the sand and gravel layer. As cobbles and boulders are present in the sand and gravel deposit, the elevation at which refusal is encountered may vary, however the piles are expected to encounter refusal at approximate elevation 69.0 to 70.0. The geotechnical resistance values recommended for HP 310 x 110 steel H-piles driven to refusal in the sand and gravel are as follows:

Factored Geotechnical Resistance at ULS = 1,600 kN

Geotechnical Reaction at SLS = 1,400 kN

An NSSP alerting the Contractor to the possibility of piles encountering refusal at varying depths on cobbles and boulders is provided in Appendix E.

8.3.1 H-pile Installation

Pile installation should be in accordance with OPSS 903.

The tips of all driven H-piles must be fitted with pile tip protection from an approved manufacturer such as Titus Steel (Standard H-point) or approved equivalent. Pile tip protection is recommended to prevent pile damage when driving into the sand and gravel layer with cobbles and boulders.

Pile driving to the design resistance must be controlled by the Hiley formula and an ultimate pile resistance to be specified by the designer in accordance with Clause 3.3.2 (b) Construction Stage of the Structural Manual. The Hiley formula need not be used until the piles are within 2.0 m of the sand and gravel deposit. The appropriate driving note is “Piles to be driven in accordance with Standard SS 103-11 using an ultimate resistance of ‘R’ kN per pile”, where ‘R’ must have a minimum value of twice the design load at ULS.

If the proposed bridge design requires that the deviation at the top of the pile be limited to tight tolerances, a driving template or other means may be required to achieve the specified maximum deviation.

8.3.2 Monitoring of Existing Bridge during Pile Driving

The existing bridge is supported on timber piles. Drawings were not available indicating the length of the timber piles, however the piles are likely supported within the very loose to compact sand/silt and possibly extend to the underlying silty clay. The possibility therefore exists for disturbance of the existing foundations during driving of new H-pile foundations.

Monitoring of the existing timber piles and bridge structure during pile driving is recommended. As a minimum, the monitoring program should include establishing reference points on each pile bent and monitoring of movements during pile driving. In addition, inspection of the existing structure should be conducted at least daily during foundation construction to identify any displacement or structural distress. A suggested text for an Nssp addressing the monitoring requirements is provided in Appendix E.

The Contractor must be prepared to jack and/or shim the bridge structure if settlement of the existing timber piles exceeds tolerable levels. Other measures to reduce the impact, such as driving with a reduced hammer energy, may be required.

8.3.3 Downdrag

The approximate 600 mm grade raise planned along the existing Highway 615 approach is considered unlikely to cause significant settlement in the underlying silty clay layer, as the increased pressures within the clay are expected to remain within the preconsolidated range. As a result, downdrag loading on the piles is not a concern at this site.

8.3.4 Lateral Resistance of Piles

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

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

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

where z = depth of embedment of pile in metres

D = pile width in metres

n_h = value in Table 8.1

γ = unit weight of soils (Table 8.1)

K_p = passive earth pressure coefficient (Table 8.1)

In cohesive soils, the lateral resistance may be calculated as follows:

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

$$p_{ult} = 9 s_u \quad (\text{kPa}) \text{ at and below a depth of } 3D \text{ and reduced to zero at the ground surface}$$

where D = pile width in metres

s_u = undrained shear strength (kPa)

Lateral resistance in the fill and underlying peat/marl layer should be neglected in the design.

Table 8.1 – Parameters for Lateral Resistance

Abutment	Elevation	n_h (kN/m^3)	K_p	s_u (kPa)	Unit Weight* (kN/m^3)	Soil Conditions
North	96.0 to 94.0	4,500	3.3	-	11	Compact sand
	94.0 to 88.0	3,000	3.0	-	10	Loose silt/sand
	88.0 to 75.0	-	-	80	10	Stiff silty clay
	75.0 to 72.0	3,000	3.0	-	10	Compact silt
	72.0 to 62.5	8,000	3.8	-	11	Very dense sand & gravel
South	96.0 to 92.0	4,500	3.0	-	11	Compact sand
	92.0 to 86.0	2,000	3.0	-	10	Loose silt/sand
	86.0 to 75.0	-	-	80	10	Stiff silty clay
	75.0 to 72.5	-	-	200	10	Hard clayey silt till
	72.5 to 70.0	8,000	3.8	-	11	Very dense sand & gravel

* Buoyant unit weight below groundwater table.

The above equations and recommended parameters may be used to analyse the interaction between a single foundation element and the surrounding soils. The lateral pressures obtained from the analysis should not exceed the ultimate lateral resistance.

The spring constant, K , for analysis may be obtained by the expression, $K = k_s L D$ (kN/m), where k_s is the coefficient of horizontal subgrade reaction (kN/m³), D is the foundation width or diameter (m) and L is the length (m) of the foundation segment or element used in the analysis. The ultimate lateral resistance on any one segment of foundation, P_{ult} , may be obtained from the expression, $P_{ult} = p_{ult} L D$. This represents the ultimate load at which the soil fails and will not support any additional load at greater displacements. It is recommended however that the total lateral resistance by one pile be limited to 110 kN at factored ULS and 40 kN at SLS.

The modulus of subgrade reaction may have to be reduced, based on the pile spacing. Where a pile group is oriented *perpendicular* to the direction of loading, group action may be considered by reducing values for k_s by a reduction factor R as follows:

Pile Spacing Perpendicular to Direction of Loading	Horizontal Subgrade Reaction Reduction Factor, R
4 D^*	1.00
1 D^*	0.50

* D is the width of the pile, and spacing is measured centre to centre

Where a pile group is oriented *parallel* to the direction of loading, group action may be considered by reducing values for k_s by a reduction factor R as follows:

Pile Spacing Parallel to Direction of Loading	Horizontal Subgrade Reaction Reduction Factor, R
8 D	1.00
6 D	0.70
4 D	0.40
3 D	0.25

Intermediate values may be obtained by interpolation.

8.4 Frost Cover

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

9 APPROACH EMBANKMENTS

The existing approach embankments are approximately 1.5 to 2.0 m high with side slopes varying locally from about 1.5H:1V to 3H:1V. The preliminary GA drawing indicates that the abutment fore slopes above the water level will be graded to an inclination of approximately 2.5H:1V and include removal of existing embankment fill under the proposed sleeper slab. A grade raise of almost 600 mm is proposed, and sheet pile wingwalls will be installed along the southeast and northwest sides of the embankments.

The foundation soils governing stability and settlement of the approach embankments consist primarily of loose to compact sand to silt and sand underlain by typically firm to stiff silty clay.

The global stability of the approach embankments was assessed using the Morgenstern-Price method of slope stability analysis. The geotechnical model and results of the analysis are shown on Figures F1 to F6 of Appendix F.

For the proposed abutment fore slopes established at inclinations of 2.5H:1V and protected from erosion, factors of safety of 2.0 and 1.7 were obtained for the north and south abutments, respectively (Figures F1 and F2). These values are considered adequate and stability is not expected to be an issue.

Currently, the existing southeast and northwest side slopes are relatively steep and a factor of safety of 1.2 was computed for the existing slope inclinations (Figures F3 and F5). With the proposed grade raise and sheet pile wingwalls installed along these sections (Figures F4 and F6), a factor of safety of 1.5 is achieved for sheet piles driven to at least Elev.94.0 and Elev.95.0 at the southeast and northwest side slopes, respectively.

The grade raise of the existing highway grade will induce immediate (elastic) settlement in the existing fill, discontinuous organic layer, native cohesionless soils and silty clay, as well as time dependent (consolidation) settlement in the organic layer and underlying native silty clay. The total settlement of the embankment foundation soils under the weight of the new fill is estimated to be between 25mm and 30mm, of which approximately 20mm will occur within the organic layer.

Periodic grading and adjustment of the sleeper slab may be required to compensate for any time dependent settlements.

10 SHEET PILE WALLS

The current design proposes the installation of sheet pile wingwalls along the northwest and southeast sides of the approach embankment. The southeast wingwall will be installed along the shoreline to form an assembly and launching area for the modular bridge.

Backfill to sheet pile walls should be in accordance with OPSS 902 and 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 sheet pile walls should be restricted in accordance with OPSS 501.

Lateral earth pressures acting on the sheet pile walls may be assumed to be distributed triangularly and to be governed by the characteristics of the wall backfill, existing fill and the underlying native soils. For a fully drained condition, the pressures should be computed in accordance with the CHBDC but generally are given by the expression:

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

Where:

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

K = earth pressure coefficient (see table below)

γ = unit weight of retained soil (see table below)

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

q = value of any surcharge (kPa)

Earth pressure coefficients for backfill to the sheet pile wall are dependent on the material used as backfill. Typical values are shown in Table 10.1.

Table 10.1 – Earth Pressure Coefficients (K)

Condition	Earth Pressure Coefficient (K)				
	OPSS Granular A or Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I, Granular B Type III, and Existing Granular Fill $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$		Native Sand to Silt and Sand $\phi = 30^\circ, \gamma = 20 \text{ kN/m}^3$
	Horizontal Surface	Sloping surface behind of wall (2H:1V)	Horizontal Surface	Sloping surface behind of wall (2H:1V)	Horizontal Surface
Active (Unrestrained system)	0.27	0.38	0.31	0.46	0.33
At rest (Restrained system)	0.43	-	0.47	-	0.50
Passive (Movement Towards Soil Mass)	3.7	-	3.3	-	3.0

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

The factors in Table 10.1 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.

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 and Type III or 1.7 m for Granular A and Granular B Type II.

Design of 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.

11 SEISMIC CONSIDERATIONS

The following seismic parameters should be used for design:

- Velocity Related Seismic Zone 0
- Zonal Velocity Ratio 0.0
- Acceleration Related Seismic Zone 0
- Zonal Acceleration Ratio 0.0
- Peak Horizontal Acceleration 0.011g

The soil profile type at this site has been classified as Type III based on firm to very stiff silty clay thickness between 13.2 m and 17.7 m. Therefore, according to Table 4.4, Clause 4.4.6.1 of the CHBDC, a Site Coefficient “S” (ground motion amplification factor) of 1.5 should be used in seismic design.

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. The coefficients of horizontal earth pressure for seismic loading presented in Table 11.1 may be used:

Table 11.1 – Earth Pressure Coefficients for Earthquake Loading

Condition	Seismic Earth Pressure Coefficient (K)		
	OPSS Granular A or Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$	OPSS Granular B Type I, Granular B Type III, or Existing Granular Fill $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	Native Sand to Sand and Silt $\phi = 30^\circ, \gamma = 20 \text{ kN/m}^3$
Active (K_{AE})*	0.28	0.32	0.34
At Rest (K_{OE})**	0.45	0.50	0.53
Passive (K_{PE})	3.7	3.2	3.0

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

** After Woods

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

12 EROSION PROTECTION

The embankment fill and native sand to silt and sand at this site are susceptible to erosion. The potential for erosion along the channel must be assessed and erosion protection measures such as rock protection provided to prevent erosion in front of the proposed H-piles and sheet piles.

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

13 EXCAVATION AND GROUNDWATER CONTROL

All excavation must be carried out in accordance with OPSS 902 and the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the existing fill within the probable depth of excavation at this site may be classed as a Type 3 soil. The cohesionless fill and native soils below the water table are classed as Type 4 soils.

Roadway protection should be provided in accordance with OPSS 539 and designed for Performance Level 2.

Based on the preliminary General Arrangement drawing, work at the abutments is not expected to require excavation below the lake level. Any excavation below the groundwater level/lake level without prior dewatering is not recommended since the inflow of water will make it difficult to maintain a dry, sound base on which to work.

The design of any dewatering system and any road protection that may be required is the responsibility of the Contractor. All shoring systems should be designed by a Professional Engineer experienced in such designs.

14 CONSTRUCTION CONCERNS

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

- Alignment of the new H-piles and sheet piles should be carefully selected to avoid the existing timber pile foundations.
- The embankment fill contains cobbles, boulders and possibly rock fill which may affect installation of H-piles and sheet piles. The Contractor must be prepared to remove, drill through and/or penetrate these obstructions.
- Driven H-piles may achieve the design resistance or refusal at different elevations within the deposit of sand and gravel with cobbles and boulders.
- Temporary construction works must not impact on the stability of the existing embankment slopes. The capability of the existing embankment to support heavy construction equipment and placement of additional fill (i.e, as a pad for support of piling rigs) must be assessed by the Contractor, and this assessment may impact the type of equipment suitable for the project.

- Pile driving may potentially impact the existing timber pile foundations. Monitoring of the existing foundations and bridge structure during installation of the new foundation is recommended. Measures such as shimming of the bridge and driving with reduced hammer energy to minimize the impact may be required.

15 CLOSURE

Engineering analysis and preparation of the report were carried out by Ms. Mei T. Cheong, P.Eng.

The report was reviewed by Mr. Murray R. Anderson and Dr. P.K. Chatterji, P.Eng. a Designated Principal Contact for MTO Foundations Projects.

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Review Principal



Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction

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



4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

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

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


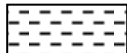



 Water Level
 Shear Strength Determination by Pocket Penetrometer

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

UNIFIED SOILS CLASSIFICATION

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

EXPLANATION OF ROCK LOGGING TERMS

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

<u>DISCONTINUITY SPACING</u>		<u>STRENGTH CLASSIFICATION</u>			
Bedding	Bedding Plane Spacing	Rock Strength	Approximate Uniaxial Compressive Strength		Field Estimation of Hardness*
			(MPa)	(psi)	
Very thickly bedded	Greater than 2m	Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Thickly bedded	0.6 to 2m				
Medium bedded	0.2 to 0.6m	Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Thinly bedded	60mm to 0.2m	Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Very thinly bedded	20 to 60mm				
Laminated	6 to 20mm	Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Thinly Laminated	Less than 6mm				

<u>TERMS</u>					
Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.	Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.	Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a percentage of total core run length.	Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen				
Fracture Index: (FI)	Frequency of natural fractures per 0.3m of core run.				

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No OFF-01

2 OF 2

METRIC

W.P. 6092-10-00 LOCATION N 1 004 0.9 E 9 994.7 Off Lake Bridge ORIGINATED BY ES
 HWY 615 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Top of Pavement DATE 2011.08.23 - 2011.08.23 CHECKED BY RPR

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									
88.6	Continued From Previous Page Silty SAND to SILT and SAND , trace to some clay Loose Grey Wet		9	SS	5		89										0 43 43 14
11.3	END OF BOREHOLE AT 11.3m. WATER LEVEL AT 2.7m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 3.0m, AUGER CUTTINGS TO 0.1m THEN ASPHALT COLD PATCH TO SURFACE.																

RECORD OF BOREHOLE No OFF-02

1 OF 4

METRIC

W.P. 6092-10-00 LOCATION N 1 003 3.5 E 9 996.0 Off Lake Bridge ORIGINATED BY ES
 HWY 615 BOREHOLE TYPE Hollow Stem Augers/Casing/NQ Coring COMPILED BY AN
 DATUM Top of Pavement DATE 2011.08.24 - 2011.08.26 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
99.9								20 40 60 80 100					
0.0	ASPHALT:(50mm)		1	GS				○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					
	SAND and GRAVEL, some silt, occasional cobbles Compact Brown Damp to Moist (FILL)		1	SS	28		99						
			2	SS	19		98						
97.6													
2.3	PEAT, silty, with decayed wood fragments Loose to Very Loose Dark Brown Wet		3	SS	5		97					136	
			4	SS	3		96					158	
96.4												150	
3.5	MARL, silty, trace sand, shell fragments Grey						96						
95.8													
4.1	SAND, some silt, trace clay, trace gravel Compact Grey Moist		5	SS	24		95						1 77 19 3
			6	SS	29		94						
							93						
92.7													
7.2	Silty SAND to SILT and SAND, trace to some clay Very Loose to Compact Grey Wet		7	SS	3		92						0 40 48 12
			8	SS	9		91						
							90						0 49 38 13

Continued Next Page

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

RECORD OF BOREHOLE No OFF-02

2 OF 4

METRIC

W.P. 6092-10-00 LOCATION N 1 003 3.5 E 9 996.0 Off Lake Bridge ORIGINATED BY ES
 HWY 615 BOREHOLE TYPE Hollow Stem Augers/Casing/NQ Coring COMPILED BY AN
 DATUM Top of Pavement DATE 2011.08.24 - 2011.08.26 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE							PLASTIC LIMIT W _P NATURAL MOISTURE CONTENT W LIQUID LIMIT W _L WATER CONTENT (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
	Continued From Previous Page							20	40	60	80	100																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						

Continued Next Page

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

METRIC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	W P W W L			
	Continued From Previous Page		15	SS	19								0 3 25 72
	Occasional sand seams		16	SS	11								
73.8 26.1	SILT, some clay Compact Grey		17	SS	12								0 0 87 13
71.2 28.7	SAND and GRAVEL, with cobbles and boulders Very Dense Grey Wet		18	SS	52								

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No OFF-02

4 OF 4

METRIC

W.P. 6092-10-00 LOCATION N 1 003 3.5 E 9 996.0 Off Lake Bridge ORIGINATED BY ES
 HWY 615 BOREHOLE TYPE Hollow Stem Augers/Casing/NQ Coring COMPILED BY AN
 DATUM Top of Pavement DATE 2011.08.24 - 2011.08.26 CHECKED BY RPR

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 (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)
	Continued From Previous Page							20	40	60	80	100					GR SA SI CL	
	SAND and GRAVEL with cobbles and boulders		1	RUN													RUN #1 TCR=46% SCR=30%	
	Boulder (355mm) at 30.5m		2	RUN														RUN #2 TCR=79% SCR=14%
			3	RUN														RUN #3 TCR=65% SCR=27%
	Cobbles (100mm and 165mm) at 32.5m		4	RUN														RUN #4 TCR=59% SCR=48%
	Boulder (680mm) at 34.0m		5	RUN														RUN #5 TCR=52% SCR=23%
			6	RUN														RUN #6 TCR=23% SCR=0%
62.5																		
37.4	END OF BOREHOLE AT 37.4m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 3.05m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) Oct.02/11 4.1 95.8 Oct.04/11 3.9 96.0 Oct.13/11 3.9 96.0 Oct.20/11 3.8 96.1 Oct.27/12 1.4 98.5																	

ONTMT4S 0840.GPJ 2012TEMPLATE(MTO).GDT 10/21/13

RECORD OF BOREHOLE No OFF-03

1 OF 4

METRIC

W.P. 6092-10-00 LOCATION N 1 003 3.1 E 9 992.0 Off Lake Bridge ORIGINATED BY SLL/JM
 HWY 615 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Top of Pavement DATE 2011.10.02 - 2011.10.14 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	*"N" VALUES			SHEAR STRENGTH kPa								
99.9								20 40 60 80 100						GR SA SI CL		
99.0	ASPHALT:(40mm) SAND, some gravel, occasional cobbles Compact Brown Moist (FILL)		1	SS	22											
			2	SS	24											
97.0																
2.9	PEAT, silty, decayed wood fragments Black Wet															
96.5																
3.4	SAND, some silt, trace clay Compact Grey Wet		3	SS	24											
94.6																
5.3	Silty SAND to SILT and SAND, trace to some clay Loose to Compact Grey Wet		4	SS	10											
				5	SS	8										
			6	SS	12											
90.5																
9.4	Silty CLAY, trace to some sand Firm to Stiff Grey															

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No OFF-03

2 OF 4

METRIC

W.P. 6092-10-00 LOCATION N 1 003 3.1 E 9 992.0 Off Lake Bridge ORIGINATED BY SLL/JM
 HWY 615 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Top of Pavement DATE 2011.10.02 - 2011.10.14 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)							
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa													
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE													
	Continued From Previous Page		7	SS	6		89											0	13	65	22
			8	SS	12		88														
			9	SS	8		87														
			10	SS	6		86														
			11	SS	6		85														
			12	SS	12		84														
			13	SS	18		83														
							82														
							81														
							80														

Continued Next Page

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

RECORD OF BOREHOLE No OFF-03

3 OF 4

METRIC

W.P. 6092-10-00 LOCATION N 1 003 3.1 E 9 992.0 Off Lake Bridge ORIGINATED BY SLL/JM
 HWY 615 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Top of Pavement DATE 2011.10.02 - 2011.10.14 CHECKED BY RPR

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													
75.8	Silty CLAY , occasional silty sand seams Very Stiff Grey		14	SS	16									0 12 47 41
24.1	SILT , some clay, trace to some sand, trace gravel Compact Grey		15	SS	15									2 9 73 16
72.8	SAND and GRAVEL , with cobbles and boulders, some silt Very Dense Grey		16	SS	100/ 0.050									
27.1	Boulder (600mm) at 27.7m													
	Boulders (230mm and 200mm) at 29.0m		17	SS	100/									

Continued Next Page

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

RECORD OF BOREHOLE No OFF-03

4 OF 4

METRIC

W.P. 6092-10-00 LOCATION N 1 003 3.1 E 9 992.0 Off Lake Bridge ORIGINATED BY SLL/JM
 HWY 615 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Top of Pavement DATE 2011.10.02 - 2011.10.14 CHECKED BY RPR

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										WATER CONTENT (%)																										
	Continued From Previous Page				0.150			20	40	60	80	100		20	40	60																												
	SAND and GRAVEL, with cobbles and boulders, some silt Grey Wet Compact																																											
			18	SS	26																																							
			19	SS	28																																							
	20	SS	100/ 0.225																																									
	21	SS	100/ 0.075																																									

ONTMT4S 0840.GPJ 2012TEMPLATE(MTO).GDT 10/21/13

RECORD OF BOREHOLE No OFF-04

1 OF 4

METRIC

W.P. 6092-10-00 LOCATION N 1 000 2.5 E 9 997.4 Off Lake Bridge ORIGINATED BY SLL
 HWY 615 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Top of Pavement DATE 2011.10.01 - 2011.10.01 CHECKED BY RPR

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						
99.9								20 40 60 80 100						
99.9	ASPHALT:(40mm)							20 40 60 80 100						
	SAND and GRAVEL, some silt Compact to Very Dense Brown Moist (FILL)		1	SS	30/ 0.125		99							
			2	SS	24		98							
	With cobbles/rock fragments		3	SS	50/ 0.150									
							97							
96.7														
3.2	PEAT, silty, decayed wood pieces Loose Black		4	SS	6							217		
96.2	Wet													
3.7	SAND, some silt, trace gravel Compact to Very Loose Grey Wet						96							
			5	SS	11		95							
			6	SS	9		94							
							93							
			7	SS	3									
							92							
91.7														
8.2	Sandy SILT, some clay Loose Grey Wet		8	SS	5		91							
							90							

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No OFF-04

2 OF 4

METRIC

W.P. 6092-10-00 LOCATION N 1 000 2.5 E 9 997.4 Off Lake Bridge ORIGINATED BY SLL
 HWY 615 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Top of Pavement DATE 2011.10.01 - 2011.10.01 CHECKED BY RPR

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								
	Continued From Previous Page		9	SS	5													0	23	58	19		
			10	SS	7																		
	Some clay layers		11	SS	4																		
85.7																							
14.2	Silty CLAY , trace sand, occasional silty seams Firm to Stiff Grey		12	SS	4																		
			13	SS	8															0	1	60	39
			14	SS	10																		
			15	SS	11																		
					</																		

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No OFF-04

3 OF 4

METRIC

W.P. 6092-10-00 LOCATION N 1 000 2.5 E 9 997.4 Off Lake Bridge ORIGINATED BY SLL
 HWY 615 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Top of Pavement DATE 2011.10.01 - 2011.10.01 CHECKED BY RPR

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													
75.2	Silty CLAY , trace sand, occasional silty seams Stiff Grey		16	SS	13									
24.7	Clayey SILT , some sand to sandy, trace gravel, occasional cobbles and boulders Hard Grey (TILL)		17	SS	100/ 0.075									
72.5														
27.4	SAND and GRAVEL , some silt to silty, with cobbles and boulders Very Dense Grey Wet Boulder (530mm) at 27.6m		18	SS	64									
70.1														
29.8	END OF BOREHOLE AT 29.8m													

Continued Next Page

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

RECORD OF BOREHOLE No OFF-04

4 OF 4

METRIC

W.P. 6092-10-00 LOCATION N 1 000 2.5 E 9 997.4 Off Lake Bridge ORIGINATED BY SLL
 HWY 615 BOREHOLE TYPE NW Casing COMPILED BY AN
 DATUM Top of Pavement DATE 2011.10.01 - 2011.10.01 CHECKED BY RPR

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																
	UPON REFUSAL ON PROBABLE BOULDERS. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 2.9m, AUGER CUTTINGS TO 0.3m, THEN ASPHALT COLD PATCH TO SURFACE.																

RECORD OF BOREHOLE No OFF-05

1 OF 4

METRIC

W.P. 6092-10-00 LOCATION N 9 996.5 E 9 998.1 Off Lake Bridge ORIGINATED BY GA
 HWY 615 BOREHOLE TYPE Casing/NQ Coring COMPILED BY AN
 DATUM Top of Pavement DATE 2011.09.19 - 2011.09.21 CHECKED BY RPR

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			20 40 60 80 100	20 40 60 80 100					
99.9														
99.8	ASPHALT:(40mm)		1	SS	17									
	SAND, trace gravel, trace silt Compact Brown to Grey Wet (FILL)		2	SS	18									
			3	SS	28									
	Boulder (300mm) at 2.3m		4	SS	50/ 0.0									
96.5			5	SS	17									
3.4	SAND, trace to some gravel Compact Grey Wet		6	SS	10									
			7	SS	15									
	Coarse grained		8	SS	7									
92.4			9	SS	4									
7.5	SILT and SAND, some clay, trace gravel Loose to Very Loose Grey Wet													

Continued Next Page

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

RECORD OF BOREHOLE No OFF-05

2 OF 4

METRIC

W.P. 6092-10-00 LOCATION N 9 996.5 E 9 998.1 Off Lake Bridge ORIGINATED BY GA
 HWY 615 BOREHOLE TYPE Casing/NQ Coring COMPILED BY AN
 DATUM Top of Pavement DATE 2011.09.19 - 2011.09.21 CHECKED BY RPR

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													
	SILT and SAND , some clay Very Loose to Loose Grey Wet		10	SS	3		89							
							88							
			11	SS	8									
							87							
86.2														
13.7	Silty CLAY , some sand, occasional silt seams Soft to Firm Grey		12	SS	7		86							
							85							
			13	SS	3									
							84							
	Varved		14	SS	4		83							
							82							
			15	SS	7		81							
							80							

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No OFF-05

3 OF 4

METRIC

W.P. 6092-10-00 LOCATION N 9 996.5 E 9 998.1 Off Lake Bridge ORIGINATED BY GA
 HWY 615 BOREHOLE TYPE Casing/NQ Coring COMPILED BY AN
 DATUM Top of Pavement DATE 2011.09.19 - 2011.09.21 CHECKED BY RPR

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													
	Silty CLAY , occasional silt seams Stiff Grey		16	SS	8									
							79							
							78							
	With sand seams		17	SS	11									
							77							
							76							
75.2														
24.7	Clayey SILT , some sand to sandy, trace gravel Hard Grey (TILL)						75							
							74							
			18	SS	38									
							73							
72.2														
27.7	SAND and GRAVEL , with cobbles and boulders, some silt Grey						72							
			1	RUN										
							71							
			2	RUN			70							

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No OFF-05

4 OF 4

METRIC

W.P. 6092-10-00 LOCATION N 9 996.5 E 9 998.1 Off Lake Bridge ORIGINATED BY GA
 HWY 615 BOREHOLE TYPE Casing/NQ Coring COMPILED BY AN
 DATUM Top of Pavement DATE 2011.09.19 - 2011.09.21 CHECKED BY RPR

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		
	Continued From Previous Page							20	40	60	80	100									
68.6	SAND and GRAVEL , with cobbles and boulders, some silt Grey		19	SS	100/0.150																
31.3	BEDROCK metavolcanic, grey		1	RUN																	
	Rubble zone (75mm) at 32.1m	2	RUN																		
	Rubble zone (25mm) at 32.8m Highly fractured	3	RUN																		
65.8		4	RUN																		
34.1	END OF BOREHOLE AT 34.1m. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) Oct.02/11 0.9 99.0 Oct.04/11 0.9 99.0 Oct.13/11 0.9 99.0 Oct.20/11 0.9 99.0 Oct.27/12 1.4 98.5																				

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

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No OFF-06

2 OF 2

METRIC

W.P. 6092-10-00 LOCATION N 9 989.2 E 9 999.7 Off Lake Bridge ORIGINATED BY ES
HWY 615 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
DATUM Top of Pavement DATE 2011.08.23 - 2011.08.23 CHECKED BY RPR

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									
9.9	Silty CLAY , some sand Firm Grey																
88.6			10	SS	5		89										0 10 65 25
11.3	END OF BOREHOLE AT 11.3m. WATER LEVEL AT 3.3m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 3.0m, AUGER CUTTINGS TO 0.05m THEN ASPHALT COLD PATCH TO SURFACE.																

Appendix B

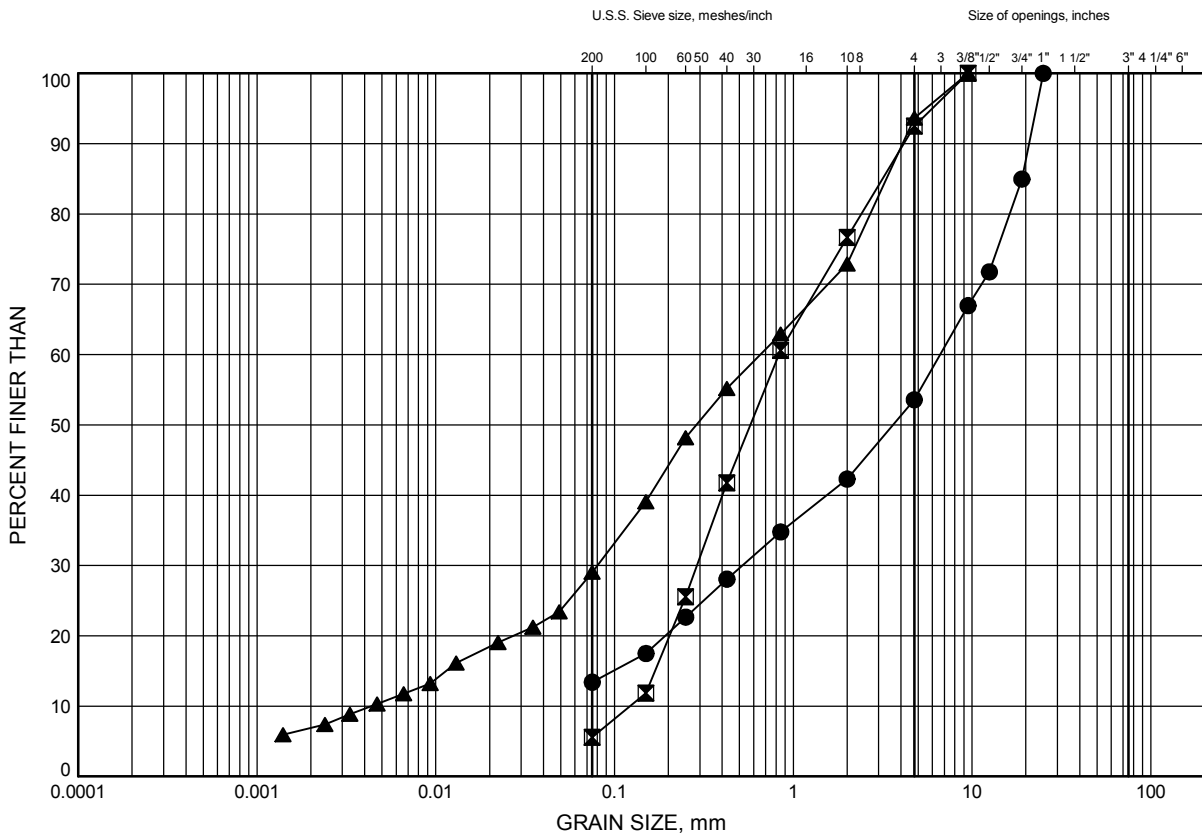
Laboratory Test Results

NWR HWY 11 Bridge

GRAIN SIZE DISTRIBUTION

FIGURE B1

SAND TO SAND & GRAVEL FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	OFF-01	1.83	98.07
⊠	OFF-05	1.07	98.83
▲	OFF-06	1.07	98.83

Date ..October 2013.....
W.P. ..6092-10-00.....

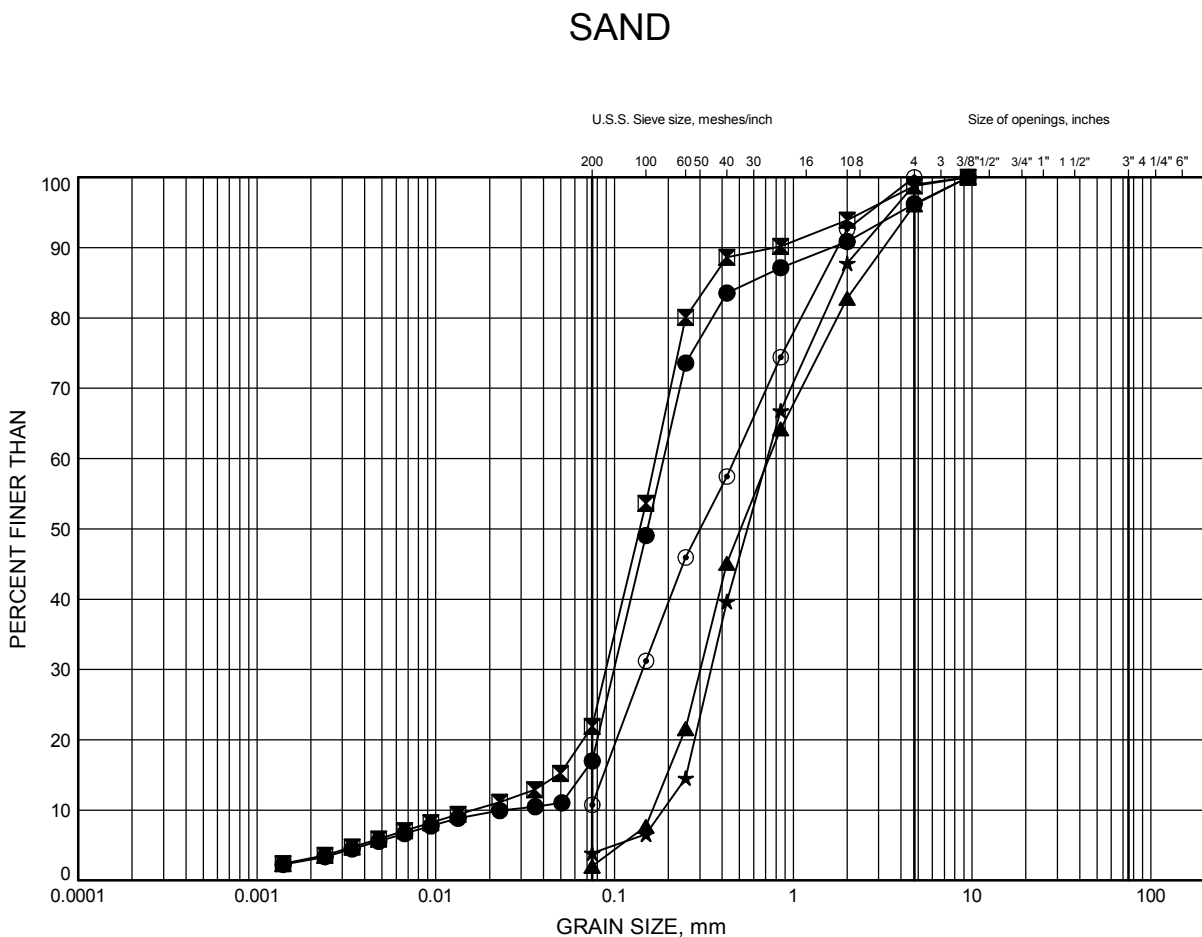


Prep'dMFA.....
Chkd.MC.....

NWR HWY 11 Bridge

GRAIN SIZE DISTRIBUTION

FIGURE B2



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	OFF-01	4.88	95.02
⊠	OFF-02	4.88	95.02
▲	OFF-06	4.88	95.02
★	OFF-06	6.40	93.50
⊙	OFF-06	9.45	90.45

Date ..October 2013.....
W.P. ..6092-10-00.....



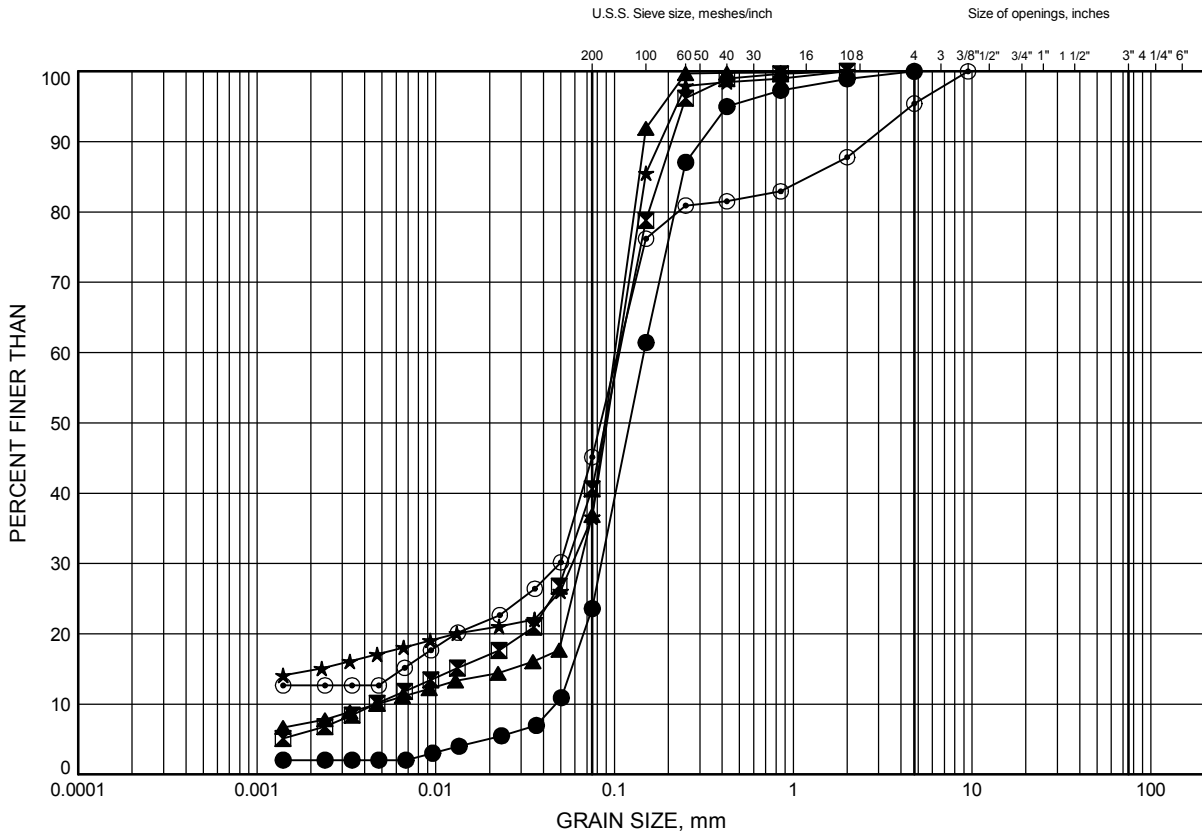
Prep'dMFA.....
Chkd.MC.....

NWR HWY 11 Bridge

GRAIN SIZE DISTRIBUTION

FIGURE B3

SILTY SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	OFF-01	6.40	93.50
⊠	OFF-01	9.45	90.45
▲	OFF-02	12.50	87.40
★	OFF-03	5.64	94.26
⊙	OFF-05	7.92	91.98

Date ..October 2013.....
W.P. ..6092-10-00.....



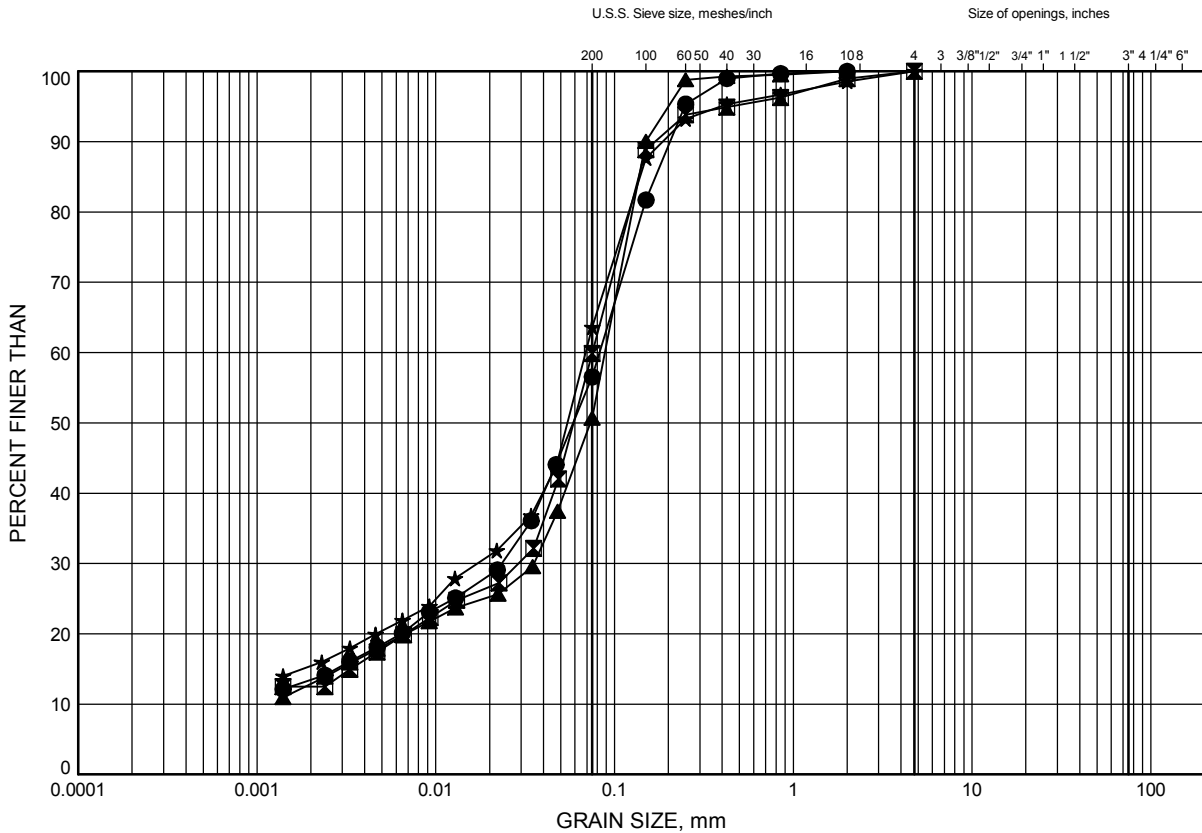
Prep'dMFA.....
Chkd.MC.....

NWR HWY 11 Bridge

GRAIN SIZE DISTRIBUTION

FIGURE B4

SILT & SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	OFF-01	10.97	88.93
⊠	OFF-02	7.92	91.98
▲	OFF-02	9.45	90.45
★	OFF-06	7.92	91.98

Date ..October 2013.....
W.P. ..6092-10-00.....



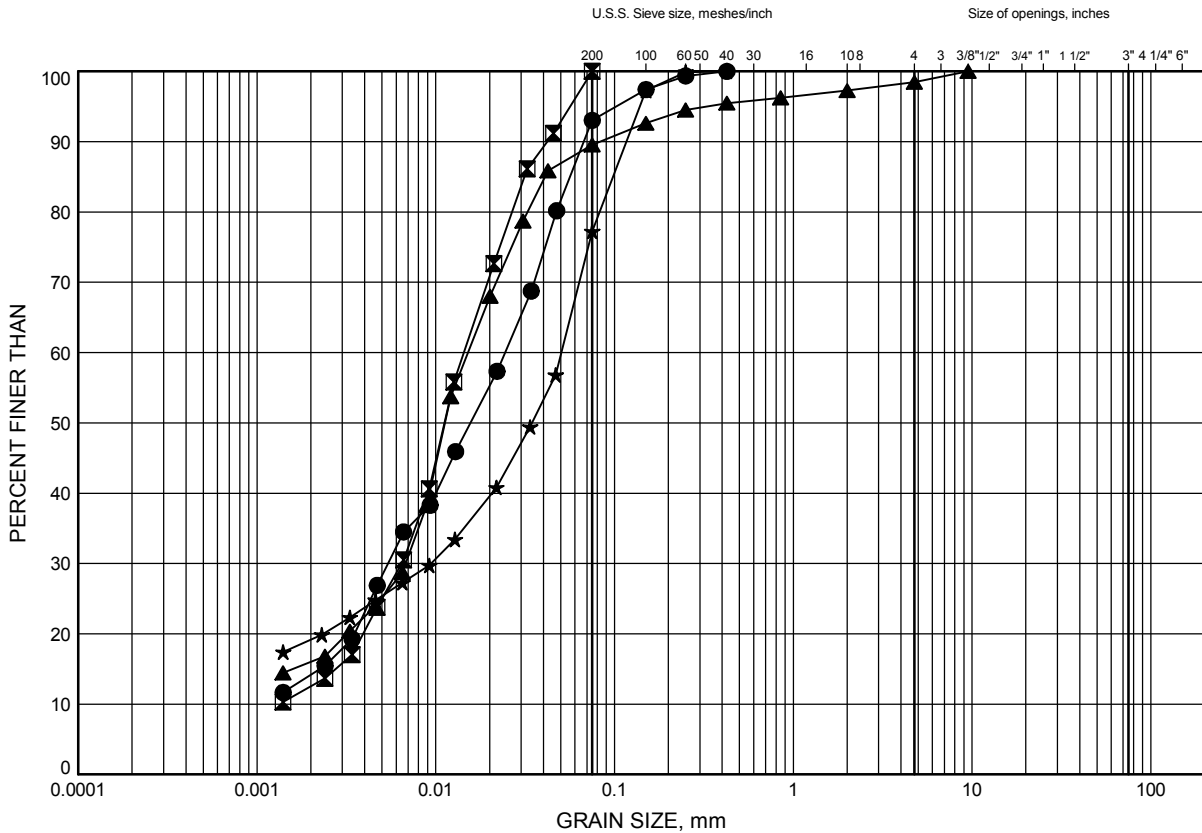
Prep'dMFA.....
Chkd.MC.....

NWR HWY 11 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)
●	OFF-02	14.02	85.88
⊠	OFF-02	26.21	73.69
▲	OFF-03	25.45	74.45
★	OFF-04	10.21	89.69

Date ..October 2013.....
W.P. ..6092-10-00.....

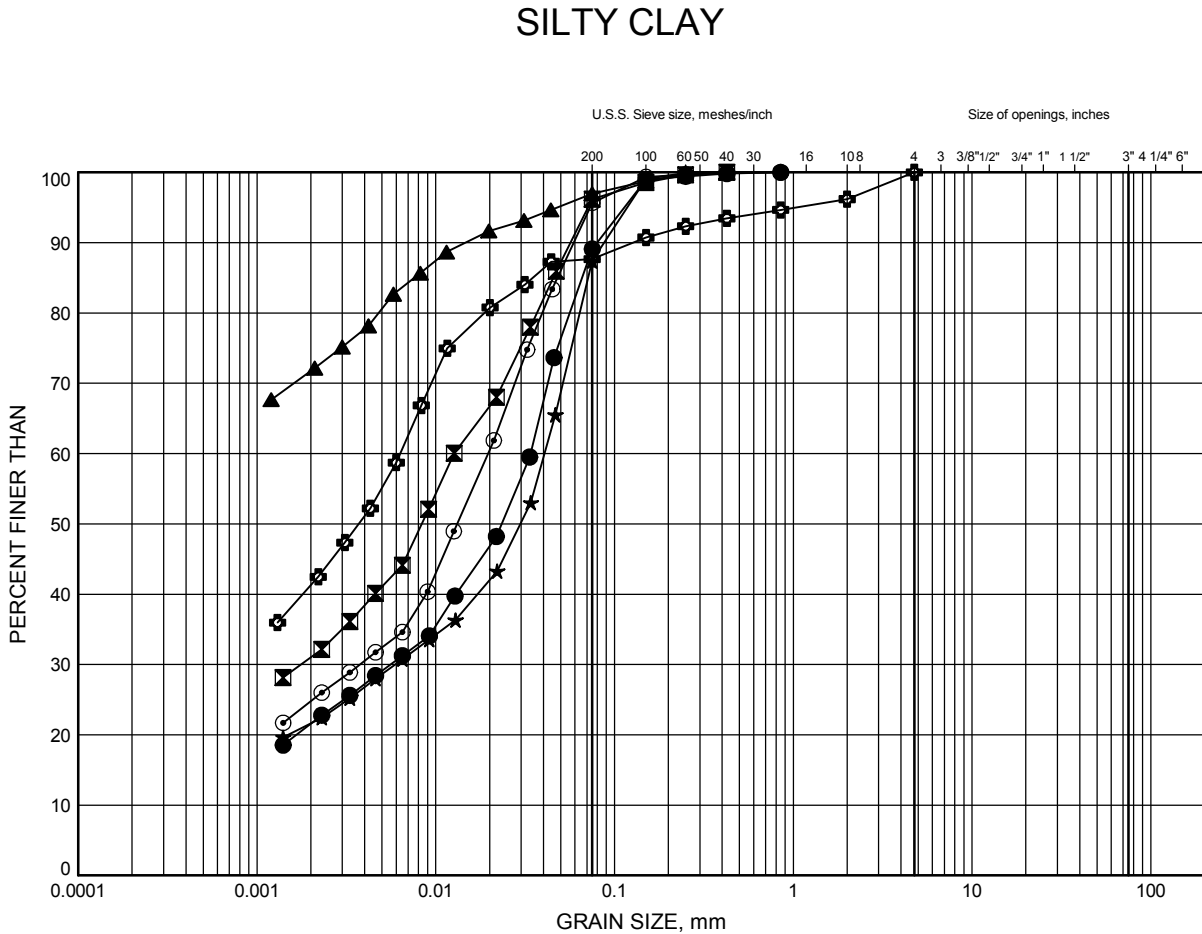


Prep'dMFA.....
Chkd.MC.....

NWR HWY 11 Bridge

GRAIN SIZE DISTRIBUTION

FIGURE B6



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	OFF-02	15.54	84.36
⊠	OFF-02	18.59	81.31
▲	OFF-02	20.12	79.78
★	OFF-03	10.21	89.69
⊙	OFF-03	14.78	85.12
⊕	OFF-03	22.40	77.50

Date ..October 2013.....
W.P. ..6092-10-00.....



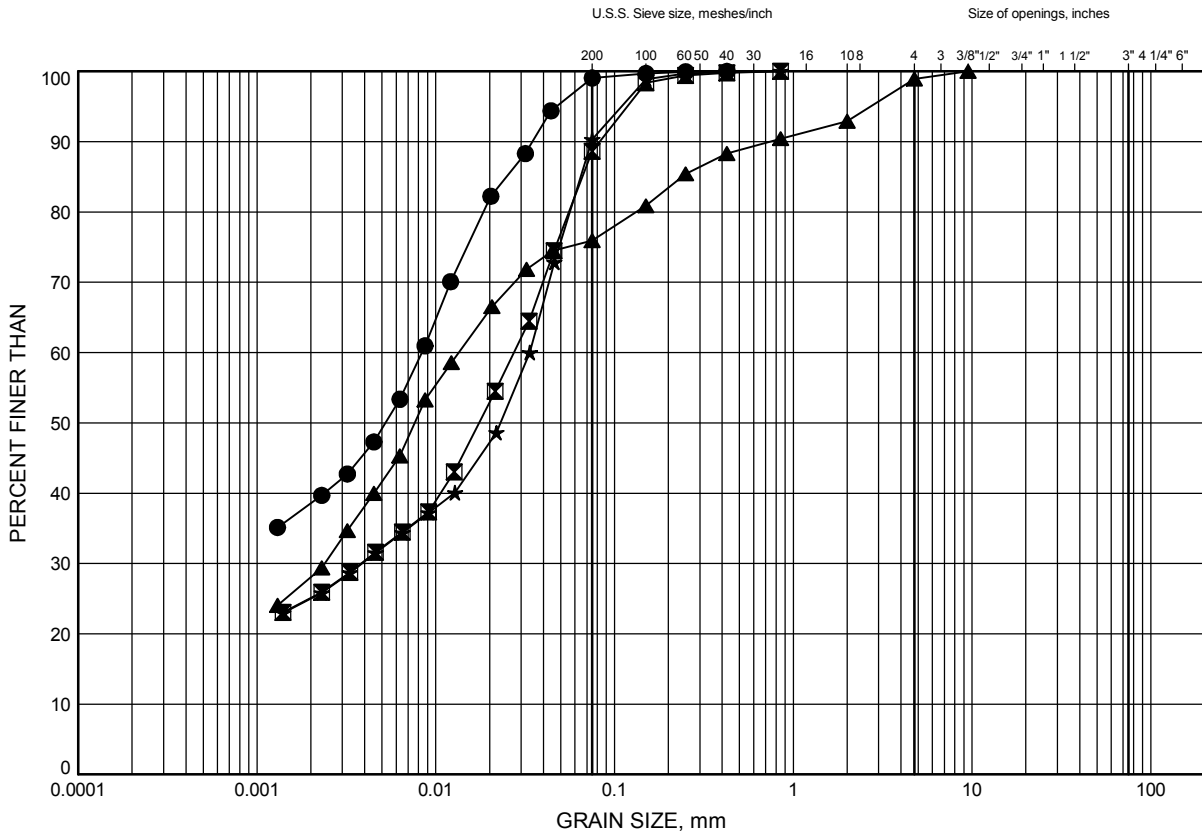
Prep'dMFA.....
Chkd.MC.....

NWR HWY 11 Bridge

GRAIN SIZE DISTRIBUTION

FIGURE B7

SILTY CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	OFF-04	16.31	83.59
⊠	OFF-05	15.54	84.36
▲	OFF-05	23.16	76.74
★	OFF-06	10.97	88.93

Date ..October 2013.....
W.P. ..6092-10-00.....

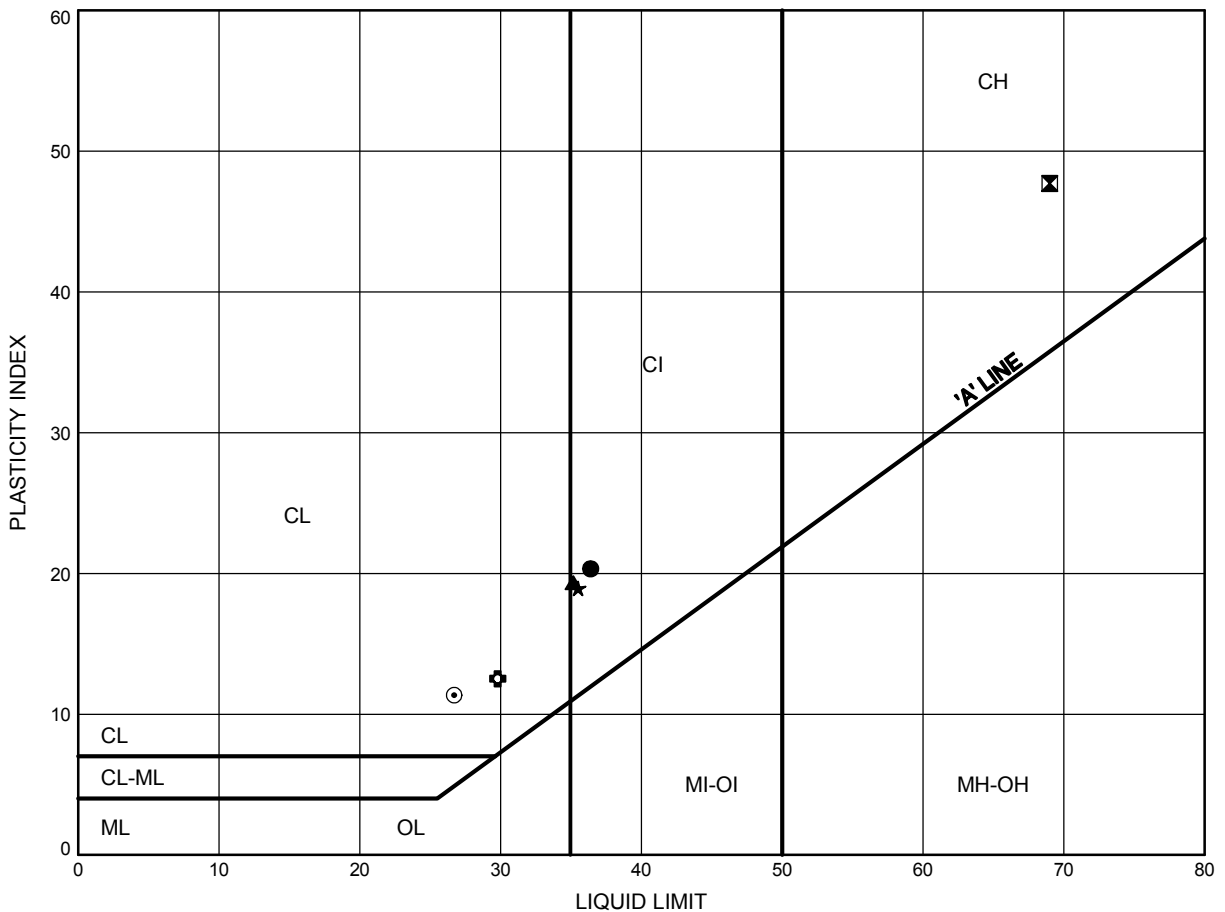


Prep'dMFA.....
Chkd.MC.....

NWR HWY 11 Bridge
ATTERBERG LIMITS TEST RESULTS

FIGURE B8

SILTY CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	OFF-02	18.59	81.31
⊠	OFF-02	20.12	79.78
▲	OFF-03	22.40	77.50
★	OFF-04	16.31	83.59
⊙	OFF-05	15.54	84.36
⊕	OFF-05	23.16	76.74

Date October 2013
W.P. 6092-10-00



Prep'd MFA
Chkd. MC

Appendix C

Site Photographs



Photograph 1 – East side of Off Lake Bridge, looking south



Photograph 2 – West side of Off Lake Bridge, looking north



Photograph 3 – Off Lake Bridge, looking north



Photograph 4 – Off Lake Bridge, looking south

Appendix D

Foundation Comparison

COMPARISON OF FOUNDATION ALTERNATIVES

Footings on Native Soil	Augered Caissons (Drilled Shaft)	Driven Steel H-Piles
<p>Advantages:</p> <ul style="list-style-type: none"> i. Generally less costly construction than deep foundation elements. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. High geotechnical resistance available for caissons socketed into bedrock. ii. Construction of caissons could continue in freezing weather. iii. Excavation and dewatering requirements are reduced. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. High geotechnical resistance available for H-piles driven into very dense sand and gravel or on bedrock. ii. Installation of piles could continue in freezing weather. iii. Excavation and dewatering requirements are minimized. iv. Pile base inspection not required. v. No special installation methods required compared to caissons.
<p>Disadvantages:</p> <ul style="list-style-type: none"> i. Low geotechnical resistance available in the native soils. ii. Suitable bearing strata or bedrock are not present within a reasonable excavation depth. iii. Temporary shoring and dewatering would be required for construction of footings on native soils. iv. Temporary excavation for footing construction may have environmental impact on the creek. v. Scour protection will be required for footings. 	<p>Disadvantages:</p> <ul style="list-style-type: none"> i. Higher unit costs than footings. ii. Caissons must be extended into sand/gravel with cobbles and boulders or socketed into very strong bedrock. iii. Penetration of cobbles and boulders may be difficult. iv. Measures will be required to provide sidewall support during drilling through cohesionless materials below groundwater. v. Base instability in sand and gravel, or difficulty in obtaining a seal in bedrock socket. Tremie concrete may be required. vi. Difficulty in cleaning and inspection of socket base. 	<p>Disadvantages:</p> <ul style="list-style-type: none"> i. Higher unit cost than footings. ii. H-piles may encounter refusal at varying depths on cobbles and boulders in the sand and gravel. iii. Potential for pile deflection or tip damage on cobbles and boulders.
NOT RECOMMENDED	NOT RECOMMENDED	RECOMMENDED

Appendix E

List of SPs and OPSS, and Suggested Text for NSSP

1. List of Special Provisions and OPSS Documents Referenced in this Report

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

2. Suggested text for NSSP on “Construction of Driven H-piles”

Installation of H-piles shall be in accordance with OPSS 903 and the following.

Cobbles, boulders and possibly rock fill are present within the existing embankment fill on site. The cobbles, boulders and rock fill may interfere with pile installation. The Contractor must be prepared to remove, dislodge or otherwise penetrate these obstructions to advance the piles while meeting the specified deflection tolerances.

The pile bearing stratum generally consists of sand and gravel with cobbles and boulders. The Contractor is alerted to the possibility that piles may achieve the design resistance or encounter refusal on cobbles and boulders at varying elevations within the sand and gravel.

The H-piles must be provided with pile tip protectors to minimize tip damage when driving through the embankment fill and into the sand and gravel deposit.

If the piles meet refusal at a depth less than the anticipated depth, the QVE must terminate driving before the pile is damaged due to over-driving. The QVE must immediately bring it to the attention of the CA. If the CA cannot resolve the issue, it must be referred to the design team for resolution.

3. Suggested text for a NSSP on “Settlement Monitoring of Existing Bridge”

The possibility exists that driving of new H-pile foundations will disturb the existing timber pile foundations supporting the existing bridge. Monitoring of the existing bridge abutments and piers is therefore required during construction of the new bridge foundations.

As a minimum, a reference point must be established over each abutment and pier of the existing structure, and the vertical and lateral positions of these points must be surveyed

relative to known, fixed reference points on a regular basis during construction of the new foundations. The suggested monitoring frequency is:

- Three readings on separate days prior to construction to establish a baseline
- Twice daily while any foundation construction or other subsurface construction is in progress
- Daily for one week after completion of foundation construction

Readings should be taken at the same time each day.

The vertical and horizontal accuracy of readings should be 2 mm. All readings must be reported to the Contract Administrator within 24 hours and immediately if any movement exceeds limits set by the structural designers.

In addition, inspection of the existing structure should be conducted at least daily during foundation construction to identify any displacement or structural distress.

The Contractor must be prepared to jack and/or shim the existing bridge structure if settlement of the existing timber piles exceeds tolerable levels. Other measures to reduce the impact, such as driving with a reduced hammer energy, may need to be implemented.

Appendix F

Slope Stability Output

File Name: 01 Off Lake - North-perm v2.gsz

Directory: H:\19\5308\40 NWR 11 Bridge 3 Culvert Rehabs\Reports & Memos\Off Lake Bridge\Analysis\02 MTC\

Name: North Abutment -Raise

Description: Grade Raise 600mm

Method: Morgenstern-Price

Minimum Slip Surface Depth: 2 m

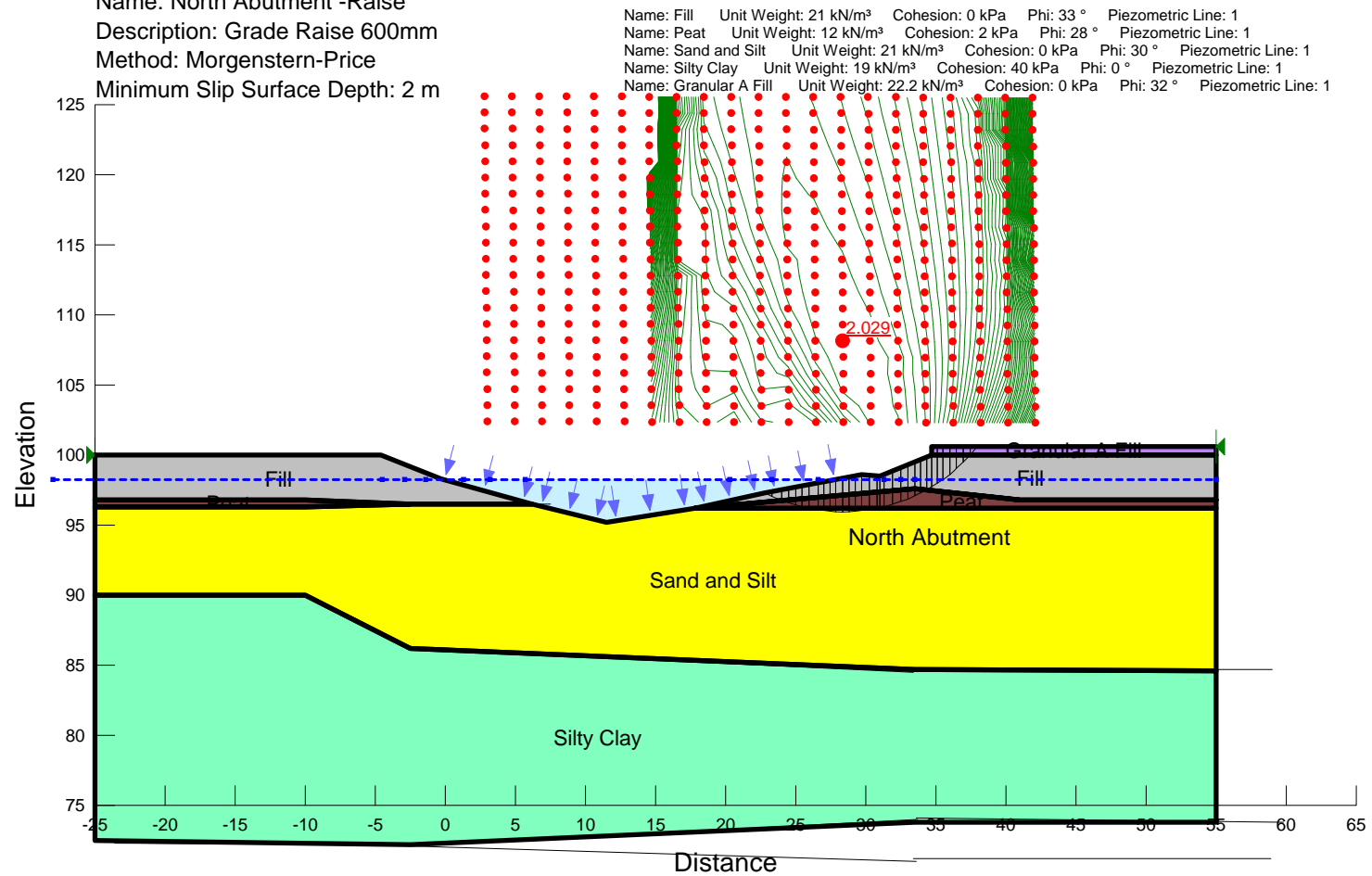


FIGURE F1

File Name: 03 Off Lake - South-perm v2.gsz

Directory: H:\19\5308\40 NWR 11 Bridge 3 Culvert Rehabs\Reports & Memos\Off Lake Bridge\Analysis\02 MTC\

Name: South Abutment -Raise

Description: Grade Raise 600mm

Method: Morgenstern-Price

Minimum Slip Surface Depth: 2 m

Name: Fill	Unit Weight: 21 kN/m ³	Cohesion: 0 kPa	Phi: 33 °	Piezometric Line: 1
Name: Peat	Unit Weight: 12 kN/m ³	Cohesion: 2 kPa	Phi: 28 °	Piezometric Line: 1
Name: Sand and Silt	Unit Weight: 21 kN/m ³	Cohesion: 0 kPa	Phi: 30 °	Piezometric Line: 1
Name: Silty Clay	Unit Weight: 19 kN/m ³	Cohesion: 40 kPa	Phi: 0 °	Piezometric Line: 1
Name: Granular A Fill	Unit Weight: 22.2 kN/m ³	Cohesion: 0 kPa	Phi: 32 °	Piezometric Line: 1

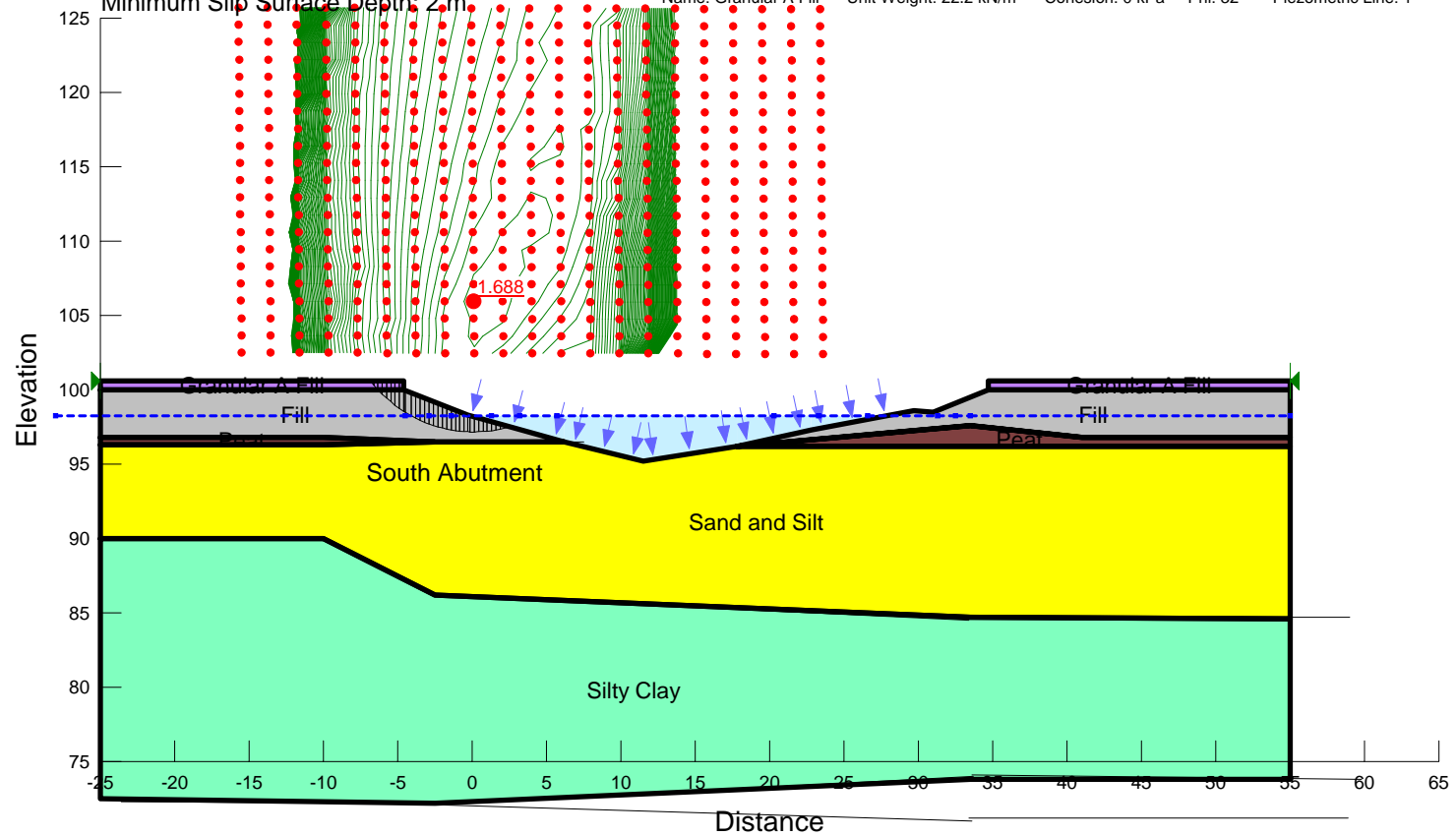


FIGURE F2

File Name: OffLake_002a.gsz

Directory: H:\19\5308\40 NWR 11 Bridge 3 Culvert Rehabs\Reports & Memos\Off Lake Bridge\Analysis\03 SP\

Name: Analysis 1

Description: South Abutment

Method: Morgenstern-Price

Minimum Slip Surface Depth: 1 m

Name: Fill	Unit Weight: 21 kN/m ³	Cohesion: 0 kPa	Phi: 33 °	Piezometric Line: 1
Name: Peat	Unit Weight: 12 kN/m ³	Cohesion: 2 kPa	Phi: 28 °	Piezometric Line: 1
Name: Sand and Silt	Unit Weight: 21 kN/m ³	Cohesion: 0 kPa	Phi: 30 °	Piezometric Line: 1
Name: Silty Clay	Unit Weight: 19 kN/m ³	Cohesion: 40 kPa	Phi: 0 °	Piezometric Line: 1

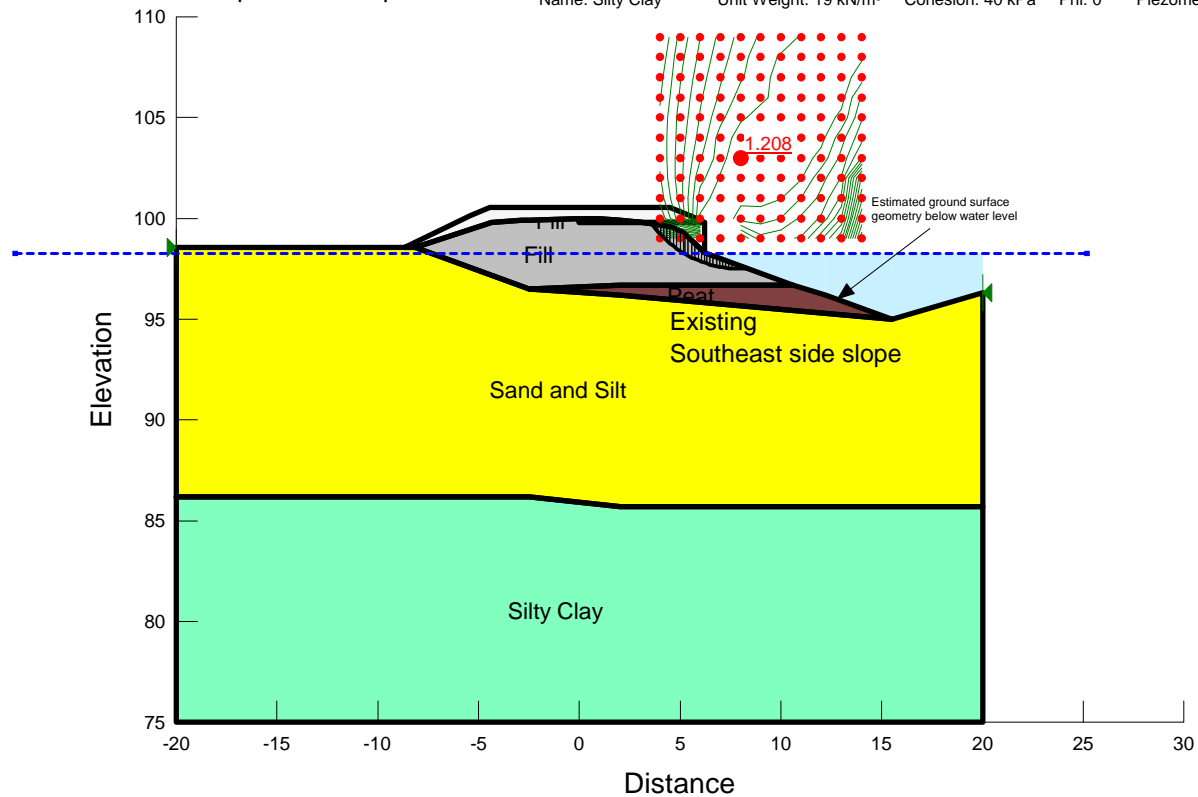


FIGURE F3

File Name: OffLake_002a.gsz

Directory: H:\19\5308\40 NWR 11 Bridge 3 Culvert Rehabs\Reports & Memos\Off Lake Bridge\Analysis\03 SP\

Name: Analysis 4

Description: South Abutment

Method: Morgenstern-Price

Minimum Slip Surface Depth: 1 m

Name: Fill	Unit Weight: 21 kN/m ³	Cohesion: 0 kPa	Phi: 33 °	Piezometric Line: 1
Name: Peat	Unit Weight: 12 kN/m ³	Cohesion: 2 kPa	Phi: 28 °	Piezometric Line: 1
Name: Sand and Silt	Unit Weight: 21 kN/m ³	Cohesion: 0 kPa	Phi: 30 °	Piezometric Line: 1
Name: Silty Clay	Unit Weight: 19 kN/m ³	Cohesion: 40 kPa	Phi: 0 °	Piezometric Line: 1
Name: Granular A Fill	Unit Weight: 22.2 kN/m ³	Cohesion: 0 kPa	Phi: 32 °	Piezometric Line: 1

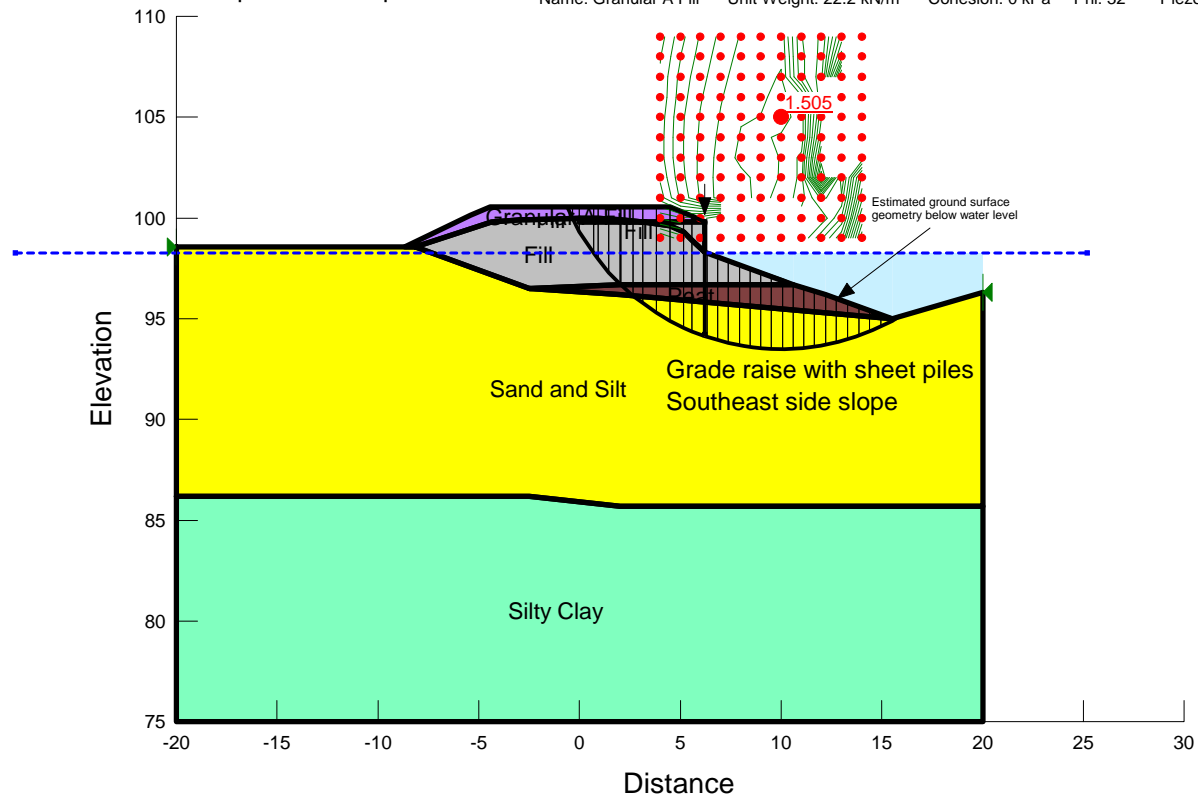


FIGURE F4

File Name: 05 Off Lake - NW-perm.gsz

Directory: H:\19\5308\40 NWR 11 Bridge 3 Culvert Rehabs\Reports & Memos\Off Lake Bridge\Analysis\02 MTC\

Name: North West-existing

Description: No sheet pile

Method: Morgenstern-Price

Minimum Slip Surface Depth: 1 m

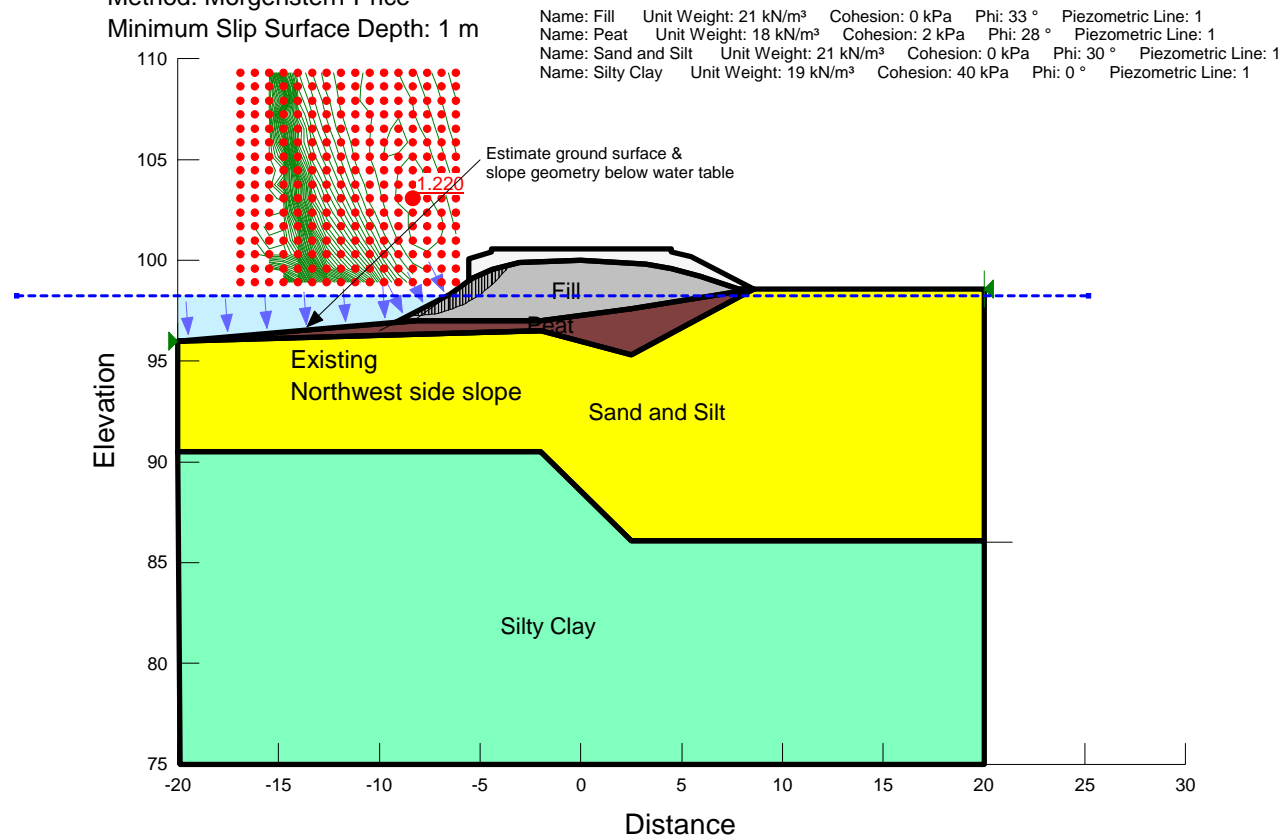


FIGURE F5

File Name: 05 Off Lake - NW-perm.gsz

Directory: H:\19\5308\40 NWR 11 Bridge 3 Culvert Rehabs\Reports & Memos\Off Lake Bridge\Analysis\02 MTC\

Name: North west - raised

Description: With sheet pile

Method: Morgenstern-Price

Minimum Slip Surface Depth: 4.5 m

Name: Fill	Unit Weight: 21 kN/m ³	Cohesion: 0 kPa	Phi: 33 °	Piezometric Line: 1
Name: Peat	Unit Weight: 18 kN/m ³	Cohesion: 2 kPa	Phi: 28 °	Piezometric Line: 1
Name: Sand and Silt	Unit Weight: 21 kN/m ³	Cohesion: 0 kPa	Phi: 30 °	Piezometric Line: 1
Name: Silty Clay	Unit Weight: 19 kN/m ³	Cohesion: 40 kPa	Phi: 0 °	Piezometric Line: 1
Name: Granular A Fill	Unit Weight: 22.2 kN/m ³	Cohesion: 0 kPa	Phi: 32 °	Piezometric Line: 1

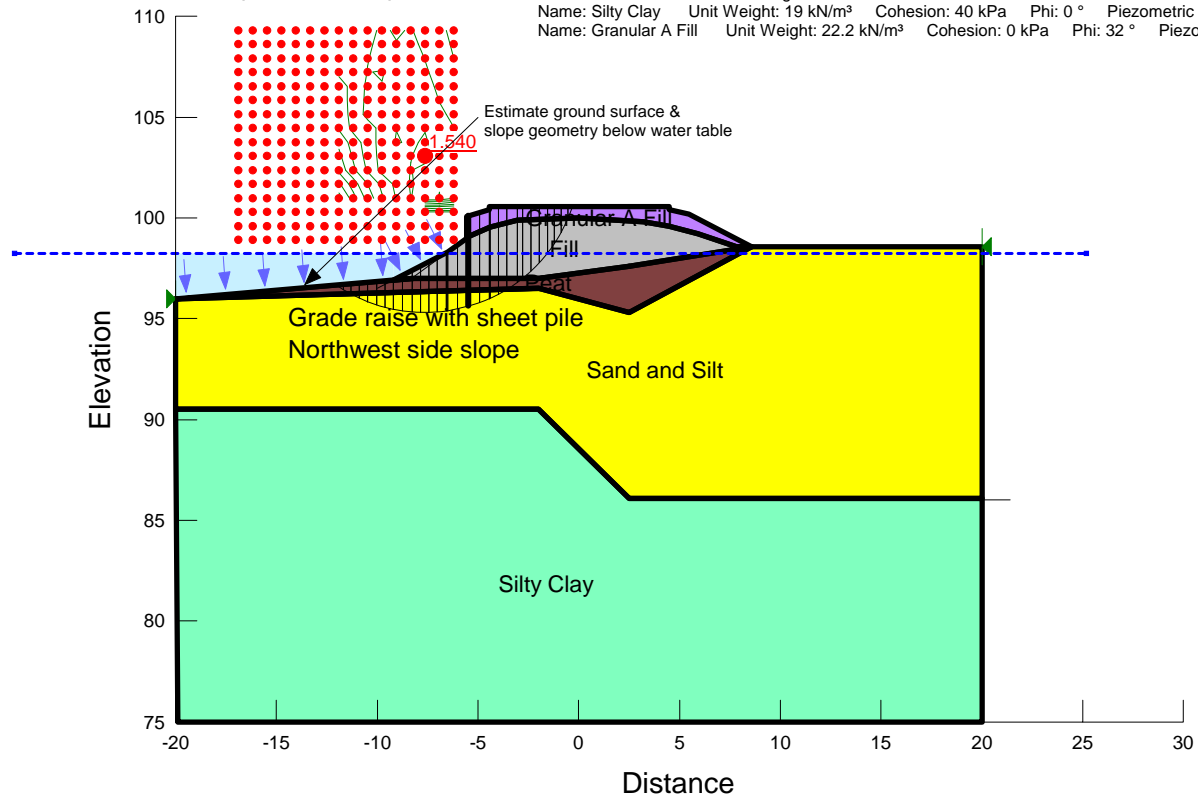


FIGURE F6

Appendix G

Borehole Locations and Soil Strata Drawings



A circular professional engineer seal for the Province of Ontario. The outer ring contains the text "LICENSED PROFESSIONAL ENGINEER" at the top and "PROVINCE OF ONTARIO" at the bottom. In the center, the name "P. K. CHATTERJI" is printed. Above the name is a handwritten signature in blue ink. Below the name is a handwritten license number "54301/13" in blue ink.

SHEET



A map of the study area in the Kootenai River region. The map shows the Kootenai River flowing from the top left towards the bottom. Highway 615 runs vertically along the right side of the river. Highway 15 runs horizontally across the middle of the map. Several lakes are labeled: Little Pine Lake, Boundary Lake, and Off Lake. A point labeled 'PLAN' is marked on Highway 615, south of Highway 15. A north arrow is located in the top left corner.

LEGEND

- [illegible]

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

REVISIONS								
	DATE	BY				DESCRIPTION		
	DESIGN LRB	CHK LRB		CODE		LOAD	DATE	OCT. 2013
	DRAWN AN	CHK		SITE 45-13		STRUCT	DWG	1

MINISTRY OF TRANSPORTATION, ONTARIO

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

CONT No
WP No 6092-10-00

HIGHWAY 615
OFF LAKE BRIDGE
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



KEYPLAN
LEGEND

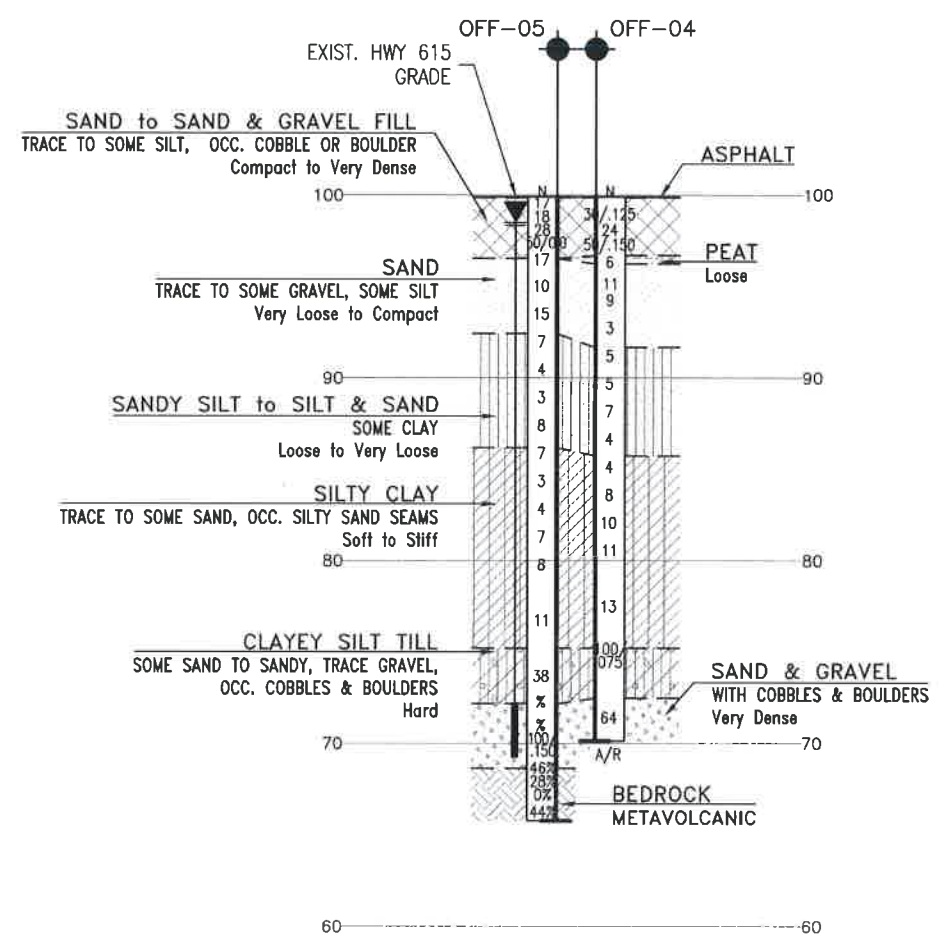
- Borehole
- Borehole and Cone
- N Blows /0.3m (Std Pen Test, 475J/blow)
- CONE Blows /0.3m (60' Cone, 475J/blow)
- PH Pressure, Hydraulic
- Water Level
- Head Artesian Water
- Piezometer
- 90% Rock Quality Designation (RQD)
- A/R Auger Refusal

NO	ELEVATION	NORTHING	EASTING
OFF-01	99.9	1 004 0.9	9 994.7
OFF-02	99.9	1 003 3.5	9 996.0
OFF-03	99.9	1 003 3.1	9 992.0
OFF-04	99.9	1 000 2.5	9 997.4
OFF-05	99.9	9 996.5	9 998.1
OFF-06	99.9	9 989.2	9 999.7

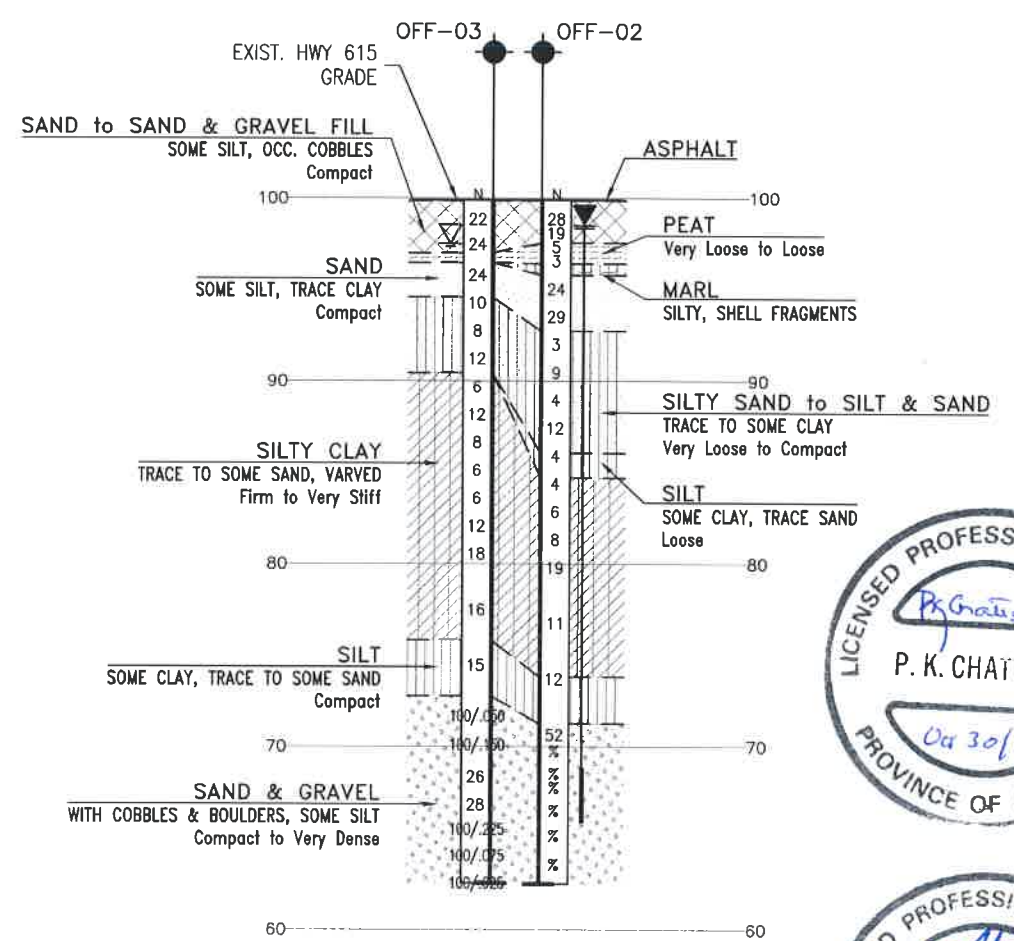
-NOTES-

- 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.

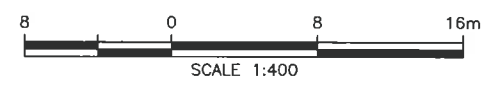
GEOCRES No. 52C-30



SECTION ALONG A-A



SECTION ALONG B-B



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STRUCT	DATE	OCT. 2013	DWG 2

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