FOUNDATION INVESTIGATION AND DESIGN REPORT
REPLACEMENT OF LITTLE GRASSY RIVER BRIDGE AT BERGLAND
HIGHWAY 621
DISTRICT OF RAINY RIVER, ONTARIO

G.W.P. 497-00-00, SITE No. 45-6

Geocres Number: 52D-14

Report to:

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted at the Little Grassy River Bridge on Highway 621 at Bergland, in the District of Rainy River, 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, a stratigraphic profile, 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 Hatch Mott MacDonald, under the Ministry of Transportation Ontario (MTO) Agreement Number 6010-E-0010.

2 SITE DESCRIPTION

The Little Grassy River Bridge at Bergland is located on Highway 621 approximately 750 m north of Highway 600, approximately 5 km east of Lake of the Woods and 25 km north of Highway 11. The existing bridge is a five-span structure supported on timber pile foundations. The bridge is approximately 34.7 m long and 8.5 m wide. The north approach to the bridge comprises an approximate 4 to 5 m high causeway extending about 50 m into the river. The south approach consists of a relatively short section of fill embankment at the river's edge, with a maximum height of about 5 m.

The section of the Little Grassy River at the bridge site comprises the east branch of the river, and flows westerly under the bridge before joining the main river flowing northwesterly towards Lake of the Woods. The site is located immediately south of the village of Bergland and is surrounded by trees and sparse residential dwellings.

Photographs in Appendix C show the general nature of the site and the existing structure.

The site lies within the physiographic region known as the Wabigoon Subprovince of the Superior Province of the Canadian Shield. The site is underlain by mafic to felsic intrusive rocks. The bedrock is overlain by glaciolacustrine fine-grained deposits of silt and clay with minor sand. Modern alluvial deposits consisting of fine sand, silt and clay with detrital organic remains underlie the river channels.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing for this project were carried out between October 27 and November 1, 2013, and comprised drilling and sampling six boreholes, identified as Boreholes LGB-01 to LGB-06. The approximate borehole locations are shown on the attached Borehole Locations and Soil Strata Drawing in Appendix G.

Boreholes LGB-02 to LGB-05 were drilled adjacent to the existing bridge abutments and were terminated in bedrock at depths of 23.8 to 30.5 m, including coring at least 3.1 m into bedrock. Boreholes LGB-01 and LGB-06 were drilled to 11.3 m depth at the south and north approaches, respectively.

The borehole locations were marked in the field and utility clearances were obtained prior to drilling. The coordinates and ground surface elevations for the boreholes were estimated from topographic plans provided by HMM.

A truck-mounted CME75 drill rig was used to advance the boreholes using a combination of hollow-stem augers, NW casing/wash-boring techniques, and NQ coring. Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT).

NQ rock coring techniques were used to advance Boreholes LGB-02 to LGB-05 into bedrock and recover core samples where possible. At the south abutment, core recovery was negligible and SPT sampling was attempted between core runs to further confirm the presence of bedrock. All rock cores were logged in the field 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 samples and rock core samples for transport to Thurber's laboratory for further examination and testing.

Groundwater conditions in the open boreholes were observed throughout the drilling operations. Groundwater conditions observed after completion of drilling were not representative of site conditions as water was introduced into the borehole during coring and wash boring operations. Standpipe piezometers were installed in two boreholes to monitor the groundwater level after drilling. The piezometers were subsequently decommissioned and the boreholes without piezometers were backfilled in general accordance with MOE Regulation 903. Completion details of the piezometers and boreholes are summarized in Table 3.1.

Table 3.1 – Borehole Completion Details

Foundation Unit	Borehole	Piezometer Tip Depth/ Elevation (m)	Completion Details
South Approach	LGB-01	None installed	Borehole backfilled bentonite holeplug to 0.1 m, then asphalt cold patch to surface.
South Abutment	LGB-02	None installed	Borehole backfilled with bentonite holeplug to 0.3 m, concrete from 0.3 m to 0.1 m, then asphalt cold patch to surface.
	LGB-03	25.6/ 301.3	Borehole backfilled with bentonite holeplug to 25.6 m, sand from 25.6 m to 23.5 m, bentonite holeplug from 23.5 m to 0.6 m, sand from 0.6 m to 0.3 m, cement from 0.3 m to 0.1m, then asphalt cold patch with flush mount to surface.
North Abutment	LGB-04	19.5/ 307.3	Borehole backfilled with bentonite holeplug to 19.5 m, sand from 19.5 m to 17.7 m, bentonite holeplug from 17.7 m to 0.6 m, cement from 0.6 m to 0.3 m, sand from 0.3 m to 0.1m, then asphalt cold patch with flush mount to surface.
	LGB-05	None installed	Borehole backfilled with bentonite holeplug to 0.3 m, concrete from 0.3 m to 0.1 m, then asphalt cold patch to surface.
North Approach	LGB-06	None installed	Borehole backfilled bentonite holeplug to 0.1 m, then asphalt cold patch to surface.

4 LABORATORY TESTING

All recovered soil samples were subjected to Visual Identification (VI) and natural moisture content determination. Selected samples were also subjected to grain size distribution analyses (sieve and hydrometer) and Atterberg Limits testing. The results of this testing program are summarized on the Record of Borehole sheets included in Appendix A and on the figures presented in Appendix B.

Bedrock core samples were subjected to geological logging. 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 assessed from the point load tests are reported on the borehole logs 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 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 site stratigraphy typically comprises sand and gravel embankment fill overlying native silty clay, underlain by a thin layer of silt to silt and sand, which in turn overlies bedrock. More detailed descriptions of the individual strata are presented below.

5.1 Asphalt

Asphalt was encountered on the roadway surface in all boreholes drilled. The asphalt was 25mm thick.

5.2 Embankment Fill

The existing embankment fill comprises sand to sand and gravel with occasional cobbles and possible boulders. The lower boundary of the fill was encountered at depths of 2.2 to 3.0 m (Elev. 324.9 to 323.8) in Boreholes LGB-01 to LGB-03 at the south end of the bridge, and at depths of 6.1 to 6.9 m (Elev. 320.7 to 319.9) in Boreholes LGB-04 to LGB-06 drilled on the causeway at the north end.

SPT N-values recorded in the fill generally ranged from 8 to 30 blows for 0.3 m penetration, indicating a typically compact relative density. SPT N-values of 65 blows for 0.3 m to 50 blows for no penetration were recorded in several instances, reflecting the presence of cobbles or boulders. Moisture contents ranged from 7% to 21%.

Seven samples of the granular embankment fill underwent laboratory grain size analysis testing, the results of which are summarized below. These results are also presented on the Record of Borehole sheets included in Appendix A. The grain size distribution curves for these samples are shown on Figures B1and B2 of Appendix B.

Soil Particles	Sand Fill (%)	Gravelly Sand (%)	Sand & Gravel Fill (%)
Gravel	0 to 7	22 to 32	47 to 81
Sand	90 to 91	65 to 77	17 to 51
Silt & Clay	2 to 10	1 to 3	2

5.3 Silty Clay

Brown to grey native silty clay with trace to some sand was encountered beneath the fill in all boreholes. In Boreholes LGB-02 to LGB-05, the lower boundary of the clay was encountered at depths of 19.8 to 20.7 m (Elev. 307.0 to 306.2), indicating a thickness of 13.7 to 17.7 m. Boreholes LGB-01 and LGB-06 were terminated in the clay at 11.3 m depth. A 1.2 m thick layer of sand with some gravel was encountered locally within the silty clay layer at 7.3 m depth in Borehole LGB-05.

SPT N-values between 6 and 24 blows per 0.3 m penetration were recorded in the silty clay, indicating a firm to very stiff consistency. The moisture content of the clay ranged from 14% to 56%, typically in the order of 25% to 35%.

Selected samples of the silty clay underwent laboratory grain size analysis testing and Atterberg Limits tests. The grain size distribution curves for tested samples of silty clay are shown on Figures B3 to B5 of Appendix B. The results of the Atterberg Limits tests are presented in Figure B8, Appendix B. The results are summarized on the Record of Borehole sheets included in Appendix A, and in the following tables:

Soil Particles	Silty Clay (%)
Gravel	0
Sand	0 to 27
Silt	21 to 70
Clay	27 to 71

Liquid Limit	30 to 82
Plastic Limit	15 to 34

The above results indicate that the silty clay varies from intermediate to high plasticity with group symbols of CI and CH.

5.4 Sand

A 1.2 m thick layer of sand with some gravel was encountered locally within the silty clay layer at 7.3 m depth (Elev. 319.5) in Borehole LGB-05. An SPT N-value of 16 blows per 0.3 m was recorded in the sand layer, indicating a compact condition. A moisture content of 25% was measured.

The results of a grain size distribution analysis conducted on the sand are shown on the Record Borehole sheets in Appendix A and in Figure B6 of Appendix B. The results are summarized below.

Soil Particles	Sand (%)
Gravel	15
Sand	67
Silt & Clay	18

5.5 Silt to Silt and Sand

A cohesionless deposit of silt to silt and sand with trace gravel, trace to some clay, occasional cobbles and possible boulders was encountered beneath the silty clay in Boreholes LGB-02 to LGB-05. The silt/sand layer was between 0.9 and 3.7 m thick, with a lower boundary on bedrock at depths of 20.7 to 24.4 m (Elev. 306.1 to 302.5).

SPT N-values obtained in the silt/sand deposit ranged from 22 to 41 blows per 0.3 m, indicating a compact to dense condition. An SPT N-value of 50 blows for no penetration obtained in Borehole LGB-02 suggests probable cobbles. Moisture contents ranged from 10% to 30%.

The results of a grain size distribution analysis conducted on two samples of the silt/sand are shown on the Record Borehole sheets in Appendix A and in Figure B7 of Appendix B. The results are summarized below.

Soil Particles	Silt/Sand (%)
Gravel	0 to 6
Sand	13 to 43
Silt	42 to 69
Clay	9 to 18

5.6 Bedrock

Bedrock was proven beneath the silt and sand deposit in Boreholes LGB-02 to LGB-05 by rock coring. The depths and elevations of the bedrock surface are summarized in Table 5.1.

Table 5.1 – Depths and Elevations of Bedrock

Borehole	Top of Bedrock	
	Depth (m)	Elevation
LGB-02	21.9	305.0
LGB-03	24.4	302.5
LGB-04	20.7	306.1
LGB-05	21.3	305.5

The bedrock is distinctively different between the north and south abutments. At the north abutment (Boreholes LGB-04 and LGB-05), 3.0 m long core samples of the bedrock were recovered, and the bedrock was described as grey, black and white gneiss. At the south abutment (Boreholes LGB-02 and LGB-03), the bedrock was cored for lengths of 4.6 and 6.1 m, with only 175 and 200 mm of core recovered in two of the core runs. Based on examination of the recovered core and observation of the core water flush, the bedrock was described as black sandstone.

Total core recovery in the gneiss bedrock was 80% to 100% and the Rock Quality Designation (RQD) was between 55% and 90%, indicating fair to good rock quality. The Fracture Index (FI) of the rock, expressed as fractures per 0.3 m core, was typically less than 3 and locally greater than 10. The unconfined compressive strength of the rock interpreted from point load tests conducted on the recovered cores ranged from 245 to 285 MPa, indicating a very strong to extremely strong rock.

At the south abutment, core recovery was typically 0%, with only two values of 12% and 13% reported. The Rock Quality Designation (RQD) was 0%, indicating very poor rock quality. In view of the poor core recovery, SPT testing was undertaken between core runs, and no penetration was achieved for 50 to 100 blows.

5.7 Water Levels

Where possible, water levels were monitored in the open boreholes during drilling operations. Wash boring and rock coring methods were used to advance the boreholes and therefore water levels recorded during or upon completion of drilling may not reflect natural groundwater levels. Standpipe piezometers were installed in two boreholes to monitor the groundwater level after completion. The water levels observed in the open boreholes upon completion and measured in the piezometers are summarized in Table 5.2.

Table 5.2 – Water Level Measurements

Borehole	Date	Water Level		Comment
		Depth (m)	Elev. (m)	
LGB-01	November 1, 2013	2.1	325.0	In open borehole
LGB-02	October 27, 2013	1.8	325.1	In open borehole
LGB-03	October 29, 2013 November 21, 2013	4.0 1.2	322.9 325.7	In open borehole In piezometer
LGB-04	October 31, 2013 November 21, 2013	2.2 1.1	324.6 325.7	In open borehole In piezometer
LGB-05	October 30, 2013	4.3	322.5	In open borehole
LGB-06	October 30, 2013	4.5	322.3	In open borehole

The preliminary GA drawing provided by HMM indicates a water level at Elevation 322.8 in the Little Grassy River on September 8, 2013. In general, the groundwater level is expected to be at or slightly above the water level in the river. The higher water levels measured in the piezometers indicate an artesian condition in the silt/sand underlying the clay deposit.

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

6 MISCELLANEOUS

Borehole locations were selected and established in the field by Thurber Engineering Ltd. The co-ordinates and the ground surface elevations for the boreholes were established based on topographic survey information provided by HMM.

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 drilling operations were supervised by Mr. George Azzopardi.

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

The report was reviewed by Mr. Murray 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 in the factual report and presents geotechnical design recommendations for design of a new bridge to replace the existing bridge on Highway 621 at Little Grassy River in the District of Rainy River, Ontario.

The existing Little Grassy River Bridge is a five-span structure supported on timber pile foundations. The bridge is approximately 34.7 m long and 8.5 m wide. The span lengths are about 8.8 m for the centre span and 6.0 m for the remaining spans. The length of the timber piles is unknown.

The north approach to the bridge comprises an approximate 4 to 5 m high causeway extending about 50 m into the river. The south approach consists of a relatively short section of fill embankment at the river's edge, with a maximum height of about 5 m.

The preliminary General Arrangement drawing provided by HMM indicates that the proposed replacement bridge will be a single span modular structure supported on steel H-piles. The span of the structure will be 30.5 m and the width will be 11.7 m. In lieu of conventional abutments, two levels of sheet pile wall, one in front of and one behind the H-pile foundations, will be installed at each abutment to retain the approach fill. Structural ramps supported on sleeper slabs will be placed at each end of the bridge.

Highway traffic will be detoured during construction to allow full bridge replacement without staging.

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

8 STRUCTURE FOUNDATIONS

The subsurface conditions encountered at the site typically consist of a pavement structure overlying 2.2 to 6.9 m of sand to sand and gravel approach fill, overlying a thick deposit of firm to very stiff silty clay and a 0.9 to 3.7 m thick layer of silt to silt and sand, underlain by bedrock encountered at depths of 20.7 to 24.4 m.

The preliminary GA drawing indicates a water level in Little Grassy River at Elevation 322.8 in September 2013. The groundwater levels measured in the piezometers were 1.1 to 1.2 m below the roadway surface (Elev. 325.7), indicative of artesian pressures in the deep silt/sand layer.

Based on existing site conditions, initial consideration was given to the following foundation types:

- 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:

- Relatively low geotechnical resistance is available in the native silty clay underlying the existing embankment fill.
- Construction of footings would require excavation of the fill to native clay below the river water level, which will require temporary shoring and dewatering. Installation of temporary shoring (i.e. sheet pile cofferdam) will be difficult due to the presence of cobbles and boulders in the embankment fill.
- Temporary excavation for footing construction may have an environmental impact on the river.
- Scour protection will be required for the footings.

In light of the above factors, the spread footings option was not developed further.

8.2 Drilled Shafts/Caissons

Caissons used to support the bridge would need to extend through the native silty clay and cohesionless silt/sand layer to found on the underlying bedrock. Artesian water pressures are present within the layer of silt/sand, and control of groundwater into the caisson excavation as well as maintaining stability of the caisson sidewalls may be problematic.

Use of a steel liner sealed into bedrock would be required; however developing an adequate seal into the bedrock at this site may prove difficult. In addition, caisson base inspection will not be possible.

Caissons are therefore not recommended at this site and this option was not developed further.

8.3 Driven Steel H-piles

8.3.1 Pile Design

The use of driven steel H-piles is considered suitable to support the structure at this site. The piles are expected to encounter refusal on bedrock encountered at 20.7 to 24.4 m (Elev. 302.5 to 306.1), as summarized in Table 8.1.

Table 8.1 – Anticipated Pile Tip Elevations on Bedrock

Foundation Unit	Borehole	Estimated Pile Tip		Factored Geotechnical Resistance at ULS (kN)	Geotechnical Reaction at SLS (kN)
		Depth Below Road Grade (m)	Elevation		
South Abutment	LGB-02	21.9	305.0	1,600	Does not govern
	LGB-03	24.4	302.5		
North Abutment	LGB-04	20.7	306.1	2,000	Does not govern
	LGB-05	21.3	305.5		

The geotechnical resistances recommended for HP 310x110 piles driven to bedrock are also presented in Table 8.1. The recommended geotechnical resistance of driven H-piles at the south pier has been reduced in consideration of the very poor quality of the bedrock encountered at this location.

The factored structural resistance of the piles at ULS must be checked by the structural designer as per Section 6.8.8 of the CHBDC.

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 through the embankment fill and silt/sand layer, and setting the piles on bedrock.

The abutments should be positioned to avoid encountering the existing timber piles while driving the new pile foundations.

8.3.2 Pile Installation

Pile installation should be in accordance with OPSS 903.

For piles installed to the tolerances shown in Clause 903.07.05.01 of the Specification, the foundation drawing should include the note “Piles to be driven to bedrock”.

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.

To facilitate pile installation, embankment fill through which piles will be driven must not contain oversize material, i.e. no particles exceeding 75 mm in size. It should be noted that cobbles and boulders were encountered in the fill forming the highway embankments. If such obstructions are encountered at the proposed location of the H-piles they will have to be removed to facilitate driving of H-piles.

The Contract Documents should contain a NSSP alerting the Bidders to the presence of cobbles and boulders within the highway embankment. An NSSP addressing this issue is included in Appendix E.

8.3.3 Downdrag

Downdrag forces will develop along the length of piles embedded in the embankment fill and silty clay due to consolidation of the clay under the weight of additional fill placed in the approaches. For design purposes, an unfactored downdrag load of 250 kN is recommended to evaluate the impact of downdrag on the abutment piles.

This downdrag load should be multiplied by a load factor of 1.25 as per CHBDC Commentary Clause C6.8.4 to obtain a factored downdrag load. In accordance with Section 6.8.4 of the CHBDC and Clause C6.8.4 of the Commentary, in the structural design of a pile, the factored downdrag load should be added to the factored permanent loads to assess the effects of downdrag. In geotechnical analysis of downdrag, live load effects should not be considered.

The location of the neutral plane for a pile or group of piles should be determined by using unfactored loads and unfactored geotechnical parameters.

As indicated in Clause C6.8.4 of the Commentary, the factored dead and downdrag load should not exceed the factored structural resistance of a pile.

8.3.4 Lateral Resistance for H-piles

The geotechnical lateral resistance acting on an H-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:

$$k_s = n_h \, z / D \qquad (kN/m^3)$$

$$p_{ult} = 3 \, \gamma \, z \, K_p \qquad (kPa)$$

where z = depth of embedment of pile in metres

D = pile width in metres

n_h = value from Table 8.2

γ = unit weight (Table 8.2)

K_p = passive earth pressure coefficient (Table 8.2)

For cohesive soils, the lateral resistance of the piles may be calculated using the following:

k_s = $67\ S_u / D$ (kN/m^3)

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

where S_u = undrained shear strength (Table 8.2)

D = pile width in metres

The parameters recommended for use with the above equations are provided in Table 8.2.

Table 8.2 – Parameters for Lateral Pile Resistance

Location	Elevation	n_h (kN/m^3)	S_u (kPa)	K_p Level Ground	K_p 30° Forward Slope	Unit Weight* (kN/m^3)	Soil Conditions
South Abutment	326.9 to 323.8	3,000	-	3.3	1.3	21.0	Sand Fill
	323.8 to 320.0	-	80	2.9	-	9.1	Silty Clay
	320.0 to 308.0	-	100	2.9	-	9.1	Silty Clay
North Abutment	326.9 to 324.6	3,000	-	3.3	1.3	21.0	Sand Fill
	324.6 to 323.8	3,000	-	3.3	1.3	11.1	Sand Fill
	323.8 to 318.0	-	80	2.9	-	8.5	Silty Clay
	318.0 to 308.0	-	100	2.9	-	8.5	Silty Clay

*Buoyant unit weight below the water table.

The above equations and recommended parameters may be used to analyze the interaction between a pile and the surrounding soil. 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/m^3), D is the pile

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width/diameter (m) and L is the length (m) of the pile segment or element used in the analysis. The ultimate lateral resistance on any one segment of pile, P_{ult}, may be obtained from the expression, $P_{ult} = p_{ult}$ L 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 160 kN at ULS and 65 kN at SLS for an HP 310x110 pile section.

For lateral soil/pile group interaction analysis, the modulus of subgrade reaction (k_s) may have to be reduced based on 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 Recommended Foundation

From a geotechnical perspective, the recommended foundation alternative to support the bridge abutments at this site is steel H-piles driven to bedrock.

8.5 Frost Cover

The design depth of frost penetration at this site is 2.3 m.

Frost protection should be provided for buried pile caps, if used, and should consist of a minimum of 2.3 m of soil cover.

9 SHEET PILE WALLS

The current design proposes the installation of steel sheet pile walls both in front of and behind the H-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 piles.

Driving of the sheet piles through the existing approach fill may encounter cobbles and possible boulders. The Contract Documents should contain a NSSP alerting the Bidders to the possibility of some sheet piles meeting refusal on the cobbles or a large boulder, and the need to remove or otherwise penetrate these obstructions. Suggested text for the NSSP is included in Appendix E. Any visible obstructions such as boulders and rock protection along the sides of the embankment should be removed prior to driving the 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 soils in front of the sheet pile should be protected from river erosion so that the sheet piles do not lose lateral support.

Backfill behind the 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 and SP 105S21.

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 abutment backfill and the underlying 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 9.1)

γ = unit weight of retained soil (see Table 9.1)

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 shown in Table 9.1.

Table 9.1 – Earth Pressure Coefficients (K)

Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35°, \gamma = 22.8\ kN/m^3$		OPSS Granular B Type I/III or Existing Sand and Gravel Fill $\phi = 32°, \gamma = 21.2\ kN/m^3$	
	Horizontal Surface	Sloping Surface behind Wall (2H:1V)	Horizontal Surface	Sloping Surface behind Wall (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48
At rest (Restrained Wall)	0.43	-	0.47	-
Passive (Movement Towards Soil Mass)	3.7	-	3.3	-

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 9.1 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 or 1.7 m for Granular A or Granular B Type II.

10 APPROACH EMBANKMENTS

Based on the preliminary GA drawing provided by HMM, a maximum 1.5m thick wedge of fill will be placed to backfill behind the sheet pile walls. The foundation soils governing settlement and stability of the approach embankments consist of existing compact sand fill and the underlying native firm to very stiff silty clay.

The existing embankments bearing on the foundation soils at this site appear to be performing satisfactorily under the existing conditions. A global slope stability analysis was conducted to assess the stability of the forward slopes with the proposed sheet pile wall abutment configuration. The analyses were carried out using the Morgenstern-Price method of slope stability analysis. The geotechnical model and results of the stability analyses are shown on Figures F1 to F4 of Appendix F. The results of the analyses indicate that adequate factors of safety exceeding 1.5 are achieved for both short and long term conditions if the sheet piles are driven to or below Elevation 319.0.

Placement of the localized zone of fill behind the sheet pile walls will induce immediate (elastic) settlement in the existing sand embankment fill and consolidation settlement in the underlying silty clay. The total settlement under the new fill loading is estimated to be in the order of 10 to 15 mm with the majority of this settlement occurring during construction of the bridge.

11 EROSION PROTECTION

Erosion protection should be provided along any soil surfaces that may be in contact with the river flow. In particular, erosion of the soils in front of the sheet pile wall abutments must be prevented to maintain stability of these walls.

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

12 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 I. Therefore, according to Clause 4.4.6.1 Table 4.4 of the CHBDC, a Site Coefficient "S" (ground motion amplification factor) of 1.0 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 12.1 may be used:

Table 12.1 – Earth Pressure Coefficients for Earthquake Loading

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

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

The potential for liquefaction of the foundations soils was assessed using the Seed and Idriss (1971) method for cohesionless soils. Using the method, it is estimated that under the existing conditions, the foundation soils at the abutments are not prone to liquefaction.

13 EXCAVATION AND GROUNDWATER CONTROL

Based on the preliminary GA drawing for the new bridge, it is expected that excavation will be carried out primarily within the existing embankment fill. This work will not extend below the river water level.

Earth excavation for foundation construction must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the sand fill and native silty clay within the probable depth of excavation may be classed as Type 3 soils above the water table and Type 4 soils below the water table.

The excavation and backfilling for foundations must be carried out in accordance with OPSS 902.

It is recommended that excavation for removal of existing structures be maintained above the water level in the river. Any excavation below the groundwater level/river level without prior dewatering is not recommended since the inflow of groundwater will make it difficult to maintain a dry, sound base on which to work.

In general, the design of the dewatering system should be the responsibility of the Contractor and the Contract Documents should alert him to this responsibility.

14 CONSTRUCTION CONCERNS

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

- Cobbles and possible boulders are present within the existing embankment fill. The Contractor must be prepared to remove or otherwise penetrate these obstructions if H-piles or sheet piles meet refusal in the fill.
- The Contractor's selection of construction equipment and methodology must include assessment of the capability of the existing embankment 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.

15 CLOSURE

Engineering analysis and preparation of the report were carried out by 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

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THURBER

Appendix A

Record of Borehole Sheets

THURBER

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

C_{pen} 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

ROCK WEATHERING CLASSIFICATION

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

SYMBOLS

CLAYSTONE

SILTSTONE

SANDSTONE

COAL

Bedrock (general)

DISCONTINUITY SPACING

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

TERMS

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

STRENGTH CLASSIFICATION

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No LGB-01

METRIC

WP#	497-00-01	LOCATION	Little Grassy at Bergland N 5 424 372.4 E 203 158.2	ORIGINATED BY	GA
HWY	621	BOREHOLE TYPE	NW Casing	COMPILED BY	AN
DATUM	Geodetic	DATE	2013.11.01 - 2013.11.01	CHECKED BY	WM

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
327.1								
0.0	**ASPHALT:** (25mm)					327		
	SAND, trace gravel, trace silt Compact Brown Moist to Wet (FILL)	1	SS	20			o	7 91 2 (SI+CL)
		2	SS	16		326	o	
		3	SS	27	∇		o	
324.9 / 2.2	Silty **CLAY**, trace sand, occasional black oxide staining Stiff to Very Stiff Brown	4	SS	9		325	o	0 3 70 27
		5	SS	8		324	o	
						323	>>3.0	
		6	SS	11		322	o	
	Some sand seams	7	SS	17		321	wP–w–wL	0 27 34 39
	Grey	8	SS	13		320, 319	o	
		9	SS	14		318	o	

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE — 20 40 60 80 100

PLASTIC LIMIT wP — NATURAL MOISTURE CONTENT w — LIQUID LIMIT wL; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m3

Continued Next Page

+3, ×3: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No LGB-01

METRIC

WP#	497-00-01	LOCATION	Little Grassy at Bergland N 5 424 372.4 E 203 158.2	ORIGINATED BY	GA
HWY	621	BOREHOLE TYPE	NW Casing	COMPILED BY	AN
DATUM	Geodetic	DATE	2013.11.01 - 2013.11.01	CHECKED BY	WM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE) 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	Silty **CLAY**, occasional sand, occasional gravel Stiff Grey						317				
			10	SS	17				○ (approx. 36)		
315.8 11.3	END OF BOREHOLE AT 11.3m. BOREHOLE OPEN TO 11.3m AND WATER LEVEL AT 2.1m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.1m, THEN ASPHALT PATCH TO SURFACE.						316				

+ ³, × ³ : Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No LGB-02

METRIC

WP#	497-00-01	LOCATION	Little Grassy at Bergland N 5 424 387.4 E 203 158.6	ORIGINATED BY	GA
HWY	621	BOREHOLE TYPE	NW Casing/NQ Coring	COMPILED BY	AN
DATUM	Geodetic	DATE	2013.10.27 - 2013.10.27	CHECKED BY	WM

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
326.9						
0.0	**ASPHALT:** (25mm)					
	Gravelly **SAND**, occasional cobbles, Compact, Brown, Damp (FILL)	1	SS	16		
		2	SS	29		32 65 3 (SI+CL)
		3	SS	24	∇	
324.7 / 2.2	**SAND**, Compact, Brown, Wet (FILL)	4	SS	11		
323.8 / 3.0	Silty **CLAY**, trace to some sand, occassional black oxide staining, Stiff to Very Stiff, Brown	5	SS	8		0 7 52 41
		6	SS	12		
	Trace gravel					
		7	SS	20		
	Some sand					
		8	SS	7		0 15 46 39
	Grey	9	SS	15		

Elevation scale: 326, 325, 324, 323, 322, 321, 320, 319, 318, 317

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%): 20 40 60

UNIT WEIGHT γ kN/m³

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No LGB-02

METRIC

WP# 497-00-01 LOCATION Little Grassy at Bergland N 5 424 387.4 E 203 158.6 ORIGINATED BY GA

HWY 621 BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY AN

DATUM Geodetic DATE 2013.10.27 - 2013.10.27 CHECKED BY WM

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	SHEAR STRENGTH kPa	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Silty **CLAY**, occasional sand, occasional gravel Stiff Grey							
		10	SS	14	316			
					315			
		11	SS	12				
					314	>> 3.0		
		12	SS	14	313			0 6 37 57
					312			
		13	SS	12				
					311	>> 2.0		
		14	SS	13	310			
					309			
	Firm	15	SS	6				
					308	>> 2.0		
					307			

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

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Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No LGB-02

METRIC

WP# 497-00-01 | LOCATION Little Grassy at Bergland N 5 424 387.4 E 203 158.6 | ORIGINATED BY GA

HWY 621 | BOREHOLE TYPE NW Casing/NQ Coring | COMPILED BY AN

DATUM Geodetic | DATE 2013.10.27 - 2013.10.27 | CHECKED BY WM

ELEV / DEPTH	DESCRIPTION (Continued From Previous Page)	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Silty **CLAY**, Very Stiff, Grey, Wet	16	SS	19		wP–w–>>wL	0 0 43 57
306.3 / 20.6	**SILT** and **SAND**, trace gravel, occasional cobbles, Very Dense, Grey, Wet	17	SS	50/ 0.0	306		
	Start coring at 21.9m						
305.0 / 21.9	**BEDROCK**, sandstone, black	1	RUN		305, 304		RUN #1 TCR=13% SCR=8% RQD=0%
		2	RUN		303		RUN #2 TCR=0% SCR=0% RQD=0%
	SPT at 24.4m No penetration for 50 blows	3	RUN		302, 301		RUN #3 TCR=0% SCR=0% RQD=0%
300.4 / 26.5	END OF BOREHOLE AT 26.5m. BOREHOLE OPEN TO 26.5m AND WATER LEVEL AT 1.8m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.3m, CONCRETE TO 0.1m, THEN ASPHALT PATCH TO SURFACE.						

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT wP, NATURAL MOISTURE CONTENT w, LIQUID LIMIT wL, WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m3; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL.

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

RECORD OF BOREHOLE No LGB-03

METRIC

WP# 497-00-01 | LOCATION Little Grassy at Bergland N 5 424 387.3 E 203 163.9 | ORIGINATED BY GA

HWY 621 | BOREHOLE TYPE NW Casing/NQ Coring | COMPILED BY AN

DATUM Geodetic | DATE 2013.10.28 - 2013.10.29 | CHECKED BY WM

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
326.9										
0.0	**ASPHALT:** (25mm)									
	Gravelly **SAND**, occasional cobbles, Compact, Brown, Moist (FILL)	1	SS	19						
		2	SS	13	326		22	77	1 (SI+CL)	
		3	SS	69	325					
	Cobbles at 2.1m to 2.6m	4	SS	50/ 0.0						
323.8 / 3.0	Silty **CLAY**, trace sand, Stiff, Brown, Wet	5	SS	12	324		0	4	44	52
		6	SS	11	323 / 322					
		7	SS	8	321		0	8	21	71
	Grey	8	SS	13	320 / 319					
		9	SS	14	318 / 317					

Column headings also include: STRAT PLOT; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m[3]; REMARKS & GRAIN SIZE DISTRIBUTION (%).

Continued Next Page

+ [3], × [3]: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No LGB-03

METRIC

WP# 497-00-01 LOCATION Little Grassy at Bergland N 5 424 387.3 E 203 163.9 ORIGINATED BY GA
HWY 621 BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY AN
DATUM Geodetic DATE 2013.10.28 - 2013.10.29 CHECKED BY WM

Continued From Previous Page

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Silty **CLAY**, occasional sand Stiff to Very Stiff Grey Wet					
		10	SS	13	316	
					315	
		11	SS	15		
					314	
		12	SS	14	313	
					312	
		13	SS	15		
					311	
		14	SS	12	310	0 7 36 57
					309	
		15	SS	12		
					308	
					307	

Column headings: SOIL PROFILE; SAMPLES; STRAT PLOT; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m3

Continued Next Page

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

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Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No LGB-03

METRIC

WP# 497-00-01 | LOCATION Little Grassy at Bergland N 5 424 387.3 E 203 163.9 | ORIGINATED BY GA

HWY 621 | BOREHOLE TYPE NW Casing/NQ Coring | COMPILED BY AN

DATUM Geodetic | DATE 2013.10.28 - 2013.10.29 | CHECKED BY WM

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
		16	SS	24		
306.2 / 20.7	**SILT** and **SAND**, trace clay, trace gravel Dense Grey Boulders at 21.3m to 22.6m				306	
					305	
					304	
		17	SS	41		6 43 42 9
	Start coring at 24.4m				303	
302.5 / 24.4	**BEDROCK**, sandstone, black SPT at 24.4m No penetration for 100 blows	1	RUN		302	RUN #1 TCR=0% SCR=0% RQD=0%
	SPT at 25.9m No penetration for 100 blows	2	RUN		301 300	RUN #2 TCR=0% SCR=0% RQD=0%
	SPT at 27.4m No penetration for 100 blows	3	RUN		299	RUN #3 TCR=0% SCR=0% RQD=0%
	SPT at 29.0m No penetration for 50 blows	4	RUN		298 297	RUN #4 TCR=12% SCR=12% RQD=12%

Water content plot (PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60): sample 16 ≈ 24%; sample 17 ≈ 11%.

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE. UNIT WEIGHT γ kN/m³.

Continued Next Page

$+^3, \times^3$: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No LGB-03

METRIC

WP# 497-00-01 LOCATION Little Grassy at Bergland N 5 424 387.3 E 203 163.9 ORIGINATED BY GA

HWY 621 BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY AN

DATUM Geodetic DATE 2013.10.28 - 2013.10.29 CHECKED BY WM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION (Continued From Previous Page)	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
296.4	SPT at 30.5m No penetration for 50 blows										
30.5	END OF BOREHOLE AT 30.5m. BOREHOLE OPEN TO 30.5m AND WATER LEVEL AT 4.0m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) Nov. 21/13 1.2 325.7										

$+^3, \times^3$: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No LGB-04

METRIC

WP# 497-00-01 LOCATION Little Grassy at Bergland N 5 424 427.4 E 203 160.0 ORIGINATED BY GA

HWY 621 BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY AN

DATUM Geodetic DATE 2013.10.31 - 2013.10.31 CHECKED BY WM

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
326.8 / 0.0	**ASPHALT:** (25mm)					
	Gravelly **SAND** Compact Brown Moist (FILL)	1	SS	30		
		2	SS	16	326	
		3	SS	26	325	29 68 3 (SI+CL)
324.5 / 2.3	**SAND**, trace gravel Compact Brown Moist (FILL)	4	SS	16	324	
		5	SS	11	323	
		6	SS	10	322	
320.7 / 6.1	Silty **CLAY**, some sand, occasional rootlets Stiff to Very Stiff Grey Wet	7	SS	9	321, 320	
		8	SS	8	319, 318	
		9	SS	16	317	0 17 28 55

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³

Continued Next Page

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No LGB-04

METRIC

WP# 497-00-01 | LOCATION Little Grassy at Bergland N 5 424 427.4 E 203 160.0 | ORIGINATED BY GA

HWY 621 | BOREHOLE TYPE NW Casing/NQ Coring | COMPILED BY AN

DATUM Geodetic | DATE 2013.10.31 - 2013.10.31 | CHECKED BY WM

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Silty **CLAY**, occasional sand, occasional gravel Stiff to Very Stiff Grey					
		10	SS	14	316	
					315	
		11	SS	17	314	
		12	SS	12	313	
					312	
		13	SS	9	311	0 7 30 63
		14	SS	6	310	
					309	
		15	SS	12	308	
307.0 / 19.8	**SILT**, some clay, sand layers				307	

Plot annotation near 309: >>2.0

Continued Next Page

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE: 20 40 60 80 100

PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%): 20 40 60

UNIT WEIGHT γ kN/m3

+3, ×3: Numbers refer to Sensitivity

20 / 15 / 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No LGB-04

METRIC

WP# 497-00-01 | LOCATION Little Grassy at Bergland N 5 424 427.4 E 203 160.0 | ORIGINATED BY GA

HWY 621 | BOREHOLE TYPE NW Casing/NQ Coring | COMPILED BY AN

DATUM Geodetic | DATE 2013.10.31 - 2013.10.31 | CHECKED BY WM

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
	SILT, some clay, sand layers Compact Grey	16	SS	22		~30		GR 0, SA 13, SI 69, CL 18
306.1 / 20.7	Start coring at 20.7m						FI	
	BEDROCK, coarse grained, grey/black/white: (GNEISS)	1	RUN		306		0 0 1 2	RUN #1 TCR=80% SCR=80% RQD=70%
	Fragmented zone at 21.9m				305			
	Occasional mechanical breaks						>10	
	Horizontal joint (25mm) at 21.4m, 21.8, 21.9m	2	RUN				2	RUN #2 TCR=100% SCR=92% RQD=55%
	Highly broken zone (125mm) at 22.7m				304		2 >5	
	Sub-horizontal joint (25mm) at 22.4m, 22.5m						0	
303.0 / 23.8	Horizontal joint (25mm) at 22.3m, 22.4m, 22.6m, 22.7m, 22.9m, 23.6m						1	

END OF BOREHOLE AT 23.4m.
BOREHOLE OPEN TO 23.4m AND WATER LEVEL AT 2.2m.
Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.

WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
Nov. 21/13	1.1	325.7

Chart legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60.

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No LGB-05

METRIC

WP# 497-00-01	LOCATION Little Grassy at Bergland N 5 424 427.8 E 203 165.0		ORIGINATED BY GA
HWY 621	BOREHOLE TYPE NW Casing/NQ Coring		COMPILED BY AN
DATUM Geodetic	DATE 2013.10.29 - 2013.10.30		CHECKED BY WM

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
326.8 / 0.0	**ASPHALT:** (25mm)
	SAND and **GRAVEL**, occasional cobbles Compact Brown Wet (FILL) Possible boulder at 1.8m
324.4 / 2.4	**SAND** Compact to Loose Brown Wet (FILL)
322.4 / 4.4	**SAND** and **GRAVEL** Compact Brown Wet (FILL)
320.7 / 6.1	Silty **CLAY**, some sand Firm Grey Wet
319.5 / 7.3	**SAND**, some gravel, some clay Compact Grey Wet
318.3 / 8.5	Silty **CLAY**, trace sand Stiff Grey Wet

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	19	
2	SS	15	
3	SS	65	0 90 10 (SI+CL)
4	SS	15	
5	SS	8	
6	SS	19	
7	SS	7	
8	SS	16	15 67 18 (SI+CL)
9	SS	15	

GROUND WATER CONDITIONS: water level symbol at approx. elev. 322.7

ELEVATION SCALE: 326, 325, 324, 323, 322, 321, 320, 319, 318, 317

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE: 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L

WATER CONTENT (%): 20 40 60

UNIT WEIGHT γ kN/m^3

Continued Next Page

$+^3, \times^3$: Numbers refer to Sensitivity

15 20 5 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No LGB-05

METRIC

WP# 497-00-01 | LOCATION Little Grassy at Bergland N 5 424 427.8 E 203 165.0 | ORIGINATED BY GA

HWY 621 | BOREHOLE TYPE NW Casing/NQ Coring | COMPILED BY AN

DATUM Geodetic | DATE 2013.10.29 - 2013.10.30 | CHECKED BY WM

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20, 40, 60, 80, 100

SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100)

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%): 20, 40, 60

UNIT WEIGHT γ kN/m3

REMARKS & GRAIN SIZE DISTRIBUTION (%): GR SA SI CL

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS	GR	SA	SI	CL
	Silty **CLAY**, trace sand Stiff to Very Stiff Grey Wet									
		10	SS	8	316					
					315	>>2.0				
		11	SS	16			0	10	43	47
					314					
		12	SS	14	313					
					312					
		13	SS	13	311					
		14	SS	6	310					
					309	>>3.0				
		15	SS	12	308		0	9	37	54
307.0 / 19.8	Sandy **SILT**, trace gravel				307					

Continued Next Page

+3, ×3: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No LGB-05

METRIC

WP#	497-00-01	LOCATION	Little Grassy at Bergland N 5 424 427.8 E 203 165.0	ORIGINATED BY	GA
HWY	621	BOREHOLE TYPE	NW Casing/NQ Coring	COMPILED BY	AN
DATUM	Geodetic	DATE	2013.10.29 - 2013.10.30	CHECKED BY	WM

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT / FI	REMARKS & GRAIN SIZE DISTRIBUTION (%)
	Sandy **SILT**, trace gravel Dense Grey Wet	16	SS	37		~24 (o)		
					306			
305.5	Start coring at 21.3m						FI	
21.3	**BEDROCK**, coarse grained, grey/black/white: (GNEISS)	1	RUN		305		1, 1, 1, 2, 0	RUN #1 TCR=100% SCR=100% RQD=87% UCS=247MPa (Average)
	Horizontal joint (25mm) at 21.4m, 21.8m, 22.1m, 22.2m Sub-horizontal joint (50mm) at 22.4m Highly broken zone (75mm) at 23.1m Horizontal joint (25mm) at 22.9m, 23.2m	2	RUN		304, 303		3, 0, 1, 1, 0	RUN #2 TCR=100% SCR=97% RQD=90% UCS=245MPa (Average)
302.4 / 24.4	END OF BOREHOLE AT 24.4m. BOREHOLE OPEN TO 24.4m AND WATER LEVEL AT 4.3m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.3m, CONCRETE TO 0.1m, THEN ASPHALT PATCH TO SURFACE.							

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20, 40, 60; UNIT WEIGHT γ kN/m³; GR SA SI CL

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No LGB-06

METRIC

WP#	497-00-01	LOCATION	Little Grassy at Bergland N 5 424 442.8 E 203 164.8	ORIGINATED BY	GA
HWY	621	BOREHOLE TYPE	NW Casing	COMPILED BY	AN
DATUM	Geodetic	DATE	2013.10.30 - 2013.10.30	CHECKED BY	WM

Column headings: SOIL PROFILE (ELEV / DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20, 40, 60, 80, 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L, WATER CONTENT (%) (20, 40, 60); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS (GR SA SI CL)
326.8 / 0.0	**ASPHALT:** (25mm)					
	SAND and **GRAVEL**, trace silt, Compact, Brown, Wet (FILL)	1	SS	30		47 51 2 (SI+CL)
		2	SS	20	326	
	Loose	3	SS	8	325	
	Compact	4	SS	11	324	
	Gravel, some sand, trace silt	5	SS	11	323	81 17 2 (SI+CL)
		6	SS	12	322	
	Wood fragments at 6.1m	7	SS	18	321	
319.9 / 6.9	Silty **CLAY**, some sand, Stiff, Grey, Wet				320	
		8	SS	9	319	0 18 26 56
					318	
		9	SS	14	317	

Groundwater level symbol ∇ shown at approx. elev. 322.4. DCPT annotation ">>3.0" at approx. elev. 318.3.

Continued Next Page

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

ONTMT4S 5121.GPJ 2012TEMPLATE(MTO).GDT 1/21/14

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No LGB-06

METRIC

WP# 497-00-01 LOCATION Little Grassy at Bergland N 5 424 442.8 E 203 164.8 ORIGINATED BY GA

HWY 621 BOREHOLE TYPE NW Casing COMPILED BY AN

DATUM Geodetic DATE 2013.10.30 - 2013.10.30 CHECKED BY WM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	Silty **CLAY**, some sand Stiff Grey Wet										
			10	SS	14		316		o (approx. 35)		
315.5 11.3	END OF BOREHOLE AT 11.3m. BOREHOLE OPEN TO 11.3m AND WATER LEVEL AT 4.5m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.1m, THEN ASPHALT PATCH TO SURFACE.										

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Appendix B

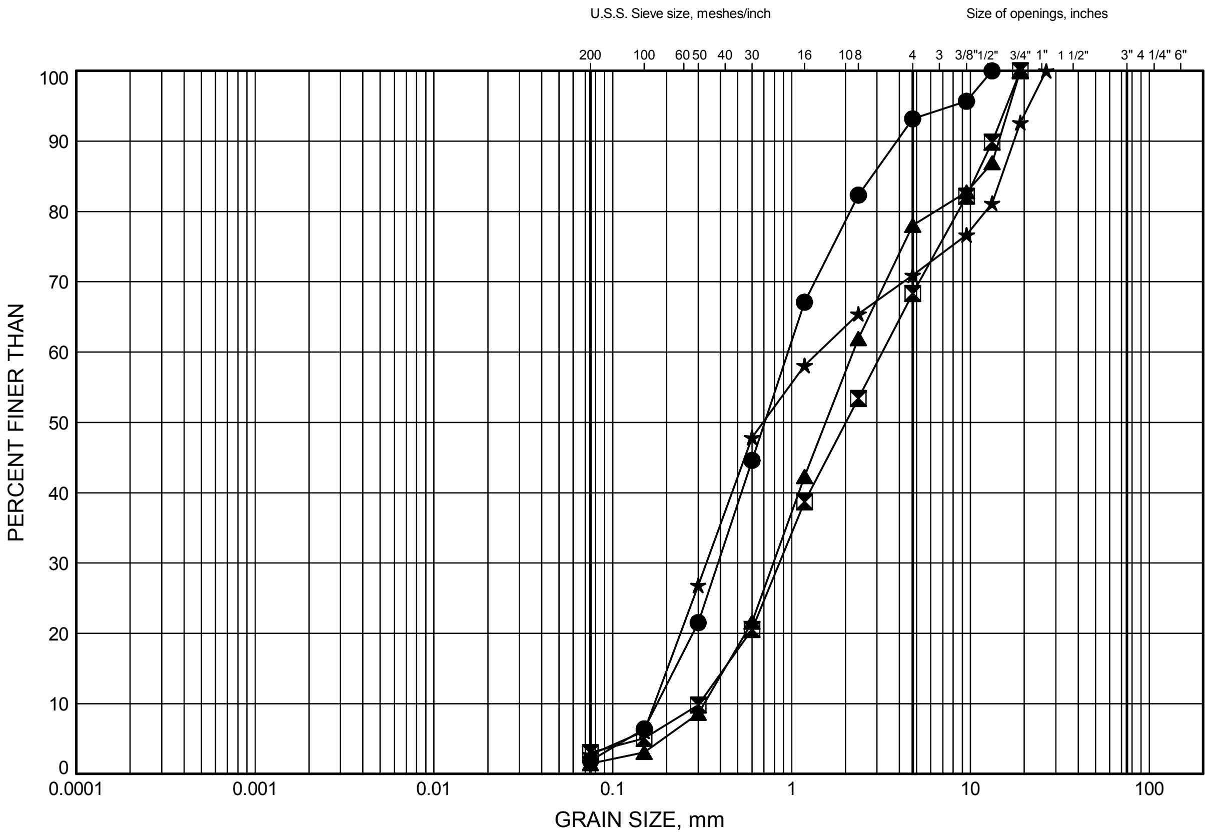
Laboratory Test Results

Little Grassy at Bergland

GRAIN SIZE DISTRIBUTION

FIGURE B1

SAND to GRAVELLY SAND FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	LGB-01	0.38	326.72
⊠	LGB-02	1.07	325.83
▲	LGB-03	1.07	325.83
★	LGB-04	1.83	324.97

Date January 2014

WP# 497-00-01

THURBER

Prep'd MFA

Chkd. MC

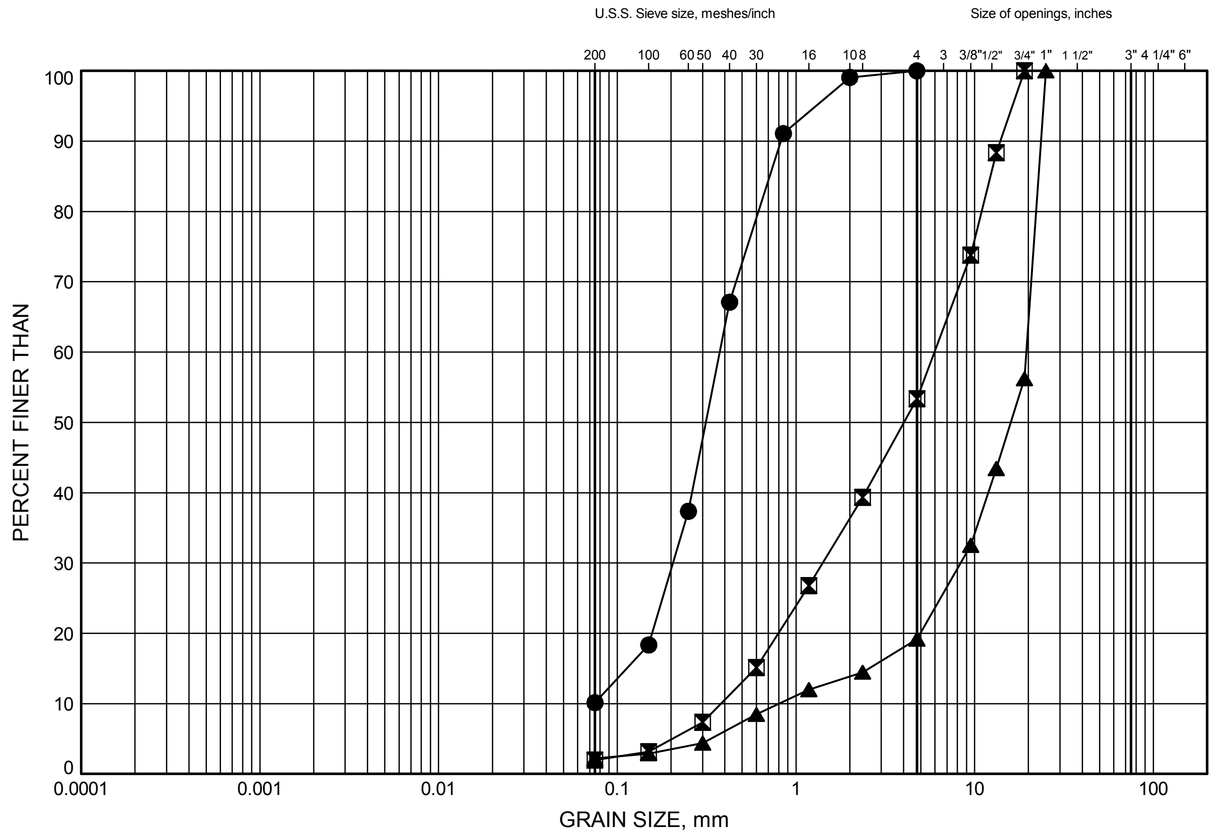
GRAIN SIZE DISTRIBUTION - THURBER 5121.GPJ 1/21/14

Little Grassy at Bergland

GRAIN SIZE DISTRIBUTION

FIGURE B2

SAND to GRAVEL FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	LGB-05	1.83	324.97
⧗	LGB-06	0.38	326.42
▲	LGB-06	3.35	323.44

Date January 2014

WP# 497-00-01

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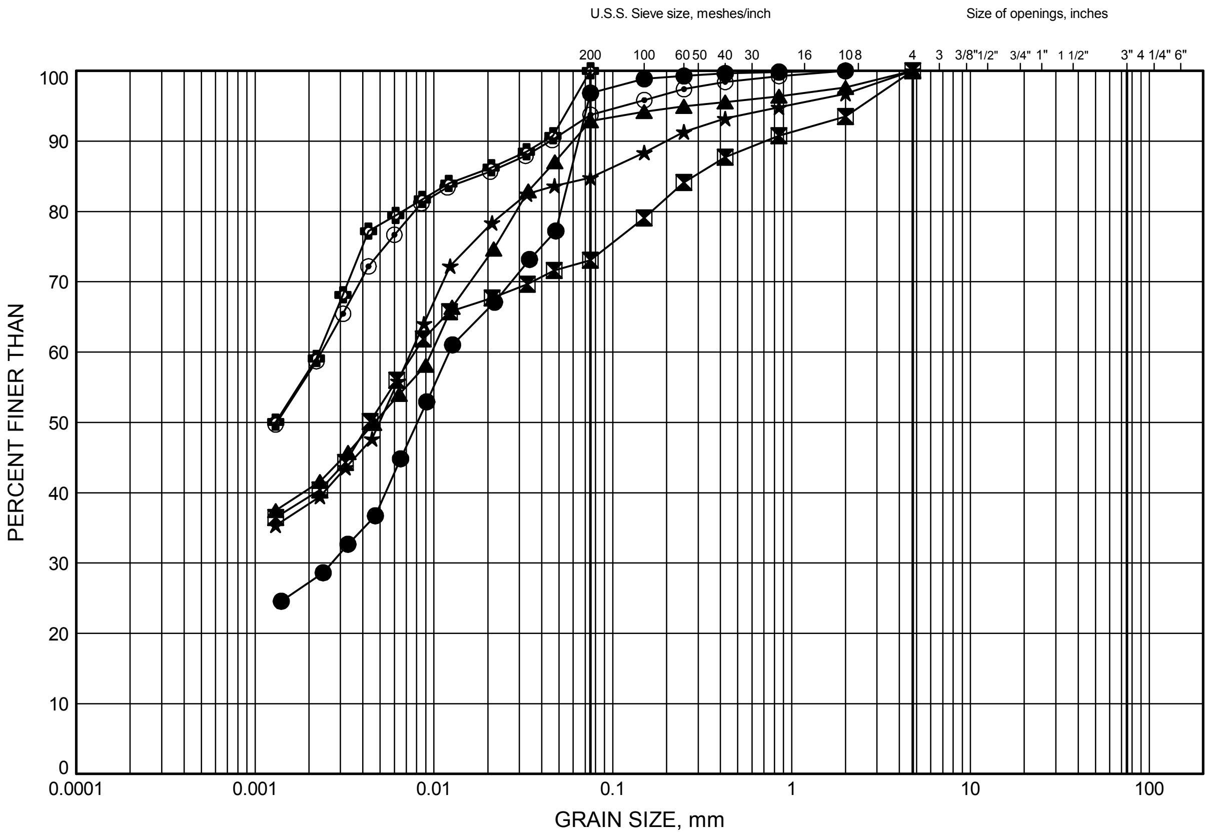
GRAIN SIZE DISTRIBUTION - THURBER 5121.GPJ 1/21/14

Little Grassy at Bergland

GRAIN SIZE DISTRIBUTION

FIGURE B3

SILTY CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	LGB-01	2.59	324.51
⧗	LGB-01	6.40	320.70
▲	LGB-02	3.35	323.54
★	LGB-02	7.92	318.97
⊙	LGB-02	14.02	312.88
✿	LGB-02	20.12	306.78

Date January 2014

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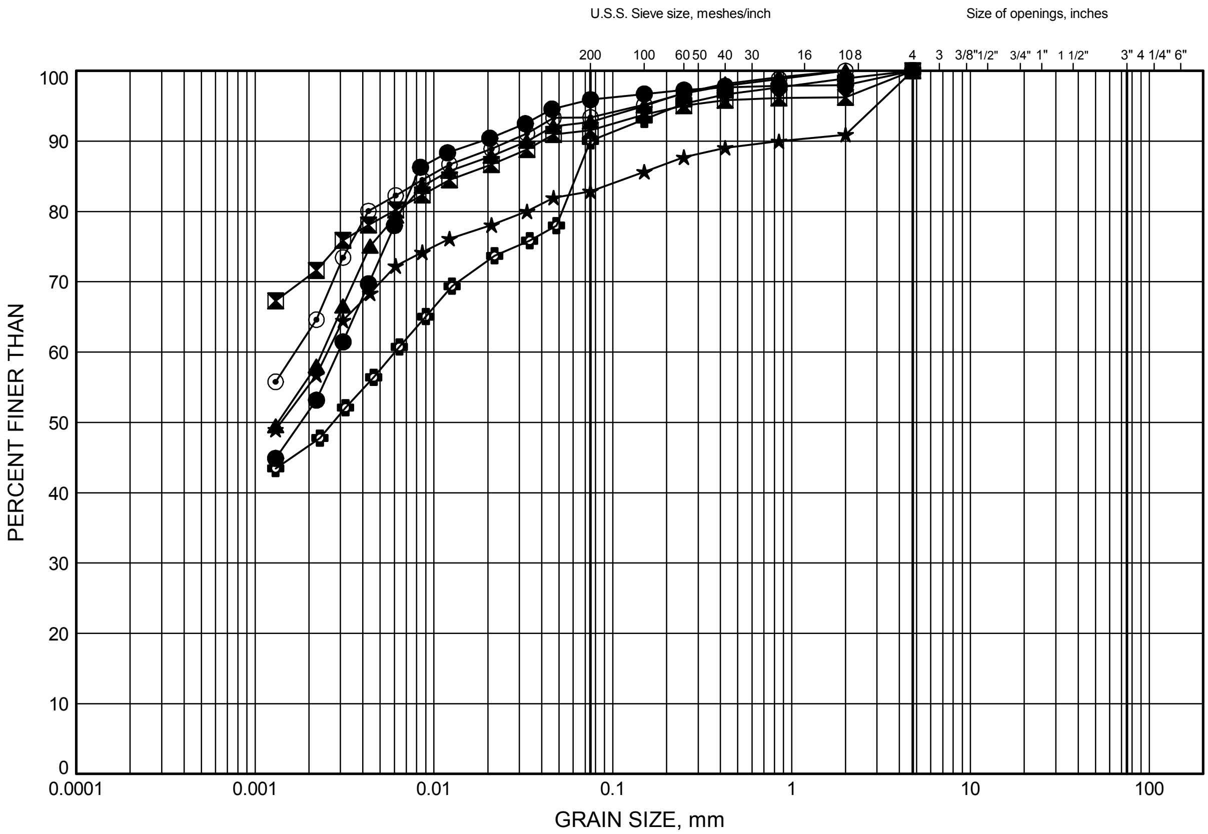
Little Grassy at Bergland

GRAIN SIZE DISTRIBUTION

FIGURE B4

SILTY CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	LGB-03	3.35	323.54
⧗	LGB-03	6.40	320.50
▲	LGB-03	17.07	309.83
★	LGB-04	9.45	317.35
⊙	LGB-04	15.54	311.25
✿	LGB-05	12.50	314.30

Date January 2014

WP# 497-00-01

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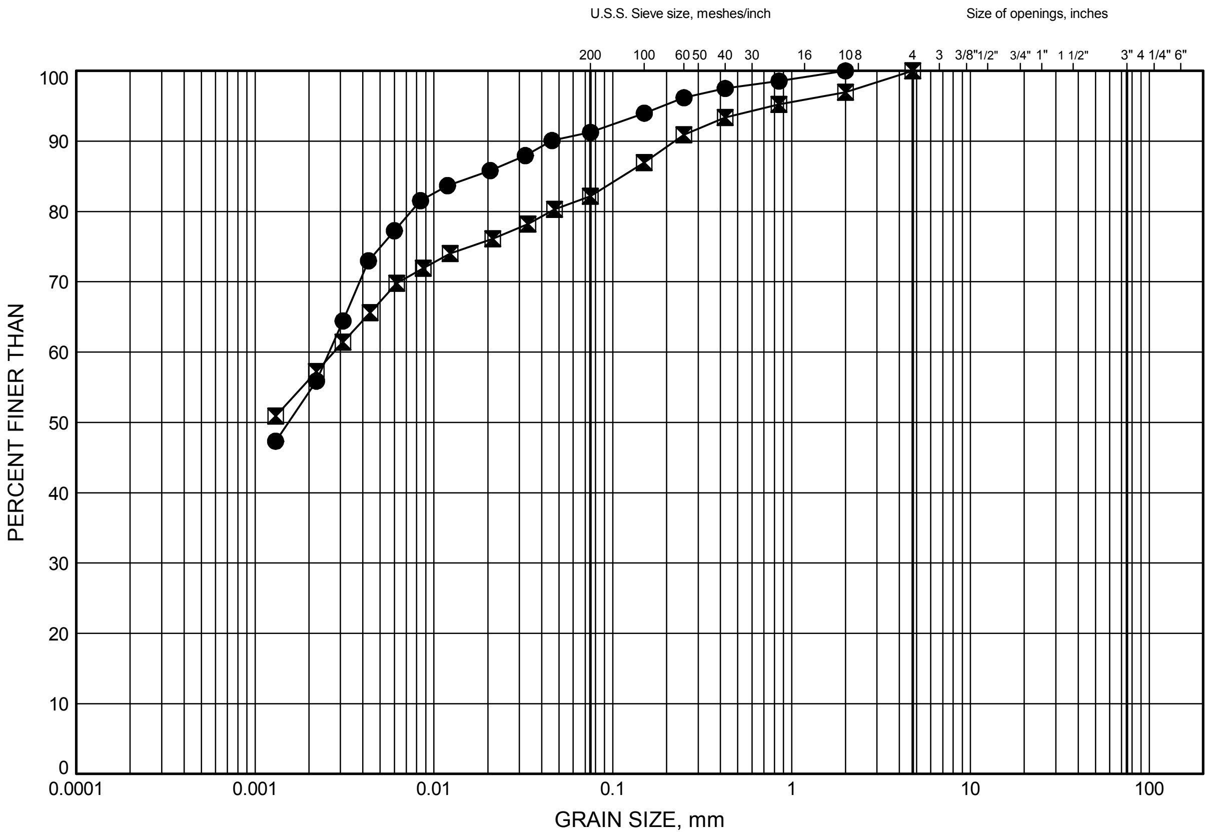
GRAIN SIZE DISTRIBUTION - THURBER 5121.GPJ 1/21/14

Little Grassy at Bergland

GRAIN SIZE DISTRIBUTION

FIGURE B5

SILTY CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	LGB-05	18.59	308.20
⧗	LGB-06	7.92	318.87

GRAIN SIZE DISTRIBUTION - THURBER 5121.GPJ 1/21/14

Date January 2014

WP# 497-00-01

THURBER

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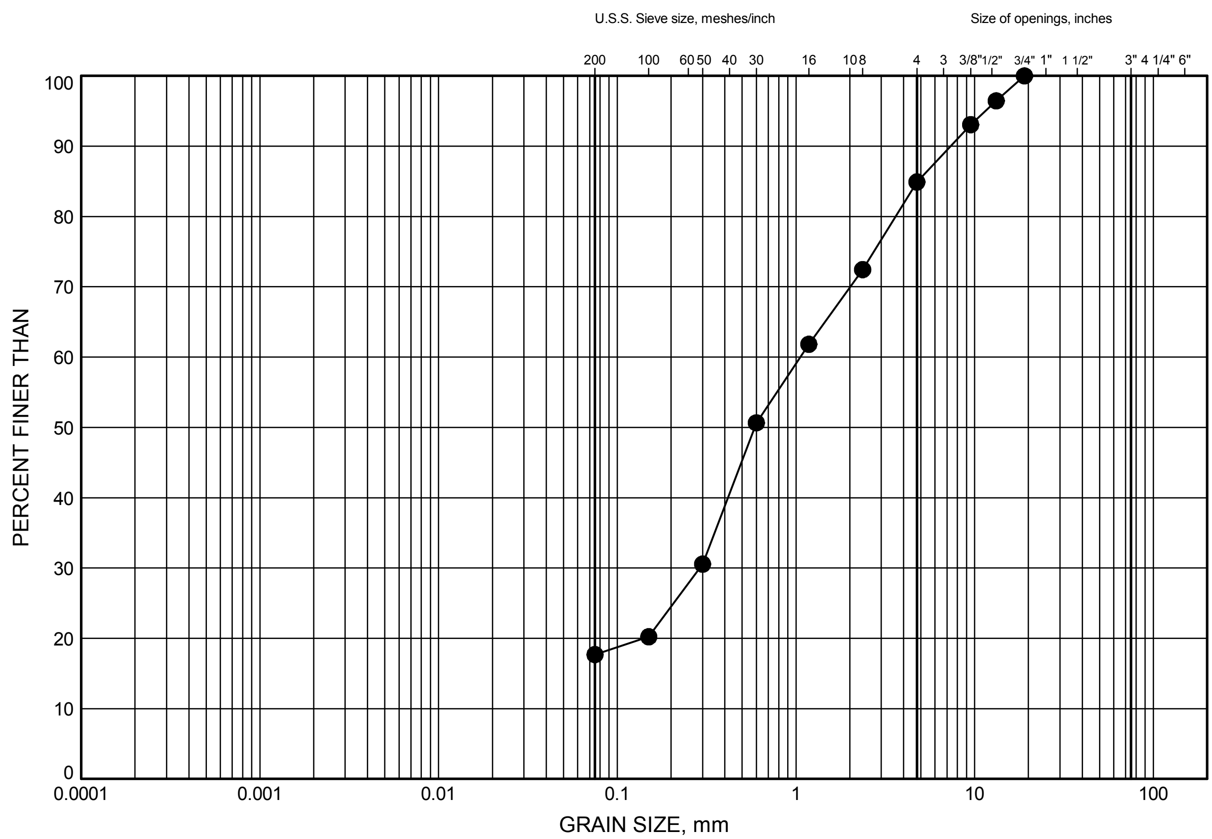
Little Grassy at Bergland

GRAIN SIZE DISTRIBUTION

FIGURE B6

SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	LGB-05	7.92	318.87

GRAIN SIZE DISTRIBUTION - THURBER 5121.GPJ 1/21/14

Date January 2014

WP# 497-00-01

THURBER

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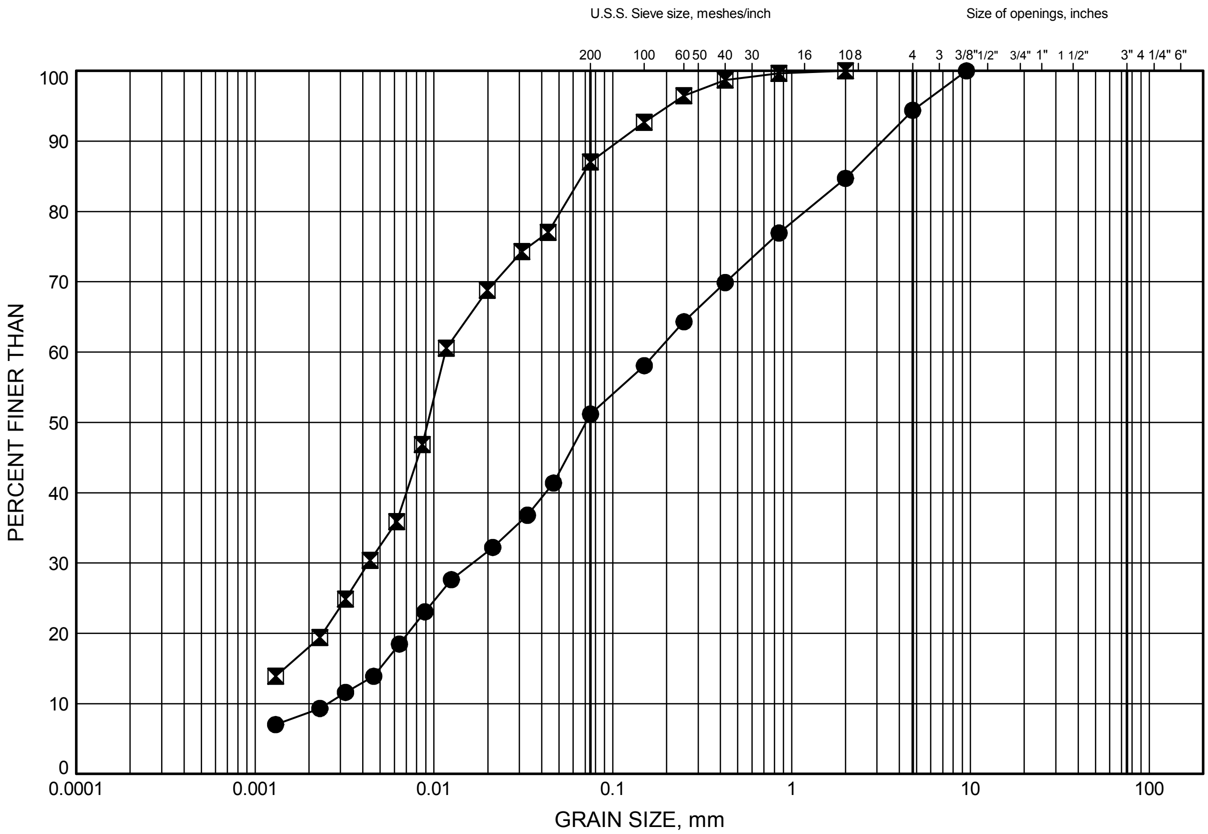
Little Grassy at Bergland

GRAIN SIZE DISTRIBUTION

FIGURE B7

SILT to SILT & SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	LGB-03	23.16	303.73
⊠	LGB-04	20.12	306.68

GRAIN SIZE DISTRIBUTION - THURBER 5121.GPJ 1/21/14

Date January 2014

WP# 497-00-01

THURBER

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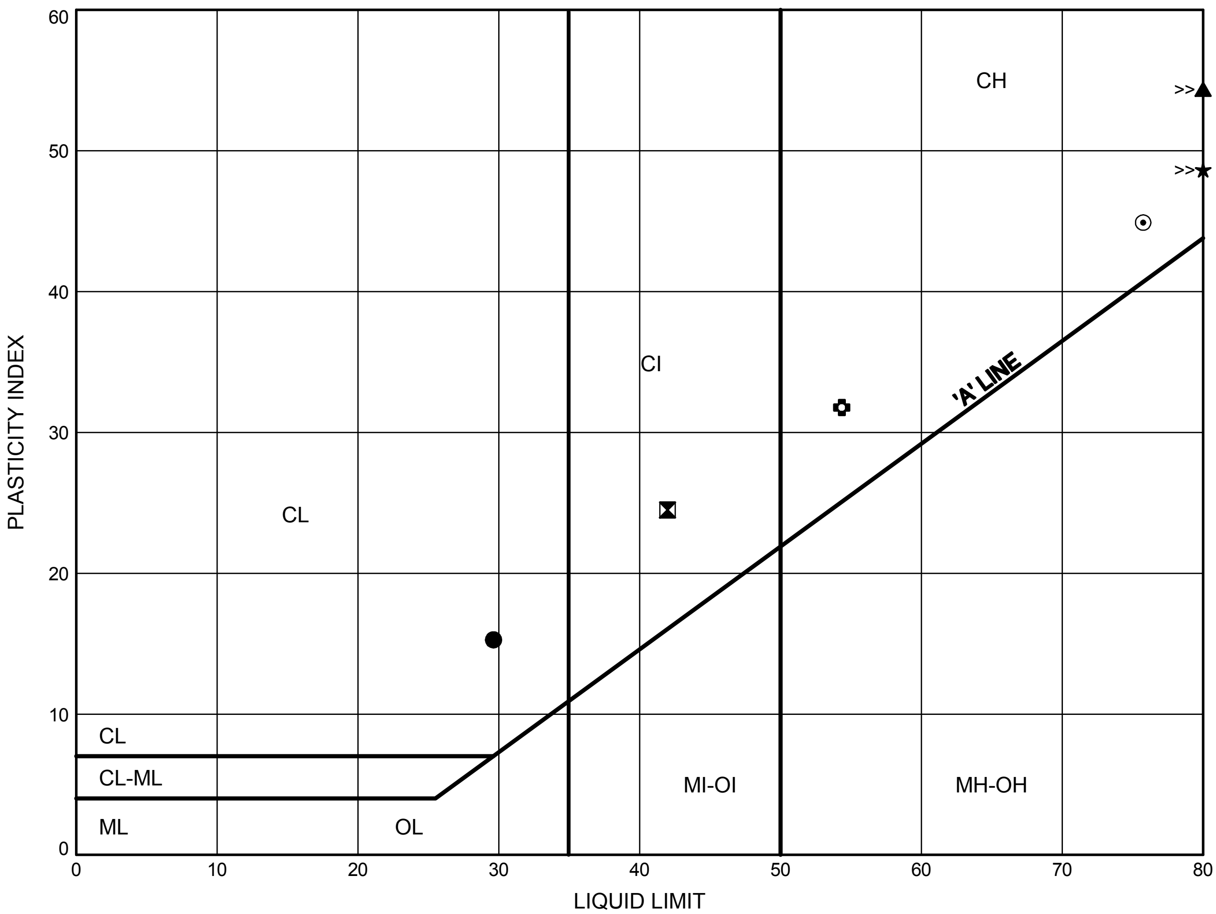
Chkd. MC

Little Grassy at Bergland

ATTERBERG LIMITS TEST RESULTS

FIGURE B8

SILTY CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	LGB-01	6.40	320.70
⧗	LGB-02	7.92	318.97
▲	LGB-02	14.02	312.88
★	LGB-02	20.12	306.78
⊙	LGB-03	6.40	320.50
✿	LGB-03	17.07	309.83

Date January 2014

WP# 497-00-01

THURBER

Prep'd MFA

Chkd. MC

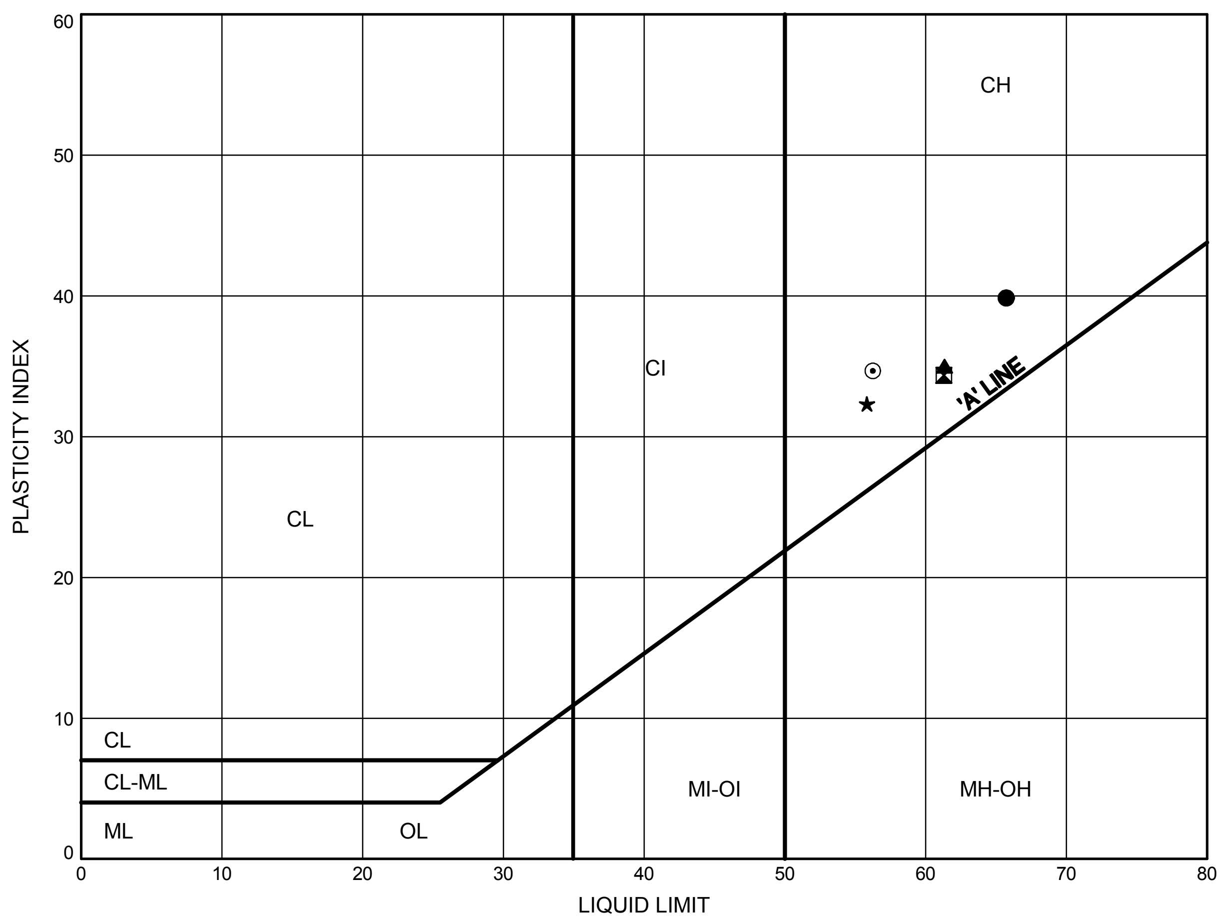
THURBALT 5121.GPJ 1/21/14

Little Grassy at Bergland

ATTERBERG LIMITS TEST RESULTS

FIGURE B9

SILTY CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	LGB-04	9.45	317.35
⧗	LGB-04	15.54	311.25
▲	LGB-05	12.50	314.30
★	LGB-05	18.59	308.20
⊙	LGB-06	7.92	318.87

THURBALT 5121.GPJ 1/21/14

Date January 2014

WP# 497-00-01

THURBER

Prep'd MFA

Chkd. MC

Appendix C

Site Photographs

Photograph 1 – Little Grassy River Bridge, looking south

Photograph 2 – East side of bridge, looking north

Appendix D

Foundation Comparison

COMPARISON OF FOUNDATION ALTERNATIVES

Footings on Native Soil	Augered Caissons	Steel H-Piles
Advantages: i. Generally less costly construction than deep foundation elements.	***Advantages:*** i. High geotechnical resistance available for caissons founded on bedrock. ii. Construction of caissons could continue in freezing weather. iii. Excavation requirements are minimized.	***Advantages:*** i. High geotechnical resistance available for H-piles driven to bedrock. ii. Installation of piles could continue in freezing weather. iii. Excavation and dewatering requirements are minimized.
Disadvantages: i. Low geotechnical resistance available in native soils. ii. Potential for settlement. iii. Excavation to native soils would extend below river level at north abutment. iv. Temporary excavation for footing construction may have environmental impact on the creek.	***Disadvantages:*** i. Higher unit costs than footings. ii. Artesian pressures are present within the silt/sand layer overlying bedrock. iii. Steel liner will be required to maintain sidewall stability. iv. Difficulties in obtaining a seal below the liner. v. Potential difficulty in cleaning and inspection of socket base.	***Disadvantages:*** i. Higher unit cost than footings on bedrock. ii. H-piles may encounter cobbles and boulders in existing embankment fill.
NOT RECOMMENDED	**NOT RECOMMENDED**	**RECOMMENDED**

THURBER

Appendix E

List of SPs and OPSS, and Suggested Text for Selected NSSP

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

- OPSS 501
- OPSS 804
- OPSS 902
- OPSS 903
- OPSS.PROV 1010
- SP 105S21

2. Suggested text for a NSSP on Sheet Pile and H-pile Installation

The existing embankment fill contains cobbles and possibly boulders.

These cobbles and boulders may impede the driving of sheet piles and H-piles, and at some locations the piles may not be able to penetrate the cobbles and boulders and reach the design depth of installation.

The Contractor shall be prepared to remove, drill through and/or penetrate these obstructions and extend the piles to the design depth.

Appendix F

Slope Stability Output

Title: Little Grassy at Bergland
Name: Analysis 1.1E
Comments: Stability Analysis
Last Edited By: Stephen Peters
Last Solved Date: 2/12/2014, 1:40:05 PM

Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1 m
Horz Seismic Load: 0
Center: (6, 331) m

New Fill	22 kN/m³	0 kPa	32 °	1
Existing Fill	21 kN/m³	0 kPa	32 °	1
Clay (ESA)	19 kN/m³	5 kPa	29 °	1

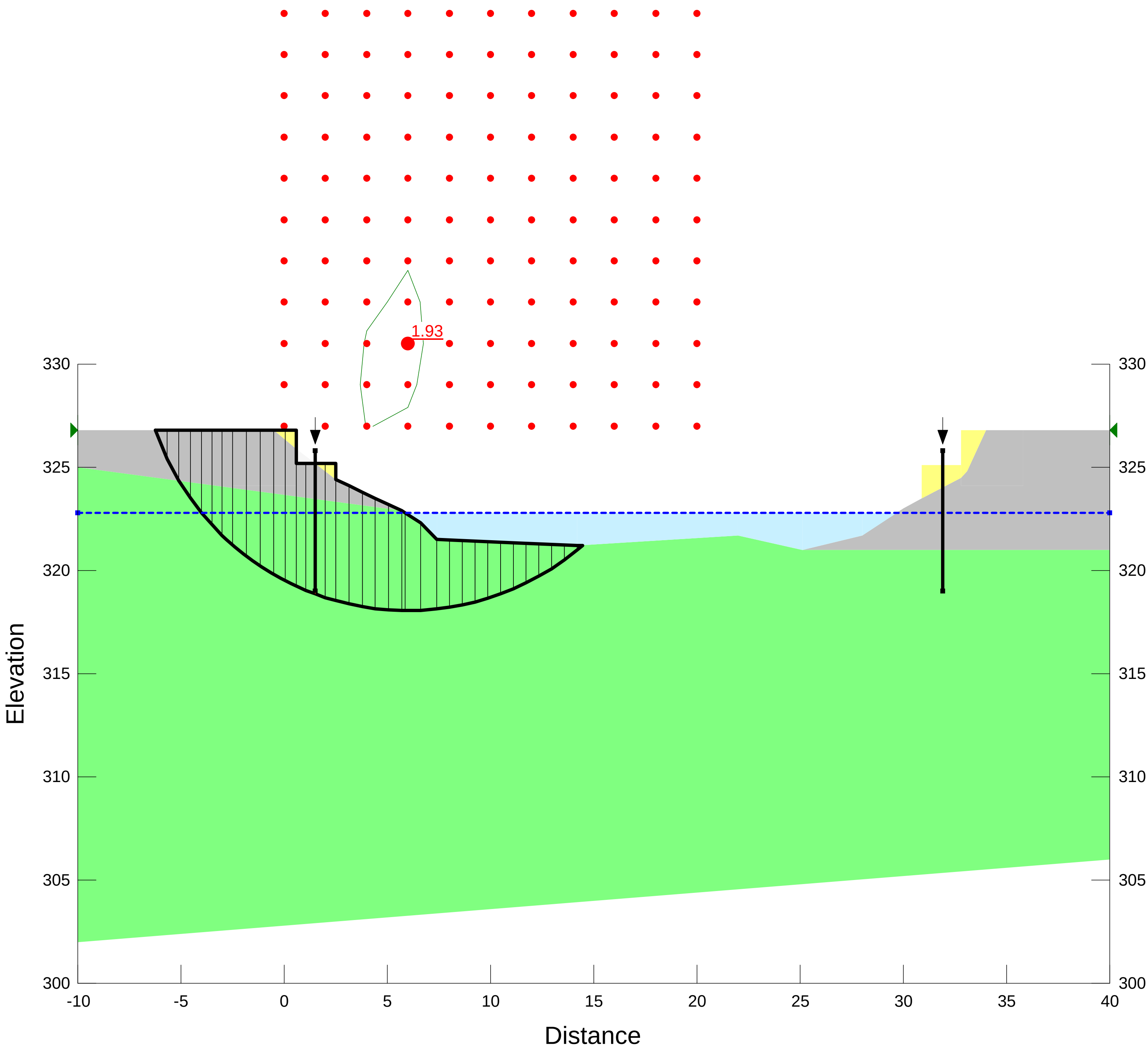


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Figure 1

Title: Little Grassy at Bergland
Name: Analysis 1.1T
Comments: Stability Analysis
Last Edited By: Stephen Peters
Last Solved Date: 2/12/2014, 1:40:09 PM

Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1 m
Horz Seismic Load: 0
Center: (4, 329) m

New Fill	22 kN/m³	0 kPa	32 °	1
Existing Fill	21 kN/m³	0 kPa	32 °	1
Clay (TSA)	19 kN/m³	80 kPa	0 °	1

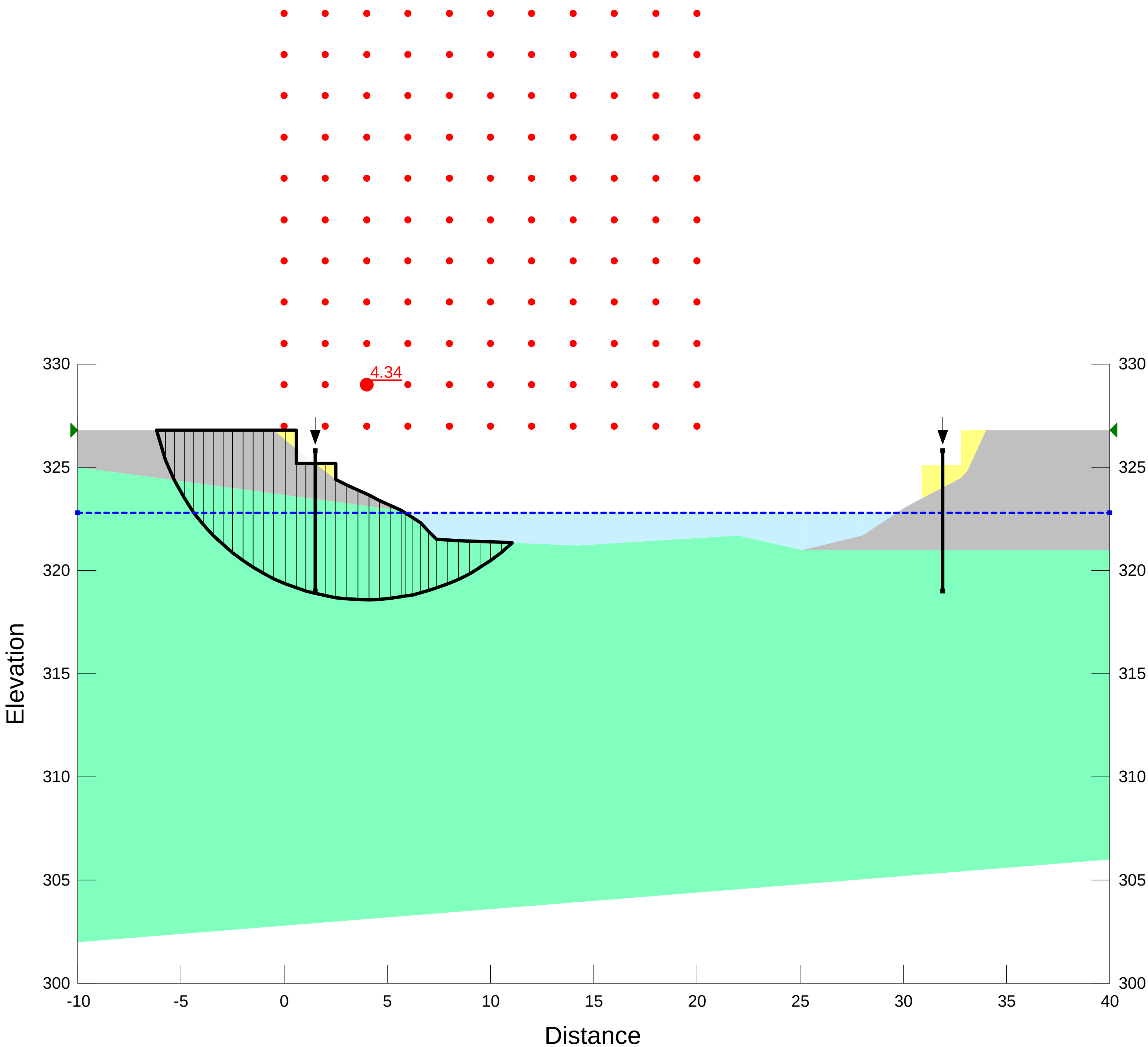

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Figure 2

Title: Little Grassy at Bergland
Name: Analysis 2.1E
Comments: Stability Analysis
Last Edited By: Stephen Peters
Last Solved Date: 2/12/2014, 1:40:51 PM

Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1 m
Horz Seismic Load: 0
Center: (30, 327) m

New Fill	22 kN/m³	0 kPa	32 °	1
Existing Fill	21 kN/m³	0 kPa	32 °	1
Clay (ESA)	19 kN/m³	5 kPa	29 °	1

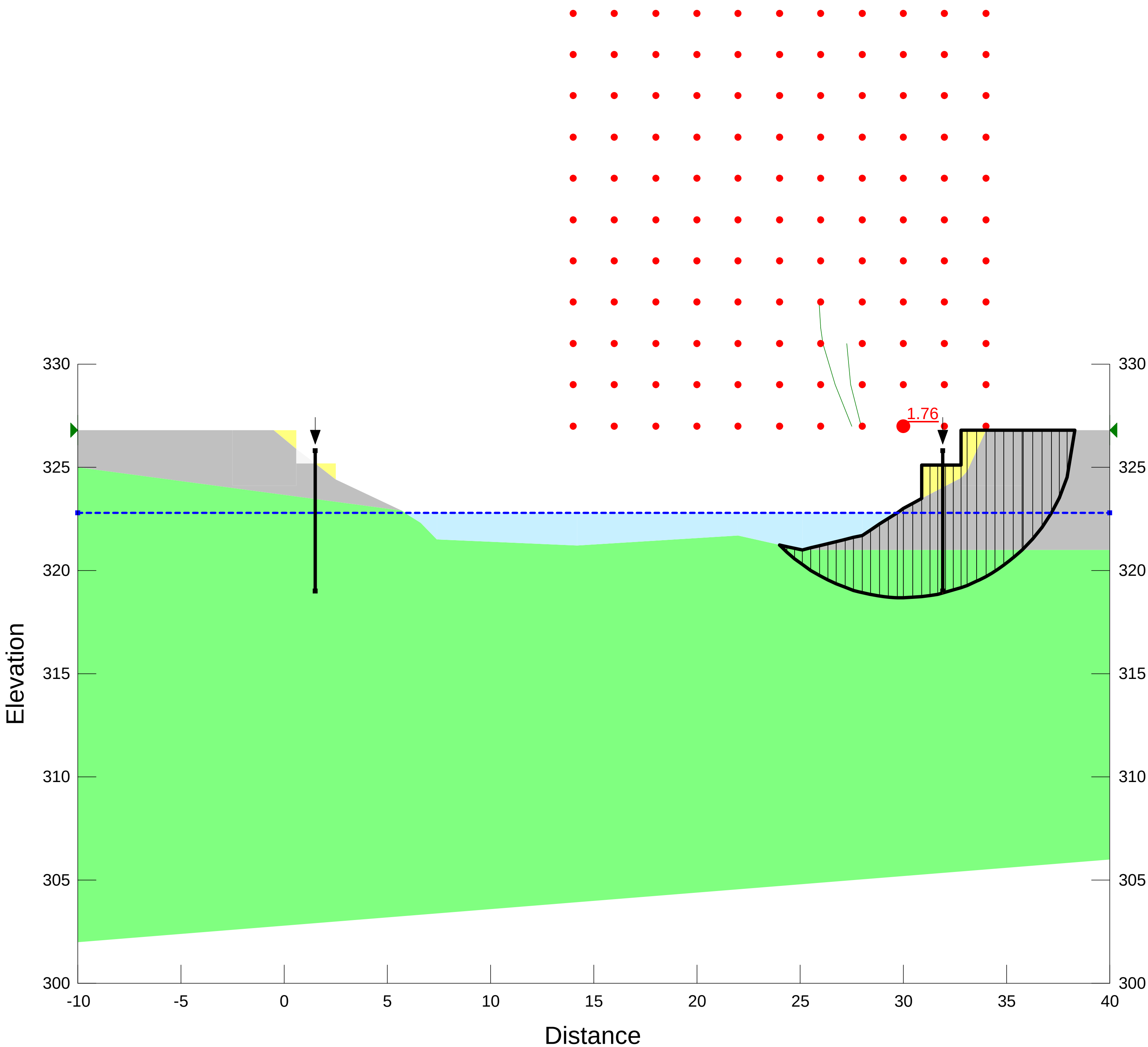

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Figure 3

Title: Little Grassy at Bergland
Name: Analysis 2.1T
Comments: Stability Analysis
Last Edited By: Stephen Peters
Last Solved Date: 2/12/2014, 1:40:55 PM

Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1 m
Horz Seismic Load: 0
Center: (30, 327) m

New Fill	22 kN/m³	0 kPa	32 °	1
Existing Fill	21 kN/m³	0 kPa	32 °	1
Clay (TSA)	19 kN/m³	80 kPa	0 °	1

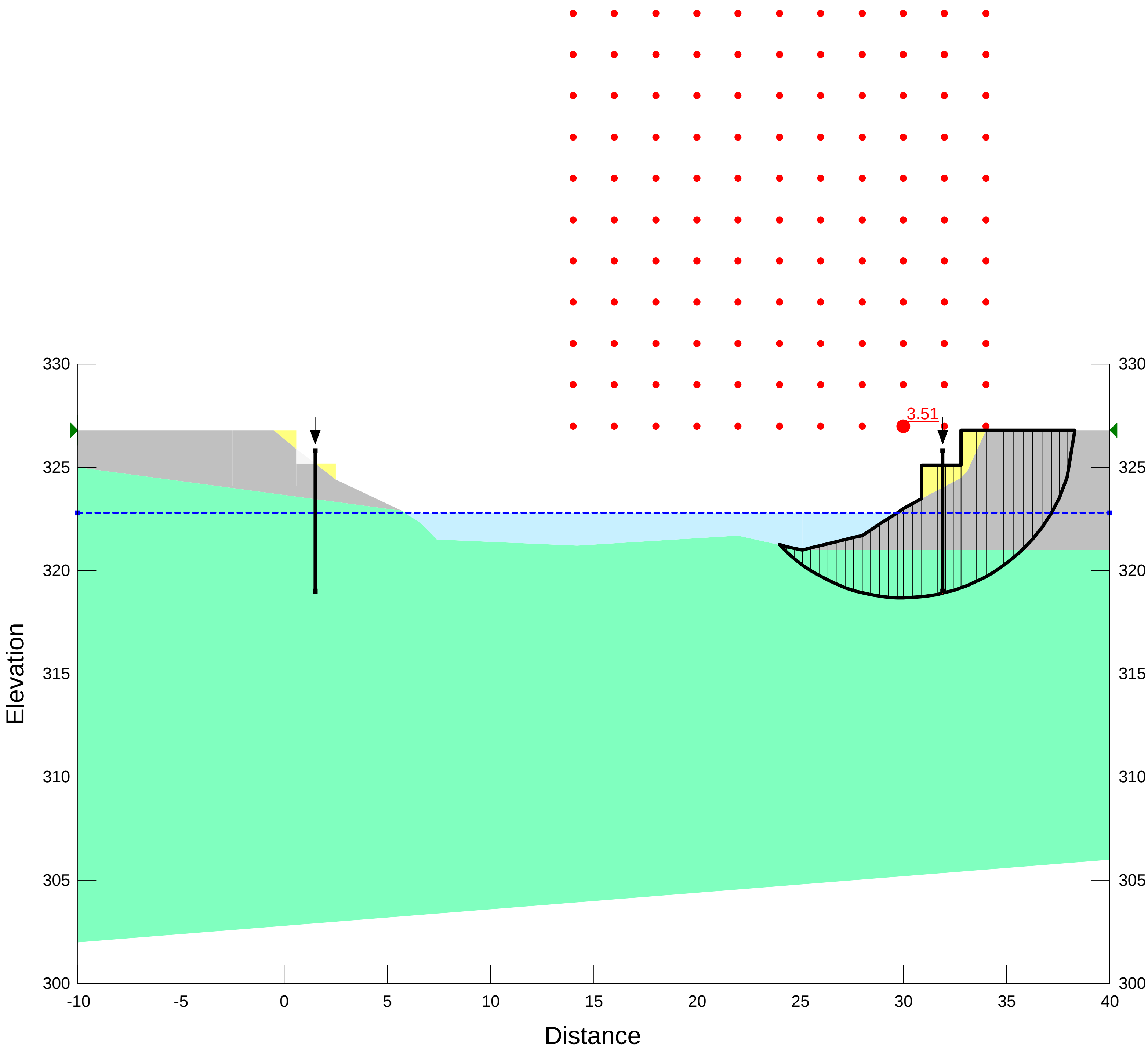

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Figure 4

Appendix G

Borehole Locations and Soil Strata Drawing

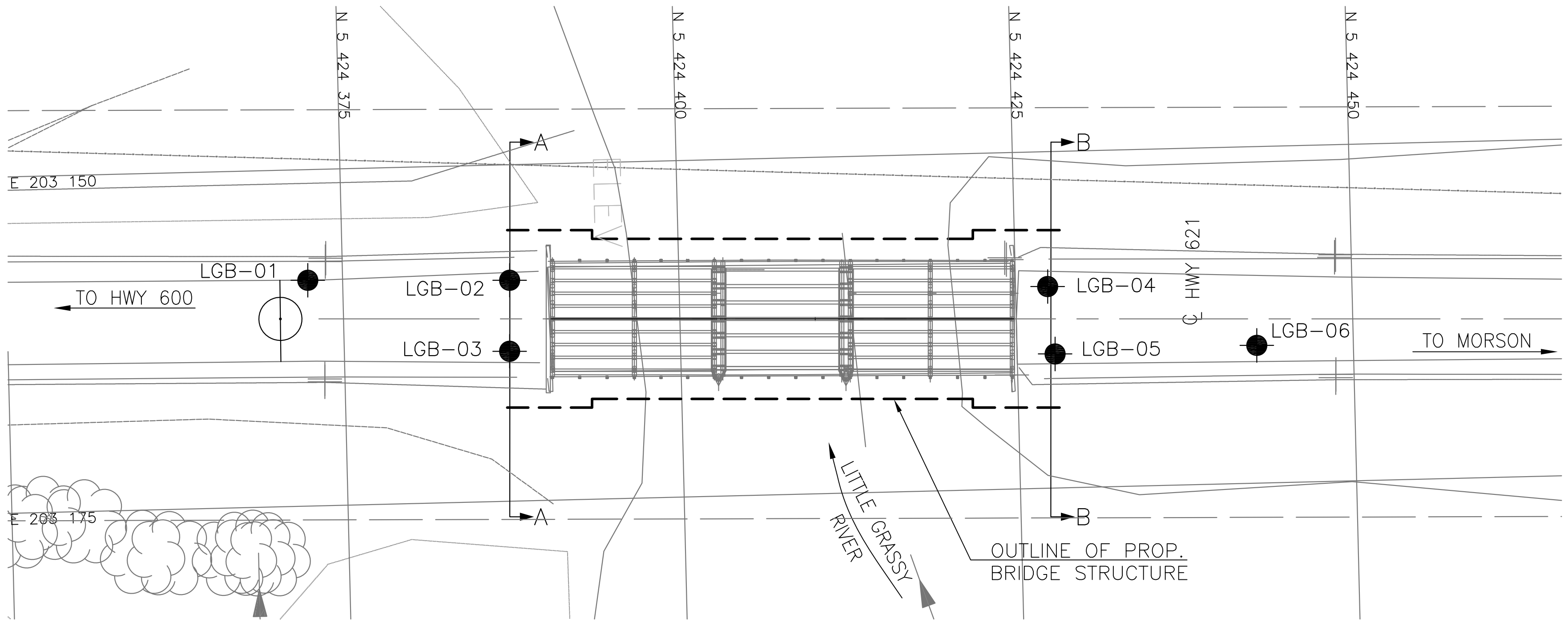
METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

CONT No 2013–6025
WP No 497–00–01

LITTLE GRASSY AT BERGLAND
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET 6



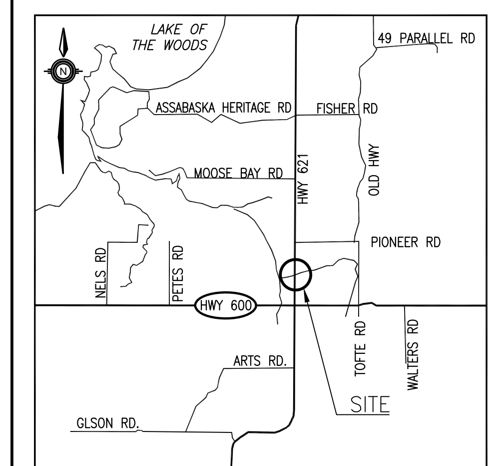
PLAN

SCALE 1:500

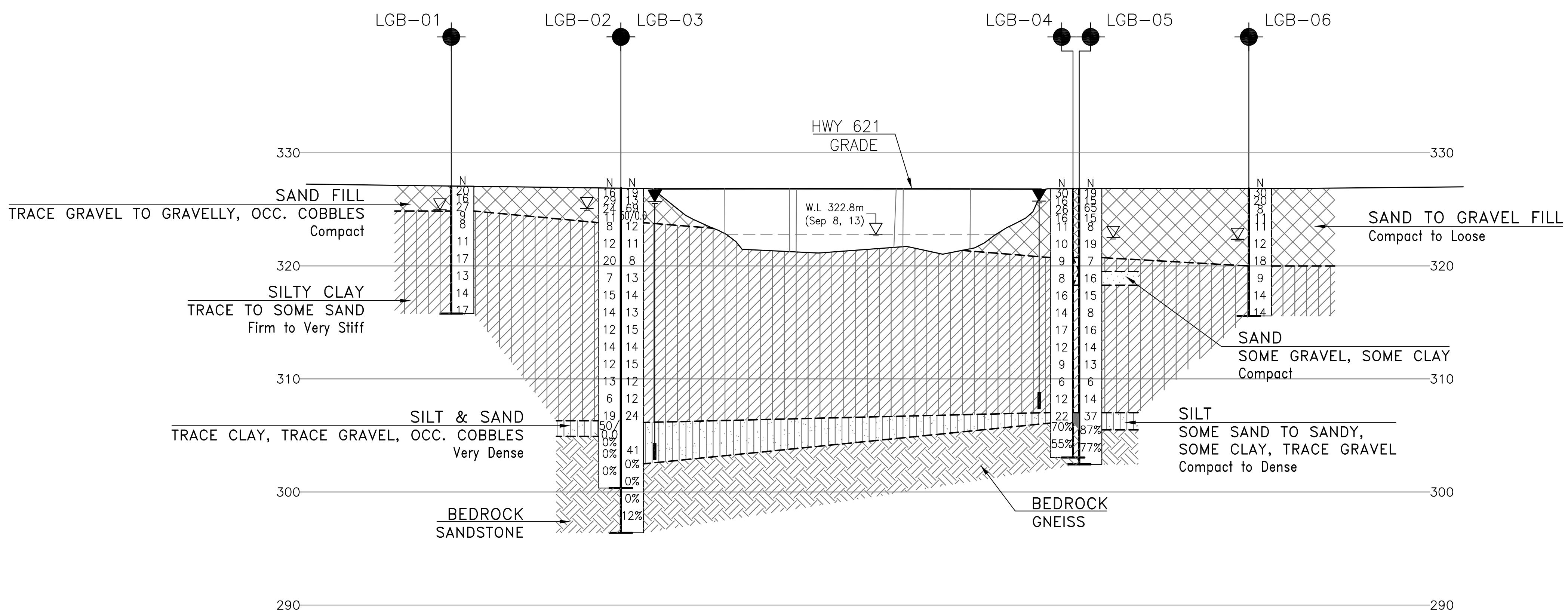
LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
Feb 13/14
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
M. R. ANDERSON
Feb 13/14
PROVINCE OF ONTARIO

THURBER ENGINEERING LTD.



KEYPLAN



PROFILE ALONG ℄ HWY 621

SCALE 1:500

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
LGB–01	327.1	5 424 372.4	203 158.2
LGB–02	326.9	5 424 387.4	203 158.6
LGB–03	326.9	5 424 387.3	203 163.9
LGB–04	326.8	5 424 427.4	203 160.0
LGB–05	326.8	5 424 427.8	203 165.0
LGB–06	326.8	5 424 442.8	203 164.8

-NOTES-

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.

GEOCRES No. 52D-14

REVISIONS	DATE	BY	DESCRIPTION		
DESIGN MC	CHK MC	CODE CAN/CSA S6–06	LOAD CL–625–ONT	DATE FEB 2014	
DRAWN AN	CHK	SITE 45–006	STRUCT	DWG 2	

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MINISTRY OF TRANSPORTATION, ONTARIO

METRIC

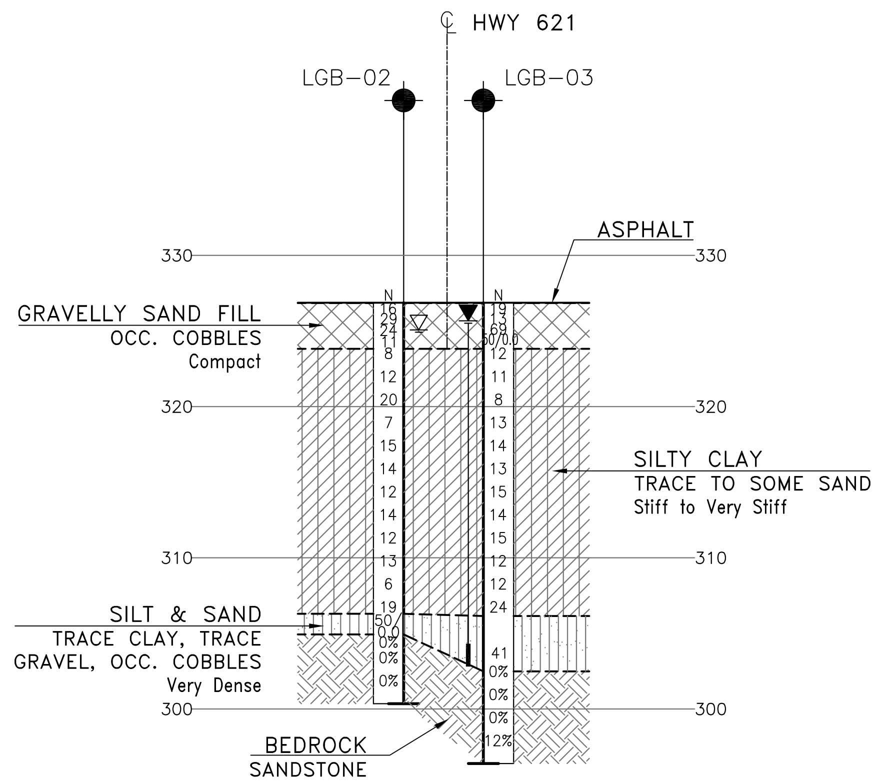
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

CONT No 2013-6025
WP No 497-00-01

LITTLE GRASSY AT BERGLAND
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET 7

THURBER ENGINEERING LTD.



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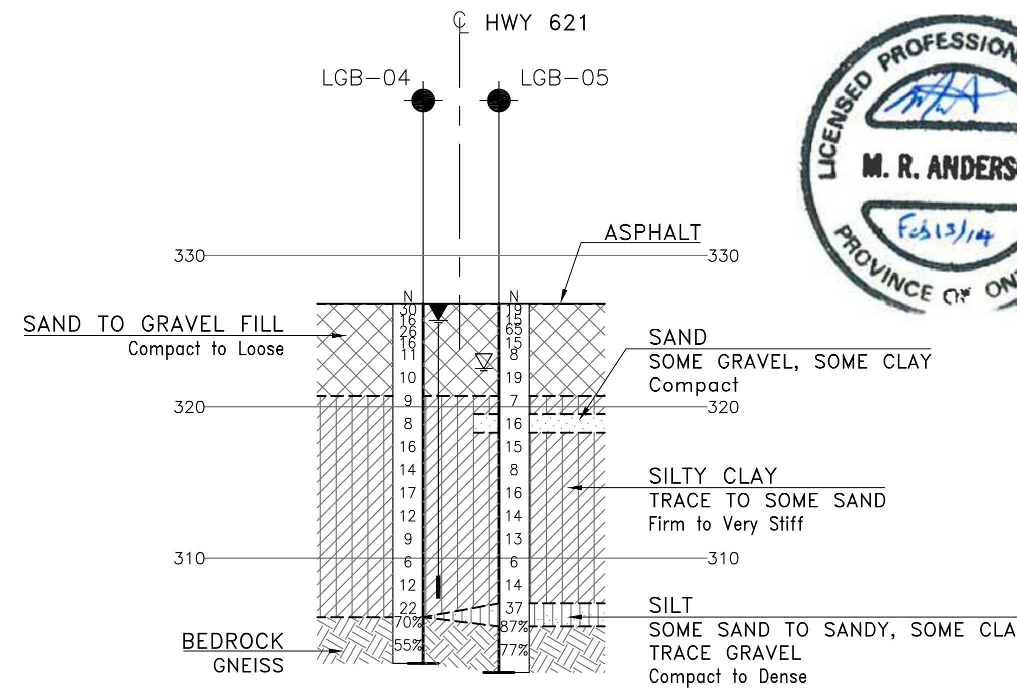

SECTION ALONG B-B

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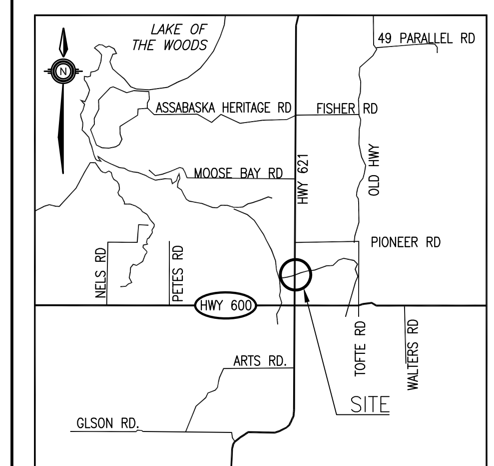

KEYPLAN

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
ǀ	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

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LGB-01	327.1	5 424 372.4	203 158.2
LGB-02	326.9	5 424 387.4	203 158.6
LGB-03	326.9	5 424 387.3	203 163.9
LGB-04	326.8	5 424 427.4	203 160.0
LGB-05	326.8	5 424 427.8	203 165.0
LGB-06	326.8	5 424 442.8	203 164.8

-NOTES-

1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

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GEOCRES No. 52D-14

REVISIONS	DATE	BY	DESCRIPTION

DESIGN MC	CHK MC	CODE CAN/CSA S6-06	LOAD CL-625-ONT	DATE FEB 2014
DRAWN AN	CHK	SITE 45-006	STRUCT	DWG 3